Technical Reference Guide

9955

V 7.1.2

Alcatel·Lucent

3DF 01955 7181 RKZZA ED.02

About the Technical Reference Guide

This document is targeted at readers with a prior knowledge of **9955**, its operation and basic functioning. It is not the *User Manual* for **9955**, and does not teach how to operate and use **9955**. It is a supplementary document containing detailed descriptions of models, algorithms and concepts adopted in **9955**. Therefore, it concerns only the appropriate personnel.

The **9955** *Technical Reference Guide* is divided into three parts with each part comprising similar topics. The first part contains descriptions of general terms, entities, ideas and concepts in **9955** that are encountered throughout its use. It is followed by the second part that consists of descriptions of entities common to all types of networks and the algorithms that are technology independent and are available in any network type. Lastly, the guide provides detailed descriptions of each basic type of network that can be modelled and studied in **9955**.

Notice

The **9955** software and the program documentation are intended for use by experienced personnel in the fields of transmission engineering and communication system design. Additional reference material, in particular the referenced CCIR, ETSI, and 3GPP recommendations and reports may be required for a complete understanding of some aspects of the program.

Restrictions to the License

The software and materials delivered with the **9955** system contain copyrighted material, trade secrets, and other proprietary material and in order to protect them you may not decompile, reverse engineer, disassemble or otherwise reduce the **9955** software to a human-perceivable form. You may not modify, network, rent, lease, loan, distribute or create derivative works based upon the software and materials in whole or in part. You may not electronically transmit the **9955** software from one computer to another or over a network.

Limited Warranty

Use of the **9955** software acknowledges this statement of limited warranty. With respect to the physical disks and physical documentation, Alcatel-Lucent Romania warrants these to be free of defects in material and workmanship for a period of ninety days from the date of delivery. Alcatel-Lucent Romania disclaims all other warranties, expressed or implied including the fitness of the program for any purpose. Alcatel-Lucent Romania assumes no liability for damages, direct or consequential, loss of profit or other similar claims.

Table of Contents

1 Antennas and Equipment . . . 21
1.1 Antenna Attenuation . . . 21
1.1.1 Calculation of Azimuth and Tilt Angles . . . 21
1.1.2 Antenna Pattern 3D Interpolation . . . 22
1.1.3 Additional Electrical Downtilt Modelling . . . 23
1.2 Antenna Pattern Smoothing . . . 23
1.3 Power Received From Secondary Antennas . . . 25
1.4 Transmitter Radio Equipment . . . 26
1.4.1 GSM Documents . . . 26
1.4.2 UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents . . . 26
1.5 Repeaters and Remote Antennas . . . 28
1.5.1 UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents . . . 28
1.5.1.1 Signal Level Calculation . . . 28
1.5.1.2 Downlink Total Gain Calculation . . . 30
1.5.1.3 Uplink Total Gain Calculation . . . 32
1.5.1.4 Repeater Noise Figure . . . 34
1.5.1.5 Appendix: Carrier Power and Interference Calculation . . . 34
1.5.2 GSM Documents . . . 37
1.5.2.1 Signal Level Calculation . . . 37
1.5.2.2 EIRP Calculation . . . 38
1.5.3 Donor-side Parameter Calculations . . . 40
1.5.3.1 Azimuth . . . 40
1.5.3.2 Mechanical Downtilt . . . 40
1.6 Beamforming Smart Antenna Models . . . 41
1.6.1 Definitions and Formulas . . . 42
1.6.1.1 Definitions . . . 42
1.6.1.2 Downlink Beamforming . . . 42
1.6.1.3 Uplink Beamforming . . . 43
1.6.1.4 Uplink Beamforming and Interference Cancellation (MMSE) . . . 43
1.6.2 Downlink Beamforming . . . 44
1.6.3 Uplink Beamforming . . . 46
1.6.4 Uplink Beamforming and Interference Cancellation (MMSE) . . . 47

2 Radio Propagation . . . 53
2.1 Path Loss Calculation Prerequisites . . . 53
2.1.1 Ground Altitude Determination . . . 53
2.1.2 Clutter Determination . . . 54
2.1.3 Geographic Profile Extraction . . . 54
2.1.4 Resolution of the Extracted Profiles . . . 56
2.2 List of Default Propagation Models . . . 57
2.3 Okumura-Hata and Cost-Hata Propagation Models . . . 58
2.3.1 Hata Path Loss Formula . . . 58
2.3.2 Corrections to the Hata Path Loss Formula . . . 58
2.3.3 Calculations in 9955 . . . 59
2.4 ITU 529-3 Propagation Model . . . 59
2.4.1 ITU 529-3 Path Loss Formula . . . 59
2.4.2 Corrections to the ITU 529-3 Path Loss Formula . . . 59
2.4.3 Calculations in 9955 . . . 60
2.5 Standard Propagation Model (SPM) . . . 60
2.5.1 SPM Path Loss Formula . . . 60
2.5.2 Calculations in 9955 . . . 61
2.5.2.1 Visibility and Distance Between Transmitter and Receiver . . . 61
2.5.2.2 Effective Transmitter Antenna Height . . . 61
2.5.2.3 Effective Receiver Antenna Height . . . 64
2.5.2.4 Correction for Hilly Regions in Case of LOS . . . 65
2.5.2.5 Diffraction . . . 65
2.5.2.6 Losses due to Clutter . . . 65
2.5.2.7 Recommendations . . . 66

2.5.3 Automatic Calibration 67
2.5.3.1 General Algorithm 67
2.5.3.2 Sample Values for SPM Path Loss Formula Parameters 68
2.5.4 Unmasked Path Loss Calculation 69
2.6 WLL Propagation Model 70
2.6.1 WLL Path Loss Formula 70
2.6.2 Calculations in 9955 70
2.7 ITU-R P.526-5 Propagation Model 71
2.7.1 ITU 526-5 Path Loss Formula 71
2.7.2 Calculations in 9955 71
2.8 ITU-R P.370-7 Propagation Model 71
2.8.1 ITU 370-7 Path Loss Formula 71
2.8.2 Calculations in 9955 71
2.9 Erceg-Greenstein (SUI) Propagation Model 73
2.9.1 SUI Terrain Types 73
2.9.2 Erceg-Greenstein (SUI) Path Loss Formula 74
2.9.3 Calculations in 9955 74
2.10 ITU-R P.1546-2 Propagation Model 75
2.10.1 Calculations in 9955 75
2.10.1.1 Step 1: Determination of Graphs to be Used 75
2.10.1.2 Step 2: Calculation of Maximum Field Strength 76
2.10.1.3 Step 3: Determination of Transmitter Antenna Height 76
2.10.1.4 Step 4: Interpolation/Extrapolation of Field Strength 76
2.10.1.5 Step 5: Calculation of Correction Factors 78
2.10.1.6 Step 6: Calculation of Path Loss 79
2.11 Sakagami Extended Propagation Model 79
2.12 Free Space Loss 81
2.13 Diffraction 81
2.13.1 Knife-edge Diffraction 81
2.13.2 3 Knife-edge Deygout Method 82
2.13.3 Epstein-Peterson Method 84
2.13.4 Deygout Method with Correction 84
2.13.5 Millington Method 84
2.14 Shadow Fading Model 85
2.14.1 Shadowing Margin Calculation 90
2.14.1.1 Shadowing Margin Calculation in Predictions 90
2.14.1.2 Shadowing Margin Calculation in Monte-Carlo Simulations 92
2.14.2 Macro-Diversity Gains Calculation 92
2.14.2.1 Uplink Macro-Diversity Gain Evaluation 93
2.14.2.1.1 Shadowing Error PDF (n Signals) 93
2.14.2.1.2 Uplink Macro-Diversity Gain 95
2.14.2.2 Downlink Macro-Diversity Gain Evaluation 95
2.14.2.2.1 Shadowing Error PDF (n Signals) 95
2.14.2.2.2 Downlink Macro-Diversity Gain 98
2.15 Path Loss Matrices 98
2.15.1 Calculation Area Determination 99
2.15.2 Validity of Path Loss Matrices 99
2.15.3 Path Loss Tuning 100
2.15.3.1 Transmitter Path Loss Tuning 101
2.15.3.2 Repeater Path Loss Tuning 102
2.16 Coverage Prediction Export and Reports 102
2.16.1 Filtering Coverage Predictions at Export 102
2.16.2 Smoothing Coverage Predictions at Export 103
2.16.3 Examples of Prediction Export Filtering and Smoothing 104
2.16.4 Coverage Prediction Reports Over Focus/Computation Zones 105
3 GSM GPRS EDGE Networks 109
3.1 Signal Level Calculations 109
3.1.1 Point Analysis 109
3.1.1.1 Profile Tab 109
3.1.1.2 Reception Tab 109
3.1.2 Signal Level-based Coverage Predictions 110
3.1.2.1 Service Area Determination 110
3.1.2.1.1 All Servers 110
3.1.2.1.2 Best Signal Level and a Margin 110
3.1.2.1.3 Second Best Signal Level and a Margin 111

3.1.2.1.4 Best Signal Level per HCS Layer and a Margin ... 111
3.1.2.1.5 Second Best Signal Level per HCS Layer and a Margin ... 111
3.1.2.1.6 HCS Servers and a Margin ... 112
3.1.2.1.7 Highest Priority HCS Server and a Margin ... 112
3.1.2.1.8 Best Idle Mode Reselection Criterion (C2) ... 112
3.1.2.2 Coverage Display ... 113
3.1.2.2.1 Coverage Resolution ... 113
3.1.2.2.2 Display Types ... 113
3.2 Interference-based Calculations ... 114
3.2.1 Carrier-to-Interference Ratio Calculation ... 114
3.2.2 Point Analysis ... 118
3.2.3 Interference-based Coverage Predictions ... 118
3.2.3.1 Service Area Determination ... 118
3.2.3.2 Coverage Area Determination ... 118
3.2.3.2.1 Interference Condition Satisfied by At Least One TRX ... 118
3.2.3.2.2 Interference Condition Satisfied by The Worst TRX ... 119
3.2.3.3 Coverage Display ... 119
3.2.3.3.1 Coverage Resolution ... 119
3.2.3.3.2 Display Types ... 119
3.3 GPRS/EDGE Calculations ... 119
3.3.1 Coding Scheme Selection and Throughput Calculation Without Ideal Link Adaptation ... 120
3.3.1.1 Calculations Based on C ... 120
3.3.1.2 Calculations Based on C/I ... 120
3.3.1.3 Calculations Based on C/(I+N) ... 121
3.3.2 Coding Scheme Selection and Throughput Calculation With Ideal Link Adaptation ... 122
3.3.2.1 Calculations Based on C ... 122
3.3.2.2 Calculations Based on C/I ... 122
3.3.2.3 Calculations Based on C/(I+N) ... 122
3.3.3 Application Throughput Calculation ... 123
3.3.4 BLER Calculation ... 123
3.3.5 GPRS/EDGE Coverage Predictions ... 123
3.3.5.1 Service Area Determination ... 123
3.3.5.1.1 All Servers ... 124
3.3.5.1.2 Best Signal Level and a Margin ... 124
3.3.5.1.3 Second Best Signal Level and a Margin ... 124
3.3.5.1.4 Best Signal Level per HCS Layer and a Margin ... 124
3.3.5.1.5 Second Best Signal Level per HCS Layer and a Margin ... 124
3.3.5.1.6 HCS Servers and a Margin ... 125
3.3.5.1.7 Highest Priority HCS Server and a Margin ... 125
3.3.5.1.8 Best Idle Mode Reselection Criterion (C2) ... 125
3.3.5.2 Coverage Display ... 126
3.3.5.2.1 Coverage Resolution ... 126
3.3.5.2.2 Display Types ... 126
3.4 Codec Mode Selection and CQI Calculations ... 128
3.4.1 Circuit Quality Indicator Calculations ... 130
3.4.2 CQI Calculation Without Ideal Link Adaptation ... 130
3.4.2.1 Calculations Based on C/N ... 130
3.4.2.2 Calculations Based on C/(I+N) ... 131
3.4.3 CQI Calculation With Ideal Link Adaptation ... 131
3.4.3.1 Calculations Based on C/N ... 131
3.4.3.2 Calculations Based on C/(I+N) ... 131
3.4.4 Circuit Quality Indicators Coverage Predictions ... 132
3.4.4.1 Service Area Determination ... 132
3.4.4.1.1 All Servers ... 132
3.4.4.1.2 Best Signal Level and a Margin ... 132
3.4.4.1.3 Second Best Signal Level and a Margin ... 133
3.4.4.1.4 Best Signal Level per HCS Layer and a Margin ... 133
3.4.4.1.5 Second Best Signal Level per HCS Layer and a Margin ... 133
3.4.4.1.6 HCS Servers and a Margin ... 133
3.4.4.1.7 Highest Priority HCS Server and a Margin ... 134
3.4.4.2 Coverage Display ... 134
3.4.4.2.1 Coverage Resolution ... 134
3.4.4.2.2 Display Types ... 134
3.5 Traffic Analysis ... 135
3.5.1 Traffic Distribution ... 135
3.5.1.1 Normal Cells (Nonconcentric, No HCS Layer) ... 135
3.5.1.1.1 Circuit Switched Services ... 135

3.5.1.1.2 Packet Switched Services. 135
3.5.1.2 Concentric Cells 135
3.5.1.2.1 Circuit Switched Services 135
3.5.1.2.2 Packet Switched Services. 135
3.5.1.3 HCS Layers 136
3.5.1.3.1 Circuit Switched Services 136
3.5.1.3.2 Packet Switched Services. 136
3.5.2 Calculation of the Traffic Demand per Subcell 136
3.5.2.1 User Profile Traffic Maps 136
3.5.2.1.1 Normal Cells (Nonconcentric, No HCS Layer) 136
3.5.2.1.2 Concentric Cells 137
3.5.2.1.3 HCS Layers. 138
3.5.2.2 Sector Traffic Maps 141
3.5.2.2.1 Normal Cells (Nonconcentric, No HCS Layer) 141
3.5.2.2.2 Concentric Cells 142
3.5.2.2.3 HCS Layers. 143
3.6 Network Dimensioning 147
3.6.1 Dimensioning Models and Quality Graphs 147
3.6.1.1 Circuit Switched Traffic 147
3.6.1.2 Packet Switched Traffic. 147
3.6.1.2.1 Throughput 147
3.6.1.2.2 Delay 150
3.6.1.2.3 Blocking Probability 150
3.6.2 Network Dimensioning Process. 152
3.6.2.1 Network Dimensioning Engine 152
3.6.2.1.1 Inputs 152
3.6.2.1.2 Outputs 152
3.6.2.2 Network Dimensioning Steps 152
3.6.2.2.1 Step 1: Timeslots Required for CS Traffic 152
3.6.2.2.2 Step 2: TRXs Required for CS Traffic and Dedicated PS Timeslots 153
3.6.2.2.3 Step 3: Effective CS Blocking, Effective CS Traffic Overflow and Served CS Traffic 153
3.6.2.2.4 Step 4: TRXs to Add for PS Traffic 154
3.6.2.2.5 Step 5: Served PS Traffic 156
3.6.2.2.6 Step 6: Total Traffic Load 156
3.7 Key Performance Indicators Calculation 156
3.7.1 Circuit Switched Traffic. 157
3.7.1.1 Erlang B. 157
3.7.1.2 Erlang C. 157
3.7.1.3 Served Circuit Switched Traffic. 157
3.7.2 Packet Switched Traffic 157
3.7.2.1 Case 1: Total Traffic Demand > Dedicated + Shared Timeslots 158
3.7.2.1.1 Traffic Load 158
3.7.2.1.2 Packet Switched Traffic Overflow 158
3.7.2.1.3 Throughput Reduction Factor 158
3.7.2.1.4 Delay 158
3.7.2.1.5 Blocking Probability 158
3.7.2.1.6 Served Packet Switched Traffic 158
3.7.2.2 Case 2: Total Traffic Demand < Dedicated + Shared Timeslots 158
3.7.2.2.1 Traffic Load 158
3.7.2.2.2 Packet Switched Traffic Overflow 159
3.7.2.2.3 Throughput Reduction Factor 159
3.7.2.2.4 Delay 159
3.7.2.2.5 Blocking Probability 159
3.7.2.2.6 Served Packet Switched Traffic 159
3.8 Neighbour Allocation 159
3.8.1 Global Allocation for All Transmitters 159
3.8.2 Allocation for a Group of Transmitters or One Transmitter 162
3.8.3 Calculation of the Neighbour Importance 162
3.8.4 Appendix: Calculation of the Inter-Transmitter Distance 163
3.9 AFP Appendices 164
3.9.1 The AFP Cost Function 164
3.9.1.1 Cost Function 165
3.9.1.2 Cost Components 166
3.9.1.2.1 Separation Violation Cost Component 166
3.9.1.2.2 Interference Cost Component. 168
3.9.1.2.3 I_DIV, F_DIV and Other Advanced Cost Parameters 169

3.9.2 The AFP Blocked Traffic Cost 170
3.9.2.1 Calculation of New Traffic Loads Including Blocked Traffic Loads 171
3.9.2.2 Recalculation of CS and PS From Traffic Loads 172
3.9.2.3 Testing the Blocked Cost Using Traffic Analysis 173
3.9.3 Interference 173
3.9.3.1 Using Interferences 173
3.9.3.2 Cumulative Density Function of C/I Levels 173
3.9.3.3 Precise Definition 174
3.9.3.4 Precise Interference Distribution Strategy 174
3.9.3.4.1 Direct Availability of Precise Interference Distribution to the AFP 174
3.9.3.4.2 Efficient Calculation and Storage of Interference Distribution 174
3.9.3.4.3 Robustness of the IM 174
3.9.3.5 Traffic Load and Interference Information Discrimination 175

4 UMTS HSPA Networks 179

4.1 General Prediction Studies 179
4.1.1 Calculation Criteria 179
4.1.2 Point Analysis 179
4.1.2.1 Profile Tab 179
4.1.2.2 Reception Tab 180
4.1.3 Coverage Studies 180
4.1.3.1 Service Area Determination 180
4.1.3.1.1 All Servers 180
4.1.3.1.2 Best Signal Level and a Margin 180
4.1.3.1.3 Second Best Signal Level and a Margin 181
4.1.3.2 Coverage Display 181
4.1.3.2.1 Plot Resolution 181
4.1.3.2.2 Display Types 181
4.2 Definitions and Formulas 182
4.2.1 Inputs 182
4.2.2 Ec/I0 Calculation 189
4.2.3 DL Eb/Nt Calculation 190
4.2.4 UL Eb/Nt Calculation 191
4.3 Active Set Management 192
4.4 Simulations 192
4.4.1 Generating a Realistic User Distribution 193
4.4.1.1 Simulations Based on User Profile Traffic Maps 193
4.4.1.1.1 Circuit Switched Service (i) 193
4.4.1.1.2 Packet Switched Service (j) 194
4.4.1.2 Simulations Based on Sector Traffic Maps 197
4.4.1.2.1 Throughputs in Uplink and Downlink 197
4.4.1.2.2 Total Number of Users (All Activity Statuses) 198
4.4.1.2.3 Number of Users per Activity Status 198
4.4.2 Power Control Simulation 199
4.4.2.1 Algorithm Initialization 200
4.4.2.2 R99 Part of the Algorithm 200
4.4.2.3 HSDPA Part of the Algorithm 205
4.4.2.3.1 HSDPA Power Allocation 205
4.4.2.3.2 Number of HS-SCCH Channels and Maximum Number of HSDPA Bearer Users 206
4.4.2.3.3 HSDPA Bearer Allocation Process 206
4.4.2.3.4 Fast Link Adaptation Modelling 209
4.4.2.3.5 MIMO Modelling 219
4.4.2.3.6 Scheduling Algorithms 220
4.4.2.3.7 Dual-Cell HSDPA 222
4.4.2.4 HSUPA Part of the Algorithm 225
4.4.2.4.1 Admission Control 226
4.4.2.4.2 HSUPA Bearer Allocation Process 228
4.4.2.4.3 Noise Rise Scheduling 230
4.4.2.4.4 Radio Resource Control 234
4.4.2.5 Convergence Criteria 234
4.4.3 Results 235
4.4.3.1 R99 Related Results 235
4.4.3.2 HSPA Related Results 236
4.4.3.2.1 Statistics Tab 237
4.4.3.2.2 Mobiles Tab 237
4.4.3.2.3 Cells Tab 241

4.4.3.2.4 Sites Tab . . . 243
4.4.4 Appendices . . . 243
4.4.4.1 Admission Control in the R99 Part . . . 243
4.4.4.2 Resources Management . . . 243
4.4.4.2.1 OVSF Codes Management . . . 243
4.4.4.2.2 Channel Elements Management . . . 245
4.4.4.2.3 Iub Backhaul Throughput . . . 246
4.4.4.3 Downlink Load Factor Calculation . . . 247
4.4.4.3.1 Downlink Load Factor per Cell . . . 247
4.4.4.3.2 Downlink Load Factor per Mobile . . . 248
4.4.4.4 Uplink Load Factor Due to One User . . . 248
4.4.4.5 Inter-carrier Power Sharing Modelling . . . 250
4.4.4.6 Best Server Determination in Monte Carlo Simulations - Old Method . . . 251
4.5 UMTS HSPA Prediction Studies . . . 253
4.5.1 Point Analysis . . . 253
4.5.1.1 AS Analysis Tab . . . 253
4.5.1.1.1 Bar Graph and Pilot Sub-Menu . . . 254
4.5.1.1.2 Downlink Sub-Menu . . . 256
4.5.1.1.3 Uplink Sub-Menu . . . 261
4.5.2 Coverage Studies . . . 265
4.5.2.1 Pilot Quality Analysis . . . 265
4.5.2.1.1 Prediction Study Inputs . . . 266
4.5.2.1.2 Study Display Options . . . 266
4.5.2.2 Downlink Service Area Analysis . . . 267
4.5.2.2.1 Prediction Study Inputs . . . 267
4.5.2.2.2 Study Display Options . . . 267
4.5.2.3 Uplink Service Area Analysis . . . 269
4.5.2.3.1 Prediction Study Inputs . . . 269
4.5.2.3.2 Study Display Options . . . 269
4.5.2.4 Downlink Total Noise Analysis . . . 270
4.5.2.4.1 Study Inputs . . . 271
4.5.2.4.2 Analysis on the Best Carrier . . . 271
4.5.2.4.3 Analysis on a Specific Carrier . . . 271
4.5.2.5 HSDPA Prediction Study . . . 272
4.5.2.5.1 Prediction Study Inputs . . . 272
4.5.2.5.2 Study Display Options . . . 272
4.5.2.6 HSUPA Prediction Study . . . 276
4.5.2.6.1 Prediction Study Inputs . . . 277
4.5.2.6.2 Calculation Options . . . 277
4.5.2.6.3 Display Options . . . 277
4.6 Automatic Neighbour Allocation . . . 279
4.6.1 Neighbour Allocation for All Transmitters . . . 279
4.6.2 Neighbour Allocation for a Group of Transmitters or One Transmitter . . . 283
4.6.3 Importance Calculation . . . 283
4.6.3.1 Importance of Intra-carrier Neighbours . . . 283
4.6.3.2 Importance of Inter-carrier Neighbours . . . 285
4.6.4 Appendices . . . 286
4.6.4.1 Calculation of the Inter-Transmitter Distance . . . 286
4.7 Primary Scrambling Code Allocation . . . 286
4.7.1 Automatic Allocation Description . . . 286
4.7.1.1 Options and Constraints . . . 286
4.7.1.2 Allocation Process . . . 288
4.7.1.2.1 Single Carrier Network . . . 288
4.7.1.2.2 Multi-Carrier Network . . . 289
4.7.1.3 Priority Determination . . . 290
4.7.1.3.1 Cell Priority . . . 290
4.7.1.3.2 Transmitter Priority . . . 292
4.7.1.3.3 Site Priority . . . 292
4.7.2 Allocation Examples . . . 293
4.7.2.1 Allocation Strategies and Use a Maximum of Codes . . . 293
4.7.2.1.1 Strategy: Clustered . . . 293
4.7.2.1.2 Strategy: Distributed . . . 294
4.7.2.1.3 Strategy: ‘One Cluster per Site . . . 295
4.7.2.1.4 Strategy: ‘Distributed per Site . . . 295
4.7.2.2 Allocate Carriers Identically . . . 296
4.8 Automatic GSM-UMTS Neighbour Allocation . . . 296
4.8.1 Overview . . . 296

4.8.2 Automatic Allocation Description . . . 297
4.8.2.1 Algorithm Based on Distance . . . 297
4.8.2.2 Algorithm Based on Coverage Overlapping . . . 298
4.8.2.3 Appendices . . . 300
4.8.2.3.1 Delete Existing Neighbours Option . . . 300

5 LTE Networks . . . 303
5.1 Definitions . . . 303
5.2 Calculation Quick Reference . . . 307
5.2.1 Downlink Transmission Powers Calculation . . . 307
5.2.2 Co- and Adjacent Channel Overlaps Calculation . . . 310
5.2.3 Signal Level Calculation (DL) . . . 310
5.2.4 Noise Calculation (DL) . . . 312
5.2.5 Interference Calculation (DL) . . . 313
5.2.6 C/N Calculation (DL) . . . 317
5.2.7 C/(I+N) Calculation (DL) . . . 317
5.2.8 Signal Level Calculation (UL) . . . 319
5.2.9 Noise Calculation (UL) . . . 320
5.2.10 Interference Calculation (UL) . . . 320
5.2.11 Noise Rise Calculation (UL) . . . 320
5.2.12 C/N Calculation (UL) . . . 321
5.2.13 C/(I+N) Calculation (UL) . . . 321
5.2.14 Calculation of Downlink Cell Resources . . . 321
5.2.15 Calculation of Uplink Cell Resources . . . 322
5.2.16 Calculation of Downlink UE Capacity . . . 323
5.2.17 Calculation of Uplink UE Capacity . . . 323
5.2.18 Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation . . . 323
5.2.19 Scheduling and Radio Resource Management . . . 325
5.2.20 User Throughput Calculation . . . 326
5.3 Available Calculations . . . 327
5.3.1 Point Analysis . . . 327
5.3.1.1 Profile View . . . 327
5.3.1.2 Reception View . . . 327
5.3.1.3 Interference View . . . 328
5.3.2 Coverage Predictions . . . 328
5.3.2.1 Downlink Signal Level Coverage Predictions . . . 328
5.3.2.2 Effective Signal Analysis Coverage Predictions . . . 329
5.3.2.3 C/(I+N)-based Coverage Predictions . . . 330
5.3.3 Calculations on Subscriber Lists . . . 332
5.3.4 Monte Carlo Simulations . . . 333
5.3.4.1 User Distribution . . . 333
5.3.4.1.1 Simulations Based on User Profile Traffic Maps and Subscriber Lists . . . 333
5.3.4.1.2 Simulations Based on Sector Traffic Maps . . . 335
5.3.4.2 Simulation Process . . . 336
5.4 Calculation Details . . . 340
5.4.1 Downlink Transmission Power Calculation . . . 340
5.4.2 Co- and Adjacent Channel Overlaps Calculation . . . 347
5.4.2.1 Conversion From Channel Numbers to Start and End Frequencies . . . 348
5.4.2.2 Co-Channel Overlap Calculation . . . 349
5.4.2.3 Adjacent Channel Overlap Calculation . . . 349
5.4.2.4 Total Overlap Ratio Calculation . . . 350
5.4.3 Signal Level and Signal Quality Calculations . . . 351
5.4.3.1 Signal Level Calculation (DL) . . . 351
5.4.3.2 Noise Calculation (DL) . . . 354
5.4.3.3 Interference Calculation (DL) . . . 355
5.4.3.4 C/N Calculation (DL) . . . 365
5.4.3.5 C/(I+N) and Bearer Calculation (DL) . . . 367
5.4.3.6 Signal Level Calculation (UL) . . . 372
5.4.3.7 Noise Calculation (UL) . . . 374
5.4.3.8 Interference Calculation (UL) . . . 375
5.4.3.8.1 Interfering Signal Level Calculation (UL) . . . 375
5.4.3.8.2 Noise Rise Calculation (UL) . . . 377
5.4.3.9 C/N Calculation (UL) . . . 378
5.4.3.10 C/(I+N) and Bearer Calculation (UL) . . . 381
5.4.4 Best Server Determination . . . 384
5.4.5 Service Area Calculation . . . 385

5.4.6 Throughput Calculation . . . 385
5.4.6.1 Calculation of Total Cell Resources . . . 385
5.4.6.1.1 Calculation of Downlink Cell Resources . . . 386
5.4.6.1.2 Calculation of Uplink Cell Resources . . . 389
5.4.6.2 Calculation UE Capacities . . . 391
5.4.6.2.1 Calculation of Downlink UE Capacity . . . 391
5.4.6.2.2 Calculation of Uplink UE Capacity . . . 391
5.4.6.3 Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation . . . 392
5.4.7 Scheduling and Radio Resource Management . . . 397
5.4.7.1 Scheduling and Radio Resource Allocation . . . 397
5.4.7.2 User Throughput Calculation . . . 403
5.5 Automatic Planning Algorithms . . . 405
5.5.1 Automatic Neighbour Planning . . . 405
5.5.2 Automatic Inter-technology Neighbour Planning . . . 408
5.5.3 Automatic Frequency Planning Using the AFP . . . 411
5.5.3.1 Constraint and Relationship Weights . . . 411
5.5.3.2 Cost Calculation . . . 412
5.5.3.3 AFP Algorithm . . . 413
5.5.4 Automatic Physical Cell ID Planning Using the AFP . . . 413
5.5.4.1 Constraint and Relationship Weights . . . 414
5.5.4.2 Cost Calculation . . . 415
5.5.4.3 AFP Algorithm . . . 417
5.5.5 Appendices . . . 417
5.5.5.1 Interference Matrix Calculation . . . 417
5.5.5.2 Distance Importance Calculation . . . 418

6 3GPP Multi-RAT Networks . . . 423

6.1 Simulations in Multi-RAT Projects . . . 423
6.1.1 Inputs . . . 423
6.1.2 Simulation Process . . . 423
6.1.2.1 Generating a Realistic User Distribution . . . 424
6.1.2.2 Simulations Based on User Profile Traffic Maps . . . 424
6.1.2.2.1 Constant Bit Rate Service (i) . . . 424
6.1.2.2.2 Variable Bit Rate Service (j) . . . 425
6.1.2.3 Simulations Based on Sector Traffic Maps . . . 429
6.1.2.3.1 Throughputs in Uplink and Downlink . . . 429
6.1.2.3.2 Total Number of Users (All Activity Statuses) . . . 430
6.1.2.3.3 Number of Users per Activity Status . . . 430
6.1.2.3.4 Distribution of terminals and mobilities . . . 431
6.1.2.4 Search and Selection of serving technologies . . . 431
6.1.2.5 Radio Resource Management in GSM . . . 432
6.1.2.5.1 MSA Definition . . . 432
6.1.2.5.2 GSM Simulation Process . . . 432
6.1.2.5.3 Servers Selection . . . 434
6.1.2.5.4 Codec Mode Assignment and DL Power Control . . . 435
6.1.2.5.5 Coding Scheme Assignment, Throughput Evaluation and DL Power Control . . . 435
6.1.2.5.6 Subcell Traffic Load Management . . . 436
6.1.2.5.7 Half-Rate Traffic Ratio Management . . . 436
6.1.2.5.8 DL Power Control Gain Management . . . 437
6.1.2.5.9 DTX Gain Management . . . 437
6.1.2.5.10 GSM Simulation Results . . . 437

7 CDMA2000 Networks . . . 441

7.1 General Prediction Studies . . . 441
7.1.1 Calculation Criteria . . . 441
7.1.2 Point Analysis . . . 441
7.1.2.1 Profile Tab . . . 441
7.1.2.2 Reception Tab . . . 442
7.1.3 Coverage Studies . . . 442
7.1.3.1 Service Area Determination . . . 442
7.1.3.1.1 All Servers . . . 442
7.1.3.1.2 Best Signal Level and a Margin . . . 442
7.1.3.1.3 Second Best Signal Level and a Margin . . . 443
7.1.3.2 Coverage Display . . . 443
7.1.3.2.1 Plot Resolution . . . 443
7.1.3.2.2 Display Types . . . 443

7.2 Definitions and Formulas . . . 444
7.2.1 Parameters Used for CDMA2000 1xRTT Modelling. . . . 444
7.2.1.1 Inputs . . . 444
7.2.1.2 Ec/I0 Calculation . . . 449
7.2.1.3 DL Eb/Nt Calculation. . . . 449
7.2.1.4 UL Eb/Nt Calculation. . . . 450
7.2.1.5 Simulation Results. . . . 452
7.2.2 Parameters Used for CDMA2000 1xEV-DO Modelling . . . 453
7.2.2.1 Inputs . . . 453
7.2.2.2 Ec/I0 and Ec/Nt Calculations . . . 457
7.2.2.3 UL Eb/Nt Calculation. . . . 458
7.2.2.4 Simulation Results. . . . 460
7.3 Active Set Management . . . 461
7.4 Simulations. . . . 462
7.4.1 Generating a Realistic User Distribution . . . 462
7.4.1.1 Number of Users, User Activity Status and User Data Rate . . . 462
7.4.1.1.1 Simulations Based on User Profile Traffic Maps . . . 462
7.4.1.1.2 Simulations Based on Sector Traffic Maps . . . 465
7.4.1.2 Transition Flags for 1xEV-DO Rev.0 User Data Rates . . . 470
7.4.1.3 User Geographical Position . . . 471
7.4.2 Network Regulation Mechanism . . . 471
7.4.2.1 CDMA2000 1xRTT Power Control Simulation Algorithm. . . . 471
7.4.2.1.1 Algorithm Initialization . . . 472
7.4.2.1.2 Presentation of the Algorithm . . . 472
7.4.2.1.3 Convergence Criterion . . . 479
7.4.2.2 CDMA2000 1xEV-DO Power/Data Rate Control Simulation Algorithm . . . 480
7.4.2.2.1 Algorithm Initialization . . . 481
7.4.2.2.2 Presentation of the Algorithm . . . 481
7.4.2.2.3 Convergence Criterion . . . 489
7.4.3 Appendices . . . 489
7.4.3.1 Admission Control. . . . 489
7.4.3.2 Resources Management. . . . 489
7.4.3.2.1 Walsh Code Management. . . . 489
7.4.3.2.2 Channel Element Management . . . 490
7.4.3.3 Downlink Load Factor Calculation . . . 491
7.4.3.3.1 Downlink Load Factor per Cell . . . 491
7.4.3.3.2 Downlink Load Factor per Mobile . . . 493
7.4.3.4 Best Server Determination in Monte Carlo Simulations - Old Method . . . 493
7.5 CDMA2000 Prediction Studies . . . 495
7.5.1 Point Analysis: The AS Analysis Tab . . . 495
7.5.1.1 Bar Graph and Pilot Sub-Menu . . . 495
7.5.1.2 Downlink Sub-Menu . . . 497
7.5.1.2.1 CDMA2000 1xRTT . . . 497
7.5.1.2.2 CDMA2000 1xEV-DO . . . 502
7.5.1.3 Uplink Sub-Menu . . . 504
7.5.1.3.1 CDMA2000 1xRTT . . . 504
7.5.1.3.2 CDMA2000 1xEV-DO . . . 508
7.5.2 Coverage Studies . . . 514
7.5.2.1 Pilot Quality Analysis . . . 514
7.5.2.2 Downlink Service Area Analysis . . . 516
7.5.2.2.1 CDMA2000 1xRTT . . . 516
7.5.2.2.2 CDMA2000 1xEV-DO . . . 517
7.5.2.3 Uplink Service Area Analysis . . . 519
7.5.2.3.1 CDMA2000 1xRTT . . . 519
7.5.2.3.2 CDMA2000 1xEV-DO . . . 521
7.5.2.4 Downlink Total Noise Analysis . . . 524
7.5.2.4.1 Analysis on the Best Carrier . . . 524
7.5.2.4.2 Analysis on a Specific Carrier . . . 525
7.6 Automatic Neighbour Allocation . . . 525
7.6.1 Neighbour Allocation for all Transmitters . . . 526
7.6.2 Neighbour Allocation for a Group of Transmitters or One Transmitter . . . 529
7.6.3 Importance Calculation . . . 529
7.6.3.1 Importance of Intra-carrier Neighbours . . . 529
7.6.3.2 Importance of Inter-carrier Neighbours . . . 531
7.6.4 Appendices . . . 532
7.6.4.1 Calculation of the Inter-Transmitter Distance . . . 532

7.7 PN Offset Allocation . . . 532
7.7.1 Automatic Allocation Description . . . 532
7.7.1.1 Options and Constraints . . . 532
7.7.1.2 Allocation Process . . . 534
7.7.1.2.1 Single Carrier Network . . . 534
7.7.1.2.2 Multi-Carrier Network . . . 534
7.7.1.2.3 Difference between Adjacent and Distributed PN-Clusters . . . 535
7.7.1.3 Priority Determination . . . 535
7.7.1.3.1 Cell Priority . . . 535
7.7.1.3.2 Transmitter Priority . . . 537
7.7.1.3.3 Site Priority . . . 537
7.7.2 Allocation Examples . . . 538
7.7.2.1 Strategy: PN Offset per Cell . . . 538
7.7.2.2 Strategy: Adjacent PN-Clusters Per Site . . . 539
7.7.2.3 Strategy: ‘Distributed PN-Clusters Per Site . . . 539
7.8 Automatic GSM-CDMA Neighbour Allocation . . . 539
7.8.1 Overview . . . 539
7.8.2 Automatic Allocation Description . . . 540
7.8.2.1 Algorithm Based on Distance . . . 540
7.8.2.2 Algorithm Based on Coverage Overlapping . . . 541
7.8.2.3 Delete Existing Neighbours Option . . . 543

8 TD-SCDMA Networks . . . 547
8.1 Definitions and Formulas . . . 547
8.1.1 Inputs . . . 547
8.1.2 P-CCPCH Eb/Nt and C/I Calculation . . . 552
8.1.3 DwPCH C/I Calculation . . . 552
8.1.4 DL TCH Eb/Nt and C/I Calculation . . . 553
8.1.5 UL TCH Eb/Nt and C/I Calculation . . . 553
8.1.6 Interference Calculation . . . 553
8.1.7 HSDPA Dynamic Power Calculations . . . 554
8.2 Signal Level Based Calculations . . . 554
8.2.1 Point Analysis . . . 554
8.2.1.1 Profile Tab . . . 555
8.2.1.2 Reception Tab . . . 555
8.2.2 RSCP Based Coverage Predictions . . . 555
8.2.2.1 Calculation Criteria . . . 555
8.2.2.2 P-CCPCH RSCP Coverage Prediction . . . 556
8.2.2.2.1 Coverage Condition . . . 556
8.2.2.2.2 Coverage Display . . . 556
8.2.2.3 Best Server P-CCPCH Coverage Prediction . . . 557
8.2.2.4 P-CCPCH Pollution Analysis Coverage Prediction . . . 557
8.2.2.5 DwPCH RSCP Coverage Prediction . . . 557
8.2.2.5.1 Coverage Condition . . . 557
8.2.2.5.2 Coverage Display . . . 557
8.2.2.6 UpPCH RSCP Coverage Prediction . . . 558
8.2.2.6.1 Coverage Condition . . . 558
8.2.2.6.2 Coverage Display . . . 558
8.2.2.7 Baton Handover Coverage Prediction . . . 559
8.2.2.7.1 Coverage Condition . . . 559
8.2.2.7.2 Coverage Display . . . 559
8.2.2.8 Scrambling Code Interference Analysis . . . 559
8.3 Monte Carlo Simulations . . . 559
8.3.1 Generating a Realistic User Distribution . . . 560
8.3.1.1 Simulations Based on User Profile Traffic Maps . . . 560
8.3.1.1.1 Circuit Switched Service (i) . . . 560
8.3.1.1.2 Packet Switched Service (j) . . . 561
8.3.1.2 Simulations Based on Sector Traffic Maps . . . 563
8.3.1.2.1 Throughputs in Uplink and Downlink . . . 563
8.3.1.2.2 Total Number of Users (All Activity Statuses) . . . 564
8.3.1.2.3 Number of Users per Activity Status . . . 565
8.3.2 Power Control Simulation . . . 565
8.3.2.1 Algorithm Initialisation . . . 566
8.3.2.2 R99 Part of the Algorithm . . . 566
8.3.2.2.1 Determination of Mi’s Best Server (SBS(Mi)) . . . 566
8.3.2.2.2 Dynamic Channel Allocation . . . 567

8.3.2.2.3 Uplink Power Control . . . 569
8.3.2.2.4 Downlink Power Control . . . 570
8.3.2.2.5 Uplink Signals Update . . . 573
8.3.2.2.6 Downlink Signals Update . . . 573
8.3.2.2.7 Control of Radio Resource Limits (Downlink Traffic Power and Uplink Load) . . . 573
8.3.2.3 HSDPA Part of the Algorithm . . . 574
8.3.2.3.1 HSDPA Power Allocation . . . 574
8.3.2.3.2 Connection Status and Number of HSDPA Users . . . 576
8.3.2.3.3 HSDPA Admission Control . . . 576
8.3.2.3.4 HSDPA Dynamic Channel Allocation . . . 577
8.3.2.3.5 Ressource Unit Saturation . . . 577
8.3.2.4 Convergence Criteria . . . 577
8.4 TD-SCDMA Prediction Studies . . . 578
8.4.1 P-CCPCH Reception Analysis (Eb/Nt) or (C/I) . . . 578
8.4.2 DwPCH Reception Analysis (C/I) . . . 579
8.4.3 Downlink TCH RSCP Coverage . . . 581
8.4.4 Uplink TCH RSCP Coverage . . . 582
8.4.5 Downlink Total Noise . . . 583
8.4.6 Downlink Service Area Analysis (Eb/Nt) or (C/I) . . . 583
8.4.7 Uplink Service Area Analysis (Eb/Nt) or (C/I) . . . 585
8.4.8 Effective Service Area Analysis (Eb/Nt) or (C/I) . . . 587
8.4.9 Cell to Cell Interference . . . 588
8.4.10 UpPCH Interference . . . 589
8.4.11 HSDPA Predictions . . . 589
8.5 Smart Antenna Modelling . . . 590
8.5.1 Modelling in Simulations . . . 591
8.5.1.1 Grid of Beams Modelling . . . 591
8.5.1.2 Adaptive Beam Modelling . . . 592
8.5.1.3 Statistical Modelling . . . 593
8.5.1.4 Beamforming Smart Antenna Models . . . 593
8.5.1.5 3rd Party Smart Antenna Modelling . . . 594
8.5.2 Construction of the Geographic Distributions . . . 594
8.5.3 Modelling in Coverage Predictions . . . 595
8.5.4 HSDPA Quality and Throughput Analysis . . . 596
8.5.4.1 Fast Link Adaptation Modelling . . . 596
8.5.4.1.1 CQI Based on P-CCPCH Quality . . . 596
8.5.4.1.2 CQI Based on HS-PDSCH Quality . . . 600
8.5.4.2 Coverage Prediction Display Options . . . 601
8.5.4.2.1 Colour per CQI . . . 601
8.5.4.2.2 Colour per Peak Throughput . . . 602
8.5.4.2.3 Colour per HS-PDSCH Ec/Nt . . . 602
8.6 N-Frequency Mode and Carrier Allocation . . . 602
8.6.1 Automatic Carrier Allocation . . . 602
8.7 Neighbour Allocation . . . 603
8.7.1 Neighbour Allocation for All Transmitters . . . 603
8.7.2 Neighbour Allocation for a Group of Transmitters or One Transmitter . . . 606
8.7.3 Importance Calculation . . . 606
8.7.4 Appendix: Calculation of the Inter-Transmitter Distance . . . 608
8.8 Scrambling Code Allocation . . . 608
8.8.1 Automatic Allocation Description . . . 609
8.8.1.1 Allocation Constraints and Options . . . 609
8.8.1.2 Allocation Strategies . . . 610
8.8.1.3 Allocation Process . . . 610
8.8.1.3.1 Single Carrier Network . . . 610
8.8.1.3.2 Multi-Carrier Network . . . 611
8.8.1.4 Priority Determination . . . 612
8.8.1.4.1 Cell Priority . . . 612
8.8.1.4.2 Transmitter Priority . . . 614
8.8.1.4.3 Site Priority . . . 615
8.8.2 Scrambling Code Allocation Example . . . 615
8.8.2.1 Single Carrier Network . . . 615
8.8.2.1.1 Strategy: Clustered . . . 616
8.8.2.1.2 Strategy: Distributed per Cell . . . 616
8.8.2.1.3 Strategy: One SYNC_DL Code per Site . . . 617
8.8.2.1.4 Strategy: Distributed per Site . . . 617
8.8.2.2 Multi Carrier Network . . . 617

8.9 Automatic GSM/TD-SCDMA Neighbour Allocation . . . 618
8.9.1 Automatic Allocation Description . . . 618
8.9.1.1 Algorithm Based on Distance . . . 619
8.9.1.2 Algorithm Based on Coverage Overlapping . . . 619
8.9.1.3 Appendices . . . 621
8.9.1.3.1 Delete Existing Neighbours Option . . . 621

9 WiMAX BWA Networks . . . 625
9.1 Definitions . . . 625
9.2 Calculation Quick Reference . . . 629
9.2.1 Co- and Adjacent Channel Overlaps Calculation . . . 629
9.2.2 Preamble Signal Level Calculation . . . 630
9.2.3 Preamble Noise Calculation . . . 631
9.2.4 Preamble Interference Calculation . . . 631
9.2.5 Preamble C/N Calculation . . . 631
9.2.6 Preamble C/(I+N) Calculation . . . 631
9.2.7 Traffic and Pilot Signal Level Calculation (DL) . . . 631
9.2.8 Traffic and Pilot Noise Calculation (DL) . . . 632
9.2.9 Traffic and Pilot Interference Calculation (DL) . . . 632
9.2.10 Traffic and Pilot C/N Calculation (DL) . . . 634
9.2.11 Traffic and Pilot C/(I+N) Calculation (DL) . . . 634
9.2.12 Traffic Signal Level Calculation (UL) . . . 634
9.2.13 Traffic Noise Calculation (UL) . . . 635
9.2.14 Traffic Interference Calculation (UL) . . . 635
9.2.15 Traffic C/N Calculation (UL) . . . 636
9.2.16 Traffic C/(I+N) Calculation (UL) . . . 636
9.2.17 Calculation of Total Cell Resources . . . 636
9.2.18 Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation . . . 637
9.2.19 Scheduling and Radio Resource Management . . . 638
9.2.20 User Throughput Calculation . . . 640
9.3 Available Calculations . . . 641
9.3.1 Point Analysis . . . 641
9.3.1.1 Profile View . . . 641
9.3.1.2 Reception View . . . 641
9.3.1.3 Interference View . . . 642
9.3.2 Coverage Predictions . . . 642
9.3.2.1 Preamble Signal Level Coverage Predictions . . . 642
9.3.2.2 Effective Signal Analysis Coverage Predictions . . . 643
9.3.2.3 C/(I+N)-based Coverage Predictions . . . 644
9.3.3 Calculations on Subscriber Lists . . . 646
9.3.4 Monte Carlo Simulations . . . 646
9.3.4.1 User Distribution . . . 647
9.3.4.1.1 Simulations Based on User Profile Traffic Maps and Subscriber Lists . . . 647
9.3.4.1.2 Simulations Based on Sector Traffic Maps . . . 649
9.3.4.2 Simulation Process . . . 650
9.4 Calculation Details . . . 653
9.4.1 Co- and Adjacent Channel Overlaps Calculation . . . 653
9.4.1.1 Conversion From Channel Numbers to Start and End Frequencies . . . 654
9.4.1.2 Co-Channel Overlap Calculation . . . 655
9.4.1.3 Adjacent Channel Overlap Calculation . . . 655
9.4.1.4 FDD – TDD Overlap Ratio Calculation . . . 656
9.4.1.5 Total Overlap Ratio Calculation . . . 657
9.4.2 Preamble Signal Level and Quality Calculations . . . 658
9.4.2.1 Preamble Signal Level Calculation . . . 658
9.4.2.2 Preamble Noise Calculation . . . 659
9.4.2.3 Preamble Interference Calculation . . . 660
9.4.2.4 Preamble C/N Calculation . . . 662
9.4.2.5 Preamble C/(I+N) Calculation . . . 662
9.4.3 Best Server Determination . . . 663
9.4.4 Service Area Calculation . . . 664
9.4.5 Permutation Zone Selection . . . 665
9.4.6 Traffic and Pilot Signal Level and Quality Calculations . . . 666
9.4.6.1 Traffic and Pilot Signal Level Calculation (DL) . . . 666
9.4.6.2 Traffic and Pilot Noise Calculation (DL) . . . 667
9.4.6.3 Traffic and Pilot Interference Calculation (DL) . . . 669
9.4.6.3.1 Traffic and Pilot Interference Signal Levels Calculation (DL) . . . 669

9.4.6.3.2 Effective Traffic and Pilot Interference Calculation (DL) 672
9.4.6.4 Traffic and Pilot C/N Calculation (DL) 676
9.4.6.5 Traffic and Pilot C/(I+N) and Bearer Calculation (DL). 678
9.4.6.6 Traffic Signal Level Calculation (UL). 680
9.4.6.7 Traffic Noise Calculation (UL). 681
9.4.6.8 Traffic Interference Calculation (UL) 682
9.4.6.8.1 Traffic Interference Signal Levels Calculation (UL) 682
9.4.6.8.2 Noise Rise Calculation (UL) 684
9.4.6.9 Traffic C/N Calculation (UL) 685
9.4.6.10 Traffic C/(I+N) and Bearer Calculation (UL) 687
9.4.7 Throughput Calculation 691
9.4.7.1 Calculation of Total Cell Resources 691
9.4.7.1.1 Calculation of Sampling Frequency 691
9.4.7.1.2 Calculation of Symbol Duration 692
9.4.7.1.3 Calculation of Total Cell Resources - TDD Networks 692
9.4.7.1.4 Calculation of Total Cell Resources - FDD Networks. 694
9.4.7.2 Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation 694
9.4.8 Scheduling and Radio Resource Management 698
9.4.8.1 Scheduling and Radio Resource Allocation. 698
9.4.8.2 User Throughput Calculation 707
9.5 Automatic Planning Algorithms 708
9.5.1 Automatic Neighbour Planning. 708
9.5.2 Automatic Inter-technology Neighbour Planning 712
9.5.3 Automatic Frequency Planning Using the AFP. 715
9.5.3.1 Constraint and Relationship Weights 715
9.5.3.2 Cost Calculation. 716
9.5.3.3 AFP Algorithm 717
9.5.4 Automatic Preamble Index Planning Using the AFP 717
9.5.4.1 Constraint and Relationship Weights 718
9.5.4.2 Cost Calculation. 719
9.5.4.3 AFP Algorithm 721
9.5.5 Automatic Zone PermBase Planning Using the AFP 721
9.5.5.1 Constraint and Relationship Weights 721
9.5.5.2 Cost Calculation. 722
9.5.5.3 AFP Algorithm 723
9.5.6 Appendices 723
9.5.6.1 Interference Matrix Calculation. 723
9.5.6.2 Distance Importance Calculation. 724

10 Wi-Fi Networks 729
10.1 Definitions 729
10.2 Calculation Quick Reference. 732
10.2.1 Co- and Adjacent Channel Overlaps Calculation 732
10.2.2 Signal Level Calculation (DL) 733
10.2.3 Noise Calculation (DL) 733
10.2.4 Interference Calculation (DL) 733
10.2.5 C/N Calculation (DL). 733
10.2.6 C/(I+N) Calculation (DL) 733
10.2.7 Signal Level Calculation (UL) 734
10.2.8 Noise Calculation (UL) 734
10.2.9 Interference Calculation (UL) 734
10.2.10 C/N Calculation (UL). 735
10.2.11 C/(I+N) Calculation (UL) 735
10.2.12 Calculation of Total Cell Resources. 735
10.2.13 Channel Throughput and Cell Capacity 735
10.2.14 Scheduling and Radio Resource Management 736
10.2.15 User Throughput Calculation 737
10.3 Available Calculations 737
10.3.1 Point Analysis 737
10.3.1.1 Profile View 737
10.3.1.2 Reception View 738
10.3.1.3 Interference View 738
10.3.2 Coverage Predictions 738
10.3.2.1 Signal Level Coverage Predictions 738
10.3.2.2 Effective Signal Analysis Coverage Predictions. 739
10.3.2.3 C/(I+N)-based Coverage Predictions 740

10.3.3 Calculations on Subscriber Lists . . . 742
10.3.4 Monte Carlo Simulations . . . 742
10.3.4.1 User Distribution . . . 742
10.3.4.1.1 Simulations Based on User Profile Traffic Maps and Subscriber Lists . . . 743
10.3.4.1.2 Simulations Based on Sector Traffic Maps . . . 744
10.3.4.2 Simulation Process . . . 745
10.4 Calculation Details . . . 747
10.4.1 Co- and Adjacent Channel Overlaps Calculation . . . 747
10.4.1.1 Conversion From Channel Numbers to Start and End Frequencies . . . 748
10.4.1.2 Co-Channel Overlap Calculation . . . 749
10.4.1.3 Adjacent Channel Overlap Calculation . . . 749
10.4.1.4 Total Overlap Ratio Calculation . . . 750
10.4.2 Signal Level and Quality Calculations . . . 751
10.4.2.1 Signal Level Calculation (DL) . . . 751
10.4.2.2 Noise Calculation (DL) . . . 752
10.4.2.3 Interference Calculation (DL) . . . 753
10.4.2.4 C/N Calculation (DL) . . . 754
10.4.2.5 C/(I+N) and Bearer Calculation (DL) . . . 755
10.4.2.6 Signal Level Calculation (UL) . . . 757
10.4.2.7 Noise Calculation (UL) . . . 758
10.4.2.8 Interference Calculation (UL) . . . 759
10.4.2.8.1 Interference Signal Levels Calculation (UL) . . . 759
10.4.2.8.2 Noise Rise Calculation (UL) . . . 759
10.4.2.9 C/N Calculation (UL) . . . 760
10.4.2.10 C/(I+N) and Bearer Calculation (UL) . . . 761
10.4.3 Best Server Determination . . . 763
10.4.4 Service Area Calculation . . . 764
10.4.5 Throughput Calculation . . . 764
10.4.5.1 Calculation of Total Cell Resources . . . 764
10.4.5.2 Channel Throughput and Cell Capacity Calculation . . . 765
10.4.6 Scheduling and Radio Resource Management . . . 767
10.4.6.1 Scheduling and Radio Resource Allocation . . . 768
10.4.6.2 User Throughput Calculation . . . 770

Chapter 1

Antennas and Equipment

This chapter provides information about the calculations related to antennas and other equipment in radio networks.

In this chapter, the following are explained:

- "Antenna Attenuation" on page 21
- "Antenna Pattern Smoothing" on page 23
- "Power Received From Secondary Antennas" on page 25
- "Transmitter Radio Equipment" on page 26
- "Repeaters and Remote Antennas" on page 28
- "Beamforming Smart Antenna Models" on page 41

1 Antennas and Equipment

1.1 Antenna Attenuation

To determine the transmitter antenna attenuation, **9955** calculates the accurate azimuth and tilt angles and performs 3D interpolation of the horizontal and vertical patterns.

1.1.1 Calculation of Azimuth and Tilt Angles

From the direction of the transmitter antenna and the receiver position relative to the transmitter, **9955** determines the receiver position relative to the direction of the transmitter antenna (i.e. the direction of the transmitter-receiver path in the transmitter antenna coordinate system).

a_{Tx} and e_{Tx} are respectively the transmitter (Tx) antenna azimuth and tilt in the coordinate system $S_0(\vec{x}, \vec{y}, \vec{z})$.

a_{Rx} and e_{Rx} are respectively the azimuth and tilt of the receiver (Rx) in the coordinate system $S_0(\vec{x}, \vec{y}, \vec{z})$.

d is the distance between the transmitter (Tx) and the receiver (Rx).

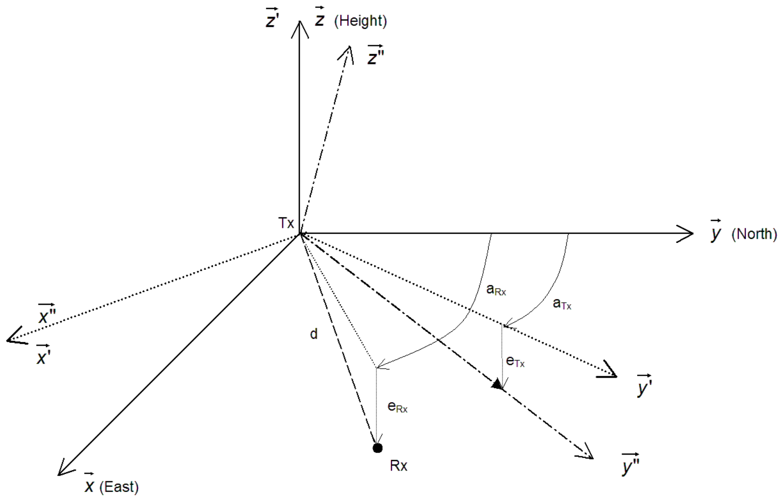


Figure 1.1: Azimuth and Tilt Computation

In the coordinate system $S_0(\vec{x}, \vec{y}, \vec{z})$, the receiver coordinates are:

$$\begin{bmatrix} x_{Rx} \\ y_{Rx} \\ z_{Rx} \end{bmatrix} = \begin{bmatrix} \cos(e_{Rx}) \cdot \sin(a_{Rx}) \cdot d \\ \cos(e_{Rx}) \cdot \cos(a_{Rx}) \cdot d \\ -\sin(e_{Rx}) \cdot d \end{bmatrix} \quad (1)$$

Let *az* and *el* respectively be the azimuth and tilt of the receiver in the transmitter antenna coordinate system $S_{Tx}(\vec{x}", \vec{y}", \vec{z}")$. These angles describe the direction of the transmitter-receiver path in the transmitter antenna coordinate system. Therefore, the receiver coordinates in $S_{Tx}(\vec{x}", \vec{y}", \vec{z}")$ are:

$$\begin{bmatrix} x"_{Rx} \\ y"_{Rx} \\ z"_{Rx} \end{bmatrix} = \begin{bmatrix} \cos(el) \cdot \sin(az) \cdot d \\ \cos(el) \cdot \cos(az) \cdot d \\ -\sin(el) \cdot d \end{bmatrix} \quad (2)$$

According to the figure above, we have the following relations:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos(a_{Tx}) & -\sin(a_{Tx}) & 0 \\ \sin(a_{Tx}) & \cos(a_{Tx}) & 0 \\ 0 & 0 & 1 \end{bmatrix} \bullet \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad (3)$$

and

$$\begin{bmatrix} x'' \\ y'' \\ z'' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(e_{Tx}) & -\sin(e_{Tx}) \\ 0 & \sin(e_{Tx}) & \cos(e_{Tx}) \end{bmatrix} \bullet \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} \qquad (4)$$

Therefore, the relation between the system $S_0(\hat{x}, \hat{y}, \hat{z})$ and the transmitter antenna system $S_{Tx}(\hat{x}'', \hat{y}'', \hat{z}'')$ is:

$$\begin{bmatrix} x'' \\ y'' \\ z'' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(e_{Tx}) & -\sin(e_{Tx}) \\ 0 & \sin(e_{Tx}) & \cos(e_{Tx}) \end{bmatrix} \bullet \begin{bmatrix} \cos(a_{Tx}) & -\sin(a_{Tx}) & 0 \\ \sin(a_{Tx}) & \cos(a_{Tx}) & 0 \\ 0 & 0 & 1 \end{bmatrix} \bullet \begin{bmatrix} x \\ y \\ z \end{bmatrix} \qquad (5)$$

We get,

$$\begin{bmatrix} x'' \\ y'' \\ z'' \end{bmatrix} = \begin{bmatrix} \cos(a_{Tx}) & -\sin(a_{Tx}) & 0 \\ \cos(e_{Tx}) \cdot \sin(a_{Tx}) & \cos(e_{Tx}) \cdot \cos(a_{Tx}) & -\sin(e_{Tx}) \\ \sin(e_{Tx}) \cdot \sin(a_{Tx}) & \sin(e_{Tx}) \cdot \cos(a_{Tx}) & \cos(e_{Tx}) \end{bmatrix} \bullet \begin{bmatrix} x \\ y \\ z \end{bmatrix} \qquad (6)$$

Then, substituting the receiver coordinates in the system S_0 from Eq. (1) and the receiver coordinates in the system S_{Tx} from Eq. (2) in Eq. (6) leads to a system where two solutions are possible:

1st solution: If $a_{Rx} = a_{Tx}$, then $az = 0$ and $el = e_{Rx} - e_{Tx}$

2nd solution: If $a_{Rx} \neq a_{Tx}$, then

$$az = atan\left[\frac{1}{\frac{\cos(e_{Tx})}{\tan(a_{Rx} - a_{Tx})} + \frac{\sin(e_{Tx}) \cdot \tan(e_{Rx})}{\sin(a_{Rx} - a_{Tx})}}\right]$$

and

$$el = atan\left[\sin(az) \cdot \left\{\frac{-\sin(e_{Tx})}{\tan(a_{Rx} - a_{Tx})} + \frac{\cos(e_{Tx}) \cdot \tan(e_{Rx})}{\sin(a_{Rx} - a_{Tx})}\right\}\right]$$

If $\sin(az) \cdot \sin(a_{Rx} - a_{Tx}) < 0$, then $az = az + 180$

1.1.2 Antenna Pattern 3D Interpolation

The direction of the transmitter-receiver path in the transmitter antenna coordinate system is given by angle values, az and el. **9955** considers these values in order to determine transmitter antenna attenuations in the horizontal and vertical patterns. It reads the attenuation *H(az)* in the horizontal pattern for the calculated azimuth angle *az* and the attenuation *V(el)* in the vertical pattern for the calculated tilt angle *el*. Then, it calculates the antenna total attenuation, $L_{antTx}(az, el)$.

$$L_{antTx}(az, el) = H(az) - \left[\frac{180 - |az|}{180} \cdot (H(0) - V(el)) + \frac{|az|}{180} \cdot (H(180) - V(180 - el))\right]$$

9955 assumes that the horizontal and vertical patterns are cross-sections of a 3D pattern. In other words, the description of the antenna pattern must satisfy the following: *H(0)=V(0)* and *H(180)=V(180)*

In case of an electrical tilt, α, the horizontal pattern is a conical section with an elevation of α degrees off the horizontal plane. Here, horizontal and vertical patterns must satisfy the following: *H(0)=V(*α*)* and *H(180)=V(180-*α*)*

If the constraints listed above are satisfied, this implies that:

- Interpolated horizontal and vertical patterns respectively fit in with the entered horizontal and vertical patterns, even in case of electrical tilt, and
- The contribution of both the vertical pattern back and front parts are taken into account.

Otherwise, only the second point is guaranteed.

- This interpolation is performed in dBs.
- Angle values in formulas are stated in degrees.
- This interpolation is not used with 3D antenna patterns.

Alcatel·Lucent

1.1.3 Additional Electrical Downtilt Modelling

The additional electrical downtilt, *AEDT*, also referred to as remote electrical downtilt or *REDT*, introduces a conical transformation of the 3D antenna pattern in the vertical axis. In order to take it into account, the vertical pattern is transformed as follows:

$V(x) = V(x - AEDT)$ when $x \in [-90,90]$

$V(x) = V(x + AEDT)$ when $x \in [90,270]$

Where, the angle values are in degrees.

The vertical pattern transformation is represented below. The left picture shows the initial vertical pattern when there is no electrical downtilt and the right one shows the vertical pattern transformation due to an electrical downtilt of 10°.

Then, **9955** proceeds as explained in the previous section. It determines the antenna attenuation in the transformed vertical pattern for the calculated tilt angle (*V(el)*) and applies the 3D interpolation formula in order to calculate the antenna total attenuation, $L_{antTx}(az, el)$.

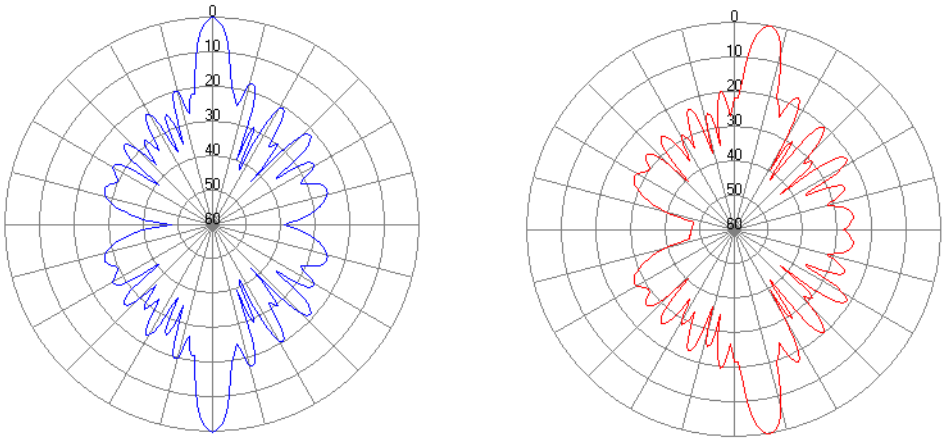


Figure 1.2: Vertical Pattern Transformation due to Electrical Downtilt

1.2 Antenna Pattern Smoothing

Empirical propagation models, like the Standard Propagation Model (SPM), require antenna pattern smoothing in the vertical plane to simulate the effects of reflections and diffractions. Signal level predictions can be improved by smoothing the high-attenuation points of the vertical pattern. You can smooth vertical as well as horizontal antenna patterns in **9955**.

The antenna pattern smoothing algorithm in **9955** first determines the peaks and nulls in the pattern within the smoothing angle ($A_{Smoothing}$) defined by the user. Peaks (*P*) are the lowest attenuation angles and nulls (*N*) are the highest attenuation angles in the pattern. Then, it determines the nulls to be smoothed ($N_{Smoothing}$) and their corresponding angles according to the defined Peak-to-Null Deviation ($D_{Peak\text{-}to\text{-}Null}$). $D_{Peak\text{-}to\text{-}Null}$ is the minimum difference of attenuation in dBs between two peaks and a null between them. Finally, **9955** smooths the pattern between 0 and the smoothing angle ($A_{Smoothing}$) by applying the smoothing to a certain smoothing factor ($F_{Smoothing}$) defined by the user.

Let's take an example of an antenna pattern to be smoothed, as shown in Figure 1.3 on page 24. Let $D_{Peak\text{-}to\text{-}Null}$ be 10 dB, $A_{Smoothing}$ = 90 degrees, and $F_{Smoothing}$ = 0.5.

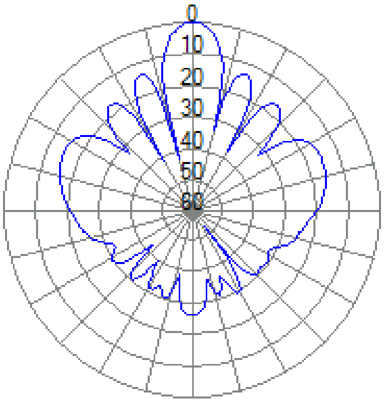


Figure 1.3: Vertical Antenna Pattern

9955 first determines the peaks and nulls in the part of the pattern to be smoothed by verifying the slopes of the pattern curve at each angle.

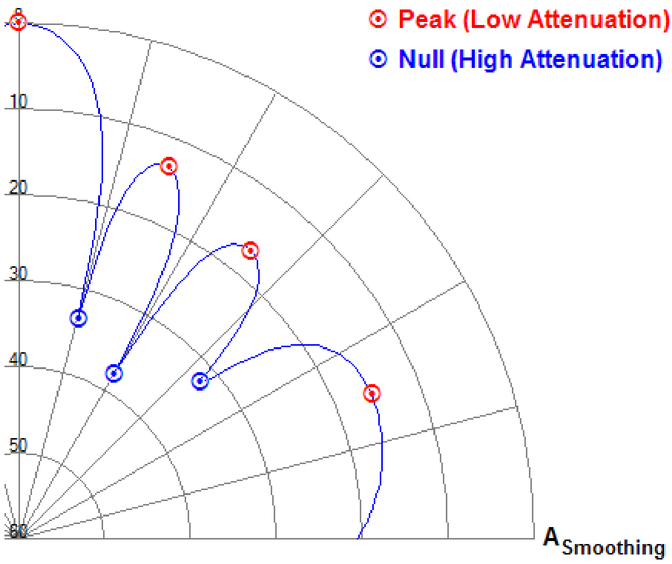


Figure 1.4: Peaks and Nulls in the Antenna Pattern

Peaks (*P*) and Nulls (*N*)

Angle (°)	Attenuation (dB)
1	0.1
15	33.5
21	13.2
30	37.6
38	16.9
49	32.2
67	15.6

Then, **9955** verifies whether the difference of attenuation at a given angle is $D_{Peak\text{-}to\text{-}Null}$ less than the before and after it. This comparison determines the nulls to be smoothed ($N_{Smoothing}$).

Nulls to be smoothed ($N_{Smoothing}$)

Angle (°)	Attenuation (dB)
15	33.5
30	37.6
49	32.2

Once the nulls are known, **9955** applies the smoothing algorithm to all the attenuation values at all the angles between the first peak, the null, and the last peak.

Smoothing Algorithm

For all nulls $n \in N_{Smoothing}$ surrounded by two peaks P_1 and P_2 at angles α_1 and α_2,

$$A_{i,\,Smoothed} = A_i - F_{Smoothing}\left[A_i - \left\{A_{\alpha_1} + \left(\frac{A_{\alpha_2} - A_{\alpha_1}}{\alpha_2 - \alpha_1}\right) \cdot (i - \alpha_1)\right\}\right]$$

Where,

i is the angle in degrees from α_1 to α_2 incremented by 1 degree,

A_{Angle} is the attenuation at any given angle which can be i, α_1 or α_2, and

$F_{Smoothing}$ is the smoothing factor defined by the user.

1.3 Power Received From Secondary Antennas

When secondary antennas are installed on a transmitter, the signal level received from it is calculated as follows:

$$P_{rec} = \frac{\left(\dfrac{P_{Tx} \cdot \left(1 - \sum_i X_i\right) \cdot \dfrac{G_{ant-m_{Tx}}}{L_{Tx}}}{L_{ant-m_{Tx}}(az_m, el_m)} + \sum_i \dfrac{P_{Tx} \cdot X_i \cdot \dfrac{G_{ant-i_{Tx}}}{L_{Tx}}}{L_{ant-i_{Tx}}(az_i, el_i)}\right)}{L_{model}}$$ (not in dB[1])

Where,

P_{Tx} is the transmitter power (P_{pilot} in UMTS HSPA and CDMA2000, $P_{P\text{-}CCPCH}$ in TD-SCDMA, $P_{Preamble}$ in WiMAX, and P_{DLRS} in LTE),

i is the secondary antenna index,

x_i is the percentage of power dedicated to the secondary antenna, *i*,

$G_{ant-m_{Tx}}$ is the gain of the main antenna installed on the transmitter,

L_{Tx} are transmitter losses (L_{Tx}=$L_{total\text{-}DL}$),

$G_{ant-i_{Tx}}$ is the gain of the secondary antenna, *i*, installed on the transmitter,

L_{model} is the path loss calculated by the propagation model,

$L_{ant-m_{Tx}}(az_m, el_m)$ is the attenuation due to main antenna pattern,

$L_{ant-i_{Tx}}(az_i, el_i)$ is the attenuation due to pattern of the secondary antenna, *i*.

The definition of angles, az and el, depends on the used calculation method.

- Method 1 (must be indicated in an Atoll.ini file):
  - az_m: the difference between the receiver antenna azimuth and azimuth of the transmitter main antenna,
  - el_m: the difference between the receiver antenna tilt and tilt of the transmitter main antenna,
  - az_i : the difference between the receiver antenna azimuth and azimuth of the transmitter secondary antenna, *i*,
  - el_i : the difference between the receiver antenna tilt and tilt of the transmitter secondary antenna, *i*,
- Method 2 (default):
  - az_m : the receiver azimuth in the coordinate system of the transmitter main antenna,
  - el_m : the receiver tilt in the coordinate system of the transmitter main antenna,
  - az_i : the receiver azimuth in the coordinate system of the transmitter secondary antenna, *i*,
  - el_i : the receiver tilt in the coordinate system of the transmitter secondary antenna, *i*.

1. *Formula cannot be directly calculated from components stated in dB and must be converted in linear values.*

1.4 Transmitter Radio Equipment

Radio equipment such as TMA, feeder and BTS, are taken into account to evaluate:

- Total UL and DL losses of transmitter ($L_{total-UL}$, $L_{total-DL}$) and transmitter noise figure (NF_{Tx}) in UMTS HSPA, CDMA2000 1xRTT 1xEV-DO, TD-SCDMA, WiMAX, and LTE documents,
- Transmitter total losses (L_{Total}) in GSM GPRS EGPRS documents.

In **9955**, the transmitter-equipment pair is modelled a single entity. The entry to the BTS is considered the reference point which is the location of the transmission/reception parameters.

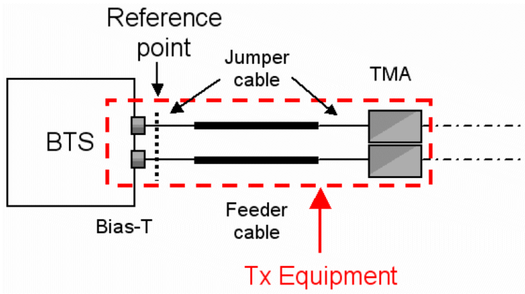


Figure 1.5: Reference Point - Location of the Transmission/Reception parameters

- According to the book “Radio network planning and optimisation for UMTS” by Laiho J., Wacker A., Novosad T., the noise figure corresponds to the loss in case of passive components. Therefore, feeder noise figure is equal to the cable uplink losses.

  $$NF_{Feeder} = L^{UL}_{Feeder}$$

- Loss and gain inputs specified in ATL documents must be positive values.

1.4.1 GSM Documents

9955 calculates DL total losses as follows:

$$L_{Total-DL} = L^{DL}_{TMA} + L^{DL}_{Feeder} + L^{DL}_{Misc} + L^{DL}_{BTS-Conf}$$

Where,

- L^{DL}_{TMA} is the TMA transmission loss.
- L^{DL}_{Feeder} is the feeder transmission loss ($L^{DL}_{Feeder} = L_{Feeder} \times l^{DL}_{Feeder} + L^{DL}_{Connector}$, where L_{Feeder}, l^{DL}_{Feeder} and $L^{DL}_{Connector}$ are respectively the feeder loss per metre, the transmission feeder length in metre and the connector transmission loss).
- L^{DL}_{Misc} are the miscellaneous transmission losses.
- $L^{DL}_{BTS-Conf}$ are the losses due to BTS configuration (BTS property).

1.4.2 UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents

As the reference point is the BTS entry, the transmitter noise figure corresponds to the BTS noise figure. Therefore, we have $NF_{TX} = NF_{BTS}$. Where NF_{BTS} is the BTS noise figure.

Uplink Total Losses

9955 calculates total UL losses as follows:

$$L_{Total-UL} = L^{UL}_{Misc} + L^{UL}_{Feeder} + L^{UL}_{BTS-Conf} + NR_{Repeaters} - G^{UL}_{Ant-div} - G_{TMA}$$

Where,

- L^{UL}_{Misc} are the miscellaneous reception losses (Transmitter property).

- L^{UL}_{Feeder} are the feeder reception losses ($L^{UL}_{Feeder} = L_{Feeder} \times l^{UL}_{Feeder} + L^{UL}_{Connector}$, where L_{Feeder}, l^{UL}_{Feeder} and $L^{UL}_{Connector}$ are respectively the feeder loss per metre (Feeder property), the reception feeder length in metre (Transmitter property) and the connector reception losses.
- $L^{UL}_{BTS-Conf}$ are the losses due to BTS configuration (BTS property).
- $G^{UL}_{Ant-div}$ is the antenna diversity gain (Transmitter property). This gain does not exist in WiMAX and LTE documents.
- $NR_{Repeaters}$ is the noise rise at transmitter due to repeaters. This parameter is taken into account only if the transmitter has active repeater(s). The noise rise at transmitter due to repeaters is calculated as follows:

  $$NR_{Repeaters} = 10 \times Log\left(1 + \sum_r \frac{1}{NIM_{Rp_r}}\right)$$

  For each active repeater (k), **9955** calculates a noise injection margin (NIM_{Rp_k}). This is the difference between the donor transmitter noise figure (NF_{TX}) and the repeater noise figure received at the donor.

  $$NIM_{Rp_r} = NF_{TX} - \left(NF_{Rp_k} + G^{Rp_k}_{amp} - L^{TX-Rp_k}\right)$$

  Where,

  - NF_{Rp_k} is the repeater noise figure,
  - $G^{Rp_k}_{amp}$ is the repeater amplification gain (repeater property),
  - L^{TX-Rp_k} are the losses between the donor transmitter and the repeater (repeater property).
  - For each active repeater (k), **9955** converts the noise injection margin (NIM_{Rp_k}) to Watt. Then, it uses the values to calculate the noise rise at the donor transmitter due to active repeaters ($NR_{Repeaters}$).
- G_{TMA} is the gain due to TMA, which is calculated as follows:

  $$G_{TMA} = NF^{WithoutTMA}_{Composite} - NF^{WithTMA}_{Composite}$$

  Where $NF^{WithTMA}_{Composite}$ and $NF^{WithoutTMA}_{Composite}$ are the composite noise figures with and without TMA respectively.

  Friis' equation is used to calculate the composite noise figure when there is a TMA.

  $$NF^{WithTMA}_{Composite} = 10 \times Log\left(10^{\frac{NF_{TMA}}{10}} + \frac{10^{\frac{NF_{Feeder}}{10}} - 1}{10^{\frac{G^{UL}_{TMA}}{10}}} + \frac{10^{\frac{NF_{BTS}}{10}} - 1}{10^{\frac{G^{UL}_{TMA}}{10}} \times 10^{\frac{G^{UL}_{Feeder}}{10}}}\right)$$

  And, $NF^{WithoutTMA}_{Composite} = NF_{BTS} + NF_{Feeder}$

  Where,

  - NF_{Feeder} is the feeder noise figure.
  - NF_{TMA} is the TMA noise figure.
  - NF_{BTS} is the BTS noise figure.
  - G^{UL}_{TMA} is the TMA reception gain.
  - G^{UL}_{Feeder} is the feeder UL gain $G^{UL}_{Feeder} = -L^{UL}_{Feeder}$.
  - L^{UL}_{Feeder} is the feeder reception loss ($L^{UL}_{Feeder} = L_{Feeder} \times l^{UL}_{Feeder} + L^{UL}_{Connector}$, where L_{Feeder}, l^{UL}_{Feeder} and $L^{UL}_{Connector}$ are respectively the feeder loss per metre, the reception feeder length in metre and the connector reception loss).

Downlink Total Losses

9955 calculates total DL losses as follows.

$$L_{Total-DL} = L^{DL}_{TMA} + L^{DL}_{Feeder} + L^{DL}_{Misc} + L^{DL}_{BTS-Conf}$$

Where,

- L^{DL}_{TMA} is the TMA transmission loss.
- L^{DL}_{Feeder} is the feeder transmission loss ($L^{DL}_{Feeder} = L_{Feeder} \times l^{DL}_{Feeder} + L^{DL}_{Connector}$, where L_{Feeder}, l^{DL}_{Feeder} and $L^{DL}_{Connector}$ are respectively the feeder loss per metre, the transmission feeder length in metre and the connector transmission losses).
- L^{DL}_{Misc} are the miscellaneous transmission losses.
- $L^{DL}_{BTS-Conf}$ are the losses due to BTS configuration (BTS property).

1.5 Repeaters and Remote Antennas

A repeater receives, amplifies, and re-transmits the radiated or conducted RF carrier both in downlink and uplink. It has a donor side and a server side. The donor side receives the signal from a donor (transmitter, repeater, or remote antenna), and the server side amplifies and re-transmits the received signal. Repeaters increase the coverage area of their donors by re-transmitting all the frequencies (TRXs in GSM, carriers in UMTS, CDMA2000 and TD-SCDMA, and channels in WiMAX and LTE documents).

Donors and repeaters may be linked through:

- **Air:** User-defined or calculated propagation losses
- **Microwave Links:** User-defined link losses
- **Optical Fibre Links:** User-defined link losses

Remote antennas are antennas located far from the transmitters, at locations that would normally require long runs of feeder cable. A remote antenna is connected to the base station with an optic fibre. Remote antennas allow you to ensure radio coverage in an area without a new base station. In **9955**, remote antennas should be connected to base stations that do not have any antennas. A remote antenna, as opposed to a repeater, does not have any equipment and therefore generates neither amplification gain nor noise.

In UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE documents, **9955** calculates the signal level received from a repeater or a remote antenna by determining the total downlink and uplink gains (described in "UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents" on page 28). In GSM documents, the received signal level from a repeater or a remote antenna is calculated by determining the EIRP transmitted by the repeater or remote antenna (described in "GSM Documents" on page 37).

The following sections describe how received signal levels, and the related downlink and uplink gains and EIRP, are calculated from a repeater or remote antenna *R* with a donor *D*.

1.5.1 UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents

1.5.1.1 Signal Level Calculation

The received signal level (dBm) on a carrier *ic* from a donor *D* at a pixel/mobile M_i via a repeater or remote antenna *R* (see Figure 1.6 on page 30) is calculated as follows:

$$C^{R}_{DL}(ic) = P^{D}_{DL}(ic) + G^{R}_{Total-DL} - L^{R-M_i}_{Path} - M_{Shadowing} - L_{Indoor} + G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$$

> If a pixel/mobile M_i receives signals from the donor D and its repeater R, the total signal strength is the sum of the two signals: $C^{D}_{DL}(ic) + C^{R}_{DL}(ic)$

The received signal level (dBm) from a pixel/mobile M_i at a donor *D* via a repeater or remote antenna *R* (see Figure 1.6 on page 30) is calculated as follows:

$$C^{M_i}_{UL} = P^{M_i}_{UL} + G^{R}_{Total-UL} - L^{R-M_i}_{Path} - M_{Shadowing} - L_{Indoor} + G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$$

Here:

- $P^{D}_{DL}(ic)$ is the downlink transmission power of a donor *D* on carrier *ic*.
- $P^{M_i}_{UL}$ is the uplink transmission power of a pixel/mobile M_i.

- $G^R_{Total-DL}$ is the total downlink gain, user-defined or calculated as explained in "Downlink Total Gain Calculation" on page 30.
- $G^R_{Total-UL}$ is the total uplink gain, user-defined or calculated as explained in "Uplink Total Gain Calculation" on page 32.
- $L^{R-M_i}_{Path}$ is the path loss (dB) calculated as follows:

  $L^{R-M_i}_{Path} = L_{Model} + L^R_{Ant}$, with:

  - L_{Model} is the path loss calculated using a propagation model.
  - L^R_{Ant} : Antenna attenuation (from antenna patterns) calculated for the antenna used by the repeater or remote antenna *R*.
- $M_{Shadowing}$ is the shadowing margin.
- L_{Indoor} is the indoor loss.
- G^{M_i} is the terminal antenna gain for the pixel/mobile M_i.
- L^{M_i} is the terminal loss for the pixel/mobile M_i.
- $L^{M_i}_{Ant}$ is the terminal antenna attenuation (from antenna patterns) calculated for the pixel/mobile M_i (available in WiMAX and LTE only).

> For calculating the useful signal level from the best serving cell, $L^{M_i}_{Ant}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L^{M_i}_{Ant}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.

- $L^{M_i}_{Body}$ is the body loss defined for the service used by the pixel/mobile M_i.

> L^{M_i}, G^{M_i}, $L^{M_i}_{Ant}$, and $L^{M_i}_{Body}$ are not used in all the calculations. For more information, see the technology-specific chapters.

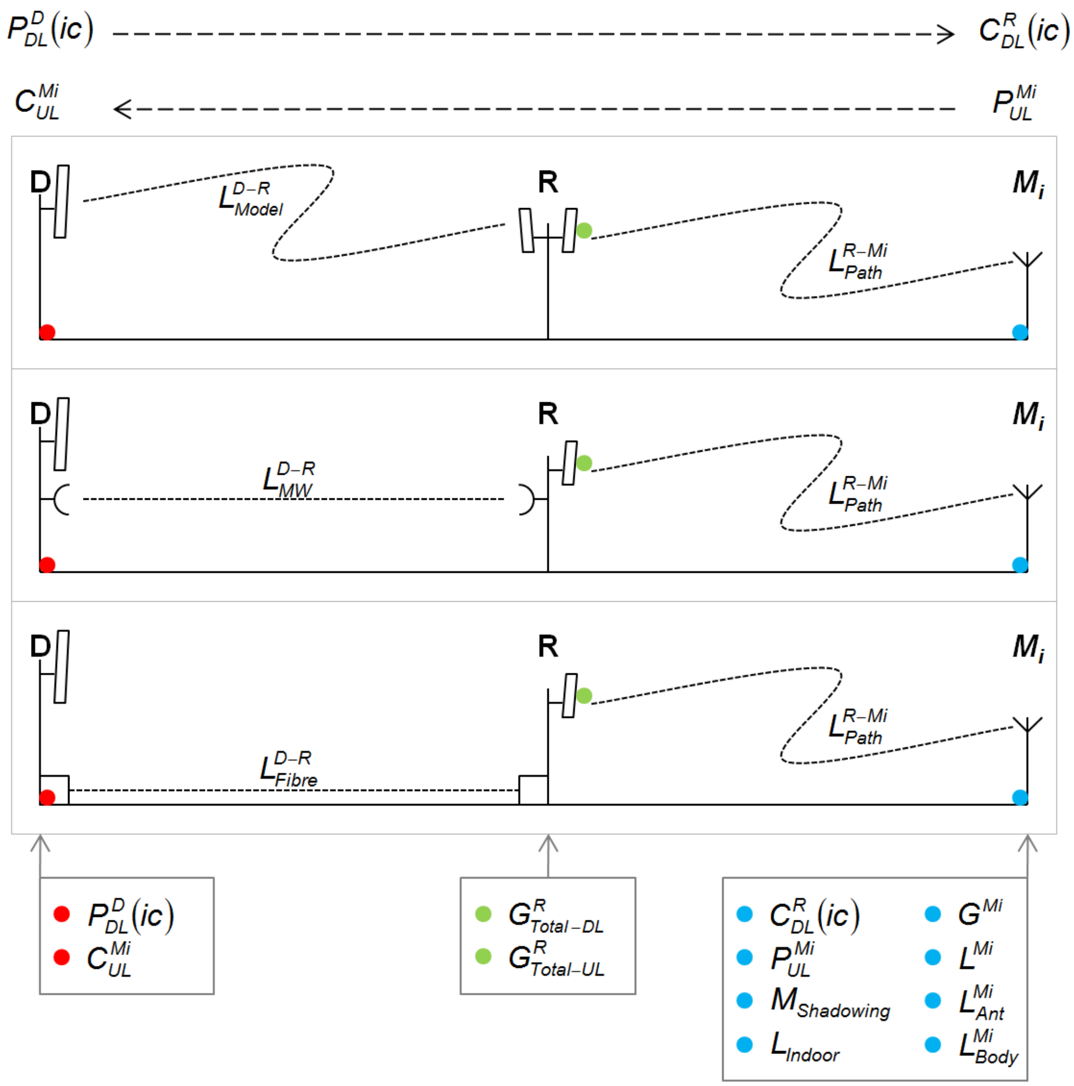


Figure 1.6: UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE: Signal Level Calculation

1.5.1.2 Downlink Total Gain Calculation

The downlink total gain is calculated from the donor transmitter reference point (●) to the repeater or remote antenna reference point (●) as follows:

Over-the-Air Repeaters

$$G_{Total-DL}^{R} = -L_{Total-DL}^{D} + G_{Ant}^{D} - L_{Model}^{D-R} + G_{Donor-Ant}^{R} - L_{\substack{Donor\\RX-Feeder}}^{R} + G_{Amp}^{R} - L_{\substack{Cov\\TX-Feeder}}^{R} + G_{Cov-Ant}^{R}$$

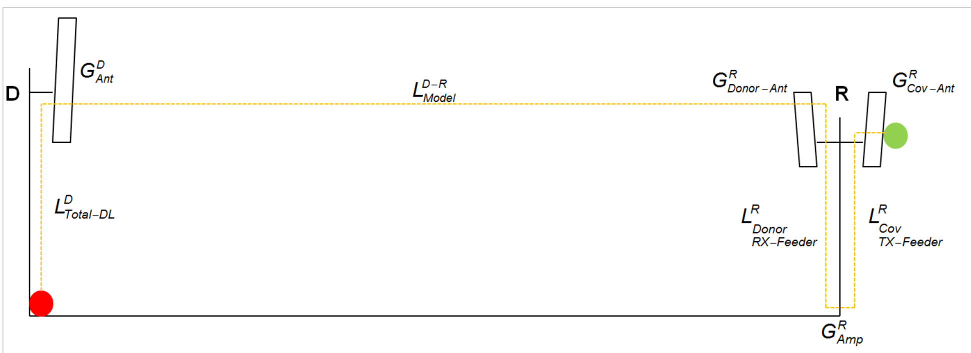


Figure 1.7: Downlink Total Gain: Over-the-Air Repeaters

Here:

- $L^{D}_{Total-DL}$ are the total downlink losses of the donor *D*.
- G^{D}_{Ant} is the gain of the antenna used at the donor *D*.
- L^{D-R}_{Model} is the path loss between the donor *D* and the repeater or remote antenna *R*. This can be user-defined or calculated using the selected propagation model. If you do not select a propagation model, the propagation losses between the donor and the repeater or remote antenna are calculated using the ITU 526-5 propagation model.
- $G^{R}_{Donor-Ant}$ is the gain of the donor-side antenna used at the repeater or remote antenna *R*.
- $L^{R}_{\substack{Donor\\RX-Feeder}}$ are the donor-side reception feeder losses for the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^{R}_{\substack{Cov\\TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

> Secondary antennas are fully supported in the evaluation of the repeater gains.

Microwave Link Repeaters

$$G^{R}_{Total-DL} = -L^{D-R}_{MW} + G^{R}_{Amp} - L^{R}_{\substack{Cov\\TX-Feeder}} + G^{R}_{Cov-Ant}$$

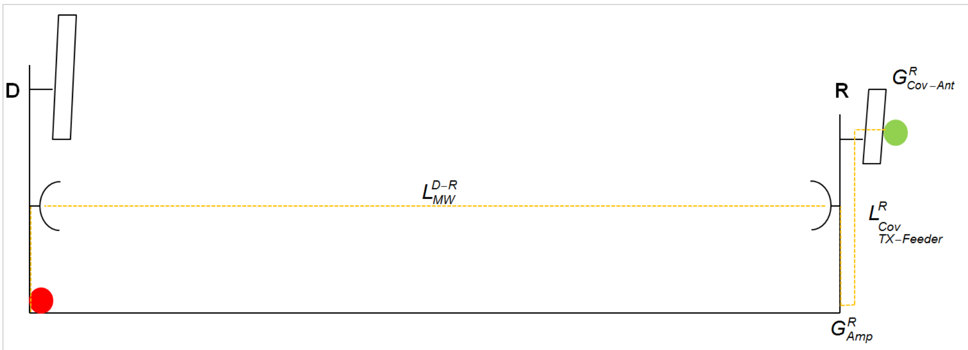


Figure 1.8: Downlink Total Gain: Microwave Link Repeaters

Here:

- L^{D-R}_{MW} are the user-defined microwave link losses between the donor *D* and the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^{R}_{\substack{Cov\\TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

Optical Fibre Link Repeaters and Remote Antennas

$$G^{R}_{Total-DL} = -L^{D-R}_{Fibre} + G^{R}_{Amp} - L^{R}_{\substack{Cov\\TX-Feeder}} + G^{R}_{Cov-Ant}$$

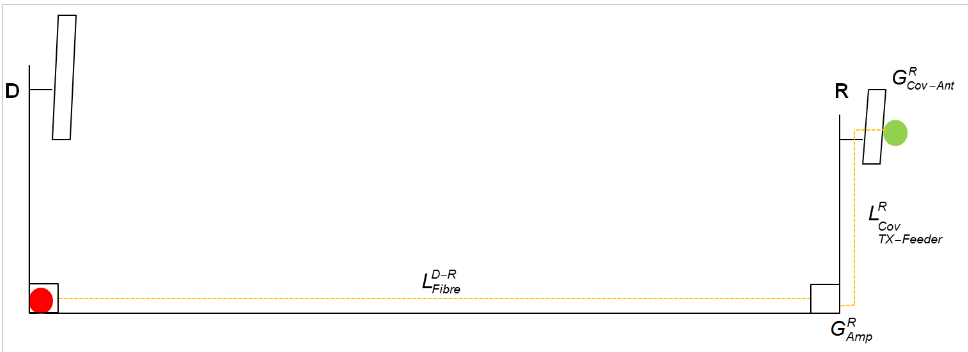


Figure 1.9: Downlink Total Gain: Optical Fibre Link Repeaters or Remote Antennas

Here:

- L^{D-R}_{Fibre} are the user-defined optical fibre link losses between the donor *D* and the repeater or remote antenna *R*.
- G^R_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^R_{\substack{Cov\\TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^R_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

Repeater Downlink Power Limitation

9955 verifies that the downlink power after amplification is consistent with the repeater equipment limitation.

$$P^D_{DL}(ic) + G^R_{Total-DL} \le P^R_{Max} + G^R_{Cov-Ant} - L^R_{\substack{Cov\\TX-Feeder}}$$

Here:

- $P^D_{DL}(ic)$ is the downlink transmission power of a donor *D* on carrier *ic*. When the donor has more than one cell, **9955** considers the highest power.
- $G^R_{Total-DL}$ is the total downlink gain, user-defined or calculated as explained in "Downlink Total Gain Calculation" on page 30.
- P^R_{Max} is the maximum downlink power allowed by the equipment.
- $L^R_{\substack{Cov\\TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^R_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

1.5.1.3 Uplink Total Gain Calculation

The uplink total gain is calculated from the repeater or remote antenna reference point (●) to the donor transmitter reference point (●) as follows:

Over-the-Air Repeaters

$$G^R_{Total-UL} = -L^D_{Total-UL} + G^D_{Ant} - L^{D-R}_{Model} + G^R_{Donor-Ant} - L^R_{\substack{Donor\\TX-Feeder}} + G^R_{Amp} - L^R_{\substack{Cov\\RX-Feeder}} + G^R_{Cov-Ant}$$

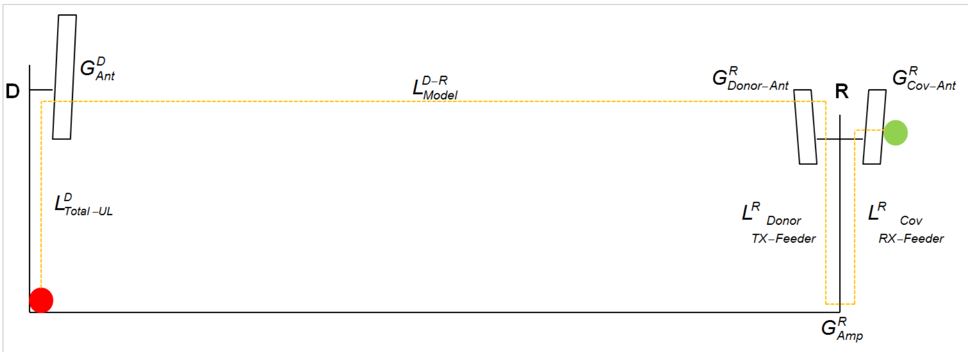


Figure 1.10: Uplink Total Gain: Over-the-Air Repeaters

Here:

- $L^{D}_{Total-UL}$ are the total uplink losses of the donor *D*.
- G^{D}_{Ant} is the gain of the antenna used at the donor *D*.
- L^{D-R}_{Model} is the path loss between the donor *D* and the repeater or remote antenna *R*. This can be user-defined or calculated using the selected propagation model. If you do not select a propagation model, the propagation losses between the donor and the repeater or remote antenna are calculated using the ITU 526-5 propagation model.
- $G^{R}_{Donor-Ant}$ is the gain of the donor-side antenna used at the repeater or remote antenna *R*.
- $L^{R}_{\substack{Donor\\TX-Feeder}}$ are the donor-side transmission feeder losses for the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^{R}_{\substack{Cov\\RX-Feeder}}$ are the coverage-side reception feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

> Secondary antennas are fully supported in the evaluation of the repeater gains.

Microwave Link Repeaters

$$G^{R}_{Total-UL} = -L^{D-R}_{MW} + G^{R}_{Amp} - L^{R}_{\substack{Cov\\RX-Feeder}} + G^{R}_{Cov-Ant}$$

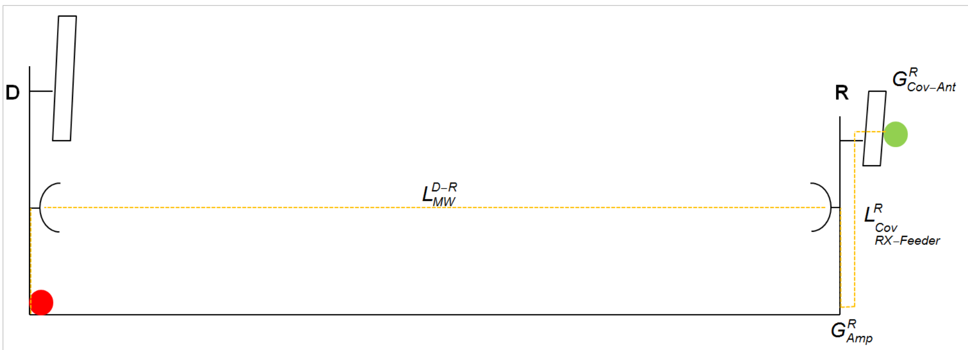


Figure 1.11: Uplink Total Gain: Microwave Link Repeaters

Here:

- L^{D-R}_{MW} are the user-defined microwave link losses between the donor *D* and the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.

- $L^{R}_{\substack{Cov\\RX-Feeder}}$ are the coverage-side reception feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

Optical Fibre Link Repeaters and Remote Antennas

$$G^{R}_{Total-UL} = -L^{D-R}_{Fibre} + G^{R}_{Amp} - L^{R}_{\substack{Cov\\RX-Feeder}} + G^{R}_{Cov-Ant}$$

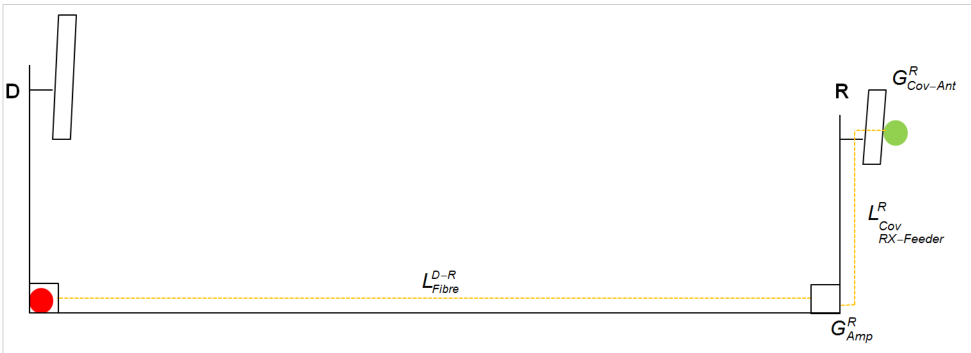


Figure 1.12: Uplink Total Gain: Optical Fibre Link Repeaters and Remote Antennas

Here:

- L^{D-R}_{Fibre} are the user-defined optical fibre link losses between the donor *D* and the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^{R}_{\substack{Cov\\RX-Feeder}}$ are the coverage-side reception feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

1.5.1.4 Repeater Noise Figure

You can define and assign a repeater equipment to each repeater. In addition to the allowed ranges of gains and powers allowed to each repeater, these equipment contain a noise figure which is applied to the repeater they are assigned to. This noise figure has an impact on the donor total reception losses. For information, see "Transmitter Radio Equipment" on page 26.

1.5.1.5 Appendix: Carrier Power and Interference Calculation

This section explains how **9955** calculates the received carrier power and interference when a transmitter has a connected repeater.

A mobile receiver receives signal from the donor transmitter as well as its repeater. Similarly, the signal from the mobile is received at the donor transmitter as well as its repeater. In practice, when a mobile receiver is in the vicinity of the donor transmitter, the signal to/from the repeater would be very weak due to high pathloss between the repeater and the mobile receiver. Similarly, when the mobile receiver is located in the vicinity of the repeater, the signal to/from the donor transmitter would be very weak due to the same reason.

9955 does not differentiate between the mobile receiver being in the transmitter coverage area or being in its repeater coverage area. **9955** adds the signals received from the donor transmitter and its repeater to generate a combined pathloss matrix that is associated with the donor transmitter and includes the effect of its repeater.

Calculation of Total Path Loss

The total pathloss, L_{Total}, is calculated by computing a downlink budget. If we take the case of a CDMA project, without considering any shadowing margin or indoor loss, the power received from the donor transmitter, Txd on a carrier *ic*, at the mobile receiver can be stated as (for a link over the air):

$$P^{D}_{Rec}(ic) = \frac{(P^{D}_{Pilot}(ic) \cdot G^{D}_{Ant})}{(L^{D}_{Total-DL} \cdot L^{D-Mi}_{Path})}$$

Where,

$P^D_{Rec}(ic)$ is the carrier power received at the receiver from the donor transmitter on a carrier *ic* (in W)

$P^D_{Pilot}(ic)$ is the pilot power of the donor transmitter on the carrier *ic* (in W)

G^D_{Ant} is the donor transmitter antenna gain.

$L^D_{Total-DL}$ is the transmission feeder loss of the donor transmitter.

L^{D-Mi}_{Path} is the path loss between the donor transmitter and the mobile receiver.

Similarly, the power received at the mobile receiver from the repeater *R* is:

$$P^R_{Rec}(ic) = \frac{(P^D_{Pilot}(ic) \cdot G^R_{Total-DL})}{L^{R-Mi}_{Path}}$$

Where,

$P^R_{Rec}(ic)$ is the carrier power received at the mobile receiver from the repeater on a carrier *ic* (in W)

$P^D_{Pilot}(ic)$ is the pilot power of the donor transmitter on the carrier *ic* (in W)

$G^R_{Total-DL}$ is the output downlink total gain of repeater linked to a donor transmitter with an air link.

L^{R-Mi}_{Path} is the path loss between the repeater and the mobile receiver

So, the total carrier power received at the mobile receiver is:

$$P^{D-R}_{Rec}(ic) = P^R_{Rec}(ic) + P^R_{Rec}(ic) = P^D_{Pilot}(ic) \cdot \left(\frac{G^D_{Ant}}{(L^D_{Total-DL} \cdot L^{D-Mi}_{Path})} + \frac{G^R_{Total-DL}}{L^{R-Mi}_{Path}}\right)$$

Since,

$$L_{Total} = \frac{P^D_{Pilot}(ic) \cdot G^D_{Ant}}{L^D_{Total-DL} \cdot P^{D-R}_{Rec}(ic)}$$

Therefore,

$$L_{Total} = \frac{P^D_{Pilot}(ic) \cdot G^D_{Ant}}{L^D_{Total-DL} \cdot P^D_{Pilot}(ic) \cdot \left(\frac{G^D_{Ant}}{(L^D_{Total-DL} \cdot L^{D-Mi}_{Path})} + \frac{G^R_{Total-DL}}{L^{R-Mi}_{Path}}\right)}$$

Hence,

$$L_{total} = \frac{G^{Txd}_{ant}}{L^{Txd}_{total-DL} \cdot \left(\frac{G^{Txd}_{ant}}{(L^{Txd}_{total-DL} \cdot L^{Txd-Rx}_{path})} + \frac{G^{Rpk}_{total-Air-DL}}{L^{Rpk-Rx}_{path}}\right)}$$

This total path loss depends on the location of the mobile receiver in realistic network scenarios. As a mobile in the donor transmitter/repeater coverage area is likely to be far from the repeater/donor transmitter coverage area, the respective pathloss value will be very large. This implies that we can study the two cases separately without influencing the results much.

- Case 1: Receiver in Donor Transmitter Coverage Area

  L^{R-Mi}_{Path} is likely to be very high, so the term $\frac{G^R_{Total-DL}}{L^{R-Mi}_{Path}}$ can be ignored. This implies that:

  $$L_{Total} = L^{D-Mi}_{Path}$$

  Considering this total pathloss value, the total received power in the uplink and in the downlink can be stated as:

  $$P^D_{Rec-DL}(ic) = \frac{(P^D_{Pilot}(ic) \cdot G^D_{Ant})}{(L^D_{Total-DL} \cdot L_{Total})} = \frac{(P^D_{Pilot}(ic) \cdot G^D_{Ant})}{(L^D_{Total-DL} \cdot L^{D-Mi}_{Path})}$$

$$P_{Rec-UL}^{D}(ic) = \frac{(P_{Output}^{Mi}(ic) \cdot G_{Ant}^{D})}{(L_{Total-UL}^{D} \cdot L_{Total})} = \frac{(P_{Output}^{Mi}(ic) \cdot G_{Ant}^{D})}{(L_{Total-UL}^{D} \cdot L_{Path}^{D-Mi})}$$

Where,

$P_{Output}^{Mi}(ic)$ is the transmitted power from the mobile terminal on the carrier *ic* (in W)

$L_{Total-UL}^{D}$ is the reception feeder loss of the transmitter

- Case 2: Receiver in Repeater Coverage Area

L_{Path}^{D-Mi} is likely to be very high, so the term $\frac{G_{Ant}^{D}}{(L_{Total-DL}^{D} \cdot L_{Path}^{D-Mi})}$ can be ignored. This implies that:

$$L_{Total} = \frac{G_{Ant}^{D}}{\left(L_{Total-DL}^{D} \cdot \left(\frac{G_{Total-DL}^{R}}{L_{Path}^{R-Mi}}\right)\right)} = \frac{G_{Ant}^{D}}{\frac{G_{Total-DL}^{R} \cdot L_{Total-DL}^{R}}{L_{Path}^{R-Mi}}}$$

$$P_{Rec-DL}^{D}(ic) = \frac{(P_{Pilot}^{D}(ic) \cdot G_{Ant}^{D})}{(L_{Total-DL}^{D} \cdot L_{Total})} = \frac{(P_{Pilot}^{D}(ic) \cdot G_{Total}^{R})}{(L_{Path}^{R-Mi})}$$

$$P_{Rec-UL}^{D} = \frac{(P_{Output}^{Mi}(ic) \cdot G_{Ant}^{D})}{(L_{Total-UL}^{D} \cdot L_{Total})} = \frac{(P_{Output}^{Mi}(ic) \cdot G_{Total}^{R})}{(L_{Path}^{R-Mi})} \cdot \frac{L_{Total-DL}^{D}}{L_{Total-UL}^{D}}$$

Where,

$P_{Output}^{Mi}(ic)$ is the transmitted power from the mobile terminal (in W)

$L_{Total-UL}^{D}$ is the reception feeder loss of the transmitter

Calculation of Eb/Nt Uplink

In the uplink, the quality level at the transmitter on a traffic channel is:

$$\left(\frac{E_b}{N_t}\right)_{UL} = \frac{C}{I} \cdot \frac{W}{R}$$

Where,

C is the carrier power received from the mobile terminal (in W)

I is the total interference (in W)

W is the spreading bandwidth (Hz)

R is the effective service data rate in the uplink (bits/s)

(W/R is the service processing gain in the uplink)

C and I are both evaluated at the same reference point, which is the entry of BTS using the following formulas.

$$C = P_{Total-UL} = \frac{P_{Output}^{Mi} \cdot G_{Ant}^{D}}{L_{Total-UL}^{D} \cdot L_{Total}}$$

$$I = I_{Total} + N_0$$

Where,

I_{Total} is the sum of the signals received from mobile terminals inside the same cell and those outside (in W)

N_0 is the transmitter equipment thermal noise (in W)

Therefore, for each mobile terminal *Mi*,

$$I_{Total} = \sum_{Mi}\left(\frac{P_{Output}^{Mi} \cdot G_{Ant}^{D}}{L_{Total-UL}^{D} \cdot L_{Total}^{Mi}}\right)$$

And,

$$N_0 = NF^D \cdot K \cdot T \cdot W$$

Where,

NF^D is the noise figure of the transmitter equipment at the reference point, i.e. the entry of the BTS

K is Boltzman constant

T is the ambient temperature (in K)

Hence

$$N_0 = NF^{BTS} \cdot K \cdot T \cdot W$$

1.5.2 GSM Documents

1.5.2.1 Signal Level Calculation

The received signal level (dBm) on a TRX type *tt* from a donor *D* at a pixel/mobile M_i via a repeater or remote antenna *R* (see Figure 1.13 on page 38) is calculated as follows:

$$C^R_{DL}(tt) = EIRP^R_{DL}(tt) - \Delta P(tt) - L_{Path}^{R-M_i} - M_{Shadowing} - L_{Indoor} + G^{M_i} - L^{M_i}$$

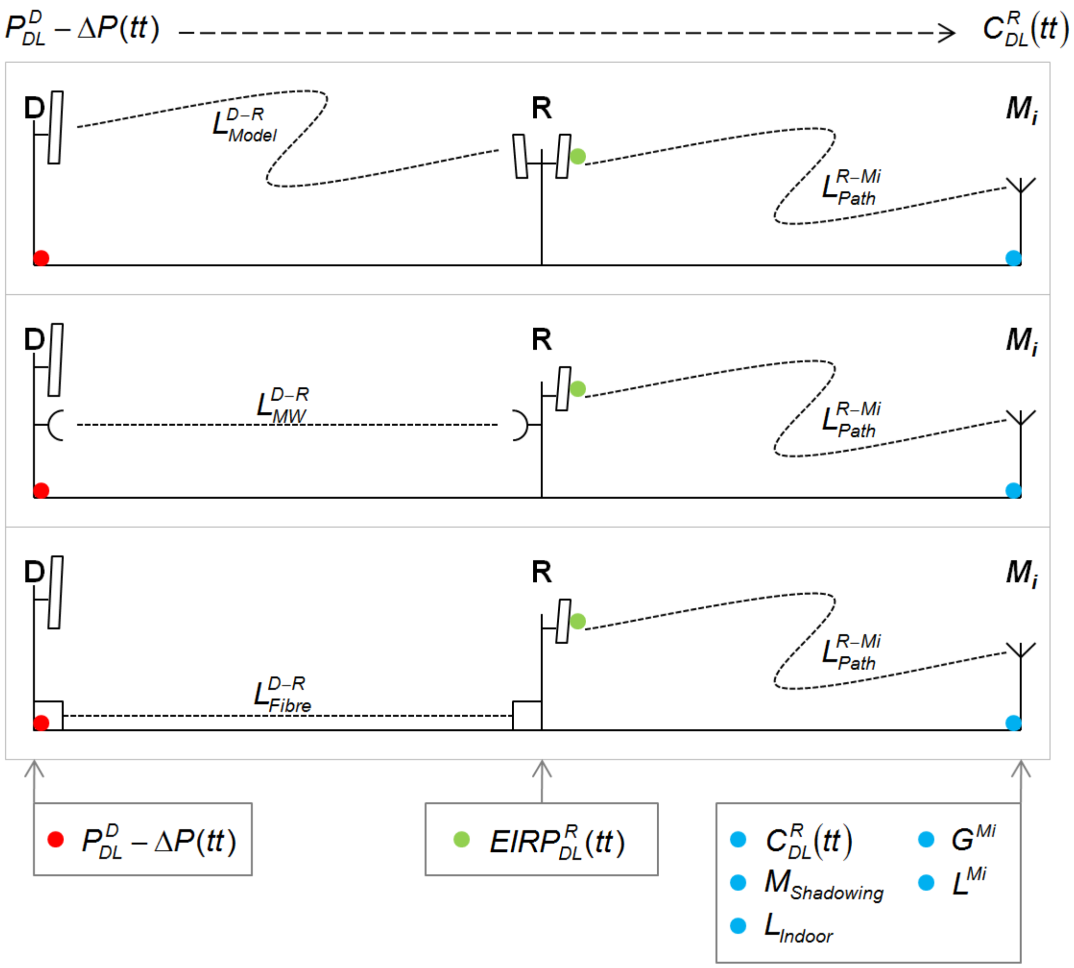
> If a pixel/mobile M_i receives signals from the donor D and its repeater R, the total signal strength is the sum of the two signals: $C^D_{DL}(tt) + C^R_{DL}(tt)$

Here:

- $EIRP^R_{DL}(tt)$ is the effective isotropic radiated power of the repeater or remote antenna *R* on the TRX type *tt*. It can be user-defined or calculated as explained in "EIRP Calculation" on page 38.
- the downlink transmission power of a donor *D* on carrier *ic*.
- $\Delta P(tt)$ is the power offset defined for the TRX type *tt*.
- $L_{Path}^{R-M_i}$ is the path loss (dB) calculated as follows:

  $L_{Path}^{R-M_i} = L_{Model} + L^R_{Ant}$, with:

  - L_{Model} is the path loss calculated using a propagation model.
  - L^R_{Ant} : Antenna attenuation (from antenna patterns) calculated for the antenna used by the repeater or remote antenna *R*.
- $M_{Shadowing}$ is the shadowing margin.
- L_{Indoor} is the indoor loss.
- G^{M_i} is the terminal antenna gain for the pixel/mobile M_i.
- L^{M_i} is the terminal loss for the pixel/mobile M_i.



s

Figure 1.13: GSM: Signal Level Calculation

1.5.2.2 EIRP Calculation

The EIRP of a repeater or remote antenna *R* is calculated at the repeater or remote antenna reference point (●) w. r. t. P^D_{DL} at the donor reference point (●) as follows:

Over-the-Air Repeaters

$$EIRP^R_{DL}(tt) = P^D_{DL} - L^D_{Total-DL} + G^D_{Ant} - L^{D-R}_{Model} + G^R_{Donor-Ant} - L^R_{\substack{Donor\\RX-Feeder}} + G^R_{Amp} - L^R_{\substack{Cov\\TX-Feeder}} + G^R_{Cov-Ant}$$

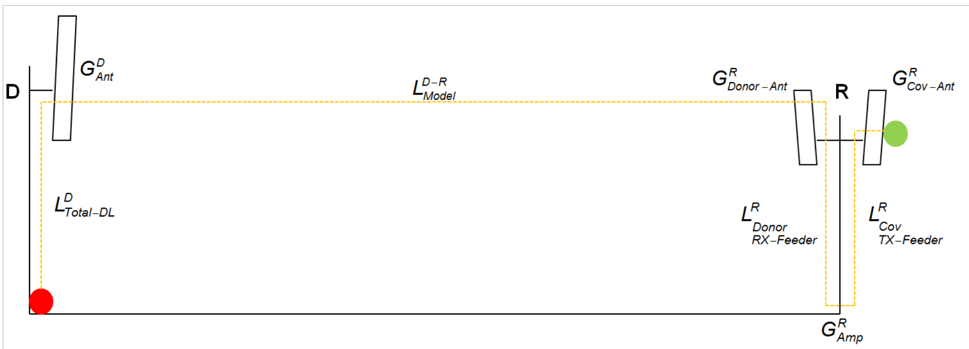


Figure 1.14: EIRP: Over-the-Air Repeaters

Here:

- P^D_{DL} is the downlink transmission power of the donor *D*.
- $L^D_{Total-DL}$ are the total downlink losses of the donor *D*.

Alcatel·Lucent

- G^{D}_{Ant} is the gain of the antenna used at the donor *D*.
- L^{D-R}_{Model} is the path loss between the donor *D* and the repeater or remote antenna *R*. This can be user-defined or calculated using the selected propagation model. If you do not select a propagation model, the propagation losses between the donor and the repeater or remote antenna are calculated using the ITU 526-5 propagation model.
- $G^{R}_{Donor-Ant}$ is the gain of the donor-side antenna used at the repeater or remote antenna *R*.
- $L^{R}_{\substack{Donor\\RX-Feeder}}$ are the donor-side reception feeder losses for the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^{R}_{\substack{Cov\\TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

> Secondary antennas are fully supported in the evaluation of the repeater gains.

Microwave Link Repeaters

$$EIRP^{R}_{DL}(tt) = P^{D}_{DL} - L^{D-R}_{MW} + G^{R}_{Amp} - L^{R}_{\substack{Cov\\TX-Feeder}} + G^{R}_{Cov-Ant}$$

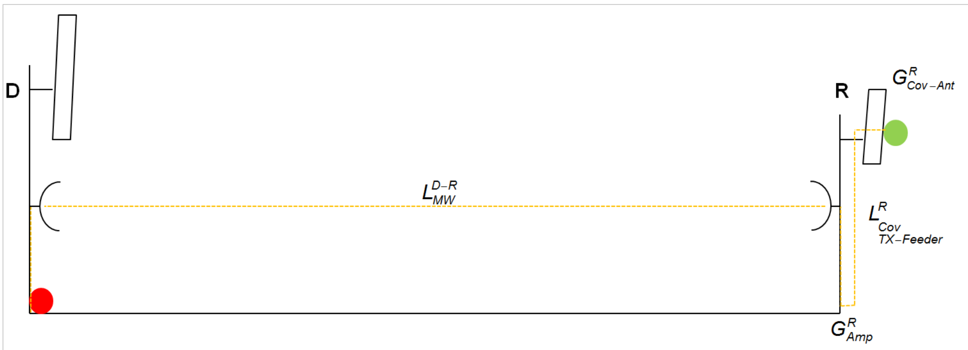


Figure 1.15: Downlink Total Gain: Microwave Link Repeaters

Here:

- P^{D}_{DL} is the downlink transmission power of the donor *D.*
- L^{D-R}_{MW} are the user-defined microwave link losses between the donor *D* and the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^{R}_{\substack{Cov\\TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

Optical Fibre Link Repeaters and Remote Antennas

$$EIRP^{R}_{DL}(tt) = P^{D}_{DL} - L^{D-R}_{Fibre} + G^{R}_{Amp} - L^{R}_{\substack{Cov\\TX-Feeder}} + G^{R}_{Cov-Ant}$$

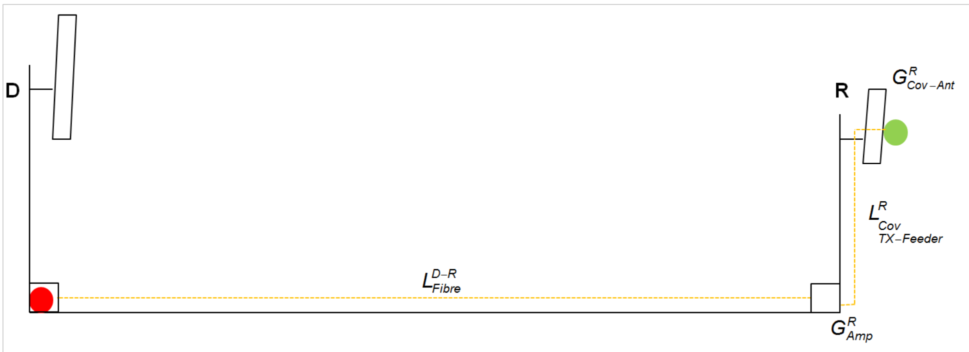


Figure 1.16: Downlink Total Gain: Optical Fibre Link Repeaters or Remote Antennas

Here:

- P^{D}_{DL} is the downlink transmission power of the donor *D.*
- L^{D-R}_{Fibre} are the user-defined optical fibre link losses between the donor *D* and the repeater or remote antenna *R*.
- G^{R}_{Amp} is the amplifier gain of the repeater *R*. For remote antennas, this is 0.
- $L^{R}_{\substack{Cov \\ TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

Repeater Downlink Power Limitation

9955 verifies that the EIRP after amplification is consistent with the repeater equipment limitation.

$$EIRP^{R}_{DL}(tt) \le P^{R}_{Max} + G^{R}_{Cov-Ant} - L^{R}_{\substack{Cov \\ TX-Feeder}}$$

Here:

- $EIRP^{R}_{DL}(tt)$ is the effective isotropic radiated power of the repeater *R* on the TRX type *tt*.
- P^{R}_{Max} is the maximum downlink power allowed by the equipment.
- $L^{R}_{\substack{Cov \\ TX-Feeder}}$ are the coverage-side transmission feeder losses for the repeater or remote antenna *R*.
- $G^{R}_{Cov-Ant}$ is the gain of the coverage-side antenna used at the repeater or remote antenna *R*.

1.5.3 Donor-side Parameter Calculations

1.5.3.1 Azimuth

This is the angle at which the donor antenna is situated with respect to the North at the repeater or remote antenna. This angle is measured clock-wise as shown in the figure below. It is the absolute horizontal angle at which the donor-side antenna of the repeater should be pointed in order to be aligned with the donor antenna.

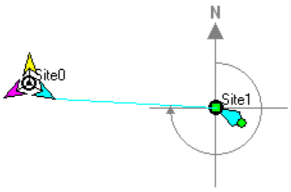


Figure 1.17: Angle from North (Azimuth)

1.5.3.2 Mechanical Downtilt

This is the tilt angle for the repeater's donor-side antenna, which ensures that it points towards the donor antenna in the vertical plane. As a general rule, downtilt angles are considered positive and uptilt angles negative.

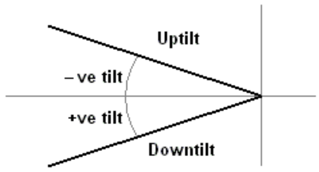


Figure 1.18: Positive/Negative Mechanical Downtilt

Since this parameter depends on the difference of heights/altitudes between the donor transmitter and the repeater, it can be automatically calculated in the repeater's Donor side properties. If the height/altitude of the antenna is modified, the corresponding tilt angle can be found out and applied using the Calculate button.

Example

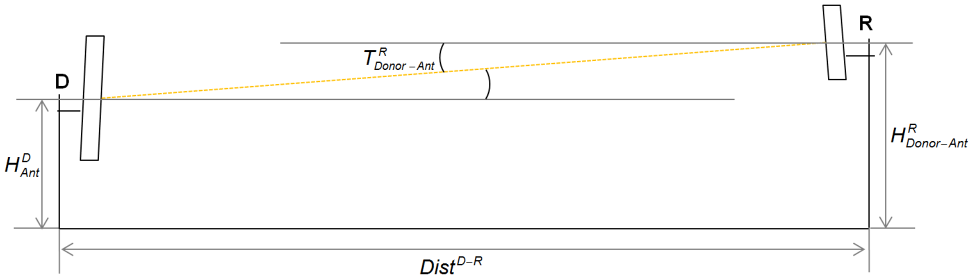


Figure 1.19: Tilt Angle Computation

The tilt angle repeater's donor-side antenna in the above figure would be:

$$T^R_{Donor-Ant} = atan\left(\frac{H^R_{Donor-Ant} - H^D_{Ant}}{D^{D-R}}\right)$$

As obvious, this angle will be negative for uptilts and positive for downtilts of the antenna.

Here:

- $H^R_{Donor-Ant}$ is the height of the donor-side antenna of the repeater or remote antenna *R*.
- H^D_{Ant} is the height of the antenna of the donor *D*.
- D^{D-R} is the distance between the antenna of the donor *D* and the antenna of the repeater or remote antenna *R*.

1.6 Beamforming Smart Antenna Models

Adaptive antenna systems use more than one antenna elements, along with smart signal processing, to locate and track various types of signals, to dynamically minimize interference, and maximize useful signal reception. The signal processor dynamically applies weights to each element of the adaptive antenna system to create array patterns in real-time.

Beamforming smart antennas dynamically create antenna patterns with a main beam pointed in the direction of the user being served, i.e., the useful signal. Adaptive algorithms can also be used in order to minimize the interference received by the cells. These algorithms are based on optimization methods such as the minimum mean square error method.

The following beamforming smart antenna models are available in **9955**. These smart antenna models support linear adaptive array systems, such as the one shown in Figure 1.20 on page 42.

- **Optimum Beamformer:** The Optimum Beamformer smart antenna model performs dynamic beamforming in downlink as explained in "Downlink Beamforming" on page 44, and beamforming and interference cancellation in uplink using the minimum mean square error algorithm as explained in "Uplink Beamforming and Interference Cancellation (MMSE)" on page 47. Smart antenna results are later on used in coverage prediction calculations.
- **Conventional Beamformer:** The Conventional Beamformer smart antenna model performs dynamic beamforming in downlink and uplink as explained in "Downlink Beamforming" on page 44 and "Uplink Beamforming" on page 46, respectively. Smart antenna results are later on used in coverage prediction calculations.

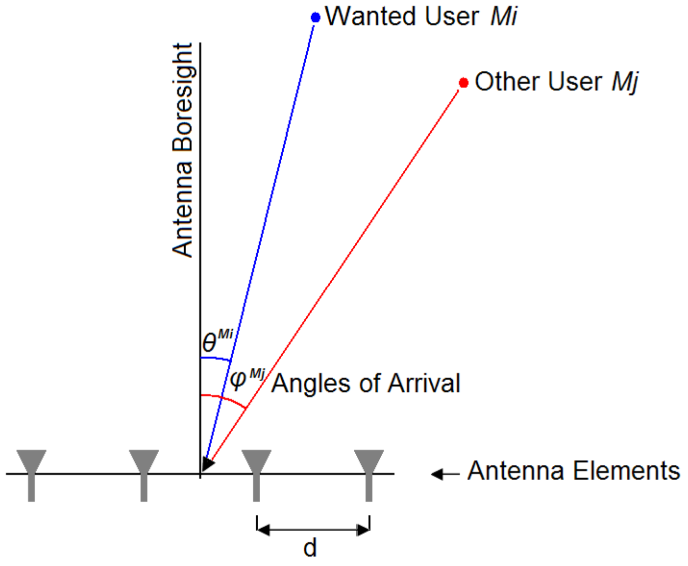


Figure 1.20: Linear Adaptive Antenna Array

In the following explanations, we assume:

- There are a total of E_{SA} elements in the adaptive antenna system.
- θ is the angle of arrival for the useful signal.
- φ is the angle at which we want to calculate the smart antenna gain.
- d is the distance between two adjacent antenna elements.

1.6.1 Definitions and Formulas

The tables in the following subsections list the parameters and formulas used in beamforming smart antenna models.

1.6.1.1 Definitions

Name	Value	Unit	Description
E_{SA}	Smart antenna model parameter	None	Number of smart antenna elements
θ	Calculation parameter	Degrees	Angle of arrival for the useful signal
φ	Calculation parameter	Degrees	Angle at which the smart antenna effect is calculated
d	$\frac{\lambda}{2}$, where λ is the wavelength of the signal	m	Distance between two adjacent antenna elements

1.6.1.2 Downlink Beamforming

Name	Value	Unit	Description
$g_n(\varphi)$	Smart antenna model parameter	None	Gain of a single element
$\vec{S}_\theta$	$\left[1, e^{j \cdot \frac{2\pi}{\lambda} \cdot d \cdot \sin\theta}, e^{j \cdot \frac{2\pi}{\lambda} \cdot 2d \cdot \sin\theta}, \ldots, e^{j \cdot \frac{2\pi}{\lambda} \cdot (E_{SA}-1)d \cdot \sin\theta}\right]^T$	None	Steering vector for the direction of θ
w_n	$e^{-j \cdot \frac{2\pi}{\lambda} \cdot nd \cdot \sin\theta}$ $e^{-j \cdot \pi \cdot n \cdot \sin\theta}$ with $d = \frac{\lambda}{2}$	None	Complex smart antenna weight
$\vec{R}_\theta$	$\vec{S}_\theta \cdot \vec{S}_\theta^H$	None	Array correlation matrix for a given user direction θ
$G_{SA}(\varphi)$	$g_n(\varphi) \cdot \vec{S}_\varphi^H \cdot \vec{R}_\theta \cdot \vec{S}_\varphi = g_n(\varphi) \cdot \vec{S}_\varphi^H \cdot \vec{S}_\theta \cdot \vec{S}_\theta^H \cdot \vec{S}_\varphi = g_n(\theta) \cdot E_{SA}^2$	None	Smart antenna gain in any direction φ

Name	Value	Unit	Description
$\vec{R}_k$	$\sum_{j=1}^{J} p_j \cdot \vec{R}_j$	None	Downlink array correlation matrix for iteration *k*
$\vec{R}_{Avg}$	$\frac{1}{K} \cdot \sum_{k=1}^{K} \vec{R}_k$	None	Average downlink array correlation matrix over a simulation (*K* iterations)

1.6.1.3 Uplink Beamforming

Name	Value	Unit	Description
$\vec{w}$	$\frac{\vec{S}_\theta}{\sqrt{E_{SA}}}$	None	Vector of E_{SA} complex weights for the conventional beamformer
R_N	$R_n + R_I = \sigma_n^2 \cdot I + \sum_{j=1}^{J} p_j \cdot \vec{S}_j \cdot \vec{S}_j^H$	None	Total noise correlation matrix
R_n	$\sigma_n^2 \cdot I$	None	Thermal noise correlation matrix
R_I	$\sum_{j=1}^{J} p_j \cdot \vec{S}_j \cdot \vec{S}_j^H$	None	Interference correlation matrix
P_N	$\vec{w}^H \cdot R_N \cdot \vec{w}$	W	Total uplink noise power
P_θ	$p_\theta \cdot \vec{w}^H \cdot \vec{S}_\theta \cdot \vec{S}_\theta^H \cdot \vec{w} = p_\theta \cdot E_{SA}$	W	Total power received from the served user
$CINR_{UL}$	$\frac{P_\theta}{P_N} = \frac{p_\theta \cdot E_{SA}}{\vec{w}^H \cdot R_N \cdot \vec{w}}$	None	C/(I+N) in the uplink (WiMAX)
Q_{UL}^{SA}	$\frac{P_\theta}{P_N} = \frac{p_\theta \cdot E_{SA}}{\vec{w}^H \cdot R_N \cdot \vec{w}}$	None	Signal quality in the uplink (TD-SCDMA)
G_{SA}	E_{SA}	None	Uplink smart antenna beamforming gain in the direction of the served user
$R_N\|_{Avg}$	$\frac{1}{K} \cdot \sum_{k=1}^{K} R_N\|_k$	W	Average noise correlation matrix
$I_{UL}(\varphi)$	$\vec{w}^H \cdot R_N\|_{Avg} \cdot \vec{w} - \sigma_n^2$	W	Uplink interference
$NR_{UL}(\varphi)$	$\frac{I_{UL}(\varphi) + \sigma_n^2}{\sigma_n^2}$	None	Angular distribution of uplink noise rise

1.6.1.4 Uplink Beamforming and Interference Cancellation (MMSE)

Name	Value	Unit	Description
$\hat{w}$	$\mu_\theta \cdot R_N^{-1} \cdot \vec{S}_\theta$	None	Vector of E_{SA} complex weights for the optimum beamformer
μ_θ	$\frac{\sqrt{E_{SA}}}{\vec{S}_\theta^H \cdot R_N^{-1} \cdot \vec{S}_\theta}$	None	MMSE optimization constant

Name	Value	Unit	Description
R_N	$R_n + R_I = \sigma_n^2 \cdot I + \sum_{j=1}^{J} p_j \cdot \vec{S}_j \cdot \vec{S}_j^H$	None	Total noise correlation matrix
R_n	$\sigma_n^2 \cdot I$	None	Thermal noise correlation matrix
R_I	$\sum_{j=1}^{J} p_j \cdot \vec{S}_j \cdot \vec{S}_j^H$	None	Interference correlation matrix
$\hat{P}_N$	$\mu_\theta^2 \cdot \vec{S}_\theta^H \cdot R_N^{-1} \cdot \vec{S}_\theta$	W	Total uplink noise power (optimum beamformer)
$\hat{P}_\theta$	$p_\theta \cdot \mu_\theta^2 \cdot (\vec{S}_\theta^H \cdot R_N^{-1} \cdot \vec{S}_\theta)^2$	W	Total power received from the served user (optimum beamformer)
$CINR_{UL}$	$\frac{P_\theta}{P_N} = \frac{\hat{P}_\theta}{\hat{P}_N} = p_\theta \cdot \vec{S}_\theta^H \cdot R_N^{-1} \cdot \vec{S}_\theta$	None	C/(I+N) in the uplink (WiMAX)
Q_{UL}^{SA}	$\frac{P_\theta}{P_N} = \frac{\hat{P}_\theta}{\hat{P}_N} = p_\theta \cdot \vec{S}_\theta^H \cdot R_N^{-1} \cdot \vec{S}_\theta$	None	Signal quality in the uplink (TD-SCDMA)
G_{SA}	$\vec{S}_\theta^H \cdot I \cdot \vec{S}_\theta = E_{SA}$	None	Uplink smart antenna beamforming gain in the direction of the served user
$R_N^{-1}\big\vert_{Avg}$	$\frac{1}{K} \cdot \sum_{k=1}^{K} R_N^{-1}\big\vert_k$	W	Average inverse noise correlation matrix
$I_{UL}(\varphi)$	$\frac{E_{SA}}{\vec{S}_\varphi^H \cdot R_N^{-1}\big\vert_{Avg} \cdot \vec{S}_\varphi} - \sigma_n^2$	W	Uplink interference
$NR_{UL}(\varphi)$	$\frac{I_{UL}(\varphi) + \sigma_n^2}{\sigma_n^2}$	None	Angular distribution of uplink noise rise

1.6.2 Downlink Beamforming

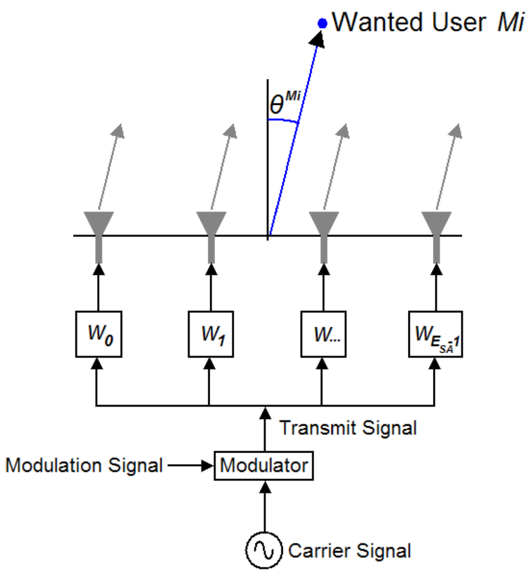


Figure 1.21: Downlink Beamforming

Beamforming dynamically creates a beam towards the served user. The smart antenna processor applies complex weights, w_n, to each antenna element in order to form a beam towards the served user. The magnitude of these complex weights is set to *1*. The beamforming is performed using only the phase of the complex weights. The steering vector, $\vec{S}_\theta$, representing the complex weights for forming a beam towards the served user, i.e., at the angle of arrival θ is given by:

$$\vec{S}_\theta = \left[1, e^{j \cdot \frac{2\pi}{\lambda} \cdot d \cdot \sin\theta}, e^{j \cdot \frac{2\pi}{\lambda} \cdot 2d \cdot \sin\theta}, \ldots, e^{j \cdot \frac{2\pi}{\lambda} \cdot (E_{SA} - 1)d \cdot \sin\theta}\right]^T$$

Where *T* represents the transpose of a matrix.

Therefore, the complex weight at any n^{th} antenna element can be given by:

$$w_n = e^{-j \cdot \frac{2\pi}{\lambda} \cdot nd \cdot \sin\theta}$$

In **9955**, $d = \frac{\lambda}{2}$, therefore, $w_n = e^{-j \cdot \pi \cdot n \cdot \sin\theta}$.

The smart antenna gain in any direction φ can be given by:

$$G_{SA}(\varphi) = g_n(\varphi) \cdot \vec{S}_\varphi^H \cdot \vec{R}_\theta \cdot \vec{S}_\varphi$$

Where *H* represents the Hilbert transform, which is the complex conjugate transpose of a matrix, $g_n(\varphi)$ is the gain of the n^{th} antenna element in the direction φ, and $\vec{R}_\theta$ is the array correlation matrix for a given user direction θ, given by:

$$\vec{R}_\theta = \vec{S}_\theta \cdot \vec{S}_\theta^H$$

For the direction of the served user, i.e., θ, the smart antenna gain is calculated as follows:

$$G_{SA}(\theta) = g_n(\theta) \cdot \vec{S}_\theta^H \cdot \vec{R}_\theta \cdot \vec{S}_\theta = g_n(\theta) \cdot \vec{S}_\theta^H \cdot \vec{S}_\theta \cdot \vec{S}_\theta^H \cdot \vec{S}_\theta = g_n(\theta) \cdot E_{SA}^2$$

The smart antenna gain includes the gain of the beamforming as well as the gain of power combination.

The smart antenna gain in dB will be $G_{SA}(\varphi) = 10 \times Log(G_{SA}(\varphi))$.

The smart antenna is able to form the beam only in the horizontal plane, therefore, the vertical pattern is assumed to remain the same.

Power Combining Gain

Cell transmission power is fed to each antenna element of the smart antenna system. Since each element transmits the same input power, this results in a gain due to power combination, i.e., the powers fed to each antenna element are combined for transmission.

Additional Processing in Monte Carlo Simulations

During Monte Carlo simulations, **9955** calculates the smart antenna gains (array correlation matrix $\vec{R}_\theta$) for each served mobile in a cell's coverage area in each iteration. The sum of these array correlation matrices for all the users served in one iteration *k* is calculated as follows:

$$\vec{R}_k = \sum_{j=1}^{J} p_j \cdot \vec{R}_j$$

Where $\vec{R}_k$ for any cell is the downlink array correlation matrix for iteration *k*, *J* is the number of served mobiles during the iteration, p_j is the EIRP transmitted towards the mobile *j*, and $\vec{R}_j$ is the array correlation matrix for the mobile *j*.

9955 calculates a moving average of the array correlation matrices calculated in each iteration. At the end of a simulation with *K* iterations, the average downlink array correlation matrix for any cell is given by:

$$\vec{R}_{Avg} = \frac{1}{K} \cdot \sum_{k=1}^{K} \vec{R}_k$$

1.6.3 Uplink Beamforming

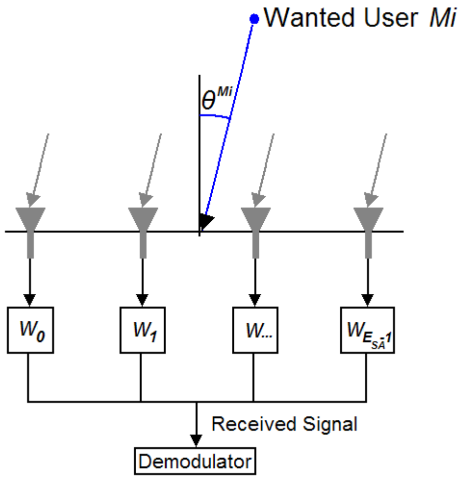


Figure 1.22: Uplink Beamforming

Let $\vec{w}$ represent the vector of E_{SA} complex weights for the beamformer. $\vec{w}$ is given by:

$$\vec{w} = \frac{\vec{S_\theta}}{\sqrt{E_{SA}}}$$

Where $\vec{S_\theta}$ is the steering vector in the direction of the served user, θ.

The total noise received in the uplink, i.e., interference and thermal noise, is stored in a total noise correlation matrix, R_N. The total noise correlation matrix is the sum of the thermal noise correlation matrix R_n, and the interference correlation matrix R_I, given by:

$$R_N = R_n + R_I = \sigma_n^2 \cdot I + \sum_{j=1}^{J} p_j \cdot \vec{S_j} \cdot \vec{S_j}^H$$

Where $R_n = \sigma_n^2 \cdot I$ and $R_I = \sum_{j=1}^{J} p_j \cdot \vec{S_j} \cdot \vec{S_j}^H$

σ_n^2 is the thermal noise power. I is the identity matrix. p_j is the power received by one element of the smart antenna from the j^{th} interfering mobile. $\vec{S_j}$ is the steering vector in the direction of the j^{th} interfering mobile, φ. J is the total number of interfering mobiles.

The total noise power, including thermal noise and interference from all uplink interferers, received by a cell is given by:

$$P_N = \vec{w}^H \cdot R_N \cdot \vec{w}$$

And, the total power received from the served user is given by:

$$P_\theta = p_\theta \cdot \vec{w}^H \cdot \vec{S_\theta} \cdot \vec{S_\theta}^H \cdot \vec{w} = p_\theta \cdot E_{SA}$$

Where p_θ is the power received by one element of the smart antenna from the served user.

In TD-SCDMA, the uplink signal quality is calculated by:

$$Q_{UL}^{SA} = \frac{P_\theta}{P_N} = \frac{p_\theta \cdot E_{SA}}{\vec{w}^H \cdot R_N \cdot \vec{w}}$$

In WiMAX, the C/(I+N) in the uplink is then calculated by:

$$CINR_{UL} = \frac{P_\theta}{P_N} = \frac{p_\theta \cdot E_{SA}}{\vec{w}^H \cdot R_N \cdot \vec{w}}$$

From the above equation, we can determine the uplink smart antenna beamforming gain in the direction of the served user, which equals the number of smart antenna elements, i.e., $G_{SA} = E_{SA}$.

Additional Processing in Monte Carlo Simulations

The noise correlation matrix R_N for each iteration *k* includes the effect of the matrix calculated for the previous iteration. The result is the angular distribution of the uplink load (TD-SCDMA) or the uplink noise rise (WiMAX), which is calculated from the noise correlation matrix obtained at the end of the last iteration of a Monte Carlo simulation. This angular distribution of the uplink load (TD-SCDMA) or the uplink noise rise (WiMAX) can be stored in the Cells table. The average of the noise correlation matrices is calculated as follows:

$$R_N\big|_{Avg} = \frac{1}{K} \cdot \sum_{k=1}^{K} R_N\big|_k$$

Where $R_N\big|_{Avg}$ is the average of the noise correlation matrices of all the iterations from $k = 1$ to K, and $R_N\big|_k$ is the noise correlation matrix of the k^{th} iteration.

The interference can be isolated from the thermal noise and can be calculated for any direction using the formula.

$$I_{UL}(\varphi) = \vec{w}^H \cdot R_N\big|_{Avg} \cdot \vec{w} - \sigma_n^2$$

Where $I_{UL}(\varphi)$ is the interfering signal in the direction φ, E_{SA} is the number of smart antenna elements, $\vec{S}_\varphi$ is the steering vector in the direction φ, and σ_n^2 is the thermal noise power.

In TD-SCDMA, the uplink load is calculated from the average noise correlation matrix. In WiMAX, the angular distribution of the uplink noise rise is given by:

$$NR_{UL}(\varphi) = \frac{I_{UL}(\varphi) + \sigma_n^2}{\sigma_n^2}$$

1.6.4 Uplink Beamforming and Interference Cancellation (MMSE)

The optimum beamformer uses the Minimum Mean Square Error algorithm in the uplink in order to cancel interference. The Minimum Mean Square Error algorithm optimizes the useful signal as well as maximizes the signal quality.

A simple null steering beamformer can cancel the interference from the most interfering $E_{SA} - 1$ interfering mobiles. The optimum beamforming method used in **9955** overcomes this limitation. It calculates the optimum smart antenna weights using the knowledge of directions and power levels of interference. These weights do not try to fully cancel $E_{SA} - 1$ interference signals, but rather try to reduce the overall received interference as much as possible.

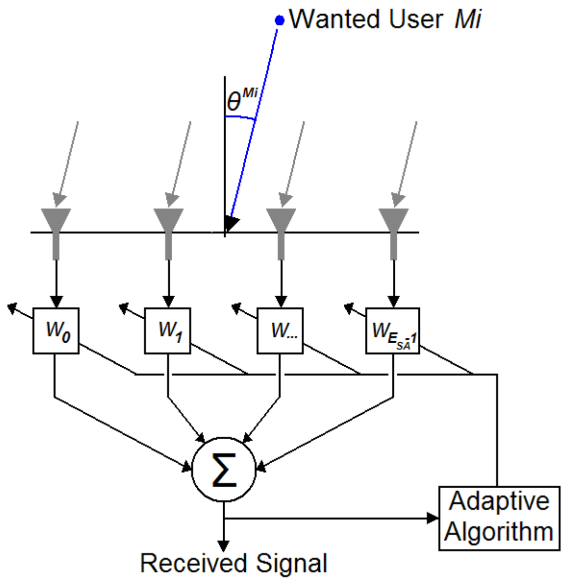


Figure 1.23: Uplink Adaptive Algorithm

Let $\hat{w}$ represent the vector of E_{SA} complex weights for the beamformer. $\hat{w}$ is given by:

$$\hat{w} = \mu_\theta \cdot R_N^{-1} \cdot \vec{S_\theta}$$

Where $\vec{S_\theta}$ is the steering vector in the direction of the served user, θ . μ_θ , which is a constant value for a given useful signal that optimizes the beamformer weights. It is given by the equation:

$$\mu_\theta = \frac{\sqrt{E_{SA}}}{\vec{S_\theta}^H \cdot R_N^{-1} \cdot \vec{S_\theta}}$$

R_N^{-1} is the inverse of the total noise correlation matrix. The total noise correlation matrix is the sum of the thermal noise correlation matrix R_n , and the interference correlation matrix R_I , given by:

$$R_N = R_n + R_I = \sigma_n^2 \cdot I + \sum_{j=1}^{J} p_j \cdot \vec{S_j} \cdot \vec{S_j}^H$$

Where $R_n = \sigma_n^2 \cdot I$ and $R_I = \sum_{j=1}^{J} p_j \cdot \vec{S_j} \cdot \vec{S_j}^H$

σ_n^2 is the thermal noise power. I is the identity matrix. p_j is the power received by one element of the smart antenna from the j^{th} interfering mobile. $\vec{S_j}$ is the steering vector in the direction of the j^{th} interfering mobile, φ . J is the total number of interfering mobiles.

The total noise power, including thermal noise and interference from all uplink interferers, received by a cell is given by:

$$\hat{P}_N = \mu_\theta^2 \cdot \vec{S_\theta}^H \cdot R_N^{-1} \cdot \vec{S_\theta}$$

And, the total power received from the served user is given by:

$$\hat{P}_\theta = p_\theta \cdot \mu_\theta^2 \cdot (\vec{S_\theta}^H \cdot R_N^{-1} \cdot \vec{S_\theta})^2$$

Where p_θ is the power received by one element of the smart antenna from the served user.

In TD-SCDMA, the uplink signal quality is calculated by:

$$Q_{UL}^{SA} = \frac{\hat{P}_\theta}{\hat{P}_N} = p_\theta \cdot \vec{S_\theta}^H \cdot R_N^{-1} \cdot \vec{S_\theta}$$

In WiMAX, the C/(I+N) in the uplink is then calculated by:

$$CINR_{UL} = \frac{\hat{P}_\theta}{\hat{P}_N} = p_\theta \cdot \vec{S_\theta}^H \cdot R_N^{-1} \cdot \vec{S_\theta}$$

From the above equation, we can determine the uplink smart antenna beamforming gain in the direction of the served user. $RSCP_{TCH-UL}$ (TD-SCDMA) or C_{UL} (WiMAX) can be calculated from the above equation by considering the interference and noise to be null, i.e., $R_N^{-1} = I$. This gives:

In TD-SCDMA, $RSCP_{TCH-UL} = p_\theta \cdot \vec{S_\theta}^H \cdot I \cdot \vec{S_\theta} = p_\theta \cdot E_{SA}$

In WiMAX, $C_{UL} = p_\theta \cdot \vec{S_\theta}^H \cdot I \cdot \vec{S_\theta} = p_\theta \cdot E_{SA}$

From the above equation, the uplink smart antenna beamforming gain equals the number of smart antenna elements, i.e., $G_{SA} = E_{SA}$.

Additional Processing in Monte Carlo Simulations

The inverse noise correlation matrix R_N^{-1} for each iteration k includes the effect of the matrix calculated for the previous iteration. Hence, **9955** is able to calculate an average of the smart antenna interference-cancellation effect. The result is the angular distribution of the uplink load (TD-SCDMA) or the uplink noise rise (WiMAX), which is calculated from the inverse of the noise correlation matrix obtained at the end of the last iteration of a Monte Carlo simulation. This angular distribution of the uplink load (TD-SCDMA) or the uplink noise rise (WiMAX) can be stored in the Cells table. The average of the inverse noise correlation matrices is calculated as follows:

$$R_N^{-1}\Big|_{Avg} = \frac{1}{K} \cdot \sum_{k=1}^{K} R_N^{-1}\Big|_k$$

Where $R_N^{-1}\Big|_{Avg}$ is the average of the inverse noise correlation matrices of all the iterations from $k = 1$ to K, and $R_N^{-1}\Big|_k$ is the inverse noise correlation matrix of the k^{th} iteration.

The interference can be isolated from the thermal noise and can be calculated for any direction using the formula.

$$I_{UL}(\varphi) = \frac{E_{SA}}{\grave{S}_\varphi^H \cdot R_N^{-1}\Big|_{Avg} \cdot \grave{S}_\varphi} - \sigma_n^2$$

Where $I_{UL}(\varphi)$ is the interfering signal in the direction φ, E_{SA} is the number of smart antenna elements, $\grave{S}_\varphi$ is the steering vector in the direction φ, and σ_n^2 is the thermal noise power.

In TD-SCDMA, the uplink load is calculated from the average inverse noise correlation matrix. In WiMAX, the angular distribution of the uplink noise rise is given by:

$$NR_{UL}(\varphi) = \frac{I_{UL}(\varphi) + \sigma_n^2}{\sigma_n^2}$$

Chapter 2

Radio Propagation

This chapter provides information about propagation models and calculations related to path loss.

In this chapter, the following are explained:

- "Path Loss Calculation Prerequisites" on page 53
- "List of Default Propagation Models" on page 57
- "Okumura-Hata and Cost-Hata Propagation Models" on page 58
- "ITU 529-3 Propagation Model" on page 59
- "Standard Propagation Model (SPM)" on page 60
- "WLL Propagation Model" on page 70
- "ITU-R P.526-5 Propagation Model" on page 71
- "ITU-R P.370-7 Propagation Model" on page 71
- "Erceg-Greenstein (SUI) Propagation Model" on page 73
- "ITU-R P.1546-2 Propagation Model" on page 75
- "Sakagami Extended Propagation Model" on page 79
- "Free Space Loss" on page 81
- "Diffraction" on page 81
- "Shadow Fading Model" on page 85
- "Path Loss Matrices" on page 98
- "Coverage Prediction Export and Reports" on page 102

2 Radio Propagation

Path loss calculations are carried out between a transmitter and a reciever using propagation models and other calculations related to radio wave propagation such as diffraction and shadow fading. Propagation models are mathematical representations of the average loss in signal strength over distance. Diffraction loss and shadow fading margins are added to this average loss in order to get more precise path loss values.

Path loss matrices are calculated for each transmitter and their results used in other calculations (coverage predictions, Monte Carlo simulations, point analysis, etc.). The method of calculation may differ depending on the analysis being performed:

Analysis type	Receiver position	Calculation	Profile extraction	Result
Coverage predictions	Centre of each bin inside the calculation area	Based on path loss matrices	Radial[a]	One value for the bin's surface area
Point analysis (Profile)	Anywhere	Real-time	Systematic	Different values inside a calculation bin
Point analysis (other)	Anywhere inside the calculation areas	Based on path loss matrices	Radial[a]	One value for the bin's surface area
Monte Carlo simulations	Mobile coordinates	Based on path loss matrices	Radial[a]	One value at the mobile location
Subscriber lists	Subscriber coordinates	Real-time	Radial[a]	One value at the subscriber location

a. With the Standard Propagation Model, you can choose between radial or systematic.

This chapter describes the various propagation models available in **9955**, and other radio wave propagation phenomena such as diffraction and shadow fading.

2.1 Path Loss Calculation Prerequisites

2.1.1 Ground Altitude Determination

9955 determines reception and transmission site altitude from Digital Terrain Model map. The method used to evaluate site altitude is based on a bilinear interpolation. It is described below.

Let us suppose a site S located inside a bin. **9955** knows the altitudes of four bin vertices, S'1, S''1, S'2 and S''2, from the DTM file (centre of each DTM pixel).

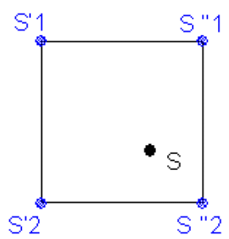


Figure 2.1: Ground Altitude Determination - 1

1. **9955** draws a vertical line through S. This line respectively intersects (S'1,S''1) and (S'2, S''2) lines at S1 and S2.

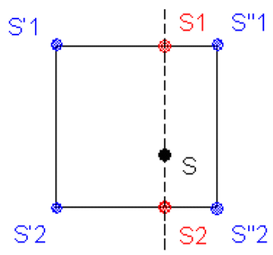


Figure 2.2: Ground Altitude Determination - 2

2. **9955** determines the S1 and S2 altitudes using a linear interpolation method.

Figure 2.3: Ground Altitude Determination - 3

3. **9955** performs a second linear interpolation to evaluate the S altitude.

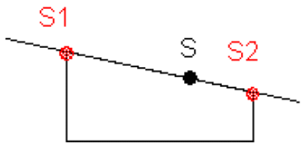


Figure 2.4: Ground Altitude Determination - 4

2.1.2 Clutter Determination

Some propagation models need clutter class and clutter height as information at receiver or along a transmitter-receiver profile.

9955 uses clutter classes file to determine the clutter class.

To evaluate the clutter height, **9955** uses clutter heights file if available in the .atl document; clutter height of a site is the height of the nearest point in the file.

Example: Let us suppose a site S. In the clutter heights file, **9955** reads clutter heights of four points around the site, S’1, S’’1, S’2 and S’’2. Here, the nearest point to S is S”2; therefore **9955** takes the S”2 clutter height as clutter height of S.

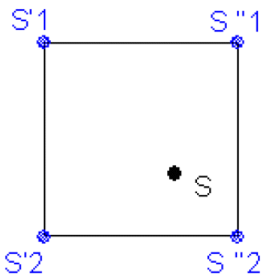


Figure 2.5: Clutter Height

If you do not have any clutter height file, **9955** takes clutter height information in clutter classes file. In this case, clutter height is an average height related to a clutter class.

2.1.3 Geographic Profile Extraction

Geographic profile extraction is needed in order to calculate diffraction losses. Profiles can be based on DTM only or on DTM and clutter both, depending on the selected propagation model.

Method 1: Radial Extraction

9955 draws radials from the site (where transmitter is located) to each calculation bin located along the transmitter calculation area border. In other words, **9955** determines a geographic profile between site and each bin centre.

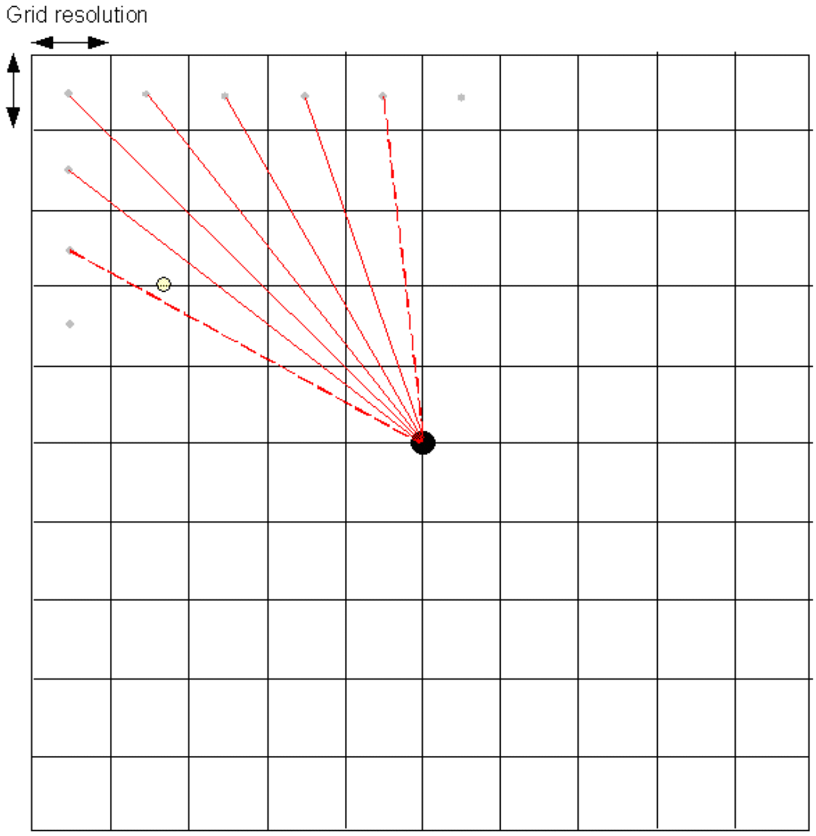


Figure 2.6: Radial calculation method

- Transmitter location
- Radials (**9955** extracts a geographic profile for each radial)
- Centres of bins located on the calculation border
- Receiver location

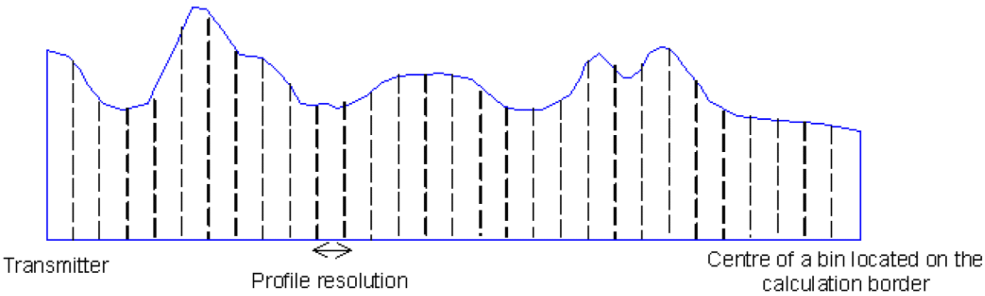


Figure 2.7: Site-bin centre profile

Depending on the calculation being carried out, the receiver may be located at the centre of a calculation bin (coverage predictions) or anywhere within a calculation bin. **9955** uses the profile nearest to the receiver for calculations (the receiver is assumed to be located on the profile).

Method 2: Systematic Extraction

9955 extracts a precise geographic profile between the site and the receiver.

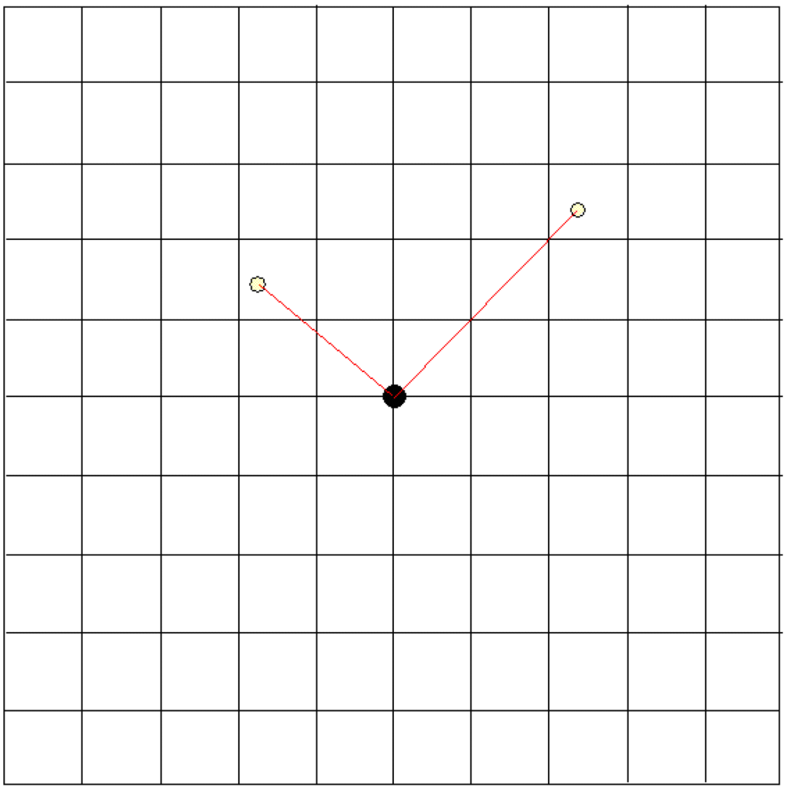


Figure 2.8: Radial calculation method

- ● Transmitter location
- —— Geographic profile
- ● Receiver location

2.1.4 Resolution of the Extracted Profiles

Geographic profile resolution depends on resolution of geographic data used by the propagation model (DTM and/or clutter). The selected profile resolution does not depend on the geographic layer order.

- If the propagation model uses both DTM and clutter heights along the profile, the profile resolution will be the highest of the two.

  Example 1 (Using the Standard Propagation Model)

  A DTM map with a 40 m resolution and a clutter heights map with a 20 m resolution are available. The profile resolution will be 20 m. It means that **9955** will extract geographic information, ground altitude and clutter height, every 20 m.

  To get ground altitude every 20 m, **9955** uses the bilinear interpolation method described in "Ground Altitude Determination" on page 53. Clutter heights are read from the clutter heights map. **9955** takes the clutter height of the nearest point every 20 m.

  Example 2 (Using the Standard Propagation Model)

  A DTM map with a 40 m resolution and a clutter classes map with a 20 m resolution are available. No clutter height file has been imported in the document. The profile resolution will be 20 m. It means that **9955** will extract geographic information, ground altitude and clutter height, every 20 m.

  To get ground altitude every 20 m, **9955** uses the bilinear interpolation method described in "Ground Altitude Determination" on page 53. **9955** uses the clutter classes map to determine clutter height. Every 20 m, it determines clutter class and takes associated average height.

- If the propagation model uses only DTM along the profile, the profile resolution will be the highest resolution among the DTM files.

  Example (Using the Cost-Hata Propagation Model)

  DTM maps with 40 m and 25 m resolutions and a clutter map with a 20 m resolution are available. The profile resolution will be 25 m. It means that **9955** will extract geographic information, only the ground altitude, every 25 m.

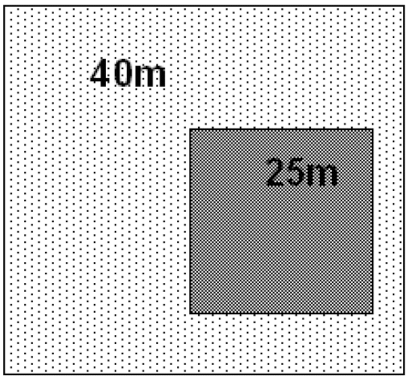
The profile resolution does not depend on the geographic layer order in the **Geo** tab of the **Explorer** window. However, the geographic layer order has influence on the usage of the data. For example, when DTM 1 is on the top of DTM 2, **9955** will use DTM 1 for extracting the profile where DTM a is available and it will use DTM 2 elsewhere.

To get ground altitude every 25 m, **9955** uses the bilinear interpolation method described in "Ground Altitude Determination" on page 53.

Geo Tab of the Explorer Window

> DTM
  > DTM 1 (25m)
  > DTM 2 (40m)

> Clutter
  > Clutter (20m)



2.2 List of Default Propagation Models

Propagation models available in **9955** are listed in the table below along with their main characteristics.

Propagation model	ITU 370-7 (Vienna 93)	ITU 1546	ITU 526-5	WLL
Frequency band	100-400 MHz	30-3000 MHz	30-10000 MHz	30-10000 MHz
Physical phenomena	Free space loss Corrected standard loss	Free space loss + corrections	Free space loss Diffraction loss	Free space loss Diffraction loss
Diffraction calculation method	-	-	Deygout (3 obstacles) Deygout corrected (3 obstacles)	Deygout (3 obstacles)
Profile based on	-	-	DTM	DTM Clutter
Profile extraction mode	-	-	Radial	Radial
Cell size	Macro cell	Macro cell	Macro cell	-
Receiver location	Rooftop	Rooftop	Street	Street Rooftop
Receiver	Fixed	Mobile	Fixed	Fixed
Use	d > 10 km Low frequencies Broadcast	1 < d < 1000 km Land and maritime mobile, broadcast	Fixed receivers WLL	Fixed receivers WLL, Microwave links, WiMAX

Propagation model	Standard Propagation Model	Erceg-Greenstein (SUI)	ITU 529-3	COST-Hata Okumura-Hata
Frequency band	150-3500 MHz	1900-6000 MHz	300-1500 MHz	150-2000 MHz
Physical phenomena	L(d, H_{Txeff}, H_{Rxeff}, Diff loss, clutter)	L(d, f, H_{Tx}, H_{Rx}) (per environment) Diffraction loss	L(d, f, H_{Rx}) (per environment) Diffraction loss	L(d, f, H_{Rx}) (per environment) Diffraction loss
Diffraction calculation method	Deygout (3 obstacles) Epstein-Peterson (3 obstacles) Deygout corrected (3 obstacles) Millington (1 obstacle)	Deygout (1 obstacle)	Deygout (1 obstacle)	Deygout (1 obstacle)
Profile based on	DTM Clutter	DTM	DTM	DTM

Propagation model	Standard Propagation Model	Erceg-Greenstein (SUI)	ITU 529-3	COST-Hata Okumura-Hata
Profile extraction mode	Radial Systematic	Radial	Radial	Radial
Cell size	Macro cell Mini cell	Macro cell Mini cell	Macro cell Mini cell	Macro cell Mini cell
Receiver location	Street Rooftop	Street	Street	Street
Receiver	Mobile and Fixed	Fixed	Mobile	Mobile
Use	1 < d < 20 km GSM, UMTS, CDMA2000, WiMAX, LTE	Urban and suburban areas 100 m < d < 8 km Fixed WiMAX	1 < d < 100 km GSM, CDMA2000, LTE	GSM, UMTS, CDMA2000, LTE

2.3 Okumura-Hata and Cost-Hata Propagation Models

2.3.1 Hata Path Loss Formula

Hata formula empirically describes the path loss as a function of frequency, receiver-transmitter distance and antenna heights for an urban environment. This formula is valid for flat, urban environments and 1.5 metre mobile antenna height.

Path loss (*Lu*) is calculated (in dB) as follows:

$$Lu = A_1 + A_2 log(f) + A_3 log(h_{Tx}) + (B_1 + B_2 log(h_{Tx}) + B_3 h_{Tx}) log d$$

f is the frequency (MHz).

h_{Tx} is the transmitter antenna height above ground (m) (*Hb* notation is also used in **9955**).

d is the distance between the transmitter and the receiver (km).

The parameters A_1, A_2, A_3, B_1, B_2, and B_3 can be user-defined. Default values are proposed in the table below:

Parameters	Okumura-Hata $f \le 1500$ MHz	Cost-Hata $f > 1500$ MHz
A_1	69.55	49.30
A_2	26.16	33.90
A_3	-13.82	-13.82
B_1	44.90	44.90
B_2	-6.55	-6.55
B_3	0	0

2.3.2 Corrections to the Hata Path Loss Formula

As described above, the Hata formula is valid for urban environment and a receiver antenna height of 1.5m. For other environments and mobile antenna heights, corrective formulas must be applied.

- For urban areas: $L_{model1} = Lu - a(h_{Rx})$
- For suburban areas: $L_{model1} = Lu - a(h_{Rx}) - 2\left(log\left(\frac{f}{28}\right)\right)^2 - 5.4$
- For quasi-open rural areas: $L_{model1} = Lu - a(h_{Rx}) - 4.78(log(f))^2 + 18.33 log(f) - 35.94$
- For open rural areas: $L_{model1} = Lu - a(h_{Rx}) - 4.78(log(f))^2 + 18.33 log(f) - 40.94$

$a(h_{Rx})$ is a correction for a receiver antenna height different from 1.5m.

- For rural/small cities: $a(h_{Rx}) = (1.1 log(f) - 0.7) h_{Rx} - (1.56 log(f) - 0.8)$
- For large cities: $a(h_{Rx}) = 3.2(log(11.75 h_{Rx}))^2 - 4.97$

When receiver antenna height equals 1.5m, $a(h_{Rx})$ is close to 0 dB regardless of frequency.

2.3.3 Calculations in 9955

Hata models take into account topo map (DTM) between transmitter and receiver and morpho map (clutter) at the receiver.

1st step: For each calculation bin, **9955** determines the clutter bin on which the receiver is located. This clutter bin corresponds to a clutter class. Then, it uses the Hata formula assigned to this clutter class to evaluate L_{model1}.

2nd step: This step depends on whether the 'Add diffraction loss' option is checked.

- If the 'Add diffraction loss' option is unchecked, **9955** stops calculations.

  $L_{model} = L_{model1}$

- If the 'Add diffraction loss' option is selected, **9955** proceeds as follows:

  a. It extracts a geographic profile between the transmitter and the receiver based on the radial calculation mode.

  b. It determines the largest obstacle along the profile in accordance with the Deygout method and evaluates losses due to diffraction L_{model2}.

  $L_{model} = L_{model1} + L_{model2}$

2.4 ITU 529-3 Propagation Model

2.4.1 ITU 529-3 Path Loss Formula

The ITU 529.3 model is a Hata-based model. For this reason, its formula empirically describes the path loss as a function of frequency, receiver-transmitter distance and antenna heights for a urban environment. This formula is valid for flat, urban environments and 1.5 metre mobile antenna height.

The standard ITU 529-3 formula, for a receiver located on a urban environment, is given by:

$$E = 69.82 - 6.16\log f + 13.82\log h_{Tx} - (44.9 - 6.55\log h_{Tx})(\log d)^b$$

where:

E is the field strength for 1 kW ERP

f is the frequency (MHz).

h_{Tx} is the transmitter antenna height above ground (m) (H_b notation is also used in **9955**)

h_{Rx} is the receiver antenna height above ground (m)

d is the distance between the transmitter and the receiver (km)

b is the distance correction

The domain of validity of such is formula is:

- Frequency range: 300-1500 MHz
- Base Station height: 30-200 m
- Mobile height: 1-10 m
- Distance range: 1-100 km

Since **9955** needs the path loss (*Lu*) formula, a conversion has to be made. One can find the following conversion formula:

$$Lu = 139.37 + 20\log f - E$$

which gives the following path loss formula for the ITU 529-3 model:

$$Lu = 69.55 + 26.16\log f - 13.82\log h_{Tx} + (44.9 - 6.55\log h_{Tx})(\log d)^b$$

2.4.2 Corrections to the ITU 529-3 Path Loss Formula

Environment Correction

As described above, the Hata formula is valid for urban environment. For other environments and mobile antenna heights, corrective formulas must be applied.

$L_{model1} = Lu - a(h_{Rx})$ for large city and urban environments

$$L_{model1} = Lu - a(h_{Rx}) - 2\left(\log\left(\frac{f}{28}\right)\right)^2 - 5.4 \text{ for suburban area}$$

$$L_{model1} = Lu - a(h_{Rx}) - 4.78(\log f)^2 + 18.33\log f - 40.94 \text{ for rural area}$$

Area Size Correction

In the formulas above, $a(h_{Rx})$ is the environment correction and is defined according to the area size.

- For rural/small cities: $a(h_{Rx}) = (1.1\log(f) - 0.7)h_{Rx} - (1.56\log(f) - 0.8)$
- For large cities: $a(h_{Rx}) = 3.2(\log(11.75h_{Rx}))^2 - 4.97$

Distance Correction

The distance correction refers to the term *b* above.

- d<20 km: $b = 1$
- d>20 km: $b = 1 + (0.14 + 1.87\times10^{-4}f + 1.07\times10^{-3}h'_{Tx})\times\left(\log\frac{d}{20}\right)^{0.8}$ with $h'_{Tx} = \frac{h_{Tx}}{\sqrt{1 + 7\times10^{-6}h_{Tx}^2}}$

2.4.3 Calculations in 9955

Hata-based models take into account topo map (DTM) between transmitter and receiver and morpho map (clutter) at the receiver.

1st step: For each calculation bin, **9955** determines the clutter bin on which the receiver is located. This clutter bin corresponds to a clutter class. Then, it uses the ITU 529-3 formula assigned to this clutter class to evaluate L_{model1}.

2nd step: This step depends on whether the 'Add diffraction loss' option is checked.

- If the 'Add diffraction loss' option is unchecked, **9955** stops calculations.

  $L_{model} = L_{model1}$

- If the 'Add diffraction loss' option is selected, **9955** proceeds as follows:

  a. It extracts a geographic profile between the transmitter and the receiver based on the radial calculation mode.

  b. It determines the largest obstacle along the profile in accordance with the Deygout method and evaluates losses due to diffraction (L_{model2}).

  $L_{model} = L_{model1} + L_{model2}$

2.5 Standard Propagation Model (SPM)

2.5.1 SPM Path Loss Formula

SPM is based on the following formula:

$$L_{model} = K_1 + K_2\log(d) + K_3\log(H_{Txeff}) + K_4\times DiffractionLoss + K_5\log(d)\times\log(H_{Txeff}) + K_6(H_{Rxeff}) + K_7\log(H_{Rxeff}) + K_{clutter}f(clutter)$$

with,

K_1: constant offset (dB).

K_2: multiplying factor for log(d).

d: distance between the receiver and the transmitter (m).

K_3: multiplying factor for log(H_{Txeff}).

HTxeff: effective height of the transmitter antenna (m).

K_4: multiplying factor for diffraction calculation. K_4 has to be a positive number.

Diffraction loss: loss due to diffraction over an obstructed path (dB).

K_5: multiplying factor for $log(d) \times log(H_{Txeff})$

K_6: multiplying factor for H_{Rxeff}

K_7: multiplying factor for $log(H_{Rxeff})$.

H_{Rxeff} : effective mobile antenna height (m).

$K_{clutter}$: multiplying factor for f(clutter).

f(clutter): average of weighted losses due to clutter.

2.5.2 Calculations in 9955

2.5.2.1 Visibility and Distance Between Transmitter and Receiver

For each calculation bin, **9955** determines:

- The distance between the transmitter and the receiver.

If the distance Tx-Rx is less than the maximum user-defined distance (break distance), the receiver is considered to be near the transmitter. **9955** will use the set of values marked “Near transmitter”.

If the distance Tx-Rx is greater than the maximum distance, receiver is considered far from transmitter. **9955** will use the set of values “Far from transmitter”.

- Whether the receiver is in the transmitter line of sight or not.

If the receiver is in the transmitter line of sight, **9955** will take into account the set of values (K1,K2)LOS. The LOS is defined by no obstruction along the direct ray between the transmitter and the receiver.

If the receiver is not in the transmitter line of sight, **9955** will use the set of values (K1,K2)NLOS.

2.5.2.2 Effective Transmitter Antenna Height

Effective transmitter antenna height (H_{Txeff}) may be calculated with six different methods.

Height Above Ground

The transmitter antenna height is above the ground (H_{Tx} in m).

$H_{Txeff} = H_{Tx}$

Height Above Average Profile

The transmitter antenna height is determined relative to an average ground height calculated along the profile between a transmitter and a receiver. The profile length depends on distance min and distance max values and is limited by the transmitter and receiver locations. Distance min and Distance max are minimum and maximum distances from the transmitter respectively.

$$H_{Txeff} = H_{Tx} + (H_{0Tx} - H_0)$$

where,

H_{0Tx} is the ground height (ground elevation) above sea level at transmitter (m).

H_0 is the average ground height above sea level along the profile (m).

> If the profile is not located between the transmitter and the receiver, H_{Txeff} equals H_{Tx} only.

Slope at Receiver Between 0 and Minimum Distance

The transmitter antenna height is calculated using the ground slope at receiver.

$$H_{Txeff} = (H_{Tx} + H_{0Tx}) - H_{0Rx} + K \times d$$

where,

H_{0Rx} is the ground height (ground elevation) above sea level at receiver (m).

K is the ground slope calculated over a user-defined distance (Distance min). In this case, Distance min is a distance from receiver.

- If $H_{Txeff} < 20m$ then, **9955** uses 20m in calculations.
- If $H_{Txeff} > 200m$ then, **9955** takes 200m.

Spot H_t

If $H_{0Tx} > H_{0Rx}$ then, $H_{Txeff} = H_{Tx} + (H_{0Tx} - H_{0Rx})$

If $H_{0Tx} \leq H_{0Rx}$ then, $H_{Txeff} = H_{Tx}$

Absolute Spot H_t

$H_{Txeff} = H_{Tx} + |H_{0Tx} - H_{0Rx}|$

Distance min and distance max are set to 3000 and 15000 m according to ITU recommendations (low frequency broadcast f < 500 Mhz) and to 0 and 15000 m according Okumura recommendations (high frequency mobile telephony).

These values are only used in the two last methods and have different meanings according to the method.

Enhanced Slope at Receiver

9955 offers a new method called "Enhanced slope at receiver" to evaluate the effective transmitter antenna height.

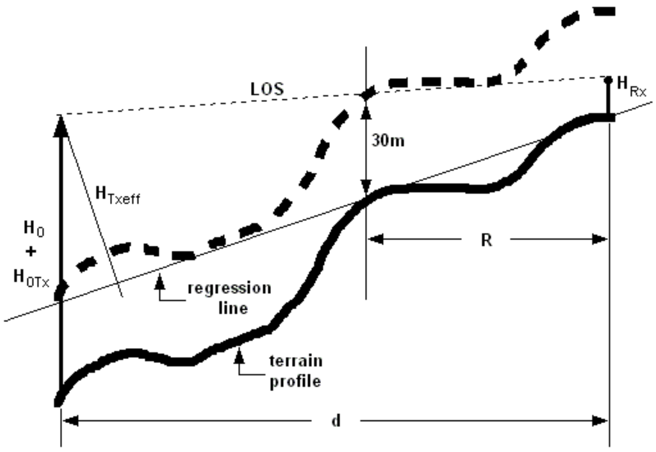


Figure 2.9: Enhanced Slope at Receiver

Let x-axis and y-axis respectively represent positions and heights. We assume that x-axis is oriented from the transmitter (origin) towards the receiver.

This calculation is achieved in several steps:

1. **9955** determines line of sight between transmitter and receiver.

   The LOS line equation is:

   $$Los(i) = (H_{0Tx} + H_{Tx}) - \frac{((H_{0Tx} + H_{Tx}) - (H_{0Rx} + H_{Rx}))}{d} Res(i)$$

   where,

   H_{Rx} is the receiver antenna height above the ground (m).

   i is the point index.

   Res is the profile resolution (distance between two points).

2. **9955** extracts the transmitter-receiver terrain profile.

3. Hills and mountains are already taken into account in diffraction calculations. Therefore, in order for them not to unfavourably influence the regression line calculation, **9955** filters the terrain profile.

   9955 calculates two filtered terrain profiles; one established from the transmitter and another from the receiver. It determines filtered height of every profile point. Profile points are evenly spaced on the basis of profile resolution. To determine filtered terrain height at a point, **9955** evaluates ground slope between two points and compares it with a threshold set to 0.05; where three cases are possible.

   Some notations defined hereafter are used in next part.

   H_{filt} is the filtered height.

   H_{orig} is the original height. Original terrain height is determined from extracted ground profile.

   - Filter starting from transmitter

     Let us assume that $H_{filt-Tx}(Tx) = H_{orig}(Tx)$

     For each point, we have three different cases:

     i. If $H_{orig}(i) > H_{orig}(i-1)$ and $\frac{H_{orig}(i) - H_{orig}(i-1)}{Res} \le 0.05$,

     Then, $H_{filt-Tx}(i) = H_{filt-Tx}(i-1) + (H_{orig}(i) - H_{orig}(i-1))$

     ii. If $H_{orig}(i) > H_{orig}(i-1)$ and $\frac{H_{orig}(i) - H_{orig}(i-1)}{Res} > 0.05$

     Then, $H_{filt-Tx}(i) = H_{filt-Tx}(i-1)$

     iii. If $H_{orig}(i) \le H_{orig}(i-1)$

     Then, $H_{filt-Tx}(i) = H_{filt-Tx}(i-1)$

     If $H_{filt}(i) > H_{orig}(i)$ additionally

     Then, $H_{filt-Tx}(i) = H_{orig}(i)$

   - Filter starting from receiver

   Let us assume that $H_{filt}(Rx) = H_{orig}(Rx)$

   For each point, we have three different cases:

     i. If $H_{orig}(i) > H_{orig}(i+1)$ and $\frac{H_{orig}(i) - H_{orig}(i+1)}{Res} \le 0.05$,

     Then, $H_{filt-Rx}(i) = H_{filt-Rx}(i+1) + (H_{orig}(i) - H_{orig}(i+1))$

     ii. If $H_{orig}(i) > H_{orig}(i+1)$ and $\frac{H_{orig}(i) - H_{orig}(i+1)}{Res} > 0.05$

     Then, $H_{filt-Rx}(i) = H_{filt-Rx}(i+1)$

     iii. 3rd case: If $H_{orig}(i) \le H_{orig}(i+1)$

     Then, $H_{filt-Rx}(i) = H_{filt-Rx}(i+1)$

     If $H_{filt}(i) > H_{orig}(i)$ additionally

     Then, $H_{filt-Rx}(i) = H_{orig}(i)$

     Then, for every point of profile, **9955** compares the two filtered heights and chooses the higher one.

     $H_{filt}(i) = max(H_{filt-Tx}(i), H_{filt-Rx}(i))$

4. **9955** determines the influence area, R. It corresponds to the distance from receiver at which the original terrain profile plus 30 metres intersects the LOS line for the first time (when beginning from transmitter).

   The influence area must satisfy additional conditions:

   - $R \ge 3000m$

- $R \geq 0.01 \cdot d$
- R must contain at least three bins.

> - When several influence areas are possible, **9955** chooses the highest one.
> - If d < 3000m, $R = d$.

5. **9955** performs a linear regression on the filtered profile within R in order to determine a regression line.

   The regression line equation is:

   $$y = ax + b$$

   $$a = \frac{\sum_i (d(i) - d_m)(H_{filt}(i) - H_m)}{\sum_i (d(i) - d_m)^2} \text{ and } b = H_m - ad_m$$

   where,

   $$H_m = \frac{1}{n}\sum_i H_{filt}(i)$$

   i is the point index. Only points within R are taken into account.

   $$d_m = d - \frac{R}{2}$$

   d(i) is the distance between *i* and the transmitter (m).

   Then, **9955** extends the regression line to the transmitter location. Therefore, its equation is:

   $$regr(i) = a \cdot (i \cdot Res) + b$$

6. Then, **9955** calculates effective transmitter antenna height, H_{Txeff} (m).

   $$H_{Txeff} = \frac{H_{0Tx} + H_{Tx} - b}{\sqrt{1 + a^2}}$$

   If H_{Txeff} is less than 20m, **9955** recalculates it with a new influence area, which begins at transmitter.

> - In case $H_{Txeff} > 1000m$, 1000m will be used in calculations.
> - If H_{Txeff} is still less than 20m, an additional correction is taken into account (7th step).

7. If H_{Txeff} is still less than 20m (even negative), **9955** evaluates path loss using $H_{Txeff} = 20m$ and applies a correction factor.

   Therefore, if $H_{Txeff} < 20m$,

   $$L_{model} = L_{model}((H_{Txeff} = 20m), d, f) + K_{lowant}$$

   where, $K_{lowant} = \frac{d}{10^5} - (0.3 \cdot (H_{Txeff} - 20)) - \frac{20 \cdot (1 - (H_{Txeff} - 20))}{\left(9.63 + \frac{d}{1000}\right) \cdot \left(6.93 + \frac{d}{1000}\right)}$

2.5.2.3 Effective Receiver Antenna Height

$$H_{Rxeff} = (H_{Rx} + H_{0Rx}) - H_{0Tx}$$

where,

H_{Rx} is the receiver antenna height above the ground (m).

H_{0Rx} is the ground height (ground elevation) above sea level at the receiver (m).

H_{0Tx} is the ground height (ground elevation) above sea level at the transmitter (m).

The calculation of effective antenna heights (H_{Rxeff} and H_{Txeff}) is based on extracted DTM profiles. They are not properly performed if you have not imported heights (DTM file) beforehand.

2.5.2.4 Correction for Hilly Regions in Case of LOS

An optional corrective term enables **9955** to correct path loss for hilly regions when the transmitter and the receiver are in Line-of-sight.

Therefore, if the receiver is in the transmitter line of sight and the Hilly terrain correction option is active, we have:

$$L_{model} = K_{1,LOS} + K_{2,LOS}log(d) + K_3log(H_{Txeff}) + K_5log(H_{Txeff})log(d) + K_6 \cdot H_{Rx} + K_{clutter}f(clutter) + K_{hill,LOS}$$

When the transmitter and the receiver are not in line of sight, the path loss formula is:

$$L_{model} = K_{1,NLOS} + K_{2,NLOS}log(d) + K_3log(H_{Txeff}) + K_4 \cdot Diffraction + K_5log(H_{Txeff})log(d) + K_6 \cdot H_{Rx} + K_{clutter}f(clutter)$$

$K_{hill,LOS}$ is determined in three steps. Influence area, R, and regression line are supposed available.

1st step: For every profile point within influence area, **9955** calculates height deviation between the original terrain profile and regression line. Then, it sorts points according to the deviation and draws two lines (parallel to the regression line), one which is exceeded by 10% of the profile points and the other one by 90%.

2nd step: **9955** evaluates the terrain roughness, Δh; it is the distance between the two lines.

3rd step: **9955** calculates $K_{hill,LOS}$.

We have $K_{hill,LOS} = K_h + K_{hf}$

If $0 < \Delta h \le 20m$, $K_h = 0$

Else $K_h = 7.73(log(\Delta h))^2 - 15.29log(\Delta h) + 6.746$

If $0 < \Delta h \le 10m$, $K_{hf} = -2 \cdot 0.1924 \cdot (H_{0Rx} + H_{Rx} - regr(i_{Rx}))$

Else $K_{hf} = -2 \cdot (-1.616(log(\Delta h))^2 + 14.75log(\Delta h) - 11.21) \cdot \frac{H_{0Rx} + H_{Rx} - regr(i_{Rx})}{\Delta h}$

i_{Rx} is the point index at receiver.

2.5.2.5 Diffraction

Four methods are available to calculate diffraction loss over the transmitter-receiver profile.

Along the transmitter-receiver profile, you may consider:

- Either ground altitude and clutter height (Consider heights in diffraction option),

  In this case, **9955** uses clutter height information from clutter heights file if available in the .atl document. Otherwise, it considers average clutter height specified for each clutter class in the clutter classes file description.
- Or only ground altitude.

2.5.2.6 Losses due to Clutter

9955 calculates *f(clutter)* over a maximum distance from receiver: $f(clutter) = \sum_{i=1}^{n} L_i w_i$

where,

L: loss due to clutter defined in the *Clutter* tab by the user (in dB).

w: weight determined through the weighting function.

n: number of points taken into account over the profile. Points are evenly spaced depending on the profile resolution.

Four weighting functions are available:

- Uniform weighting function: $w_i = \frac{1}{n}$
- Triangular weighting function: $w_i = \frac{d_i}{\sum_{j=1}^{n} d_j}$
- $d_i = D - d'_i$, where d'_i is the distance between the receiver and the *ith* point and D is the maximum distance defined.
- Logarithmic weighting function: $w_i = \frac{\log\left(\frac{d_i}{D}+1\right)}{\sum_{j=1}^{n}\log\left(\frac{d_j}{D}+1\right)}$
- Exponential weighting function: $w_i = \frac{e^{\frac{d_i}{D}}-1}{\sum_{j=1}^{n} e^{\frac{d_j}{D}}-1}$

The chart below shows the weight variation with the distance for each weighting function.

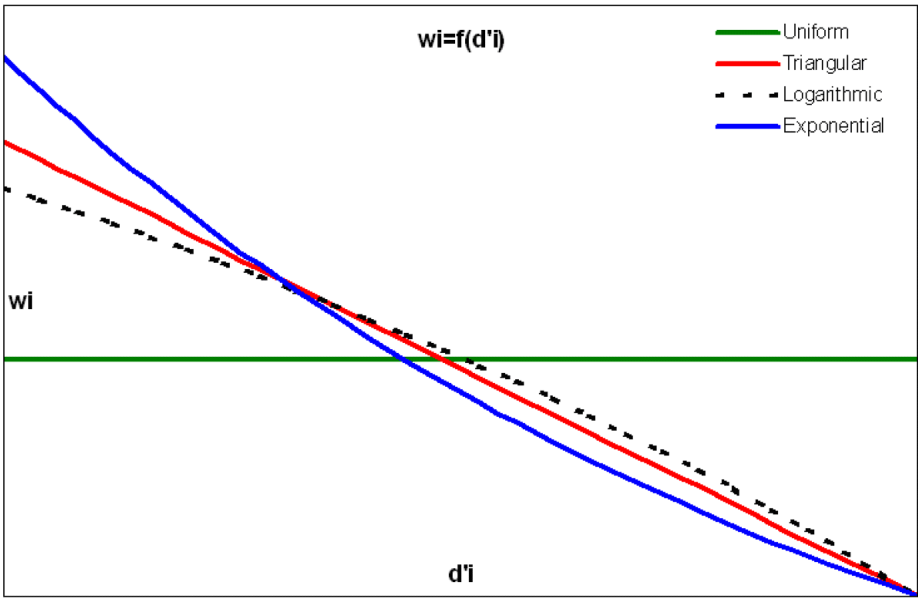


Figure 2.10: Losses due to Clutter

2.5.2.7 Recommendations

Beware that the clutter influence may be taken into account in two terms, *Diffraction loss* and *f(clutter)* at the same time. To avoid this, we advise:

1. Not to consider clutter heights to evaluate diffraction loss over the transmitter-receiver profile if you specify losses per clutter class.

   This approach is recommended if the **clutter height information is statistical** (clutter roughly defined, no altitude).

Or

2. Not to define any loss per clutter class if you take clutter heights into account in the diffraction loss.

   In this case, *f(clutter)=0*. Losses due to clutter are only taken into account in the computed *Diffraction loss* term.

   This approach is recommended if the clutter height information is either **semi-deterministic** (clutter roughly defined, altitude defined with an average height per clutter class) or **deterministic** (clutter sharply defined, altitude defined with an average height per clutter class or - even better - via a clutter height file).

In case of semi-deterministic clutter information, specify receiver clearance (m) per clutter class. Both ground altitude and clutter height are considered along the whole transmitter-receiver profile except over a specific distance around the receiver (clearance), where **9955** proceeds as if there was only the DTM map. The clearance information is used to model streets.

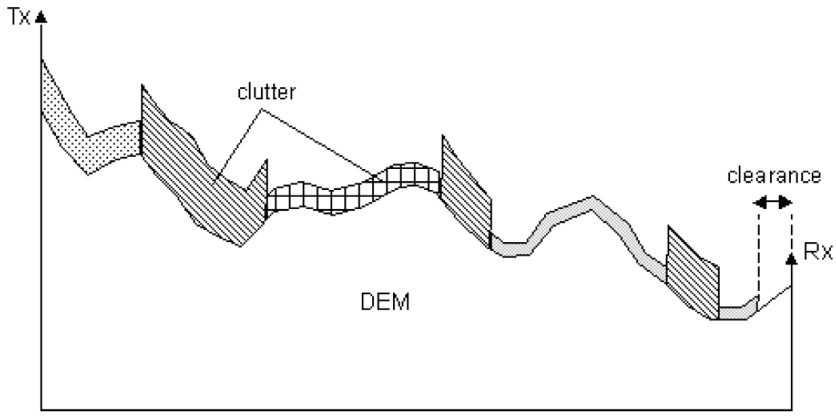


Figure 2.11: Tx-Rx profile

In the above figure, the ground altitude and clutter height (in this case, average height specified for each clutter class in the clutter classes map description) are taken into account along the profile.

Clearance definition is not necessary in case of deterministic clutter height information. Clutter height information is accurate enough to be used directly without additional information such as clearance. Two cases can be considered:

1. If the receiver is in the street (clutter height lower than receiver height), **9955** calculates the path loss by considering potentially some diffraction loss at reception.
2. If the receiver is supposed to be inside a building (clutter height higher than receiver height), **9955** does not consider any difraction (and clearance) from the building but takes into account the indoor loss as an additional penetration loss.

- To consider indoor losses in building only when using a deterministic clutter map (clutter height map), the 'Indoor Coverage' box must not be checked in predictions unless this loss will be counted twice inside buildings (on the entire reception clutter class and not only inside the building).
- Even with no clearance, the clutter height (extracted either from clutter class or clutter height folders) is never considered at the last profile point.

2.5.3 Automatic Calibration

The goal of this tool is to calibrate parameters and methods of the SPM formula in a simple and reproducible way. Calibration is based on imported CW measurement data. It is the process of limiting the difference between predicted and measured values. For a complete description of the calibration procedure (including the very important prerequisite filtering work on the CW measurement points), please refer to the User Manual and the SPM Calibration Guide.

The following SPM formula parameters can be estimated:

- K_1, K_2, K_3, K_4, K_5, K_6 and K_7
- Losses per clutter class ($K_{clutter}$ must be user-defined)
- Effective antenna height method
- Diffraction method

Automatic model calibration provides a mathematical solution. The relevance of this mathematical solution with a physical and realistic solution must be determined before committing these results.

You must keep in mind that the model calibration and its result (standard deviation and root mean square) strongly depend on the CW measurement samples you use. A calibrated model must restore the behaviour of CW measurements depending on their configuration on a large scale, and not just totally coincide with a few number of CW measurements. The calibrated model has to give correct results for every new CW measurement point in the same geographical zone, without having been calibrated on these new CW measurements.

2.5.3.1 General Algorithm

Propagation model calibration is a special case of the more general Least-Square problems, i.e. given a real m x n matrix A, and a real m-vector b, find a real n-vector x_0 that minimises the Euclidean length of Ax - b.

Here,

m is the number of measurement points,

n is the number of parameters to calibrate, A is the values of parameter associated variables (log(d), log(heff), etc.) at each measurement point, and

b is the vector of measurement values.

The vector x_0 is the set of parameters found at the end of the calibration.

The theoretical mathematical solution of this problem was found by Gauss (around 1830). Further enhancements to the original method were proposed in the 60's in order to solve the numerical instability problem.

In 1974, Lawson & Hanson [2] proposed a theoretical solution of the least-square problem with general linear inequality constraints on the vector x_0. **9955** implementation is based on this method, which is explained in detail in [1].

References:

[1] Björck A. "Numerical Methods for Least Square Problems", SIAM, 1996.

[2] Lawson C.L., Hanson R.J. "Solving Least Squares Problems", SIAM, 1974.

2.5.3.2 Sample Values for SPM Path Loss Formula Parameters

The following tables list some sample orders of magnitudes for the different parameters composing the Standard Propagation Model formula.

	Minimum	Typical	Maximum
K_1	Variable	Variable	Variable
K_2	20	44.9	70
K_3	-20	5.83	20
K_4	0	0.5	0.8
K_5	-10	-6.55	0
K_6	-1	0	0
K_7	-10	0	0

It is recommended to set K_6 to 0, and use K_7 instead of K_6. K_6 is a multiplicative coefficient to a value in dB, which means that slight variations in K_6 have considerable impact on the path loss.

K_1 depends on the frequency and the technology. Here are some sample values:

Project type	Frequency (MHz)	K_1
GSM 900	935	12.5
GSM 1800	1805	22
GSM 1900	1930	23
UMTS	2045[a]	23.8
1xRTT	1900	23
WiMAX	2300	25.6
	2500	26.8
	2700	27.9
	3300	30.9
	3500	31.7

a. *2045 MHz = (2140 + 1950)/2. It is the average of the downlink and uplink centre frequencies of the band.*

The above K1 values for WiMAX are extrapolated estimates for different frequency ranges. It is highly recommended to calibrate the SPM using measurement data collected on the field for WiMAX networks before using the SPM for predictions.

All K paramaters can be defined by the automatic calibration wizard. Since $K_{clutter}$ is a constant, its value is strongly dependant on the values given to the losses per clutter classes. From experience, typical losses (in dB) per clutter class are:

Dense urban	From 4 to 5
Woodland	From 2 to 3
Urban	0

Suburban	From -5 to -3
Industrial	From -5 to -3
Open in urban	From -6 to -4
Open	From -12 to -10
Water	From -14 to -12

These values have to be entered only when considering **statistical clutter class maps only**.

The Standard Propagation Model is derived from the Hata formulae, valid for urban environments. The above values are normalized for urban clutter types (0 dB for urban clutter class). Positive values correspond to more dense clutter classes and negative values to less dense clutter classes.

2.5.4 Unmasked Path Loss Calculation

You can use the SPM to calculate unmasked path losses. Unmasked path losses are calculated by not taking into account the transmitter antenna patterns, i.e., the attenuation due to the transmitter antenna pattern is not included. Such path losses are useful when using path loss matrices calculated by **9955** with automatic optimisation tools.

The instance of the SPM available by default, under the Propagation Models folder in the Modules tab, has the following characteristics:

- **Signature:** {D5701837-B081-11D4-931D-00C04FA05664}
- **Type:** Atoll.StdPropagModel.1

You can access these parameters in the Propagation Models table by double-clicking the Propagation Models folder in the Modules tab.

To make the SPM calculate path losses excluding the antenna pattern attenuation, you have to change the type of the SPM to:

- **Type:** Atoll.StdPropagModelUnmasked.1

However, changing the type only does not invalidate the already calculated path loss matrices, because the signature of the propagation model is still the same. If you want **9955** to recognize that the SPM has changed, and to invalidate the path loss matrices calculated with this model, you have to change the signature of the model as well. The default signature for the SPM that calculates unmasked path loss matrices is:

- **Signature:** {EEE060E5-255C-4C1F-B36C-A80D3D972583}

The above signature is a default signature. **9955** automatically creates different signatures for different instances of the same propagation model. Therefore, it is possible to create different instances of the SPM, with different parameter settings, and create unmasked versions of these instances.

You can change the signature and type of the original instance of the SPM, but it is recommended to make a copy of the SPM in order not to lose the original SPM parameters. So, you will be able to keep different versions of the SPM, those that calculate path losses with antenna pattern attenuation, and others that calculate path losses without it.

The usual process flow of an ACP working on an **9955** document through the API would be to:

1. Backup the storage directory of path loss matrices.
2. Set a different storage directory for calculating and storing unmasked path loss matrices.
3. Select the SPM used, backup it’s signature, and change its signature and type as shown above.
4. Perform optimisation using the path loss matrices calculated by the unmasked version of the SPM.
5. Restore the type and the signature of the SPM.
6. Reset the path loss storage directory to the original one.

- It is not possible to calibrate the unmasked version of the SPM using measurement data.
- You can also use Atoll.ini options, AngleCalculation = 2000 and AngleCalculation = 3000, for calculating unmasked path losses and angles of incidence, respectively. These options are only available for the propagation models available with **9955** by default. Please refer to the *Administrator Manual* for details.
- Using the SPM, you can also calculate the angles of incidence by creating a new instance of the SPM with the following characteristics:
  Type: Atoll.StdPropagModelIncidence.1
  Signature: {659F0B9E-2810-4e59-9F0D-DA9E78E1E64B}
- The "masked" version of the algorithm has not been changed. It still takes into account Atoll.ini options. However, the "unmasked" version does not take Atoll.ini options into account.
- It's highly recommended to use one method (Atoll.ini options) or the other one (new identifier & signature) but not to combine both.

2.6 WLL Propagation Model

2.6.1 WLL Path Loss Formula

$$L_{model} = L_{FS} + F_{Diff} \times L_{Diff}$$

Where L_{FS} is the free space loss calculated using the formula entered in the model properties, L_{Diff} is the diffraction loss calculated using the 3-obstacle Deygout method, and F_{Diff} is the diffraction multiplying factor defined in the model properties.

2.6.2 Calculations in 9955

Free Space Loss

For free space loss calculation, see "Free Space Loss" on page 81.

Diffraction

9955 calculates diffraction loss along the transmitter-receiver profile built from DTM and clutter maps. Therefore, losses due to clutter are taken into account in diffraction losses. **9955** takes clutter height information from the clutter heights file if available in the .atl document. Otherwise, it considers average clutter height specified for each clutter class in the clutter classes file description.

The Deygout construction (considering 3 obstacles) is used. This method is described under "Diffraction" on page 81. The final diffraction losses are determined by multiplying the diffraction losses calculated using the Deygout method by the Diffraction multiplying factor defined in the model properties.

- Receiver Clearance

  Define receiver clearance (m) per clutter class when clutter height information is either statistical or semi-deterministic. Both ground altitude and clutter height are considered along the whole profile except over a specific distance around the receiver (clearance), where **9955** proceeds as if there was only the DTM map (see **SPM** part). **9955** uses the clearance information to model streets.

  If the clutter is deterministic, do not define any receiver clearance (m) per clutter class. In this case, clutter height information is accurate enough to be used directly without additional information such as clearance (**9955** can locate streets).

- Receiver Height

  Entering receiver height per clutter class enables **9955** to consider the fact that receivers are fixed and located on the roofs.

- Visibility

  If the option 'Line of sight only' is not selected, **9955** computes L_{model} on each calculation bin using the formula defined above. When selecting the option 'Line of sight only', **9955** checks for each calculation bin if the *Diffraction loss* (as defined in the Diffraction loss: Deygout part) calculated along profile equals 0.

  - In this case, receiver is considered in 'line of sight' and **9955** computes L_{model} on each calculation bin using the formula defined above.

- Otherwise, **9955** considers that L_{model} tends to infinity.

2.7 ITU-R P.526-5 Propagation Model

2.7.1 ITU 526-5 Path Loss Formula

$$L_{model} = L_{FS} + L_{Diff}$$

Where L_{FS} is the free space loss calculated using the formula entered in the model properties and L_{Diff} is the diffraction loss calculated using the 3-obstacle Deygout method.

2.7.2 Calculations in 9955

Free Space Loss

For free space loss calculation, see "Free Space Loss" on page 81.

Diffraction

9955 calculates diffraction loss along the transmitter-receiver profile is built from the DTM map. The Deygout construction (considering 3 obstacles), with or without correction, is used. These methods are described under "Diffraction" on page 81.

2.8 ITU-R P.370-7 Propagation Model

2.8.1 ITU 370-7 Path Loss Formula

If d<1 km, $L_{model} = L_{FS}$

If d>1000 km, $L_{model} = 1000$

If 1<d<1000 km, $L_{model} = max(L_{FS}, CorrectedStandardLoss)$

d is the distance between the transmitter and the receiver (km).

2.8.2 Calculations in 9955

Free Space Loss

For free space loss calculation, see "Free Space Loss" on page 81.

Corrected Standard Loss

This formula is given for a 60 dBm (1kW) transmitter power.

$$CorrectedStandardLoss = 60 - C_n - A_{H_{Rxeff}} - A_{cl} - 108.75 + 31.54 - 20logf$$

where,

C_n is the field strength received in dBµV/m,

$A_{H_{Rxeff}}$ is a correction factor for effective receiver antenna height (dB),

A_{cl} is the correction for terrain clearance angle (dB),

f is the frequency in MHz.

- C_n Calculation

  The C_n value is determined from charts $C_n=f(d, H_{Txeff})$.

  In the following part, let us assume that $C_n=E_n(d,H_{Txeff})$ (where $E_n(d,H_{Txeff})$ is the field received in dBµV/m) is read from charts for a distance, d (in km), and an effective transmitter antenna height, H_{Txeff} (in m).

  First of all, **9955** evaluates the effective transmitter antenna height, H_{Txeff}, as follows:

If $0 \le d < 3km$, $H_{Txeff} = H_{0Tx} + H_{Tx} - H_{0Rx}$

If $3 \le d < 15km$, $H_{Txeff} = H_{0Tx} + H_{Tx} - H_0(3;d)$

If $15 < d$, $H_{Txeff} = H_{0Tx} + H_{Tx} - H_0(3;15)$

where,

H_{Tx} is the transmitter antenna height above the ground (m).

H_{0Tx} is the ground height (ground elevation) above sea level at the transmitter (m).

$H_0(3;d)$ is the average ground height (m) above sea level for the profile between a point 3 km from transmitter and the receiver (located at d km from transmitter).

$H_0(3;15)$ is the average ground height (m) above sea level for the profile between a point 3 km and another 15 km from transmitter.

Then, depending on d and H_{Txeff}, **9955** determines C_n using bilinear interpolation as follows.

If $37.5\ H_{Txeff}\ 1200$, $C_n = E_n(d,H_{Txeff})$

Otherwise, **9955** considers $d_{horizon} = 4.1 \cdot \sqrt{H_{Txeff}}$ (d is stated in km)

Therefore,

If $H_{Txeff} < 37.5$

If $d \ge d_{horizon}$, we have $C_n = E_n(d + 25 - d_{horizon}, 37.5)$

Else $C_n = E_n(d, 37.5) - E_n(d_{horizon}, 37.5) + E_n(25, 37.5)$

If $H_{Txeff} > 1200$

If $d \ge d_{horizon}$, we have $C_n = E_n(d + 142 - d_{horizon}, 1200)$

Else $C_n = E_n(d, 1200) - E_n(d_{horizon}, 1200) + E_n(142, 1200)$

- A_{HRxeff} Calculation

$$A_{H_{Rxeff}} = \frac{c}{6} \cdot 20 \cdot \log\left(\frac{H_{Rx}}{10}\right)$$

where,

H_{Rx} is the user-defined receiver height,

c is the height gain factor.

> *c* values are provided in the recommendation 370-7; for example, *c=4* in a rural case.

- A_{cl} Calculation

If f $\le$ 300 MHz, $A_{cl} = 8.1 - [6.9 + 20\log(\sqrt{((\nu - 0.1)^2 + 1)} + (\nu - 0.1))]$

Otherwise, $A_{cl} = 14.9 - [6.9 + 20\log(\sqrt{((\nu - 0.1)^2 + 1)} + (\nu - 0.1))]$

With $\nu = -\theta \cdot \sqrt{4000 \cdot \frac{f}{300}}$

where,

θ is the clearance angle (in radians) determined according to the recommendation 370-7 (figure 19),

f is the frequency stated in MHz.

2.9 Erceg-Greenstein (SUI) Propagation Model

Erceg-Greenstein propagation model is a statistical path loss model derived from experimental data collected at 1.9 GHz in 95 macrocells. The model is for suburban areas, and it distinguishes between different terrain categories called the Stanford University Interim Terrain Models. This propagation model is well suited for distances and base station antenna heights that are not well-covered by other models. The path loss model applies to base antenna heights from 10 to 80 m, base-to-terminal distances from 0.1 to 8 km, and three distinct terrain categories.

The basic path loss equation of the Erceg-Greenstein propagation model is:

$$PL = A + 10 \cdot a(H_{BS}) \cdot Log_{10}\left(\frac{d}{d_0}\right)$$

Where $A = 20 \cdot Log_{10}\left(\frac{4\pi d_0}{\lambda}\right)$. This is a fixed quantity which depends upon the frequency of operation. *d* is the distance between the base station antenna and the receiver terminal and d_0 is a fixed reference distance (100 m). $a(H_{BS})$ is the correction factor for base station antenna heights, H_{BS}:

$$a(H_{BS}) = a - b \cdot H_{BS} + \frac{c}{H_{BS}}$$

Where $10\ m \leq H_{BS} \leq 80\ m$, and *a*, *b*, and *c* are correction coefficients which depend on the SUI terrain type.

The Erceg-Greenstein propagation model is further developed through the correction factors introduced by the Stanford University Interim model. The standards proposed by the IEEE working group 802.16 include channel models developed by Stanford University. The basic path loss equation with correction factors is presented below:

$$PL = A + 10 \cdot a(H_{BS}) \cdot Log_{10}\left(\frac{d}{d_0}\right) + a(f) - a(H_R)$$

Where *a(f)* is the correction factor for the operating frequency, $a(f) = 6 \cdot Log_{10}\left(\frac{f}{2000}\right)$, with *f* being the operating frequency in MHz. $a(H_R)$ is the correction factor for the receiver antenna height, $a(H_R) = X \cdot Log_{10}\left(\frac{H_R}{2}\right)$, where *d* depends on the terrain type.

- $a(H_R) = 0$ for $H_R = 2$ m.
- References:
  - [1] V. Erceg et. al, "An empirically based path loss model for wireless channels in suburban environments," IEEE J. Select Areas Commun., vol. 17, no. 7, July 1999, pp. 1205-1211.
  - [2] Abhayawardhana, V.S.; Wassell, I.J.; Crosby, D.; Sellars, M.P.; Brown, M.G.; "Comparison of empirical propagation path loss models for fixed wireless access systems," Vehicular Technology Conference, 2005. IEEE 61st Volume 1, 30 May-1 June 2005 Page(s):73 - 77 Vol. 1

2.9.1 SUI Terrain Types

The SUI models are divided into three types of terrains[2], namely A, B and C.

- Type A is associated with maximum path loss and is appropriate for **hilly terrain with moderate to heavy tree densities**.
- Type B is characterised with either mostly **flat terrains with moderate to heavy tree densities** or **hilly terrains with light tree densities**.
- Type C is associated with minimum path loss and applies to **flat terrain with light tree densities**.

The constants used for *a*, *b*, and *c* are given in the table below.

Model Parameter	Terrain A	Terrain B	Terrain C
a	4.6	4.0	3.6
b **(m^{-1})**	0.0075	0.0065	0.005

2. *The word 'terrain' is used in the original definition of the model rather than 'environment'. Hence it is used interchangeably with 'environment' in this description.*

Model Parameter	Terrain A	Terrain B	Terrain C
c (m)	12.6	17.1	20
X	10.8	10.8	20

2.9.2 Erceg-Greenstein (SUI) Path Loss Formula

The Erceg-Greenstein (SUI) propagation model formula can be simplified from the following equation:

$$PL = 20 \cdot Log_{10}\left(\frac{4\pi d_0}{\lambda}\right) + 10 \cdot a(H_{BS}) \cdot Log_{10}\left(\frac{d}{d_0}\right) + a(f) - a(H_R) \qquad (1)$$

to the equation below:

$$PL = -7.366 + 26 \cdot Log_{10}(f) + 10 \cdot a(H_{BS}) \cdot (1 + Log_{10}(d)) - a(H_R) \qquad (2)$$

Where,

- f is the operating frequency in MHz
- d is the distance from the transmitter to the received in m in equation (1) and in km in equation (2)
- H_{BS} is the transmitter height in m
- H_R is the receiver height in m

The above equation is divided into two parts in **9955**:

$$PL = Lu - a(H_R)$$

Where,

$$Lu = -7.366 + 26 \cdot Log_{10}(f) + 10 \cdot a(H_{BS}) \cdot (1 + Log_{10}(d))$$

The above path loss formulas are valid for $d > d_0$, i.e. $d > 100$ m. For $d < 100$ m, the path loss has been restricted to the free space path loss with correction factors for operating frequency and receiver height:

$$PL = 20 \cdot Log_{10}\left(\frac{4 \cdot \pi \cdot d}{\lambda}\right) + a(f) - a(H_R) \text{ instead of } PL = 20 \cdot Log_{10}\left(\frac{4 \cdot \pi \cdot d}{\lambda}\right)$$

Where *a(f)* and *a(Hr)* have the same definition as given above. Simplifying the above equation, we get,

$$PL = 12.634 + 26 \cdot Log_{10}(f) + 20 \cdot Log_{10}(d) - a(H_R) \text{, or } Lu = 12.634 + 26 \cdot Log_{10}(f) + 20 \cdot Log_{10}(d)$$

The above equation is not user-modifiable in **9955** except for the coefficient of $Log_{10}(f)$, i.e. 26. **9955** uses the same coefficient as the one you enter for $Log_{10}(f)$ in **9955** for the case $d > d_0$.

> You can get the same resulting equation by setting *a(hBS)* = 2.

2.9.3 Calculations in 9955

The Erceg-Greenstein (SUI) propagation model takes DTM into account between the transmitter and the receiver, and it can also take clutter into account at the receiver location.

1st step: For each pixel in the calculation radius, **9955** determines the clutter bin on which the receiver is located. This clutter bin corresponds to a clutter class. **9955** uses the Erceg-Greenstein (SUI) path loss formula assigned to this clutter class to evaluate path loss.

2nd step: This step depends on whether the 'Add diffraction loss' option is selected or not.

- If the 'Add diffraction loss' option is not selected, 1st step gives the final path loss result.
- If the 'Add diffraction loss' option is selected, **9955** proceeds as follows:
  - **a.** It extracts a geographic profile between the transmitter and the receiver using the radial calculation method.
  - **b.** It determines the largest obstacle along the profile in accordance with the Deygout method and evaluates losses due to diffraction $L_{Diffraction}$. For more information on the Deygout method, see "3 Knife-edge Deygout Method" on page 82.

  The final path loss is the sum of the path loss determined in 1st step and $L_{Diffraction}$.

Shadow fading is computed in **9955** independent of the propagation model. For more information on the shadow fading calculation, see "Shadow Fading Model" on page 85.

2.10 ITU-R P.1546-2 Propagation Model

This propagation model is based on the P.1546-2 recommendations of the ITU-R. These recommendations extend the P.370-7 recommendations, and are suited for operating frequencies from 30 to 3000 MHz. The path loss is calculated by this propagation model with the help of graphs available in the recommendations. The graphs provided in the recommendations represent field (or signal) strength, given in $db(\mu V/m)$, as a function of distance for:

- Nominal frequencies, f_n : 100, 600, and 1000 MHz

  The graphs provided for 100 MHz are applicable to frequencies from 30 to 300 MHz, those for 600 MHz are applicable to frequencies from 300 to 1000 MHz, and the graphs for 1000 MHz are applicable to frequencies from 1000 to 3000 MHz. The method for interpolation is described in the recommendations (Annex 5, § 6).

- Transmitter antenna heights, h_1 : 10, 20, 37.5, 75, 150, 300, 600, and 1200 m

  For any values of h_1 from 10 to 3000 m, an interpolation or extrapolation from the appropriate two curves is used, as described in the recommendations (Annex 5, § 4.1). For h_1 below 10 m, the extrapolation to be applied is given in Annex 5, § 4.2. It is possible for the value of h_1 to be negative, in which case the method is given in Annex 5, § 4.3.

- Time variability, t : 1, 10, and 50 %

  The propagation curves represent the field strength values exceeded for 1, 10 and 50 % of time.

- Receiver antenna height, h_2 : 10 m

  For land paths, the graphs represent field strength values for a receiver antenna height above ground, equal to the representative height of the clutter around the receiver. The minimum value of the representative height of clutter is 10 m. For sea paths, the graphs represent field strength values for a receiver antenna height of 10 m.

  For other values of receiver antenna height, a correction is applied according to the environment of the receiver. The method for calculating this correction is given in Annex 5, § 9.

These recommendations are not valid for transmitter-receiver distances less than 1 km or greater than 1000 km. Therefore in **9955**, the path loss between a transmitter and a receiver over less than 1 km is the same as the path loss over 1 km. Similarly, the path loss between a transmitter and a receiver over more than 1000 km is the same as the path loss over 1000 km.

Moreover, these recommendations are not valid for transmitter antenna heights less than the average clutter height surrounding the transmitter.

- The cold sea graphs are used for calculations over warm and cold sea both.
- The mixture of land and sea paths is not supported by **9955**.

2.10.1 Calculations in 9955

The input to the propagation model are the transmission frequency, transmitter and receiver heights, the distance between the transmitter and the receiver, the precentage of time the field strength values are exceeded, the type of environment (i.e., land or sea), and the clutter at the receiver location.

In the following calculations, f is the transmission frequency, d is the transmitter-receiver distance, and t is the percentage of time for which the path loss has to be calculated.

The following calculations are performed in **9955** to calculate the path loss using this propagation model.

2.10.1.1 Step 1: Determination of Graphs to be Used

First of all, the upper and lower nominal frequencies are determined for any given transmission frequency. The upper and lower nominal frequencies are the nominal frequencies (100, 600, and 2000 MHz) between which the transmission frequency is located, i.e., $f_{n1} < f < f_{n2}$.

Once f_{n1} and f_{n1} are known, along with the information about the percentage of time t and the type of path (land or sea), the sets of graphs which will be used for the calculation are also known.

2.10.1.2 Step 2: Calculation of Maximum Field Strength

A field strength must not exceed a maximum value, E_{Max}, which is given by:

$E_{Max} = E_{FS} = 106.9 - 20 \times Log(d)$ for land paths, and

$E_{Max} = E_{FS} + E_{SE} = 106.9 - 20 \times Log(d) + 2.38\{1 - exp(-d/8.94)\} \times Log(50/t)$ for sea paths.

Where E_{FS} is the free space field strength for 1 kW ERP, E_{SE} is an enhancement for sea graphs.

2.10.1.3 Step 3: Determination of Transmitter Antenna Height

The transmitter antenna height to be used in the calculation depends on the type and length of the path.

- Land paths

  $h_1 = h_{eff}$

- Sea paths

  $h_1 = Max(1, h_a)$

Here, all antenna heights (i.e., h_1, h_{eff}, and h_a) are in expressed in m. h_a is the antenna height above ground and h_{eff} is the effective height of the transmitter antenna, which is its height over the average level of the ground between distances of $0.2 \times d$ and *d* km from the transmitter in the direction of the receiver.

2.10.1.4 Step 4: Interpolation/Extrapolation of Field Strength

The interpolations are performed in series in the same order as described below. The first interpolation/extrapolation is performed over the field strength values, E, from the graphs for transmitter antenna height to determine E_{h1}. The second interpolation/extrapolation is performed over the interpolated/extrapolated values of E_{h1} to determine E_d. And, the thrid and final interpolation/extrapolation is performed over the interpolated/extrapolated values of E_d to determine E_f.

Step 4.1: Interpolation/Extrapolation of Field Strength for Transmitter Antenna Height

If the value of h_1 coincides with one of the eight heights for which the field strength graphs are provided, namely 10, 20, 37.5, 75, 150, 300, 600, and 1200 m, the required field strength is obtained directly from the corresponding graph. Otherwise:

- If $10\ m < h_1 < 3000\ m$

  The field strength is interpolated or extrapolated from field strengths obtained from two curves using the following equation:

  $$E_{h1} = E_{Low} + (E_{Up} - E_{Low}) \times \frac{Log(h_1/h_{Low})}{Log(h_{Up}/h_{Low})}$$

  Where $h_{Low} = 600\ m$ if $h_1 > 1200\ m$, otherwise h_{Low} is the nearest nominal effective height below h_1, $h_{Up} = 1200\ m$ if $h_1 > 1200\ m$, otherwise h_{Up} is the nearest nominal effective height above h_1, E_{Low} is the field strength value for h_{Low} at the required distance, and E_{Up} is the field strength value for h_{Up} at the required distance.

- If $0\ m < h_1 < 10\ m$

  - For land path if the transmitter-receiver distance is less than the smooth-Earth horizon distance $d_H(h_1) = 4.1 \times \sqrt{h_1}$, i.e., if $d < 4.1 \times \sqrt{h_1}$,

    $E_{h1} = E_{10}(d_H(10)) + E_{10}(d) - E_{10}(d_H(h_1))$, or

    $E_{h1} = E_{10}(12.9\ km) + E_{10}(d) - E_{10}(d_H(h_1))$ because $d_H(10) = 12.9\ km$

  - For land path if the transmitter-receiver distance is greater than or equal to the smooth-Earth horizon distance $d_H(h_1) = 4.1 \times \sqrt{h_1}$, i.e., if $d \geq 4.1 \times \sqrt{h_1}$,

    $E_{h1} = E_{10}(d_H(10) + d - d_H(h_1))$, or $E_{h1} = E_{10}(12.9\ km + d - d_H(h_1))$ because $d_H(10) = 12.9\ km$

    Where $E_x(y)$ is the field strength value read for the transmitter-receiver distance of *y* from the graph available for the transmitter antenna height of *x*.

If in the above equation, $d_H(10) + d - d_H(h_1) > 1000\ km$ even though $d \le 1000\ km$, the field strength is determined from linear extrapolation for Log (distance) of the graph given by:

$$E_{h1} = E_{Low} + (E_{Up} - E_{Low}) \times \frac{Log(d/D_{Low})}{Log(D_{Up}/D_{Low})}$$

Where D_{Low} is penultimate tabulation distance (km), D_{Up} is the final tabulation distance (km), E_{Low} is the field strength value for D_{Low}, and E_{Up} is the field strength value for D_{Up}.

- For sea path, h_1 should not be less than 1 m. This calculation requires the distance at which the path has 0.6 of the first Fresnel zone just unobstructed by the sea surface. This distance is given by:

  $D_{h1} = D_{0.6}(f, h_1, (h_2 = 10\ m))$ (km)

  Where $D_{0.6} = Max\left(0.001, \frac{D_f \times D_h}{D_f + D_h}\right)$ (km) with $D_f = 0.0000389 \times f \times h_1 \times h_2$ (frequency-dependent term), and $D_h = 4.1 \times (\sqrt{h_1} + \sqrt{h_2})$ (asymptotic term defined by the horizon distance).

  If $d > D_{h1}$ the 0.6 Fresnel clearance distance for the sea path where the transmitter antenna height is 20 m is also calculated as:

  $D_{20} = D_{0.6}(f, (h_1 = 20\ m), (h_2 = 10\ m))$ (km)

  Once D_{h1} and D_{20} are known, the field strength for the required distance is given by:

$$E_{h1} = \begin{cases} E_{Max} & for\ \ d \le D_{h1} \\ E_{D_{h1}} + (E_{D_{20}} - E_{D_{h1}}) \times \dfrac{Log(d/D_{h1})}{Log(D_{20}/D_{h1})} & for\ \ D_{h1} < d < D_{20} \\ E' \times (1 - F_S) + E'' \times F_S & for\ \ d \ge D_{20} \end{cases}$$

  Where E_{Max} is the maximum field strength at the required distance as calculated in "Step 2: Calculation of Maximum Field Strength" on page 76, $E_{D_{h1}}$ is E_{Max} for $d = D_{h1}$,

  $E_{D_{20}} = E_{10}(D_{20}) + (E_{20}(D_{20}) - E_{10}(D_{20})) \times \frac{Log(h1/10)}{Log(20/10)}$, $E' = E_{10}(d) + (E_{20}(d) - E_{10}(d)) \times \frac{Log(h1/10)}{Log(20/10)}$, and E'' is the field strength calculated as described for land paths. $E_{10}(y)$ and $E_{20}(y)$ are field strengths interpolated for distance *y* and $h_1 = 10\ m\ and\ 20\ m$, respectively, and $F_S = (d - D_{20})/d$.

- If $h_1 < 0\ m$

  A correction is applied to the field strength, E_{h1}, calculated in the above description in order to take into account the diffraction and tropospheric scattering. This correction is the maximum of the diffraction correction,, and tropospheric scattering correction, .

  $C_{h1} = Max(C_{h1d}, C_{h1t})$

  Where $C_{h1d} = 6.03 - J(\nu)$ with $J(\nu) = [6.9 + 20 \times Log(\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1)]$ and $\nu = K_\nu \times \theta_{eff2}$, $\theta_{eff2} = arctan\left(\frac{-h_1}{9000}\right)$, and K_ν is 1.35 for 100 MHz, 3.31 for 600 MHz, 6.00 for 2000 MHz.

  $C_{h1t} = 30 \times Log\left(\frac{\theta_e}{\theta_e + \theta_{eff2}}\right)$ with $\theta_e = \frac{180 \times d}{a \times \pi \times k}$, $a = 6370\ km$ (radius of the Earth), and $k = 4/3$ is the effective Earth radius factor for mean refractivity conditions.

Step 4.2: Interpolation/Extrapolation of Field Strength for Transmitter-Receiver Distance

In the field strength graphs in the recommendations, the field strength is plotted against distance from 1 km to 1000 km. The distance values for which field strengths are tabulated are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675, 700, 725, 750, 775, 800, 825, 850, 875, 900, 925, 950, 975, 1000. If the transmitter-receiver distance is a value from this list, then interpolation of field strength is not required and the field strength can be directly read from the graphs.

If the transmitter-receiver distance does not coincide with the list of distances for which the field strengths are accurately available from the graphs, the field strength are linearly interpolated or extrapolated for the logarithm of the distance using the following equation:

$$E_d = E_{Low} + (E_{Up} - E_{Low}) \times \frac{Log(d/d_{Low})}{Log(d_{Up}/d_{Low})}$$

Where d_{Low} is the lower value of the nearest tabulated distance to d, d_{Up} is the higher value of the nearest tabulated distance to d, E_{Low} is the field strength value for d_{Low}, and E_{Up} is the field strength value for d_{Up}.

Step 4.3: Interpolation/Extrapolation of Field Strength for Transmission Frequency

The field strength at the transmission frequency is interpolated from the graphs available for the upper and lower nominal frequencies as follows:

$$E_f = E_{Low} + (E_{Up} - E_{Low}) \times \frac{Log(f/f_{Low})}{Log(f_{Up}/f_{Low})}$$

Where f_{Low} is the lower nominal frequency (100 MHz if $f < 600$ MHz, 600 MHz otherwise), f_{Up} is the higher nominal frequency (600 MHz if $f < 600$ MHz, 2000 MHz otherwise), E_{Low} is the field strength value for f_{Low}, and E_{Up} is the field strength value for f_{Up}.

In the case of transmission frequencies below 100 MHz or above 2000 MHz, the field strength values are extrapolated from the two nearer nominal frequency values. The above equation is used for all land paths and sea paths.

2.10.1.5 Step 5: Calculation of Correction Factors

Step 5.1: Correction for Receiver Antenna Height

The receiver antenna height correction depends on the type of path and clutter in which the receiver is located. The field strength values given by the graphs for land paths are for a reference receiver antenna at a height, R (m), representative of the height of the clutter surrounding the receiver, subject to a minimum height value of 10 m. Examples of reference heights are 20 m for an urban area, 30 m for a dense urban area, and 10 m for a suburban area. For sea paths the notional value of R is 10 m.

For land paths, the elevation angle of the arriving ray is taken into account by calculating a modified representative clutter height R', given by $R' = Max\left(1, \frac{(1000 \times d \times R - 15 \times h_1)}{1000 \times d - 15}\right)$.

Note that for $h_1 < 6.5 \times d + R$, $R' \approx R$.

The different correction factors are calculated as follows:

- For land path in urban and suburban zones

$$C_{Receiver} = \begin{cases} 6.03 - J(\nu) & for \;\; h_2 < R' \\ (3.2 + 6.2 \times Log(f)) \times Log\left(\frac{h_2}{R'}\right) & for \;\; h_2 \geq R' \end{cases}$$

With $J(\nu) = [6.9 + 20 \times Log(\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1)]$ and $\nu = 0.0108 \times \sqrt{f} \times \sqrt{(R' - h_2) \times arctan\left(\frac{R' - h_2}{27}\right)}$.

If $R' < 10\ m$, $C_{Receiver}$ is reduced by $(3.2 + 6.2 \times Log(f)) \times Log\left(\frac{10}{R'}\right)$.

- For land path other zones

$$C_{Receiver} = (3.2 + 6.2 \times Log(f)) \times Log\left(\frac{h_2}{10}\right)$$

- For sea path

  d_{10} and d_{h2} are determined as distances at which at which the path has 0.6 of the first Fresnel zone just unobstructed by the sea surface with $h_2 = 10\ m$ and variable h_2, respectively. These distances are given by

$d_{10} = D_{0.6}(f, h_1, (h_2 = 10\ m))$ and $d_{h2} = D_{0.6}(f, h_1, h_2)$ (km), respectively. Here $D_{0.6} = Max\left(0.001, \frac{D_f \times D_h}{D_f + D_h}\right)$ as explained earlier.

- If $h_2 > 10\ m$, $C_{Receiver} = (3.2 + 6.2 \times Log(f)) \times Log\left(\frac{h_2}{10}\right)$
- If $h_2 < 10\ m$ and $d > d_{10}$, $C_{Receiver} = (3.2 + 6.2 \times Log(f)) \times Log\left(\frac{h_2}{10}\right)$
- If $h_2 < 10\ m$ and $d < d_{10}$ and $d < d_{h2}$, $C_{Receiver} = 0$
- If $h_2 < 10\ m$ and $d < d_{10}$ and $d > d_{h2}$, $C_{Receiver} = (3.2 + 6.2 \times Log(f)) \times Log\left(\frac{h_2}{10}\right) \times \left(\frac{Log(d/d_{h2})}{Log(d_{10}/d_{h2})}\right)$

Step 5.2: Correction for Short Urban/Suburban Paths

This correction is only applied when the path loss is to be calculated over land paths, over a transmitter-receiver distance less than 15 km, in urban and suburban zones. This correction takes into account the presence of buildings in these zones. The buildings are assumed to be of uniform height.

The correction represents a reduction in the field strength due to building clutter. It is added to the field strength and is given by:

$$C_{Building} = -3.3(Log(f))(1 - 0.85 \times Log(d))(1 - 0.46 \times Log(1 + h_a - R))$$

Where h_a is the antenna height above the ground, and *R* is the clutter height of the clutter class where the receiver is located.

This correction is only applied when $d < 15\ km$ and $h_1 - R < 150\ m$.

Step 5.3: Correction for Receiver Clearance Angle

This correction is only applied when the path loss is to be calculated over land paths, and over a transmitter-receiver distance less than 16 km. This correction gives more precise field strength prediction over small reception areas. The correction is added to the field strength and is given by:

$$C_{Clearance} = J(\nu') - J(\nu)$$

Where $J(\nu) = [6.9 + 20 \times Log(\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1)]$, $\nu' = 0.036 \times \sqrt{f}$, and $\nu = 0.065 \times \theta_{Clearance} \times \sqrt{f}$

$\theta_{Clearance}$ is the clearance angle in degrees determined from:

- θ : The elevation angle of the line from the receiver which just clears all terrain obstructions in the direction of the transmitter over a distance of up to 16 km but not going beyond the transmitter.
- θ_{Ref} : The reference angle, $\theta_{Ref} = arctan\left(\frac{h_{1S} - h_{2S}}{1000 \times d}\right)$.

  Where h_{1S} and h_{2S} are the heights of the transmitter and the receiver above sea level, respectively.

2.10.1.6 Step 6: Calculation of Path Loss

First, the final field strength is calculated from the interpolated/extrapolated field strength, E_f, by applying the corrections calculated earlier. The calculated field strength is given by:

$$E_{Calc} = E_f + C_{Receiver} + C_{Building} + C_{Clearance}$$

The resulting field strength is given by $E = Min(E_{Calc}, E_{Max})$, from which the path loss (basic transmission loss, L_B) is calculated as follows:

$$L_B = 139 - E + 20 \times Log(f)$$

2.11 Sakagami Extended Propagation Model

The Sakagami extended propagation model is based on the simplification of the extended Sakagami-Kuboi propagation model. The Sakagami extended propagation model is valid for frequencies above 3 GHz. Therefore, it is only available in WiMAX documents by default.

The Sakagami-Kuboi propagation model requires detailed information about the environment, such as widths of the streets where the receiver is located, the angles formed by the street axes and the directions of the incident waves, heights of the buildings close to the receiver, etc. The path loss formula for the Sakagami-Kuboi propagation model is [1]:

$$L_{Model} = 100 - 7.1 \times Log(W) + 0.023 \times \varphi + 1.4 \times Log(h_s) + 6.1 \times Log(H_1) - \left[24.37 - 3.7 \times \left(\frac{H}{h_{b0}}\right)^2\right] \times Log(h_b) + [43.2 - 3.1 \times Log(h_b)] \times Log(d) + 20 \times Log(f) + e^{13 \times (Log(f) - 3.23)}$$

Where,

- W is the width (in meters) of the streets where the receiver is located
- φ is the angle (in degrees) formed by the street axes and the direction of the incident wave
- h_s is the height (in meters) of the buildings close to the receiver
- H_1 is the average height (in meters) of the buildings close to the receiver
- h_b is the height (in meters) of the transmitter antenna with respect to the observer
- h_{b0} is the height (in meters) of the transmitter antenna with respect to the ground level
- H is the average height (in meters) of the buildings close to the base station
- d is the separation (in kilometres) between the transmitter and the receiver
- f is the frequency (in MHz)

The Sakagami-Kuboi propagation model is valid for:

5 m	**< *W* <**	**50 m**
0°	< φ <	90°
5 m	< h_s <	80 m
5 m	< H_1 <	50 m
20 m	< h_b <	100 m
0.5 km	< d <	10 km
450 MHz	< f <	2200 MHz
	$h_{b0} \geq H$	

Studies [2] have shown that the Sakagami-Kuboi propagation model can be extended to frequencies higher than 3 GHz, which also allows a simplification in terms of the input required by the model.

The path loss formula for the extended Sakagami-Kuboi propagation model is:

$$L_{Model} = 54 + 40 \times Log(d) - 30 \times Log(h_b) + 21 \times Log(f) + a$$

Where a is a corrective factor with three components:

$$a = a(H_0) + a(W) + a(h_m) = 11 \times Log\left(\frac{H_0}{20}\right) - 7.1 \times Log\left(\frac{W}{20}\right) - 5 \times Log\left(\frac{h_m}{1.5}\right)$$

- W is the width (in meters) of the streets where the receiver is located
- H_0 (= h_s = H_1) is the height (in meters) of the buildings close to the receiver
- h_b (= h_{b0}) is the height (in meters) of the transmitter antenna with respect to the ground
- h_m is the height (in meters) of the receiver antenna
- H is the average height (in meters) of the buildings close to the base station
- d is the separation (in metres) between the transmitter and the receiver
- f is the frequency (in GHz)

The extended Sakagami-Kuboi propagation model is valid for:

5 m	< W <	50 m
10 m	< H_0 <	30 m
10 m	< h_b <	100 m
0.1 km	< d <	3 km
0.8 GHz	< f <	8 GHz
1.5 m	< h_m <	5 m

Studies also show that above 3 GHz, the path loss predicted by the extended model is almost independant of the input parameters such as street widths and angles. Therefore, the extended Sakagami-Kuboi propagation model can be simplified to the extended Sakagami propagation model:

$$L_{Model} = 54 + 40 \times Log(d) - 30 \times Log(h_b) + 21 \times Log(f) - 5 \times Log(h_m)$$

The extended Sakagami propagation model is valid for:

10 m	$< h_b <$	100 m
0.1 km	$< d <$	3 km
3 GHz	$< f <$	8 GHz
1.5 m	$< h_m <$	5 m

The path loss calculation formula of the Sakagami extended propagation model resembles the formula of the Standard Propagation Model. In **9955**, this model is in fact a copy of the Standard Propagation Model with the following values assigned to the K coefficients:

K1	65.4 (calculated for 3.5 GHz)
K2	40
K3	-30
K4	0
K5	0
K6	0
K7	-5

For more information on the Standard Propagation Model, see "Standard Propagation Model (SPM)" on page 60.

References:

- [1] Manuel F. Catedra, Jesus Perez-Arriaga, "Cell Planning for Wireless Communications," Artech House Publishers, 1999.
- [2] Koshiro Kitao, Shinichi Ichitsubo, "Path Loss Prediction Formula for Urban and Suburban Areas for 4G Systems," IEEE, 2006.

2.12 Free Space Loss

The calculation of free space loss is based on ITU 525 recommendations.

$$L_{FS} = 32.4 + 20log(f) + 20log(d)$$

where,

f is the frequency in MHz,

d is the Tx-Rx distance in km,

Free space loss is stated in dB.

2.13 Diffraction

The calculation of diffraction is based on ITU 526-5 recommendations. General method for one or more obstacles (knife-edge diffraction) is used to evaluate diffraction losses (*Diffraction loss* in dB). Four construction modes are implemented in **9955**. All of them are based on this same physical principle presented hereafter, but differ in the way they consider one or several obstacles. Calculations take the earth curvature into account through the effective Earth radius concept (K factor=1.333).

2.13.1 Knife-edge Diffraction

The procedure checks whether a knife-edge obstructs the first Fresnel zone constructed between the transmitter and the receiver. The diffraction loss, $J(\nu)$, depends on the obstruction parameter (ν), which corresponds to the ratio of the obstruction height (h) and the radius of the Fresnel zone (R).

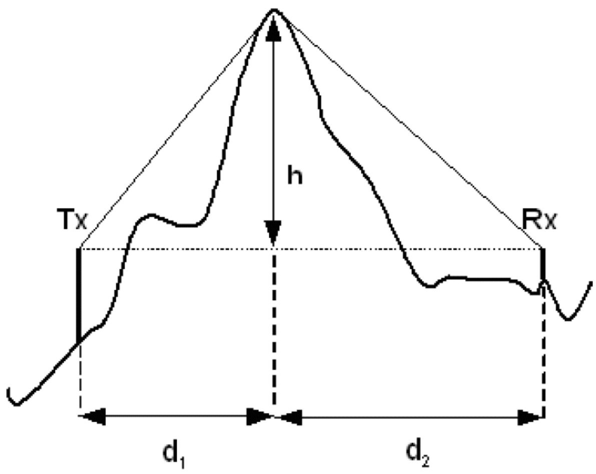


Figure 2.12: Knife-Edge Diffraction

$$R = \sqrt{\frac{c_0 \cdot n \cdot d_1 \cdot d_2}{f \cdot (d_1 + d_2)}}$$

where,

n is the Fresnel zone index,

c_0 is the speed of light (2.99792 x10^8 ms^{-1}),

f is the frequency in Hz

d_1 is the distance from the transmitter to obstacle in m,

d_2 is the distance from obstacle to receiver in m.

We have: $\nu = \frac{h}{r}$

where,

$r = \frac{R}{\sqrt{2}}$

h is the obstruction height (height from the obstacle top to the Tx-Rx axis).

Hence,

For 1 knife-edge method, if $\nu \geq -0.7$, $J(\nu) = 6.9 + 20 \cdot log(\sqrt{(\nu - 0.1)^2 + 1} + (\nu - 0.1))$

Else, $J(\nu) = 0$

In case of multiple-knife edge method, the minimum ν required to estimate diffraction loss is -0.78.

2.13.2 3 Knife-edge Deygout Method

The Deygout construction, limited to a maximum of three edges, is applied to the entire profile from transmitter to receiver. This method is used to evaluate path loss incurred by multiple knife-edges. Deygout method is based on a hierarchical knife-edge sorting used to distinguish the main edges, which induce the largest losses, and secondary edges, which have a lesser effect. The edge hierarchy depends on the obstruction parameter (ν) value.

1 Obstacle

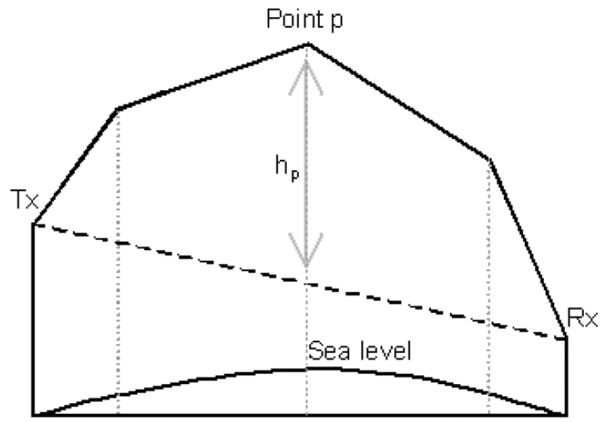


Figure 2.13: Deygout Construction – 1 Obstacle

A straight line between transmitter and receiver is drawn and the height of the obstacle above the Tx-Rx axis, h_i, is calculated. The obstruction position, d_i, is also recorded. ν_i are evaluated from these data. The point with the highest ν value is termed the principal edge, p, and the corresponding loss is J(νp).

Therefore, we have

$$DiffractionLoss = J(\nu_p)$$

3 Obstacles

Then, the main edge (point *p*) is considered as a secondary transmitter or receiver. Therefore, the profile is divided in two parts: one half profile, between the transmitter and the knife-edge section, another half, constituted by the knife-edge-receiver section.

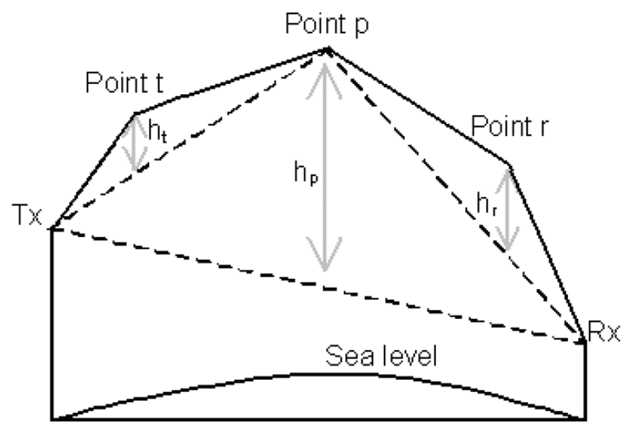


Figure 2.14: Deygout Construction – 3 Obstacles

The same procedure is repeated on each half profile to determine the edge with the higher ν. The two obstacles found, (points t and r), are called 'secondary edges'. Losses induced by the secondary edges, $J(\nu_t)$ and $J(\nu_r)$, are then calculated.

Once the edge hierarchy is determined, the total loss is evaluated by adding all the intermediary losses obtained.

Therefore, if $\nu_p > 0$

we have $DiffractionLoss = J(\nu_p) + J(\nu_t) + J(\nu_r)$

Otherwise, If $\nu_p > -0.7$, $DiffractionLoss = J(\nu_p)$

In case of ITU 526-5 and WLL propagation models, *Diffraction loss* term is determined as follows:

- If $\nu_p > -0.78$, we have $DiffractionLoss = J(\nu_p) + (J(\nu_t) + J(\nu_r)) \cdot t$
- Otherwise $DiffractionLoss = 0$

Here, $t = min\left(\frac{J(\nu_p)}{6}, 1\right)$

2.13.3 Epstein-Peterson Method

The Epstein-Peterson construction is limited to a maximum of three edges. First, Deygout construction is applied to determine the three main edges over the whole profile as described above. Then, the main edge height, h_p, is recalculated according to the Epstein-Peterson construction. h_p is the height above a straight line connecting *t* and *r* points. The main edge position d_p is recorded and ν_p and $J(\nu_p)$ are evaluated from these data.

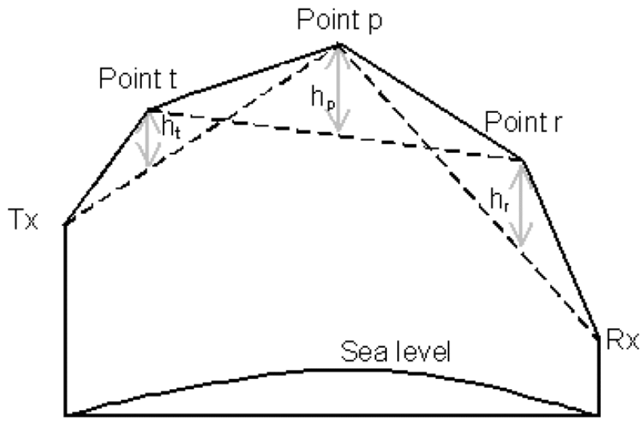


Figure 2.15: Epstein-Peterson Construction

Therefore, we have

$DiffractionLoss = J(\nu_p) + J(\nu_t) + J(\nu_r)$

2.13.4 Deygout Method with Correction

The Deygout method with correction (ITU 526-5) is based on the Deygout construction (3 obstacles) plus an empirical correction, *C*.

Therefore, If $\nu_p > 0$,

we have $DiffractionLoss = J(\nu_p) + J(\nu_t) + J(\nu_r) + C$

Otherwise $DiffractionLoss = J(\nu_p) + C$

In case of ITU 526-5 propagation model, *Diffraction loss* term is determined as follows:

- If $\nu_p > -0.78$, we have $DiffractionLoss = J(\nu_p) + t \cdot (J(\nu_t) + J(\nu_r) + C)$
- Otherwise $DiffractionLoss = 0$

Here, $t = min\left(\frac{J(\nu_p)}{6}, 1\right)$ and $C = 8.0 + 0.04d$ with *d* = distance stated in km between the transmitter and the receiver.

2.13.5 Millington Method

The Millington construction, limited to a single edge, is applied over the entire profile. Two horizon lines are drawn at the transmitter and at the receiver. A straight line between the transmitter and the receiver is defined and the height of the intersection point between the two horizon lines above the Tx-Rx axis, h_h, is calculated. The position d_h is recorded and then, from these values, ν_h and $J(\nu_h)$ are evaluated using the same previous formulas.

Therefore, we have

$$DiffractionLoss = J(\nu_h)$$

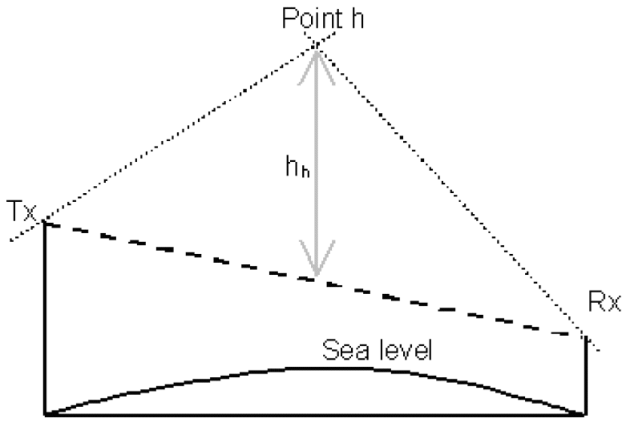


Figure 2.16: Millington Construction

2.14 Shadow Fading Model

Propagation models predict the mean path loss as a function of transmission and reception parameters such as frequency, antenna heights, and distance, etc. Therefore, the predicted path loss between a transmitter and a receiver is constant, in a given environment and for a given distance. However, in reality different types of clutter may exist in the transmitter-receiver path. Therefore, the path losses for the same distance could be different along paths that pass throught different types of environments. The location of the receiver in different types of clutter causes variations with respect to the mean path loss values given by the path loss models. Some paths undergo more loss while others are less obstructed and may have higher received signal strength. The variation of path loss with respect to the mean path loss values predicted by the propagation models, depending on the type of environment is called shadow fading (shadowing) or slow fading. "Slow" fading implies that the variations in the path loss due to shadow fading occur comparatively slower than the fast fading effect (Rayleigh fading), which is due to the mobile receiving multipath copies of a signal.

Different types of clutter (buildings, hills, etc.) make large shadows that cause variations in the path loss over long distances. As a mobile passes under a shadow, the path loss to the mobile keeps varying from point to point. Shadow fading varies as the mobile moves, while fast fading can vary even if the mobile remains at the same location or moves over very small distances. It is crucial to account for the shadow fading in order to predict the reliability of coverage provided by any mobile cellular system.

The shadowing effect is modelled by a log-normal (Gaussian) distribution, as shown in Figure 2.17 on page 85, whose standard deviation σ depends on the type of clutter.

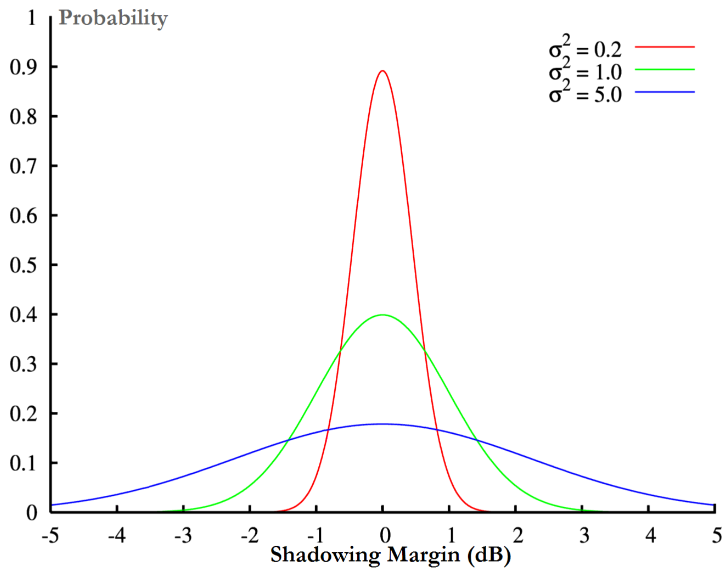


Figure 2.17: Log-normal Probability Density Function

Different clutter types have different shadowing effects. Therefore, each clutter type in **9955** can have a different standard deviation representing its shadowing characteristics. For different standard deviations, the shape of the Gaussian distribution curve remains similar, as shown in Figure 2.17 on page 85.

The accuracy of this model depends upon:

- The suitability of the range of standard deviation used for each clutter class,
- The definition (bin size) of the digital map,
- How up-to-date the digital map is,
- The number of clutter classes,
- The accuracy of assignment of clutter classes.

Shadowing is applied to the predicted path loss differently depending on the technology, and whether it is applied to predictions or simulations. The following sections explain how shadowing margins are calculated and applied to different technology documents.

Shadowing margins are calculated for a given cell edge coverage probability. The cell edge coverage probability is the probability of coverage at a pixel located at the cell edge, and corresponds to the reliability of coverage that you are planning to achieve at the cell edge. For example, a cell edge coverage probability of 75 % means that the users located at the cell edge will receive adequate signal level during 75 % of the time. Therefore, a coverage prediction with a cell edge coverage probability of x % means that the signal level predicted on each pixel is reliable x % of the time, and the overall predicted coverage area is reliable at least x % of the time.

References:

- [1] Saunders S. "Antennas and propagation for Wireless Communication Systems" pp. 180-198
- [2] Holma H., Toskala A. "WCDMA for UMTS"
- [3] Jhong S., Leonard M. "CDMA systems engineering handbook" pp. 309-315, 1051-1053"
- [4] Remy J.G., Cueugnet J., Siben C. "Systèmes de radiocommunications avec les mobiles" pp. 309-310
- [5] Laiho J., Wacker A., Novosad T. "Radio network planning and optimisation for UMTS" pp. 80-81

GSM GPRS EGPRS Documents

The shadowing margins are calculated as explained in "Shadowing Margin Calculation in Predictions" on page 90, and applied to signal level or C/I as explained below.

- Signal Level-Based Predictions

  Signal level-based predictions include coverage predictions (Coverage by Transmitter, Coverage by Signal Level, and Overlapping Zones) and calculations in point analysis tabs (Profile and Reception) that require calculation of the received signal level only, and do not depend on interference.

  In these calculations (signal level calculations), a shadowing margin ($M_{Shadowing - model}$) is applied to the received signal level calculated for each pixel. The shadowing margin is calculated for a given cell edge coverage probability, and depends on the model standard deviation (σ_{model} in dB) associated to the clutter class where the receiver is located.

- Interference-Based Predictions

  Interference-based predictions include coverage predictions (Coverage by C/I Level, Interfered Zones, Coverage by GPRS/EDGE Coding Scheme, RLC/MAC Throughout/Timeslot, Application Throughput/Timeslot, Circuit Quality Indicator Analysis) and calculations in point analysis window's Interference tab that require calculation of the received signal level and interference received from other base stations.

  In these calculations, (C/I calculations), the shadowing margin ($M_{Shadowing - C/I}$) is applied to the ratio of the carrier power (*C*) and the interfering signal levels (*I*) received from the interfering base stations. This shadowing margin is calculated for a given cell edge coverage probability and depends on the C/I standard deviation ($\sigma_{C/I}$ in dB) associated to the clutter class where the receiver is located.

UMTS HSPA and CDMA2000 1xRTT 1xEV-DO Documents

The shadowing margins are calculated as explained in "Shadowing Margin Calculation in Predictions" on page 90 and "Shadowing Margin Calculation in Monte-Carlo Simulations" on page 92, and applied to signal level, E_c/I_0, or E_b/N_t as explained below.

- Signal Level-Based Predictions

Signal level-based predictions include coverage predictions (Coverage by Transmitter, Coverage by Signal Level, and Overlapping Zones) and calculations in point analysis tabs (Profile and Reception) that require calculation of the received signal level only, and do not depend on interference.

In these calculations (signal level calculations), a shadowing margin ($M_{Shadowing-model}$) is applied to the received signal level calculated for each pixel. The shadowing margin is calculated for a given cell edge coverage probability, and depends on the model standard deviation (σ_{model} in dB) associated to the clutter class where the receiver is located.

- Interference+noise-Based Predictions

  Interference+noise-based predictions include coverage predictions (Pilot Quality Analysis, Downlink Total Noise, Service Area Analyses, Handoff Status, etc.) and point analysis (AS Analysis tab) that require calculation of the received signal level and interference and noise received from other base stations.

  In these calculations, the shadowing margins ($M_{Shadowing-Ec/Io}$, $M_{Shadowing-(Eb/Nt)_{DL}}$, or $M_{Shadowing-(Eb/Nt)_{UL}}$) are applied to E_c/I_0 or Eb/Nt. These shadowing margins are calculated for a given cell edge coverage probability and depend on the E_c/I_0 or Eb/Nt standard deviations ($\sigma_{Ec/Io}$, $\sigma_{(Eb/Nt)_{DL}}$, or $\sigma_{(Eb/Nt)_{UL}}$, in dB) associated to the clutter class where the receiver is located.

- Macro-Diversity Gains

  9955 calculates the uplink and downlink macro-diversity gains ($G^{UL}_{macro-diversity}$ and $G^{DL}_{macro-diversity}$) depending on the receiver handover status. These gains are respectively taken into account to evaluate the uplink Eb/Nt in case of soft handover and the downlink Ec/Io from best server. For detailed description of the calculation of macro-diversity gains, please refer to "Macro-Diversity Gains Calculation" on page 92.

- Monte-Carlo Simulations

  Random values for shadowing margins are calculated for each transmitter-receiver link and applied to the predicted signal level. A shadowing margin for each transmitter-receiver link in each simulation is obtained by taking a random value from the probability density distribution for the appropriate clutter class. The probability distribution is a log-normal distribution as explained above.

TD-SCDMA Documents

The shadowing margins are calculated as explained in "Shadowing Margin Calculation in Predictions" on page 90 and "Shadowing Margin Calculation in Monte-Carlo Simulations" on page 92, and applied to signal level or interference+noise predictions as explained below.

- Signal Level-Based Predictions

  Signal level-based predictions include coverage predictions (Best Server and RSCP P-CCPCH Coverages, P-CCPCG Pollution Analysis, Baton Handover Coverage, DwPCH and UpPCH Coverages, Cell to Cell Interference, and Scrambling Code Interference) and calculations in point analysis tabs (Profile and Reception) that require calculation of the received signal level only, and do not depend on interference.

  In these calculations (signal level calculations), a shadowing margin ($M_{Shadowing-model}$) is applied to the received signal level calculated for each pixel. The shadowing margin is calculated for a given cell edge coverage probability, and depends on the model standard deviation (σ_{model} in dB) associated to the clutter class where the receiver is located.

- Interference+noise-Based Predictions

  Interference+noise-based predictions include coverage predictions (P-CCPCH Eb/Nt and C/I Coverages, Service Area Analsyses for downlink and uplink Eb/Nt and C/I, etc.) that require calculation of the received signal level and interference received from other base stations.

  In these calculations, the shadowing margins ($M_{Shadowing-(Eb/Nt)_{P-CCPCH}}$, $M_{Shadowing-(Eb/Nt)_{DL}}$, or $M_{Shadowing-(Eb/Nt)_{UL}}$) are applied to Eb/Nt. These shadowing margins are calculated for a given cell edge coverage probability and depend on the Eb/Nt standard deviations ($\sigma_{(Eb/Nt)_{P-CCPCH}}$, $\sigma_{(Eb/Nt)_{DL}}$, or $\sigma_{(Eb/Nt)_{UL}}$, in dB) associated to the clutter class where the receiver is located.

- Monte-Carlo Simulations

  Random values for shadowing margins are calculated for each transmitter-receiver link and applied to the predicted signal level. A shadowing margin for each transmitter-receiver link in each simulation is obtained by taking a random value from the probability density distribution for the appropriate clutter class. The probability distribution is a log-normal distribution as explained above.

WiMAX Documents

The shadowing margins are calculated as explained in "Shadowing Margin Calculation in Predictions" on page 90 and "Shadowing Margin Calculation in Monte-Carlo Simulations" on page 92 , and applied to signal level or C/(I+N) as explained below.

- Signal Level-Based Predictions

  Signal level-based predictions include coverage predictions (Coverage by Transmitter, Coverage by Signal Level, and Overlapping Zones) and calculations in point analysis tabs (Profile and Reception) that require calculation of the received signal level only, and do not depend on interference.

  In these calculations (signal level calculations), a shadowing margin ($M_{Shadowing-model}$) is applied to the received signal level calculated for each pixel. The shadowing margin is calculated for a given cell edge coverage probability, and depends on the model standard deviation (σ_{model} in dB) associated to the clutter class where the receiver is located.

- Interference+noise-Based Predictions

  Interference-based predictions include coverage predictions (Coverage by C/(I+N) Level, Coverage by Bearer, Coverage by Throughput, etc.) that require calculation of the received signal level and interference.

  In these calculations, (C/(I+N) calculations), in addition to the shadowing margin ($M_{Shadowing-model}$) applied to the received signal level calculated for each pixel, the ratio $M_{Shadowing-model} - M_{Shadowing-C/I}$ is applied to the interfering signal levels (I). $M_{Shadowing-C/I}$ is calculated for a given cell edge coverage probability and depends on the C/I standard deviation ($\sigma_{C/I}$ in dB) associated to the clutter class where the receiver is located.

  The reason why the ratio $M_{Shadowing-model} - M_{Shadowing-C/I}$ is used can be understood from the following derivation (linear, not it dB):

  Inputs

  - C_P : The predicted received carrier power without any shadowing margin.
  - I_P : The predicted received interference power without any shadowing margin.
  - m_C : Shadowing margin based on the model standard deviation ($10^{\frac{M_{Shadowing-model}}{10}}$)
  - $m_{C/I}$: Shadowing margin based on the C/I standard deviation ($10^{\frac{M_{Shadowing-C/I}}{10}}$)
  - N : Thermal noise

  Calculations

  The effective received carrier power is given by:

  $$C = m_C \times C_P$$

  The effective C/I is given by:

  $$\frac{C}{I} = m_{C/I} \times \frac{C_P}{I_P}$$

  The above equations lead to:

  $$I = \frac{C}{m_{C/I} \times \frac{C_P}{I_P}} = \frac{m_C \times C_P}{m_{C/I} \times \frac{C_P}{I_P}} = \frac{m_C}{m_{C/I}} \times I_P$$

  Where $\frac{m_C}{m_{C/I}}$ corresponds to $M_{Shadowing-model} - M_{Shadowing-C/I}$ in dB.

  Therefore, the effective C/(I+N) is given by:

  $$\frac{C}{(I+N)} = \frac{m_C \times C_P}{\left(\frac{m_C}{m_{C/I}} \times I_P + N\right)}$$

- Monte-Carlo Simulations

Random values for shadowing margins are calculated for each transmitter-receiver link and applied to the predicted signal level. A shadowing margin for each transmitter-receiver link in each simulation is obtained by taking a random value from the probability density distribution for the appropriate clutter class. The probability distribution is a log-normal distribution as explained above.

LTE Documents

The shadowing margins are calculated as explained in "Shadowing Margin Calculation in Predictions" on page 90 and "Shadowing Margin Calculation in Monte-Carlo Simulations" on page 92 , and applied to signal level or C/(I+N) as explained below.

- Signal Level-Based Predictions

  Signal level-based predictions include coverage predictions (Coverage by Transmitter, Coverage by Signal Level, and Overlapping Zones) and calculations in point analysis tabs (Profile and Reception) that require calculation of the received signal level only, and do not depend on interference.

  In these calculations (signal level calculations), a shadowing margin ($M_{Shadowing-model}$) is applied to the signal level calculated for each pixel. The shadowing margin is calculated for a given cell edge coverage probability, and depends on the model standard deviation (σ_{model} in dB) associated to the clutter class where the receiver is located.

- Interference+noise-Based Predictions

  Interference-based predictions include coverage predictions (Coverage by C/(I+N) Level, Coverage by Bearer, Coverage by Throughput, etc.) that require calculation of the received signal level and received interference.

  In these calculations, (C/(I+N) calculations), in addition to the shadowing margin ($M_{Shadowing-model}$) applied to the signal level calculated for each pixel, the ratio $M_{Shadowing-model} - M_{Shadowing-C/I}$ is applied to the interfering signal levels (I). $M_{Shadowing-C/I}$ is calculated for a given cell edge coverage probability and depends on the C/I standard deviation ($\sigma_{C/I}$ in dB) associated to the clutter class where the receiver is located.

  The reason why the ratio $M_{Shadowing-model} - M_{Shadowing-C/I}$ is used can be understood from the following derivation (linear, not it dB):

  Inputs

  - C_P : The predicted received carrier power without any shadowing margin.
  - I_P : The predicted received interference power without any shadowing margin.
  - m_C : Shadowing margin based on the model standard deviation ($10^{\frac{M_{Shadowing-model}}{10}}$)
  - $m_{C/I}$: Shadowing margin based on the C/I standard deviation ($10^{\frac{M_{Shadowing-C/I}}{10}}$)
  - N : Thermal noise

  Calculations

  The effective received carrier power is given by:

  $$C = m_C \times C_P$$

  The effective C/I is given by:

  $$\frac{C}{I} = m_{C/I} \times \frac{C_P}{I_P}$$

  The above equations lead to:

  $$I = \frac{C}{m_{C/I} \times \frac{C_P}{I_P}} = \frac{m_C \times C_P}{m_{C/I} \times \frac{C_P}{I_P}} = \frac{m_C}{m_{C/I}} \times I_P$$

  Where $\frac{m_C}{m_{C/I}}$ corresponds to $M_{Shadowing-model} - M_{Shadowing-C/I}$ in dB.

  Therefore, the effective C/(I+N) is given by:

$$\frac{C}{(I+N)} = \frac{m_C \times C_P}{\left(\frac{m_C}{m_{C/I}} \times I_P + N\right)}$$

- Monte-Carlo Simulations

  Random values for shadowing margins are calculated for each transmitter-receiver link and applied to the predicted signal level. A shadowing margin for each transmitter-receiver link in each simulation is obtained by taking a random value from the probability density distribution for the appropriate clutter class. The probability distribution is a log-normal distribution as explained above.

2.14.1 Shadowing Margin Calculation

The following sections describe the calculation method used for determining different shadowin margins.

The following shadowing margins are calculated using the method described below:

Network Type	Standard Deviation	$M_{Shadowing}$	Applied to
GSM GPRS EGPRS	σ_{model}	$M_{Shadowing-model}$	C
	$\sigma_{C/I}$	$M_{Shadowing-C/I}$	C/I
UMTS HSPA	σ_{model}	$M_{Shadowing-model}$	C
	$\sigma_{Ec/Io}$	$M_{Shadowing-Ec/Io}$	E_c/I_0
	$\sigma_{(Eb/Nt)_{DL}}$	$M_{Shadowing-(Eb/Nt)_{DL}}$	E_b/N_t (DL)
	$\sigma_{(Eb/Nt)_{UL}}$	$M_{Shadowing-(Eb/Nt)_{UL}}$	E_b/N_t (UL)
CDMA2000	σ_{model}	$M_{Shadowing-model}$	C
	$\sigma_{Ec/Io}$	$M_{Shadowing-Ec/Io}$	E_c/I_0
	$\sigma_{(Eb/Nt)_{DL}}$	$M_{Shadowing-(Eb/Nt)_{DL}}$	E_b/N_t (DL)
	$\sigma_{(Eb/Nt)_{UL}}$	$M_{Shadowing-(Eb/Nt)_{UL}}$	E_b/N_t (UL)
TD-SCDMA	σ_{model}	$M_{Shadowing-model}$	C
	$\sigma_{(Eb/Nt)_{P-CCPCH}}$	$M_{Shadowing-(Eb/Nt)_{P-CCPCH}}$	E_b/N_t P-CCPCH
	$\sigma_{(Eb/Nt)_{DL}}$	$M_{Shadowing-(Eb/Nt)_{DL}}$	E_b/N_t (DL)
	$\sigma_{(Eb/Nt)_{UL}}$	$M_{Shadowing-(Eb/Nt)_{UL}}$	E_b/N_t (UL)
WiMAX	σ_{model}	$M_{Shadowing-model}$	C and C/(I+N)
	$\sigma_{C/I}$	$M_{Shadowing-C/I}$	C/(I+N)
LTE	σ_{model}	$M_{Shadowing-model}$	C and C/(I+N)
	$\sigma_{C/I}$	$M_{Shadowing-C/I}$	C/(I+N)

2.14.1.1 Shadowing Margin Calculation in Predictions

Shadowing margins, $M_{Shadowing}$, are calculated from standard deviation values defined for the clutter class where the pixel (probe mobile) is located, and required cell edge coverage probability, and applied to the path loss, L_{path}.

Shadowing Error PDF (1 Signal)

The measured path loss in dB can be expressed as a Gaussian random variable:

$$L = L_{path} + \sigma_{dB} \times G(0, 1)$$

where,

- L_{path} is the predicted path loss,

- σ_{dB} is the user-defined standard deviation of the error,
- G(0,1) is a zero-mean unit-variance Gaussian random variable.

Therefore, the probability density function (pdf) for the random (shadowing) part of path loss is:

$$p_L(x) = \frac{1}{\sigma_{dB}\sqrt{2\pi}} \times e^{-\frac{x^2}{2\sigma_{dB}^2}}$$

The probability that the shadowing error exceeds z dB is

$$P_L(x > z) = \int_z^{\infty} p_L(x)dx = \frac{1}{\sigma_{dB}\sqrt{2\pi}} \times \int_z^{\infty} e^{-\frac{x^2}{2\sigma_{dB}^2}}dx$$

Normalising x by dividing it by σ_{dB}:

$$P_L(x > z) = \frac{1}{\sqrt{2\pi}} \times \int_{\frac{z}{\sigma_{dB}}}^{\infty} e^{-\frac{x^2}{2}}dx = Q\left(\frac{z}{\sigma_{dB}}\right)$$

where *Q* is the complementary cumulative function.

To ensure a given cell edge coverage probability, R_L, for the predicted value, a shadowing margin, $M_{Shadowing}$, is added to the link budget.

Confidence in the prediction can be expressed as:

$$C_d = P'_{Tx} - L \geq P_{rec} \Leftrightarrow L \leq P'_{Tx} - P_{rec} \Leftrightarrow G(0, 1) \times \sigma_{dB} \leq M_{Shadowing}$$

where,

- P_{rec} is the signal level predicted at the receiver. $P_{rec} = P'_{Tx} - L_{path} - M_{Shadowing}$
- $P'_{Tx} = EIRP + G_{antRx} - L_{Rx}$
- EIRP is the effective isotropic radiated power of the transmitter.
- L_{Rx} are receiver losses.
- G_{antRx} is the receiver antenna gain.

The shadowing margin is calculated such that:

$$P(C_d \geq P_{rec}) = R_L(M_{Shadowing}) = 1 - P_L(x - M_{Shadowing} > 0) = 1 - Q\left(\frac{M_{Shadowing}}{\sigma_{dB}}\right)$$

A lookup table is used for mapping the values of Q vs. a set of cell edge coverage probabilities.

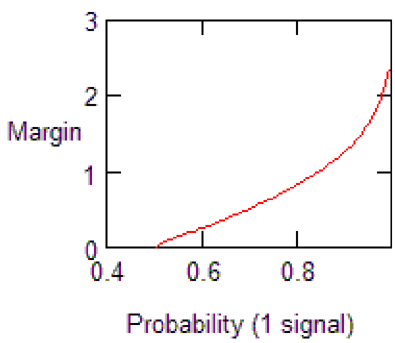


Figure 2.18: Normalised Margin $Margin = \frac{M_{Shadowing}}{\sigma_{dB}}$

In interference-based predictions, where signal to noise ratio is calculated, the shadowing margin is only applied to the signal from the interfered transmitter (C). We consider that the interference value is not altered by the shadowing margin. Random variations also exist in the interfering signals, but taking only the average interference gives accurate results. [3] explains how a certain level of interference is maintained by congestion control in CDMA-based networks.

2.14.1.2 Shadowing Margin Calculation in Monte-Carlo Simulations

Shadowing margins, $M_{Shadowing}$, are calculated from standard deviation values defined for the clutter class where the pixel (probe mobile) is located, and required cell edge coverage probability, and added to the path loss, L_{path}.

Random values are generated during Monte-Carlo simulation. Each user is assigned a service, a mobility type, an activity status, a geographic position and a random shadowing value.

For each link, path loss (L) can be broken down to $L = L_{path} + \xi$.

Here, ξ is a zero mean gaussian random variable $G(0, \sigma_{dB})$ representing variation due to shadowing. It can be expressed as the sum of two uncorrelated zero mean gaussian random variables, ξ_L and ξ_P. ξ_L models the error related to the receiver's location (surrounding environment), and remains the same for all links between the receiver and the base stations from which it is receiving signals. ξ_P models the error related to the path between the transmitter and the receiver.

Therefore, in case of two links, we have:

$\xi_1 = \xi_L + \xi_P^1$ for link 1

$\xi_2 = \xi_L + \xi_P^2$ for link 2

Standard deviations of $\xi_L(\sigma_L)$ and $\xi_P^i(\sigma_P)$ can be calculated from ξ_i, the model standard deviation (σ_{model}), and the correlation coefficient (ρ) between ξ_1 and ξ_2.

Assuming all ξ_P have the same standard deviations, we have:

$$\sigma_{model}^2 = \sigma_L^2 + \sigma_P^2$$

$$\rho = \frac{\sigma_L^2}{\sigma_{model}^2}$$

Therefore,

$$\sigma_P^2 = \sigma_{model}^2 \times (1 - \rho)$$

$$\sigma_L^2 = \sigma_{model}^2 \times \rho$$

ρ is set to 0.5 in **9955**, which gives:

$$\sigma_L = \frac{\sigma_{model}}{\sqrt{2}} \text{ and } \sigma_P = \frac{\sigma_{model}}{\sqrt{2}}$$

Therefore, to model shadowing error common to all the signals received at a receiver ($E_{Shadowing-model}^{Receiver}$), values are randomly generated for each receiver. These values have a zero-mean gaussian distribution with a standard deviation of $\left(\frac{\sigma_{model}}{\sqrt{2}}\right)$, where (σ_{model}) is the model standard deviation associated with the receiver's clutter class.

Next, **9955** generates another random value for each transmitter-receiver pair. This values represents the shadowing error not related to the location of the receiver ($E_{Shadowing-model}^{Path}$). These values also have a zero-mean gaussian distribution with a standard deviation $\left(\frac{\sigma_{model}}{\sqrt{2}}\right)$.

So, we have:

$$E_{Shadowing-model} = E_{Shadowing-model}^{Receiver} + E_{Shadowing-model}^{Path}$$

Random shadowing error has its mean value at zero. Hence, this shadowing modelling method has no impact on the simulated network load. On the other hand, as shadowing errors on the transmitter-receiver links are uncorrelated, the method influences the calculated macro-diversity gain in case the mobile is in soft handover.

2.14.2 Macro-Diversity Gains Calculation

The following sections explain how uplink and downlink macro-diversity gains are calculated in UMTS HSPA and CDMA2000 1xRTT 1xEV-DO documents for predictions and AS Analysis tab of the point analysis tool.

The calculation and use of macro-diversity gains can be disabled through the Atoll.ini file.
For more information, see the *Administrator Manual*.

2.14.2.1 Uplink Macro-Diversity Gain Evaluation

In UMTS HSPA and CDMA2000 1xRTT 1xEV-DO, mobiles may be in soft handoff (mobile connected to cells located on different sites). In this case, we can consider the shadowing error pdf described below.

2.14.2.1.1 Shadowing Error PDF (n Signals)

For each link, path loss (L) can be broken down as:

$$L = L_{path} + \xi$$

ξ is a zero mean gaussian random variable $G(0, \sigma_{dB})$ representing variation due to shadowing. It can be expressed as the sum of two uncorrelated zero mean gaussian random variables, ξ_L and ξ_P. ξ_L models error related to the receiver local environment; it is the same whichever the link. ξ_P models error related to the path between transmitter and receiver.

Therefore, in case of two links, we have:

$\xi_1 = \xi_L + \xi_P^1$ for the link 1

$\xi_2 = \xi_L + \xi_P^2$ for the link 2

Knowing ξ_i, the uplink Eb/Nt standard deviation $(\sigma_{(Eb/Nt)_{UL}})$ and the correlation coefficient ρ between ξ_1 and ξ_2, we can calculate standard deviations of $\xi_L(\sigma_L)$ and $\xi_P(\sigma_P)$ (assuming all ξ_P have the same standard deviations).

We have:

$$\sigma^2_{(Eb/Nt)_{UL}} = \sigma_L^2 + \sigma_P^2$$

$$\rho = \frac{\sigma_L^2}{\sigma^2_{(Eb/Nt)_{UL}}}$$

Therefore,

$$\sigma_P^2 = \sigma^2_{(Eb/Nt)_{UL}} \times (1 - \rho)$$

$$\sigma_L^2 = \sigma^2_{(Eb/Nt)_{UL}} \times \rho$$

2 Signals Without Recombination

In technologies supporting soft handoff (UMTS and CDMA2000), cell is interference limited. As for one link, to ensure a required cell edge coverage probability R_L for the prediction, we add to each link budget a shadowing margin, $M^{2signals}_{Shadowing-(Eb/Nt)_{UL}}$.

Prediction reliability in order to have Eb/Nt higher or equal to Eb/Nt from the best server can be expressed as:

$$\frac{C_{d_1}}{N_1} = P'_{Tx1} - L_1 - N_1 \geq CI^1_{pred} \Leftrightarrow \xi_1 \leq P'_{Tx1} - L_{path_1} - N_1 - CI^1_{pred}$$

or

$$\frac{C_{d_2}}{N_2} = P'_{Tx2} - L_2 - N_2 \geq CI^1_{pred} \Leftrightarrow \xi_2 \leq P'_{Tx2} - L_{path_2} - N_2 - CI^1_{pred}$$

where

CI^i_{pred} is the quality level (signal to noise ratio) predicted at the receiver for link i.

N_i is the noise level for link i.

We note:

$$M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} = P'_{Txi} - L_{path_i} - N_i - CI^i_{pred}$$

and

$$\Delta^2_1 = CI^1_{pred} - CI^2_{pred}$$

Δ^2_1 is the minimum needed margin on each link.

Therefore, the probability of having a quality at least equal to the best predicted one is:

$$R^{noMRC}_L(M^{2signals}_{Shadowing-(Eb/Nt)_{UL}}) = 1 - P_{L1,L2}\left(\frac{C_{d_1}}{N_1} < CI^1_{pred}, \frac{C_{d_2}}{N_2} < CI^1_{pred}\right)$$

$$R^{noMRC}_L(M^{2signals}_{Shadowing-(Eb/Nt)_{UL}}) = 1 - P_{\xi_1,\xi_2}(\xi_1 > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}}, \xi_2 > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta^2_1)$$

We can express it using ξ_L, ξ^1_P and ξ^2_P

$$P_{\xi_1,\xi_2}\left(\xi_1 > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}}, \xi_2 > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta^2_1 \middle| \xi_L = \Delta_L\right)$$
$$= P_{\xi_L}(\Delta_L) \times P_{\xi^1_P,\xi^2_P}(\xi^1_P > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta_L, \xi^2_P > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta^2_1 - \Delta_L)$$

$$P_{\xi_1,\xi_2}\left(\xi_1 > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}}, \xi_2 > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta^2_1 \middle| \xi_L = \Delta_L\right)$$
$$= P_{\xi_L}(\Delta_L) \times P_{\xi_P}(\Delta^1_P > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta_L) \times P_{\xi_P}(\Delta^2_P > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta^2_1 - \Delta_L)$$

$$R^{noMRC}_L(M^{2signals}_{Shadowing-(Eb/Nt)_{UL}})$$
$$= \left(1 - \int_{-\infty}^{\infty} P_{\xi_L}(\Delta_L) \times P_{\xi_P}(\Delta^1_P > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta_L) \times P_{\xi_P}(\Delta^2_P > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta^2_1 - \Delta_L) d\Delta_L\right)$$

$$P_{\xi_P}(\Delta^i_P > M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta_L)$$
$$= \left(\frac{1}{\sigma_P\sqrt{2\pi}} \int_{(M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta_L)}^{\infty} e^{\frac{-x^2}{2\sigma^2_P}} dx = Q\left(\frac{M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta_L}{\sigma_P}\right)\right)$$

Then, we have:

$$R^{noMRC}_L(M^{2signals}_{Shadowing-(Eb/Nt)_{UL}})$$
$$= \left(1 - \int_{-\infty}^{\infty} P_{\xi_L}(\Delta_L) \times Q\left(\frac{M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta_L}{\sigma_P}\right) \times Q\left(\frac{M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - \Delta^2_1 - \Delta_L}{\sigma_P}\right) d\Delta_L\right)$$

If we introduce user defined standard deviation $(\sigma_{(Eb/Nt)_{UL}})$ and correlation coefficient (ρ), and consider that P_{ξ_L} is a Gaussian pdf:

$$R^{noMRC}_L(M^{2signals}_{Shadowing-(Eb/Nt)_{UL}})$$
$$= \left(1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{\frac{-x^2_L}{2}} \times Q\left(\frac{M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - x_L\sigma_{(Eb/Nt)_{UL}}\sqrt{\rho}}{\sigma_{(Eb/Nt)_{UL}}\sqrt{1-\rho}}\right) \times Q\left(\frac{M^{2signals}_{Shadowing-(Eb/Nt)_{UL}} - x_L\sigma_{(Eb/Nt)_{UL}}\sqrt{\rho} - \Delta^2_1}{\sigma_{(Eb/Nt)_{UL}}\sqrt{1-\rho}}\right) dx_L\right)$$

n Signals Without Recombination

We can generalize the previous expression to n signals (n is the number of available signals - **9955** may consider up to 3 signals):

$$R_L^{noMRC}(M^{nsignals}_{Shadowing-(Eb/Nt)_{UL}})$$

$$= \left(1 - \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{\frac{-x_L^2}{2}} \times Q\left(\frac{M^{nsignals}_{Shadowing-(Eb/Nt)_{UL}} - x_L\sigma_{(Eb/Nt)_{UL}}\sqrt{\rho}}{\sigma_{(Eb/Nt)_{UL}}\sqrt{1-\rho}}\right) \times Q\left(\frac{M^{nsignals}_{Shadowing-(Eb/Nt)_{UL}} - x_L\sigma_{(Eb/Nt)_{UL}}\sqrt{\rho} - \Delta_1^2}{\sigma_{(Eb/Nt)_{UL}}\sqrt{1-\rho}}\right) dx_L\right)$$

The case where softer handoff occurs (two signals from co-site cells) is equivalent to the one signal case. The Softer/soft case is equivalent to the two signals case. For the path associated with the softer recombination, we will use combined SNR to calculate the availability of the link.

Correlation Coefficient Determination

There is currently no agreed model for predicting correlation coefficient (ρ) between ξ_1 and ξ_2. Two key variables influence correlation:

- The angle between the two signals. If this angle is small, correlation is high.
- The relative values of the two signal lengths. If angle is 0 and lengths are the same, correlation is zero. Correlation is different from zero when path lengths differ.

A simple model has been found [1]:

$$\rho = \left(\frac{\varphi_T}{\varphi}\right)^{\gamma}\sqrt{\frac{D1}{D2}} \text{ when } \phi_T \le \phi \le \pi$$

φ_T is a function of the mean size of obstacles near the receiver and γ is also linked to the receiver environment.

In a normal handover status, assuming a hexagonal design for sites, φ is close to π (+/- π/3) and *D1/D2* is close to 1.

In [1,5], $\rho = 0.5$ when $\gamma = 0.3$ and $\varphi_T = \frac{\pi}{10}$.

In **9955**, ρ is set to 0.5.

2.14.2.1.2 Uplink Macro-Diversity Gain

9955 determines the uplink macro-diversity gain ($G^{UL}_{macro-diversity}$) from the shadowing margins calculated in case of one signal and n signals.

Therefore, we have:

$$G^{UL}_{macro-diversity} = M^{nsignals}_{Shadowing-(Eb/Nt)_{UL}} - M_{Shadowing-(Eb/Nt)_{UL}}$$

Where n is the number of cell-mobile signals.

2.14.2.2 Downlink Macro-Diversity Gain Evaluation

In UMTS HSPA and CDMA2000 1xRTT 1xEV-DO, in case of soft handoff, mobiles are able to switch from one cell to another if the best pilot drastically fades. To model this function, we have to consider the probability of fading over the shadowing margin, both for the best signal and for all the other available signals, in the shadowing margin calculation.

Let us consider the shadowing error pdf described below.

2.14.2.2.1 Shadowing Error PDF (n Signals)

For each link, path loss (*L*) can be broken down as:

$$L = L_{path} + \xi$$

ξ is a zero mean gaussian random variable $G(0, \sigma_{dB})$ representing variation due to shadowing. It can be expressed as the sum of two uncorrelated zero mean gaussian random variables, ξ_L and ξ_P. ξ_L models the error related to the receiver local environment, which is the same for all links. ξ_P models the error related to the path between the transmitter and the receiver.

Therefore, in case of two links, we have:

$\xi_1 = \xi_L + \xi_P^1$ for the link 1

$\xi_2 = \xi_L + \xi_P^2$ for the link 2

Knowing ξ_i, the Ec/Io standard deviation $(\sigma_{Ec/Io})$ and the correlation coefficient ρ between ξ_1 and ξ_2, we can calculate standard deviations of $\xi_L(\sigma_L)$ and $\xi_P(\sigma_P)$ (assuming all ξ_P have the same standard deviations).

We have:

$$\sigma_{Ec/Io}^2 = \sigma_L^2 + \sigma_P^2$$

$$\rho = \frac{\sigma_L^2}{\sigma_{Ec/Io}^2}$$

Therefore,

$$\sigma_P^2 = \sigma_{Ec/Io}^2 \times (1-\rho)$$

$$\sigma_L^2 = \sigma_{Ec/Io}^2 \times \rho$$

2 Available Signals

In technologies supporting soft handoff (UMTS and CDMA2000) cells are interference limited. As for one link, to ensure a required cell edge coverage probability R_L for the prediction, we add a shadowing margin, $M_{Shadowing-Ec/Io}^{2signals}$, to each link budget.

Prediction reliability to have $\frac{Ec}{Io} \geq \left(\frac{Ec}{Io}\right)_{pred}$ for the best server can be expressed as:

$$\frac{Ec_1}{Io} = P_{pilot_1} - L_1 - Io \geq \left(\frac{Ec}{Io}\right)_{pred}^1 \Leftrightarrow \xi_1 \leq P_{pilot_1} - L_{m_1} - Io - \left(\frac{Ec}{Io}\right)_{pred}^1$$

Or

$$\frac{Ec_2}{Io} = P_{pilot_2} - L_2 - Io \geq \left(\frac{Ec}{Io}\right)_{pred}^1 \Leftrightarrow \xi_2 \leq P_{pilot_2} - L_{m_2} - Io - \left(\frac{Ec}{Io}\right)_{pred}^1$$

We note:

$$M_{Shadowing-Ec/Io}^{2signals} = P_{pilot_i} - L_{m_i} - Io - \left(\frac{Ec}{Io}\right)_{pred}^1$$

$$\Delta_1^2 = \left(\frac{Ec}{Io}\right)_{pred}^1 - \left(\frac{Ec}{Io}\right)_{pred}^2$$

Δ_1^2 is the minimum needed margin on each link.

Therefore, probability of having a quality at least equal to the best predicted one is:

$$R_L^{noMRC}(M_{Shadowing-Ec/Io}^{2signals}) = 1 - P_{L1,L2}\left(\frac{Ec_1}{Io} < \left(\frac{Ec}{Io}\right)_{pred}^1, \frac{Ec_2}{Io} < \left(\frac{Ec}{Io}\right)_{pred}^1\right)$$

$$R_L^{noMRC}(M_{Shadowing-Ec/Io}^{2signals}) = 1 - P_{\xi 1,\xi 2}(\xi_1 > M_{Shadowing-Ec/Io}^{2signals}, \xi_2 > M_{Shadowing-Ec/Io}^{2signals} - \Delta_1^2)$$

We can express it by using ξ_L, ξ_P^1 and ξ_P^2

$$P_{\xi 1,\xi 2}(\xi_1 > M_{Shadowing-Ec/Io}^{2signals}, \xi_2 > M_{Shadowing-Ec/Io}^{2signals} - \Delta_1^2 | \xi_L = \Delta_L)$$
$$= P_{\xi_L}(\Delta_L) \times P_{\xi_P^1,\xi_P^2}(\xi_P^1 > M_{Shadowing-Ec/Io}^{2signals} - \Delta_L, \xi_P^2 > M_{Shadowing-Ec/Io}^{2signals} - \Delta_1^2 - \Delta_L)$$

$$P_{\xi 1,\xi 2}(\xi_1 > M_{Shadowing-Ec/Io}^{2signals}, \xi_2 > M_{Shadowing-Ec/Io}^{2signals} - \Delta_1^2 | \xi_L = \Delta_L)$$
$$= P_{\xi_L}(\Delta_L) \times P_{\xi_P}(\Delta_P^1 > M_{Shadowing-Ec/Io}^{2signals} - \Delta_L) \times P_{\xi_P}(\Delta_P^2 > M_{Shadowing-Ec/Io}^{2signals} - \Delta_1^2 - \Delta_L)$$

$$R_L^{noMRC}(M_{Shadowing-Ec/Io}^{2signals})$$

$$= 1-\int_{-\infty}^{\infty} P_{\xi_L}(\Delta_L)\times P_{\xi_p}(\Delta_P^1 > M_{Shadowing-Ec/Io}^{2signals}-\Delta_L)\times P_{\xi_p}(\Delta_P^2 > M_{Shadowing-Ec/Io}^{2signals}-\Delta_1^2-\Delta_L)d\Delta_L$$

$$P_{\xi_p}(\Delta_P^i > M_{Shadowing-Ec/Io}^{2signals}-\Delta_L) = \frac{1}{\sigma_P\sqrt{2\pi}}\int_{\gamma_{SHO}-\Delta_L}^{\infty} e^{\frac{-x^2}{2\sigma_P^2}}dx = Q\left(\frac{M_{Shadowing-Ec/Io}^{2signals}-\Delta_L}{\sigma_P}\right)$$

Then, we have:

$$R_L^{noMRC}(M_{Shadowing-Ec/Io}^{2signals}) = 1-\int_{-\infty}^{\infty} P_{\xi_L}(\Delta_L)\times Q\left(\frac{M_{Shadowing-Ec/Io}^{2signals}-\Delta_L}{\sigma_P}\right)\times Q\left(\frac{M_{Shadowing-Ec/Io}^{2signals}-\Delta_1^2-\Delta_L}{\sigma_P}\right)d\Delta_L$$

If we introduce a user defined Ec/Io standard deviation (σ) and a correlation coefficient (ρ) and consider that P_{ξ_L} is a Gaussian pdf:

$$R_L^{noMRC}(M_{Shadowing-Ec/Io}^{2signals})$$

$$= 1-\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{\frac{-x_L^2}{2}}\times Q\left(\frac{M_{Shadowing-Ec/Io}^{2signals}-x_L\sigma_{Ec/Io}\sqrt{\rho}}{\sigma_{Ec/Io}\sqrt{1-\rho}}\right)\times Q\left(\frac{M_{Shadowing-Ec/Io}^{2signals}-\Delta_1^2-x_L\sigma_{Ec/Io}\sqrt{\rho}}{\sigma_{Ec/Io}\sqrt{1-\rho}}\right)dx_L$$

n Available Signals

We can generalize the previous expression for n signals (n is the number of available signals - **9955** may consider up to 3 signals):

$$R_L^{noMRC}(M_{Shadowing-Ec/Io}^{nsignals})$$

$$= 1-\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{\frac{-x_L^2}{2}}\times Q\left(\frac{M_{Shadowing-Ec/Io}^{nsignals}-x_L\sigma_{Ec/Io}\sqrt{\rho}}{\sigma_{Ec/Io}\sqrt{1-\rho}}\right) x\prod_{i=2}^{n} Q\left(\frac{M_{Shadowing-Ec/Io}^{nsignals}-\Delta_1^i-x_L\sigma_{Ec/Io}\sqrt{\rho}}{\sigma_{Ec/Io}\sqrt{1-\rho}}\right)dx_L$$

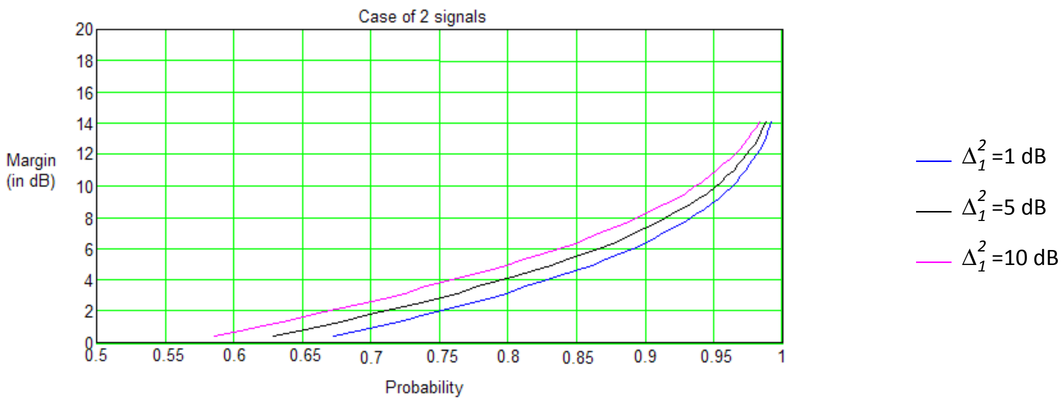


Figure 2.19: Margin - Probability (Case of 2 Signals)

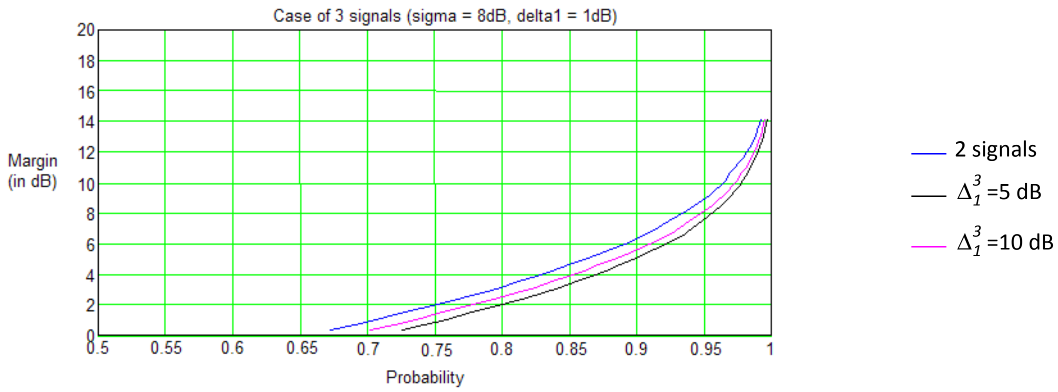


Figure 2.20: Margin - Probability (Case of 3 Signals with sigma = 8dB, delta1 = 1dB)

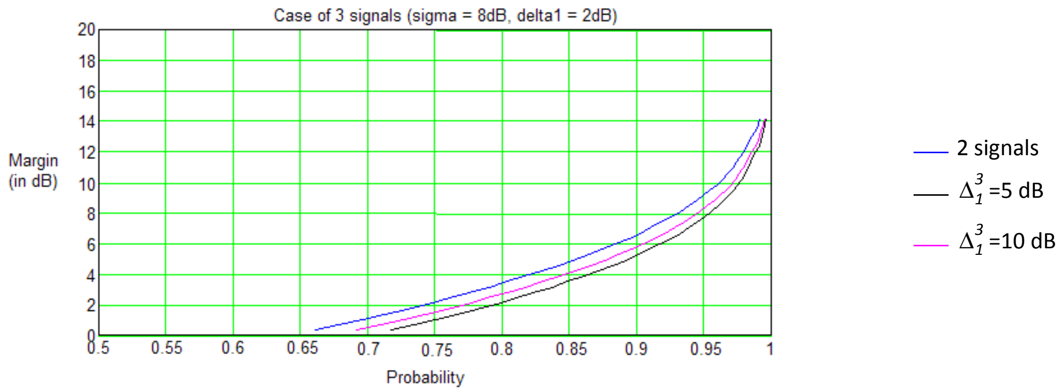


Figure 2.21: Margin - Probability (Case of 3 Signals with sigma = 8dB, delta1 = 2dB)

Correlation Coefficient Determination

For further information about determination of the correlation coefficient, please see "Correlation Coefficient Determination" on page 98.

2.14.2.2.2 Downlink Macro-Diversity Gain

9955 determines the downlink macro-diversity gain ($G^{DL}_{macro-diversity}$) from the shadowing margins calculated in case of one signal and n signals.

Therefore, we have:

$$G^{DL}_{macro-diversity} = M^{nsignals}_{Shadowing-Ec/Io} - M_{Shadowing-Ec/Io}$$

Where n is the number of available signals.

2.15 Path Loss Matrices

9955 is able to calculate two path loss matrices per transmitter, a first matrix over a smaller radius computed with a high resolution and a propagation model (main matrix), and a second matrix over a larger radius computed with a low resolution and another propagation model (extended matrix).

To be considered for calculations, a transmitter must fulfil the following conditions:

- It must be active,
- It must satisfy filter criteria defined in the **Transmitters** folder, and
- It must have a calculation area.

In the rest of the document, a transmitter fulfilling the conditions detailed above will be called TBC transmitter.

The path loss matrix size of a TBC transmitter depends on its calculation area. **9955** determines a path loss value (L_{path}) on each calculation bin (calculation bin is defined by the resolution) of the calculation area of the TBC transmitter. You may have one or two path loss matrices per TBC transmitter.

2.15.1 Calculation Area Determination

Transmitter calculation area is made of a rectangle or a square depending on transmitter calculation radius and the computation zone**.**

Calculation radius enables **9955** to define a square around the transmitter. One side of the square equals twice the entered calculation radius.

Since the computation zone can be made of one or several polygons, transmitter calculation area corresponds to the intersection area between its calculation square and the rectangle containing the computation zone area(s).

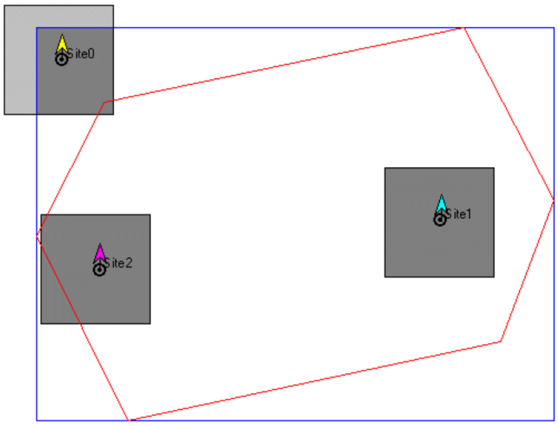


Figure 2.22: Example 1: Single Calculation Area

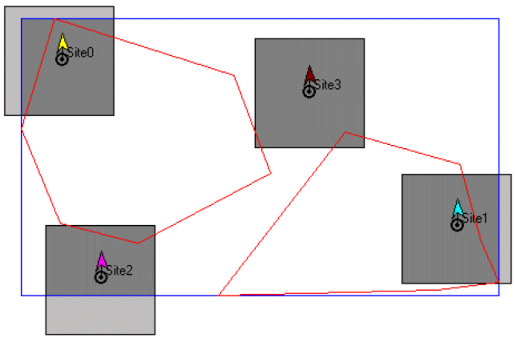


Figure 2.23: Example 2: Multiple Calculation Areas

Computation zone

Rectangle containing the computation zone(s)

Calculation area defined (square)

Transmitter

Actual calculation area on which **9955** calculates path losses

2.15.2 Validity of Path Loss Matrices

Most geographic data modifications and some radio data changes make path loss matrices invalid. This table lists these modifications and also changes that have an impact only on coverage predictions.

Modification	Matrix validity	Impact on	Calculate	Force calculation
Frequency	Invalid	Path loss matrices	Sufficient	Not necessary
Antenna coordinates (site coordinate: X and Y, Dx and Dy)	Invalid	Path loss matrices	Sufficient	Not necessary
Antenna[a] height	Invalid	Path loss matrices	Sufficient	Not necessary

Modification	Matrix validity	Impact on	Calculate	Force calculation
Antenna[a] pattern	Invalid	Path loss matrices	Sufficient	Not necessary
Downtilt[a]	Invalid	Path loss matrices	Sufficient	Not necessary
Azimuth[a]	Invalid	Path loss matrices	Sufficient	Not necessary
% Power (secondary antennas)	Invalid	Path loss matrices	Sufficient	Not necessary
Site position/altitude	Invalid	Path loss matrices	Sufficient	Not necessary
Grid resolution (main or extended)	Invalid	Path loss matrices	Sufficient	Not necessary
Propagation model (main or extended)	Invalid	Path loss matrices	Sufficient	Not necessary
Propagation model parameters	Invalid	Path loss matrices	Sufficient	Not necessary
Calculation areas (Calculation areas gets smaller)	Valid	Coverage predictions	Sufficient	Not necessary
Calculation areas (Calculation areas gets larger)	Invalid	Path loss matrices	Sufficient	Not necessary
Receiver height	Invalid	Path loss matrices	Sufficient	Not necessary
Receiver losses	Valid	Coverage predictions	Sufficient	Not necessary
Receiver gain	Valid	Coverage predictions	Sufficient	Not necessary
Receiver antenna	Valid	Coverage predictions	Sufficient	Not necessary
Geographic layer order	Invalid	Path loss matrices	Insufficient[b]	Necessary
Geographic file resolution	Invalid	Path loss matrices	Insufficient[b]	Necessary
New DTM map	Invalid	Path loss matrices	Insufficient[b]	Necessary
Clutter class edition	Invalid	Path loss matrices	Insufficient[b]	Necessary
Coverage prediction resolution	Valid	Coverage predictions	Sufficient	Not necessary
Cell edge coverage probability	Valid	Coverage predictions	Sufficient	Not necessary
Coverage prediction conditions	Valid	Coverage predictions	Sufficient	Not necessary
Coverage prediction display options	Valid	Coverage predictions	Sufficient	Not necessary

a. *Modification of any parameter related to main or other antennas makes matrix invalid.*
b. *Except if this action has an impact on the site positions/altitudes.*

2.15.3 Path Loss Tuning

9955 can tune path loss matrices obtained from propagation results by the use of real measurements (CW Measurements or Test Mobile Data). For each measured transmitter, **9955** tries to merge measurements and predictions on the same points and to smooth the surrounding points of the path loss matrices for homogeneity reasons. A transmitter path loss matrix can be tuned several times by the use of several measurement paths. All these tuning paths are stored in a catalogue. This catalogue is stored under a .tuning folder containing a .dbf file and one .pts file per tuned transmitter. Since a tuning file can contain several measurement paths, all these measurements are added to the tuning file.

For more information on the tuning files, see the *Administrator Manual*.

2.15.3.1 Transmitter Path Loss Tuning

The same algorithm is used for CW Measurement and Test Mobile Data. It is also the same for main and extended matrices.

Path Losses tuning will be done using two steps.

1. Total matrix correction

   A mean error is calculated between each measured value and the corresponding bin in the pathloss matrix. Mean error is calculated for each pathloss matrix (main and extended) of each transmitter. This mean error is then applied to all the matrix bins. This tuning is done to smooth the local corrections (step 2) of measured values and not the tuned bins.

2. Local correction for each measured value

   For each measured value, an ellipse is used to define the pathloss area which has to be tuned. The main axis of the ellipse is oriented to the transmitter.The ellipse is user-defined by two parameters:

   - The radius of the axis parallel to the Profile (*A*)
   - The radius of the axis perpendicular to the Profile (*B*)

Let's take *M* a measurement value and P_i the path loss value at point *i*, before any tuning.

> *M* is limited by the minimum measurement threshold defined in the interface.

The squared elliptic distance between *i* and *M* is given by:

$$D_i = \frac{(X_i - X_M)^2}{A^2} + \frac{(Y_i - Y_M)^2}{B^2}$$

Where:

X_i and X_M are the X-coordinates of *i* and *M* respectively

Y_i and Y_M are the Y-coordinates of *i* and *M* respectively

The mean error for the first tuning is given by:

$$E = \left(\frac{1}{n}\right) \times \sum_i e_i$$

Where e_i is the error between measurement and prediction at point *i*

> *E* is limited by the maximum total correction defined in the interface.

Then, the path loss value is tuned using *E*:

$$P_i|_{new} = P_i|_{old} + E$$

Finally, a second tuning (R_i) is applied where:

$$R_i = (1 - D_i) \times (M - g - P_i|_{new}) \text{ so } R_i = (1 - D_i) \times (M - g - (P_i|_{old} + E))$$

Where g is (measurement gain - losses).

> R_i is limited by the maximum local correction defined in the interface.

So, the final tuned path loss is:

$$P_i|_{tuned} = P_i|_{new} + R_i \text{ so } P_i|_{tuned} = P_i|_{old} + E + R_i$$

When several ellipses overlap a pathloss bin, the final tuned path loss is given by:

$$P_i|_{tuned} = \frac{\left(\sum_j (1-d_j)P_j|_{tuned}\right)}{\left(n - \sum_j d_j\right)}$$

Where n is the number of overlapping ellipses

2.15.3.2 Repeater Path Loss Tuning

In the case of repeaters, **9955** provides only a composite measured value per pixel which is a combination of the contribution of both a transmitter and one or several repeaters. In order to tune the path loss matrices of donor transmitters and repaters, its is mandatory to split the contribution of each element in the measured value as starting point.

Let's take M the measured value.

$$M = M_d + M_r$$

where :

M_d represents the contribution of the donor transmitter in the measured value.

M_r represents the contribution of the repeater in the measured value.

All the values are used in Watts.

If C_d and C_r represent respectively the filtered signal level from the donor transmitter and the repeater on a pixel, one can define the contribution of each element as follows:

$M_d = M \times \frac{C_d}{C_d + C_r}$ and $M_r = M \times \frac{C_r}{C_d + C_r}$.

Following the path loss tuning process described in "Transmitter Path Loss Tuning" on page 101, the donor transmitter (resp. the repeater) is then tuned using M_d (resp. M_r) values.

2.16 Coverage Prediction Export and Reports

2.16.1 Filtering Coverage Predictions at Export

Raster and vector coverage predictions can be filtered at export in order to exclude holes and islands. Predictions are filtered by setting the colour of a pixel to the dominant colour of the bounding box, i.e., surrounding pixels, using a dispersion factor: $exp(-D^2/(X/2\pi))$.

Here, D is the distance from the pixel to be coloured to each pixel within the bounding box and X is the value at that pixel.

In other words, the pixel will be coloured by the most representative value within this bounding box.

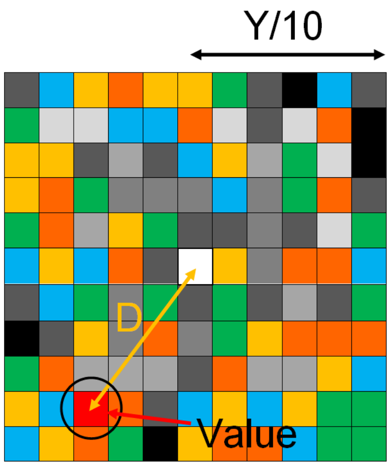


Figure 2.24: Bounding box for prediction filtering

The user-defined filtering percentage Y gives the size of the bounding box: $Y/10$ pixels in each direction. In other words, the bounding box is increased by one pixel every 10 % (since Y is defined as a percentage).

2.16.2 Smoothing Coverage Predictions at Export

Vector coverage predictions can be smoothed at export in orer to simplify its contours. Predictions are smoothed by reducing the number of points defining the contours of the polygons using a vertex reduction routine that successively reduces the number of closely clustered vertices (vertex reduction within tolerance of prior vertex cluster, Douglas-Peucher polyline simplification).

Two smoothing methods exist for defining the degree of coverage smoothing: smoothing by percentage and smoothing by the maximum number of points.

Smoothing by Percentage

The user-defined smoothing percentage Z gives the approximation tolerance: $\frac{\sqrt{2}}{2} \times R \times \frac{Z}{20}$, where R is the user-defined export resolution. Tolerance is the interval within which **9955** tries to reduce the number of points.

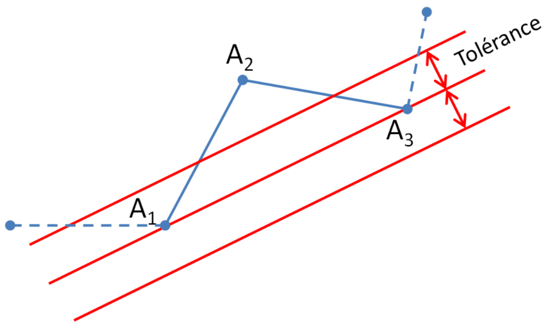


Figure 2.25: Smoothing Tolerance Definition

For example, for three successive points, A_1, A_2, and A_3 as shown in Figure 2.26 on page 103, A_2 will be deleted if within this tolerance (and A_1 and A_3 will be directly linked) and A_2 will be conserved if outside this tolerance.

Figure 2.26: Smoothing by Percentage

Smoothing by Number of Points

The second method consists in defining a maximum number of points to be deleted. This number of points helps the algorithm to determine the optimised tolerance (see "Smoothing by Percentage" on page 103) such that, with this obtained tolerance, the number of points to be deleted will be lower than this value.

Let's consider the following example (1). Starting from the maximum possible tolerance, the number of points to be filtered out are estimated (circled in red in the following example (2)). If this number is greater than the maximum number of points defined by the user, **9955** reduces the tolerance until reaching the requested maximum number of points or less (3). The first the number of points respecting the constraint is obtained, smoothing is applied by deleting these points and linking the remaining closest points (4).

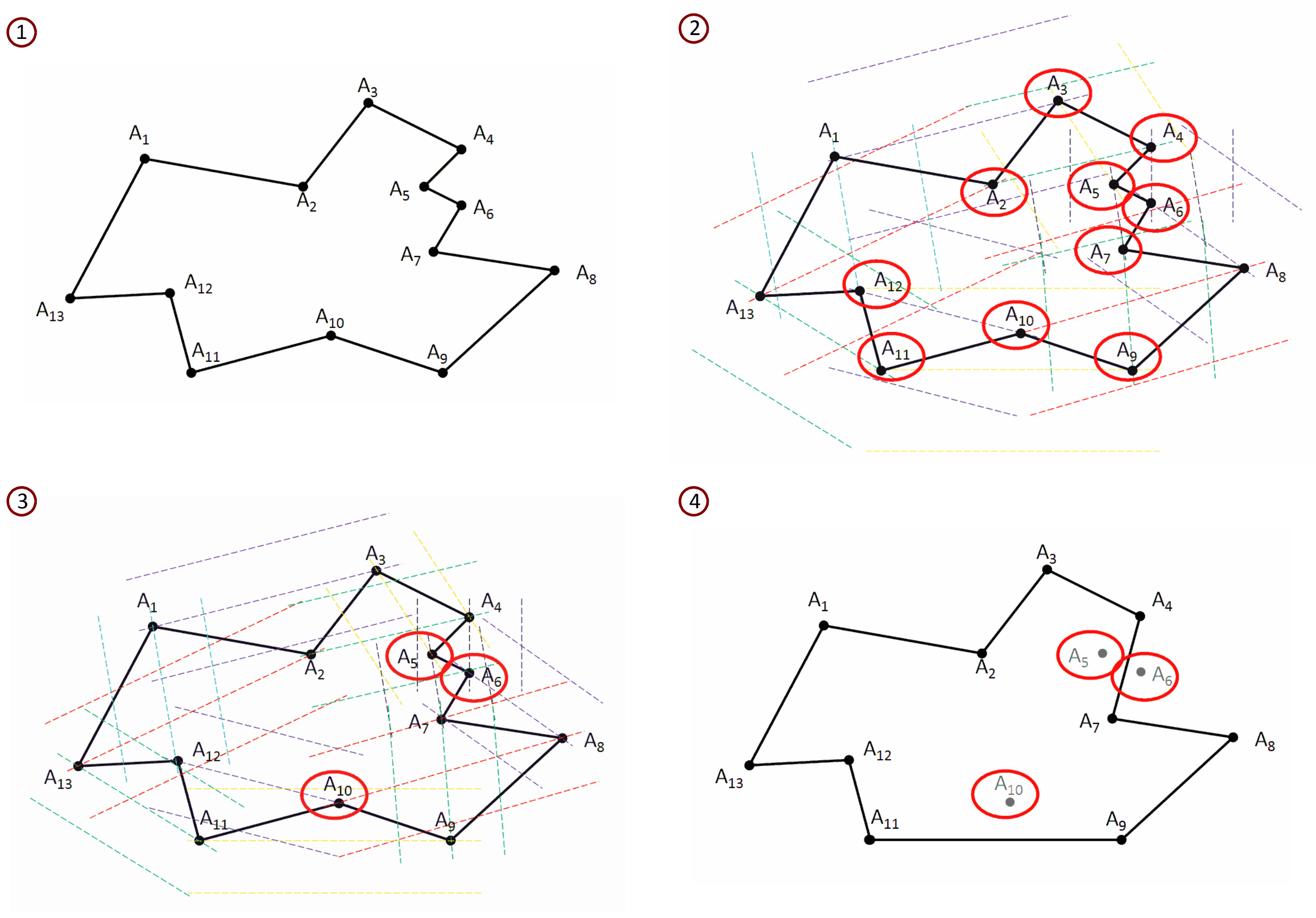


Figure 2.27: Smoothing by Number of Points

2.16.3 Examples of Prediction Export Filtering and Smoothing

Figure 2.28 on page 105 shows the original signal level coverage prediction whose filtered and smoothed exported results are presented in Figure 2.29 on page 105.

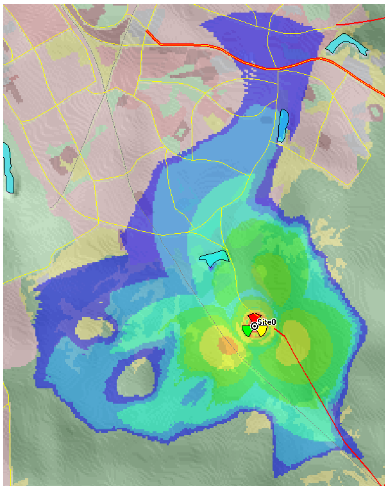


Figure 2.28: Bounding box for prediction filtering

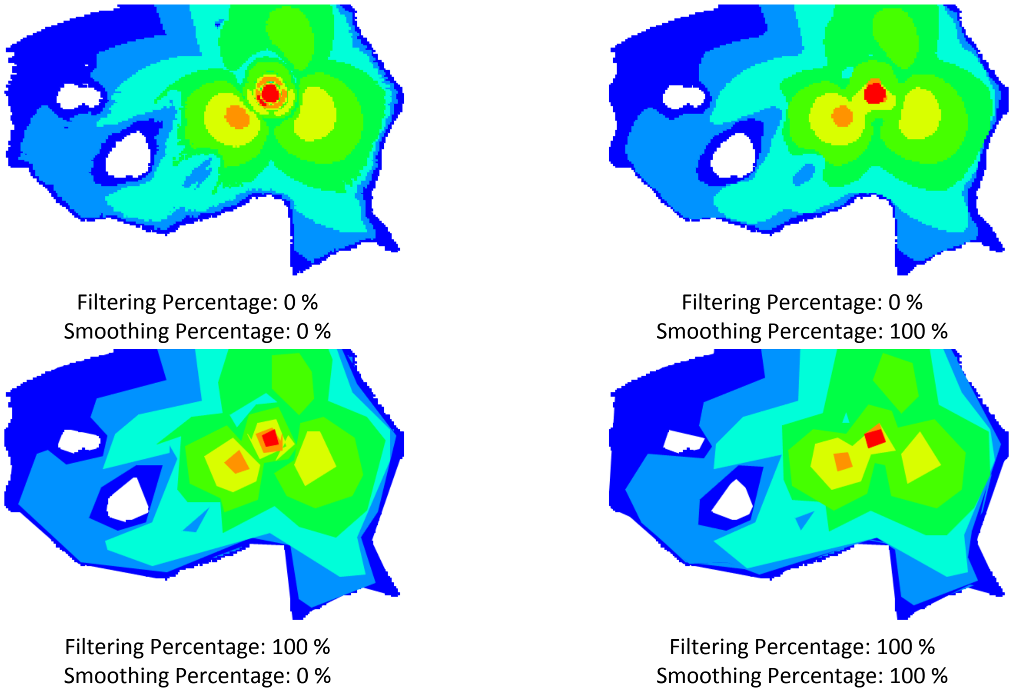


Figure 2.29: Exported prediction with filtering and smoothing

2.16.4 Coverage Prediction Reports Over Focus/Computation Zones

Statistics are calculated in coverage prediction reports over the focus zone or the computation zone, if no focus zone exists, or the covered area, if neither zone exists.

If the reference surface area for the statistics is based on a focus or computation zone, there may be minute inaccuracies in the calculated statistics because of the difference in the surface area calculation methods:

- The surface areas of the zones (polygons) are calculated by triangulation.
- The surface area of a coverage predictions is calculated by counting the number of covered pixels and multiplying this number with the area of one pixel, calculated from resolution of the coverage prediction.

At the border of the focus or computation zone, a pixel is considered inside the zone if its centre is inside. Otherwise, the pixel is considered outside the zone. This estimation may give rise to inaccuracies.

Chapter 3

GSM GPRS EDGE Networks

This chapter describes GSM GPRS EDGE calculations.

In this chapter, the following are explained:

- "Signal Level Calculations" on page 109
- "Interference-based Calculations" on page 114
- "GPRS/EDGE Calculations" on page 119
- "Codec Mode Selection and CQI Calculations" on page 128
- "Traffic Analysis" on page 135
- "Network Dimensioning" on page 147
- "Key Performance Indicators Calculation" on page 156
- "Neighbour Allocation" on page 159
- "AFP Appendices" on page 164

3 GSM GPRS EDGE Networks

This chapter describes all the calculations performed in **9955** GSM/GPRS/EDGE documents. The first four sections describe the signal level, interference, GPRS/EDGE-specific, and CQI calculations, respectively. The following three sections explain the traffic analysis, network dimensioning, and KPI calculation processes. The last section describes the neighbour allocation process in GSM.

- All the calculations are performed on TBC (to be calculated) transmitters. For the definition of TBC transmitters please refer to "Path Loss Matrices" on page 98.
- Logarithms used in this chapter (Log function) are base-10 unless stated otherwise.

3.1 Signal Level Calculations

Three parameters can be studied in point analysis (*Profile* tab) and in signal level-based coverage predictions:

Studied Parameter	Formulas
Signal level (P_{rec}^{Txi})	Signal level received from a transmitter on a TRX type $P_{rec}^{Txi}(tt) = EIRP(tt) - \Delta P(tt) - L_{path}^{Txi} - M_{Shadowing-model} - L_{Indoor} + (G_{ant_{Rx}} - L_{Rx})$
Path loss (L_{path}^{Txi})	$L_{path}^{Txi} = L_{model} + L_{ant_{Tx}}$
Total losses (L_{total}^{Txi})	$L_{total}^{Txi} = (L_{path}^{Txi} + M_{Shadowing-model} + L_{Indoor} + L_{Tx} + L_{Rx}) - (G_{ant_{Tx}} + G_{ant_{Rx}})$

Where,

- *EIRP* is the effective isotropic radiated power of the transmitter,
- L_{model} is the loss on the transmitter-receiver path (path loss) calculated by the propagation model,
- $L_{ant_{Tx}}$ is the transmitter antenna attenuation (from antenna patterns),
- $M_{Shadowing-model}$ is the shadowing margin. This parameter is taken into account when the option "Shadowing taken into account" is selected,
- L_{Indoor} are the indoor losses, taken into account when the option "Indoor coverage" is selected,
- L_{Rx} are the receiver losses,
- $G_{ant_{Rx}}$ is the receiver antenna gain,
- ΔP is the power offset defined for the selected TRX type in the transmitter property dialog,
- *tt* is the TRX type (in the GSM GPRS EDGE.mdb document template, there are three possible TRX types, BCCH, TCH and inner TCH).

3.1.1 Point Analysis

3.1.1.1 Profile Tab

For a selected transmitter, it is possible to display the signal level received from a TRX type ($P_{rec}^{Txi}(tt)$), the path loss, L_{path}^{Txi}, or the total losses, L_{total}^{Txi}. Path loss and total losses are the same for all TRX types.

If the power reduction values defined for all the subcells are the same, the received signal level from the selected transmitter will be the same for all TRX types.

3.1.1.2 Reception Tab

Analysis provided in the Reception tab is based on path loss matrices. Therefore, it is possible to display the signal levels received from TBC transmitters for which path loss matrices have been calculated over their calculation areas.

For each transmitter, **9955** can display the signal level received from a TRX type ($P_{rec}^{Txi}(tt)$), the path loss, L_{path}^{Txi}, or the total losses, L_{total}^{Txi}. Path loss and total losses are the same for all TRX types.

If the power reduction values defined for all the subcells are the same, the received signal level from the selected transmitter will be the same for all TRX types.

Reception level bars are displayed in the order of decreasing signal level. The number of displayed bars depends on the signal level received from the best server. Bars are only displayed for transmitters whose signal level is within a 30 dB margin from the best server signal level.

> You can use a value other than 30 dB for the margin from the best server signal level, for example a smaller value for improving the calculation speed. For more information on defining a different value for this margin, see the *Administrator Manual*.

3.1.2 Signal Level-based Coverage Predictions

For each TBC transmitter, Txi, **9955** calculates the selected parameter on each pixel inside the Txi calculation area. In other words, each pixel inside the Txi calculation area is considered a probe (non-interfering) receiver.

Coverage prediction parameters to be set are:

- The coverage conditions in order to determine the service area of each TBC transmitter, and
- The display settings to select the displayed parameter and its shading levels.

3.1.2.1 Service Area Determination

9955 uses parameters entered in the *Condition* tab of the coverage prediction properties dialogue to determine the areas where coverage will be displayed.

We can distinguish eight cases as below. Let us assume that:

- Each transmitter, Txi, belongs to a Hierarchical Cell Structure (HCS) layer, k, with a defined priority and a defined reception threshold.
- No max range is set.

3.1.2.1.1 All Servers

The service area of Txi corresponds to the pixels where:

$$MinimumThreshold \le P_{rec}^{Txi}(tt) < MaximumThreshold$$

> For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

3.1.2.1.2 Best Signal Level and a Margin

The service area of Txi corresponds to the pixels where:

$$MinimumThreshold \le P_{rec}^{Txi}(tt) < MaximumThreshold$$

> For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

And $P_{rec}^{Txi}(tt) \ge \underset{j \ne i}{Best}(P_{rec}^{Txj}(tt)) - M$

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.1.2.1.3 Second Best Signal Level and a Margin

The service area of Txi corresponds to the pixels where:

$$MinimumThreshold \leq P_{rec}^{Txi}(tt) < MaximumThreshold$$

> For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

And $P_{rec}^{Txi}(tt) \geq \underset{j \neq i}{2^{nd}Best}\,(P_{rec}^{Txj}(tt)) - M$

Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the second highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the second highest or within a 2 dB margin from the second highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 3rd best servers.

3.1.2.1.4 Best Signal Level per HCS Layer and a Margin

For each HCS layer, k, the service area of Txi corresponds to the pixels where:

$$MinimumThreshold \leq P_{rec}^{Txi}(tt) < MaximumThreshold$$

> For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

And $P_{rec}^{Txi}(BCCH) \geq \underset{j \neq i}{Best}\,(P_{rec}^{Txj}(BCCH)) - M$

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.1.2.1.5 Second Best Signal Level per HCS Layer and a Margin

For each HCS layer, k, the service area of Txi corresponds to the pixels where:

$$MinimumThreshold \leq P_{rec}^{Txi}(tt) < MaximumThreshold$$

> For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

And $P_{rec}^{Txi}(BCCH) \geq \underset{j \neq i}{2^{nd}Best}\,(P_{rec}^{Txj}(BCCH)) - M$

Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the second highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the second highest or within a 2 dB margin from the second highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 3rd best servers.

3.1.2.1.6 HCS Servers and a Margin

The service area of Txi corresponds to the pixels where:

$$MinimumThreshold \leq P_{rec}^{Txi}(tt) < MaximumThreshold$$

> For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

And $P_{rec}^{Txi}(BCCH) \geq \underset{j \neq i}{Best}(P_{rec}^{Txj}(BCCH)) - M$

And the received $P_{rec}^{Txi}(tt)$ exceeds the reception threshold defined per HCS layer.

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.1.2.1.7 Highest Priority HCS Server and a Margin

The service area of Txi corresponds to the pixels where:

$$MinimumThreshold \leq P_{rec}^{Txi}(tt) < MaximumThreshold$$

> For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

And $P_{rec}^{Txi}(BCCH) \geq \underset{j \neq i}{Best}(P_{rec}^{Txj}(BCCH)) - M$

And Txi belongs to the HCS layer with the highest priority. The highest priority is defined by the priority field (0: lowest).

And the received $P_{rec}^{Txi}(tt)$ exceeds the reception threshold defined per HCS layer.

> In the case two layers have the same priority, the traffic is served by the transmitter for which the difference between the received signal strength and the HCS threshold is the highest. The way the competition is managed between layers with the same priority can be modified. For more information, see the *Administrator Manual*.

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.1.2.1.8 Best Idle Mode Reselection Criterion (C2)

Such type of coverage is useful :

- To compare idle and dedicated mode best servers for voice traffic
- Display the GPRS/EDGE best server map (based on GSM idle mode)

The path loss criterion C1 used for cell selection and reselection is defined by:

$$C1 = P_{rec}^{Txi}(BCCH) - MinimumThreshold(BCCH)$$

The path loss criterion (GSM03.22) is satisfied if $C1 > 0$.

The reselection criterion C2 is used for cell reselection only and is defined by:

$$C2 = C1 + CELL\_RESELECT\_OFFSET$$

Where $CELL\_RESELECT\_OFFSET$ is the Cell Reselect Offset defined for the transmitter.

The service area of Txi corresponds to the pixels where:

$$MinimumThreshold \le P_{rec}^{Txi}(BCCH) < MaximumThreshold$$

For pure signal level-based calculations (not C/I or C/(I+N)), $P_{rec}^{Txi}(tt)$ can be replaced with L_{total}^{Txi} or L_{path}^{Txi}.

And $C2^{Txi}(BCCH) = \underset{j}{Best}(C2^{Txj}(BCCH))$

The *Best* function considers the highest value from a list of values.

On each pixel, the transmitter with the highest C2 value is kept. It corresponds to the best server in idle mode. C2 is defined as an integer in the 3GPP specifications, therefore, the C2 values in the above calculations are rounded down to the nearest integer.

3.1.2.2 Coverage Display

3.1.2.2.1 Coverage Resolution

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

3.1.2.2.2 Display Types

It is possible to display the coverage predictions with colours depending on any transmitter attribute or other criteria such as:

Signal Level (in dBm, dBµV, dBµV/m)

9955 calculates signal level received from the transmitter on each pixel of each transmitter service area. A pixel of a service area is coloured if the signal level is greater than or equal to the defined minimum thresholds (pixel colour depends on signal level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as transmitter service areas. Each layer shows the different signal levels available in the transmitter service area.

Best Signal Level (in dBm, dBµV, dBµV/m)

9955 calculates signal levels received from transmitters on each pixel of each transmitter service area. When other serviceWhen other service areas overlap the studied one, **9955** chooses the highest value. A pixel of a service area is coloured if the signal level is greater than or equal to the defined thresholds (the pixel colour depends on the signal level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the signal level from the best server exceeds a defined minimum threshold.

Path Loss (dB)

9955 calculates path loss from the transmitter on each pixel of each transmitter service area. A pixel of a service area is coloured if path loss is greater than or equal to the defined minimum thresholds (pixel colour depends on path loss). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as service areas. Each layer shows the different path loss levels in the transmitter service area.

Total Losses (dB)

9955 calculates total losses from the transmitter on each pixel of each transmitter service area. A pixel of a service area is coloured if total losses is greater than or equal to the defined minimum thresholds (pixel colour depends on total losses). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as service areas. Each layer shows the different total losses levels in the transmitter service area.

Best Server Path Loss (dB)

9955 calculates signal levels received from transmitters on each pixel of each transmitter service area. When other service areas overlap the studied one, **9955** determines the best transmitter and evaluates path loss from the best transmitter. A pixel of a service area is coloured if the path loss is greater than or equal to the defined thresholds (pixel colour depends on path loss). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the path loss from the best server exceeds a defined minimum threshold.

Best Server Total Losses (dB)

9955 calculates signal levels received from transmitters on each pixel of each transmitter service area. Where service areas overlap the studied one, **9955** determines the best transmitter and evaluates total losses from the best transmitter. A pixel of a service area is coloured if the total losses is greater than or equal to the defined thresholds (pixel colour depends on total losses). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the total losses from the best server exceed a defined minimum threshold.

Number of Servers

9955 evaluates how many service areas cover a pixel in order to determine the number of servers. The pixel colour depends on the number of servers. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the number of servers is greater than or equal to a defined minimum threshold.

Cell Edge Coverage Probability (%)

On each pixel of each transmitter service area, the coverage corresponds to the pixels where the signal level from this transmitter fulfils signal conditions defined in Conditions tab with different cell edge coverage probabilities. There is one coverage area per transmitter in the explorer.

Best Cell Edge Coverage Probability (%)

On each pixel of each transmitter service area, the coverage corresponds to the pixels where the best signal level received fulfils signal conditions defined in Conditions tab. There is one coverage area per cell edge coverage probability in the explorer.

Best C2 (dBm)

9955 calculates C2 values received from transmitters on each pixel of each transmitter service area. When other service areas overlap the studied one, **9955** chooses the highest value. A pixel of a service area is coloured if the C2 value is greater than or equal to the defined thresholds (the pixel colour depends on the C2 value). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the best C2 value exceeds a defined minimum threshold.

3.2 Interference-based Calculations

Interference-based calculations include all the calculations that involve the calculation of interference received from interfering transmitters in addition to the signal level received from the server.

3.2.1 Carrier-to-Interference Ratio Calculation

MSA (Mobile Station Allocation) Definition

A wide-ranging definition of an MSA, Mobile Station Allocation, can be that it is a list of channels and an associated MAIO. More precisely, for different frequency hopping modes, this definition can be:

- **Non-hopping (NH):** An MSA is the channel assigned to a TRX used by a mobile.

TRX index	Channel list	MAIO	MSA
1	53	-	(53,-)
2	54	-	(54,-)

- **Baseband hopping (BBH):** An MSA is the Mobile Allocation List (MAL) and the TRX index.

TRX index	Channel list	MAIO	MSA
1	53	*	([53,54,55],0)
2	54	*	([53,54,55],1)
3	55	*	([53,54,55],2)

- **Synthesised frequency hopping (SFH):** An MSA is the Mobile Allocation List (MAL) and the Mobile Allocation Index Offset (MAIO).

TRX index	Channel list	MAIO	MSA
1	53 54 55 56	2	([53,54,55,56],2)
2	53 54 55 56	3	([53,54,55,56],3)

From the point of view of a mobile station, BBH and SFH work in the same way.

Notations and Assumptions

In the following description:

- *v* is a victim transmitter,
- *MSAS(v)* is the set of MSAs (Mobile Station Allocations) associated to *v*,

  The number of *MSAS(v)* depends on TRX types to be analysed. You may study a given TRX type *tt* (there will be as many *MSA(v)* as TRXs allocated to the subcell *(v,tt)*) or all the TRX types (the number of *MSA(v)* will correspond to the number of TRXs allocated to *v*).

  Several MSAs, *m*, are related to a transmitter. Therefore, **9955** calculates the C/I $\left(\frac{C^v(m)}{I^v(m)}\right)$ for each victim transmitter *v* with MSA *m* ($m \in$ *MSAS(v)*).

  9955 considers the most interfered MSA, therefore, the displayed C/I or C/(I+N) are $\left(\frac{C}{I}\right)_v = \underset{k}{Min}\left(\frac{C^v(m)}{I^v(m)}\right)$ or $\left(\frac{C}{I+N_{tot}}\right)_v = \underset{k}{Min}\left(\frac{C^v(m)}{I^v(m)+N_{tot}}\right)$, respectively. If the Detailed Results check box is selected, the C/I values for all MSAs are displayed.

- *i* is any potential interfering transmitter (TBC transmitters whose calculation areas intersect the service area of v),
- *MSAS(i)* is the set of MSAs related to potential interferers *i*,
- *INT(v)* is the set of transmitters that interfere v,
- $C^v(m)$ is the carrier power level received from *v* on *m*,
- $I^v(m)$ corresponds to the interference received from interfering transmitters *i* on *m*,
- $M_{Shadowing}$ used in the C/I calculation is based on the C/I standard deviation.

> The C/I shadowing margin is applied on the carrier power level. The interference levels are not changed.

Calculations

The carrier power level is the power received from the victim transmitter at the receiver.

$$C^v(m) = P^v_{rec}(m)$$

If the interference conditions are based on C/(I+N), **9955** takes the total noise N_{tot} into account. The total noise is the sum of the thermal noise $N_{thermal}$ (-121 dBm by default or user-defined), the noise figure *NF*, and the inter-technology downlink noise rise $NR^{v,DL}_{inter-technology}$.

$$N_{tot} = N_{thermal} + NF + NR^{v,DL}_{inter-technology}$$

Interference can be received from interfering transmitters *i* on co-channel and adjacent channels. Interference may also be received from the transmitters of another technology.

Therefore, $I^v m = I^v_{co} m + I^v_{adj} m + I^{DL}_{inter-technology} - G^i_{PC} - G^v_{Div}$

where G^i_{PC} is the average power control gain defined for the interfering transmitter *i* and G^v_{Div} is the diversity gain defined for the considered subcell.

Each interference component is explained below.

Co- and Adjacent Channel Interference:

$I^v_{co}(m)$ is the interference received at *v* on *m* on co-channel, given by:

$$I^v_{co}(m) = \sum_{i \in INT(v)} \left(\sum_{n \in MSAS(i)} p^{v,i}_{m,n} \times P^i_{rec}(n) \times T_i(n) \right)_{co}$$

$I^v_{adj}(m)$ is the interference received at *v* on *m* on adjacent channels, given by:

$$I^v_{adj}(m) = \sum_{i \in INT(v)} \left(\sum_{n \in MSAS(i)} p^{v,i}_{m,n} \times \frac{P^i_{rec}(n)}{F} \times T_i(n) \right)_{adj}$$

Here, $P^i_{rec}(n)$ is the carrier power level received from *i* on *n*.

$T_i(n)$ is occupancy of the MSA *n*:

$$T_i(n) = L^i_{traffic}(n) \times f^i_{act}(n)$$

$L^i_{traffic}(n)$ is the traffic load defined for the MSA *n* or *i*. It can be set to 100% in the coverage prediction properties.

$f^i_{act}(n)$ is the activity factor defined for the MSA *n* of *i*. If the subcell *(i,tt)* supports DTX, the value specified in the coverage prediction properties is used. Otherwise, the activity factor is 1.

> BCCH TRXs are always on. Therefore, DTX and traffic loads do not impact the interference from BCCH. In other words, $f^i_{act}(n) = 1$ and $L^i_{traffic}(n) = 1$ for the BCCH TRXs of the interferers.

$p^{v,i}_{m,n}$ is the probability of having a co- or adjacent channel collision between MSAs *n* and *m*, depending on the used frequency hopping mode.

- **Collision Probability for Non Hopping Mode:**

  $p^{v,i}_{m,n} = 1$

- **Collision Probability for BBH and SFH Modes:**

  MSA *m* of *v* can be defined as the pair ([f_1,f_2,….f_n], MAIO) and MSA *n* of *i* as the pair ([f'_1,f'_2,….f'_n], MAIO’) (where f and f’ are channels).

  An occurence $OCCUR(f^v_m, f^i_n)$ refers to the event when a channel *f* of *m* encounters a channel *f’* of *n* during hopping. A collision occurs when *f* and *f’* are co- or adjacent channels:

  $Collision = OCCUR(f^v_m, f^i_n)$ such that $\left|f^v_m - f^i_n\right| = 0 \text{ or } 1$

  The probability of collision is the ratio of the number of collisions to the number of occurences:

  $$p^{v,i}_{m,n} = \frac{n_{collision}}{n_{occurence}}$$

  The probility of collision depends on the correlation between *m* and *n*. There can be two cases:

  i. MSAs *m* and *n* are correlated

  m and *n* must have identical HSN and synchronisation. The number of occurrences depends on the MAL size, MAIO, and MAIO’.

  Example:

	Schematic view of hopping sequences
MSA *m* of *v* ([34 37 39], MAIO=0)	**34** *37* 39
MSA *n* of *i* ([38 36 34], MAIO'=2)	*38* 36 **34**

Here, the number of occurrences is 3, the number of co-channel collisions is 1, and the number of adjacent channel collisions is 1. Therefore,

$$(p_{m,n}^{v,i})_{co} = \frac{1}{3} \text{ and } (p_{m,n}^{v,i})_{adj} = \frac{1}{3}$$

ii. MSAs *m* and *n* are not correlated

m and *n* do not have identical HSN and synchronisation. The probability of collision is the same for all the channels.

Example:

	Schematic view of hopping sequences
MSA *m* of *v* ([34 37 39], MAIO=0)	34 37 39
MSA *n* of *i* ([38 36 34], MAIO'=2)	38 36 34

Here, the number of occurrences is 9, the number of co-channel collisions is 1, and the number of adjacent channel collisions is 3. Therefore,

$$(p_{m,n}^{v,i})_{co} = \frac{1}{9} \text{ and } (p_{m,n}^{v,i})_{adj} = \frac{1}{3}$$

Diversity gain:

G_{Div}^{v} is the diversity gain defined for the victim subcell.

Two types of diversity modes can be defined. In Tx Diversity, the signal is transmitted as many times that there are antennas. In, the signal is successively transmitted on the various antennas.

For Tx Diversity mode, the diversity gain is defined as:

$$G_{Div}^{v} = 3dB + G_{clutter}^{Tx\_Div}$$

where $G_{clutter}^{Tx\_Div}$ is the additional transmit diversity gain defined for the clutter class on which is located *m*.

For Antenna Hopping mode, the diversity gain is defined as:

$$G_{Div}^{v} = G_{clutter}^{Ant\_Div}$$

where $G_{clutter}^{Ant\_Div}$ is the antenna hopping gain defined for the clutter class on which is located *m*.

Inter-technology Downlink Interference:

$I_{inter-technology}^{DL}$ is the total inter-technology interference level on *m* due to transmitters in a linked **9955** document.

The interference from a transmitter Tx in a linked **9955** document is given as:

$$I_{inter-technology}^{DL} = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i,f}^{Tx}}$$

Where ic_i is the i^{th} frequency used by the transmitter Tx within its list of frequencies, $P_{Transmitted}^{Tx}(ic_i)$ is the total transmitted Tx power on ic_i, L_{total}^{Tx} are the total losses between the transmitter Tx and the receiver, and $ICP_{ic_i,f}^{Tx}$ is the inter-technology channel protection between the frequencies used by the transmitter Tx and the victim transmitter *v*.

- In case of frequency hopping, the ICP value is weighted according to the fractional load.
- In the ICP, the frequency gap is based on the defined base frequency for each technology (e.g., 935 MHz in GSM 900)

3.2.2 Point Analysis

Analysis provided in the Interference tab is based on path loss matrices. Therefore, it is possible to display the interference levels received from TBC transmitters for which path loss matrices have been calculated over their calculation areas.

9955 displays the following at the receiver:

- The carrier power level received from the victim transmitter *v* on the most interfered MAS *m*,
- Co-channel, adjacent channel, or both co- and adjacent channel interference received from interfering transmitters *i* on MAS *m* (for further information about noise calculation, please refer to Signal to noise calculation: noise calculation part),

Interferers are sorted in the order of descending carrier power levels.

- Neither DTX nor traffic load of TRXs are taken into account to evaluate interference levels. Therefore, we have $T_i(n) = L^i_{traffic}(n) \times f^i_{act}(n) = 1$.
- The C/I shadowing margin is applied on the carrier power level. The interference levels are not changed.

3.2.3 Interference-based Coverage Predictions

Two interference-based coverage predictions are available:

- Coverage by C/I Level: Provides a global analysis of the network quality.

  9955 calculates the C/I on each pixel within the service area of studied transmitters, determines the pixels where the calculated C/I exceeds the defined minimum threshold, and colours these pixels depending on C/I value.

- Interfered Zones: Shows the areas where a transmitter is interfered.

  9955 calculates the C/I on each pixel within the service area of studied transmitters, determines the pixels where the calculated C/I is lower than the defined maximum threshold, and colours these pixels depending on colour of the interfered transmitter.

For each TBC transmitter, Txi, **9955** calculates the selected parameter on each pixel inside the Txi calculation area. In other words, each pixel inside the Txi calculation area is considered a probe (non-interfering) receiver.

Coverage prediction parameters to be set are:

- The coverage conditions in order to determine the service area of each TBC transmitter,
- The interference conditions to meet for a pixel to be covered, and
- The display settings to select the displayed parameter and its shading levels.

The thermal noise (N = -121 dBm, by default) is used in the calculations if the coverage prediction is based on C/(I+N). This value can be modified by the user.

3.2.3.1 Service Area Determination

9955 uses parameters entered in the *Condition* tab of the coverage prediction properties dialogue to determine the areas where coverage will be displayed. Service areas are determined in the same manner as for signal level-based coverage predictions. See "Service Area Determination" on page 110 for more information.

3.2.3.2 Coverage Area Determination

For each victim transmitter *v*, coverage area corresponds to pixels where $\left(\frac{C}{I}\right)_v$ or $\left(\frac{C}{I+N}\right)_v$ is between the lower and upper thresholds defined in the coverage prediction properties.

The two options defining the thresholds are explained below.

3.2.3.2.1 Interference Condition Satisfied by At Least One TRX

In this case, the coverage area of a transmitter Txi corresponds to the pixels where:

$$Minimum\ \ threshold \leq \left(\frac{C}{I}\right)_v\Big|_{TRX_j} < Maximum\ threshold\ \text{ or }\ Minimum\ \ threshold \leq \left(\frac{C}{I+N}\right)_v\Big|_{TRX_j} < Maximum\ threshold$$

Where, TRX_j is any TRX belonging to Txi.

3.2.3.2.2 Interference Condition Satisfied by The Worst TRX

In this case, the coverage area of a transmitter Txi corresponds to the pixels where:

$$Minimum\ \ threshold \leq \left(\frac{C}{I}\right)_v\Big|_{TRX_j} < Maximum\ threshold\ \text{ or }\ Minimum\ \ threshold \leq \left(\frac{C}{I+N}\right)_v\Big|_{TRX_j} < Maximum\ threshold$$

Where, TRX_j is the TRX (belonging to Txi) with the worst C/I or C/(I+N) at the pixel.

3.2.3.3 Coverage Display

3.2.3.3.1 Coverage Resolution

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

3.2.3.3.2 Display Types

It is possible to display the coverage predictions with colours depending on any transmitter attribute or other criteria such as:

C/I Level

Each pixel of the transmitter coverage area is coloured if the calculated C/I (or C/(I+N)) level is greater than or equal to the specified minimum thresholds (pixel colour depends on C/I (or C/(I+N)) level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as transmitter coverage areas. Each layer shows the different C/I levels available in the transmitter coverage area.

Max C/I Level

9955 compares calculated C/I (or C/(I+N)) levels received from transmitters on each pixel of each transmitter coverage area where coverage areas overlap the studied one and chooses the highest value. A pixel of a coverage area is coloured if the C/I (or C/(I+N)) level is greater than or equal to the specified thresholds (the pixel colour depends on the C/I (or C/(I+N)) level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the highest received C/I level exceeds a defined minimum threshold.

Min C/I Level

9955 compares C/I (or C/(I+N)) levels received from transmitters on each pixel of each transmitter coverage area where the coverage areas overlap the studied one and chooses the lowest value. A pixel of a coverage area is coloured if the C/I (or C/(I+N)) level is greater than or equal to the specified thresholds (the pixel colour depends on the C/I (or C/(I+N)) level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the lowest received C/I level exceeds a defined minimum threshold.

3.3 GPRS/EDGE Calculations

GPRS/EDGE calculations include coding scheme selection and throughput calculation. Coding schemes may be selected using ideal link adaptation or without it. Once coding schemes have been selected, throughputs corresponding to these coding schemes are readily determined from the look-up tables.

The following sections describe the two categories of calculations, i.e., with and without ideal link adaptations. Ideal link adaptation implies that the selected coding scheme corresponds to the highest available throughput under the given radio conditions.

GPRS/EDGE calculations may be based on signal levels (C) alone, on C/I, or on C/(I+N). For calculating the noise, either the noise figure defined for the calculations or that of the selected terminal type is used.

Different GPRS/EDGE configurations may be defined for transmitter and terminals. In this case, **9955** only selects the coding schemes that are common in the two. If no terminal type is defined for the calculation, or if the terminal type does not have any GPRS/EDGE configuration assigned to it, **9955** only uses the GPRS/EDGE configuration of the transmitter. Similarly, if a transmitter does not have any GPRS/EDGE configuration assigned to it, **9955** only uses the GPRS/EDGE configuration of the terminal type. If both the transmitter and the terminal type do not have any GPRS/EDGE configuration assigned to them, no coding scheme selection and throughput calculation is carried out.

In the following calculations, we assume that:

- $P^{Txi}_{rec}(TRX)$ is the signal level received from the selected TRX type (*tt*) or on all the TRXs of Txi on each pixel of the Txi coverage area,
- $P^{Txi}_{Backoff}(TRX)$ is the Power Backoff defined for the subcell for 8PSK, 16QAM, or 32QAM modulations,
- *CS* is the set of all available coding schemes,
- $(Reception\ Threshold)_{CS}$ are the values of reception thresholds for the coding schemes available in the GPRS/EDGE configuration,
- $\left(\frac{C}{I}\ Threshold\right)_{CS}$ are the values of C/I thresholds for the coding schemes available in the GPRS/EDGE configuration,
- $\left(\frac{C}{I+N}\ Threshold\right)_{CS}$ are the values of C/(I+N) thresholds for the coding schemes available in the GPRS/EDGE configuration,
- The priorities of the coding scheme lists are as follows: DBS > DAS > MCS > CS.

When the calculations are based on C/I and C/(I+N):

- **9955** calculates the carrier-to-interference ratio for all the GPRS/EDGE TBC transmitters but takes into account all the TBC transmitters (GSM and GPRS/EDGE) to evaluate the interference.
- The reception thresholds given for signal level C are internally converted to C/N thresholds (where N is the thermal noise defined in the document database at -121 dBm by default) in order to be indexed by C/(I+N) values. C/I thresholds are also indexed by the C/(I+N) value.

> The selection of coding schemes is mainly based on the radio conditions mentionned above. Nevertheless, you can optionally define some specific coding scheme graphs accoding to a specific hopping mode, mobility type, frequency band and MAL. As an example, you can model the gain due to longer MALs in coding scheme selection.

For more information on interference (*I*) calculation, see "Carrier-to-Interference Ratio Calculation" on page 114.

3.3.1 Coding Scheme Selection and Throughput Calculation Without Ideal Link Adaptation

3.3.1.1 Calculations Based on C

Coding Scheme Selection

9955 selects a coding scheme, *cs*, from among the coding schemes available in the GPRS/EDGE configuration, such that:

For each TRX type, *tt*, $cs = Lowest\left(CS\Big|_{P^{Txi}_{rec}(TRX) - P^{Txi}_{Backoff}(TRX) > (Reception\ Threshold)_{CS}}\right)$

The selected coding scheme, *cs*, is the coding scheme with the lowest coding scheme number from the lowest priority coding scheme list.

Throughput Calculation

Once the coding scheme *cs* is selected, **9955** reads the corresponding throughput value for the received signal level from the Throughput=f(C) graph associated with *cs*.

3.3.1.2 Calculations Based on C/I

Coding Scheme Selection

9955 selects two coding schemes from among the coding schemes available in the GPRS/EDGE configuration, such that:

For each TRX type, *tt*, $cs_C = Lowest\left(CS\Big|_{P^{Txi}_{rec}(TRX) - P^{Txi}_{Backoff}(TRX) > (Reception\ Threshold)_{CS}}\right)$

And, $cs_{C/I} = Lowest\left(CS \middle| \frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I} > \left(\frac{C}{I}\ Threshold\right)_{CS} \right)$

cs_C is the coding scheme determined from the signal level, and $cs_{C/I}$ is the coding scheme determined from the C/I level. Both coding schemes are the coding schemes with the lowest coding scheme number from the lowest priority coding scheme list.

The selected coding scheme, *cs*, is the coding scheme with the lower coding scheme number among cs_C and $cs_{C/I}$: $cs = Min(cs_C, cs_{C/I})$.

Throughput Calculation Based on the Worst Case Between C and C/I

For the coding scheme cs_C determined above, a throughput value, TP_C, corresponding to the signal level is determined from the TP = f(C) graph.

For the coding scheme $cs_{C/I}$ determined above, a throughput value, $TP_{C/I}$, corresponding to the C/I is determined from the TP = f(C/I) graph.

The resulting throughput *TP* is the lower of the two values, TP_C and $TP_{C/I}$: $TP = Min(TP_C, TP_{C/I})$.

3.3.1.3 Calculations Based on C/(I+N)

Coding Scheme Selection

9955 selects two coding schemes from among the coding schemes available in the GPRS/EDGE configuration, such that:

For each TRX type, *tt*, $cs_{C/N} = Lowest\left(CS \middle| \frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{N} > \left(\frac{C}{I+N}\ Threshold\right)_{CS} \right)$

And, $cs_{C/(I+N)} = Lowest\left(CS \middle| \frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I+N} > \left(\frac{C}{I+N}\ Threshold\right)_{CS} \right)$

$cs_{C/N}$ is the coding scheme determined from the C/N, and $cs_{C/(I+N)}$ is the coding scheme determined from the C/(I+N) level. Both coding schemes are the coding schemes with the lowest coding scheme numbers from the lowest priority coding scheme list.

The selected coding scheme, *cs*, is the coding scheme with the higher coding scheme number among $cs_{C/N}$ and $cs_{C/(I+N)}$: $cs = Max(cs_{C/N}, cs_{C/(I+N)})$.

Throughput Calculation Based on Interpolation Between C/N and C/(I+N)

For the coding scheme $cs_{C/N}$ determined above, the TP = f(C) graph is internally converted to TP = f(C/N) graph. A throughput value, $TP_{C/N}$, corresponding to the C/(I+N) is determined from the TP = f(C/N) graph.

For the coding scheme $cs_{C/(I+N)}$ determined above, the TP = f(C/I) graph is internally converted to TP = f(C/(I+N)) graph. A throughput value, $TP_{C/(I+N)}$, corresponding to the C/(I+N) is determined from the TP = f(C/(I+N)) graph.

The final throughput is computed by interpolating between the throughput values obtained from these two graphs. The throughput interpolation method consists in interpolating $TP_{C/N}$ and $TP_{C/(I+N)}$ according to the respective weights of I and N values.

The resulting throughput *TP* is given by: $TP = \alpha \times TP_{C/N} + (1 - \alpha) \times TP_{C/(I+N)}$

Where $\alpha = \frac{pN}{p(I+N)}$, *pN* is the thermal noise power (value in Watts), and *p(I+N)* is the interferences + thermal noise power (value in Watts).

3.3.2 Coding Scheme Selection and Throughput Calculation With Ideal Link Adaptation

3.3.2.1 Calculations Based on C

Throughput Calculation

For the received signal level, and coding schemes whose reception thresholds are lower than the received signal level, **9955** determines the highest throughput from the $TP = f(C)$ graphs available in the GPRS/EDGE configuration.

$$TP_C = Highest(TP = f(C = P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX))) \quad \forall \left(CS \Big|_{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX) > (Reception\ Threshold)_{CS}} \right)$$

Coding Scheme Selection

The selected coding scheme, *cs*, is the one corresponding to the highest throughput calculated above.

If there are more than one coding schemes providing the highest throughput at the pixel, the selected coding scheme, *cs*, is the one with the lowest coding scheme number from the lowest priority coding scheme list.

3.3.2.2 Calculations Based on C/I

Throughput Calculation Based on Worst Case Between C and C/I

For the received signal level, and coding schemes whose reception thresholds are lower than the received signal level, **9955** determines the highest throughput from the $TP = f(C)$ graphs available in the GPRS/EDGE configuration.

$$TP_C = Highest(TP = f(C = P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX))) \quad \forall \left(CS \Big|_{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX) > (Reception\ Threshold)_{CS}} \right)$$

For the received C/I, and coding schemes whose C/I thresholds are lower than the received C/I, **9955** determines the highest throughput from the $TP = f(C/I)$ graphs available in the GPRS/EDGE configuration.

$$TP_{C/I} = Highest\left(TP = f\left(C/I = \frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I}\right)\right) \quad \forall \left(CS \Big|_{\frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I} > \left(\frac{C}{I}\ Threshold\right)_{CS}} \right)$$

The resulting throughput *TP* is the lower of the two values, TP_C and $TP_{C/I}$.

$$TP = Min(TP_C, TP_{C/I})$$

Coding Scheme Selection

The selected coding scheme, *cs*, is the one corresponding to the lower of the two highest throughputs calculated above.

If there are more than one coding schemes providing the highest throughputs at the pixel, the selected coding scheme, *cs*, is the one with the lowest coding scheme number from the lowest priority coding scheme list.

3.3.2.3 Calculations Based on C/(I+N)

Throughput Calculation Based on Interpolation Between C/N and C/(I+N)

9955 internally converts the TP = f(C) graphs into TP = f(C/N) graphs. For the received C/(I+N), and coding schemes whose C/(I+N) thresholds are lower than the received C/(I+N), **9955** determines the highest throughput from the TP = f(C/N) graphs available in the GPRS/EDGE configuration.

$$TP_{C/N} = Highest\left(TP = f\left(\frac{C}{N} = \frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I + N}\right)\right) \quad \forall \left(CS \Big|_{\frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I + N} > \left(\frac{C}{I + N}\ Threshold\right)_{CS}} \right)$$

9955 internally converts the TP = f(C/I) graphs into TP = f(C/(I+N)) graphs. For the received C/(I+N), and coding schemes whose C/(I+N) thresholds are lower than the received C/(I+N), **9955** determines the highest throughput from the TP = f(C/(I+N)) graphs available in the GPRS/EDGE configuration.

$$TP_{C/(I+N)} = Highest\left(TP = f\left(\frac{C}{I+N} = \frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I+N}\right)\right) \quad \forall\left(CS\Big|_{\frac{P_{rec}^{Txi}(TRX) - P_{Backoff}^{Txi}(TRX)}{I+N} > \left(\frac{C}{I+N}\ Threshold\right)_{CS}}\right)$$

The final throughput is computed by interpolating between the throughput values obtained from these two graphs. The throughput interpolation method consists in interpolating $TP_{C/N}$ and $TP_{C/(I+N)}$ according to the respective weights of I and N values.

The resulting throughput *TP* is given by: $TP = \alpha \times TP_{C/N} + (1-\alpha) \times TP_{C/(I+N)}$

Where $\alpha = \frac{pN}{p(I+N)}$, *pN* is the thermal noise power (value in Watts), and *p(I+N)* is the interferences + thermal noise power (value in Watts).

Coding Scheme Selection

The selected coding scheme, *cs*, is the one corresponding to the higher of the two highest throughputs calculated above.

If there are more than one coding schemes providing the highest throughputs at the pixel, the selected coding scheme, *cs*, is the one with the highest coding scheme number from the highest priority coding scheme list.

3.3.3 Application Throughput Calculation

Application throughput is calculated from the RLC/MAC throughput as follows:

$$TP_{Application} = TP_{RLC/MAC} \times \frac{SF}{100} - TP_{Offset}$$

Where $TP_{RLC/MAC}$ is the RLC/MAC throughput, and TP_{Offset} and SF are the throughput offset (kbps) and the throughput scaling factor (%) defined for the selected service.

3.3.4 BLER Calculation

Block error rate is calculated as follows:

$$BLER = \begin{cases} \frac{TP}{TP_{MAX}} & If(TP \le TP_{MAX}) \\ 0 & If(TP > TP_{MAX}) \end{cases}$$

Where *TP* is the throughput per timeslot calculated for a pixel and TP_{MAX} is the maximum throughput per timeslot read from the GPRS/EDGE configuration used for the calculations.

3.3.5 GPRS/EDGE Coverage Predictions

Two GPRS/EDGE coverage predictions are available:

- Coverage by GPRS/EDGE Coding Scheme: Shows the areas where various coding schemes are available.
- Packet Throughput and Quality Analysis: Shows the throughputs corresponding to the coding schemes available.

For each TBC transmitter, Txi, **9955** calculates the selected parameter on each pixel inside the Txi calculation area. In other words, each pixel inside the Txi calculation area is considered a probe (non-interfering) receiver.

Coverage prediction parameters to be set are:

- The coverage conditions in order to determine the service area of each TBC transmitter,
- The interference conditions to meet for a pixel to be covered, and
- The display settings to select the displayed parameter and its shading levels.

The thermal noise (N = -121 dBm, by default) is used in the calculations if the coverage prediction is based on C/(I+N). This value can be modified by the user.

3.3.5.1 Service Area Determination

9955 uses parameters entered in the *Condition* tab of the coverage prediction properties dialogue to determine the areas where coverage will be displayed.

We can distinguish eight cases as below. Let us assume that:

- Each transmitter, Txi, belongs to a Hierarchical Cell Structure (HCS) layer, k, with a defined priority and a defined reception threshold.
- Each transmitter, Txi, is GPRS/EDGE-capable.
- No max range is set.

3.3.5.1.1 All Servers

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(tt)$$

3.3.5.1.2 Best Signal Level and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(tt)$$

And $P_{rec}^{Txi}(tt) \ge \underset{j \ne i}{Best}(P_{rec}^{Txj}(tt)) - M$

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.3.5.1.3 Second Best Signal Level and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(tt)$$

And $P_{rec}^{Txi}(tt) \ge \underset{j \ne i}{2^{nd}Best}(P_{rec}^{Txj}(tt)) - M$

Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the second highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the second highest or within a 2 dB margin from the second highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 3rd best servers.

3.3.5.1.4 Best Signal Level per HCS Layer and a Margin

For each HCS layer, k, the service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(tt)$$

And $P_{rec}^{Txi}(BCCH) \ge \underset{j \ne i}{Best}(P_{rec}^{Txj}(BCCH)) - M$

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.3.5.1.5 Second Best Signal Level per HCS Layer and a Margin

For each HCS layer, k, the service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(tt)$$

And $P_{rec}^{Txi}(BCCH) \geq \underset{j \neq i}{2^{nd}Best}\left(P_{rec}^{Txj}(BCCH)\right) - M$

Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the second highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the second highest or within a 2 dB margin from the second highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 3rd best servers.

3.3.5.1.6 HCS Servers and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \leq P_{rec}^{Txi}(tt)$$

And $P_{rec}^{Txi}(BCCH) \geq \underset{j \neq i}{Best}\left(P_{rec}^{Txj}(BCCH)\right) - M$

And the received $P_{rec}^{Txi}(tt)$ exceeds the reception threshold defined per HCS layer.

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.3.5.1.7 Highest Priority HCS Server and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \leq P_{rec}^{Txi}(tt)$$

And $P_{rec}^{Txi}(BCCH) \geq \underset{j \neq i}{Best}\left(P_{rec}^{Txj}(BCCH)\right) - M$

And Txi belongs to the HCS layer with the highest priority. The highest priority is defined by the priority field (0: lowest).

And the received $P_{rec}^{Txi}(tt)$ exceeds the reception threshold defined per HCS layer.

> In the case two layers have the same priority, the traffic is served by the transmitter for which the difference between the received signal strength and the HCS threshold is the highest. The way the competition is managed between layers with the same priority can be modified. For more information, see the *Administrator Manual*.

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.3.5.1.8 Best Idle Mode Reselection Criterion (C2)

Such type of coverage is useful:

- To compare idle and dedicated mode best servers for voice traffic
- Display the GPRS/EDGE best server map (based on GSM idle mode)

The path loss criterion C1 used for cell selection and reselection is defined by:

$$C1 = P_{rec}^{Txi}(BCCH) - MinimumThreshold(BCCH)$$

The path loss criterion (GSM03.22) is satisfied if $C1 > 0$.

The reselection criterion C2 is used for cell reselection only and is defined by:

$$C2 = C1 + CELL\_RESELECT\_OFFSET$$

Where $CELL\_RESELECT\_OFFSET$ is the Cell Reselect Offset defined for the transmitter.

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \leq P_{rec}^{Txi}(BCCH)$$

And $C2^{Txi}(BCCH) = \underset{j}{Best}\,(C2^{Txj}(BCCH))$

The *Best* function considers the highest value from a list of values.

On each pixel, the transmitter with the highest C2 value is kept. It corresponds to the best server in idle mode. C2 is defined as an integer in the 3GPP specifications, therefore, the C2 values in the above calculations are rounded down to the nearest integer.

3.3.5.2 Coverage Display

3.3.5.2.1 Coverage Resolution

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

3.3.5.2.2 Display Types

It is possible to display the coverage predictions with colours depending on criteria such as:

Coverage by GPRS/EDGE Coding Scheme: Coding Schemes

Only the pixels with a coding scheme assigned are coloured. The pixel colour depends on the assigned coding scheme. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas. Each layer shows the coding schemes available in the transmitter coverage area.

Coverage by GPRS/EDGE Coding Scheme: Best Coding Schemes

On each pixel, **9955** chooses the highest coding scheme available from the TRXs of different transmitters covering that pixel. Only the pixels with a coding scheme assigned are coloured. The pixel colour depends on the assigned coding scheme. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as possible coding schemes. Each layer shows the areas where a given coding scheme can be used.

Packet Throughput and Quality Analysis: RLC/MAC Throughput/Timeslot (kbps)

A pixel of the coverage area is coloured if the calculated RLC/MAC throughput per timeslot from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the RLC/MAC throughput per timeslot. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and throughput display thresholds. Each layer shows the RLC/MAC throughput that a transmitter can provide on one timeslot.

Packet Throughput and Quality Analysis: Best RLC/MAC Throughput/Timeslot (kbps)

A pixel of the coverage area is coloured if the calculated highest RLC/MAC throughput per timeslot from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the highest RLC/MAC throughput per timeslot. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the best RLC/MAC throughput that any transmitter can provide on one timeslot.

Packet Throughput and Quality Analysis: Average RLC/MAC Throughput/Timeslot (kbps)

A pixel of the coverage area is coloured if the calculated average RLC/MAC throughput per timeslot from all the transmitters covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the average RLC/MAC throughput per timeslot. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the average RLC/MAC throughput that all the transmitters can provide on one timeslot.

Packet Throughput and Quality Analysis: Application Throughput/Timeslot (kbps)

A pixel of the coverage area is coloured if the calculated application throughput per timeslot from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the application throughput per timeslot. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and throughput display thresholds. Each layer shows the application throughput that a transmitter can provide on one timeslot.

Packet Throughput and Quality Analysis: Best Application Throughput/Timeslot (kbps)

A pixel of the coverage area is coloured if the calculated highest application throughput per timeslot from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the highest application throughput per timeslot. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the best application throughput that any transmitter can provide on one timeslot.

Packet Throughput and Quality Analysis: Average Application Throughput/Timeslot (kbps)

A pixel of the coverage area is coloured if the calculated average application throughput per timeslot from all the transmitters covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the average application throughput per timeslot. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the average application throughput that all the transmitters can provide on one timeslot.

Packet Throughput and Quality Analysis: Max Application Throughput (kbps)

A pixel of the coverage area is coloured if the calculated application throughput from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the application throughput for all the timeslots supported by the selected terminal type (Number of Simultaneous Carriers x Number of DL Timeslots). The number of DL timeslots is the minimum between the number of DL timeslots defined in the selected terminal and service. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and throughput display thresholds. Each layer shows the application throughput that a transmitter can provide on all available timeslots in the terminal.

Packet Throughput and Quality Analysis: Best Max Application Throughput (kbps)

A pixel of the coverage area is coloured if the calculated highest application throughput from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the highest application throughput for all the timeslots supported by the selected terminal type (Number of Simultaneous Carriers x Number of DL Timeslots). The number of DL timeslots is the minimum between the number of DL timeslots defined in the selected terminal and service. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the highest application throughput that any transmitter can provide on all available timeslots in the terminal.

Packet Throughput and Quality Analysis: Average Max Application Throughput (kbps)

A pixel of the coverage area is coloured if the calculated average application throughput from all the transmitters covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the average application throughput for all the timeslots supported by the selected terminal type (Number of Simultaneous Carriers x Number of DL Timeslots). The number of DL timeslots is the minimum between the number of DL timeslots defined in the selected terminal and service. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the average application throughput that all the transmitters can provide on all available timeslots in the terminal.

Packet Throughput and Quality Analysis: User Throughput (kbps)

A pixel of the coverage area is coloured if the calculated user throughput from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the user throughput for all the timeslots supported by the selected terminal type (Number of Simultaneous Carriers x Number of DL Timeslots). The number of DL timeslots is the minimum between the number of DL timeslots defined in the selected terminal and service. The user throughput is calculated by applying the throughput reduction factor, determined using the selected dimensioning model, to the application throughput. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and throughput display thresholds. Each layer shows the user throughput that a transmitter can provide on all available timeslots in the terminal.

Packet Throughput and Quality Analysis: Max User Throughput (kbps)

A pixel of the coverage area is coloured if the calculated highest user throughput from any transmitter covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the highest user throughput for all the timeslots supported by the selected terminal type (Number of Simultaneous Carriers x Number of DL Timeslots). The number of DL timeslots is the minimum between the number of DL timeslots defined in the selected terminal and service. The user throughput is calculated by applying the throughput reduction factor, determined using the selected dimensioning model, to the application throughput. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the highest user throughput that any transmitter can provide on all available timeslots in the terminal.

Packet Throughput and Quality Analysis: Average User Throughput (kbps)

A pixel of the coverage area is coloured if the calculated average user throughput from all the transmitters covering that pixel exceeds the defined minimum threshold. The pixel colour depends on the average user throughput for all the timeslots supported by the selected terminal type (Number of Simultaneous Carriers x Number of DL Timeslots). The number of DL timeslots is the minimum between the number of DL timeslots defined in the selected terminal and service. The user throughput is calculated by applying the throughput reduction factor, determined using the selected dimensioning model, to the application throughput. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as throughput display thresholds. Each layer shows the average user throughput that all the transmitters can provide on all available timeslots in the terminal.

Packet Throughput and Quality Analysis: BLER (%)

A pixel of the coverage area is coloured if the calculated BLER from any transmitter exceeds the defined minimum threshold. The pixel colour depends on the BLER. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and BLER display thresholds. Each layer shows the BLERs that the covered pixels experience on one timeslot.

Packet Throughput and Quality Analysis: Max BLER (%)

A pixel of the coverage area is coloured if the calculated highest BLER from all the transmitters exceeds the defined minimum threshold. The pixel colour depends on the BLER. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as BLER display thresholds. Each layer shows the BLER that the covered pixels experience on one timeslot.

3.4 Codec Mode Selection and CQI Calculations

9955 supports FR, HR, EFR, and AMR codec modes. A codec configuration contains codec mode adaptation thresholds and quality graphs for circuit quality indicators. **9955** has the following circuit quality indicators included by default:

- **FER or Frame Erasure Rate:** The number of frames in error divided by the total number of frames. These frames are usually discarded, in which case this can be called the Frame Erasure Rate.
- **BER or Bit Error Rate:** BER is a measurement of the raw bit error rate in reception before the decoding process begins. Any factor that impacts the decoding performance, such as frequency hopping, will impact the correlation between BER and FER, or the perceived end-user voice quality.
- **MOS or Mean Opinion Score:** Voice quality can be quantified using mean opinion score (MOS). MOS values can only be measured in a test laboratory environment. MOS values range from 1 (bad) to 5 (excellent). Different voice codecs have slightly different FER to MOS correlation since the smaller the voice codec bit rate is, the more sensitive it becomes to frame erasures.

The default codec configurations in **9955** include default FER, BER, and MOS quality graphs with respect to the carrier to interference ratio, and codec mode adaptation thresholds (calculated from the FER vs. C/I graphs for all codec modes at 5 % FER).

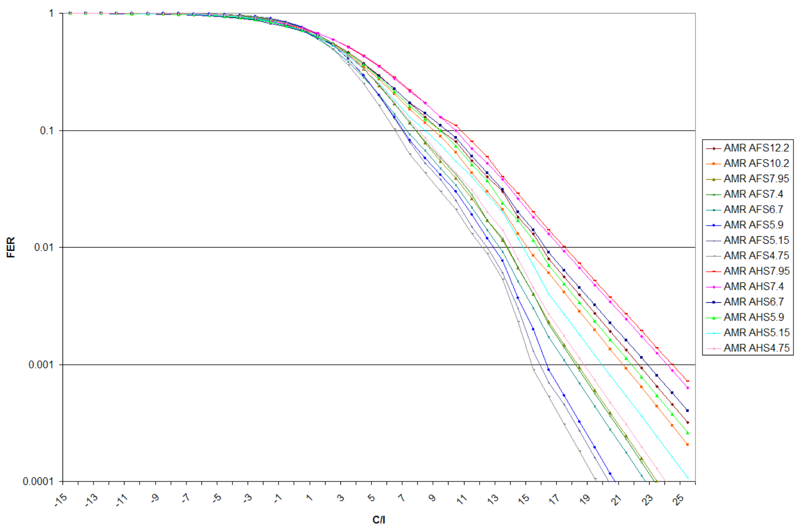


Figure 3.1: FER vs. C/I Graphs

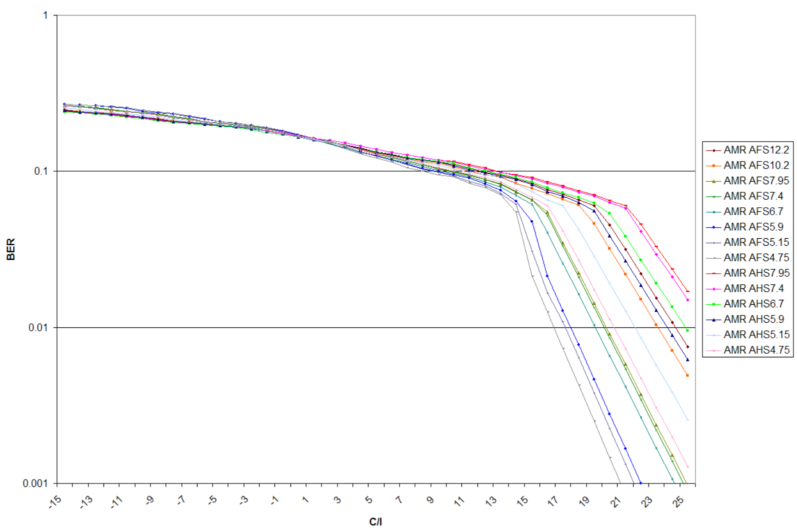


Figure 3.2: BER vs. C/I Graphs

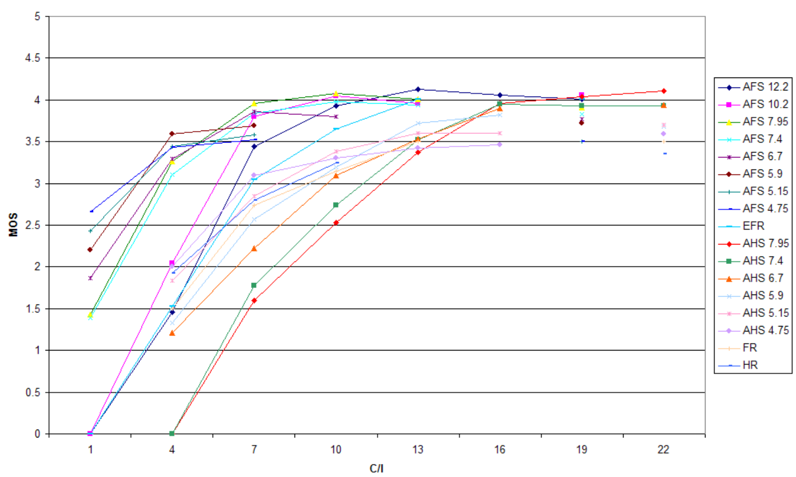


Figure 3.3: MOS vs. C/I Graphs

The graphs are based on:

[1] T. Halonen, J. Romero, J. Melero; GSM, GPRS and EDGE performance – Evolution towards 3G/UMTS, John Wiley and Sons Ltd.

[2] J. Wigard, P. Mogensen; A simple mapping from C/I to FER and BER for a GSM type of air interface.

[3] 3GPP Specifications TR 26.975 V6.0.0; Performance characterization of the Adaptive Multi-Rate (AMR) speech codec (Release 6)

3.4.1 Circuit Quality Indicator Calculations

Circuit quality indicator calculations include codec mode selection and CQI calculation. Codec modes may be selected using ideal link adaptation or without it. Once codec modes have been selected, CQI corresponding to these codec modes are determined from the look-up tables.

The following sections describe the two categories of calculations, i.e., with and without ideal link adaptations. Ideal link adaptation implies that the selected codec mode corresponds to the best value of the reference CQI under the given radio conditions. Without ideal link adaptation, the codec mode is selected based on the codec adaptation thresholds.

CQI calculations may be based on C/N or on C/(I+N). For calculating the noise, either the noise figure defined for the calculations or that of the selected terminal type is used.

Different codec configurations may be defined for transmitter and terminals. In this case, **9955** only selects the codec modes that are common in the two. If no terminal type is defined for the calculation, or if the terminal type does not have any codec configuration assigned to it, **9955** only uses the codec configuration of the transmitter. Similarly, if a transmitter does not have any codec configuration assigned to it, **9955** only uses the codec configuration of the terminal type. If both the transmitter and the terminal type do not have any codec configuration assigned to them, no codec mode selection and CQI calculation is carried out.

If more than one codec modes satisfy the C/N or C/I conditions, **9955** selects the higher priority codec mode.

In the following calculations, we assume that:

- $P_{rec}^{Txi}(TRX)$ is the signal level received from the selected TRX type (*tt*) or on all the TRXs of Txi on each pixel of the Txi coverage area,
- *CM* is the set of all available codec modes,
- $(Adaptation\ Threshold)_{CM}$ are the values of adaptation thresholds for the codec modes available in the codec configuration,

  The computed noise N is compared to the codec configuration reference noise N_{Ref}. If the values are the same, the defined graphs are used as is, otherwise the graphs are downshifted by the difference $N - N_{Ref}$.

When the calculations are based on C/(I+N):

- **9955** calculates the carrier-to-interference ratio for all the TBC transmitters with codec configurations assigned, but takes into account all the TBC transmitters (with and without codec configurations) to evaluate the interference.

The selection of codec modes is mainly based on the radio conditions mentionned above. Nevertheless, you can optionally define some specific codec mode graphs accoding to a specific hopping mode, mobility type, frequency band and MAL. As an example, you can model the gain due to longer MALs in codec mode selection.

For more information on interference (*I*) calculation, see "Carrier-to-Interference Ratio Calculation" on page 114.

Ideal link adaptation for circuit quality indicator studies is defined at the codec configuration level. If the ideal link adaptation option is checked, **9955** will select the codec mode, for the transmitter under study, according to the codec quality graphs (CQI = f(C/N) and CQI = f(C/I)) related to the defined reference CQI, which may be different from the CQI being calculated. Otherwise, **9955** will use the adaptation thresholds defined in the Adaptation Thresholds tab to determine the codec mode to be used in the studies.

3.4.2 CQI Calculation Without Ideal Link Adaptation

3.4.2.1 Calculations Based on C/N

9955 selects the highest priority codec mode, *cm*, from among the codec modes available in the codec configuration:

For each TRX type, *tt*, $cm = \text{Highest Priority}\left(CM \Big|_{\frac{P_{rec}^{Txi}(TRX)}{N} > (\text{Adaptation Threshold})_{CM}} \right)$

For $\frac{P_{rec}^{Txi}(TRX)}{N}$, **9955** determines the CQI from the CQI=f(C/N) graph associated to the selected codec mode, *cm*.

3.4.2.2 Calculations Based on C/(I+N)

9955 selects the highest priority codec mode, *cm*, from among the codec modes available in the codec configuration:

For each TRX type, *tt*, $cm = \text{Highest Priority}\left(CM \Big|_{\frac{P_{rec}^{Txi}(TRX)}{I+N} > (\text{Adaptation Threshold})_{CM}} \right)$

For $\frac{P_{rec}^{Txi}(TRX)}{I+N}$, **9955** determines the CQI from the CQI=f(C/I) graph associated to the selected codec mode, *cm*.

3.4.3 CQI Calculation With Ideal Link Adaptation

3.4.3.1 Calculations Based on C/N

Ideal link adaptation is used by a codec configuration according to a defined reference CQI (MOS by default).

9955 calculates signal level received from Txi on each pixel of Txi coverage area and converts it into C/N values as described earlier. Then, **9955** filters all the codec modes that satisfy the C/N criterion (defined by the CQI = f(C/N) graphs for the reference CQI) and are common between the transmitter and the terminal type codec configuration.

The selected codec mode among these filtered codec modes will be,

For each TRX type, *tt*, $cm = \text{Highest Priority}\left(CM \Big|_{CQI_{Ref} = \text{Highest}\left(CQI = f\left(\frac{C}{N} = \frac{P_{rec}^{Txi}(TRX)}{N_{tot}} \right) \right)} \right)$, for MOS

Or, $cm = \text{Highest Priority}\left(CM \Big|_{CQI_{Ref} = \text{Lowest}\left(CQI = f\left(\frac{C}{N} = \frac{P_{rec}^{Txi}(TRX)}{N_{tot}} \right) \right)} \right)$, for BER and FER

Where, *cm* is the codec mode with the highest priority among the set of codec modes *CM* for which the reference CQI gives the highest or the lowest value at the received C/N level, $\frac{P_{rec}^{Txi}(TRX)}{N_{tot}}$.

If more than one codec mode graphs give the same value for reference CQI, then **9955** selects the codec mode with the highest priority.

From the CQI = f(C/N) graph associated to the selected codec mode *cm*, **9955** evaluates the CQI for which the study was performed corresponding to $\frac{P_{rec}^{Txi}(TRX)}{N_{tot}}$ for the selected codec mode.

3.4.3.2 Calculations Based on C/(I+N)

Ideal link adaptation is used by a codec configuration according to a defined reference CQI (MOS by default).

9955 calculates the C/I level received from the transmitter on each pixel of Txi coverage area, for each TRX and converts it into C/(I+N). Then, **9955** filters all the codec modes that satisfy the C/(I+N) criteria (defined by the CQI = f(C/I) graphs for the reference CQI) and are common between the transmitter and the terminal type codec configuration.

The selected codec mode among these filtered codec modes will be, For each TRX type, *tt*, $cm = \text{Highest Priority}\left(CM \Big|_{CQI_{Ref} = \text{Highest}\left(CQI = f\left(\frac{C}{I} = \frac{P_{rec}^{Txi}(TRX)}{I + N_{tot}} \right) \right)} \right)$, for MOS

Or, $cm = \text{Highest Priority}\left(CM \Big|_{CQI_{Ref} = \text{Lowest}\left(CQI = f\left(\frac{C}{I} = \frac{P_{rec}^{Txi}(TRX)}{I + N_{tot}} \right) \right)} \right)$, for BER and FER

Where, *cm* is the codec mode with the highest priority among the set of codec modes *CM* for which the reference CQI gives the highest or the lowest value at the received C/(I+N) level, $\frac{P_{rec}^{Txi}(TRX)}{I + N_{tot}}$.

If more than one codec mode graphs give the same value for reference CQI, then **9955** selects the codec mode with the highest priority.

From the CQI = f(C/I) graph associated to the selected codec mode *cm* (indexed with the C/(I+N) values), **9955** evaluates the CQI for which the study was performed corresponding to $\frac{P_{rec}^{Txi}(TRX)}{I + N_{tot}}$ for the selected codec mode.

3.4.4 Circuit Quality Indicators Coverage Predictions

The Circuit Quality Indicators coverage predictions show the areas BER, FER, and MOS values in the transmitter coverage areas.

For each TBC transmitter, Txi, **9955** calculates the selected parameter on each pixel inside the Txi calculation area. In other words, each pixel inside the Txi calculation area is considered a probe (non-interfering) receiver.

Coverage prediction parameters to be set are:

- The coverage conditions in order to determine the service area of each TBC transmitter,
- The interference and quality indicator conditions to meet for a pixel to be covered, and
- The display settings to select the displayed parameter and its shading levels.

The thermal noise (N = -121 dBm, by default) is used in the calculations if the coverage prediction is based on C/(I+N). This value can be modified by the user.

3.4.4.1 Service Area Determination

9955 uses parameters entered in the *Condition* tab of the coverage prediction properties dialogue to determine the areas where coverage will be displayed.

We can distinguish seven cases as below. Let us assume that:

- Each transmitter, Txi, belongs to a Hierarchical Cell Structure (HCS) layer, k, with a defined priority and a defined reception threshold.
- Each transmitter, Txi, has a codec configuration assigned.
- No max range is set.

3.4.4.1.1 All Servers

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(BCCH)$$

3.4.4.1.2 Best Signal Level and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(BCCH)$$

And $P_{rec}^{Txi}(BCCH) \ge \underset{j \ne i}{Best}\,(P_{rec}^{Txj}(BCCH)) - M$

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.

- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.4.4.1.3 Second Best Signal Level and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(BCCH)$$

And $P_{rec}^{Txi}(BCCH) \ge \underset{j \neq i}{2^{nd}Best}\ (P_{rec}^{Txj}(BCCH)) - M$

Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the second highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the second highest or within a 2 dB margin from the second highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 3rd best servers.

3.4.4.1.4 Best Signal Level per HCS Layer and a Margin

For each HCS layer, k, the service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(BCCH)$$

And $P_{rec}^{Txi}(BCCH) \ge \underset{j \neq i}{Best}\ (P_{rec}^{Txj}(BCCH)) - M$

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.4.4.1.5 Second Best Signal Level per HCS Layer and a Margin

For each HCS layer, k, the service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(BCCH)$$

And $P_{rec}^{Txi}(BCCH) \ge \underset{j \neq i}{2^{nd}Best}\ (P_{rec}^{Txj}(BCCH)) - M$

Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the second highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the second highest or within a 2 dB margin from the second highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 3rd best servers.

3.4.4.1.6 HCS Servers and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(BCCH)$$

And $P_{rec}^{Txi}(BCCH) \ge \underset{j \neq i}{Best}\ (P_{rec}^{Txj}(BCCH)) - M$

And the received $P_{rec}^{Txi}(BCCH)$ exceeds the reception threshold defined per HCS layer.

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.4.4.1.7 Highest Priority HCS Server and a Margin

The service area of Txi corresponds to the pixels where:

$$SubcellReceptionThreshold \le P_{rec}^{Txi}(BCCH)$$

And $P_{rec}^{Txi}(BCCH) \ge \underset{j \ne i}{Best}\ (P_{rec}^{Txj}(BCCH)) - M$

And Txi belongs to the HCS layer with the highest priority. The highest priority is defined by the priority field (0: lowest).

And the received $P_{rec}^{Txi}(BCCH)$ exceeds the reception threshold defined per HCS layer.

> In the case two layers have the same priority, the traffic is served by the transmitter for which the difference between the received signal strength and the HCS threshold is the highest. The way the competition is managed between layers with the same priority can be modified. For more information, see the *Administrator Manual*.

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received signal level from *Txi* is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received signal level from *Txi* is either the highest or within a 2 dB margin from the highest.
- If *M* = -2 dB, **9955** considers pixels where the received signal level from *Txi* is 2 dB higher than the signal levels from transmitters which are 2nd best servers.

3.4.4.2 Coverage Display

3.4.4.2.1 Coverage Resolution

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

3.4.4.2.2 Display Types

It is possible to display the coverage predictions with colours depending on criteria such as:

BER

Only the pixels with a codec mode assigned are coloured. The pixel colour depends on the BER value. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and BER display thresholds. Each layer shows the BER in the transmitter coverage area.

FER

Only the pixels with a codec mode assigned are coloured. The pixel colour depends on the FER value. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and FER display thresholds. Each layer shows the FER in the transmitter coverage area.

MOS

Only the pixels with a codec mode assigned are coloured. The pixel colour depends on the MOS value. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as transmitter coverage areas and MOS display thresholds. Each layer shows the MOS in the transmitter coverage area.

Max BER

Only the pixels with a codec mode assigned are coloured. The pixel colour depends on the highest BER value among the BER values for all the transmitters covering the pixel. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as BER display thresholds. Each layer shows the BER value.

Max FER

Only the pixels with a codec mode assigned are coloured. The pixel colour depends on the highest FER value among the FER values for all the transmitters covering the pixel. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as FER display thresholds. Each layer shows the FER value.

Max MOS

Only the pixels with a codec mode assigned are coloured. The pixel colour depends on the highest MOS value among the MOS values for all the transmitters covering the pixel. Coverage consists of several independent layers whose visibility in the map window can be managed. There are as many layers as MOS display thresholds. Each layer shows the MOS value.

3.5 Traffic Analysis

When starting a traffic analysis, **9955** distributes the traffic from maps to transmitters of each layer according to the compatibility criteria defined in the transmitter, services, mobility type, terminal type properties. Transmitters considered in traffic analysis are the active and filtered transmitters that belong to the focus zone.

- If no focus zone exists in the .atl document, **9955** takes into account the computation zone.
- For details of the average timeslot capacity calculation, see the Network Dimensioning section (calculation of minimum reduction factor).

3.5.1 Traffic Distribution

3.5.1.1 Normal Cells (Nonconcentric, No HCS Layer)

3.5.1.1.1 Circuit Switched Services

A user with a given circuit switched service, *c*, a terminal, *t*, and a mobility type, *m*, will be distributed to the BCCH and TCH subcells of a transmitter if:

- The terminal, *t*, works on the frequency band used by the BCCH subcell,
- The terminal, *t*, works on the frequency band used by the TCH subcell.

3.5.1.1.2 Packet Switched Services

A user with a given packet switched service, *p*, a terminal, *t*, and a mobility type, *m*, will be distributed to the BCCH and TCH subcells of a transmitter if:

- The transmitter is an GPRS/EDGE station (option specified in the transmitter property dialog),
- The terminal, *t*, is technologically compatible with the transmitter,
- The terminal, *t*, works on the frequency band used by the BCCH subcell,
- The terminal, *t*, works on the frequency band used by the TCH subcell.

3.5.1.2 Concentric Cells

In case of concentric cells, TCH_INNER TRX type has the highest priority to carry traffic.

3.5.1.2.1 Circuit Switched Services

A user with a given circuit switched service, *c*, a terminal, *t*, and a mobility type, *m*, will be distributed to the TCH_INNER, BCCH and TCH subcells of a transmitter if:

- The terminal, *t*, works on the frequency band used by the BCCH subcell,
- The terminal, *t*, works on the frequency band(s) used by the TCH_INNER and TCH subcells.

3.5.1.2.2 Packet Switched Services

A user with a given packet switched service, *p*, a terminal, *t*, and a mobility type, *m*, will be distributed to the TCH_INNER, BCCH and TCH subcells of a transmitter if:

- The transmitter is an GPRS/EDGE station (option specified in the transmitter property dialog),

- The terminal, *t*, is technologically compatible with the transmitter,
- The terminal, *t*, works on the frequency band used by the BCCH subcell,
- The terminal, *t*, works on the frequency band(s) used by the TCH_INNER and TCH subcells.

3.5.1.3 HCS Layers

For each HCS layer, *k*, you may specify the maximum mobile speed supported by the transmitters of the layer.

3.5.1.3.1 Circuit Switched Services

A user with a given circuit switched service, *c*, a terminal, *t*, and a mobility type, *m*, will be distributed to the BCCH and TCH subcells (and TCH_INNER in case of concentric cells) of a transmitter if:

- The terminal, *t*, works on the frequency band used by the BCCH subcell,
- The terminal, *t*, works on the frequency band(s) used by the TCH_INNER and TCH subcells,
- The user's mobility, *m*, is less than the maximum speed supported by the layer, *k*.

3.5.1.3.2 Packet Switched Services

A user with a given packet switched service, *p*, a terminal, *t*, and a mobility type, *m*, will be distributed to the BCCH and TCH subcells (and TCH_INNER in case of concentric cells) of a transmitter if:

- The transmitter is an GPRS/EDGE station (option specified in the transmitter property dialog),
- The terminal, *t*, is technologically compatible with the transmitter,
- The terminal, *t*, works on the frequency band used by the BCCH subcell,
- The terminal, *t*, works on the frequency band(s) used by the TCH_INNER and TCH subcells,
- The user mobility, *m*, is less than the maximum speed supported by the layer, *k*.

3.5.2 Calculation of the Traffic Demand per Subcell

Here we assume that:

- Users considered for evaluating the traffic demand fulfil the compatibility criteria defined in the transmitter, services, mobility, terminal properties as explained above.
- **9955** distributes traffic on subcell service areas, which are determined using the option "Best signal level per HCS layer" with a 0dB margin and the subcell reception threshold as lower threshold.
- Same traffic is distributed to the BCCH and TCH subcells.

3.5.2.1 User Profile Traffic Maps

3.5.2.1.1 Normal Cells (Nonconcentric, No HCS Layer)

Number of subscribers ($X_{up,\,m}$) for each TCH subcell *(Txi, TCH)*, per user profile *up* with a given mobility *m,* is inferred as:

$$X_{up,\,m}(Txi,\,TCH) = S_{up,\,m}(Txi,\,TCH) \times D$$

Where $S_{up,m}$ is the TCH service area containing the user profile *up* with the mobility *m* and *D* is the user profile density.

For each behaviour described in the user profile *up*, **9955** calculates the probability for the user to be connected with a given service using a terminal *t*.

Circuit Switched Services

For a circuit switched service *c*, we have:

$$p_{up(c,\,t)} = \frac{N_{call} \times d}{3600}$$

Where N_{call} is the number of calls per hour and *d* is the average call duration (in seconds).

Then, **9955** evaluates the traffic demand, $D_{up(c,\,t),\,m}$, in Erlangs for the subcell *(Txi, TCH)* service area.

$$D_{up(c,\,t),\,m}(Txi,\,TCH) = X_{up,\,m}(Txi,\,TCH) \times p_{up(c,\,t)}$$

Packet Switched Services (Max Rate)

For a max rate packet switched service *p*, we have:

$$p_{up(p,\,t)} = \frac{N_{call} \times V \times 8}{3600}$$

Where N_{call} is the number of calls per hour and *V* is the transmitted data volume per call (in Kbytes).

Then, **9955** evaluates the traffic demand, $D_{up(p,\,t),\,m}$, in kbits/s for the subcell *(Txi, TCH)* service area.

$$D_{up(p,\,t),\,m}(Txi,\,TCH) \;=\; X_{up,\,m}(Txi,\,TCH) \times p_{up(p,\,t)}$$

Packet Switched Services (Constant Bit Rate)

For a constant bit packet switched service *p*, we have:

$$p_{up(p,\,t)} \;=\; \frac{N_{call} \times d}{3600}$$

Where N_{call} is the number of calls per hour and *d* is the average call duration (in seconds).

Then, **9955** evaluates the traffic demand, $D_{up(p,\,t),\,m}$, in kbits/s for the subcell *(Txi, TCH)* service area.

$$D_{up(p,\,t),\,m}(Txi,\,TCH) \;=\; X_{up,\,m}(Txi,\,TCH) \times p_{up(p,\,t)}$$

3.5.2.1.2 Concentric Cells

In case of concentric cells, **9955** distributes a part of traffic on the TCH_INNER service area (TCH_INNER is the highest priority traffic carrier) and the remaining traffic on the outer ring served by the TCH subcell. The traffic spread over the TCH_INNER subcell may overflow to the TCH subcell. In this case, the traffic demand is the same on the TCH_INNER subcell but increases on the TCH subcell.

- Traffic overflowing from the TCH_INNER to the TCH is not uniformly spread over the TCH service area. It is still located on the TCH_INNER service area.

Number of subscribers ($X_{up,\,m}$) for each TCH_INNER *(Txi, TCH_INNER)* and TCH *(Txi, TCH)* subcell, per user profile *up* with a given mobility *m,* is inferred as:

$$X_{up,\,m}(Txi,TCH\_INNER) \;=\; S_{up,\,m}(Txi,TCH\_INNER) \times D$$

$$X_{up,\,m}(Txi,TCH) \;=\; [S_{up,\,m}(Txi,TCH) - S_{up,\,m}(Txi,TCH\_INNER)] \times D$$

$S_{up,\,m}(Txi,TCH\_INNER)$ and $S_{up,\,m}(Txi,TCH)$ respectively refer to the TCH_INNER and TCH subcell service areas containing the user profile *up* with the mobility *m*. *D* is the user profile density.

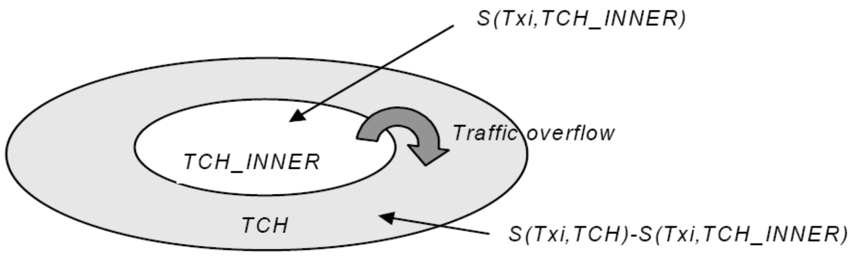


Figure 3.4: Representation of a Concentric Cell TXi

Circuit Switched Services

For each user of the user profile *up* using a circuit switched service *c* with a terminal *t*, **9955** calculates the probability ($p_{up(c,\,t)}$) of the user being connected. Calculations are detailed in "Circuit Switched Services" on page 135.

Then, **9955** evaluates the traffic demand, $D_{up(c,\,t),\,m}$, in Erlangs in the (*Txi, TCH_INNER*) and *(Txi, TCH)* subcell service areas.

$$D_{up(c,\,t),\,m}(Txi,TCH\_INNER) \;=\; X_{up,\,m}(Txi,TCH\_INNER) \times p_{up(c,\,t)}$$

$$D_{up(c,\,t),\,m}(Txi,TCH) \;=\; X_{up,\,m}(Txi,TCH) \times p_{up(c,\,t)} + D_{up(c,\,t),\,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER)$$

Where $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (in %) specified for the TCH_INNER subcell.

Packet Switched Services (Max Rate)

For each user of the user profile *up* using a max rate packet switched service *p* with a terminal *t*, probability of the user being connected ($p_{up(p,\,t)}$) is calculated as explained in "Packet Switched Services" on page 135.

9955 evaluates the traffic demand, $D_{up(p,t),m}$, in kbits/s in the *(Txi, TCH_INNER)* and *(Txi, TCH)* subcell service areas.

$$D_{up(p,t),m}(Txi,TCH\_INNER) = X_{up,m}(Txi,TCH\_INNER) \times p_{up(p,t)}$$

$$D_{up(p,t),m}(Txi,TCH) = X_{up,m}(Txi,TCH) \times p_{up(p,t)} + D_{up(p,t),m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER)$$

Where $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (in %) specified for the TCH_INNER subcell.

Packet Switched Services (Constant Bit Rate)

For each user of the user profile *up* using a constant bit packet switched service *p* with a terminal *t*, probability of the user being connected ($p_{up(p,t)}$) is calculated as explained in "Packet Switched Services" on page 135.

9955 evaluates the traffic demand, $D_{up(p,t),m}$, in kbits/s in the *(Txi, TCH_INNER)* and *(Txi, TCH)* subcell service areas.

$$D_{up(p,t),m}(Txi,TCH\_INNER) = X_{up,m}(Txi,TCH\_INNER) \times p_{up(p,t)}$$

$$D_{up(p,t),m}(Txi,TCH) = X_{up,m}(Txi,TCH) \times p_{up(p,t)} + D_{up(p,t),m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER)$$

Where $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (in %) specified for the TCH_INNER subcell.

3.5.2.1.3 HCS Layers

We assume two HCS layers: the micro layer has a higher priority than the macro layer. Txi belongs to the micro layer and Txj to the macro. The traffic contained in the input traffic map can be assigned to all the HCS layers.

Normal Cells

9955 distributes traffic on the TCH service areas. The traffic capture is calculated with the option "Best signal level per HCS layer" meaning that there is an overlap between HCS layers service areas. Let $S^{macro}_{overlapping}(Txj, TCH)$ denote this area (TCH service area of the macro layer overlapped by the TCH service area of the micro layer). Traffic on the overlapping area is distributed to the TCH subcell of the micro layer because it has a higher priority. On this area, traffic of the micro layer may overflow to the macro layer. In this case, the traffic demand is the same on the TCH subcell of the micro layer but increases on the TCH subcell of the macro layer.

> Traffic overflowing to the macro layer is not uniformly spread over the TCH service area of Txj. It is only located on the overlapping area.

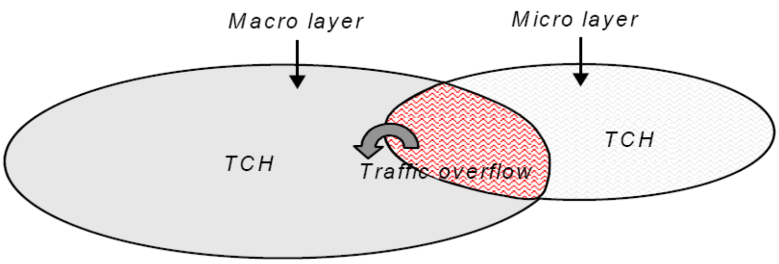


Figure 3.5: Representation of Micro and Macro Layers

9955 evaluates the traffic demand on the micro layer (higher priority) as explained above. For further details, please refer to formulas for normal cells. Then, it proceeds with the macro layer (lower priority).

Number of subscribers ($X^{macro}_{up,m}$) for each TCH subcell *(Txj, TCH)* of the macro layer, per user profile *up* with the mobility *m,* is inferred as:

$$X^{macro}_{up,m}(Txj, TCH) = [S^{macro}_{up,m}(Txj, TCH) - S^{macro}_{up,m-overlapping}(Txj, TCH)] \times D$$

Where $S^{macro}_{up,m}(Txj, TCH)$ is the TCH service area of Txj containing the user profile *up* with the mobility *m* and *D* is the profile density.

For each user described in the user profile *up* with the circuit switched service *c* and the terminal *t*, the probability for the user being connected ($p_{up(c,t)}$) is calculated as explained in "Circuit Switched Services" on page 135.

Then, **9955** evaluates the traffic demand, $D^{macro}_{up(c,t),m}$, in Erlangs in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{up(c,\,t),m}(Txj,\,TCH) = X^{macro}_{up,\,m}(Txj,\,TCH) \times p_{up(c,\,t)} + D^{micro}_{up(c,\,t),m}(Txi,\,TCH) \times \frac{S^{macro}_{up,m-overlapping}(Txj,\,TCH)}{S^{micro}_{up,\,m}(Txi,\,TCH)} \times O_{max}(Txi,\,TCH)$$

For each user described in the user profile *up* with the packet switched service *p* and the terminal *t*, probability for the user to be connected ($p_{up(p,\,t)}$) is calculated as explained in "Packet Switched Services" on page 135.

Then, **9955** evaluates the traffic demand, $D^{macro}_{up(p,\,t),\,m}$, in kbits/s in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{up(p,\,t),m}(Txj,\,TCH) = X^{macro}_{up,\,m}(Txj,\,TCH) \times p_{up(p,\,t)} + D^{micro}_{up(p,\,t),m}(Txi,\,TCH) \times \frac{S^{macro}_{up,m-overlapping}(Txj,\,TCH)}{S^{micro}_{up,\,m}(Txi,\,TCH)} \times O_{max}(Txi,\,TCH)$$

Where $O_{max}(Txi,\,TCH)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH subcell of Txi (micro layer) and $S^{micro}_{up,\,m}(Txi,\,TCH)$ is the TCH service area of Txi containing the user profile *up* with the mobility *m*.

Concentric Cells

9955 evaluates the traffic demand on the micro layer (higher priority HCS layer) as explained above. For further details, please refer to formulas given in case of concentric cells. Then, it proceeds with the macro layer (lower priority HCS layer).

The traffic capture is calculated with the option “Best signal level per HCS layer”. It means that there are overlapping areas between HCS layers where traffic is spread according to the layer priority. On these areas, traffic of the higher priority layer may overflow.

The TCH_INNER service area of the macro layer is overlapped by the micro layer. This area consists of two parts: an area overlapped by the TCH service area of the micro layer $S^{macro}_{overlapping-(Txi,\,TCH)}(Txj,TCH\_INNER)$ and another overlapped by the TCH_INNER service area of the micro layer $S^{macro}_{overlapping-(Txi,TCH\_INNER)}(Txj,TCH\_INNER)$.

Let us consider three areas, S_1, S_2 and S_3.

$$S_1 = S^{macro}_{up,\,m}(Txj,TCH\_INNER) - S^{macro}_{up,\,m-overlapping-(Txi,\,TCH)}(Txj,TCH\_INNER)$$

$$S_2 = S^{macro}_{up,\,m-overlapping-(Txi,TCH\_INNER)}(Txj,TCH\_INNER)$$

$$S_3 = S^{macro}_{up,\,m-overlapping-(Txi,\,TCH)}(Txj,TCH\_INNER) - S_2$$

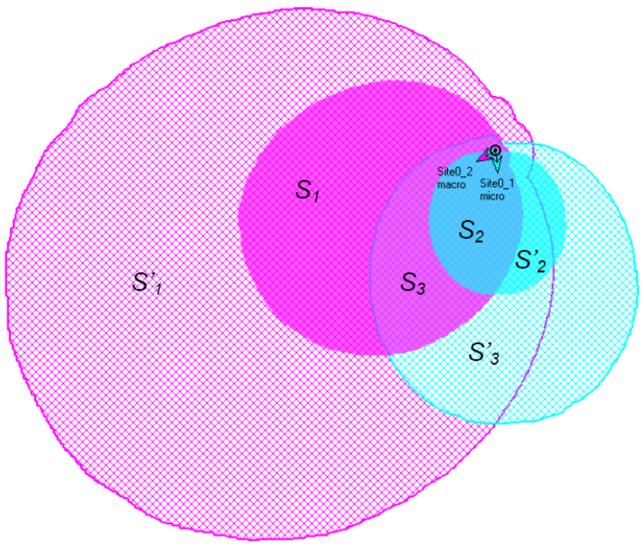


Figure 3.6: Concentric Cells

Where $S^{macro}_{up,\,m}(Txj,TCH\_INNER)$ is the TCH_INNER subcell service area of Txj containing the user profile *up* with the mobility *m*. We only consider the overlapping areas containing the user profile *up* with the mobility *m*.

On S_1, the number of subscribers per user profile *up* with a given mobility *m* ($X^{macro}_{up,\,m}$) is inferred:

$$X^{macro}_{up,\,m}(Txj,TCH\_INNER) = S_1 \times D$$

Where D is the user profile density.

The traffic spread over the TCH_INNER service area of the micro layer may overflow on the TCH subcell. The traffic overflowing to the TCH subcell is located on the TCH_INNER service area. On S_2, the TCH subcell traffic coming from the TCH_INNER subcell traffic overflow may overflow proportional to R_2.

$$R_2 = \frac{S_2}{S_{up,m}^{micro}(Txi, TCH\_INNER)}$$

The traffic spread over the ring served by the TCH subcell of the micro layer only may overflow on S_3 proportional to R_3.

$$R_3 = \frac{S_3}{S_{up,m}^{micro}(Txi, TCH) - S_{up,m}^{micro}(Txi, TCH\_INNER)}$$

Where $S_{up,m}^{micro}(Txi, TCH)$ and $S_{up,m}^{micro}(Txi, TCH\_INNER)$ are the TCH and TCH_INNER service areas of Txi respectively containing the user profile *up* with the mobility *m*.

For each user described in the user profile *up* with a circuit switched service *c* and a terminal *t*, the probability for the user being connected ($p_{up(c,t)}$) is calculated as explained in "Circuit Switched Services" on page 135. Then, **9955** evaluates the traffic demand, $D_{up(c,t),m}^{macro}$, in Erlangs in the subcell *(Txj, TCH_INNER)* service area.

$$D_{up(c,t),m}^{macro}(Txj, TCH\_INNER) = \begin{array}{l} X_{up,m}^{macro}(Txj, TCH\_INNER) \times p_{up(c,t)} + \\ R_2 \times D_{up(c,t),m}^{micro}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R_3 \times X_{up,m}^{micro}(Txi, TCH) \times p_{up(c,t)} \times O_{max}(Txi, TCH) \end{array}$$

For each user described in the user profile *up* with a packet switched service *p* and a terminal *t*, probability for the user to be connected ($p_{up(p,t)}$) is calculated as explained in "Packet Switched Services" on page 135.

Then, **9955** evaluates the traffic demand, $D_{up(p,t),m}^{macro}$, stated in kbits/s in the subcell *(Txj, TCH_INNER)* service area.

$$D_{up(p,t),m}^{macro}(Txj, TCH\_INNER) = \begin{array}{l} X_{up,m}^{macro}(Txj, TCH\_INNER) \times p_{up(p,t)} + \\ R_2 \times D_{up(p,t),m}^{micro}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R_3 \times X_{up,m}^{micro}(Txi, TCH) \times p_{up(p,t)} \times O_{max}(Txi, TCH) \end{array}$$

Where $O_{max}(Txi, TCH)$ and $O_{max}(Txi, TCH\_INNER)$ are the maximum rates of traffic overflow (stated in %) specified for the TCH and TCH_INNER subcells of Txi respectively.

The area of the TCH ring of the macro layer is overlapped by the micro layer. There are two parts: an area overlapped by the TCH service area of the micro layer $S_{overlapping-(Txi,TCH)}^{macro}(Txj, TCH -- TCH\_INNER)$ and another one by the TCH_INNER service area of the micro layer $S_{overlapping-(Txi,TCH\_INNER)}^{macro}(Txj, TCH -- TCH\_INNER)$.

Let us consider three areas, S'_1, S'_2 and S'_3.

$$S'_1 = S_{up,m}^{macro}(Txj, TCH) - S_{up,m}^{macro}(Txj, TCH\_INNER) - S_{up,m-overlapping-(Txi,TCH)}^{macro}(Txj, TCH -- TCH\_INNER)$$

$$S'_2 = S_{up,m-overlapping-(Txi,TCH\_INNER)}^{macro}(Txj, TCH -- TCH\_INNER)$$

$$S'_3 = S_{up,m-overlapping-(Txi,TCH)}^{macro}(Txj, TCH -- TCH\_INNER) - S'_2$$

Where $S_{up,m}^{macro}(Txj, TCH)$ and $S_{up,m}^{macro}(Txj, TCH\_INNER)$ are the TCH and TCH_INNER subcell service areas of Txj respectively. We only consider the overlapping areas containing the user profile *up* with the mobility *m*.

On S'_1, the number of subscribers per user profile *up* with a given mobility *m* ($X_{up,m}^{macro}$) is inferred:

$$X_{up,m}^{macro}(Txj, TCH) = S'_1 \times D$$

Where D is the user profile density.

The traffic spread over the TCH_INNER service area of the micro layer may overflow on the TCH subcell. The traffic overflowing on the TCH subcell is located on the TCH_INNER service area. On S'_2, the TCH subcell traffic coming from the TCH_INNER subcell traffic overflow may overflow proportionally to R'_2.

$$R'_2 = \frac{S'_2}{S^{micro}_{up,m}(Txi, TCH\_INNER)}$$

The traffic spread over the ring served by the TCH subcell of the micro layer only may overflow on S'_3 proportional to R'_3.

$$R'_3 = \frac{S'_3}{S^{micro}_{up,m}(Txi, TCH) - S^{micro}_{up,m}(Txi, TCH\_INNER)}$$

Where $S^{micro}_{up,m}(Txi, TCH)$ and $S^{micro}_{up,m}(Txi, TCH\_INNER)$ are the TCH and TCH_INNER service areas of Txi respectively containing the user profile *up* with the mobility *m*.

For each user described in the user profile *up* with a circuit switched service *c* and a terminal *t*, the probability for the user being connected ($p_{up(c,t)}$) is calculated as explained in "Circuit Switched Services" on page 135.

Then, **9955** evaluates the traffic demand, $D^{macro}_{up(c,t),m}$, in Erlangs in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{up(c,t),m}(Txj, TCH) = \begin{array}{l} X^{macro}_{up,m}(Txj, TCH) \times p_{up(c,t)} + \\ D^{macro}_{up(c,t),m}(Txj, TCH\_INNER) \times O_{max}(Txj, TCH\_INNER) + \\ R'_2 \times D^{micro}_{up(c,t),m}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R'_3 \times X^{micro}_{up,m}(Txi, TCH) \times p_{up(c,t),m} \times O_{max}(Txi, TCH) \end{array}$$

For each user described in the user profile *up* with a packet switched service *p* and a terminal *t*, the probability for the user being connected ($p_{up(p,t)}$) is calculated as explained in "Packet Switched Services" on page 135.

Then, **9955** evaluates the traffic demand, $D^{macro}_{up(p,t),m}$, in kbits/s in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{up(p,t),m}(Txj, TCH) = \begin{array}{l} X^{macro}_{up,m}(Txj, TCH) \times p_{up(p,t)} + \\ D^{macro}_{up(p,t),m}(Txj, TCH\_INNER) \times O_{max}(Txj, TCH\_INNER) + \\ R'_2 \times D^{micro}_{up(p,t),m}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R'_3 \times X^{micro}_{up,m}(Txi, TCH) \times p_{up(p,t),m} \times O_{max}(Txi, TCH) \end{array}$$

Where $O_{max}(Txi, TCH)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH subcell of Txi (micro layer), $O_{max}(Txi, TCH\_INNER)$ the maximum rate of traffic overflow indicated for the TCH_INNER subcell of Txi (macro layer), $O_{max}(Txj, TCH\_INNER)$ the maximum rate of traffic overflow indicated for the TCH_INNER subcell of Txj (macro layer) and $X^{micro}_{up,m}(Txi, TCH)$ the number of subscribers with the user profile *up* and mobility *m* on the TCH service area of Txi (as explained in "Concentric Cells" on page 135).

3.5.2.2 Sector Traffic Maps

We assume that the traffic map is built from a coverage by transmitter prediction calculated for the TCH subcells with options:

- "HCS Servers" and no margin if the network only consists of normal cells and concentric cells,
- "Highest Priority HCS Server" and no margin in case of HCS layers.

When creating the traffic map, you have to specify the traffic demand per transmitter and per service (throughput for a max rate packet switched service and Erlangs for a circuit switched or constant bit rate packet switched service) and the global distribution of terminals and mobility types.

Let $E_c(Txi, TCH)$ denote the Erlangs for the circuit switched service, *c*, on the TCH subcell of Txi.

Let $T_p(Txi, TCH)$ denote the throughput of the packet switched service (Max Bit Rate), *p*, on the TCH subcell of Txi.

Let $E_p(Txi, TCH)$ denote the Erlangs for the packet switched service (Constant Bit Rate), *p*, on the TCH subcell of Txi.

We assume that 100% of users have the terminal, *t*, and the mobility type, *m*.

3.5.2.2.1 Normal Cells (Nonconcentric, No HCS Layer)

For each circuit switched service, *c*, **9955** evaluates the traffic demand, $D_{c,t,m}$, in Erlangs in the subcell *(Txi, TCH)* service area.

$$D_{c,t,m}(Txi, TCH) = E_c(Txi, TCH)$$

For each packet switched service (Max Bit Rate), *p*, **9955** evaluates the traffic demand, $D_{p,t,m}$, in kbits/s in the subcell *(Txi, TCH)* service area.

$$D_{p,t,m}(Txi, TCH) = T_p(Txi, TCH)$$

For each packet switched service (Constant Bit Rate), *p*, **9955** evaluates the traffic demand, $D_{p,t,m}$, in kbits/s in the subcell *(Txi, TCH)* service area.

$$D_{p,t,m}(Txi, TCH) = E_p(Txi, TCH) \times TP_{p,GBR}$$

where $TP_{p,GBR}$ is the guaranteed bit rate of the constant bit rate packet switched service *p*.

3.5.2.2.2 Concentric Cells

In case of concentric cells, **9955** distributes a part of traffic on the TCH_INNER service area (TCH_INNER is the highest priority traffic carrier) and the remaining traffic, on the ring served by the TCH subcell only. The traffic spread over the TCH_INNER subcell may overflow to the TCH subcell. In this case, the traffic demand is the same on the TCH_INNER subcell and rises on the TCH subcell.

> Traffic overflowing from the TCH_INNER to the TCH is not uniformly spread over the TCH service area. It is only located on the TCH_INNER service area.

For each circuit switched service, *c*, **9955** evaluates the traffic demand, $D_{c,t,m}$, in Erlangs in the subcell, *(Txi, TCH_INNER)* and *(Txi, TCH),* service areas.

$$D_{c,t,m}(Txi,TCH\_INNER) = \frac{S(Txi,TCH\_INNER)}{S(Txi, TCH)} \times E_c(Txi, TCH)$$

and

$$D_{c,t,m}(Txi,TCH) = \frac{(S(Txi,TCH) - S(Txi,TCH\_INNER))}{S(Txi, TCH)} \times E_c(Txi, TCH) + D_{c,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER)$$

For each packet switched service (Max Bit Rate), *p*, **9955** evaluates the traffic demand, $D_{p,t,m}$, in kbits/s in the subcell, *(Txi, TCH_INNER)* and *(Txi, TCH),* service areas.

$$D_{p,t,m}(Txi,TCH\_INNER) = \frac{S(Txi,TCH\_INNER)}{S(Txi, TCH)} \times T_p(Txi, TCH)$$

and

$$D_{p,t,m}(Txi,TCH) = \frac{(S(Txi,TCH) - S(Txi,TCH\_INNER))}{S(Txi, TCH)} \times T_p(Txi, TCH) + D_{p,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER)$$

Where $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell, $S(Txi,TCH)$ and $S(Txi,TCH\_INNER)$ are the TCH and TCH_INNER service areas of Txi respectively.

For each packet switched service (Constant Bit Rate), *p*, **9955** evaluates the traffic demand, $D_{p,t,m}$, in kbits/s in the subcell, *(Txi, TCH_INNER)* and *(Txi, TCH),* service areas.

$$D_{p,t,m}(Txi,TCH\_INNER) = \frac{S(Txi,TCH\_INNER)}{S(Txi, TCH)} \times E_p(Txi, TCH) \times TP_{p,GBR}$$

and

$$D_{p,t,m}(Txi,TCH) = \frac{(S(Txi,TCH) - S(Txi,TCH\_INNER))}{S(Txi, TCH)} \times E_p(Txi, TCH) \times TP_{p,GBR} + D_{p,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER)$$

Where $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell, $S(Txi,TCH)$ and $S(Txi,TCH\_INNER)$ are the TCH and TCH_INNER service areas of Txi respectively.

3.5.2.2.3 HCS Layers

We assume we have two HCS layers: the micro layer has a higher priority and the macro layer has a lower one. Txi belongs to the micro layer and Txj to the macro one. The traffic contained in the input traffic map can be assigned to all the HCS layers.

Normal Cells

9955 distributes traffic on the TCH service areas. The traffic capture is calculated with the option “HCS Servers”. It means that there is an overlapping area between HCS layers. Let $S^{macro}_{overlapping}(Txj, TCH)$ denote the TCH service area of the macro layer overlapped by the TCH service area of the micro layer. Traffic on the overlapping area is distributed to the TCH subcell of the micro layer (higher priority layer). On this area, traffic of the micro layer may overflow to the macro layer. In this case, the traffic demand is the same on the TCH subcell of the micro layer but rises on the TCH subcell of the macro layer.

> Traffic overflowing on the macro layer is not uniformly spread over the TCH service area of Txj. It is only located on the overlapping area.

9955 starts evaluating the traffic demand on the micro layer (highest priority HCS layer).

For each circuit switched service, *c*, **9955** calculates the traffic demand, $D^{micro}_{c,t,m}$, in Erlangs in the subcell *(Txi, TCH)* service area.

$$D^{micro}_{c,t,m}(Txi, TCH) = E_c(Txi, TCH)$$

For each packet switched service (Max Bit Rate), *p*, **9955** calculates the traffic demand, $D^{micro}_{p,t,m}$, in kbits/s in the subcell *(Txi, TCH)* service area.

$$D^{micro}_{p,t,m}(Txi, TCH) = T_p(Txi, TCH)$$

For each packet switched service (Constant Bit Rate), *p*, **9955** calculates the traffic demand, $D^{micro}_{p,t,m}$, in kbits/s in the subcell *(Txi, TCH)* service area.

$$D^{micro}_{p,t,m}(Txi, TCH) = E_p(Txi, TCH) \times TP_{p,GBR}$$

Then, **9955** proceeds with the macro layer (lower priority HCS layer).

For each circuit switched service, *c*, **9955** calculates the traffic demand, $D^{macro}_{c,t,m}$, in Erlangs in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{c,t,m}(Txj, TCH) = E_c(Txj, TCH) + D^{micro}_{c,t,m}(Txi, TCH) \times \frac{S^{macro}_{overlapping}(Txj, TCH)}{S^{micro}(Txi, TCH)} \times O_{max}(Txi, TCH)$$

For each packet switched service (Max Bit Rate), *p*, **9955** calculates the traffic demand, $D^{macro}_{p,t,m}$, in kbits/s in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{p,t,m}(Txj, TCH) = T_p(Txj, TCH) + D^{micro}_{p,t,m}(Txi, TCH) \times \frac{S^{macro}_{overlapping}(Txj, TCH)}{S^{micro}(Txi, TCH)} \times O_{max}(Txi, TCH)$$

Where $O_{max}(Txi, TCH)$ is the maximum rate of traffic overflow (in %) specified for the TCH subcell of Txi (micro cell) and $S^{micro}(Txi, TCH)$ the TCH service area of Txi.

For each packet switched service (Constant Bit Rate), *p*, **9955** calculates the traffic demand, $D^{macro}_{p,t,m}$, in kbits/s in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{p,t,m}(Txj, TCH) = E_p(Txi, TCH) \times TP_{p,GBR} + D^{micro}_{p,t,m}(Txi, TCH) \times \frac{S^{macro}_{overlapping}(Txj, TCH)}{S^{micro}(Txi, TCH)} \times O_{max}(Txi, TCH)$$

Where $O_{max}(Txi, TCH)$ is the maximum rate of traffic overflow (in %) specified for the TCH subcell of Txi (micro cell) and $S^{micro}(Txi, TCH)$ the TCH service area of Txi.

You can restrict the traffic assignement of each traffic map to a specific HCS layer in the running options of the traffic capture. If you do so, no overflow occurs between HCS layers and the only overflow which is considered occurs within concentric cells (See "Concentric Cells" on page 135).

Concentric Cells

9955 evaluates the traffic demand on the micro layer as explained above in case of concentric cells and then proceeds with the macro layer (lower priority layer).

The traffic capture is calculated with the option "HCS Servers". It means that there is overlapping areas between HCS layers where traffic is spread over according to the layer priority. On these areas, traffic of the higher priority layer may overflow.

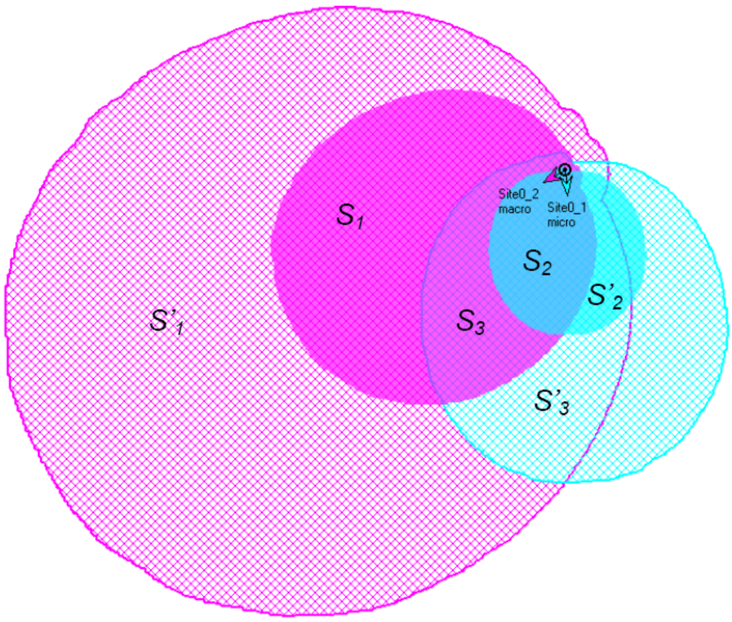


Figure 3.7: Concentric Cells

The TCH_INNER service area of the macro layer is overlapped by the micro layer. This area consists of two parts: an area overlapped by the TCH service area of the micro layer $S^{macro}_{overlapping-(Txi,\,TCH)}(Txj, TCH\_INNER)$ and another overlapped by the TCH_INNER service area of the micro layer $S^{macro}_{overlapping-(Txi, TCH\_INNER)}(Txj, TCH\_INNER)$.

Let us consider three areas, S_1, S_2 and S_3.

$$S_1 = S^{macro}(Txj, TCH\_INNER) - S^{macro}_{overlapping-(Txi,\,TCH)}(Txj, TCH\_INNER)$$

$$S_2 = S^{macro}_{overlapping-(Txi, TCH\_INNER)}(Txj, TCH\_INNER)$$

$$S_3 = S^{macro}_{overlapping-(Txi,\,TCH)}(Txj, TCH\_INNER) - S_2$$

Where $S^{macro}(Txj, TCH\_INNER)$ is the TCH_INNER subcell service area of Txj.

The traffic specified for Txj in the map description ($E_c(Txj,\ TCH)$) is spread over S_1 proportionally to R_1.

$$R_1 = \frac{S_1}{S^{map}(Txj,\ TCH)}$$

$S^{map}(Txj,\ TCH)$ is the TCH service area of Txj in the traffic map with the option "Best signal level of the highest priority layer".

The traffic spread over the TCH_INNER service area of the micro layer may overflow to the TCH subcell. The traffic overflowing to the TCH subcell is located on the TCH_INNER service area. On S_2, the TCH subcell traffic coming from the TCH_INNER subcell traffic overflow may overflow proportional to R_2.

$$R_2 = \frac{S_2}{S^{micro}(Txi, TCH\_INNER)}$$

The traffic spread over the ring only served by the TCH subcell of the micro layer may overflow on S_3 proportional to R_3.

$$R_3 = \frac{S_3}{S^{micro}(Txi,TCH) - S^{micro}(Txi,TCH\_INNER)}$$

For each circuit switched service, *c*, **9955** calculates the traffic demand, $D^{macro}_{c,t,m}$, in Erlangs in the subcell *(Txj, TCH_INNER)* service area.

$$D^{macro}_{c,t,m}(Txj,TCH\_INNER) = \begin{array}{l} R_1 \times E_c(Txj, TCH) + \\ R_2 \times D^{micro}_{c,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R_3 \times \frac{(S^{micro}(Txi, TCH) - S^{micro}(Txi,TCH\_INNER))}{S^{micro}(Txi, TCH)} \times E_c(Txi, TCH) \times O_{max}(Txi, TCH) \end{array}$$

For each packet switched service (Max Bit Rate), *p*, **9955** calculates the traffic demand, $D^{macro}_{p,t,m}$, in kbits/s in the subcell *(Txj, TCH_INNER)* service area.

$$D^{macro}_{p,t,m}(Txj,TCH\_INNER) = \begin{array}{l} R_1 \times T_p(Txj, TCH) + \\ R_2 \times D^{micro}_{p,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R_3 \times \frac{(S^{micro}(Txi, TCH) - S^{micro}(Txi,TCH\_INNER))}{S^{micro}(Txi, TCH)} \times T_p(Txi, TCH) \times O_{max}(Txi, TCH) \end{array}$$

Where $O_{max}(Txi, TCH)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH subcell of Txi, $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell of Txi and $S^{micro}(Txi, TCH)$ is the TCH subcell service area of Txi.

For each packet switched service (Constant Bit Rate), *p*, **9955** calculates the traffic demand, $D^{macro}_{p,t,m}$, in kbits/s in the subcell *(Txj, TCH_INNER)* service area.

$$D^{macro}_{p,t,m}(Txj,TCH\_INNER) = \begin{array}{l} R_1 \times E_p(Txi, TCH) \times TP_{p,GBR} + \\ R_2 \times D^{micro}_{p,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R_3 \times \left(\begin{array}{c} \frac{(S^{micro}(Txi, TCH) - S^{micro}(Txi,TCH\_INNER))}{S^{micro}(Txi, TCH)} \\ \times \\ E_p(Txi, TCH) \times TP_{p,GBR} \times O_{max}(Txi, TCH) \end{array} \right) \end{array}$$

Where $O_{max}(Txi, TCH)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH subcell of Txi, $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell of Txi and $S^{micro}(Txi, TCH)$ is the TCH subcell service area of Txi.

The area of the TCH ring of the macro layer is overlapped by the micro layer. There are two parts: an area overlapped by the TCH service area of the micro layer $S^{macro}_{overlapping-(Txi,TCH)}(Txj,TCH -- TCH\_INNER)$ and another overlapped by the TCH_INNER service area of the micro layer $S^{macro}_{overlapping-(Txi,TCH\_INNER)}(Txj,TCH -- TCH\_INNER)$.

Let us consider three areas, S'_1, S'_2 and S'_3.

$$S'_1 = S^{macro}(Txj, TCH) - S^{macro}(Txj,TCH\_INNER) - S^{macro}_{overlapping-(Txi,TCH)}(Txj,TCH -- TCH\_INNER)$$

$$S'_2 = S^{macro}_{overlapping-(Txi,TCH\_INNER)}(Txj,TCH -- TCH\_INNER)$$

$$S'_3 = S^{macro}_{overlapping-(Txi,TCH)}(Txj,TCH -- TCH\_INNER) - S'_2$$

Where $S^{macro}(Txj, TCH)$ and $S^{macro}(Txj,TCH\_INNER)$ are the TCH and TCH_INNER subcell service areas of Txj respectively.

The traffic specified for Txj in the map description ($E_c(Txj, TCH)$) is spread over S'_1 proportional to R'_1.

$$R'_1 = \frac{S'_1}{S^{map}(Txj, TCH)}$$

$S^{map}(Txj, TCH)$ is the TCH service area of Txj in the traffic map with the option “Best signal level of the highest priority layer”.

The traffic spread over the TCH_INNER service area of the micro layer may overflow to the TCH subcell. The traffic overflowing to the TCH subcell is located on the TCH_INNER service area. On S'_2, the TCH subcell traffic coming from the TCH_INNER subcell traffic overflow may overflow proportional to R'_2.

$$R'_2 = \frac{S'_2}{S^{micro}(Txi,TCH\_INNER)}$$

The traffic spread over the ring only served by the TCH subcell of the micro layer may overflow on S'_3 proportional to R'_3.

$$R'_3 = \frac{S'_3}{S^{micro}(Txi,TCH) - S^{micro}(Txi,TCH\_INNER)}$$

For each circuit switched service, *c*, **9955** calculates the traffic demand, $D^{macro}_{c,t,m}$, in Erlangs in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{c,t,m}(Txj, TCH) = \begin{array}{l} R'_1 \times E_c(Txj, TCH) + \\ D^{macro}_{c,t,m}(Txj,TCH\_INNER) \times O_{max}(Txj,TCH\_INNER) + \\ R'_2 \times D^{micro}_{c,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R'_3 \times \dfrac{(S^{micro}(Txi,TCH) - S^{micro}(Txi,TCH\_INNER))}{S^{micro}(Txi,TCH)} \times E_c(Txi, TCH) \times O_{max}(Txi, TCH) \end{array}$$

For each packet switched service (Max Bit Rate), *p*,**9955** calculates the traffic demand, $D^{macro}_{p,t,m}$, in kbits/s in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{p,t,m}(Txj, TCH) = \begin{array}{l} R'_1 \times T_p(Txj, TCH) + \\ D^{macro}_{c,t,m}(Txj,TCH\_INNER) \times O_{max}(Txj,TCH\_INNER) + \\ R'_2 \times D^{micro}_{p,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R'_3 \times \dfrac{(S^{micro}(Txi,TCH) - S^{micro}(Txi,TCH\_INNER))}{S^{micro}(Txi,TCH)} \times T_p(Txi, TCH) \times O_{max}(Txi, TCH) \end{array}$$

Where $O_{max}(Txj,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell of Txj, $O_{max}(Txi, TCH)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH subcell of Txi, $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell of Txi, $S^{micro}(Txi,TCH)$ is the TCH subcell service area of Txi and $S^{micro}(Txi,TCH\_INNER)$ is the TCH_INNER subcell service area of Txi.

For each packet switched service (Constant Bit Rate), *p*,**9955** calculates the traffic demand, $D^{macro}_{p,t,m}$, in kbits/s in the subcell *(Txj, TCH)* service area.

$$D^{macro}_{p,t,m}(Txj, TCH) = \begin{array}{l} R'_1 \times E_p(Txi, TCH) \times TP_{p,GBR} + \\ D^{macro}_{c,t,m}(Txj,TCH\_INNER) \times O_{max}(Txj,TCH\_INNER) + \\ R'_2 \times D^{micro}_{p,t,m}(Txi,TCH\_INNER) \times O_{max}(Txi,TCH\_INNER) \times O_{max}(Txi, TCH) + \\ R'_3 \times \left(\begin{array}{c} \dfrac{(S^{micro}(Txi,TCH) - S^{micro}(Txi,TCH\_INNER))}{S^{micro}(Txi,TCH)} \\ \times \\ E_p(Txi, TCH) \times TP_{p,GBR} \times O_{max}(Txi, TCH) \end{array} \right) \end{array}$$

Where $O_{max}(Txj,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell of Txj, $O_{max}(Txi, TCH)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH subcell of Txi, $O_{max}(Txi,TCH\_INNER)$ is the maximum rate of traffic overflow (stated in %) specified for the TCH_INNER subcell of Txi, $S^{micro}(Txi,TCH)$ is the TCH subcell service area of Txi and $S^{micro}(Txi,TCH\_INNER)$ is the TCH_INNER subcell service area of Txi.

3.6 Network Dimensioning

9955 is capable of dimensioning a GSM GPRS EDGE network with a mixture of circuit and package switched services. This section describes the technical details of **9955**'s dimensioning engine.

3.6.1 Dimensioning Models and Quality Graphs

In **9955**, a dimensioning model is an entity utilized by the dimensioning engine along with other inputs (traffic, limitations, criteria, etc.) in the process of dimensioning. A dimensioning model defines the QoS KPIs to be taken into account when dimensioning a network for both circuit and packet switched traffic. The user can define either to use Erlang B or Erlang C queuing model for circuit switched traffic and can define which KPIs to consider when dimensioning the network for packet switched traffic. The dimensioning engine will only utilize the quality curves of the KPI selected. The KPIs not selected are supposed to be either already satisfactory or not relatively important.

3.6.1.1 Circuit Switched Traffic

The network dimensioning for circuit switched traffic is performed using the universally accepted and adopted Erlang B and Erlang C formulas. The dimensioning criterion in these formulas is the Grade of Service or the allowed blocking probability of the circuit switched traffic.

In the Erlang B approach, this Grade of Service is defined as the percentage of incoming circuit switched calls that are blocked due to lack of resources or timeslots. This formula implies a loss system. The blocked calls are supposed to be lost and the caller has to reinitiate it.

In the Erlang C approach, the Grade of Service is the percentage of incoming calls that are placed in a waiting queue when there are no resources available, until some resources or timeslots are liberated. This queuing system has no lost calls. As the load on the system increases, the average waiting time in the queue also increases.

These formulas and their details are available in many books. For example, Wireless Communications Principles and Practice by Theodore S. Rappaport, Prentice Hall.

Following the common practice, network dimensioning in **9955** is based on the principle that a voice or GSM call has priority over data transmission. Therefore, as explained later in the network dimensioning steps, **9955** first performs network dimensioning according to the circuit switched traffic present in the subcell in order to ensure the higher priority service availability before performing the same for the packet switched traffic.

3.6.1.2 Packet Switched Traffic

Since packet switched traffic does not occupy an entire timeslot the whole time, it is much more complicated to study than circuit switched traffic. Packet traffic is intermittent and bursty. Whenever there is packet data to be transferred, a Temporary Block Flow (TBF) is initiated for transferring these packets. Multiple TBFs can be multiplexed on the same timeslot. This implies that there can be many packet switched service users that have the same timeslots assigned for packet data transfer but at different intervals of time.

This multiplexing of a number of packet switched service users over the same timeslots incurs a certain reduction in the throughput (data transfer rate) for each multiplexed user. This reduction in the throughput is more perceivable when the system traffic load is high. The following parts describe the three most important Key Performance Indicators in GPRS/EDGE networks and how they are modelled in **9955**.

3.6.1.2.1 Throughput

Throughput is defined as the amount of data delivered to the Logical Link Control Layer in a given unit of time. Each temporary block flow (TBF), and hence each user, has an associated measured throughput sample in a given network. Each network will have a different throughput probability distribution depending on the load and network configuration. Instead of using the precise probability distributions, it is more practical to compute the average and percentile throughput values.

In GPRS, the resources are shared between the users being served, and consequently, the throughput is reduced as the number of active users increases. This reduction in user perceived throughput is modelled through a reduction factor. The throughput experienced by a user accessing a particular service can be calculated as:

User throughput = Number of allocated timeslots x Timeslot capacity x Reduction Factor

Or

User throughput per allocated timeslot = Timeslot capacity x Reduction Factor

Timeslot Capacity

The timeslot capacity is the average throughput per fully utilized timeslot. It represents the average throughput from the network point of view. It mainly depends on the network's propagation conditions and criteria in the coverage area of a transmitter (carrier power, carrier-to-interference distribution, etc.). It is a measure of how much data the network is able to transfer with 1 data Erlang, or in other words, how efficiently the hardware resources are being utilized by the network. It may also depend on the RLC protocol efficiency.

9955 computes the average timeslot capacity during the traffic analysis and is used to determine the minimum throughput reduction factor. But since this information is displayed in the network dimensioning results (only due to relevance), this information has been considered as a part of the network dimensioning process in this document.

Timeslot Utilisation

Timeslot utilization takes into account the average number of timeslots that are available for packet switched traffic. It is a measure of how much the network is loaded with data services. Networks with timeslot utilisation close to 100% are close to saturation and the end-user performance is likely to be very poor.

In **9955** this parameter is termed as the Load (Traffic load for circuit switched traffic and packet switched traffic load for packet switched traffic). It is described in more detail in the Network dimensioning steps section.

Reduction Factor

Reduction factor takes into account the user throughput reduction due to timeslot sharing among many users. The figure below shows how the peak throughput available per timeslot is reduced by interference and sharing.Reduction factor is a function of the number of timeslots assigned to a user (N_u), number of timeslots available in the system (N_s) and the average system packet switched traffic load (L_p) (utilization of resources in the system). Data Erlangs or data traffic is given by:

$$Data\ Erlangs = L_P \times N_S$$

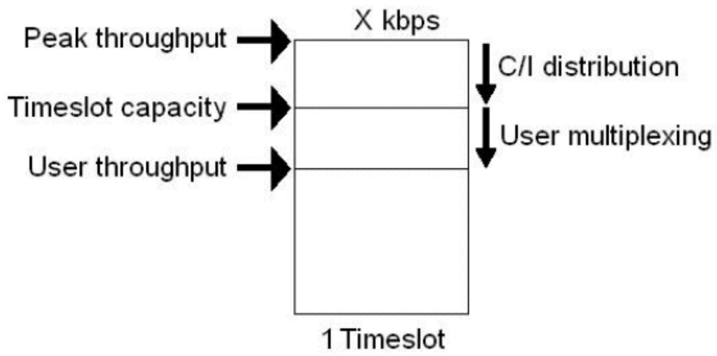


Figure 3.8: Reduction of Throughput per Timeslot

More precisely, the reduction factor is a function of the ratio N_s/N_u (N_p). N_p models the equivalent timeslots that are available for the packet switched traffic in the system. For example, a 24-timeslot system with each user assigned 3 timeslots per connection can be modelled by a single timeslot connection system with 8 timeslots in total.

The formula for reduction factor can be derived following the same hypotheses followed by Erlang in the derivation of the blocking probability formulas (Erlang B and Erlang C).

Let X be a random variable that measures the reduction factor in a certain system state:

$$X \equiv \begin{cases} 0 & if\ n = 0 \\ 1 & if\ 0 < n \le N_P \\ \dfrac{N_P}{n} & if\ n > N_P \end{cases}$$

Where n is the instantaneous number of connections in the system. The throughput reduction factor is defined as:

$$RF \equiv \sum_{n=0}^{\infty} X \cdot \frac{P(X = n)}{P(X = 0)}$$

Or,

$$RF = \sum_{n=0}^{\infty} X \cdot \frac{P(X=n)}{\sum_{i=0}^{\infty} P(X=i)}$$

Here, P(X=n) is the probability function of having n connections in the system. Under the same assumptions as those of the Erlang formulas, the probability function can be written as:

$$P(X=n) = \frac{\frac{(L_P \cdot N_P)^n}{n!}}{\sum_{i=0}^{N_P} \frac{(L_P \cdot N_P)^i}{i!} + \sum_{i=N_P+1}^{\infty} \frac{(L_P \cdot N_P)^i}{N_P! \cdot N_P^{(i-N_P)}}} \qquad if\ 0 \le n \le N_P$$

$$P(X=n) = \frac{\frac{(L_P \cdot N_P)^n}{N_P! \cdot N_P^{(i-N_P)}}}{\sum_{i=0}^{N_P} \frac{(L_P \cdot N_P)^i}{i!} + \sum_{i=N_P+1}^{\infty} \frac{(L_P \cdot N_P)^i}{N_P! \cdot N_P^{(i-N_P)}}} \qquad if\ n > N_P$$

Hence the reduction factor can finally be written as:

$$RF = \frac{\sum_{i=1}^{N_P} \frac{(L_P \cdot N_P)^i}{i!} + \sum_{i=N_P+1}^{\infty} \frac{(L_P \cdot N_P)^i}{N_P! \cdot N_P^{(i-N_P)}} \cdot \left(\frac{N_P}{i}\right)}{\sum_{i=1}^{N_P} \frac{(L_P \cdot N_P)^i}{i!} + \sum_{i=N_P+1}^{\infty} \frac{(L_P \cdot N_P)^i}{N_P! \cdot N_P^{(i-N_P)}}}$$

This formula is not directly applicable in any software application due to the summations up to infinity. **9955** uses the following version of this formula that is exactly the same formula without the summation overflow problem.

$$RF = \frac{\sum_{n=1}^{N_P} \frac{(L_P \cdot N_P)^n}{n!} - \left[\frac{N_P^{(N_P+1)}}{N_P!} \cdot \left(ln(1-L_P) + \sum_{n=1}^{N_P} \frac{L_P^n}{n}\right)\right]}{\sum_{n=1}^{N_P} \frac{(L_P \cdot N_P)^n}{n!} + \frac{(L_P \cdot N_P)^{N_P}}{N_P!} \cdot \frac{L_P}{1-L_P}}$$

The default quality curves for the Reduction Factor have been derived using the above formula. Each curve is for a fixed number of timeslots available for packet switched traffic (N_p) describing the reduction factor at different values of packet switched traffic load (L_p). The figure below contains all the reduction factor quality curves in **9955**. The Maximum reduction factor can be 1, implying a maximum throughput, and the minimum can be 0, implying a saturated system with no data throughput.

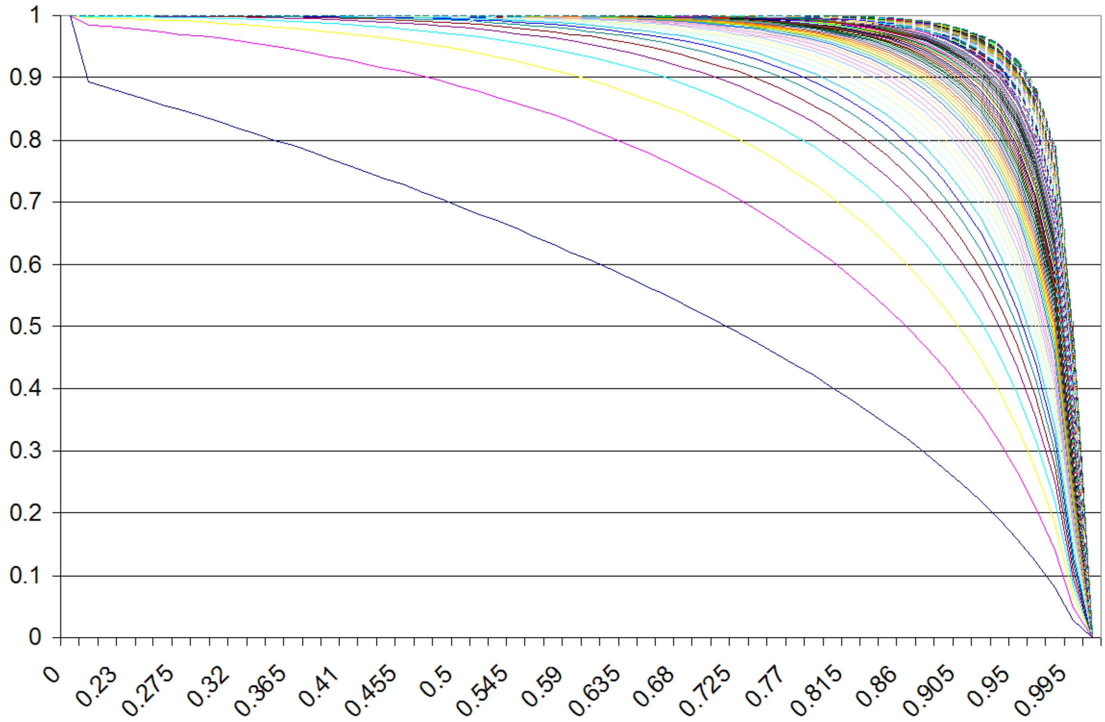


Figure 3.9: Reduction Factor for Different Packet Switched Traffic Loads (L_p, X-axis)

Each curve in the above figure represents an equivalent number of packet switched timeslots, N_P.

3.6.1.2.2 Delay

Delay is the time required for an LLC PDU to be completely transferred from the SGSN to the MS, or vice versa. As the delay is a function of the delays and the losses incurred at the packet level, the network parameters, such as the packet queue length, and different protocol properties, such as the size of the LLC PDU, become important. It is also quite dependent upon the radio access round trip time (RA RTT) and has a considerable impact on the application level performance viewed by the user.

The delay parameter is a user level parameter rather than being a network level quantity, like throughput per cell, timeslot capacity, TBF blocking and reduction factor, hence it is difficult to model and is currently under study. Hence, no default curve is presently available for delay in **9955**.

3.6.1.2.3 Blocking Probability

In GPRS, there is no blocking as in circuit switched connections. If a new temporary block flow (TBF) establishment is requested and there are already M users per timeslot, M being the maximum limit of multiplexing per timeslot (Multiplexing factor), the request is queued in the system to be established later when resources become available.

Supposing that M number of users can be multiplexed over a single timeslot (PDCH), we can have a maximum of M * N_p users in the system. This implies that if a new TBF is requested when there are already M * N_p users active, it will be blocked and placed in a queue. So the blocking probability is the probability of having M * N_p + 1 users in the system or more, meaning,

$$P(X = n) \qquad for\ n = (M \cdot N_P) + 1$$

as in this case n is always greater than N_p, we have,

$$P(X = n) = \frac{\dfrac{(L_P \cdot N_P)^n}{N_P! \cdot N_P^{(i - N_P)}}}{\displaystyle\sum_{i=0}^{N_P} \frac{(L_P \cdot N_P)^i}{i!} + \sum_{i=N_P+1}^{\infty} \frac{(L_P \cdot N_P)^i}{N_P! \cdot N_P^{(i - N_P)}}}$$

So, the Blocking Probability can be given as:

$$BP = \sum_{n = M \cdot N + 1}^{\infty} P(X = n) = \frac{\displaystyle\sum_{n = M \cdot N_P + 1}^{\infty} \frac{(L_P \cdot N_P)^n}{N_P! \cdot N_P^{(1 - N_P)}}}{\displaystyle\sum_{i = 0}^{N_P} \frac{(L_P \cdot N_P)^i}{i!} + \sum_{i = N_P + 1}^{\infty} \frac{(L_P \cdot N_P)^i}{N_P! \cdot N_P^{(1 - N_P)}}}$$

Eliminating the summations to infinity, the blocking probability can be stated in a simpler form:

$$BP = \frac{\dfrac{(L_P \cdot N_P)^{M \cdot N_P}}{N_P! \cdot N_P^{(M \cdot N_P - N_P)}} \cdot \dfrac{L_P}{1 - L_P}}{\displaystyle\sum_{i = 0}^{N_P} \frac{(L_P \cdot N_P)^i}{i!} + \frac{(L_P \cdot N_P)^{N_P}}{N_P!} \cdot \frac{L_P}{1 - L_P}}$$

The above formula has been used to generate the default quality curves for blocking probability in **9955**.

These graphs are generated for a user multiplexing factor of 8 users per timeslot. Each curve represents an equivalent number of packet switched timeslots, N_P.

The curves depict the blocking probabilities for different number of available connections (N_p) at different packet switched traffic loads (L_p) for a fixed user multiplexing factor of 8. The figure below contains all the blocking probability curves for packet switched traffic dimensioning in **9955**. The blocking probability increases with the packet switched traffic load, which implies that as the packet switched traffic increases for a given number of timeslots, the system starts to get more and more loaded, hence there is higher probability of having a temporary block flow placed in a waiting queue.

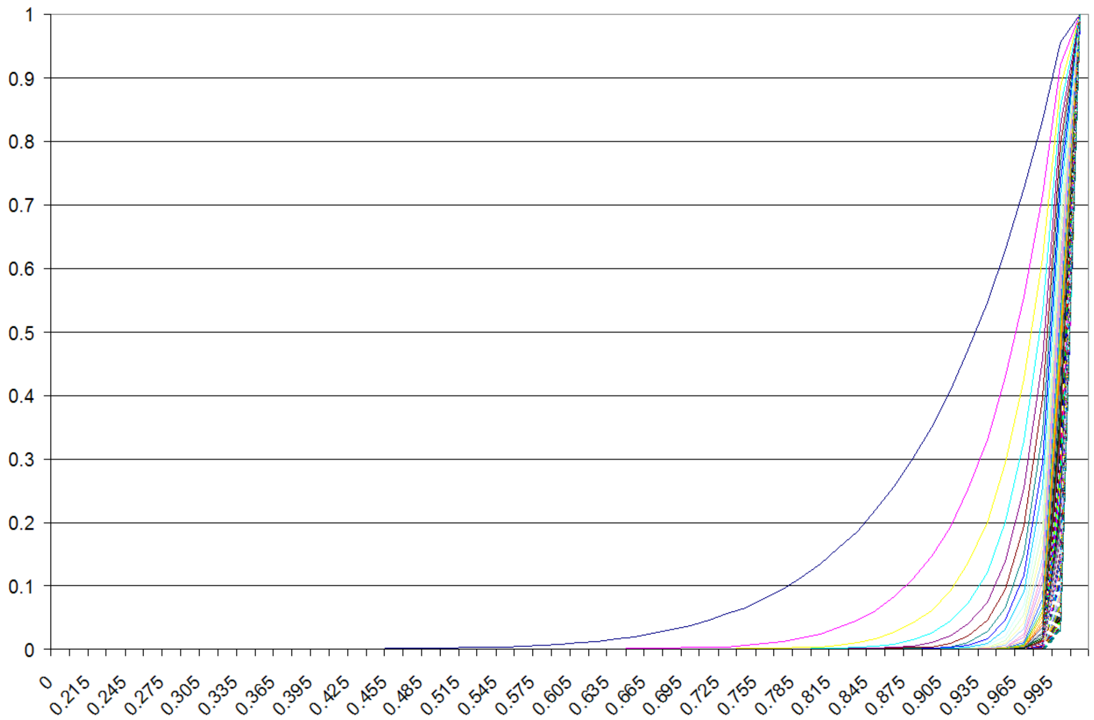


Figure 3.10: Blocking Probability for Different Packet Switched Traffic Loads (L_p, X-axis)

Reference: T. Halonen, J. Romero, J. Melero; GSM, GPRS and EDGE performance – Evolution towards 3G/UMTS, John Wiley and Sons Ltd.

3.6.2 Network Dimensioning Process

The network dimensioning process is described below in detail. As the whole dimensioning process is in fact a chain of small processes that have there respective inputs and outputs, with outputs of a preceding one being the inputs to the next, the best method is to detail each process individually in form of steps of the global dimensioning process.

3.6.2.1 Network Dimensioning Engine

During the dimensioning process, **9955** first computes the number of timeslots required to accommodate the circuit switched traffic. Then it calculates the number of timeslots to add in order to satisfy the demand of packet switched traffic. This is performed using the quality curves entered in the dimensioning model used. If the dimensioning model has been indicated to take all three KPIs in to account (throughput reduction factor, delay and blocking probability), the number of timeslots to be added is calculated such that:

- The throughput reduction factor is greater than the minimum throughput reduction factor,
- Delay is less than the maximum permissible delay defined in the service properties, and
- The blocking probability is less than the maximum allowable blocking probability defined in the service properties.

The figure below depicts a simplified flowchart of the dimensioning engine in **9955**.

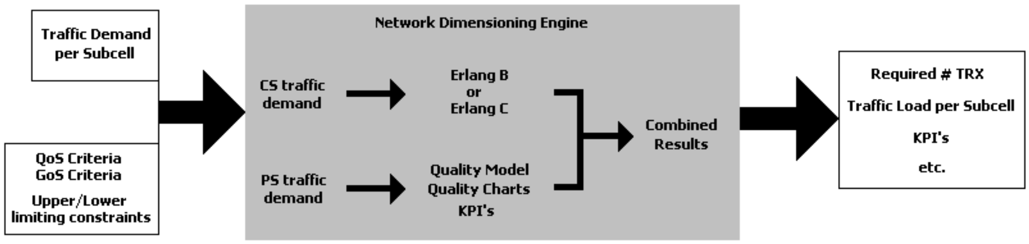


Figure 3.11: Network Dimensioning Process

On the whole, following are the inputs and outputs of the network dimensioning process:

3.6.2.1.1 Inputs

- Circuit switched traffic demand
- Packet switched traffic demand
- Timeslot configurations defined for each subcell
- Target traffic overflow rate and Half-rate traffic ratio for each subcell
- Service availability criteria: minimum required throughput per user, maximum permissible delay, maximum allowable blocking probability etc.
- Dimensioning model parameters: Maximum number of TRXs per transmitter, dimensioning model for circuit switched traffic, number of minimum dedicated packet switched timeslots per transmitter, maximum number of TRXs added for packet switched services, KPIs to consider, and their quality curves.

3.6.2.1.2 Outputs

- Number of required TRXs per transmitter
- Number of required shared, circuit switched and packet switched timeslots
- Traffic load
- Served circuit switched traffic
- Served packet switched traffic
- Effective rate of traffic overflow
- Actual KPI values: throughput reduction factor, delay and blocking probability

3.6.2.2 Network Dimensioning Steps

This section describes the entire process step by step as it is actually performed in **9955**. Details of the calculations of the parameters that are calculated during each step are described as well.

3.6.2.2.1 Step 1: Timeslots Required for CS Traffic

9955 computes the number of timeslots required to accommodate the circuit switched traffic assigned to each subcell. **9955** takes the circuit switched traffic demand (Erlangs) either user-defined or calculated in the traffic analysis and assigned to the current subcell and the maximum blocking probability defined for the circuit switched service, and computes the required number of timeslots to satisfy this demand using the Erlang B or Erlang C formula (as defined by the user).

If the user-defined target rate of traffic overflow per subcell, O_{Target}, is greater than the maximum blocking rate defined in the services properties, it is going to be taken as the Grade of Service required for that subcell instead of the maximum blocking rate of the service.

For the blocking probability GoS and circuit switched traffic demand TD_C, **9955** determines the required number of timeslots $TS_{req.\ C}$ for each subcell using formulas described below. In fact, **9955** searches for $TS_{req.\ C}$ value until the defined grade of service is reached.

For Erlang B, we have:

$$GoS = \frac{\dfrac{(TD_C)^{TS_{reqC}}}{(TS_{reqC})!}}{\displaystyle\sum_{k=0}^{TS_{reqC}} \frac{(TD_C)^k}{k!}}$$

For Erlang C, we have:

$$GoS = \frac{(TD_C)^{TS_{reqC}}}{(TD_C)^{TS_{reqC}} + (TS_{reqC})! \cdot \left(1 - \dfrac{TD_C}{TS_{reqC}}\right) \cdot \displaystyle\sum_{k=0}^{TS_{reqC}-1} \frac{(TD_C)^k}{k!}}$$

9955 considers the effect of half-rate circuit switched traffic by taking into account a user-defined percentage of half-rate traffic. **9955** computes the effective equivalent number of full-rate timeslots that will be required to carry the total traffic with the defined percentage of half-rate traffic.

If the number of timeslots required to accommodate the full-rate circuit switched traffic is $TS_{req.\ FR}$, and the percentage of half-rate traffic within the subcell is defined by HR, then the effective number of equivalent full-rate circuit switched timeslots $TS_{eff.}$ that can carry this traffic mix is calculated by:

$$TS_{eff} = TS_{reqFR} \times \left(1 - \frac{HR}{2}\right)$$

9955 employs this simplified approach to integrating half-rate circuit switched traffic, which provides approximately the same results as obtained by using the half-rate traffic charts.

3.6.2.2.2 Step 2: TRXs Required for CS Traffic and Dedicated PS Timeslots

This stage of the network dimensioning process computes the number of TRXs required to carry the circuit switched traffic demand through the number of required timeslots calculated above and the timeslot configuration defined by the user in the network settings. **9955** distributes the number of required circuit switched timeslots calculated in Step 1 taking into account the presence of dedicated packet switched timeslots in each TRX according to the timeslot configurations.

If a timeslot configuration defines a certain number of dedicated packet switched timeslots pre-allocated in certain TRXs, those timeslots will not be considered capable of carrying circuit switched traffic and hence will not be allocated. For example, if 4 timeslots have been marked as packet switched timeslots in the first TRX and **9955** computes 8 timeslots for carrying a certain circuit switched traffic demand, then the number of TRXs to be allocated cannot be 1 even if there is no packet switched traffic considered yet.

The total numbers of timeslots that carry circuit switched and packet switched traffic respectively are the sums of respective dedicated and shared timeslots:

$TS_P = TS_S + TS_{P,\, dedicated}$ and $TS_C = TS_S + TS_{C,\, dedicated}$

3.6.2.2.3 Step 3: Effective CS Blocking, Effective CS Traffic Overflow and Served CS Traffic

In this step, the previously calculated number of required TRXs is used to compute the effective blocking rate for the circuit switched traffic. This is performed by using the Erlang B or Erlang C formula with the circuit switched traffic demand and the number of required TRXs as inputs and computing the Grade of Service (or blocking probability). It then calculates the effective traffic overflow rate, $O_{eff.}$.

In case of Erlang B formula, the effective rate of traffic overflow for the circuit switched traffic is the same as the circuit switched blocking rate. While in case of the Erlang C model, the circuit switched traffic is supposed to be placed in an infinite-length waiting queue. This implies that there is no overflow in this case.

From this data, it also computes the served circuit switched traffic. This is the difference of the circuit switched traffic demand and the percentage of traffic that overflows from the subcell to other subcells calculated above. Hence, for an effective traffic overflow rate of $O_{eff.}$ and the circuit switched traffic demand of TD_C, the served circuit switched traffic ST_C is computed as:

$$ST_C = TD_C \cdot (1 - O_{eff})$$

3.6.2.2.4 Step 4: TRXs to Add for PS Traffic

This step is the core of the dimensioning process for packet switched services. First of all, **9955** computes the number of TRXs to be added to carry the packet switched traffic demand. This is the number of TRXs that contain dedicated packet switched and shared timeslots.

To determine this number of TRXs, **9955** calculates the equivalent average packet switched traffic demand in timeslots by studying each pixel covered by the transmitter. This calculation is in fact performed in the traffic analysis process or is user-defined in the subcells table. Knowing the traffic demand per pixel of the covered area in terms of kbps and the maximum attainable throughput per pixel (according to the C and/or C/I conditions and the coding scheme curves in the GPRS/EDGE configuration), **9955** calculates the average traffic demand in packet switched timeslots by:

$$TD_{P_{Timeslots}} = \sum_{pixel} \left\lceil \frac{Traffic\ demand\ per\ pixel\ (kbps)}{Throughput\ per\ pixel\ (kbps)} \right\rceil$$

The average timeslot capacity of a transmitter is calculated by dividing the packet switched traffic demand over the entire coverage area (in kbps) by the packet switched traffic demand in timeslots calculated above.

With the number of timeslots required to serve the circuit switched traffic, the timeslots required for packet switched traffic and their respective distributions according to the timeslot configurations being known, **9955** calculates the number of timeslots available for carrying the packet switched traffic demand. These timeslots can be dedicated packet switched timeslots and the shared ones. So, following the principle that shared timeslots are potential carriers of both traffic types,

$$TS_P = TS_S + TS_{P,\ dedicated}$$

$$TS_C = TS_S + TS_{C,\ dedicated}$$

The packet switched traffic load is calculated by the formula:

$$L_P = \frac{(ST_C - TS_{C,\ dedicated} + TD_{P_{Timeslots}})}{TS_P}$$

The second important parameter for the calculation of Reduction Factor, Delay and Blocking Probability is the equivalent number of available timeslots for packet switched traffic, i.e. N_P. This is computed by dividing the total number of timeslots available for carrying packet switched traffic by the number of downlink timeslots defined in the mobile terminal properties. So, N_P is calculated at this stage as:

$$N_P = \frac{TS_P}{TS_{Terminal}}$$

Where, $TS_{Terminal}$ is the number of timeslots that a terminal will use in packet switched calls.

The number timeslots that a terminal can use in packet switched calls is the product of the number of available DL timeslots for packet-switched services (on a frame) and the number of simultaneous carriers (in case of EDGE evolution).

The number of timeslots that a terminal will use in packet switched calls is determined by taking the lower of the maximum number of timeslots on a carrier for packet switched service defined in the service properties and the maximum number of timeslots that a mobile terminal can use for packet switched services (see above) on acarrier.

$$TS_{Terminal} = min(TS_{Max,\ Service}, TS_{Max,\ TerminalType})$$

and $TS_{Max,\ TerminalType} = TS_{DL,\ TerminalType} \times Carriers_{DL,\ TerminalType}$

Here, the min(X,Y) function yields the lower value among X and Y as result.

Now, knowing the packet switched traffic load, L_P, and the equivalent number of available timeslots, N_P, **9955** finds out the KPIs that have been selected before launching the dimensioning process using the quality curves stored in the dimensioning model.

This particular part of this step can be iterative if the KPIs to consider in dimensioning are not satisfied in the first try. If the KPIs calculated above are within acceptable limits as defined by the user, it means that the dimensioning process has acceptable results. If these KPIs are not satisfied, then **9955** increases the number of TRXs calculated for carrying packet switched traffic by 1 (each increment adding 8 more timeslots for carrying packet switched traffic as the least unit that can be physically added or removed is a TRX) and resumes the computations from Step 3. It then recalculates the packet switched traffic load, L_P, and the equivalent number of available timeslots, N_P. Then it recomputes the KPIs with these new values of L_P and N_P. If the KPIs are within satisfactory limits the results are considered to be acceptable. Otherwise, **9955** performs another iteration to find the best possible results.

The calculated values of all the KPIs are compared with the ones defined in the service properties. The values for maximum Delay and Blocking probability are defined directly in the properties but the minimum throughput reduction factor is calculated by **9955** using the user's inputs: minimum throughput per user and required availability. This calculation is in fact performed during the traffic analysis process, but since it is relevant to the dimensioning procedure, it is displayed in a column in the dimensioning results so that the user can easily compare the minimum requirement on the reduction factor KPI with the resulting one. If dimensioning is not based on a traffic analysis, the minimum throughput reduction factor is a user-defined parameter.

Minimum Throughput Reduction Factor Calculation

The minimum throughput reduction factor is computed using the input data: minimum required throughput per user defined in the service properties, the average throughput per timeslot deduced from the throughput curves stored in the GPRS/EDGE configuration properties for each coding scheme, the total number of downlink timeslots defined in the properties of the mobile terminal (See $TS_{Max, TerminalType}$ defintion above) and the required availability defined in the service properties.

It is at the stage of calculating the average timeslot capacity per transmitter that **9955** studies each covered pixel for carrier power or carrier-to-interference ratio. According to the measured carrier power or carrier-to-interference ratio, **9955** deduces the maximum throughput available on that pixel through the throughput vs. C or throughput vs. C/I curves of the GPRS/EDGE configuration.

The throughput per timeslot per pixel $TP_{TS, Pixel}$ can be either a function of carrier power C, or carrier power C and the carrier-to-interference ratio C/I, depending on the user-defined traffic analysis RF conditions criteria. Therefore,

$$TP_{TS, Pixel} = f(C)$$

Or

$$TP_{TS, Pixel} = f(C) \text{ and } TP_{TS, Pixel} = f\left(\frac{C}{I}\right)$$

The required availability parameter defines the percentage of pixels within the coverage area of the transmitter that must satisfy the minimum throughput condition. This parameter renders user-manageable flexibility to the throughput requirement constraint.

To calculate the minimum throughput reduction factor for the transmitter, **9955** computes the minimum throughput reduction factor for each pixel using the formula:

$$RF_{min, Pixel} = \frac{TP_{user, min}}{TP_{TS, Pixel} \times TS_{Terminal}}$$

Once the minimum reduction factor for each pixel is known, **9955** calculates the global minimum reduction factor that is satisfied by the percentage of covered pixels defined in the required availability. The following example may help in understanding the concept and calculation method.

Example: Let the total number of pixels, covered by a subcell S, be 1050. The reliability level set to 90%. This implies that the required minimum throughput for the given service will be available at 90% of the pixels covered. This, in turn, implies that there will be a certain limit on the reduction factor, i.e. if the actual reduction factor in that subcell becomes less than a minimum required, the service will not be satisfactory.

9955 computes the minimum reduction factor at each pixel using the formula mentioned above, and outputs the following results:

RF_{min}	Number of pixels
0.3	189
0.36	57
0.5	20
0.6	200
0.72	473
0.9	23
0.98	87

So for a reliability level of 90%, the corresponding RF_{min} will be the one provided at least 90% of the pixels covered, i.e. 945 pixels. The corresponding value of the resulting RF_{min} in this example hence turns out to be 0.9, since this value covers 962 pixels in total. Only 87 of the covered pixels imply an RF_{min} of 0.98. These will be the pixels that do not provide satisfactory service.

This calculation is performed for each service type available in the subcell coverage area. The final minimum throughput reduction factor is the highest one amongst all calculated for each service separately.

The minimum throughput reduction factor RF_{min} value is a minimum requirement that must be fulfilled by the network dimensioning process when the Reduction Factor KPI is selected in the dimensioning model.

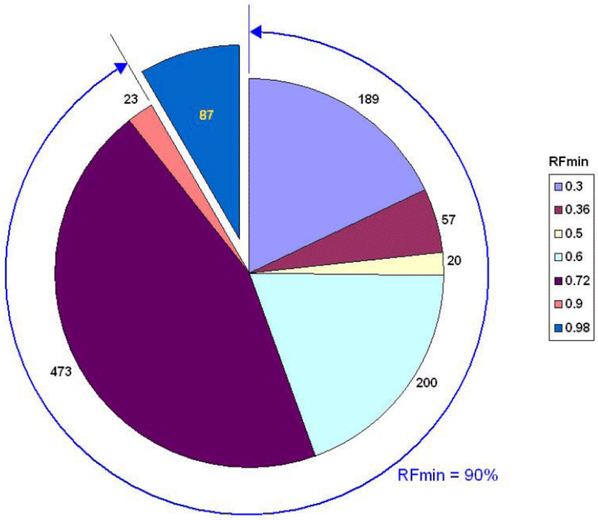


Figure 3.12: Minimum Throughput Reduction Factor

3.6.2.2.5 Step 5: Served PS Traffic

9955 calculates the served packet switched traffic using the number of timeslots available to carry the packet switched traffic demand. As the result of the above iterative step, **9955** always finds the best possible answer in terms of number of timeslots required to carry the packet switched traffic demand unless the requirement exceeds the maximum limit on the number of the packet switched traffic timeslots defined in the dimensioning model properties. Hence, there is no packet traffic overflow unless the packet switched traffic demand requires more TRXs than the maximum allowed

3.6.2.2.6 Step 6: Total Traffic Load

This step calculates the final result of the dimensioning process, i.e. the total traffic load. The total traffic load L is calculated as:

$$L = \frac{ST_C + ST_P}{TS_{C,\,dedicated} + TS_{P,\,dedicated} + TS_S}$$

Where,

- ST_C is the served circuit switched traffic
- ST_P is the served packet switched traffic
- $TS_{C,\,dedicated}$ is the number of dedicated circuit switched timeslots
- $TS_{P,\,dedicated}$ is the number of dedicated packet switched timeslots
- TS_S is the number of shared timeslots

3.7 Key Performance Indicators Calculation

This feature calculates the current values for all circuit switched and packet switched Key Performance Indicators as a measure of the current performance of the network. It can be used to evaluate an already dimensioned network in which recent traffic changes have been made in limited regions to infer the possible problematic areas and then to improve the network dimensioning with respect to these changes.

The concept of this computation is the inverse of that of the dimensioning process. In this case, **9955** has the results of the dimensioning process already committed and known. **9955** then computes the current values for all the KPIs knowing the number of required TRXs, the respective numbers of shared and dedicated timeslots and the circuit switched and packet switched traffic demands.

The computation algorithm utilizes the parameters set in the dimensioning model properties and the quality curves for the throughput reduction factor, delay and the blocking probability.

The following conventional relations apply:

If,

- $TS_{C,\,dedicated}$ is the number of timeslots dedicated to the circuit switched traffic,
- $TS_{P,\,dedicated}$ is the number of timeslots dedicated to the packet switched traffic,
- TS_S is the number of shared timeslots for a transmitter,

Then, the number of timeslots available for the circuit switched traffic, TS_C, is defined as:

$$TS_C = TS_S + TS_{C,\,dedicated}$$

And the number of timeslots available for the packet switched traffic, TS_P, is given by:

$$TS_P = TS_S + TS_{P,\,dedicated}$$

3.7.1 Circuit Switched Traffic

For each subcell, **9955** has already calculated the effective traffic overflow rate and the blocking rate during the dimensioning process. Also knowing the circuit switched traffic demand, TD_C, and the number of timeslots available for circuit switched traffic, TS_C, the blocking probability can be easily computed using the Erlang formulas or tables.

3.7.1.1 Erlang B

Under the current conditions of circuit switched traffic demand, TD_C, and the number of timeslots available for the circuit switched traffic, TS_C, the percentage of blocked circuit switched traffic can be computed through:

$$\%\ of\ blocked\ traffic = \frac{\dfrac{(TD_C)^{TS_C}}{(TS_C)!}}{\displaystyle\sum_{k=0}^{TS_C} \frac{(TD_C)^k}{k!}}$$

In a network dimensioning based on Erlang B model, the circuit switched traffic overflow rate, O_C, is the same as the percentage of traffic blocked by the subcell calculated above.

3.7.1.2 Erlang C

Similarly, under the current conditions of circuit switched traffic demand, TD_C, and the number of timeslots available for the circuit switched traffic, TS_C, the percentage of delayed circuit switched traffic can be computed through:

$$\%\ of\ traffic\ delayed = \frac{(TD_C)^{TS_C}}{(TD_C)^{TS_C} + (TS_C)! \cdot \left(1 - \dfrac{TD_C}{TS_C}\right) \cdot \displaystyle\sum_{k=0}^{TS_C - 1} \frac{(TD_C)^k}{k!}}$$

If the circuit switched traffic demand, TD_C, is higher than the number of timeslots available to accommodate circuit switched traffic, the column for this result will be empty signifying that there is a percentage of circuit switched traffic actually being rejected rather than just being delayed under the principle of Erlang C model.

The circuit switched traffic overflow rate, O_C, will be 0 if the circuit switched traffic demand, TD_C, is less than the number of timeslots available for the circuit switched traffic, TS_C.

If, on the other hand, the circuit switched traffic demand, TD_C, is higher than the number of timeslots available to carry the circuit switched traffic, TS_C, then there will be a certain percentage of circuit switched traffic that will overflow from the subcell. This circuit switched traffic overflow rate, O_C, is calculated as:

$$O_C = \frac{TD_C - TS_C}{TD_C}$$

3.7.1.3 Served Circuit Switched Traffic

The result of the above two processes will be a traffic overflow rate for the circuit switched traffic for each subcell, O_C. The served circuit switched traffic, ST_C, is calculated as:

$$ST_C = TD_C \cdot (1 - O_C)$$

3.7.2 Packet Switched Traffic

Identifying the total traffic demand, TD_T, (circuit switched traffic demand + packet switched traffic demand) as:

$$TD_T = TD_C + TD_P$$

The following two cases can be considered.

3.7.2.1 Case 1: Total Traffic Demand > Dedicated + Shared Timeslots

In the case where the total number of timeslots available is less than the total traffic demand, there will be packet switched data traffic that will be rejected by the subcell as it will not be able to accommodate it. The following results are expected in this case:

3.7.2.1.1 Traffic Load

The traffic load will be 100%, as the subcell will have more traffic to carry than it can. This implies that the system will be loaded to the maximum and even saturated. Hence the user level quality of service is bound to be very unsatisfactory.

3.7.2.1.2 Packet Switched Traffic Overflow

In a 100% loaded, or even saturated subcell, the packet switched data calls will start being rejected because of shortage of available resources. Hence there will be a perceptible packet switched traffic overflow in this subcell, O_P. This overflow rate is calculated as show below:

$$O_P = \left[1 - \frac{\{(TS_{C,\,dedicated} + TS_{P,\,dedicated} + TS_S) - ST_C\}}{TD_P}\right] \times 100$$

3.7.2.1.3 Throughput Reduction Factor

The resulting throughput reduction factor for a 100% loaded or saturated subcell will be 0. Hence, the throughput perceived by the packet switched service user will be 0, implying a very bad quality of service.

3.7.2.1.4 Delay

Again for a 100% loaded or saturated subcell, the delay at the packet switched service user end will be infinite as there is no data transfer (throughput = 0).

3.7.2.1.5 Blocking Probability

All the data packets will be rejected by the system since it is saturated and has no free resources to allocate to incoming data packets. Hence, the blocking probability will be 100%.

3.7.2.1.6 Served Packet Switched Traffic

With the packet switched data traffic overflowing from the subcell, there will be a part of that traffic that is not served. The served packet switched data traffic, ST_P, is calculated on the same principle as the served circuit switched traffic:

$$ST_P = TD_P \cdot (1 - O_P)$$

3.7.2.2 Case 2: Total Traffic Demand < Dedicated + Shared Timeslots

In the case where the total traffic demand is less than the number of timeslots available to carry the traffic, the subcell will not be saturated and there will be some deducible values for all the data KPIs. In a normally loaded subcell, the packet switched data traffic will have no overflow percentage. This is due to the fact that the packet switched data traffic is rather placed in a waiting queue than be rejected.

Therefore, there will be a within limits packet switched traffic load, L_P, calculated as under:

$$L_P = \frac{(ST_C - TS_{C,\,dedicated} + TD_{P_{Timeslots}})}{TS_P}$$

The second parameter for computing the KPIs from the quality curves of the dimensioning model is the number of equivalent timeslots available for the packet switched data traffic, N_P, which is calculated in the same manner as in the dimensioning process as well:

$$N_P = \frac{TS_P}{TS_{Terminal}}$$

These parameters calculated, now **9955** can compute the required KPIs through their respective quality curves.

3.7.2.2.1 Traffic Load

The traffic load is computed knowing the total traffic demand and the total number of timeslots available to carry the entire traffic demand:

$$Traffic\ Load = \frac{TD_T}{TS_{C,\ dedicated} + TS_{P,\ dedicated} + TS_S}$$

3.7.2.2.2 Packet Switched Traffic Overflow

In a normally loaded subcell, no packet switched data calls will be rejected. The packet switched traffic overflow will, therefore, be 0.

3.7.2.2.3 Throughput Reduction Factor

The resulting throughput reduction factor for a normally loaded subcell is calculated through the throughput reduction factor quality curve for given packet switched traffic load, L_P, and number of equivalent timeslots, N_P.

3.7.2.2.4 Delay

The resulting delay the subcell is calculated through the delay quality curve for given packet switched traffic load, L_P, and number of equivalent timeslots, N_P.

3.7.2.2.5 Blocking Probability

The resulting blocking probability for a normally loaded subcell is calculated through the blocking probability quality curve for given packet switched traffic load, L_P, and number of equivalent timeslots, N_P.

3.7.2.2.6 Served Packet Switched Traffic

As there is no overflow of the packet switched traffic demand from the subcell under consideration, the served packet switched traffic will be the same as the packet switched traffic demand:

$$ST_P = TD_P$$

3.8 Neighbour Allocation

The intra-technology neighbour allocation algorithm takes into account all the TBC transmitters. It means that all the TBC transmitters of the .atl document are potential neighbours.

The transmitters to be allocated will be called TBA transmitters. They must fulfil the following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters or a single transmitter.

Only TBA transmitters may be assigned neighbours.

> If no focus zone exists in the .atl document, **9955** takes into account the computation zone.

3.8.1 Global Allocation for All Transmitters

We assume a reference transmitter A and a candidate neighbour, transmitter B.

When automatic allocation starts, **9955** checks following conditions:

- The distance between both transmitters must be less than the user-definable maximum inter-site distance. If the distance between the reference transmitter and the candidate neighbour is greater than this value, then the candidate neighbour is discarded.

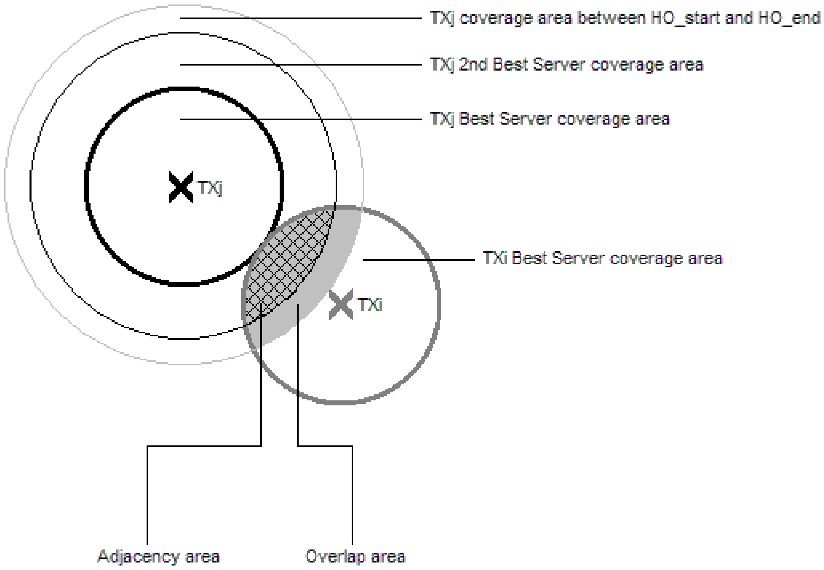
  9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Appendix: Calculation of the Inter-Transmitter Distance" on page 163.

- The calculation options,

Force co-site transmitters as neighbours: This option enables you to force transmitters located on the reference transmitter site in the candidate neighbour list. This constraints can be weighted among the others and ranks the neighbours through the importance field (see after).

Force adjacent transmitters as neighbours: This option enables you to force transmitters geographically adjacent to the reference transmitter in the candidate neighbour list. This constraints can be weighted among the others and ranks the neighbours through the importance field (see after).

Adjacence criterion: Geographically adjacent transmitters are determined on the basis of their Best Server coverages in 2G (GSM GPRS EDGE) projects. More precisely, a transmitter TXi is considered adjacent to another transmitter TXj if there exists at least one pixel of TXi Best Server coverage area where TXj is the 2nd Best Server. The ranking of the adjacent neighbour transmitter increases with the number of these pixels. The figure below shows the above concept.



- When this option is checked, adjacent cells are sorted and listed from the most adjacent to the least, depending on the above criterion. Adjacence is relative to the number of pixels satisfying the criterion.
- This criteria is only applicable to transmitters belonging to the same HCS layer. The geographic adjacency criteria is not the same in 3G (UMTS HSPA, CDMA2000) projects.

Force neighbour symmetry: This option enables user to force the reciprocity of a neighbourhood link. Therefore, if the reference transmitter is a candidate neighbour of another transmitter, the later will be considered as candidate neighbour of the reference transmitter.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a transmitter to be candidate neighbour of the reference transmitter.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept.

- There must be an overlapping zone ($S_A \cap S_B$) with a given cell edge coverage probability where:
- S_A is the area where the received signal level from the transmitter A is greater than a minimum signal level. S_A is the coverage area of reference transmitter A restricted between two boundaries; the first boundary represents the start of the handover area (best server area of A plus the handover margin named “handover start”) and the second boundary shows the end of the handover area (best server area of A plus the margin called “handover end”)
- S_B is the coverage area where the candidate transmitter B is the best server.

9955 calculates either the percentage of covered area ($\frac{S_A \cap S_B}{S_A} \times 100$) if the option “Take into account Covered Area” is selected, or the percentage of traffic covered on the overlapping area $S_A \cap S_B$ for the option “Take into account Covered Traffic”. Then, it compares this value to the % minimum covered area (minimum percentage of covered area for the option “Take into account Covered Area” or minimum percentage of covered traffic for the option “Take into account Covered Traffic”). If this percentage is not exceeded, the candidate neighbour B is discarded.

The coverage condition can be weighted among the others and ranks the neighbours through the importance field (see number 4 below).

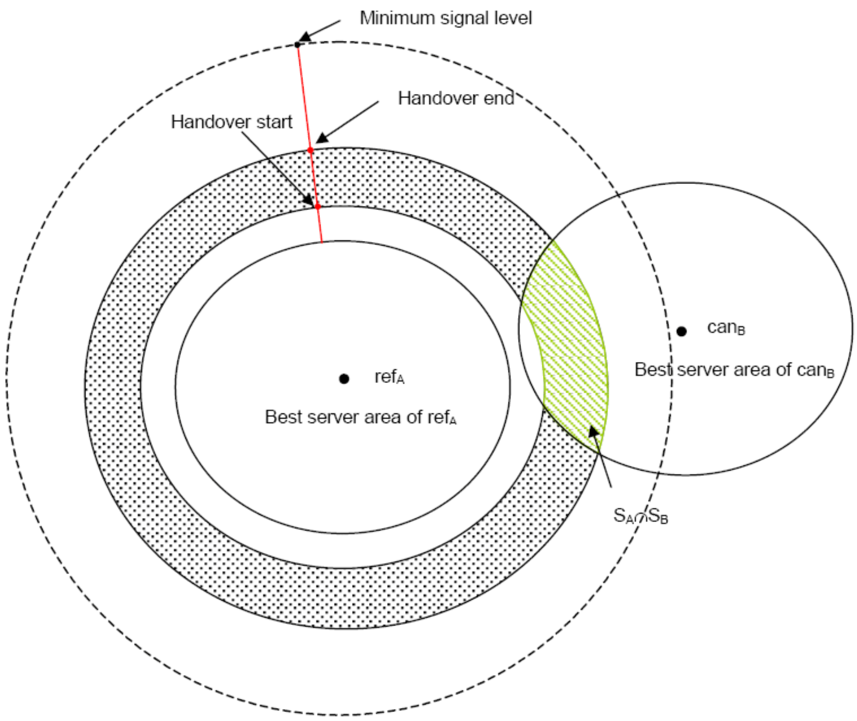


Figure 3.13: Overlapping Zones

- The importance values are used by the allocation algorithm to rank the neighbours according to the allocation reason, and to quantify the neighbour importance.

9955 lists all neighbours and ranks them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each transmitter is exceeded. If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference transmitter is 8. Among these 15 candidate neighbours, only 8 (having the highest importances) will be allocated to the reference transmitter.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site, adjacent, coverage or symmetric. For neighbours accepted for co-site, adjacency and coverage reasons, **9955** displays the percentage of area meeting the coverage conditions (or the percentage of covered traffic on this area) and the corresponding surface area (km^2) (or the traffic covered on the area in Erlangs), the percentage of area meeting the adjacency conditions and the corresponding surface area (km^2). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

- No coverage prediction is needed to perform an automatic neighbour allocation. When starting an automatic neighbour allocation, **9955** automatically calculates the path loss matrices if not found.
- **9955** uses traffic map(s) selected in the default traffic analysis in order to determine the percentage of traffic covered in the overlapping area.
- When the option “Force adjacent transmitters as neighbours” is used, the margin “handover start” is not taken into account. **9955** considers a fixed value of 0 dB.
- A forbidden neighbour must not be listed as neighbour except if the neighbourhood relationship already exists and the Delete existing neighbours option is unchecked when you start the new allocation. In this case, **9955** displays a warning in the Event viewer indicating that the constraint on the forbidden neighbour will be ignored by algorithm because the neighbour already exists.
- The force neighbour symmetry option enables the users to consider the reciprocity of a neighbourhood link. This reciprocity is allowed only if the neighbour list is not already full. Thus, if transmitter B is a neighbour of the transmitter A while transmitter A is not a neighbour of the transmitter B, two cases are possible:
- 1st case: There is space in the transmitter B neighbour list: the transmitter A will be added to the list. It will be the last one.
- 2nd case: The transmitter B neighbour list is full: **9955** will not include transmitter A in the list and will cancel the link by deleting transmitter B from the transmitter A neighbour list.
- When the options “Force exceptional pairs” and “Force symmetry” are selected, **9955** considers the constraints between exceptional pairs in both directions so as to respect symmetry condition. On the other hand, if neighbourhood relationship is forced in one direction and forbidden in the other one, symmetry cannot be respected. In this case, **9955** displays a warning in the Event viewer.
- In the Results, **9955** displays only the transmitters for which it finds new neighbours. Therefore, if a transmitter has already reached its maximum number of neighbours before starting the new allocation, it will not appear in the Results table.

3.8.2 Allocation for a Group of Transmitters or One Transmitter

In this case, **9955** allocates neighbours to:

- TBA transmitters,
- Neighbours of TBA transmitters marked as exceptional pair, adjacent and symmetric,
- Neighbours of TBA transmitters that satisfy coverage conditions.

Automatic neighbour allocation parameters are described in "Global Allocation for All Transmitters" on page 159.

3.8.3 Calculation of the Neighbour Importance

The neighbour importance depends on the distance from the reference transmitter and on the neighbourhood cause (cf. table below); this value varies between 0 and 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	Only if the Delete existing neighbours option is not selected and in case of a new allocation	Existing importance
Exceptional pair	Only if the Force exceptional pairs option is selected	100 %
Co-site transmitter	Only if the Force co-site cells as neighbours option is selected	Importance Function (IF)
Adjacent transmitter	Only if the Force adjacent cells as neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	Only if the % minimum covered area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	Only if the Force neighbour symmetry option is selected	Importance Function (IF)

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers the following factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

$$(Di) = 1 - \frac{d}{d_{max}}$$

d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Appendix: Calculation of the Inter-Transmitter Distance" on page 163.

d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The adjacency factor (A): the percentage of adjacency,
- The overlapping factor (O): the percentage of overlapping.

The minimum and maximum importance assigned to each of the above factors can be defined.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	30%
Adjacency factor (A)	Min(A)	30%	Max(A)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The Importance Function is evaluated as follows:

Neighbourhood cause		Importance Function	Resulting IF using the default values from the table above
Co-site	Adjacent		
No	No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+20%{10%(Di)+90%(O)}
No	Yes	Min(A)+Delta(A){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	30%+30%{10%(Di)+30%(O) +60%(A)}
Yes	Yes	Min(C)+Delta(C){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	60%+40%{10%(Di)+30%(O) +60%(A)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours, adjacent neighbours, and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.
- By adding an option in the atoll.ini file, the neighbour allocation and importance calculation can be based on the distance criterion only. For more information, see the *Administrator Manual*.

3.8.4 Appendix: Calculation of the Inter-Transmitter Distance

9955 takes into account the real distance (D in m) and azimuths of antennas in order to calculate the effective inter-transmitter distance (d in m).

$$d = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

where x = 0.3% so that the maximum D variation does not exceed 1%.

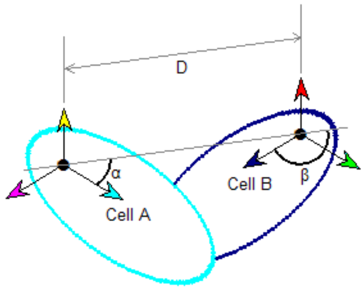


Figure 3.14: Inter-Transmitter Distance Computation

The formula above implies that two cells facing each other will have a smaller effective distance than the real physical distance. It is this effective distance that will be taken into account rather than the real distance.

3.9 AFP Appendices

3.9.1 The AFP Cost Function

The notations listed hereafter are used to describe the cost function:

- TRG: Group of TRXs
- TRGs: Set of all the TRGs
- ⇔: If and only if
- $|g|$: Size of any group g
- ARFCN: Set of all the frequencies
- 2^{ARFCN} : Set of all the subsets of frequencies
- $\lfloor x \rfloor$: The largest integer $\leq x$
- $A_{i,g}$: Number of times a group $g \in 2^{ARFCN}$ is assigned to TRG_i in the assignment A

  For example:

  - When i is NH, $A_{i,g} = 1 \Leftrightarrow$ g is a single member group containing one of the frequencies assigned at TRG_i.

    If |g| is not 1 or if g does not contain a frequency assigned at i, then $A_{i,g} = 0$.

  - When i is BBH, $A_{i,g}$ can be either 0 or equal to the number of TRXs in TRG_i.

    $A_{i,g}$ = Number of TRXs in TRG_i ⇔ g is the set of frequencies assigned to TRXs of TRG_i. (|g| = number of TRXs in TRG_i).

    When we talk about "TRXs of *i* using g", and in the case of BBH, then there are |g| such virtual TRXs, each using the entire group g and having a virtual MAIO [0, |g| - 1].

  - When i is SFH, $A_{i,g}$ must be less than or equal to the umber of TRXs in TRG_i. $A_{i,g} = n \Leftrightarrow$ g is the set of frequencies assigned to n TRXs of TRG_i.

    We assume all the groups assigned to TRG_i to have the same length.

- TS_i: Number of timeslots available for each TRX in TRG_i
- TL_i: Traffic load of TRG_i (calculated or user-defined)

  $TL_i = \#Erlangs$ of a single TRX in TRG_i divided by TS_i

- TSU_i: Downlink timeslot use ratio (due to DTX) at TRG_i
- CF_i: Cost factor of TRG_i (AFP Weight)
- $QMIN_i$: Minimum required quality (in C/I) at TRG_i
- $PMAX_i$: Percentage permitted to have quality lower than $QMIN_i$ at TRG_i
- REQ_i: Required number of TRXs at TRG_i

A communication uses the group *g* in TRG_i if its mobile allocation is g. The probability to be interfered is denoted by $P_{i,i',g}(A)$ (*i'* is the TRX index). Different TRX indexes may have different MAIOs. $P_{i,i',g}(A)$ is a function of the whole frequency assignment. The precise definition of the term "to be interfered" is provided afterwards. The probability penalty due to violating a separation constraint is $P_{i,i',g}(A)$. It is a function of the whole frequency assignment as well.

The term "Atom" will be used in the following context:

For two TRGs, i and k,

$$ATOM(i) \equiv ATOM(k)$$

i and k are synchronised, have the same HSN, the same MAL length and the same hopping mode.

NH TRGs or BBH TRGs are always in separate atoms. If two TRGs interfere but are not in the same atom, these can be taken as unsynchronised. The quality of unsynchronised TRGs is a function of all possible frequency combinations. For synchronised TRGs, pairs of frequencies emitted at the same time are known.

3.9.1.1 Cost Function

The **9955** AFP cost function is a TRX based cost and not an interference matrix entry based cost. It counts the impaired traffic of the network TRXs in weighted Erlangs.

The cost function Ψ is reported to the user during the AFP progress with the help of its 5 components: Ψ_{mis}, Ψ_{sep}, Ψ_{comp}, Ψ_{corr} and Ψ_{dom}.

$$\Psi = \Psi_{mis} + \Psi_{sep} + \Psi_{comp} + \Psi_{corr} + \Psi_{dom}$$

where,

Ψ_{mis} represents the missing TRX cost component

Ψ_{sep} represents the separation component

Ψ_{comp} represents the additional cost component (interference, cost of changing a TRX)

Ψ_{corr} represents the corrupted TRX cost component

Ψ_{dom} represents the out-of-domain frequency assignment cost component

$$\Psi_{mis} = \sum_{i \in TRGs} (MIS\_TRX_i \times \lambda) \times TL_i \times CF_i \times TS_i$$

$$\Psi_{corr} = \sum_{i \in TRGs} (CORR\_TRX_i \times \Omega) \times TL_i \times CF_i \times TS_i$$

$$\Psi_{dom} = \sum_{i \in TRGs} (DOM\_TRX_i \times \omega) \times TL_i \times CF_i \times TS_i$$

$$\Psi_{sep} = \sum_{i \in TRGs} \left(\sum_{\substack{g \in 2^{ARFCN} \\ i' \in \text{TRXs of } i \text{ using } g}} \delta'_{i,i',g}(A) \right) \times TL_i \times CF_i \times TS_i$$

$$\Psi_{comp} = \sum_{i \in TRGs} \left(\sum_{\substack{g \in 2^{ARFCN} \\ i' \in \text{TRXs of } i \text{ using } g}} \delta''_{i,i',g}(A) \right) \times TL_i \times CF_i \times TS_i$$

In the above equations,

- i' is the TRX index belonging to $\{0, 1, ..., A_{i,g} - 1\}$.
- MIS_TRX_i is the number of missing TRXs for the subcell *i*.

$$MIS\_TRX_i = MAX\left[0, REQ_i - \sum_{g \in 2^{ARFCN}} A_{i,g}\right]$$

- λ is the cost value for a missing TRX. This value can vary between 0 and 10. The default cost value is set to 1 and can be modified in the AFP module properties dialog.

- $CORR\_TRX_i$ is the number of corrupted TRXs for the subcell *i*.
- Ω is the cost value of a corrupted TRX. This value can vary between 0 and 10. The default cost value is set to 10 and can be modified in the AFP module properties dialog.
- DOM_TRX_i is the number of TRXs, for the subcell *i*, having out-of-domain frequencies assigned.
- ω is the cost value of a TRX with out-of-domain frequencies assigned. This value can vary between 0 and 1. The default cost value is set to 0.5 and can be modified in the AFP module properties dialog.

  And, as mentioned earlier, a virtual TRX is considered in case of BBH.

  If *i'* is valid, the algorithm evaluates the cost of a valid TRX. This cost has two components, $\delta'_{i, i', g}(A)$ and $\delta''_{i, i', g}(A)$.

- $\delta'_{i, i', g}(A)$ is the separation violation probability penalty.
- $\delta''_{i, i', g}(A)$ is complementary probability penalty due to interference and the cost of modifying a TRX.

  If the option “Take into account the cost of all the TRXs” available in the AFP module properties dialog is selected, then,

  $\delta'_{i, i', g}(A) = P'_{i, i', g}(A)$ and $\delta''_{i, i', g}(A) = P''_{i, i', g}(A)$

  Or if the option “Do not include the cost of TRXs having reached their quality target” available in the AFP module properties dialog is selected, the algorithm compares $P'_{i, i', g}(A) + P''_{i, i', g}(A)$ with the quality target specified for *i*, P_{MAX}:

  If $P'_{i, i', g}(A) + P''_{i, i', g}(A) > P_{MAX}$,

  Then $\delta'_{i, i', g}(A) = P'_{i, i', g}(A)$ and $\delta''_{i, i', g}(A) = P''_{i, i', g}(A)$.

  Otherwise,

  Both $\delta'_{i, i', g}(A)$ and $\delta''_{i, i', g}(A)$ will be equal 0.

$P'_{i, i', g}(A)$ is the same as $\delta'_{i, i', g}(A)$ (separation violation probability penalty) and $P''_{i, i', g}(A)$ the same as $\delta''_{i, i', g}(A)$ (complementary probability penalty due to interference and the cost of modifying a TRX) in most cases. These are explained in detail in the next sections.

3.9.1.2 Cost Components

Separation violation and interference cost components are described hereafter. Parameters considered in the cost function components can be fully controlled by the user. Some of these parameters are part of the general data model (quality requirements, percentage of interference allowed per subcell), while others (such as separation costs and diversity gains) can be managed through the properties dialog of the **9955** AFP module.

3.9.1.2.1 Separation Violation Cost Component

The separation violation cost component is evaluated for each TRX. Estimation is based on costs specified for the required separations.

Let $SEP\_CONSTR_{i, k}$ denote the required separation constraint between TRG_i and TRG_k. Let $Cost_{s, z}$ denote the user defined separation penalty for a required separation “s” and actual separation “z”. $SEP_{i, k, v}$ is used instead of $Cost_{SEP\_CONSTR_{i, k}, z}$ as abbreviation.

> The AFP module properties dialog takes probability percentages as inputs while this document deals in probability values.

$\xi_{ii'kgg'k'}$ is considered to be the effect of a separation violation on the i' th TRX of TRG_i assigned the group g, caused by the k' th TRX of TRG_k assigned the group g'.

γ denotes the overall weight of the separation violation cost component. This value can be between 0 and 1, set to 1 by default. It can be modified in the AFP module properties dialog.

γik represents the weight of the specific separation constraint between i and k. This specific weight depends on the type of separation violation and follows the following priority rule:

1. Exceptional pairs
2. Co-transmitters
3. Co-site
4. Neighbours

For example, if a pair of subcells are co-site and neighbours at the same time, they will be considered as co-site because higher priority. Hence, γik of these subcells will be the weight of co-site relations. If only a neighbour relation exists between two subcells, then γik will be further weighted by the neighbour relation importance. The value of γik remains between 0 and 1. The default weights of each type of separation are available in the Separation cost tab.

If $ATOM(i) \neq ATOM(k)$

$$\text{Then } \xi_{ii'kgg'k'} = \gamma \times \gamma ik \times \frac{\sum_{\substack{f \in g \\ f \in g'}} SEP_{i,k,|f-f'|}}{|g| \times |g'|}$$, which is same for all values of k.

If $ATOM(i) = ATOM(k)$

$$\text{Then } \xi_{ii'kgg'k'} = \gamma \times \gamma ik \times \frac{\sum_{f\_n \in \{0, 1, \ldots, F\_N-1\}} SEP_{i,k,|g_{\upsilon} - g'_{\tau}|}}{F\_N}$$

In the above equations, $F\_N(g)$ is the number of frames in the MAL g. $F\_N(g) = |g|$.

Since $F\_N(g) = F\_N(g')$, we shortly denote the two as F_N.

Let f_n denote the instantaneous frame number from 0 to F_N.

While $\upsilon = (f\_n + MAIO_{A_{i,g,i'}}) \text{ modulo} F\_N$ and g_{υ} is the υ^{th} frequency in g,

And $\tau = (f\_n + MAIO_{A_{k,g',k'}}) \text{ modulo} F\_N$ and g'_{τ} is the τ^{th} frequency in g'.

In addition, frequencies belonging to a MAL with a low fractional load, and breaking a separation constraint, should not be weighted equally as in a non-hopping separation breaking case. Therefore, the cost is weighted by an interferer diversity gain.

$$\hat{G}_{i,k,g,g'} = \frac{1}{10^{(0.1 \times SEP\_GAIN(i,k,|g|,|g'|))}}$$

The separation gain, denoted by $SEP\_GAIN(i, k, |g|, |g'|)$ is basically a function of the MAL length (and, of course, of the hopping mode). With frequency hopping, the effects of DTX and traffic load become more significant (due to the consideration of the average case instead of the worst case). For this reason, it is possible to consider these effects in $SEP\_GAIN(i, k, |g|, |g'|)$ through the relevant option available in the Advanced tab of the AFP module properties dialog. Without this option, the $SEP\_GAIN(i, k, |g|, |g'|)$ is:

$$SEP\_GAIN(i, k, |g|, |g'|) = I\_DIV(|g|)$$

$I\_DIV(|g|)$ is the user defined interferer diversity gain (dB) for a given MAL length. It is used in $P_{i,i',g}(A)$ definition as well.

On the other hand, if this option is selected, the $SEP\_GAIN(i, k, |g|, |g'|)$ becomes,

$$SEP\_GAIN(i, k, |g|, |g'|) = I\_DIV(|g|) + \left(0.5 \times TSU\_GAIN(k) \times min\left(10, 4 + \left((2 + I\_DIV(|g|)) \times \frac{(2 + ASYN\_GAIN(i, k, |g'|))}{4}\right)\right)\right)$$

Where $TSU\_GAIN(k) = log_{10}\left(\frac{1}{TL_k \times TSU_k}\right)$, And $ASYN\_GAIN(i, k, |g'|) = \begin{cases} 0 & \text{if } ATOM(i) = ATOM(k) \\ I\_DIV(|g'|) & \text{Otherwise} \end{cases}$

More than one separation violations may exist for a TRX. Many "small" $\hat{G}_{i, k, g, g'}$ and $\xi'_{ii'kgg'}$ have to be combined to form one cost element, the $P'_{i, i', g}(A)$. This is done through iterating over all violating assignments and by summing up an equivalent to the probability of not being violated while considering each separation violation as an independent probability event. This sum is naturally limited to 100% of the TRX traffic, and is given by,

$$P'_{i, i', g}(A) = \left(1 - \prod_{\substack{k \in TRGs \\ g' \in 2^{ARFCN} \\ k' \in TRXs\ of\ k\ using\ g'}} (1 - \xi_{ii'kgg'k'} \times \hat{G}_{i, k, g, g'}) \right)$$

In the above formula, if $(k = i)$, then $(k' \neq i')$, so that interference with itself is not taken into account.

3.9.1.2.2 Interference Cost Component

The interference cost component is evaluated for each TRX. Its estimation is based on interference histograms calculated for pairs of subcells. In addition, it takes into account frequency and interferer diversity gains and models frequency hopping and gain due to DTX.

> Interference histograms are described in User Manual (GSM GPRS EDGE project management, GSM GPRS EDGE network optimisation, GSM GPRS EDGE generic AFP management). Interference histograms can also be exported to files. For further description, refer to "Interference" on page 173.

When estimating $P''_{i, i', g}(A)$, the following problems are encountered:

- The QMINi C/I quality indicator corresponds to the accumulated interference level of all interferers while the C/I interference histograms correspond to pair-wise interferences.
- Both QMINi and the histograms correspond to a single frequency. In case of a MAL containing more than one frequencies, interferences on several different frequencies of a MAL must be combined.

  This estimation, presented below, is the simplest possible as it solves the first problem by linear summation and truncation at the value of 1 and it solves the second problem by averaging and adding the two diversity gains:

- $F\_DIV(|g|)$, the frequency diversity gain, and
- $I\_DIV(|g|)$, the interferer diversity gain.

Hereafter, α denotes the global weight of interference cost component. This value can vary between 0 and 1 and is set to 0.35 by default, which can be modified in the AFP module properties dialog.

Let $F\_N(g)$ be the number of frames in the MAL *g*. $F\_N(g) = |g|$.

Let f_n denote the instantaneous frame number from 0 to F_N.

Let $MAIO_{A_{k, g', j}}$ be the *j*'th MAIO of $A_{k, g'}$, where *j* is one of the $\{0, 1, ..., A_{k, g'} - 1\}$ TRXs.

The value of $MAIO_{A_{k, g', j}}$ is one of $\{0, 1, ..., |g'|\}$

If TRG_k is NH, then $MAIO_{A_{k, g', j}} = 0$.

If TRG_k is BBH, then $MAIO_{A_{k, g', j}} = j$.

As said earlier, in case of BBH, we consider $|g'|$ virtual TRXs, the *j*th TRX has the MAIO j.

Let g_i be the *i*th frequency in the group *g*.

Similar to the definition of $\xi_{ii'kgg'k'}$, $\xi'_{ii'kgg'k'}$ is defined as an interference event. $\xi'_{ii'kgg'k'}$ is the effect interference on the i' th TRX of TRG_i assigned the group g, caused by the k' th TRX of TRG_k assigned the group g'.

If $ATOM(i) \neq ATOM(k)$

Then $\xi'_{ii'kgg'k'} = \sum_{f \in g,\ f' \in g'} \frac{Probability\left(\frac{C}{I_{ik}} < Q\_UB_{i,k,f,f'}\right)}{|g| \times |g'|}$

Where $Q\_UB_{i,k,f,f'} = QMIN_i - \lfloor |f - f'| \times ADJ\_SUP + INTERF\_GAIN(i, k, |g|, |g'|) \rfloor$

If $ATOM(i) = ATOM(k)$

Then,

Since $F\_N(g) = F\_N(g')$, these are both represented by F_N.

$$\xi_{ii'kgg'k'} = \sum_{f\_n \in \{0, 1, \ldots, F\_N - 1\}} \left\{ \frac{Probability\left(\frac{C}{I_{ik}} < Q\_UB_{i,k,f,f'}\right)}{F\_N} \right\}$$

Where,

$f = g_{\upsilon}$,

$f' = g'_{\tau}$,

$\upsilon = (f\_n + MAIO_{A_{i,g,i'}})$ modulo F_N,

$\tau = (f\_n + MAIO_{A_{k,g',k'}})$ modulo F_N,

$Q\_UB_{i,k,f,f'} = QMIN_i - \lfloor |f - f'| \times ADJ\_SUP + INTERF\_GAIN(i, k, |g|, |g'|) \rfloor$

Therefore, we have, $P''_{i,i',g}(A) = 1 - \left\{ (1 - P'_{i,i',g}(A)) \times \prod_{\substack{k \in TRGs \\ g' \in 2^{ARFCN} \\ k' \in TRXs\ of\ k\ using\ g'}} (1 - \xi_{ii'kgg'k'}) \right\} - P'_{i,i',g}(A)$

In the above formula, if $(i = k)$, then $(k' \neq i')$, so that interference with itself is not taken into account.

The sum is limited to 100% of the TRX traffic. $INTERF\_GAIN(i, k, |g|, |g'|)$ is quite similar to $SEP\_GAIN(i, k, |g|, |g'|)$. The only difference is the frequency diversity gain, $F\_DIV(|g|)$, added to $SEP\_GAIN(i, k, |g|, |g'|)$.

3.9.1.2.3 I_DIV, F_DIV and Other Advanced Cost Parameters

When combining interference effects (or separation violation effects) on different frequencies belonging to a MAL, the following considerations should be taken into account:

1. Non-linearity of Frame Error Rate (FER) with respect to average C/I conditions and MAL length.
2. Interference Diversity Gain. This factor represents that the effect of average negative effects over user geographic location are directly proportional to the MAL length.
3. Frequency Diversity Gain. This factor models the gain due to diversity of multi-path effects and should be applied to the interference cost component only.
4. The fact that long MALs with synthesized hopping permit discarding the worst case estimation and include a gain due to DTX and low traffic load at the interferer end.

The Advanced properties tab shown in the figure below facilitates modelling these effects.

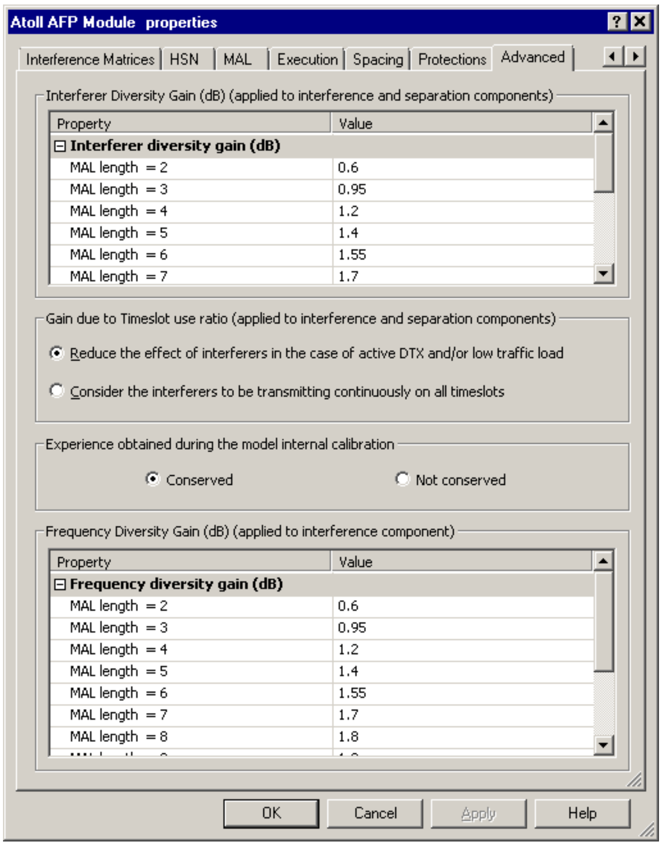


Figure 3.15: The Advanced tab of the AFP module Properties dialogue

The Interference Diversity Gain table lists the values of I_DIV provided as a functions of MAL length. This gain is applied to the interference cost component and to the separation constraint violation cost component. Therefore, it provides a means to model the non-linear FER effects and interference diversity both. The default values in this table correspond to the curve $y = 2 \times log_{10}(x)$. This equation generates values somewhat lower than empirical best-found values (this is because we prefer a slightly pessimistic cost function to be on the safe side).

The other table contains the F_DIV values, which are the same as the I_DIV values by default.

3.9.2 The AFP Blocked Traffic Cost

This section provides additional information on the AFP cost components used for the optimisation of the number of TRXs. This optimisation is performed for each traffic pool in the network. In most cases, the traffic pool is equivalent to a transmitter and corresponds to the BCCH and TCH subcells. In more complex cases, a traffic pool may include additional subcells, and more than one traffic pools may exist per transmitter.

The cost component described below, and the recalculation of traffic loads, is only used when the AFP performs the oprimisation of the number of TRXs.

The notations listed hereafter are used for the description.

- {BCCH, TCH(1), TCH(2), ..., TCH(n)}: Subcells of a traffic pool.

  For concentric cells, at least two traffic pools exist per transmitter. The BCCH subcell may not always be part of the pool's TRX types.

- {d(0), d(1), d(2), ..., d(n)}: Number of required TRXs of each TRX type in the pool
- {ts(0), ts(1), ts(2), ..., ts(n)}: Numbers of traffic timeslots
- {L(0), L(1), L(2), ..., L(n)}: Traffic loads
- {CF(0), CF(1), CF(2), ..., CF(n)}: AFP cost factors
- CS (Erlangs): Overall circuit-switched traffic demand of the traffic pool (Subcells table or traffic analysis results)
- PS (Data Timeslots): Overall packet-switched traffic demand of the traffic pool (Subcells table or traffic analysis results)

  If CS or PS is less than 1, its value is set to 1 in order to avoid working with transmitters carrying no traffic.

- {nb(0), nb(1), nb(2), ..., nb(n)}: Number of TRXs in the frequency plan
- {HR(0), HR(1), HR(2), ..., HR(n)}: TCH HR use ratios

3.9.2.1 Calculation of New Traffic Loads Including Blocked Traffic Loads

During the optimisation of the number of TRXs, traffic loads are calculated in order to determine the blocked traffic loads $BL(\overrightarrow{nb})$. The blocked traffic load is then multiplied by the AFP cost weight and the number of timeslots to calculate the blocked traffic cost.

Without the optimisation of the number of required TRXs, the network's weighted Erlangs are calculated as follows:

$$WE = \sum_{i=0}^{n} d(i) \times ts(i) \times L(i) \times CF(i)$$

With the optimisation of the number of TRXs, the network's weighted Erlangs are calculated as follows:

$$WE = \sum_{i=0}^{n} nb(i) \times ts(i) \times \{BL(\overrightarrow{nb}) + L(\overrightarrow{nb})\} \times CF(i)$$

$BL(\overrightarrow{nb})$ and $L(\overrightarrow{nb})$ represent the load estimation and the blocked load estimation of the AFP. They are calculated at traffic pool level for the vector {nb(0), nb(1), nb(2), …, nb(n)} as follows:

$$BL(\overrightarrow{nb}) + L(\overrightarrow{nb}) = \frac{PS + \left\{CS \times \left(1 - \frac{\lceil HR \rceil}{2}\right)\right\}}{Max\left(1, \sum_{i=0}^{n} nb(i) \times ts(i)\right)}$$

Where $\lceil HR \rceil = Max_{i=0}^{n}(HR(i))$

$BL(\overrightarrow{nb})$ is determined from the above equation once $L(\overrightarrow{nb})$ is known. $L(\overrightarrow{nb})$ is obtained from the Erlang B equation applied to the traffic pool demand and the total number of timeslots (TTS):

$$TTS = Max\left(1, \sum_{i=0}^{n} \frac{nb(i) \times ts(i)}{\left(1 - \frac{\lceil HR \rceil}{2}\right)}\right)$$

The Max() function above gives 1 timeslot when there is no TRX.

$$P_{Blocking} = ErlangB(CS, TTS)$$

The above equations give the number of served circuit-switched timeslots (SCS):

$$SCS = \left(1 - \frac{\lceil HR \rceil}{2}\right) \times CS \times (1 - P_{Blocking})$$

The number of served packet-switched timeslots (SPS) is obtained as follows:

$$SPS = Min\left\{PS, Max\left(1, \sum_{i=0}^{n} nb(i) \times ts(i)\right) - SCS\right\}$$

$L(\overrightarrow{nb})$ is given by:

$$L(\overrightarrow{nb}) = \frac{SCS + SPS}{Max\left(1, \sum_{i=0}^{n} nb(i) \times ts(i)\right)}$$

$BL(\overrightarrow{nb})$ is given by:

$$BL(\overrightarrow{nb}) = \frac{PS + CS \times \left(1 - \frac{\lceil HR \rceil}{2}\right)}{Max\left(1, \sum_{i=0}^{n} nb(i) \times ts(i)\right)} - L(\overrightarrow{nb})$$

Once $L(\overrightarrow{nb})$ and $BL(\overrightarrow{nb})$ are known, $L(\overrightarrow{nb})$ replaces TLi in the cost function (See "The AFP Cost Function" on page 164), and $BL(\overrightarrow{nb})$ is used to generate a new cost component, the blocked Erlangs of the pool:

$$\sum_{i=0}^{n} nb(i) \times ts(i) \times BL(\overrightarrow{nb}) \times CF(i)$$

3.9.2.2 Recalculation of CS and PS From Traffic Loads

In earlier versions, the detailed traffic demand information is not available. In order to guide the AFP to generate it from the loads, the following two equations with three variables must be solved. The equations are solvable due to the monotone nature of the Erlang B function.

Inputs for a given traffic pool:

- {d(0), d(1), d(2), ..., d(n)}: Number of required TRXs of each TRX type in the pool
- L: Traffic load
- TTS': $TTS' = Max\left(1, \sum_{i=0}^{n} \frac{d(i) \times ts(i)}{\left(1 - \frac{\lceil HR \rceil}{2}\right)}\right)$
- MB: Maximum blocking rate (between 0 and 1).

The ratio of packet-switched demand is given by:

$$R = \frac{PS}{PS + CS \times \left(1 - \frac{\lceil HR \rceil}{2}\right)}$$

Here, we assume that a traffic load of 1 is generated by a demand of (1+MB)*TTS’ which generates a blocking rate of MB. In other words, the ratio is calculated so that the worst case blocking rate is BM, giving a load of 1.

The following equations are solved to find PS’, CS’, and R’, which are calculated for a traffic load of 1.

$$MB = ErlangB(CS', TTS')$$

$$R' = \frac{PS'}{PS' + CS' \times \left(1 - \frac{\lceil HR \rceil}{2}\right)}$$

$$(1 + MB) \times TTS' = \frac{PS'}{\left(1 - \frac{\lceil HR \rceil}{2}\right)} + CS'$$

When the traffic load of a pool is not 1, PS is different from PS’ and CS is different from CS’. Here, however, we assume that R’ = R. This assumption implies that R is more or less the same as MB for big traffic pools and considerably larger than MB for smaller pools.

The following equations are solved to find PS, CS, and R, which are calculated for the actual traffic loads.

$$R = \frac{PS}{PS + CS \times \left(1 - \frac{\lceil HR \rceil}{2}\right)}$$

$$P_{Blocking} = ErlangB(CS, TTS')$$

$$SCS = \left(1 - \frac{\lceil HR \rceil}{2}\right) \times CS \times (1 - P_{Blocking})$$

$$SPS = Min\left\{PS, Max\left(1, \sum_{i=0}^{n} d(i) \times ts(i)\right) - SCS\right\}$$

$$SCS + SPS = \sum_{i=0}^{n} d(i) \times ts(i) \times L(i)$$

The above five equations are solved to get the values of the five variables PS, PC, $P_{Blocking}$, SCS, SPS, and calculate the cost.

3.9.2.3 Testing the Blocked Cost Using Traffic Analysis

As long as the conditions below hold truw, the blocked cost calculation in the AFP and the effective overflow calculation in the KPI calculation and dimensioning use the same algorithm. The conditions are:

- The AFP cost factors are 1,
- The HR ratios are the same within the subcells of a traffic pool,
- The dimensioning model is based on Erlang B,
- The timeslot configurations are the default ones,
- There exists at least one TRX in the traffic pool (and at least one Erlang of traffic),
- All transmitters belong to the same HCS Layer.

Effective Overflow rate = $1 - \frac{L(\overrightarrow{nb})}{L(\overrightarrow{nb}) + BL(\overrightarrow{nb})}$

Output: New values for CS and PS.

3.9.3 Interference

This appendix provides a high-level overview of interference taken into account by the AFP.

3.9.3.1 Using Interferences

If interferences are to be taken into account by the AFP, they must be calculated or imported beforehand. In order to do this, the user should previously decide to **take interferences into account** (enabling the loading of all the potential interferers). Otherwise, **9955** does not allow performing their computation by disabling the histogram part in the corresponding dialogue.

3.9.3.2 Cumulative Density Function of C/I Levels

For each [interfered subcell, interfering subcell] pair, **9955** calculates a C/I value on each pixel of the interfered subcell service area (as if the two subcells share the same channel). Then, **9955** integrates these C/I values to determine a C/I distribution and transforms this distribution function into a cumulative density function in the normal way.

In **9955**, both the IM_{co} and IM_{adj} are represented by this Cumulative Density function This implies that each query for the probability to have C/I conditions worse than X dB requires a single memory access: the co-channel interference probability at X dB. In order to deduce the adjacent interference probability value, **9955** looks up the cumulative density function at the value corresponding to X - Y dB, Y dB being the adjacency suppression value. The following example may be helpful in further clarifying this concept:

Example: Let [TX1, BCCH] and [TX2, BCCH] be the interfered and interfering subcells respectively. The service areas for both have been defined by Best Server with 0 dB margin. The interference probability is stated in percentage of interfered area.

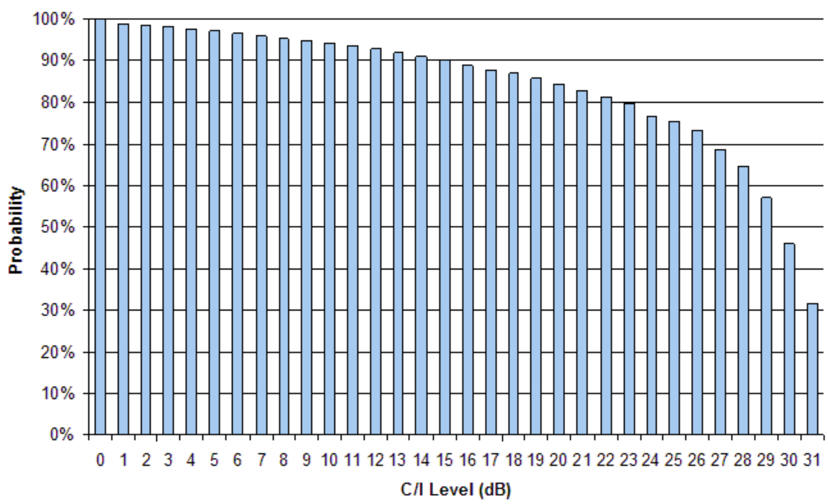


Figure 3.16: The cumulative density of C/I levels between [TX1, BCCH] and [TX2, BCCH]

In this case, we observe that the probability for C/I (BCCH of TX2 effecting the BCCH of TX1) being greater than 0 is 100% (which is normal because TX1 is the Best Server). The probability of having a C/I value at least equal to 31 dB is 31.1%. For a required C/I level of 12 dB on the BCCH of TX1, the interference probability is 6.5% (as this requirement is fulfilled with a probability of 93.5%).

The subcell power offset does not enter the calculation results in the .clc file. It is added later by the AFP interface. On the other hand, its influence on the subcell service zone is taken into account in the .clc file.

3.9.3.3 Precise Definition

$Pci(v, n, C\_I)$ is defined to be the probability of a communication (call) occupying a timeslot in subcell v (victim) to have C/I conditions of C_I with respect to a co-channel interference from the BCCH TRX of cell n (neighbour). We assume C_I values to be discrete and in dB. CDF(Pci) is the cumulative density function of Pci:

$$CDF(Pci(v, n, C\_I)) = \sum_{x > C\_I} Pci(v, n, x)$$

3.9.3.4 Precise Interference Distribution Strategy

Why does **9955** calculate and maintain precise interference distributions, while the most common solution (used by most other tools) is rather to compress the information into two values: the co-channel and adjacent-channel interference probabilities?

The reason is simply that it,

- improves the AFP result,
- introduces very little (or no) overhead, and
- creates more generic interference information.

3.9.3.4.1 Direct Availability of Precise Interference Distribution to the AFP

In the presence of frequency hopping, and when one or more frequencies are common (or adjacent) in two interfering MAL sequences, the hopping gain depends on following factors:

- the MAL length,
- the traffic load on the interferer TRX,
- DTX level, and
- the number of common (and adjacent) frequencies in the two MALs.

All these factors cannot be pre-calculated since it is the AFP that determines the MAL length and the MAL frequencies.

3.9.3.4.2 Efficient Calculation and Storage of Interference Distribution

In the innermost loop of the calculation process **9955** increments a counter each time a C/I level has a certain value. In the case of a two-entry IM, there are only two counters for each [interfered, interferer] pair. In the case of precise distribution information, there are about 40 counters per pair. In both cases, the number of operations is the same: one increment of an integer value. Once **9955** finishes the counting for an [interfered, interferer] pair, it compresses the information from the counters to a Cumulative Density Function (CDF) representation. In this way, access to interference probability at a certain level is instantaneous. Thus, the only overheads are the read / write times to the files and the memory occupation at running time. These two overheads are negligible and do not affect the calculations, the heaviest part of the task.

3.9.3.4.3 Robustness of the IM

By having precise C/I distributions calculated and exported, the user is free to change the following settings without the need for recalculating their interference distributions:

1. Quality requirements of network elements (required C/I, % Probability Max, ...),
2. C/I weighting (the interference levels above and below the C/I target),
3. Separation requirements and/or neighbour relations,
4. Hopping gain values, DTX activities, traffic load levels, HSNs, synchronisation information,
5. Any frequency assignment setting (MAL length directives, frequency domains, assignment strategies, number of required TRXs, cost function parameters, ...), or
6. Remove equipment

By not mixing any of the elements above, the interference information keeps its original probability units and is easier to check and validate. Therefore, the user spends less time on interference recalculations than in the case of a two-entry matrix (where “everything” is included).

3.9.3.5 Traffic Load and Interference Information Discrimination

9955 maintains the traffic load separate from the interference information. The reasons for implementing this strategy are explained here.

Let us look at the possible alternatives to this strategy:

1. **The mixed option:** The interference information contains the traffic information as well. In this way, each IM entry will contain the quantity of traffic interfered if a co-channel / adjacent channel reuse exists.
2. **The separated option:** The AFP has separate access to traffic load information and to interference probabilities (As in **9955**).

Knowing the difference between the two alternative solutions explains why the second strategy has been opted for for **9955**. However, in detail, this has been done because:

- Option 2 is a superset that contains option 1. But option 1, being a subset, does not contain option 2 (i.e. once the information are mixed they cannot be separated).
- It does not create any overhead (the size of the additional information is negligible compared to the size of the IM).
- It helps keeping the unit definitions simpler.
- It is facilitates merging IMs with different traffic units.
- The traffic information can be used for weighting the separation violation component.
- The traffic load can be used in deciding whether a TRX can be left uncreated.

  For example, if there are too many TRXs at a site and the user wishes that the AFP remove one of them, in order to be able to not violate site constraints, the AFP must know the traffic loads in order to choose a low load TRX to be removed.

- The gain introduced by the traffic load of the interferer depends on the hopping mode and the MAL size. Incorporating this gain in the IM (as a result of the mixed option) means that the IMs become hopping-mode and MAL-size dependent. This is a bad idea since the AFP should be able to change the MAL. And the user should be able to change the hopping mode without recalculating the IM. In addition, an IM calculated externally to **9955**, with a non-hopping BCCH can be used for the hopping TCH.

A third option also exists. Though, this option is so practically useless due to its inefficiency. It consists in mixing IM and traffic but still keeping the traffic in its isolated form. This is again a bad idea because of the unit definition and the variety of IM sources. It involves less benefits than the option chosen in **9955**.

Chapter 4

UMTS HSPA Networks

This chapter describes UMTS HSPA calculations.

In this chapter, the following are explained:

- "General Prediction Studies" on page 179
- "Definitions and Formulas" on page 182
- "Active Set Management" on page 192
- "Simulations" on page 192
- "UMTS HSPA Prediction Studies" on page 253
- "Automatic Neighbour Allocation" on page 279
- "Primary Scrambling Code Allocation" on page 286
- "Automatic GSM-UMTS Neighbour Allocation" on page 296

4 UMTS HSPA Networks

4.1 General Prediction Studies

4.1.1 Calculation Criteria

Three criteria can be studied in point analysis (*Profile* tab) and in common coverage studies. Study criteria are detailed in the table below:

Study criteria	Formulas
Signal level (P_{rec}) in dBm	Signal level received from a transmitter on a carrier (cell) $P_{rec}(ic) = EIRP(ic) - L_{path} - M_{Shadowing-model} - L_{Indoor} + G_{term} - L_{term}$
Path loss (L_{path}) in dBm	$L_{path} = L_{model} + L_{ant_{Tx}}$
Total losses (L_{total}) in dBm	$L_{total} = (L_{path} + L_{Tx} + L_{term} + L_{indoor} + M_{Shadowing-model}) - (G_{Tx} + G_{term})$

where,

EIRP is the effective isotropic radiated power of the transmitter,

ic is a carrier number,

L_{model} is the loss on the transmitter-receiver path (path loss) calculated by the propagation model,

$L_{ant_{Tx}}$ is the transmitter antenna attenuation (from antenna patterns),

$M_{Shadowing-model}$ is the shadowing margin. This parameter is taken into account when the option “Shadowing taken into account” is selected,

L_{Indoor} are the indoor losses, taken into account when the option “Indoor coverage” is selected,

L_{term} are the receiver losses,

G_{term} is the receiver antenna gain,

G_{Tx} is the transmitter antenna gain,

L_{Tx} is the transmitter loss ($L_{Tx} = L_{total-DL}$). For information on calculating transmitter loss, see "UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents" on page 26.

- $EIRP(ic) = P_{pilot}(ic) + G_{Tx} - L_{Tx}$ ($P_{pilot}(ic)$ is the cell pilot power).
- It is possible to analyse the best carrier. In this case, **9955** takes the highest pilot power of cells to calculate the signal level received from a transmitter.
- **9955** considers that G_{term} and L_{term} equal zero.

4.1.2 Point Analysis

4.1.2.1 Profile Tab

9955 displays either the signal level received from the selected transmitter on a carrier ($P_{rec}(ic)$), or the highest signal level received from the selected transmitter on the best carrier.

For a selected transmitter, it is also possible to study the path loss, L_{path}, or the total losses, L_{total}. Path loss and total losses are the same on any carrier.

4.1.2.2 Reception Tab

Analysis provided in the Reception tab is based on path loss matrices. So, you can study reception from TBC transmitters for which path loss matrices have been computed on their calculation areas.

For each transmitter, **9955** displays either the signal level received on a carrier, ($P_{rec}(ic)$), or the highest signal level received on the best carrier.

Reception bars are displayed in a decreasing signal level order. The maximum number of reception bars depends on the signal level received from the best server. Only reception bars of transmitters whose signal level is within a 30 dB margin from the best server can be displayed.

- For a selected transmitter, it is also possible to study the path loss, L_{path}, or the total losses, L_{total}. Path loss and total losses are the same on any carrier.
- You can use a value other than 30 dB for the margin from the best server signal level, for example a smaller value for improving the calculation speed. For more information on defining a different value for this margin, see the *Administrator Manual*.

4.1.3 Coverage Studies

For each TBC transmitter, Txi, **9955** determines the selected criterion on each pixel inside the Txi calculation area. In fact, each pixel within the Txi calculation area is considered as a potential (fixed or mobile) receiver.

Coverage study parameters to be set are:

- The study conditions in order to determine the service area of each TBC transmitter,
- The display settings to select how to colour service areas.

4.1.3.1 Service Area Determination

9955 uses parameters entered in the *Condition* tab of the coverage study property dialogue to predetermine areas where it will display coverage.

We can distinguish three cases:

4.1.3.1.1 All Servers

The service area of Txi corresponds to the bins where:

$$MinimumThreshold \le P_{rec}^{Txi}(ic)(or\ L_{total}^{Txi}\ or\ L_{path}^{Txi}\ ) < MaximumThreshold$$

4.1.3.1.2 Best Signal Level and a Margin

The service area of Txi corresponds to the bins where:

$$MinimumThreshold \le P_{rec}^{Txi}(ic)(or\ L_{total}^{Txi}\ or\ L_{path}^{Txi}\ ) < MaximumThreshold$$

And

$$P_{rec}^{Txi}(ic) \ge \underset{j \ne i}{Best}\ (P_{rec}^{Txj}(ic)) - M$$

M is the specified margin (dB).

Best function: considers the highest value.

- If the margin equals 0 dB, **9955** will consider bins where the signal level received from *Txi* is the highest.
- If the margin is set to 2 dB, **9955** will consider bins where the signal level received from *Txi* is either the highest or 2dB lower than the highest.
- If the margin is set to -2 dB, **9955** will consider bins where the signal level received from *Txi* is 2dB higher than the signal levels from transmitters, which are 2nd best servers.

4.1.3.1.3 Second Best Signal Level and a Margin

The service area of Txi corresponds to the bins where:

$$MinimumThreshold \le P_{rec}^{Txi}(ic)(or\ L_{total}^{Txi}\ or\ L_{path}^{Txi}\ ) < MaximumThreshold$$

And

$$P_{rec}^{Txi}(ic) \ge \underset{j \ne i}{2^{nd}Best}\ (P_{rec}^{Txj}(ic)) - M$$

M is the specified margin (dB).

2nd Best function: considers the second highest value.

- If the margin equals 0 dB, **9955** will consider bins where the signal level received from *Txi* is the second highest.
- If the margin is set to 2 dB, **9955** will consider bins where the signal level received from *Txi* is either the second highest or 2dB lower than the second highest.
- If the margin is set to -2 dB, **9955** will consider bins where the signal level received from *Txi* is 2dB higher than the signal levels from transmitters, which are 3rd best servers.

4.1.3.2 Coverage Display

4.1.3.2.1 Plot Resolution

Prediction plot resolution is independent of the matrix resolutions and can be defined on a per study basis. Prediction plots are generated from multi-resolution path loss matrices using bilinear interpolation method (similar to the one used to evaluate site altitude).

4.1.3.2.2 Display Types

It is possible to display the transmitter service area with colours depending on any transmitter attribute or other criteria such as:

Signal Level (in dBm, dBµV, dBµV/m)

9955 calculates signal level received from the transmitter on each pixel of each transmitter service area. A pixel of a service area is coloured if the signal level is greater than or equal to the defined minimum thresholds (pixel colour depends on signal level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as transmitter service areas. Each layer shows the different signal levels available in the transmitter service area.

Best Signal Level (in dBm, dBµV, dBµV/m)

9955 calculates signal levels received from transmitters on each pixel of each transmitter service area. Where other service areas overlap the studied one, **9955** chooses the highest value. A pixel of a service area is coloured if the signal level is greater than or equal to the defined thresholds (the pixel colour depends on the signal level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the signal level from the best server exceeds a defined minimum threshold.

Path Loss (dB)

9955 calculates path loss from the transmitter on each pixel of each transmitter service area. A pixel of a service area is coloured if path loss is greater than or equal to the defined minimum thresholds (pixel colour depends on path loss). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as service areas. Each layer shows the different path loss levels in the transmitter service area.

Total Losses (dB)

9955 calculates total losses from the transmitter on each pixel of each transmitter service area. A pixel of a service area is coloured if total losses is greater than or equal to the defined minimum thresholds (pixel colour depends on total losses). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as service areas. Each layer shows the different total losses levels in the transmitter service area.

Best Server Path Loss (dB)

9955 calculates signal levels received from transmitters on each pixel of each transmitter service area. Where other service areas overlap the studied one, **9955** determines the best transmitter and evaluates path loss from the best transmitter. A pixel of a service area is coloured if the path loss is greater than or equal to the defined thresholds (pixel colour depends on path loss). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the path loss from the best server exceeds a defined minimum threshold.

Best Server Total Losses (dB)

9955 calculates signal levels received from transmitters on each pixel of each transmitter service area. Where service areas overlap the studied one, **9955** determines the best transmitter and evaluates total losses from the best transmitter. A pixel of a service area is coloured if the total losses is greater than or equal to the defined thresholds (pixel colour depends on total losses). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the total losses from the best server exceed a defined minimum threshold.

Number of Servers

9955 evaluates how many service areas cover a pixel in order to determine the number of servers. The pixel colour depends on the number of servers. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the number of servers is greater than or equal to a defined minimum threshold.

Cell Edge Coverage Probability (%)

On each pixel of each transmitter service area, the coverage corresponds to the pixels where the signal level from this transmitter fulfils signal conditions defined in Conditions tab with different Cell edge coverage probabilities. There is one coverage area per transmitter in the explorer.

Best Cell Edge Coverage Probability (%)

On each pixel of each transmitter service area, the coverage corresponds to the pixels where the best signal level received fulfils signal conditions defined in Conditions tab. There is one coverage area per cell edge coverage probability in the explorer.

4.2 Definitions and Formulas

Input parameters and formulas used in simulations and predictions (coverage predictions and point analysis) are detailed in the tables below.

4.2.1 Inputs

This table lists simulation and prediction inputs (calculation options, quality targets, active set management conditions, etc.).

Name	Value	Unit	Description
F_{ortho}	Clutter parameter	None	Orthogonality factor
F_{MUD}^{Tx}	Site equipment parameter	None	MUD factor
F_{MUD}^{Term}	Terminal parameter - HSDPA properties	None	MUD factor
ic	Frequency band parameter	None	Carrier number
$AS\_Th(Txi, ic)$	Cell parameter	None	Threshold for macro diversity specified for a transmitter on a given carrier ic
Q_{pilot}^{req}	$\left(\frac{E_c}{I_0}\right)_{threshold}$ Mobility parameter	None	Ec/I0 target on downlink for the best server
$RSCP_{pilot}^{CM-activation}$	Global parameter	None	Pilot RSCP threshold for compressed mode activation
$Q_{pilot}^{CM-activation}$	Global parameter	None	Ec/I0 threshold for compressed mode activation
Q_{req}^{DL}	$\left(\frac{E_b}{N_t}\right)_{req}^{DL}$ (Reception equipment, R99 bearer, Mobility) parameter	None	Eb/Nt target on downlink
ΔQ_{req}^{DL}	Global parameter	None	Downlink Eb/Nt target increase due to compressed mode activation

Name	Value	Unit	Description
Q_{req}^{UL}	$\left(\frac{E_b}{N_t}\right)_{req}^{UL}$ (Reception equipment, R99 bearer, Mobility) parameter	None	Eb/Nt target on uplink
ΔQ_{req}^{UL}	Global parameter	None	Uplink Eb/Nt target increase due to compressed mode activation
$N_{max}^{CE-UL}(N_l)$	Site parameter	None	Number of channel elements available for a site on uplink
$N_{max}^{CE-DL}(N_l)$	Site parameter	None	Number of channel elements available for a site on downlink
$N^{CE-UL}(N_l)$	Simulation result	None	Number of channel elements of a site consumed by users on uplink
$N^{CE-DL}(N_l)$	Simulation result	None	Number of channel elements of a site consumed by users on downlink
$N^{Overhead-CE-UL}$	Site equipment parameter - UL overhead resources for common channels/cell	None	Number of channel elements used by the cell for common channels on uplink
$N^{Overhead-CE-DL}$	Site equipment parameter - DL overhead resources for common channels/cell	None	Number of channel elements used by the cell for common channels on downlink
$N^{R99-TCH-CE-UL}$	(R99 bearer, site equipment) parameter	None	Number of channel elements used for R99 traffic channels on uplink
$N^{R99-TCH-CE-DL}$	(R99 bearer, site equipment) parameter	None	Number of channel elements used for R99 traffic channels on downlink
$N^{HSUPA-CE}$	(HSUPA bearer, site equipment) parameter	None	Number of channel elements consumed by the HSUPA bearer on uplink
$T_{Iub-max}^{UL}(N_l)$	Site parameter	kbps	Maximum Iub backhaul throughput for a site in the uplink
$T_{Iub-max}^{DL}(N_l)$	Site parameter	kbps	Maximum Iub backhaul throughput for a site in the downlink
$T_{Iub}^{UL}(N_l)$	Simulation result	kbps	Iub backhaul throughput for a site in the uplink
$T_{Iub}^{DL}(N_l)$	Simulation result	kbps	Iub backhaul throughput for a site in the downlink
$T_{Iub}^{Overhead-DL}$	Site equipment parameter	kbps	Iub throughput required by the cell for common channels in the downlink
$Overhead_{Iub}^{HSDPA}$	Site equipment parameter	%	HSDPA Iub backhaul overhead
$T_{E1/T1/Ethernet}$	Site equipment parameter	kbps	Throughput carried by an E1/T1/ Ethernet link
$T_{Iub}^{R99-TCH-UL}$	(R99 bearer, site equipment) parameter	kbps	Iub backhaul throughput consumed by the R99 bearer in the uplink
$T_{Iub}^{R99-TCH-DL}$	(R99 bearer, site equipment) parameter	kbps	Iub backhaul throughput consumed by the R99 bearer in the downlink
T_{Iub}^{HSUPA}	(HSUPA bearer, site equipment) parameter	kbps	Iub backhaul throughput consumed by the HSUPA bearer in the uplink
$N_{max}^{Codes}(Txi, ic)$	Simulation constraint	None	Maximum number of 512 bit-length OVSF codes available per cell (512)
$N^{Codes}(Txi, ic)$	Simulation result	None	Number of 512 bit-length OVSF codes used by the cell
$N^{Overhead-Codes}$	Site equipment parameter - DL overhead resources for common channels/cell	None	Number of 256 bit-length OVSF codes used by the cell for common channels

Name	Value	Unit	Description
$N_{max}^{Codes-HSPDSCH}(Txi, ic)$	Cell parameter (for HSDPA only)	None	Maximum number of 16 bit-length OVSF codes available per cell for HS-PDSCH
$N_{min}^{Codes-HSPDSCH}(Txi, ic)$	Cell parameter (for HSDPA only)	None	Minimum number of 16 bit-length OVSF codes available per cell for HS-PDSCH
NF_{term}	Terminal parameter	None	Terminal Noise Figure
NF_{Tx}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	Transmitter Noise Figure
K	$1.38\ 10^{-23}$	J/K	Boltzman constant
T	293	K	Ambient temperature
W	3.84 MHz	Hz	Spreading Bandwidth
$NR_{inter-technology}^{Tx, DL}$	Cell parameter	None	Inter-technology downlink noise rise
$NR_{inter-technology}^{Tx, UL}$	Cell parameter Only used in uplink interference-based calculations of the Monte-Carlo simulation	None	Inter-technology uplink noise rise
$RF(ic, ic_{adj})$	Network parameter If not defined, it is assumed that there is no inter-carrier interference	None	Interference reduction factor between two adjacent carriers ic and ic_{adj}
$ICP_{ic_i, ic}^{Tx, m}$	Network parameter If not defined, it is assumed that there is no inter-technology downlink interferences due to external transmitters	None	Inter-technology Channel Protection between the signal transmitted by Tx and received by m assuming the frequency gap between ic_i (external network) and ic
X^{UL}	Cell parameter (user-defined or simulation result)	%	Total uplink load factor of the cell
X_{R99}^{UL}	Simulation result	%	Uplink cell load contribution due to R99 traffic
X_{HSUPA}^{UL}	Cell parameter	%	Uplink cell load contribution due to HSUPA traffic
X_{max}^{UL}	Simulation constraint (global parameter or cell parameter)	%	Maximum uplink load factor of the cell
$\%Power_{max}^{DL}$	Simulation constraint (global parameter or cell parameter)	%	Maximum percentage of used power
N_0^{Tx}	$NF_{Tx} \times K \times T \times W \times NR_{inter-technology}^{Tx, UL}$	W	Thermal noise at transmitter
N_0^{Term}	$NF_{Term} \times K \times T \times W \times NR_{inter-technology}^{Tx, DL}$	W	Thermal noise at terminal
R_c	$W \cdot 10^{-3}$ W	bps	Chip rate
$f_{rake\ efficiency}^{UL}$	Site equipment parameter	None	Uplink rake receiver efficiency factor
$f_{rake\ efficiency}^{DL}$	Terminal parameter	None	Downlink rake receiver efficiency factor
$R_{nominal}^{DL}$	R99 bearer parameter	kbps	R99 bearer downlink nominal bit rate
$F_{spreading}^{DL}(Active\ user)$	R99 bearer parameter	None	Downlink spreading factor for active users
$F_{spreading}^{DL}(Inactive\ user)$	R99 bearer parameter	None	Downlink spreading factor for inactive users

Name	Value	Unit	Description
r_c^{DL}	R99 bearer parameter	None	Ratio between DPCCH and DPCH transmission duration on downlink DPCCH and DPCH respectively refer to the Dedicated Physical Control Channel and Dedicated Physical Channel
R_{max}^{DL}	Cell parameter	kbps	Maximum connection rate per user on downlink
$R_{nominal}^{UL}$	R99 bearer parameter	kbps	R99 bearer uplink nominal bit rate
f_{act}^{UL}	Service parameter	kbps	Uplink activity factor for the service
f_{act}^{DL}	Service parameter	kbps	Downlink activity factor for the service
$f_{act-ADPCH}^{UL}$	Service parameter	kbps	Uplink activity factor on E-DPCCH channels
$f_{act-ADPCH}^{DL}$	Service parameter	kbps	Downlink Activity factor on A-DPCH channel
T_{min}^{UL}	Service parameter	kbps	Minimum required bit rate that the service should have in order to be available in the uplink
T_{min}^{DL}	Service parameter	kbps	Minimum required bit rate that the service should have in order to be available in the downlink
T_{max}^{UL}	Service parameter	kbps	Maximum bit rate that the service can require in the uplink
T_{max}^{DL}	Service parameter	kbps	Maximum bit rate that the service can require in the downlink
r_c^{UL}	R99 bearer parameter	None	Ratio between the DPCCH and DPCH powers transmitted on uplink DPCCH and DPCH respectively refer to the Dedicated Physical Control Channel and Dedicated Physical Channel
R_{max}^{UL}	Cell parameter	kbps	Maximum connection rate per user on uplink
G_p^{DL}	$\frac{W}{R_{nominal}^{DL}}$	None	Service downlink processing gain
G_p^{UL}	$\frac{W}{R_{nominal}^{UL}}$	None	Service uplink processing gain
$I_{HSDPABearer}$	HSDPA bearer parameter	None	Index of the HSDPA bearer obtained by the user in the cell *(Txi,ic)*
$R_{RLC-peak}^{DL}(I_{HSDPABearer})$	HSDPA bearer parameter	kbps	RLC peak rate supported by the HSDPA bearer
$R_{RLC-peak}^{DL}(Tx, ic)$	Without MIMO: $R_{RLC-peak}^{DL}(I_{HSDPABearer})$ With MIMO (transmit diversity): $R_{RLC-peak}^{DL}(I_{HSDPABearer})$ With MIMO (spatial multiplexing): $R_{RLC-peak}^{DL}(I_{HSDPABearer}) \times (1 + f_{SM-Gain} \times (G_{SM}^{Max} - 1)))$	kbps	RLC peak rate provided to the user in the cell *(Txi,ic)* in the downlink

Name	Value	Unit	Description
$R^{DL}_{RLC-peak}$	HSDPA study result **For single-carrier HSDPA users** $R^{DL}_{RLC-peak}(Tx, ic)$ **For dual-cell HSDPA users** $\sum_{ic \in Tx} R^{DL}_{RLC-peak}(Tx, ic)$	kbps	RLC peak rate provided to the user in the downlink
$C_{HSDPABearer}$	$\frac{R^{DL}_{Guaranteed}}{R^{DL}_{RLC-peak}(I_{HSDPABearer})}$	%	HSDPA bearer consumption for a packet (HSPA - Constant Bit Rate) service user
$T^{DL}_{RLC-peak}$	HSDPA study result	kbps	RLC peak throughput supported by the HSDPA bearer
T^{DL}_{RLC-Av}	HSDPA study result	kbps	Average RLC throughput supported by the HSDPA bearer
R^{DL}_{MAC}	HSDPA study result	kbps	MAC rate supported by the HSDPA bearer
T^{DL}_{MAC}	HSDPA study result	kbps	MAC throughput supported by the HSDPA bearer
$T^{DL}_{application}$	HSDPA study result	kbps	User application throughput on downlink
$T^{UL}_{application}$	HSUPA study result	kbps	User application throughput on uplink
$T^{UL}_{application-Av}$	HSUPA study result	kbps	User average application throughput on uplink
$I_{HSUPABearer}$	HSUPA Bearer parameter	None	Index of the HSUPA bearer obtained in the cell *(Txi,ic)*
N_{Rtx} $(I_{HSUPABearer})$	HSUPA bearer selection parameter	kbps	Maximum number of retransmissions a HARQ process will perform for a block of data before moving on to a new block of data, for the HSUPA bearer index
$R^{UL}_{RLC-peak}$ $(I_{HSUPABearer})$	HSUPA bearer parameter	kbps	RLC peak rate supported by the HSUPA bearer
$R^{UL}_{RLC-peak}$	HSUPA study result $R^{UL}_{RLC-peak}(I_{HSUPABearer})$	kbps	RLC peak rate provided to the user in the cell *(Txi,ic)* in the uplink
$C_{HSUPABearer}$	$\frac{R^{UL}_{Guaranteed}}{R^{UL}_{RLC-peak}(I_{HSUPABearer})}$	%	HSUPA bearer consumption for a packet (HSPA - Constant Bit Rate) service user
$T^{UL}_{RLC-Min}$	HSUPA study result	kbps	Minimum RLC throughput supported by the HSUPA bearer
T^{UL}_{RLC-Av}	HSUPA study result	kbps	Average RLC throughput supported by the HSUPA bearer
R^{UL}_{MAC}	HSUPA study result	kbps	MAC rate supported by the HSUPA bearer
ΔR	Service parameter (for HSDPA only)	kbps	Throughput offset
SF_{Rate}	Service parameter (for HSDPA only)	%	Scaling factor
$P_{max}(Txi)$	Transmitter parameter	W	Maximum shared power Available only if the inter-carrier power sharing option is activated
$P_{SCH}(Txi, ic)$	Cell parameter	W	Cell synchronisation channel power

Name	Value	Unit	Description
$P_{OtherCCH}(Txi, ic)$	Cell parameter	W	Cell other common channels (except CPICH and SCH) power
$P_{pilot}(Txi, ic)$	Cell parameter	W	Cell pilot power
$P_{HSDPA}(Txi, ic)$	Cell parameter (user-defined or simulation result) (for HSDPA only) $P_{HS-PDSCH}(Txi, ic) + n_{HS-SCCH} \times P_{HS-SCCH}(Txi, ic)$	W	Available cell HSDPA power HSDPA: High Speed Downlink Packet Access
$P_{HS-PDSCH}(Txi, ic)$	Simulation result (for HSDPA only)	W	Cell HS-PDSCH power HS-PDSCH: High Speed Physical Downlink Shared Channel
$P_{HS-SCCH}(Txi, ic)$	Cell parameter (for HSDPA only)	W	Cell HS-SCCH power HS-SCCH: High Speed Shared Control Channel
$n_{HS-SCCH}$	Cell parameter (for HSDPA only)		number of HS-SCCH channels managed by the cell
$P_{Headroom}(Txi, ic)$	Cell parameter (for HSDPA only)	W	Cell headroom power
$P_{max}(Txi, ic)$	Cell parameter	W	Maximum Cell power
$P_{tch}(Txi, ic)$	Simulation result	W	R99 traffic channel power transmitted on carrier ic
P_{tch}^{min}	R99 bearer parameter	W	Minimum power allowed on R99 traffic data channel
P_{tch}^{max}	R99 bearer parameter	W	Maximum power allowed on R99 traffic data channel
$P_{HSUPA}(Txi, ic)$	Cell parameter	W	Cell HSUPA power HSUPA: High Speed Uplink Packet Access
$P_{tx-HSDPA}(Txi, ic)$	Simulation result	W	Transmitter HSDPA power transmitted on carrier ic
$P_{tx-R99}(Txi, ic)$	Simulation result $P_{pilot}(Txi, ic) + P_{SCH}(Txi, ic) + P_{OtherCCH}(Txi, ic) + \sum_{\substack{tch(ic)\text{ used for}\\ R99\text{ users}}} P_{tch}(Txi, ic) + \sum_{\substack{tch(ic)\text{ used for}\\ HSUPA\text{ users}}} P_{tch}(Txi, ic) \times f_{act-ADPCH}^{DL}$	W	Transmitter R99 power transmitted on carrier ic
$P_{tx}(Txi, ic)$	Cell parameter (user-defined or simulation result) $P_{tx-R99}(Txi, ic) + P_{tx-HSDPA}(Txi, ic) + P_{HSUPA}(Txi, ic)$	W	Transmitter total power transmitted on carrier ic
$P_{term-R99}$	Calculated in the simulation but not displayed	W	Terminal power transmitted to obtain the R99 radio bearer
$P_{term-HSUPA}$	Calculated in the simulation but not displayed	W	Terminal power transmitted to obtain the HSUPA radio bearer
P_{term}	Simulation result $P_{term-R99} \times f_{act-ADPCH}^{UL} + P_{term-HSUPA}$ for HSPA users $P_{term-R99}$ for R99 users	W	Total power transmitted by the terminal
P_{term}^{min}	Terminal parameter	W	Minimum terminal power allowed
P_{term}^{max}	Terminal parameter	W	Maximum terminal power allowed
ρ_{BTS}	BTS parameter	%	Percentage of BTS signal correctly transmitted
ρ_{term}	Terminal parameter	%	Percentage of terminal signal correctly transmitted
α	Clutter parameter	%	Percentage of pilot finger - percentage of signal received by the terminal pilot finger

Name	Value	Unit	Description
G_{Tx}	Antenna parameter	None	Transmitter antenna gain
G_{Term}	Terminal parameter	None	Terminal gain
G_{Div}^{DL}	R99 bearer parameter - Depends on the transmitter Tx diversity	None	Gain due to transmit diversity
G_{Div}^{UL}	R99 bearer parameter - Depends on the transmitter Rx diversity	None	Gain due to receive diversity
G_{SM}^{Max}	MIMO configuration parameter	dB	Maximum spatial multiplexing gain for a given number of transmission and reception antennas
G_{TD}^{DL}	MIMO configuration parameter	dB	Downlink Transmit Diversity gain for a given number of transmission and reception antenna ports
$f_{SM-Gain}$	Clutter parameter	None	Spatial multiplexing gain factor
ΔG_{TD}^{DL}	Clutter parameter	dB	Additional diversity gain in downlink
L_{Tx}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	Transmitter loss[a]
L_{body}	Service parameter	None	Body loss
L_{Term}	Terminal parameter	None	Terminal loss
L_{indoor}	Clutter (and, optionally, frequency band) parameter		Indoor loss
L_{path}	Propagation model result	None	Path loss
$M_{Shadowing-model}$	Result calculated from cell edge coverage probability and model standard deviation	None	Model Shadowing margin Only used in prediction studies
$M_{Shadowing-Ec/Io}$	Result calculated from cell edge coverage probability and Ec/I0 standard deviation	None	Ec/I0 Shadowing margin Only used in prediction studies
$G_{macro-diversity}^{DL}$	$G_{macro-diversity}^{DL} = M_{Shadowing-Ec/Io}^{npaths} - M_{Shadowing-Ec/Io}$ n=2 or 3	None	DL gain due to availability of several pilot signals at the mobile [b].
$M_{Shadowing-(Eb/Nt)_{DL}}$	Result calculated from cell edge coverage probability and DL Eb/Nt standard deviation	None	DL Eb/Nt Shadowing margin Only used in prediction studies
$M_{Shadowing-(Eb/Nt)_{UL}}$	Result calculated from cell edge coverage probability and UL Eb/Nt standard deviation	None	UL Eb/Nt Shadowing margin Only used in prediction studies
$G_{macro-diversity}^{UL}$	$G_{macro-diversity}^{UL} = M_{Shadowing-(Eb/Nt)_{UL}}^{npaths} - M_{Shadowing-(Eb/Nt)_{UL}}$ n=2 or 3 Global parameter (default value)	None	UL quality gain due to signal diversity in soft handoff[c].
$E_{Shadowing}$	Simulation result	None	Random shadowing error drawn during Monte-Carlo simulation Only used in simulations

Name	Value	Unit	Description
L_T	In prediction studies[d] For Ec/I0 calculation $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}}$ For DL Eb/Nt calculation $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{DL}}}{G_{Tx} \times G_{term}}$ For UL Eb/Nt calculation $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$ In simulations $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}}$	None	Transmitter-terminal total loss
$P_c(Txi, ic)$	$\frac{P_{pilot}(Txi, ic)}{L_T}$	W	Chip power received at terminal
$P_b^{DL}(Txi, ic)$	$\frac{P_{tch}(Txi, ic)}{L_T}$	W	Bit power received at terminal on carrier ic
$P_{tot}^{DL}(Txi, ic)$	$\frac{P_{tx}(Txi, ic)}{L_T}$	W	Total power received at terminal from a transmitter on carrier *ic*
$P_{traf}^{DL}(Txi, ic)$	$\sum_{tch(ic)} \frac{P_{tch}(Txi, ic)}{L_T}$	W	Total power received at terminal from traffic channels of a transmitter on carrier *ic*
$P_b^{UL}(ic)$	$\frac{P_{term}}{L_T}$	W	Bit power received at transmitter on carrier *ic* used by terminal
$P_{b-R99}^{UL}(ic)$	$\frac{P_{term-R99}}{L_T}$	W	Bit power received at transmitter on carrier *ic* used by terminal
$P_{b-DPDCH}^{UL}(ic)$	$P_{b-R99}^{UL}(ic) \times (1 - r_c^{UL})$	W	Bit power received at transmitter on DPDCH from a terminal on carrier *ic*

a. $L_{Tx} = L_{total-UL}$ *on uplink and* $L_{Tx} = L_{total-DL}$ *on downlink. For information on calculating transmitter losses on uplink and downlink, see* *"UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents" on page 26.*

b. $M_{Shadowing-Ec/Io}^{npaths}$ *corresponds to the shadowing margin evaluated from the shadowing error probability density function (n paths) in case of downlink Ec/I0 modelling.*

c. $M_{Shadowing-(Eb/Nt)_{UL}}^{npaths}$ *corresponds to the shadowing margin evaluated from the shadowing error probability density function (n paths) in case of uplink soft handoff modelling.*

d. *In uplink prediction studies, only carrier power level is downgraded by the shadowing margin (*$M_{Shadowing-(Eb/Nt)_{UL}}$*). In downlink prediction studies, carrier power level and intra-cell interference are downgraded by the shadowing model (*$M_{Shadowing-(Eb/Nt)_{DL}}$ *or* $M_{Shadowing-Ec/Io}$*) while extra-cell interference level is not. Therefore,* $M_{Shadowing-(Eb/Nt)_{DL}}$ *or* $M_{Shadowing-Ec/Io}$ *is set to 1 in downlink extra-cell interference calculation.*

4.2.2 Ec/I0 Calculation

This table details the pilot quality (Q_{pilot} or Ec/Io) calculations.

Name	Value	Unit	Description
$I_{intra}^{DL}(txi, ic)$	$P_{tot}^{DL}(txi, ic) - \rho_{BTS} \times \alpha \times \left(P_{tot}^{DL}(txi, ic) - \frac{P_{SCH}(txi, ic)}{L_T} \right)$	W	Downlink intra-cell interference at terminal on carrier *ic*

Name	Value	Unit	Description
$I^{DL}_{extra}(ic)$	$\sum\limits_{txj, j \neq i} P^{DL}_{tot}(txj, ic)$	W	Downlink extra-cell interference at terminal on carrier *ic*
$I^{DL}_{inter-carrier}(ic)$	$\dfrac{\sum\limits_{txj, \forall j} P^{DL}_{tot}(txj, ic_{adj})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference at terminal on carrier *ic*
$I^{DL}_{inter-technology}(ic)$	$\sum\limits_{n_i} \dfrac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic}}$	W	Downlink inter-technology interference at terminal on carrier *ic* [a]
$I^{DL}_{0}(ic)$	Without Pilot: $I^{DL}_{intra}(txi, ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic) + N^{Term}_{0} - (1 - \alpha) \times \rho_{BTS} \times P_c(txi, ic)$ Total noise: $P^{DL}_{tot}(txi, ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic) + N^{Term}_{0}$	W	Total received noise at terminal on carrier *ic*
$Q_{pilot}(txi, ic) \Leftrightarrow \left(\dfrac{E_c}{I_0}\right)$	$\dfrac{\rho_{BTS} \times \alpha \times P_c(txi, ic)}{I^{DL}_{0}(ic)}$	None	Quality level at terminal on pilot for carrier *ic*

a. *In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.*

4.2.3 DL Eb/Nt Calculation

This table details calculations of downlink traffic channel quality (Q^{DL}_{tch} or $\left(\frac{Eb}{Nt}\right)_{DL}$).

Name	Value	Unit	Description
$I^{DL}_{intra}(txi, ic)$	$P^{DL}_{tot}(txi, ic) - \rho_{BTS} \times F_{ortho} \times \left(P^{DL}_{tot}(txi, ic) - \dfrac{P_{SCH}(txi, ic)}{L_T}\right)$	W	Downlink intra-cell interference at terminal on carrier *ic*
$I^{DL}_{extra}(ic)$	$\sum\limits_{txj, j \neq i} P^{DL}_{tot}(txj, ic)$	W	Downlink extra-cell interference at terminal on carrier *ic*
$I^{DL}_{inter-carrier}(ic)$	$\dfrac{\sum\limits_{txj, \forall j} P^{DL}_{tot}(txj, ic_{adj})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference at terminal on carrier *ic*
$I^{DL}_{inter-technology}(ic)$	$\sum\limits_{n_i} \dfrac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic}}$	W	Downlink inter-technology interference at terminal on carrier *ic* [a]
$N^{DL}_{tot}(ic)$	$I^{DL}_{intra}(ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic) + N^{Term}_{0}$	W	Total received noise at terminal on carrier *ic*
$Q^{DL}_{tch}(txi, ic) \Leftrightarrow \left(\dfrac{E_b}{N_t}\right)_{DL}$	Without useful signal: $\dfrac{\rho_{BTS} \times P^{DL}_{b}(txi, ic)}{N^{DL}_{tot}(ic) - (1 - F_{ortho}) \times \rho_{BTS} \times P^{DL}_{b}(txi, ic)} \times G^{DL}_{Div} \times G^{DL}_{p}$ Total Noise: $\dfrac{\rho_{BTS} \times P^{DL}_{b}(txi, ic)}{N^{DL}_{tot}(ic)} \times G^{DL}_{Div} \times G^{DL}_{p}$	None	Quality level at terminal on a traffic channel from one transmitter on carrier *ic* [b]
$Q^{DL}(ic)$	$f^{DL}_{rake\ efficiency} \times \sum\limits_{tx_k \in ActiveSet} Q^{DL}_{tch}(tx_k, ic)$	None	Quality level at terminal using carrier *ic* due to combination of all transmitters of the active set (Macro-diversity conditions).

Name	Value	Unit	Description
G_{SHO}^{DL}	$\frac{Q^{DL}(ic)}{Q_{tch}^{DL}(BestServer, ic)}$	None	Soft handover gain on downlink
$P_{tch}^{req}(txi, ic)$	$\frac{Q_{req}^{DL}}{Q^{DL}(ic)} \times P_{tch}(txi, ic)$	W	Required transmitter traffic channel power to achieve Eb/Nt target at terminal on carrier ic

a. *In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.*

b. *Calculation option may be selected in the Global parameters tab. The chosen option will be taken into account only in simulations. In point analysis and coverage studies,* ***9955*** *uses the option "Total noise" to evaluate DL and UL Eb/Nt.*

4.2.4 UL Eb/Nt Calculation

This table details calculations of uplink traffic channel quality (Q_{tch}^{UL} or $\left(\frac{Eb}{Nt}\right)_{UL}$).

Name	Value	Unit	Description
$I_{tot}^{UL_{intra}}(txi, ic)$	$\sum_{\substack{term \\ txi}} P_b^{UL}(ic)$	W	Total power received at transmitter from intra-cell terminals using carrier ic
$I_{tot}^{UL_{extra}}(txi, ic)$	$\sum_{\substack{term \\ txj, j \neq i}} P_b^{UL}(ic)$	W	Total power received at transmitter from extra-cell terminals using carrier ic
$I_{inter-carrier}^{UL}(txi, ic)$	$\frac{\sum_{\substack{term \\ txj, \forall j}} P_b^{UL}(ic_{adj})}{RF(ic, ic_{adj})}$	W	Uplink inter-carrier interference at terminal on carrier ic
$I_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL_{extra}}(txi, ic) + (1 - F_{MUD}^{Tx} \times \rho_{term}) \times I_{tot}^{UL_{intra}}(txi, ic) + I_{inter-carrier}^{UL}(txi, ic)$	W	Total received interference at transmitter on carrier ic
$N_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL}(txi, ic) + N_0^{tx}$	W	Total noise at transmitter on carrier ic (Uplink interference)
$Q_{tch}^{UL}(txi, ic) \Leftrightarrow \left(\frac{E_b}{N_t}\right)_{UL}$	Without useful signal: $\frac{\rho_{term} \times P_{b-DPDCH}^{UL}(ic)}{N_{tot}^{UL}(txi, ic) - (1 - F_{MUD}^{Tx}) \times \rho_{term} \times P_b^{UL}(ic)} \times G_{Div}^{UL} \times G_p^{UL}$ Total noise: $\frac{\rho_{term} \times P_{b-DPDCH}^{UL}(ic)}{N_{tot}^{UL}(txi, ic)} \times G_{Div}^{UL} \times G_p^{UL}$	None	Quality level at transmitter on a traffic channel for carrier ic [a]

Name	Value	Unit	Description
$Q^{UL}(ic)$	No HO: $Q^{UL}_{tch}(txi, ic)$ Softer HO: $f^{UL}_{rake\ efficiency} \times \sum_{\substack{tx_k \in ActiveSet \\ (samesite)}} Q^{UL}_{tch}(tx_k, ic)$ Soft, softer/soft HO (No MRC): $\underset{tx_k \in ActiveSet}{Max}\ (Q^{UL}_{tch}(tx_k, ic)) \times G^{UL}_{macro-diversity}$ Softer/soft HO (MRC): $\underset{\substack{tx_k, tx_l \in ActiveSet \\ tx_k \in samesite \\ tx_l \in othersite}}{Max} \left(f^{UL}_{rake\ efficiency} \times \sum_{tx_k} Q^{UL}_{tch}(tx_k, ic), Q^{UL}_{tch}(tx_l, ic) \right)$ $\times G^{UL}_{macro-diversity}$	None	Quality level at site using carrier *ic* due to combination of all transmitters of the active set located at the same site and taking into account increasing of the quality due to macro-diversity (macro-diversity gain). In simulations $G^{UL}_{macro-diversity} = 1$.
G^{UL}_{SHO}	$\frac{Q^{UL}(ic)}{Q^{UL}_{tch}(BestServer, ic)}$	None	Soft handover gain on uplink
$P^{req}_{term}(ic)$	$\frac{Q^{UL}_{req}}{Q^{UL}(ic)} \times P_{term}$	W	Required terminal power to achieve Eb/Nt target at transmitter on carrier *ic*

a. *Calculation option may be selected in the Global parameters tab. The chosen option will be taken into account only in simulations. In point analysis and coverage studies, **9955** uses the option "Total noise" to evaluate DL and UL Eb/Nt.*

4.3 Active Set Management

The mobile's active set (AS) is the list of the transmitters to which the mobile is connected. The active set may consist of one or more transmitters; depending on whether the service supports soft handover and on the terminal active set size. The terminal frequency bands are taken into account and transmitters in the mobile's active set must use a frequency band supported by the terminal. Finally, the quality of the pilot (Ec⁄I0) is what determines whether or not a transmitter can belong to the active set. The active set management is detailed hereafter. Cells entering a mobile's active set must satisfy the following conditions:

- The best server (first cell entering active set)

  The pilot quality from the best serving cell must exceed the Ec/I0 threshold. Best server cell is the one with the highest pilot quality.

- Other cells in the active set
  - Must use the same carrier as the best server,
  - The pilot quality difference between other candidate cells and the best server must be less than the AS threshold specified for the best server,
  - Other candidate cells must belong to the neighbour list of the best server if it is located on a site where the equipment imposes this restriction (the "restricted to neighbours" option selected in the equipment properties).

4.4 Simulations

The simulation process consists of two steps:

1. **Obtaining a realistic user distribution**

   9955 generates a user distribution using a Monte-Carlo algorithm, which requires traffic maps and data as input. The resulting user distribution complies with the traffic database and maps provided to the algorithm.

   Each user is assigned a service, a mobility type, and an activity status by random trial, according to a probability law that uses the traffic database.

The user activity status is an important output of the random trial and has direct consequences on the next step of the simulation and on the network interferences. A user may be either active or inactive. Both active and inactive users consume radio resources and create interference.

Then, **9955** randomly assigns a shadowing error to each user using the probability distribution that describes the shadowing effect.

Finally, another random trial determines user positions in their respective traffic zone and whether they are indoors or outdoors (according to the clutter weighting and the indoor ratio per clutter class defined for the traffic maps).

2. **Power control simulation**

4.4.1 Generating a Realistic User Distribution

During the simulation, a first random trial is performed to determine the number of users and their activity status. Four activity status are modelled:

- Active UL: the user is active on UL and inactive on DL
- Active DL: the user is active on DL and inactive on UL
- Active UL+DL: the user is active on UL and on DL
- Inactive: the user is inactive on UL and on DL

The determination of the number of users and the activity status allocation depend on the type of traffic cartography used.

> **9955** determines the total number of users attempting connection in each simulation based on the Poisson distribution. This may lead to slight variations in the total numbers of users in different simulations. To have the same total number of users in each simulation of a group, add the following lines in the Atoll.ini file:
> [Simulation]
> RandomTotalUsers=0

4.4.1.1 Simulations Based on User Profile Traffic Maps

User profile environment based traffic maps: Each pixel of the map is assigned an environment class which contains a list of user profiles with an associated mobility type and a given density (number of subscribers with the same profile per km²).

User profile traffic maps: Each polygon and line of the map is assigned a density of subscribers with given user profile and mobility type. If the map is composed of points, each point is assigned a number of subscribers with given user profile and mobility type.

The user profile models the behaviour of the different subscriber categories. Each user profile contains a list of services and their associated parameters describing how these services are accessed by the subscriber.

From environment (or polygon) surface (S) and user profile density (D), a number of subscribers (X) per user profile is inferred.

$X = S \times D$

> - When user profile traffic maps are composed of lines, the number of subscribers (X) per user profile is calculated from the line length (L) and the user profile density (D) (nb of subscribers per km) as follows: $X = L \times D$
> - The number of subscribers (X) is an input when a user profile traffic map is composed of points.

For each behaviour described in a user profile, according to the service, frequency use and exchange volume, **9955** calculates the probability for the user being active in uplink and in downlink at an instant t.

4.4.1.1.1 Circuit Switched Service (i)

User profile parameters for circuit switched services are:

- The used terminal (equipment used for the service (from the Terminals table)),
- The average number of calls per hour N_{call},
- The average duration of a call (seconds) d.

The number of users and their distribution per activity status is determined as follows:

- Calculation of the service usage duration per hour (p_0 : probability of a connection):

$$p_o = \frac{N_{call} \times d}{3600}$$

- Calculation of the number of users trying to access the service i (n_i):

$$n_i = X \times p_0$$

Next, we can take into account activity periods during the connection in order to determine the activity status of each user.

- Calculation of activity probabilities:

Probability of being inactive on UL and DL: $p_{inactive} = (1 - f_{act}^{UL}) \times (1 - f_{act}^{DL})$

Probability of being active on UL only: $p_{UL} = f_{act}^{UL} \times (1 - f_{act}^{DL})$

Probability of being active on DL only: $p_{DL} = f_{act}^{DL} \times (1 - f_{act}^{UL})$

Probability of being active both on UL and DL: $p_{UL+DL} = f_{act}^{UL} \times f_{act}^{DL}$

Where, f_{act}^{UL} and f_{act}^{DL} are respectively the UL and DL activity factors defined for the circuit switched service i.

- Calculation of number of users per activity status:

Number of inactive users on UL and DL: $n_i^{inactive} = n_i \times p_{inactive}$

Number of users active on UL and inactive on DL: $n_i(UL) = n_i \times p_{UL}$

Number of users active on DL and inactive on UL: $n_i(DL) = n_i \times p_{DL}$

Number of users active on UL and DL both: $n_i(UL + DL) = n_i \times p_{UL+DL}$

Therefore, a user when he is connected can have four different activity status: either active on both links, or inactive on both links, or active on UL only, or active on DL only.

4.4.1.1.2 Packet Switched Service (j)

User profile parameters for packet switched services are:

- The used terminal (equipment used for the service (from the Terminals table)),
- The average number of packet sessions per hour N_{sess},
- The volume (in kbytes) which is transferred on the downlink V_{DL} and the uplink V_{UL} during a session.

A packet session consists of several packet calls separated by a reading time. Each packet call is defined by its size and may be divided in packets of fixed size (1500 Bytes) separated by an inter arrival time.

In **9955**, a packet session is described by following parameters:

$N_{packet-call}^{UL}$: Average number of packet calls on the uplink during a session,

$N_{packet-call}^{DL}$: Average number of packet calls on the downlink during a session,

$\Delta T_{packet-call}^{UL}$: Average time (millisecond) between two packets calls on the uplink ,

$\Delta T_{packet-call}^{DL}$: Average time (millisecond) between two packets calls on the downlink ,

ΔT_{packet}^{UL}: Average time (millisecond) between two packets on the uplink ,

ΔT_{packet}^{DL}: Average time (millisecond) between two packets on the downlink ,

S_{packet}^{UL}: Packet size (Bytes) on uplink,

S_{packet}^{DL}: Packet size (Bytes) on downlink.

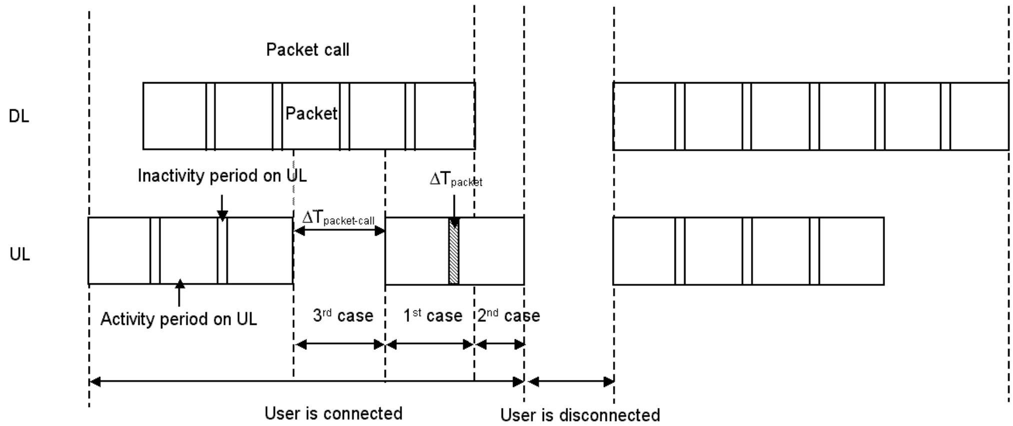


Figure 4.1: Description of a Packet Session

The number of users and their distribution per activity status is determined as follows:

- Calculation of the average packet call size (kBytes):

$$S^{UL}_{packet-call} = \frac{V_{UL}}{N^{UL}_{packet-call} \times f^{UL}_{eff}} \text{ and } S^{DL}_{packet-call} = \frac{V_{DL}}{N^{DL}_{packet-call} \times f^{DL}_{eff}}$$

Where f^{UL}_{eff} and f^{DL}_{eff} are the UL and DL efficiency factors defined for the packet switched service j.

> For packet (HSDPA) and packet (HSPA) services, f^{UL}_{eff} and f^{DL}_{eff} are set to 1.

- Calculation of the average number of packets per packet call:

$$N^{UL}_{packet} = int\left(\frac{S^{UL}_{packet-call}}{S^{UL}_{packet}/1024}\right) + 1 \text{ and } N^{DL}_{packet} = int\left(\frac{S^{DL}_{packet-call}}{S^{DL}_{packet}/1024}\right) + 1$$

> 1kBytes = 1024Bytes.

- Calculation of the average duration of inactivity within a packet call (s):

$$(D^{UL}_{Inactivity})_{packet-call} = \frac{(N^{UL}_{packet} - 1) \times \Delta T^{UL}_{packet}}{1000} \text{ and } (D^{DL}_{Inactivity})_{packet-call} = \frac{(N^{DL}_{packet} - 1) \times \Delta T^{DL}_{packet}}{1000}$$

- Calculation of the average duration of inactivity in a session (s):

$$(D^{UL}_{Inactivity})_{session} = N^{UL}_{packet-call} \times (D^{UL}_{Inactivity})_{packet-call} \text{ and } (D^{DL}_{Inactivity})_{session} = N^{DL}_{packet-call} \times (D^{DL}_{Inactivity})_{packet-call}$$

- Calculation of the average duration of activity in a session (s):

$$(D^{UL}_{Activity})_{session} = N^{UL}_{packet-call} \times \frac{N^{UL}_{packet} \times S^{UL}_{packet} \times 8}{R^{UL}_{average} \times 1000} \text{ and } (D^{DL}_{Activity})_{session} = N^{DL}_{packet-call} \times \frac{N^{DL}_{packet} \times S^{DL}_{packet} \times 8}{R^{DL}_{average} \times 1000}$$

Where $R^{UL}_{average}$ and $R^{DL}_{average}$ are the uplink and downlink average requested rates defined for the service j.

Therefore, the average duration of a connection (in s) is:

$$D^{UL}_{Connection} = (D^{UL}_{Activity})_{session} + (D^{UL}_{Inactivity})_{session} \text{ and } D^{DL}_{Connection} = (D^{DL}_{Activity})_{session} + (D^{DL}_{Inactivity})_{session}$$

- Calculation of the service usage duration per hour (probability of a connection):

$$p^{UL}_{Connection} = \frac{N_{sess}}{3600} \times D^{UL}_{Connection} \text{ and } p^{DL}_{Connection} = \frac{N_{sess}}{3600} \times D^{DL}_{Connection}$$

- Calculation of the probability of being connected:

$$p_{Connected} = 1-(1-p^{UL}_{Connection})\times(1-p^{DL}_{Connection})$$

Therefore, the number of users who want to get the service j is:

$$n_j = X\times p_{Connected}$$

As you can see on the picture above, we have to consider three possible cases when a user is connected:

- 1st case: At a given time, packets are downloaded and uploaded.

In this case, the probability of being connected is:

$$p^{UL+DL}_{Connected} = \frac{p^{UL}_{Connection}\times p^{DL}_{Connection}}{p_{Connected}}$$

- 2nd case: At a given time, packet are uploaded (no packet is downloaded).

Here, the probability of being connected is:

$$p^{UL}_{Connected} = \frac{p^{UL}_{Connection}\times(1-p^{DL}_{Connection})}{p_{Connected}}$$

- 3rd case: At a given time, packet are downloaded (no packet is uploaded).

In this case, the probability of being connected is:

$$p^{DL}_{Connected} = \frac{p^{DL}_{Connection}\times(1-p^{UL}_{Connection})}{p_{Connected}}$$

Now, we have to take into account activity periods during the connection in order to determine the activity status of each user.

- Calculation of the probability of being active:

$$f^{UL} = \frac{(D^{UL}_{Activity})_{session}}{((D^{UL}_{Inactivity})_{session}+(D^{UL}_{Activity})_{session})}$$ and $$f^{DL} = \frac{(D^{DL}_{Activity})_{session}}{((D^{DL}_{Inactivity})_{session}+(D^{DL}_{Activity})_{session})}$$

Therefore, we have:

- 1st case: At a given time, packets are downloaded and uploaded.

The user can be active on UL and inactive on DL; this probability is:

$$p^1_{UL} = f^{UL}\times(1-f^{DL})\times p^{UL+DL}_{Connected}$$

The user can be active on DL and inactive on UL; this probability is:

$$p^1_{DL} = f^{DL}\times(1-f^{UL})\times p^{UL+DL}_{Connected}$$

The user can be active on both links; this probability is:

$$p^1_{UL+DL} = f^{UL}\times f^{DL}\times p^{UL+DL}_{Connected}$$

The user can be inactive on both links; this probability is:

$$p^1_{inactive} = (1-f^{UL})\times(1-f^{DL})\times p^{UL+DL}_{Connected}$$

- 2nd case: At a given time, packet are uploaded (no packet is downloaded).

The user can be active on UL and inactive on DL; this probability is:

$$p^2_{UL} = f^{UL}\times p^{UL}_{Connected}$$

The user can be inactive on both links; this probability is:

$$p^2_{inactive} = (1-f^{UL})\times p^{UL}_{Connected}$$

- 3rd case: At a given time, packet are downloaded (no packet is uploaded).

The user can be active on DL and inactive on UL; this probability is:

$$p^3_{DL} = f^{DL}\times p^{DL}_{Connected}$$

The user can be inactive on both links; this probability is:

$p^3_{inactive} = (1 - f^{DL}) \times p^{DL}_{Connected}$

- Calculation of number of users per activity status

Number of inactive users on UL and DL: $n_j^{inactive} = n_j \times (p^1_{inactive} + p^2_{inactive} + p^3_{inactive})$

Number of users active on UL and inactive on DL: $n_j(UL) = n_j \times (p^1_{UL} + p^2_{UL})$

Number of users active on DL and inactive on UL: $n_j(DL) = n_j \times (p^1_{DL} + p^3_{DL})$

Number of users active on UL and DL: $n_j(UL + DL) = n_j \times p^1_{UL + DL}$

Therefore, a user when he is connected can have four different activity status: either active on both links, or inactive on both links, or active on UL only, or active on DL only.

> The user distribution per service and the activity status distribution between the users are average distributions. And the service and the activity status of each user are randomly drawn in each simulation. Therefore, if you compute several simulations at once, the average number of users per service and average numbers of inactive, active on UL, active on DL and active on UL and DL users, respectively, will correspond to calculated distributions. But if you check each simulation, the user distribution between services as well as the activity status distribution between users is different in each of them.

4.4.1.2 Simulations Based on Sector Traffic Maps

Sector traffic maps can be based on live traffic data from OMC (Operation and Maintenance Centre). Traffic is spread over the best server coverage area of each transmitter and each coverage area is assigned either the throughputs in the uplink and in the downlink or the number of users per activity status or the total number of users (including all activity statuses).

4.4.1.2.1 Throughputs in Uplink and Downlink

When selecting **Throughputs in Uplink and Downlink**, you can input the throughput demands in the uplink and downlink for each sector and for each listed service.

9955 calculates the number of users active in uplink and in downlink in the Txi cell using the service (N_{UL} and N_{DL}) as follows:

$$N_{UL} = \frac{R_t^{UL}}{R^{UL}_{average}} \text{ and } N_{DL} = \frac{R_t^{DL}}{R^{DL}_{average}}$$

R_t^{UL} is the kbits per second transmitted in UL in the Txi cell to supply the service.

R_t^{DL} is the kbits per second transmitted in DL in the Txi cell to supply the service.

$R^{DL}_{average}$ is the downlink average requested throughput defined for the service,

$R^{UL}_{average}$ is the uplink average requested throughput defined for the service.

N_{UL} and N_{DL} values include:

- Users active in uplink and inactive in downlink ($n_i(UL)$),
- Users active in downlink and inactive in uplink ($n_i(DL)$),
- And users active in both links ($n_i(UL+DL)$).

9955 takes into account activity periods during the connection in order to determine the activity status of each user.

Activity probabilities are calculated as follows:

Probability of being inactive in UL and DL: $p_{inactive} = (1 - f^{UL}_{act}) \times (1 - f^{DL}_{act})$

Probability of being active in UL only: $p_{UL} = f^{UL}_{act} \times (1 - f^{DL}_{act})$

Probability of being active in DL only: $p_{DL} = f^{DL}_{act} \times (1 - f^{UL}_{act})$

Probability of being active both in UL and DL: $p_{UL + DL} = f^{UL}_{act} \times f^{DL}_{act}$

Where, f_{act}^{UL} and f_{act}^{DL} are respectively the UL and DL activity factors defined for the service i.

Then, **9955** calculates the number of users per activity status:

We have:

$$(p_{UL} + p_{UL+DL}) \times (n_j(UL) + n_j(DL) + n_j(UL+DL)) = N_{UL}$$

$$(p_{DL} + p_{UL+DL}) \times (n_j(UL) + n_j(DL) + n_j(UL+DL)) = N_{DL}$$

Therefore, we have:

Number of users active in UL and DL both: $n_i(UL+DL) = min\left(\frac{N_{UL} \times p_{UL+DL}}{p_{UL} + p_{UL+DL}}, \frac{N_{DL} \times p_{UL+DL}}{p_{DL} + p_{UL+DL}}\right)$

Number of users active in UL and inactive in DL: $n_i(UL) = N_{UL} - n_i(UL+DL)$

Number of users active in DL and inactive in UL: $n_i(DL) = N_{DL} - n_i(UL+DL)$

Number of inactive users in UL and DL: $n_i^{inactive} = \frac{(n_j(UL) + n_j(DL) + n_j(UL+DL))}{1 - p_{inactive}} \times p_{inactive}$

Therefore, a connected user can have four different activity status: either active in both links, or inactive in both links, or active in UL only, or active in DL only.

4.4.1.2.2 Total Number of Users (All Activity Statuses)

When selecting **Total Number of Users (All Activity Statuses)**, you can input the number of connected users for each sector and for each listed service (n_i).

9955 takes into account activity periods during the connection in order to determine the activity status of each user.

Activity probabilities are calculated as follows:

Probability of being inactive in UL and DL: $p_{inactive} = (1 - f_{act}^{UL}) \times (1 - f_{act}^{DL})$

Probability of being active in UL only: $p_{UL} = f_{act}^{UL} \times (1 - f_{act}^{DL})$

Probability of being active in DL only: $p_{DL} = f_{act}^{DL} \times (1 - f_{act}^{UL})$

Probability of being active both in UL and DL: $p_{UL+DL} = f_{act}^{UL} \times f_{act}^{DL}$

Where, f_{act}^{UL} and f_{act}^{DL} are respectively the UL and DL activity factors defined for the service i.

Then, **9955** calculates the number of users per activity status:

Number of inactive users in UL and DL: $n_i^{inactive} = n_i \times p_{inactive}$

Number of users active in UL and inactive in DL: $n_i(UL) = n_i \times p_{UL}$

Number of users active in DL and inactive in UL: $n_i(DL) = n_i \times p_{DL}$

Number of users active in UL and DL both: $n_i(UL+DL) = n_i \times p_{UL+DL}$

Therefore, a connected user can have four different activity status: either active in both links, or inactive in both links, or active in UL only, or active in DL only.

4.4.1.2.3 Number of Users per Activity Status

When selecting **Number of Users per Activity Status**, you can directly input the number of inactive users ($n_i^{inactive}$), the number of users active in the uplink ($n_i(UL)$), in the downlink ($n_i(DL)$) and in the uplink and downlink ($n_i(UL+DL)$), for each sector and for each service.

> The activity status distribution between users is an average distribution. In fact, in each simulation, the activity status of each user is randomly drawn. Therefore, if you compute several simulations at once, average numbers of inactive, active on UL, active on DL and active on UL and DL users correspond to the calculated distribution. But if you check each simulation, the activity status distribution between users is different in each of them.

4.4.2 Power Control Simulation

The power control algorithm simulates the way a UMTS network regulates itself by using uplink and downlink power controls in order to minimize interference and maximize capacity.

HSDPA users (i.e., Packet (HSDPA - Best Effort), Packet (HSPA - Best Effort), Packet (HSDPA - Variable Bit Rate), Packet (HSPA - Variable Bit Rate) and Packet (HSPA - Constant Bit Rate) service users) are linked to the A-DPCH radio bearer (an R99 radio bearer). Therefore, the network uses a A-DPCH power control on UL and DL and then it performs fast link adaptation on DL in order to select an HSDPA radio bearer. For HSUPA users (i.e., Packet (HSPA - Best Effort), Packet (HSPA - Variable Bit Rate) and Packet (HSPA - Constant Bit Rate) service users), the network first uses a E-DPCCH/A-DPCH power control on UL and DL, checks that there is an HSDPA connection on downlink and then carries out noise rise scheduling in order to select an HSUPA radio bearer on uplink. **9955** simulates these network regulation mechanisms with an iterative algorithm and calculates, for each user distribution, network parameters such as cell power, mobile terminal power, active set and handoff status for each terminal. During each iteration of the algorithm, all the users (i.e., Circuit (R99), Packet (R99), Packet (HSDPA - Best Effort), Packet (HSPA - Best Effort), Packet (HSDPA - Variable Bit Rate), Packet (HSPA - Variable Bit Rate), and Packet (HSPA - Constant Bit Rate) service users) selected during the user distribution generation (1st step) attempt to connect one by one to network transmitters. The process is repeated until the network is balanced, i.e., until the convergence criteria (on UL and DL) are satisfied.

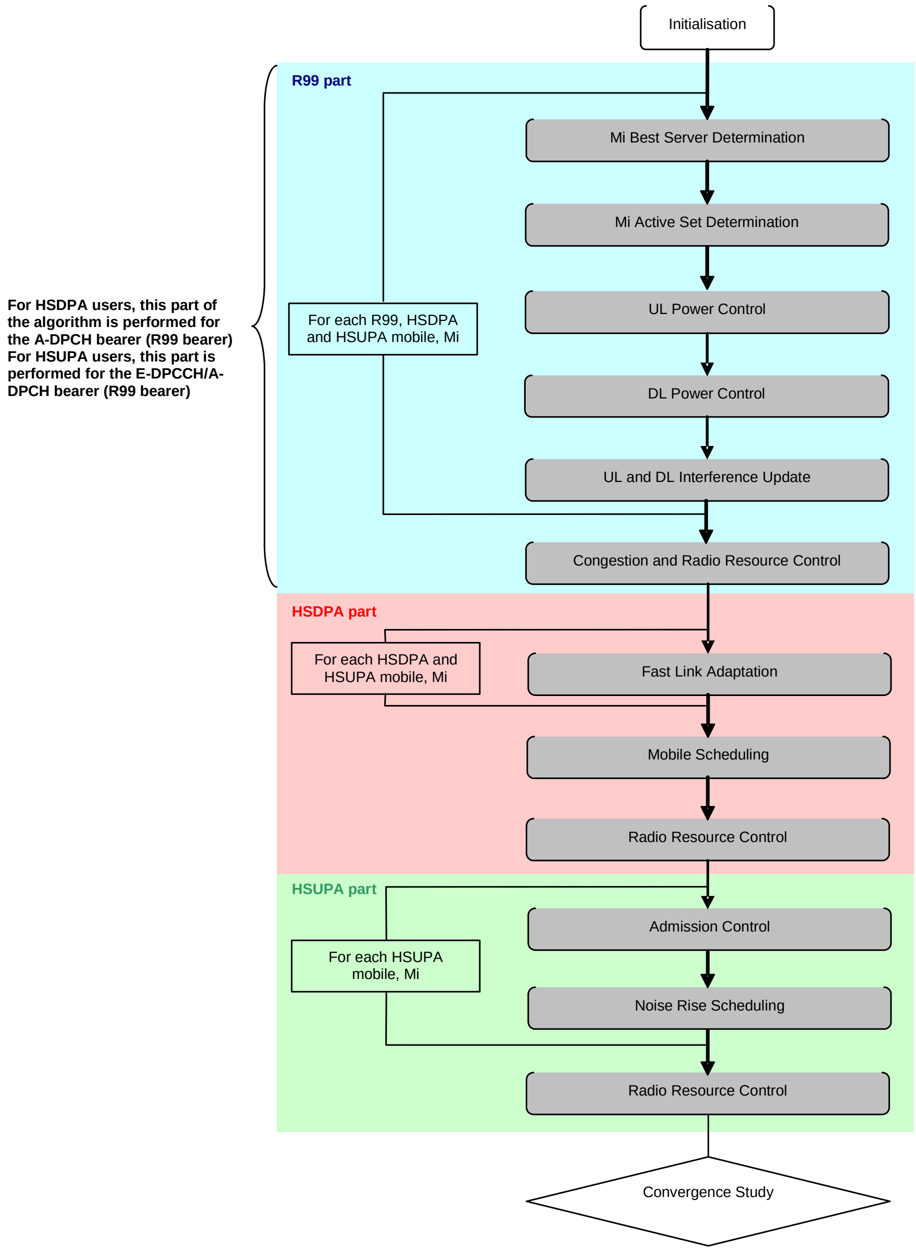


Figure 4.2: UMTS HSPA Power Control Algorithm

As shown in Figure 4.2 on page 199, the simulation algorithm is divided in three parts. All users are evaluated by the R99 part of the algorithm. HSDPA and HSUPA bearer users, unless they have been rejected during the R99 part of the algorithm, are then evaluated by the HSDPA part of the algorithm. Finally, HSUPA bearer users, unless they have been rejected during the R99 or HSDPA parts of the algorithm, are then evaluated by the HSUPA part of the algorithm.

The steps of this algorithm are detailed below.

4.4.2.1 Algorithm Initialization

The total power transmitted by the base station *txi* on the carrier ic_m, $P_{Tx}(txi, ic_m)$, is initialised to $P_{pilot}(txi, ic_m) + P_{SCH}(txi, ic_m) + P_{otherCCH}(txi, ic_m) + P_{HSDPA}(txi, ic_m) + P_{HSUPA}(txi, ic)$.

Uplink powers received by the base station *txi* on carrier ic_m, $I_{tot}^{UL_{intra}}(txi, ic_m)$, $I_{tot}^{UL_{extra}}(txi, ic_m)$ and $I_{inter-carrier}^{UL}(txi, ic_m)$ are initialised to 0 W (i.e. no connected mobile).

Therefore, we have: $(X_{R99}^{UL}(txi, ic_m))_k = \dfrac{I_{tot}^{UL}(txi, ic_m)}{N_{tot}^{UL}(txi, ic_m)} = 0$

4.4.2.2 R99 Part of the Algorithm

The algorithm is detailed for any iteration *k*. X_k is the value of the *X* (variable) at the iteration *k*. In the algorithm, all Q_{req}^{UL} and Q_{req}^{DL} thresholds depend on the user mobility type and are defined in the R99 bearer property dialogue. All variables are described in **Definitions and formulas** part. The bearer downgrading is not dealt with.

The algorithm applies to single frequency band networks and to dual-band networks. Dual-band terminals can have the following configurations:

- Configuration 1: The terminal can work on *f1* and *f2* without any priority (select "All" as main frequency band in the terminal property dialogue).
- Configuration 2: The terminal can work on *f1* and *f2* but *f1* has a higher priority (select "*f1*" as main frequency band and "*f2*" as secondary frequency band in the terminal property dialogue).

For each mobile M_b

Determination of M_b's Best Serving Cell

For each transmitter *txi* containing M_b in its calculation area and working on the main frequency band supported by the M_b's terminal (i.e. either *f1* for a single frequency band network, or *f1* or *f2* for a dual-band terminal with the configuration 1, or *f1* for a dual-band terminal with the configuration 2).

Calculation of $Q_{pilot_k}(txi, ic, Mb) = \dfrac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, ic)}{P_{tot}^{DL}(txi, ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{Term}}$

If user selects “without Pilot”

$$Q_{pilot_k}(txi, ic, Mb) = \frac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, ic)}{\left(\begin{array}{c} I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) \\ + N_0^{Term} - (1-\alpha) \times \rho_{BTS} \times P_c(txi, M_b, ic) \end{array}\right)}$$

Determination of the candidate cells, *(tx_{BS},ic)*.

For each carrier *ic*, selection of the transmitter with the highest $Q_{pilot_k}(txi, M_b, ic)$, $(tx_{BS}, ic)(M_i)$.

Analysis of candidate cells, *(tx_{BS},ic)*.

For each pair *(tx_{BS},ic)*, calculation of the uplink load factor:

$$(X_{R99}^{UL}(tx_{BS}, ic))_k = \frac{I_{tot}^{UL}(tx_{BS}, ic)}{N_{tot}^{UL}(tx_{BS}, ic)} + \Delta X^{UL}$$

ΔX^{UL} corresponds to the load rise due to the mobile. For information on how this parameter is calculated, see "Admission Control in the R99 Part" on page 243.

Rejection of bad candidate cells if the pilot is not received or if the uplink load factor is exceeded during the admission load control (if simulation respects a loading factor constraint and M_b was not connected in previous iteration)

If $Q_{pilot_k}(tx_{BS}, M_b, ic) < Q_{req}^{pilot}(Mobility(M_b))$ then *(tx_{BS},ic)* is rejected by M_b

If $(X_{R99}^{UL}(tx_{BS}, ic))_k > X_{max}^{UL}$, then (tx_{BS},ic) is rejected by M_b

Else

Keep (tx_{BS},ic) as good candidate cell

For dual band terminals with the configuration 1 or terminals working on one frequency band only, if no good candidate cell has been selected, M_b has failed to be connected to the network and is rejected.

For dual band terminals with the configuration 2, if no good candidate cell has been selected, try to connect M_b to transmitters *txi* containing M_b in their calculation area and working on the secondary frequency band supported by the M_b's terminal (i.e. f2). If no good candidate cell has been selected, M_b has failed to be connected to the network and is rejected.

For each NodeB having candidate cells, determination of the best carrier, ic_{BS}, within the set of candidate cells of the NodeB.

For DC-HSDPA users, this carrier is referred to as the "anchor" carrier.

If a given carrier is specified for the service requested by M_b

$ic_{BS}(M_b)$ is the carrier specified for the service

Else the carrier selection mode defined for the site equipment is considered.

If carrier selection mode is “Min. UL Load Factor”

$ic_{BS}(M_b)$ is the carrier where we obtain the lowest $(X_{R99}^{UL}(tx_{BS}, ic))_k$

Else if carrier selection mode is “Min. DL Total Power”

$ic_{BS}(M_b)$ is the carrier where we obtain the lowest $P_{tx}(tx_{BS}, ic)_k$

Else if carrier selection mode is “Random”

$ic_{BS}(M_b)$ is randomly selected

Else if carrier selection mode is "Sequential"

$ic_{BS}(M_b)$ is the first carrier where $(X_{R99}^{UL}(tx_{BS}, ic))_k \le X_{max}^{UL}$

Endif

Determination of the best serving cell, (tx_{BS},ic_{BS})

$(tx_{BS},ic_{BS})_k(M_b)$ is the best serving cell ($BestCell_k(M_b)$) and its pilot quality is $Q_{pilot_k}^{max}(M_b)$

In the following lines, we will consider ic as the carrier used by the best serving cell

Selection of the second serving cell for DC-HSDPA (Dual-cell HSDPA) users

If M_b is a DC-HSDPA user and if tx_{BS} supports DC-HSDPA and has several carriers, selection of the second carrier, ic_2.

For each carrier other than the best serving carrier, ic_p, calculation of $Q_{pilot_k}(tx_{BS}, ic_p, M_b)$

Selection of the carrier, ic_2, with the highest $Q_{pilot_k}(tx_{BS}, ic_p, M_b)$

If $Q_{pilot_k}(tx_{BS}, ic_2, M_b) < Q_{req}^{pilot}(Mobility(M_b))$ then (tx_{BS},ic_2) is rejected by M_b

Else

Keep (tx_{BS},ic_2) as second serving cell

Active Set Determination

For each station *txi* containing M_b in its calculation area, using ic, and, if neighbours are used, neighbour of $BestCell_k(M_b)$

Calculation of $Q_{pilot_k}(txi, M_b, ic) = \dfrac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, ic)}{P_{tot}^{DL}(txi, ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{Term}}$

If user selects “without Pilot”

$$Q_{pilot_k}(txi, M_b, ic) = \frac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, ic)}{\left(\begin{array}{c} I_{intra}^{DL}(txi, ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) \\ + N_0^{Term} - (1-\alpha) \times \rho_{BTS} \times P_c(txi, M_b, ic) \end{array}\right)}$$

Rejection of *txi* from the active set if difference with the best server is too high

If $Q_{pilot_k}^{max}(M_b) - Q_{pilot_k}(txi, M_b, ic) > AS\_Th(BestCell_k(M_b))$ then *txi* is rejected

Else *txi* is included in the M_b active set

Rejection of a station if the mobile active set is full

Station with the lowest Q_{pilot_k} in the active set is rejected

EndFor

Uplink Power Control

Calculation of the terminal power required by M_b to obtain the R99 radio bearer: $P_{term}^{R99-req}(M_b, ic)_k$

For each cell *(txi,ic)* of the M_b active set

Calculation of quality level on M_b traffic channel at *(txi,ic)*, with the minimum power allowed on traffic channel for the M_b service

$$P_{b-R99}^{UL}(txi, M_b, ic) = \frac{P_{term-R99}^{req}(M_b, ic)_{k-1}}{L_T(txi, M_b)}$$

$$P_{b-DPDCH}^{UL}(txi, M_b, ic) = P_{b-R99}^{UL}(txi, M_b, ic) \times (1 - r_c^{UL})$$

$$P_{b-DPCCH}^{UL}(txi, M_b, ic) = P_{b-R99}^{UL}(txi, M_b, ic) \times r_c^{UL}$$

$P_{b-R99}^{UL}(txi, M_b, ic) = P_{b-DPCCH}^{UL}(txi, M_b, ic) + P_{b-DPDCH}^{UL}(txi, M_b, ic)$ if the user is active,

$P_{b-R99}^{UL}(txi, M_b, ic) = P_{b-DPCCH}^{UL}(txi, M_b, ic)$ if the user is inactive,

$$Q_{tch}^{UL}(txi, M_b, ic)_k = \frac{\rho_{term} \times P_{b-DPDCH}^{UL}(txi, M_b, ic)_k}{N_{tot}^{UL}(txi, ic) - (1 - F_{MUD}^{Tx}) \times \rho_{term} \times P_{b-R99}^{UL}(txi, M_b, ic)_{k-1}} \times G_p^{UL}(Service(M_b)) \times G_{div}^{UL}$$

If user selects "Total noise",

$$Q_{tch}^{UL}(txi, M_b, ic)_k = \frac{\rho_{term} \times P_{b-DPDCH}^{UL}(txi, M_b, ic)_k}{N_{tot}^{UL}(txi, ic)} \times G_p^{UL}(Service(M_b)) \times G_{div}^{UL}$$

End For

If (M_b is in not in handoff)

$$Q_k^{UL}(M_b) = Q_{tch}^{UL}(txi, M_b, ic)_k$$

Else if (M_i is in softer handoff)

$$Q_k^{UL}(M_b) = f_{rake\ efficiency}^{UL} \times \sum_{txi \in ActiveSet} Q_{tch}^{UL}(txi, M_b, ic)_k$$

Else if (M_b is in soft, or softer/soft without MRC)

$$Q_k^{UL}(M_b) = \underset{txi \in ActiveSet}{Max} \left(Q_{tch}^{UL}(txi, M_b, ic)_k\right) \times (G_{macro-diversity}^{UL})_{2\ links}$$

Else if (M_b is in soft/soft)

$$Q_k^{UL}(M_b) = \underset{txi \in ActiveSet}{Max}\ (Q_{tch}^{UL}(txi, M_b, ic)_k) \times (G_{macro-diversity}^{UL})_{3\ links}$$

Else if (M_b is in softer/soft with MRC)

$$Q_k^{UL}(M_b) = Max\left(f_{rake\ efficiency}^{UL} \times \sum_{\substack{txi \in ActiveSet \\ (samesite)}} Q_{tch}^{UL}(ic), \underset{other\ site}{Q}{}_{tch}^{UL}(ic)\right) \times (G_{macro-diversity}^{UL})_{2\ links}$$

End If

$$P_{term-R99}^{req}(M_b, ic)_k = \frac{Q_{req}^{UL}(Service(M_b), Mobility(M_b))}{Q_k^{UL}(M_b)} \times P_{term-R99}^{req}(M_b, ic)_{k-1}$$

If compressed mode is operated,

> Compressed mode is operated if M_i and S_j support compressed mode, and
>
> - Either $Q_{pilot_k}^{Resulting}(txi, M_b, ic) \le Q_{pilot}^{CM-activation}$ if the Ec/I0 Active option is selected,
> - Or $P_c(txi, M_b, ic) \le RSCP_{pilot}^{CM-activation}$ if the RSCP Active option is selected.

$$P_{term-R99}^{req}(M_b, ic)_k = \frac{Q_{req}^{UL}(Service(M_b), Mobility(M_b)) \times \Delta Q_{req}^{UL}((Service(M_b), Mobility(M_b)))}{Q_k^{UL}(M_b)} \times P_{term-R99}^{req}(M_b, ic)_{k-1}$$

If $P_{term-R99}^{req}(M_b, ic)_k < P_{term}^{min}(M_b)$ then $P_{term-R99}^{req}(M_b, ic)_k = P_{term}^{min}(txi, M_b)$

If $P_{term-R99}^{req}(M_b, ic)_k > P_{term}^{max}(M_b)$ then M_b cannot select any cell and its active set is cleared

If $R_{nominal}^{UL}(M_b) \ge R_{max}^{UL}(txi, ic)$ then M_b cannot be connected

Endif

Downlink Power Control

If (mobile does not use a packet switched service that is inactive on the downlink)

For each cell *(tx_i,ic)* in M_b active set

Calculation of quality level on *(txi,ic)* traffic channel at M_b with the minimum power allowed on traffic channel for the M_b service

$$P_b^{DL}(txi, M_b, ic) = \frac{P_{tch}^{min}(Service(M_b))}{L_T(txi, M_b)}$$

$$Q_{tch}^{DL}(txi, M_b, ic)_k = \frac{\rho_{BTS} \times P_b^{DL}(txi, M_b, ic)_k}{N_{tot}^{DL}(ic) - (1 - F_{ortho}) \times \rho_{BTS} \times P_b^{DL}(txi, M_b, ic)_{k-1}} \times G_p^{DL}(Service(M_b)) \times G_{div}^{DL}$$

If the user selects the option "Total noise"

$$Q_{tch}^{DL}(txi, M_b, ic)_k = \frac{\rho_{BTS} \times P_b^{DL}(txi, M_b, ic)_k}{N_{tot}^{DL}(ic)} \times G_p^{DL}(Service(M_b)) \times G_{div}^{DL}$$

End For

$$Q_k^{DL}(M_b) = f_{rake\ efficiency}^{DL} \times \sum_{txi \in ActiveSet} Q_{tch}^{DL}(txi, M_b, ic)_k$$

Do

For each cell *(txi,ic)* in M_b active set

Calculation of the required power for DL traffic channel between *(txi,ic)* and M_b:

$$P_{tch}^{req}(txi, M_b, ic)_k = \frac{Q_{req}^{DL}(Service(M_b), Mobility(M_b))}{Q_k^{DL}(M_b)} \times P_{tch}^{min}(Service(M_b))$$

If compressed mode is operated.

$$P_{tch}^{req}(txi, M_b, ic)_k = \frac{Q_{req}^{DL}(Service(M_b), Mobility(M_b)) \times \Delta Q_{req}^{DL}((Service(M_b), Mobility(M_b)))}{Q_k^{DL}(M_b)} \times P_{tch}^{min}(Service(M_b))$$

Compressed mode is operated if M_i and S_j support compressed mode, and

- Either $Q_{pilot_k}^{Resulting}(txi, M_b, ic) \leq Q_{pilot}^{CM-activation}$ if the Ec/I0 Active option is selected,
- Or $P_c(txi, M_b, ic) \leq RSCP_{pilot}^{CM-activation}$ if the RSCP Active option is selected.

If $P_{tch}^{req}(txi, M_b, ic)_k > P_{tch}^{max}(Service(M_b))$ then (txi, ic) is set to P_{tch}^{max}

Recalculation of a decreased Q_{req}^{DL} (a part of the required quality is managed by the cells set to P_{tch}^{max})

$$P_b^{DL}(txi, M_b, ic) = \frac{P_{tch}^{req}(Service(M_b))}{L_T(txi, M_b)}$$

$$Q_{tch}^{DL}(txi, M_b, ic)_k = \frac{\rho_{BTS} \times P_b^{DL}(txi, M_b, ic)}{N_{tot}^{DL}(ic) - (1 - F_{ortho}) \times \rho_{BTS} \times P_b^{DL}(txi, M_b, ic)} \times G_p^{DL}(Service(M_b)) \times G_{div}^{DL}$$

If the user is inactive, then his contribution to interference in the calculation of $N_{tot}^{DL}(ic)$ is $P_b^{DL}(txi, M_b, ic) \times r_c^{DL}$.

EndFor

$$Q_k^{DL}(M_b) = f_{rake\ efficiency}^{DL} \times \sum_{txi \in ActiveSet} Q_{tch}^{DL}(txi, M_b, ic)_k$$

While $Q_k^{DL}(M_b) < Q_{req}^{DL}(Service(M_b), Mobility(M_b))$ and M_b active set is not empty

If $R_{nominal}^{DL}(M_b) \geq R_{max}^{DL}(txi, ic)$ then M_b cannot be connected

Endif

Uplink and Downlink Interference Update

Update of interference on active mobiles only (old contributions of mobiles and stations are replaced by the new ones).

For each cell *(txi,ic)*

Update of $N_{tot}^{UL}(txi, ic)$

EndFor

For each mobile M_i

Update of $N_{tot}^{DL}(ic)$

EndFor

EndFor

Control of Radio Resource Limits (OVSF Codes, Cell Power, Channel Elements, Iub Backhaul Throughput)

For each cell *(txi,ic)*

While $\frac{P_{tx}(txi, ic)_k}{P_{max}} > \%Power_{max}^{DL}$

Rejection of the mobile with the lowest service priority starting from the last admitted

EndFor

For each cell *(txi,ic)*

While $N^{Codes}(txi, ic)_k > N^{Codes}_{max}(txi, ic)$

Rejection of the mobile with the lowest service priority starting from the last admitted

EndFor

For each NodeB, *Ni*

While $N^{CE-DL}(N_i)_k > N^{CE-DL}_{max}(N_i)$

Rejection of the mobile with the lowest service priority starting from the last admitted

While $N^{CE-UL}(N_i)_k > N^{CE-UL}_{max}(N_i)$

Rejection of the mobile with the lowest service priority starting from the last admitted

EndFor

For each NodeB, *Ni*

While $T^{DL}_{Iub}(N_I)_k > T^{DL}_{Iub-max}(N_I)$

Rejection of the mobile with the lowest service priority starting from the last admitted

While $T^{UL}_{Iub}(N_I)_k > T^{UL}_{Iub-max}(N_I)$

Rejection of the mobile with the lowest service priority starting from the last admitted

EndFor

Uplink Load Factor Control

For each cell *(txi,ic)* with $X^{UL}_{R99}(txi, ic) > X^{UL}_{max}$

Rejection of the mobile with the lowest service priority starting from the last admitted

EndFor

While at least one cell with $X^{UL}_{R99}(txi, ic) > X^{UL}_{max}$ exists.

4.4.2.3 HSDPA Part of the Algorithm

Packet (HSDPA - Best Effort), Packet (HSPA - Best Effort), Packet (HSDPA - Variable Bit Rate) and Packet (HSPA - Variable Bit Rate) service users active on DL as well as all packet (HSPA - Constant Bit Rate) service users (i.e., active and incative), unless they have been rejected during the R99 part of the algorithm, are then evaluated by the HSDPA part of the algorithm.

4.4.2.3.1 HSDPA Power Allocation

The total transmitted power of the cell ($P_{tx}(ic)$) is the sum of the transmitted R99 power, the HSUPA power and the transmitted HSDPA power.

$$P_{tx}(ic) = P_{tx-R99}(ic) + P_{tx-HSDPA}(ic) + P_{HSUPA}(ic)$$

- In case of a static HSDPA power allocation strategy, **9955** checks in the simulation that:

$$P_{tx}(ic) \le P_{max}(ic) \times \%Power^{DL}_{max}$$

where:

$\%Power^{DL}_{max}$ is the maximum DL load allowed.

Therefore, if the maximum DL load is set to 100%, we have:

$$P_{tx}(ic) \le P_{max}(ic)$$

- In case of dynamic HSDPA power allocation strategy, **9955** checks in the simulation that:

$$P_{tx-R99}(ic) + P_{HSUPA}(ic) \le P_{max}(ic) \times \%Power^{DL}_{max}$$

And it calculates the available HSDPA power as follows:

$$P_{HSDPA}(ic) = P_{max}(ic) - P_{Headroom}(ic) - P_{tx-R99}(ic) - P_{HSUPA}(ic)$$

4.4.2.3.2 Number of HS-SCCH Channels and Maximum Number of HSDPA Bearer Users

The number of HS-SCCH channels ($n_{HS-SCCH}$) is the maximum number of HS-SCCH channels that the cell can manage. This parameter is used to manage the number of Best Effort and Variable Bit Rate service users simultaneously connected to an HSDPA bearer. This parameter is not taken into account for packet (HSPA - Constant Bit Rate) service users as HS-SCCH-less operation (i.e., HS-DSCH transmissions without any accompanying HS-SCCH) is performed.

Each packet (HSDPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service user consumes one HS-SCCH channel. Therefore, at a time (over a transmission time interval), the number of these users connected to an HSDPA bearer cannot exceed the number of HS-SCCH channels per cell.

The maximum number of HSDPA users (n_{max}) corresponds to the maximum number of HSDPA bearer users that the cell can support. Here, all HSDPA bearer users, i.e., packet (HSDPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) service users, are taken into consideration.

Let us assume there are 30 HSDPA bearer users in the cell:

- 10 packet (HSPA - Constant Bit Rate) service users with any activity status.
- 2 packet (HSDPA - Variable Bit Rate) service users active on DL.
- 18 packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users active on DL.

All users are connected to the A-DCH R99 bearer. Finally, the number of HS-SCCH channels and the maximum number of HSDPA users respectively equal 4 and 25.

The scheduler manages the maximum number of users within each cell. Packet (HSPA - Constant Bit Rate) service users have the highest priority and are processed first, in the order established during the generation of the user distribution. After processing the packet (HSPA - Constant Bit Rate) service users, **9955** processes the remaining HSDPA bearer users (i.e., packet (HSDPA - Variable Bit Rate), packet (HSPA - Variable Bit Rate), packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users). Variable Bit Rate service users have the highest priority and are managed before Best Effort service users. For each type of service, the scheduler ranks the users according to the selected scheduling technique. Users are treated as described in the figure below.

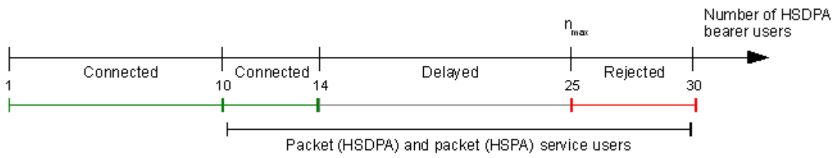


Figure 4.3: Connection status of HSDPA bearer users

- All packet (HSPA - Constant Bit Rate) service users may be served if there are enough HSDPA power, Iub backhaul throughput and OVSF codes available in order for them to obtain the lowest HSDPA bearer that provides a RLC peak rate higher or equal to the minimum throughput demand defined for the service. In this case, they will be connected. Else, they will be rejected.
- The two packet (HSDPA - Variable Bit Rate) service users may be simultaneously served if there are enough HSDPA power, Iub backhaul throughput and OVSF codes available in order for them to obtain an HSDPA bearer that provides a RLC peak rate higher or equal to the minimum throughput demand defined for the service. In this case, they will be connected. Else, they will be rejected.
- Then, among the packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users:
  - The first two users may be simultaneously served if there are enough HSDPA power, Iub backhaul throughput and OVSF codes available in order for them to obtain an HSDPA bearer. In this case, they will be connected. Else, they will be delayed.
  - The next eleven ones will be delayed since there are no longer HS-SCCH channels available. Their connection status will be "HS-SCCH Channels Saturation".
  - Finally, the last five users will be rejected beacuse the maximum number of HSDPA user has been fixed to 25. Their connection status will be "HSDPA Scheduler Saturation".

4.4.2.3.3 HSDPA Bearer Allocation Process

The HSDPA bearer allocation process depends on the type of service requested by the user. As explained before, packet (HSPA - Constant Bit Rate) service users have the highest priority and are processed first, in the order established during the generation of the user distribution. After processing the packet (HSPA - Constant Bit Rate) service users, the scheduler ranks the remaining HSDPA bearer users (i.e., Variable bit rate and best effort service users) and shares the cell radio resources between them. Variable Bit Rate service users have the highest priority and are managed before Best Effort service users.

Packet (HSPA - Constant Bit Rate) Service Users

Let us focus on the ten packet (HSPA - Constant Bit Rate) service users mentioned in the example of the previous paragraph "Number of HS-SCCH Channels and Maximum Number of HSDPA Bearer Users" on page 206. Fast link adaptation is carried out on these users in order to determine if they can obtain an HSDPA bearer that provides a RLC peak rate higher or equal to the service minimum throughput demand. As HS-SCCH less operation is performed, only HSDPA bearers using the QPSK modulation and two HS-PDSCH channels at the maximum can be selected and allocated to the users. The users are processed in the order established during the generation of the user distribution and the cell's available HSDPA power is shared between them as explained below. Several Packet (HSPA - Constant Bit Rate) service users can share the same HSDPA bearer. Then, **9955** calculates the HSDPA bearer consumption (C in %) for each user and takes into account this parameter when it determines the resources consumed by the user (i.e., the HSDPA power used, the number of OVSF codes and the Iub backhaul throughput).

In the bearer allocation process shown below, the 10 packet (HSPA - Constant Bit Rate) service users are represented by M_j, with j = 1 to 10. And, the initial values of their respective HSDPA powers is 0, i.e. $P_{HSDPA}(B(M_X)) = 0$, where X = 0 to 10. These power values are assigned one by one by the scheduler, so that with their allocated values, looped back to the starting point, are used in successive steps.

For the user, M_j, with j varying from 1 to 10:

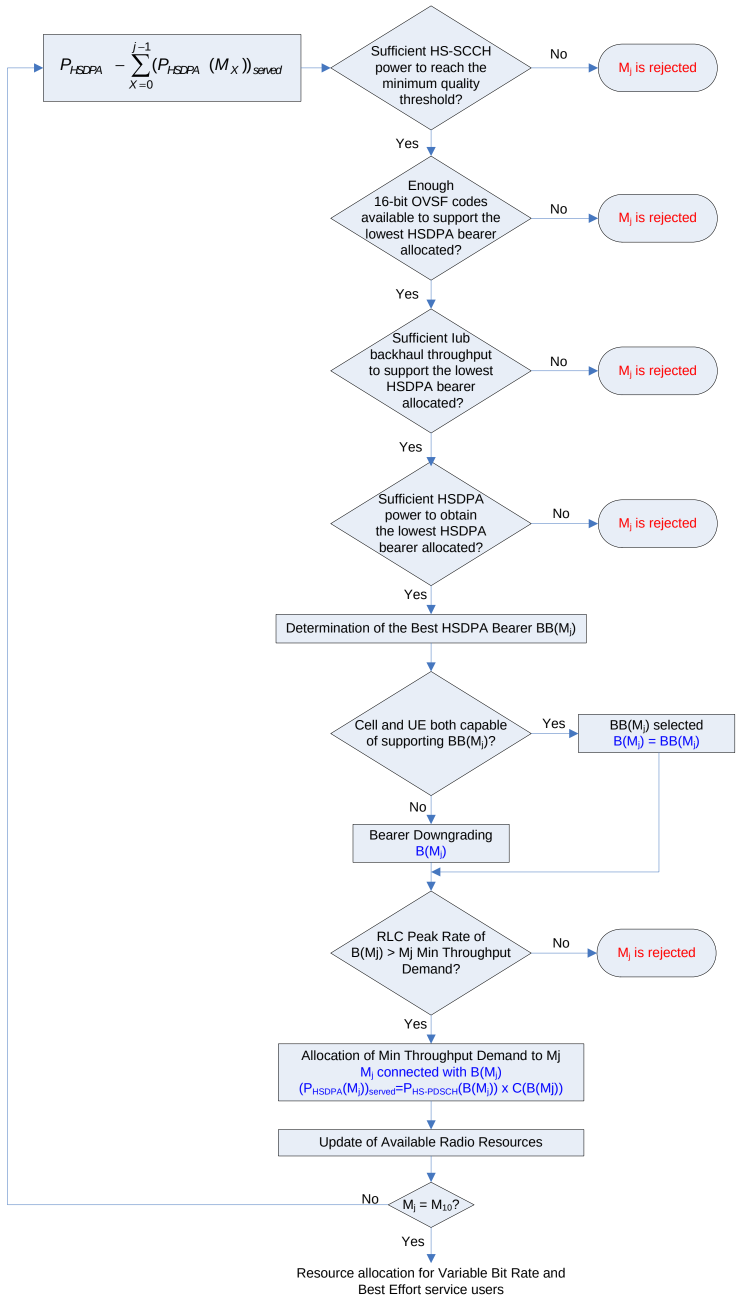


Figure 4.4: HSDPA Bearer Allocation Process for Packet (HSPA - Constant Bit Rate) Service Users

Packet (HSDPA - Variable Bit Rate) Service Users

After processing the packet (HSPA - Constant Bit Rate) service users, the scheduler shares the cell's remaining resources between packet (HSDPA - Variable Bit Rate) and packet (HSPA - Variable Bit Rate) service users. Let us focus on the two packet (HSDPA - Variable Bit Rate) service users mentioned in the example of the previous paragraph, "Number of HS-SCCH Channels and Maximum Number of HSDPA Bearer Users" on page 206. A new fast link adaptation is carried out on these users in order to determine if they can obtain an HSDPA bearer that provides a RLC peak rate higher or equal to the service minimum throughput demand. They are processed in the order defined by the scheduler and the cell's HSDPA power available after all Packet (HSPA - Constant Bit Rate) service users have been served is shared between them as explained below.

In the bearer allocation process shown below, the 2 packet (HSDPA - Variable Bit Rate) service users are represented by M_j, with j = 1 to 2. And, the initial values of their respective HSDPA powers is 0, i.e. $P_{HSDPA}(B(M_X)) = 0$, where X = 0 to 2. These power values are assigned one by one by the scheduler, so that with their allocated values, looped back to the starting point, are used in successive steps.

For the user, M_j, with j varying from 1 to 2:

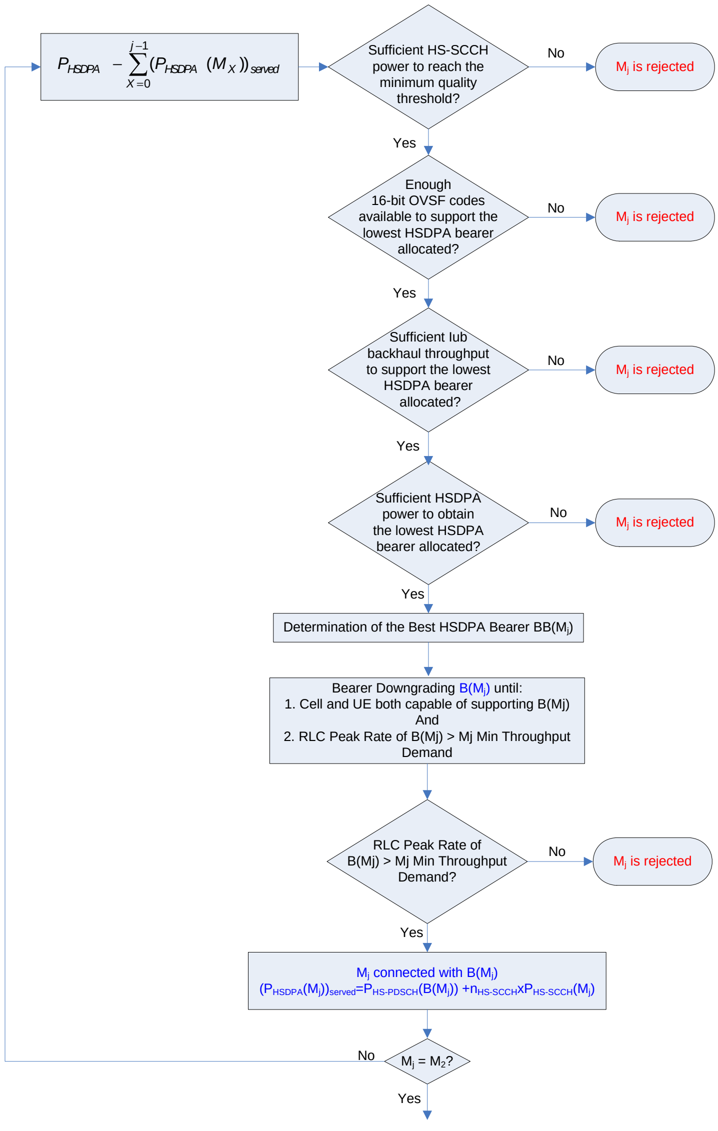


Figure 4.5: HSDPA Bearer Allocation Process for Packet (HSDPA - Variable Bit Rate) and Packet (HSPA - Variable Bit Rate) Service Users

Packet (HSDPA - Best Effort) and Packet (HSPA - Best Effort) Service Users

After processing the packet (HSDPA - Variable Bit Rate) service users, the scheduler shares the cell's remaining resources between packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users. Let us focus on the packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users, especially on the first four users mentioned in the example of the previous paragraph, "Number of HS-SCCH Channels and Maximum Number of HSDPA Bearer Users" on page 206. A new fast link adaptation is carried out on these users in order to determine if they can obtain an HSDPA bearer. They are processed in the order defined by the scheduler and the cell's HSDPA power available after all Constant Bit Rate and Variable Bit Rate service users have been served is shared between them as explained below.

In the bearer allocation process shown below, the 4 packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users are represented by M_j, with j = 1 to 4. And, the initial values of their respective HSDPA powers is 0, i.e. $P_{HSDPA}(B(M_X)) = 0$, where X = 0 to 4. These power values are assigned one by one by the scheduler, so that with their allocated values, looped back to the starting point, are used in successive steps.

For the user, M_j, with j varying from 1 to 4:

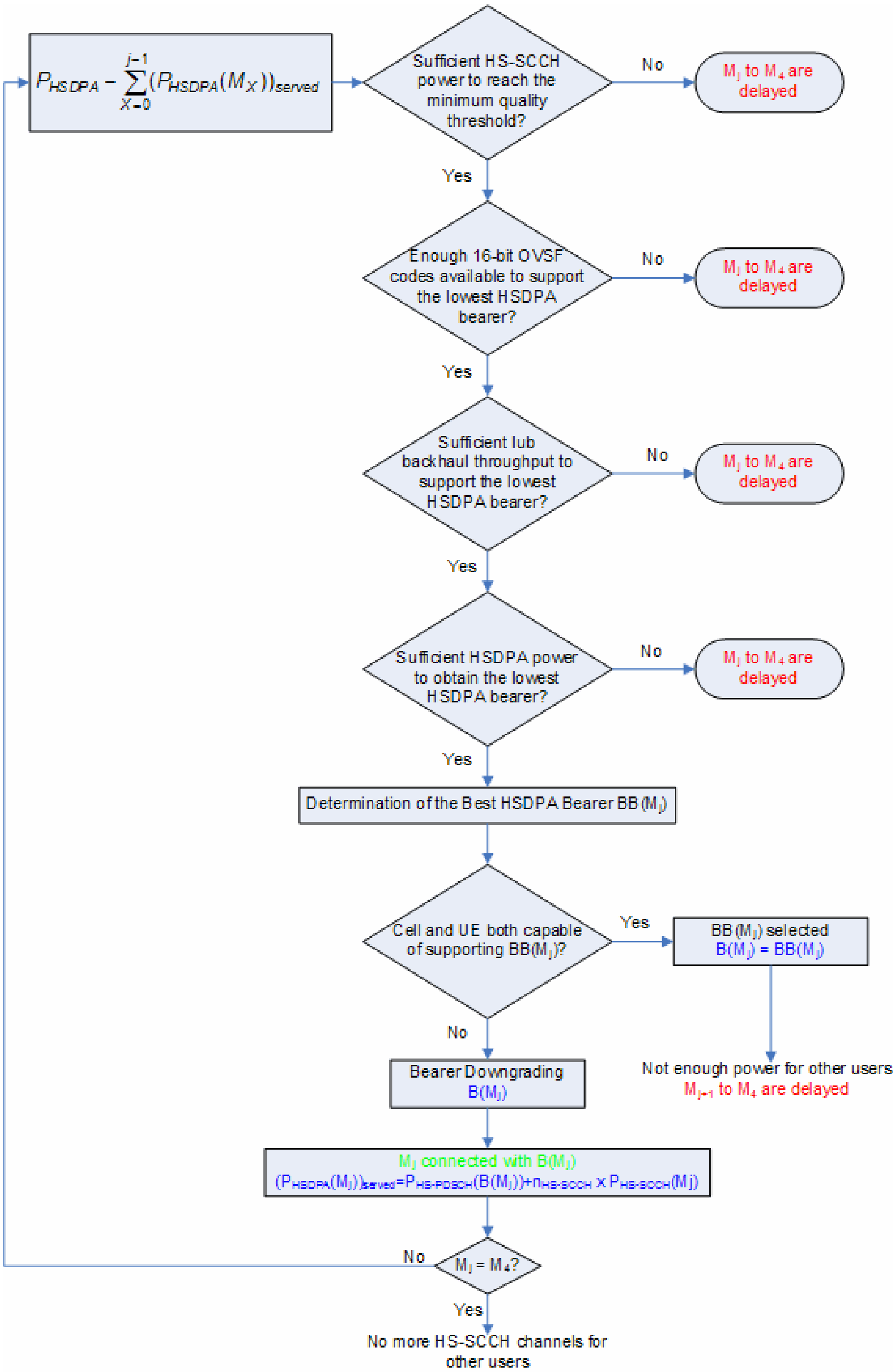


Figure 4.6: HSDPA Bearer Allocation Process for Packet (HSDPA - Best Effort) and Packet (HSPA - Best Effort) Service Users

4.4.2.3.4 Fast Link Adaptation Modelling

Fast link adaptation (or Adaptive Modulation and Coding) is used in HSDPA. The power on the HS-DSCH channel is transmitted at a constant power while the modulation, the coding and the number of codes are changed to adapt to the radio conditions variations. Based on the reported channel quality indicator (CQI), the node-B may change every 2ms the modulation (QPSK, 16QAM, 64QAM), the coding and the number of codes during a communication.

9955 calculates for each user either the best pilot quality (CPICH Ec/Nt) or the best HS-PDSCH quality (HS-PDSCH Ec/Nt); this depends on the option selected in Global parameters (HSDPA part): CQI based on CPICH quality or CQI based on HS-PDSCH quality (CQI means channel quality indicator). Then, it determines the HS-PDSCH CQI, calculates the best bearer that can be used and selects the suitable bearer so as to comply with cell and terminal user equipment HSDPA capabilities. Once the bearer selected, **9955** finds the highest downlink rate that can be provided to the user and may calculate the application throughput.

CQI Based on CPICH Quality

When the option “CQI based on CPICH quality” is selected, **9955** proceeds as follows.

1. CPICH Quality Calculation

Let us assume the following notation: $\left(\frac{Ec}{Nt}(ic)\right)_{pilot}$ corresponds to the CPICH quality.

Two options, available in Global parameters, may be used to calculate Nt: option Without useful signal or option Total noise.

Therefore, we have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{pilot} = \frac{\rho_{BTS} \times \alpha \times P_{c_i}(ic)}{N_{tot}^{DL}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{pilot} = \frac{\rho_{BTS} \times \alpha \times P_{c_i}(ic)}{N_{tot}^{DL}(ic) - (1-\alpha) \times \rho_{BTS} \times P_{c_i}(ic)}$$ for the without useful signal option.

With

$$N_{tot}^{DL}(ic) = I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term}$$

$$I_{intra}^{DL}(ic) = \underset{txi}{P_{tot}^{DL}(ic)} + \rho_{BTS} \times (1 - F_{MUD}^{term}) \times (1-\alpha) \times \left(\underset{txi}{P_{tot}^{DL}(ic)} - \frac{P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\underset{txi}{P_{tot}^{DL}(ic)} - \frac{P_{SCH}(ic)}{L_T}\right)$$

$$I_{extra}^{DL}(ic) = \sum_{txj, j \neq i} P_{tot}^{DL}(ic)$$

$$I_{inter-carrier}^{DL}(ic) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(ic_{adj})}{RF(ic, ic_{adj})}$$

ic_{adj} is a carrier adjacent to *ic*.

$RF(ic, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I_{inter-technology}^{DL}(ic)$ is the inter-technology interference at the receiver on *ic*.

$$I_{inter-technology}^{DL}(ic) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic}^{Tx, m}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP_{ic_i, ic}^{Tx, m}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic.

$$P_{c_i}(ic) = \frac{P_{pilot}(ic)}{L_{T_i}}$$

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}}$$ [3]

ρ_{BTS}, α and N_0^{term} are defined in "Inputs" on page 182.

3. *In the HSDPA coverage prediction,* L_T *is calculated as follows:*

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing - Ec/Io}}{G_{Tx} \times G_{term}})$$

9955 performs intra-cell interference computations based on the total power. You can instruct **9955** to use maximum power by adding the following lines in the Atoll.ini file:

[CDMA]
PmaxInIntraItf = 1

In this case, **9955** considers the following formula:

$$\left[I_{intra}^{DL}(ic) = \frac{P_{max}(ic)}{L_T} + \rho_{BTS} \times (1 - F_{MUD}^{term}) \times (1 - \alpha) \times \left(\frac{P_{max}(ic) - P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\frac{P_{max}(ic) - P_{SCH}(ic)}{L_T}\right)\right]$$

2. CPICH CQI Determination

Let us assume the following notation: $(CQI)_{pilot}$ corresponds to the CPICH CQI. $(CQI)_{pilot}$ is read in the table $(CQI)_{pilot} = f\left(\left(\frac{Ec}{Nt}(ic)\right)_{pilot}\right)$. This table is defined for the terminal reception equipment and the selected mobility.

3. HS-PDSCH Quality Calculation

9955 proceeds as follows:

1st step: **9955** calculates the HS-SCCH power ($P_{HS-SCCH}$).

$P_{HS-SCCH}(ic)$ is the HS-SCCH power on carrier *ic*. It is either fixed by the user (when the option "HS-SCCH Power Dynamic Allocation"in the cell property dialogue is unchecked) or dynamically calculated (when the option "HS-SCCH Power Dynamic Allocation" is selected).

In this case, the HS-SCCH power is controlled so as to reach the required HS-SCCH Ec/Nt (noted $\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH}^{req}$). It is specified in mobility properties.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N_{tot}^{DL}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N_{tot}^{DL}(ic) - (1 - F_{ortho}) \times (1 - F_{MUD}^{term}) \times \rho_{BTS} \times P_{c_i}(ic)}$$ for the without useful signal option.

With

$$N_{tot}^{DL}(ic) = I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term}$$

$$I_{intra}^{DL}(ic) = \frac{P_{tot}^{DL}(ic)}{txi} + \rho_{BTS} \times (1 - F_{MUD}^{term}) \times (1 - F_{ortho}) \times \left(\frac{P_{tot}^{DL}(ic)}{txi} - \frac{P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\frac{P_{tot}^{DL}(ic)}{txi} - \frac{P_{SCH}(ic)}{L_T}\right)$$

$$I_{extra}^{DL}(ic) = \sum_{txj, j \neq i} P_{tot}^{DL}(ic)$$

$$I_{inter-carrier}^{DL}(ic) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(ic_{adj})}{RF(ic, ic_{adj})}$$

ic_{adj} is a carrier adjacent to *ic*.

$RF(ic, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I_{inter-technology}^{DL}(ic)$ is the inter-technology interference at the receiver on *ic*.

$$I^{DL}_{inter-technology}(ic) = \sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx,m}_{ic_i,ic}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP^{Tx,m}_{ic_i,ic}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic.

$$P_{c_i}(ic) = \frac{P_{HS-SCCH}(ic)}{L_{T_i}}$$

and

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}} \ (^4)$$

ρ_{BTS}, F_{ortho}, F^{term}_{MUD} and N^{term}_0 are defined in "Inputs" on page 182.

Therefore,

$$P_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{req}_{HS-SCCH} \times N^{DL}_{tot}(ic)}{\rho_{BTS}} \right) \times L_{T_i}$$ for the total noise option,

And

$$P_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{req}_{HS-SCCH} \times N^{DL}_{tot}(ic)}{\rho_{BTS} \times \left(1 + (1 - F_{ortho}) \times (1 - F^{term}_{MUD}) \times \left(\frac{Ec}{Nt}(ic)\right)^{req}_{HS-SCCH}\right)} \right) \times L_{T_i}$$ for the without useful signal option.

2nd step: **9955** calculates the HS-PDSCH power ($P_{HS-PDSCH}$).

$P_{HSDPA}(ic)$ is the power available for HSDPA on the carrier *ic*. This parameter is either a simulation output, or a user-defined cell input.

$$P_{HSDPA}(ic) = P_{HS-PDSCH}(ic) + n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

Therefore, we have:

$$P_{HS-PDSCH}(ic) = P_{HSDPA}(ic) - n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

$n_{HS-SCCH}$ is the number of HS-SCCH channels.

3rd step: Then, **9955** evaluates the HS-PDSCH quality

Let us assume the following notation: $\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH}$ corresponds to the HS-PDSCH quality.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N^{DL}_{tot}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N^{DL}_{tot}(ic) - (1 - F_{ortho}) \times (1 - F^{term}_{MUD}) \times \rho_{BTS} \times \frac{P_{c_i}(ic)}{n}}$$ for the without useful signal option.

---

4. *In the HSDPA coverage prediction,* L_T *is calculated as follows:*

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}})$$

Here, **9955** works on the assumption that five HS-PDSCH channels are used (n=5).

With

$$N_{tot}^{DL}(ic) = I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term}$$

$$I_{intra}^{DL}(ic) = \frac{P_{tot}^{DL}(ic)}{txi} + \rho_{BTS} \times (1 - F_{MUD}^{term}) \times (1 - F_{ortho}) \times \left(\frac{P_{tot}^{DL}(ic)}{txi} - \frac{P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\frac{P_{tot}^{DL}(ic)}{txi} - \frac{P_{SCH}(ic)}{L_T}\right)$$

$$I_{extra}^{DL}(ic)) = \sum_{txj, j \neq i} P_{tot}^{DL}(ic)$$

$$I_{inter-carrier}^{DL}(ic) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(ic_{adj})}{RF(ic, ic_{adj})}$$

ic_{adj} is a carrier adjacent to *ic*.

$RF(ic, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I_{inter-technology}^{DL}(ic)$ is the inter-technology interference at the receiver on *ic*.

$$I_{inter-technology}^{DL}(ic) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic}^{Tx, m}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP_{ic_i, ic}^{Tx, m}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic.

$$P_{c_i}(ic) = \frac{P_{HS-PDSCH}(ic)}{L_{T_i}}$$

And

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}} \quad ([5])$$

ρ_{BTS}, F_{ortho}, F_{MUD}^{term} and N_0^{term} are defined in "Inputs" on page 182.

9955 performs intra-cell interference computations based on the total power. You can instruct **9955** to use maximum power by adding the following lines in the Atoll.ini file:

[CDMA]
PmaxInIntraItf = 1

In this case, **9955** considers the following formula:

$$I_{intra}^{DL}(ic) = \frac{P_{max}(ic)}{L_T} + \rho_{BTS} \times (1 - F_{MUD}^{term}) \times (1 - \alpha) \times \left(\frac{P_{max}(ic) - P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\frac{P_{max}(ic) - P_{SCH}(ic)}{L_T}\right)$$

4. HS-PDSCH CQI Determination

The best bearer that can be used depends on the HS-PDSCH CQI. Let us assume the following notation: $(CQI)_{HS-PDSCH}$ corresponds to the HS-PDSCH CQI. **9955** calculates $(CQI)_{HS-PDSCH}$ as follows:

$$(CQI)_{HS-PDSCH} = (CQI)_{pilot} - P_{pilot} + P_{HS-PDSCH}$$

---

5. *In the HSDPA coverage prediction,* L_T *is calculated as follows:*

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}})$$

5. HSDPA Bearer Selection

9955 selects the HSDPA bearer associated to this CQI (in the table Best Bearer=f(HS-PDSCH CQI) defined for the terminal reception equipment and the user mobility) and compatible with the user equipment and cell capabilities.

HSDPA bearers can be classified into two categories:

- HSDPA bearers using QPSK and 16QAM modulations: They can be selected for all users connected to HSPA and HSPA+ capable cells. The number of HS-PDSCH channels required by the bearer must not exceed the maximum number of HS-PDSCH codes available for the cell.

  For Variable Bit Rate service users, the selected HSDPA must provide a RLC peak rate between the minimum and the maximum throughput demands defined for the service.

  For packet (HSPA - Constant Bit Rate) service users, HS-SCCH-less operation (i.e., HS-DSCH transmissions without any accompanying HS-SCCH) is performed. In this case, the UE is not informed about the transmission format and has to revert to blind decoding of the transport format used on the HS-DSCH. Complexity of blind detections in the UE is decreased by limiting the transmission formats that can be used (i.e., the HSDPA bearers available). Therefore, only HSDPA bearers using the QPSK modulation and two HS-PDSCH channels at the maximum can be selected and allocated to these users. Additionally, the selected HSDPA bearer must provide a RLC peak rate higher or equal to the minimum throughput demand defined for the service.

- HSDPA bearers using 64QAM modulation (improvement introduced by the release 7 of the 3GPP UTRA specifications, referred to as HSPA+): These HSDPA bearers can be allocated to Variable Bit Rate and Best Effort service users connected to cells with HSPA+ capabilities only. The number of HS-PDSCH channels required by the bearer must not exceed the maximum number of HS-PDSCH codes available for the cell. For Variable Bit Rate service users, the selected HSDPA must provide a RLC peak rate between the minimum and the maximum throughput demands defined for the service. These HSDPA bearers cannot be allocated to packet (HSPA - Constant Bit Rate) service users.

9955 considers an HSDPA bearer as compatible with the user equipment if:

- The transport block size does not exceed the maximum transport block size supported by the user equipment.
- The number of HS-PDSCH channels required by the bearer does not exceed the maximum number of HS-PDSCH channels that the terminal can use.
- The modulation is supported by the user equipment.

When there are several HSDPA bearers compatible, **9955** selects the HSDPA bearer that provides the highest RLC peak rate. When several HSDPA bearers can supply the same RLC peak rate, **9955** chooses the HSDPA bearer with the highest modulation scheme. Finally, if no HSDPA bearer is compatible, **9955** allocates a lower HSDPA bearer compatible with the user equipment and cell capabilities which needs fewer resources.

Let's consider the following examples.

Example1: One packet (HSDPA - Best Effort) user with category 13 user equipment and a 50km/h mobility.

The user equipment capabilities are:

- Maximum transport block size: 35280 bits
- Maximum number of HS-PDSCH channels: 15
- Highest modulation supported: 64QAM
- MIMO Support: No

Document1: HSDPA UE Categories

Index	Category Name	Max Number of HS-PDSCH Channels	Min Number of TTI Between Two Used TTIs	Max Transport Block Size (bits)	Highest modulation	MIMO Support	Multi-cell mode
1	Category 1	5	3	7 298	16QAM	No	None
2	Category 2	5	3	7 298	16QAM	No	None
3	Category 3	5	2	7 298	16QAM	No	None
4	Category 4	5	2	7 298	16QAM	No	None
5	Category 5	5	1	7 298	16QAM	No	None
6	Category 6	5	1	7 298	16QAM	No	None
7	Category 7	10	1	14 411	16QAM	No	None
8	Category 8	10	1	14 411	16QAM	No	None
9	Category 9	15	1	20 251	16QAM	No	None
10	Category 10	15	1	27 952	16QAM	No	None
11	Category 11	5	2	3 630	QPSK	No	None
12	Category 12	5	1	3 630	QPSK	No	None
13	Category 13	15	1	35 280	64QAM	No	None
14	Category 14	15	1	42 192	64QAM	No	None
15	Category 15 (MIMO)	15	1	23 370	16QAM	Yes	None
16	Category 16 (MIMO)	15	1	27 952	16QAM	Yes	None

Figure 4.7: HSDPA UE Categories Table

The cell to which the user is connected supports HSPA+ functionalities (i.e. 64QAM modulation in the DL and MIMO systems) and the maximum number of HS-PDSCH channels is 15.

1st case: The CQI experienced by the user equals 26. Therefore, **9955** can choose between two HSDPA bearers, the bearer indexes 26 and 31.

Characteristics of the bearer index 26 are:

- Transport block size: 17237 bits
- Number of HS-PDSCH channels used: 12
- 16QAM modulation is used
- RLC Peak Rate: 8.32 Mb/s

Characteristics of the bearer index 31 are:

- Transport block size: 15776 bits
- Number of HS-PDSCH channels used: 10
- 64QAM modulation is used
- RLC Peak Rate: 7.36 Mb/s

Both HSDPA bearers are compatible with the user equipment and cell capabilities. **9955** selects the HSDPA bearer that provides the highest RLC peak rate, i.e. the bearer index 26.

Document1: HSDPA Radio Bearers

Radio Bearer Index	Transport Block Size (bits)	Number of Used HS-PDSCH Channels	RLC Peak Rate (bps)	Modulation
13	2 279	4	960 000	QPSK
14	2 583	4	1.12e+006	QPSK
15	3 319	5	1.44e+006	QPSK
16	3 565	5	1.6e+006	16QAM
17	4 189	5	1.92e+006	16QAM
18	4 664	5	2.08e+006	16QAM
19	5 287	5	2.4e+006	16QAM
20	5 887	5	2.856e+006	16QAM
21	6 554	5	3.04e+006	16QAM
22	7 168	5	3.36e+006	16QAM
23	9 719	7	4.48e+006	16QAM
24	11 418	8	5.28e+006	16QAM
25	14 411	10	6.72e+006	16QAM
26	17 237	12	8.32e+006	16QAM
27	21 754	15	1.024e+007	16QAM
28	23 370	15	1.104e+007	16QAM
29	24 222	15	1.152e+007	16QAM
30	25 558	15	1.216e+007	16QAM
31	15 776	10	7.36e+006	64QAM
32	21 768	12	1.024e+007	64QAM
33	26 504	13	1.248e+007	64QAM
34	32 264	14	1.536e+007	64QAM
35	38 576	15	1.824e+007	64QAM
36	39 984	15	1.904e+007	64QAM
37	42 192	15	2e+007	64QAM

Figure 4.8: HSDPA Radio Bearers Table

2nd case: The CQI experienced by the user equals 27. Therefore, **9955** can choose between two HSDPA bearers, the bearer indexes 27 and 32.

Characteristics of the bearer index 27 are:

- Transport block size: 21754 bits
- Number of HS-PDSCH channels used: 15
- 16QAM modulation is used
- RLC Peak Rate: 10.24 Mb/s

Characteristics of the bearer index 32 are:

- Transport block size: 21768 bits
- Number of HS-PDSCH channels used: 12
- 64QAM modulation is used
- RLC Peak Rate: 10.24 Mb/s

Both HSDPA bearers are compatible with the user equipment and cell capabilities and the RLC peak rate they provide is the same. **9955** selects the HSDPA bearer using the highest modulation scheme, i.e. the bearer index 32.

Example 2: One packet (HSDPA - Best Effort) user experiencing a CQI of 26.

Therefore, **9955** can choose between two HSDPA bearers, the bearer indexes 26 and 31.

Characteristics of the bearer index 26 are:

- Transport block size: 17237 bits
- Number of HS-PDSCH channels used: 12
- 16QAM modulation is used
- RLC Peak Rate: 8.32 Mb/s

Characteristics of the bearer index 31 are:

- Transport block size: 15776 bits
- Number of HS-PDSCH channels used: 10
- 64QAM modulation is used
- RLC Peak Rate: 7.36 Mb/s

1st case: The user equipment category is 9. The cell to which the user is connected supports HSPA+ functionalities (i.e. 64QAM modulation in the DL and MIMO systems) and the maximum number of HS-PDSCH channels is 15.

The user equipment characteristics are the following:

- Maximum transport block size: 20251 bits
- Maximum number of HS-PDSCH channels: 15
- Highest modulation supported: 16QAM
- MIMO Support: No

The bearer index 31 cannot be selected because it requires a modulation scheme not supported by the terminal. Only the bearer index 26 is compatible with the user equipment capabilities. **9955** selects it.

2nd case: The user equipment category is 8. The cell to which the user is connected supports HSPA+ functionalities (i.e. 64QAM modulation in the DL and MIMO systems) and the maximum number of HS-PDSCH channels is 15.

The user equipment characteristics are the following:

- Maximum transport block size: 14411 bits
- Maximum number of HS-PDSCH channels: 10
- Highest modulation supported: 16QAM
- MIMO Support: No

Here, none of HSDPA bearers are compatible with the user equipment capabilities.

The bearer index 31 cannot be selected because it requires a modulation scheme not supported by the terminal. With the bearer index 26, the number of HS-PDSCH channels (12) exceeds the maximum number of HS-PDSCH channels the terminal can use (10), and the transport block size (17237 bits) exceeds the maximum transport block size (14411 bits) the terminal can carried.

In the HSDPA Radio Bearer table, **9955** selects a lower HSDPA bearer compatible with cell and UE category capabilities. It selects the bearer index 25.

- The number of HS-PDSCH channels (10) does not exceed the maximum number of HS-PDSCH channels the terminal can use (10) and the maximum number of HS-PDSCH channels available at the cell level (15),
- The transport block size (14411 bits) does not exceed the maximum transport block size (14411 bits) the terminal can carried.
- 16QAM modulation is supported by the terminal and the cell.

3rd case: The user equipment category is 13. The cell to which the user is connected supports HSPA functionalities and the maximum number of HS-PDSCH channels is 15.

The user equipment capabilities are:

- Maximum transport block size: 35280 bits
- Maximum number of HS-PDSCH channels:15
- Highest modulation supported: 64QAM
- MIMO Support: No

The bearer index 31 cannot be selected because it requires a modulation scheme not supported by the cell. On the other hand, the bearer index 26 is compatible with cell and UE category capabilities. Therefore, it is allocated.

6. HS-PDSCH Quality Update

Once the bearer selected, **9955** exactly knows the number of HS-PDSCH channels. Therefore, when the method “Without useful signal” is used, it may recalculate the HS-PDSCH quality with the real number of HS-PDSCH channels (A default value (5) was taken into account in the first HS-PDSCH quality calculation).

CQI Based on HS-PDSCH Quality

When the option “CQI based on HS-PDSCH quality” is selected, **9955** proceeds as follows.

1. HS-PDSCH Quality Calculation

9955 proceeds as follows:

1st step: **9955** calculates the HS-SCCH power ($P_{HS-SCCH}$).

$P_{HS-SCCH}(ic)$ is the HS-SCCH power on carrier *ic*. It is either fixed by the user (when the option "HS-SCCH Power Dynamic Allocation"in the cell property dialogue is unchecked) or dynamically calculated (when the option "HS-SCCH Power Dynamic Allocation" is selected).

In this case, the HS-SCCH power is controlled so as to reach the required HS-SCCH Ec/Nt (noted $\left(\frac{Ec}{Nt}(ic)\right)^{req}_{HS-SCCH}$). It is specified in mobility properties.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N^{DL}_{tot}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N^{DL}_{tot}(ic) - (1 - F_{ortho}) \times (1 - F^{term}_{MUD}) \times \rho_{BTS} \times P_{c_i}(ic)}$$ for the without useful signal option.

With

$$N^{DL}_{tot}(ic) = I^{DL}_{intra}(ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic) + N^{term}_0$$

$$I^{DL}_{intra}(ic) = P^{DL}_{tot}(ic)_{txi} + \rho_{BTS} \times (1 - F^{term}_{MUD}) \times (1 - F_{ortho}) \times \left(P^{DL}_{tot}(ic)_{txi} - \frac{P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(P^{DL}_{tot}(ic)_{txi} - \frac{P_{SCH}(ic)}{L_T}\right)$$

$$I^{DL}_{extra}(ic) = \sum_{txj, j \neq i} P^{DL}_{tot}(ic)$$

$$I^{DL}_{inter-carrier}(ic) = \frac{\sum_{txj, \forall j} P^{DL}_{tot}(ic_{adj})}{RF(ic, ic_{adj})}$$

ic_{adj} is a carrier adjacent to *ic*.

$RF(ic, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I^{DL}_{inter-technology}(ic)$ is the inter-technology interference at the receiver on *ic*.

$$I^{DL}_{inter-technology}(ic) = \sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP^{Tx, m}_{ic_i, ic}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic.

$$P_{c_i}(ic) = \frac{P_{HS-SCCH}(ic)}{L_{T_i}}$$

And

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}}$$ [6]

ρ_{BTS}, F_{ortho}, F^{term}_{MUD} and N^{term}_0 are defined in "Inputs" on page 182.

Therefore,

6. *In the HSDPA coverage prediction,* L_T *is calculated as follows:*

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}})$$

$$P_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{req}_{HS-SCCH} \times N^{DL}_{tot}(ic)}{\rho_{BTS}}\right) \times L_{T_i}$$ for the total noise option,

And

$$P_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{req}_{HS-SCCH} \times N^{DL}_{tot}(ic)}{\rho_{BTS} \times \left(1 + (1-F_{ortho}) \times (1-F^{term}_{MUD}) \times \left(\frac{Ec}{Nt}(ic)\right)^{req}_{HS-SCCH}\right)}\right) \times L_{T_i}$$ for the without useful signal option.

2nd step: **9955** calculates the HS-PDSCH power ($P_{HS-PDSCH}$)

$P_{HSDPA}(ic)$ is the power available for HSDPA on the carrier *ic*. This parameter is either a simulation output, or a user-defined cell input.

$$P_{HSDPA}(ic) = P_{HS-PDSCH}(ic) + n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

Therefore, we have:

$$P_{HS-PDSCH}(ic) = P_{HSDPA}(ic) - n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

$n_{HS-SCCH}$ is the number of HS-SCCH channels.

3rd step: Then, **9955** evaluates the HS-PDSCH quality

Let us assume the following notation: $\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH}$ corresponds to the HS-PDSCH quality.

Two options, available in Global parameters, may be used to calculate Nt: option Without useful signal or option Total noise.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N^{DL}_{tot}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N^{DL}_{tot}(ic) - (1-F_{ortho}) \times (1-F^{term}_{MUD}) \times \rho_{BTS} \times \frac{P_{c_i}(ic)}{n}}$$ for the without useful signal option.

Here, **9955** works on the assumption that five HS-PDSCH channels are used (n=5). Then, it calculates the HS-PDSCH CQI and the bearer to be used. Once the bearer selected, **9955** exactly knows the number of HS-PDSCH channels and recalculates the HS-PDSCH quality with the real number of HS-PDSCH channels.

With

$$N^{DL}_{tot}(ic) = I^{DL}_{intra}(ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic) + N^{term}_{0}$$

$$I^{DL}_{intra}(ic) = \frac{P^{DL}_{tot}(ic)}{txi} + \rho_{BTS} \times (1-F^{term}_{MUD}) \times (1-F_{ortho}) \times \left(\frac{P^{DL}_{tot}(ic)}{txi} - \frac{P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\frac{P^{DL}_{tot}(ic)}{txi} - \frac{P_{SCH}(ic)}{L_T}\right)$$

$$I^{DL}_{extra}(ic)) = \sum_{txj, j \neq i} P^{DL}_{tot}(ic)$$

$$I^{DL}_{inter-carrier}(ic) = \frac{\sum_{txi, \forall i} P^{DL}_{tot}(ic_{adj})}{RF(ic, ic_{adj})}$$

ic_{adj} is a carrier adjacent to *ic*.

$RF(ic, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I^{DL}_{inter-technology}(ic)$ is the inter-technology interference at the receiver on *ic*.

$$I_{inter-technology}^{DL}(ic) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic}^{Tx, m}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP_{ic_i, ic}^{Tx, m}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by m assuming the frequency gap between ic_i (external network) and ic.

$$P_{c_i}(ic) = \frac{P_{HS-PDSCH}(ic)}{L_{T_i}}$$

And

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}} \quad (^7)$$

ρ_{BTS}, F_{ortho}, F_{MUD}^{term} and N_0^{term} are defined in "Inputs" on page 182.

9955 performs intra-cell interference computations based on the total power. You can instruct **9955** to use maximum power by adding the following lines in the Atoll.ini file:

```
[CDMA]
PmaxInIntraItf = 1
```

In this case, **9955** considers the following formula:

$$I_{intra}^{DL}(ic) = \frac{P_{max}(ic)}{L_T} + \rho_{BTS} \times (1 - F_{MUD}^{term}) \times (1 - \alpha) \times \left(\frac{P_{max}(ic) - P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\frac{P_{max}(ic) - P_{SCH}(ic)}{L_T}\right)$$

2. HS-PDSCH CQI Determination

Let us assume the following notation: $(CQI)_{HS-PDSCH}$ corresponds to the HS-PDSCH CQI. $(CQI)_{HS-PDSCH}$ is read in the table $(CQI)_{HS-PDSCH} = f\left(\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH}\right)$. This table is defined for the terminal reception equipment and the specified mobility.

3. HSDPA Bearer Selection

The bearer is selected as described in "HSDPA Bearer Selection" on page 214.

4.4.2.3.5 MIMO Modelling

MIMO - Transmit Diversity

If the user is connected to a cell that supports HSPA+ with transmit diversity and if he has a MIMO-capable terminal (i.e., a terminal with an HSDPA UE category supporting MIMO), he will benefit from downlink diversity gain on the HS-PDSCH Ec/Nt.

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} + G_{TD}^{DL} + \Delta G_{TD}^{DL} \text{ in dB}$$

Where

G_{TD}^{DL} is the downlink transmit diversity gain (in dB) corresponding to the numbers of transmission and reception antenna ports (respectively defined in the transmitter and terminal properties).

ΔG_{TD}^{DL} is the additional diversity gain in downlink (in dB). It is defined for the clutter class of the user.

---

7. *In the HSDPA coverage prediction, L_T is calculated as follows:*

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}})$$

MIMO - Spatial Multiplexing

If the user is connected to a cell that supports HSPA+ with spatial multiplexing and if he has a MIMO-capable terminal (i.e., a terminal with an HSDPA UE category supporting MIMO), he will benefit from the spatial multiplexing gain in its RLC peak rate.

In this case, the RLC peak rate obtained by the user is the following:

$$R^{DL}_{RLC-peak} = R^{DL}_{RLC-peak}(Index_{HSDPABearer}) \times (1 + f_{SM-Gain} \times (G^{Max}_{SM} - 1))$$

Where

$R^{DL}_{RLC-peak}(Index_{HSDPABearer})$ is the RLC peak rate that the selected HSDPA bearer ($Index_{HSDPABearer}$) can provide in the cell *(Txi, ic)*. It is read in the HSDPA Radio Bearer table.

G^{Max}_{SM} is the maximum spatial multiplexing gain (in dB) for a given number of transmission and reception antennas (respectively defined in the transmitter and terminal properties).

$f_{SM-Gain}$ is the spatial multiplexing gain factor defined for the clutter

4.4.2.3.6 Scheduling Algorithms

The scheduler manages the maximum number of users within each cell. Packet (HSPA - Constant Bit Rate) service users have the highest priority and are processed first, in the order established during the generation of the user distribution. After processing the packet (HSPA - Constant Bit Rate) service users, the scheduler processes the remaining HSDPA bearer users (i.e., Variable Bit Rate and Best Effort service users). Variable Bit Rate service users have the highest priority and are managed before Best Effort service users. For each type of service, the scheduler ranks the users according the scheduling technique. Three scheduling algorithms are available, Max C/I, Round Robin and Proportional Fair. Impact they have on the simulation result is described in the tables below.

Let us consider a cell with 16 packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users. All of them are active on DL and connected to the A-DCH R99 bearer. There is neither Constant Bit Rate service user, nor Variable Bit Rate service user in the cell and the number of HS-SCCH channels and the maximum number of HSDPA users have been respectively set to 4 and 15.

Max C/I

15 users (where 15 corresponds to the maximum number of HSDPA users defined) enters the scheduler in the same order as in the simulation. Then, they are sorted in descending order by the channel quality indicator (CQI), i.e. in a best bearer descending order.

Mobiles	Simulation Rank	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M1	2	2400	2400+3.4	Connected
M2	15	2400	1440+3.4	Connected
M3	8	2080	160+3.4	Connected
M4	9	2080	3.4	Delayed
M5	10	2080	3.4	Delayed
M6	12	2080	3.4	Delayed
M7	13	2080	3.4	Delayed
M8	14	2080	3.4	Delayed
M9	7	1920	3.4	Delayed
M10	1	1600	3.4	Delayed
M11	3	1600	3.4	Delayed
M12	4	1600	3.4	Delayed
M13	5	1600	3.4	Delayed
M14	6	1600	3.4	Delayed
M15	11	1440	3.4	Delayed
M16	16	2080	0	Scheduler Saturation

Round Robin

Users are taken into account in the same order than the one in the simulation (random order).

Mobiles	Simulation Rank	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M1	1	1600	1600+3.4	Connected
M2	2	2400	960+3.4	Connected
M3	3	1600	3.4	Delayed
M4	4	1600	3.4	Delayed
M5	5	1600	3.4	Delayed
M6	6	1600	3.4	Delayed
M7	7	1920	3.4	Delayed
M8	8	2080	3.4	Delayed
M9	9	2080	3.4	Delayed
M10	10	2080	3.4	Delayed
M11	11	1440	3.4	Delayed
M12	12	2080	3.4	Delayed
M13	13	2080	3.4	Delayed
M14	14	2080	3.4	Delayed
M15	15	2400	3.4	Delayed
M16	16	2080	0	Scheduler Saturation

Proportional Fair

15 users (where 15 corresponds to the maximum number of HSDPA users defined) enters the scheduler in the same order as in the simulation. Then, they are sorted in an ascending order according to a new random parameter which corresponds to a combination of the user rank in the simulation and the channel quality indicator (CQI).

For a user *i*, the random parameter RP_i is calculated as follows:

$$RP_i = 50 \times R_i^{Simu} + 50 \times R_i^{CQI}$$

Where,

R_i^{Simu} is the user rank in the simulation.

R_i^{CQI} is the user rank according to the CQI.

> You can change the default weights by editing the atoll.ini file. For more information, see the *Administrator Manual.*

Mobiles	Simulation Rank	CQI Rank	RP	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M1	2	1	150	2400	2400	Connected
M2	1	10	550	1600	960	Connected
M3	8	3	550	2080	160	Connected
M4	9	4	650	2080	3.4	Delayed
M5	3	11	700	1600	3.4	Delayed
M6	10	5	750	2080	3.4	Delayed
M7	4	12	800	1600	3.4	Delayed
M8	7	9	800	1920	3.4	Delayed
M9	15	2	850	2400	3.4	Delayed
M10	5	13	900	1600	3.4	Delayed
M11	12	6	900	2080	3.4	Delayed
M12	6	14	1000	1600	3.4	Delayed
M13	13	7	1000	2080	3.4	Delayed

Mobiles	Simulation Rank	CQI Rank	RP	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M14	14	8	1100	2080	3.4	Delayed
M15	11	15	1300	1440	3.4	Delayed
M16	16	-	-	2080	0	Scheduler Saturation

4.4.2.3.7 Dual-Cell HSDPA

For transmitters that support dual-cell HSDPA mode, the sheduler manages a single queue of users at the Node B. All users belonging to the transmitter, i.e., dual-cell HSDPA and single-carrier HSDPA users, are ranked together in a unique list. Dual-cell HSDPA users are considered twice in the list as they may be assigned two different HSDPA bearers in the two cells.

Packet (HSPA - Constant Bit Rate) service users have the highest priority and are processed first, in the order established during the generation of the user distribution. After processing the packet (HSPA - Constant Bit Rate) service users, the scheduler processes the remaining HSDPA bearer users (i.e., Variable Bit Rate and Best Effort service users). Variable Bit Rate service users have the highest priority and are managed before Best Effort service users. For each type of service, the scheduler ranks the users according the scheduling technique (Max C/I, Round Robin and Proportional Fair). After the HSDPA users have been ranked, the scheduler allocates HSDPA resources to each user following the calculated order as long as there are resources available. Even if there is a unique list of users at the transmitter level, the resources of each cell are not shared and each carrier has its own pool of resources (number of HS-SCCH channels, maximum number of HSDPA users, HSDPA power, number of OVSF codes). Only site-level resources (such as the Iub throughput and the channel elements) are shared between the users of the two cells.

Let us consider a dual-cell HSDPA transmitter with 16 packet (HSDPA - Best Effort) and packet (HSPA - Best Effort) service users. There is neither Constant Bit Rate service user, nor Variable Bit Rate service users. All users are active in DL and connected to the A-DCH R99 bearer. Among the users, there are 6 dual-cell HSDPA users (i.e., terminal with UE categories 21 to 24).

Simulation Rank	Dual-cell HSDPA Support	Carriers	Comments
1	Yes	1 and 2	Anchor carrier: 2
2	No	2	
3	No	1	
4	Yes	1 and 2	Anchor carrier: 2
5	No	1	
6	No	2	
7	No	1	
8	No	2	
9	Yes	1 and 2	Anchor carrier: 1
10	No	1	
11	No	2	
12	Yes	1 and 2	Anchor carrier: 1
13	No	2	
14	Yes	1 and 2	Anchor carrier: 1
15	No	1	
16	Yes	1 and 2	Anchor carrier: 2

In each cell, the number of HS-SCCH channels and the maximum number of HSDPA bearer users have been respectively set to 4 and 7.

The scheduling algorithms defined for the two cells are the same as the one selected for the transmitter.

Each dual-cell HSDPA user is counted twice, once in each cell, as he may be assigned two different HSDPA bearers in the two cells. Therefore, the scheduler manages the users ranked 1st to 11th (i.e. 4 single-carrier users connected to the first carrier, 4 single-carrier users connected to the second carrier and 3 dual-cell users). Users ranked 12th to 16th are rejected because the maximum number of HSDPA bearer users that the scheduler can manage in a cell is exceeded.

Impact the scheduling algorithms have on the simulation results is described in the tables below.

Max C/I

7 users from each cell (where 7 corresponds to the maximum number of HSDPA users defined for each cell), i.e., a total of 14 users enter the scheduler in the same order as in the simulation. Then, they are sorted in the order of decreasing channel quality indicator (CQI), i.e. in a best bearer descending order.

Mobiles	Carrier	Simulation Rank	CQI	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M1	1	5	21	3040	3040+3.4	Connected
M2 (DC-HSDPA)	2	4	19	2400	2400+3.4	Connected
M3	2	8	18	2080	1440+3.4	Connected
M2 (DC-HSDPA)	1	4	17	1920	1920	Connected
M4 (DC-HSDPA)	1	9	17	1920	960+3.4	Connected
M5	1	3	16	1600	3.4	Delayed
M4 (DC-HSDPA)	2	9	16	1600	1120	Connected
M6	2	2	15	1440	3.4	Delayed
M7	1	7	14	1120	3.4	Delayed
M8	1	10	14	1120	3.4	Delayed
M9 (DC-HSDPA)	2	1	13	960	3.4	Delayed
M10	2	6	13	960	3.4	Delayed
M9 (DC-HSDPA)	1	1	12	800	0	Delayed
M11	2	11	12	800	3.4	Delayed
M12 (DC-HSDPA)	1 2	12	14 15	1120 1440	0	Scheduler Saturation
M13	2	13	17	1920	0	Scheduler Saturation
M14 (DC-HSDPA)	1 2	14	13 15	960 1440	0	Scheduler Saturation
M15	1	15	17	1920	0	Scheduler Saturation
M16 (DC-HSDPA)	1 2	16	12 14	800 1120	0	Scheduler Saturation

The scheduled dual-cell HSDPA users have the following status:

- The user ranked 4th (here M2) is connected to an HSDPA bearer in each cell. He obtains a total DL data rate of 4323.4 kbps (2403.4+1920).
- The user ranked 9th (here M4) is connected to an HSDPA bearer in each cell. He obtains a total DL data rate of 2083.4 kbps (963.4+1120).
- The first user (here M9) is delayed in the two cells. He obtains a total DL data rate of 3.4 kbps.

Round Robin

7 users from each cell (where 7 corresponds to the maximum number of HSDPA users defined for each cell), i.e., a total of 14 users enter the scheduler in the same order as in the simulation.

Mobiles	Carrier	Simulation Rank	CQI	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M1 (DC-HSDPA)	1	1	12	800	800	Connected
M1 (DC-HSDPA)	2	1	13	960	960+3.4	Connected

Mobiles	Carrier	Simulation Rank	CQI	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M2	2	2	15	1440	1440+3.4	Connected
M3	1	3	16	1600	1600+3.4	Connected
M4 (DC-HSDPA)	2	4	19	2400	1600+3.4	Connected
M4 (DC-HSDPA)	1	4	17	1920	960	Connected
M5	1	5	21	3040	480+3.4	Connected
M6	2	6	13	960	160+3.4	Connected
M7	1	7	14	1120	3.4	Delayed
M8	2	8	18	2080	3.4	Delayed
M9 (DC-HSDPA)	2	9	16	1600	0	Delayed
M9 (DC-HSDPA)	1	9	17	1920	3.4	Delayed
M10	1	10	14	1120	3.4	Delayed
M11	2	11	12	800	3.4	Delayed
M12 (DC-HSDPA)	1 2	12	14 15	1120 1440	0	Scheduler Saturation
M13	2	13	17	1920	0	Scheduler Saturation
M14 (DC-HSDPA)	1 2	14	13 15	960 1440	0	Scheduler Saturation
M15	1	15	17	1920	0	Scheduler Saturation
M16 (DC-HSDPA)	1 2	16	12 14	800 1120	0	Scheduler Saturation

The scheduled dual-cell HSDPA users have the following status:

- The first user (here M1) is connected to an HSDPA bearer in each cell. He obtains a total DL data rate of 1763.4 kbps (800+963.4).
- The user ranked 4th (here M4) is connected to an HSDPA bearer in each cell. He obtains a total DL data rate of 2563.4 kbps (1603.4+960).
- The user ranked 9th (here M9) is delayed in the two cells. He obtains a total DL data rate of 3.4 kbps.

Proportional Fair

7 users from each cell (where 7 corresponds to the maximum number of HSDPA users defined for each cell), i.e., a total of 14 users enter the scheduler in the same order as in the simulation. Then, they are sorted in an ascending order according to a new random parameter which corresponds to a combination of the user rank in the simulation and the channel quality indicator (CQI).

For a user *i*, the random parameter RP_i is calculated as follows:

$$RP_i = 50 \times R_i^{Simu} + 50 \times R_i^{CQI}$$

Where,

R_i^{Simu} is the user rank in the simulation.

R_i^{CQI} is the user rank according to the CQI.

> You can change the default weights by editing the atoll.ini file. For more information, see the *Administrator Manual.*

Mobiles	Carrier	Simulation Rank	CQI	CQI Rank	RP	Best Bearer (kbps)	DL Obtained Rate (kbps)	Connection Status
M1 DC-HSDPA	2	4	19	2	300	2400	2400+3.4	Connected
M2	1	5	21	1	300	3040	3040+3.4	Connected
M1 DC-HSDPA	1	4	17	4	400	1920	1440	Connected
M3	1	3	16	6	450	1600	800+3.4	Connected
M4	2	2	15	8	500	1440	1120+3.4	Connected
M5	2	8	18	3	550	2080	800+3.4	Connected
M6 DC-HSDPA	2	1	13	11	600	960	480+3.4	Connected
M6 DC-HSDPA	1	1	12	13	700	800	0	Delayed
M7 DC-HSDPA	1	9	17	5	700	1920	3.4	Delayed
M8	1	7	14	9	800	1120	3.4	Delayed
M7 DC-HSDPA	2	9	16	7	800	1600	0	Delayed
M9	2	6	13	12	900	960	3.4	Delayed
M10	1	10	14	10	1000	1120	3.4	Delayed
M11	2	11	12	14	1250	800	3.4	Delayed
M12 (DC-HSDPA)	1 2	12	14 15	1120 1440	0	Scheduler Saturation	0	Scheduler Saturation
M13	2	13	17	1920	0	Scheduler Saturation	0	Scheduler Saturation
M14 (DC-HSDPA)	1 2	14	13 15	960 1440	0	Scheduler Saturation	0	Scheduler Saturation
M15	1	15	17	1920	0	Scheduler Saturation	0	Scheduler Saturation
M16 (DC-HSDPA)	1 2	16	12 14	800 1120	0	Scheduler Saturation	0	Scheduler Saturation

The scheduled dual-cell HSDPA users have the following status:

- The user ranked 4th (here M1) is connected to an HSDPA bearer in each cell. He obtains a total DL data rate of 3843.4 kbps (2403.4+1440).
- The first user (here M6) is connected to an HSDPA bearer in his anchor cell and delayed in the other cell. He obtains a total DL data rate of 483.4 kbps (483.4+0).
- The user ranked 9th (here M7) is delayed in the two cells. He obtains a total DL data rate of 3.4 kbps.

4.4.2.4 HSUPA Part of the Algorithm

Packet (HSPA - Variable Bit Rate) and Packet (HSPA - Best Effort) service users active in the UL as well as all packet (HSPA - Constant Bit Rate) service users (i.e., active and inactive), unless they have been rejected during the R99 or HSDPA parts of the algorithm, are then evaluated by the HSUPA part of the algorithm. **9955** manages the maximum number of users within each cell. Packet (HSPA - Constant Bit Rate) service users have the highest priority and are processed first, in the order established during the generation of the user distribution. Then, **9955** considers packet (HSPA - Variable Bit Rate) service users in the order established during the generation of the user distribution and lastly, it processes packet (HSPA - Best Effort) service users in the order established during the generation of the user distribution.

Let us assume there are 12 HSUPA bearer users in the cell:

- 3 packet (HSPA - Constant Bit Rate) service users with any activity status. All of them have been connected to an HSDPA bearer.
- 2 packet (HSPA - Variable Bit Rate) service users. They have been connected to an HSDPA bearer.
- 7 packet (HSPA - Best Effort) service users active on UL. The first two users have been connected to an HSDPA bearer, the last one has been rejected and the remaining four have been delayed in the HSDPA part.

Finally, the maximum number of HSUPA users equals 10.

In this case, **9955** will consider the first ten HSUPA bearer users only and will reject the last two users in order not to exceed the maximum number of HSUPA users allowed in the cell (their connection status is "HSUPA scheduler saturation").

Mobiles	Service	Simulation Rank	HSDPA Connection Status	Evaluation by the HSUPA part of the algorithm
M1	Packet (HSPA - Constant Bit Rate)	4	Connected	Yes
M2	Packet (HSPA - Constant Bit Rate)	7	Connected	Yes
M3	Packet (HSPA - Constant Bit Rate)	9	Connected	Yes
M4	Packet (HSPA - Variable Bit Rate)	3	Connected	Yes
M5	Packet (HSPA - Variable Bit Rate)	5	Connected	Yes
M6	Packet (HSPA - Best Effort)	1	Connected	Yes
M7	Packet (HSPA - Best Effort)	2	Connected	Yes
M8	Packet (HSPA - Best Effort)	6	Delayed	Yes
M9	Packet (HSPA - Best Effort)	8	Delayed	Yes
M10	Packet (HSPA - Best Effort)	10	Delayed	Yes
M11	Packet (HSPA - Best Effort)	11	Delayed	No
M12	Packet (HSPA - Best Effort)	12	Rejected	No

4.4.2.4.1 Admission Control

During admission control, **9955** selects a list of HSUPA bearers for each user. The selected HSUPA bearers have to be compatible with the user equipment and capabilities of each HSUPA cell of the active set.

For packet (HSPA - Constant Bit Rate) service users, the list is restricted to HSUPA bearers that provide a RLC peak rate higher than the minimum throughput demand.

For packet (HSPA - Variable Bit Rate) service users, the list of compatible bearers is restricted to HSUPA bearers that provide a RLC peak rate between the maximum and the minimum throughput demands.

Let us focus on one packet (HSPA - Best Effort) service user with category 3 user equipment and a 50km/h mobility. This user is connected to one cell only. The cell supports HSPA+ functionalities, i.e the cell supports QPSK and 16QAM modulations in the UL.

HSUPA user equipment categories are provided in the HSUPA User Equipment Categories table. The capabilities of the category 3 user equipment are:

- Maximum Number of E-DPDCH codes: 2
- TTI 2 ms: No so it supports 10 ms TTI
- Minimum Spreading Factor: 4
- Maximum Block Size for a 2ms TTI: no value
- Maximum Block Size for a 10ms TTI: 14484 bits
- Highest Modulation Supported: QPSK

Document1: HSUPA UE Categories

Index	Category Name	TTI 2 ms	Min Spreading Factor	Max Block Size for a 2 ms TTI (bits)	Max Block Size for a 10 ms TTI (bits)	Highest modulation	Max Number of E-DPDCH Codes
1	Category 1	☐	4		7 110	QPSK	1
2	Category 2	☑	4	2 798	14 484	QPSK	2
3	Category 3	☐	4		14 484	QPSK	2
4	Category 4	☑	2	5 772	20 000	QPSK	2
5	Category 5	☐	2		20 000	QPSK	2
6	Category 6	☑	2	11 484	20 000	QPSK	4
7	Category 7	☑	2	22 996	20 000	16QAM	4

Figure 4.9: HSUPA UE Categories Table

HSUPA bearer characteristics are provided in the HSUPA Bearer table. An HSUPA bearer is described with following characteristics:

- Radio Bearer Index: The bearer index number.
- TTI Duration (ms): The TTI duration in ms. The TTI can be 2 or 10 ms.
- Transport Block Size (Bits): The transport block size in bits.
- Number of E-DPDCH Codes: The number of E-DPDCH channels used.
- Minimum Spreading Factor: The smallest spreading factor used.

- Modulation: the modulation used (QPSK or 16QAM)
- RLC Peak Rate (bps): The RLC peak rate represents the peak rate without coding (redundancy, overhead, addressing, etc.).

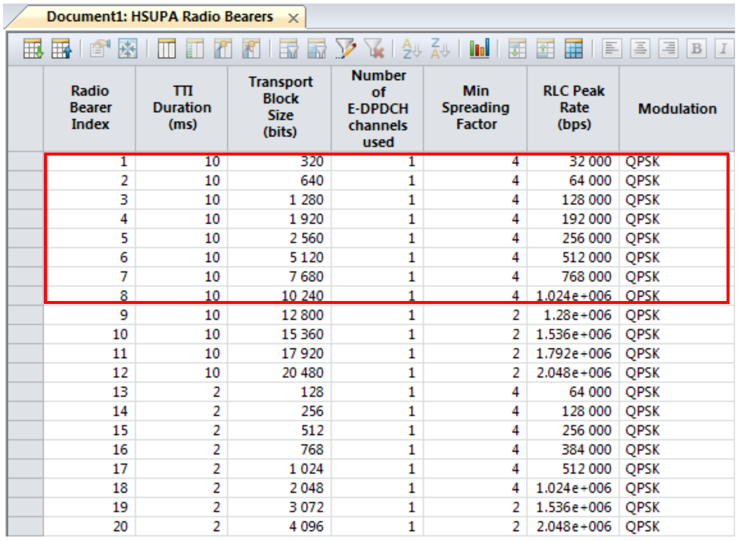
HSUPA bearers can be classified into two categories:

- HSUPA bearers using QPSK modulation: They can be selected for users connected to HSPA and HSPA+ capable cells.
- HSUPA bearers using 16QAM modulation (improvement introduced by the release 7 of the 3GPP UTRA specifications, referred to as HSPA+). These HSUPA bearers can be allocated to users connected to cells with HSPA+ capabilities only.

9955 considers an HSUPA bearer as compatible with the category 3 user equipment if:

- The TTI duration used by the bearer is supported by the user equipment (10 ms).
- The transport block size does not exceed the maximum transport block size supported by the user equipment (14484 bits):
- The number of E-DPDCH channels required by the bearer does not exceed the maximum number of E-DPDCH channels that the terminal can use (2).
- The minimum spreading factor used by the bearer is not less than the smallest spreading factor supported by the terminal (4).
- The modulation required by the bearer is supported by the terminal.

The HSUPA bearers compatible with category 3 user equipment are framed in red:



Document1: HSUPA Radio Bearers

Radio Bearer Index	TTI Duration (ms)	Transport Block Size (bits)	Number of E-DPDCH channels used	Min Spreading Factor	RLC Peak Rate (bps)	Modulation
1	10	320	1	4	32 000	QPSK
2	10	640	1	4	64 000	QPSK
3	10	1 280	1	4	128 000	QPSK
4	10	1 920	1	4	192 000	QPSK
5	10	2 560	1	4	256 000	QPSK
6	10	5 120	1	4	512 000	QPSK
7	10	7 680	1	4	768 000	QPSK
8	10	10 240	1	4	1.024e+006	QPSK
9	10	12 800	1	2	1.28e+006	QPSK
10	10	15 360	1	2	1.536e+006	QPSK
11	10	17 920	1	2	1.792e+006	QPSK
12	10	20 480	1	2	2.048e+006	QPSK
13	2	128	1	4	64 000	QPSK
14	2	256	1	4	128 000	QPSK
15	2	512	1	4	256 000	QPSK
16	2	768	1	4	384 000	QPSK
17	2	1 024	1	4	512 000	QPSK
18	2	2 048	1	4	1.024e+006	QPSK
19	2	3 072	1	2	1.536e+006	QPSK
20	2	4 096	1	2	2.048e+006	QPSK

Figure 4.10: HSUPA Radio Bearers Table

Then, during admission control, **9955** checks that the lowest compatible bearer in terms of the required E-DPDCH Ec⁄Nt does not require a terminal power higher than the maximum terminal power allowed.

9955 uses the HSUPA Bearer Selection table. Among the compatible HSUPA bearers, **9955** chooses the one with the lowest required Ec/Nt threshold.

Here, this is the index 1 HSUPA bearer; the required Ec/Nt threshold to obtain this bearer is -21.7dB.

Then, from the required Ec/Nt threshold, $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH}$, **9955** calculates the required terminal power, $P^{req}_{term-HSUPA}$.

$$P^{req}_{term-HSUPA} = \left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH} \times L_T \times N^{UL}_{tot}$$

With

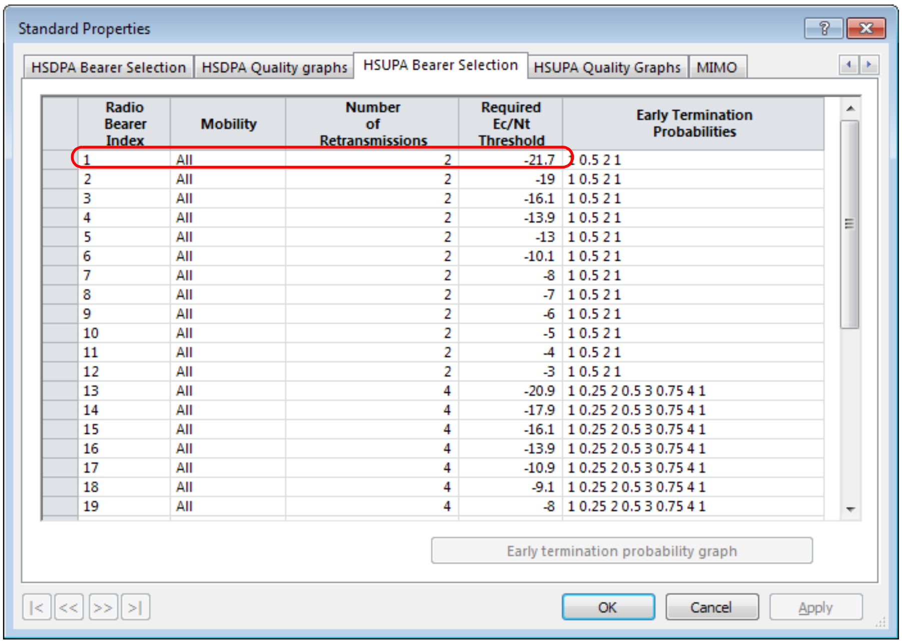
$$N^{UL}_{tot}(ic) = (1 - F^{tx}_{MUD} \times \rho_{term}) \times I^{UL_{intra}}_{tot}(ic) + I^{UL_{extra}}_{tot}(ic) + I^{UL}_{inter-carrier}(ic) + N^{tx}_0$$

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}} \quad (^{8})$$

8. *In the HSUPA coverage prediction,* L_T *is calculated as follows:*

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}})$$

ρ_{term}, F_{MUD}^{tx}, $I_{tot}^{UL_{intra}}$, $I_{tot}^{UL_{extra}}$, $I_{inter-carrier}^{UL}$ and N_0^{tx} are defined in "Inputs" on page 182.



Radio Bearer Index	Mobility	Number of Retransmissions	Required Ec/Nt Threshold	Early Termination Probabilities
1	All	2	-21.7	1 0.5 2 1
2	All	2	-19	1 0.5 2 1
3	All	2	-16.1	1 0.5 2 1
4	All	2	-13.9	1 0.5 2 1
5	All	2	-13	1 0.5 2 1
6	All	2	-10.1	1 0.5 2 1
7	All	2	-8	1 0.5 2 1
8	All	2	-7	1 0.5 2 1
9	All	2	-6	1 0.5 2 1
10	All	2	-5	1 0.5 2 1
11	All	2	-4	1 0.5 2 1
12	All	2	-3	1 0.5 2 1
13	All	4	-20.9	1 0.25 2 0.5 3 0.75 4 1
14	All	4	-17.9	1 0.25 2 0.5 3 0.75 4 1
15	All	4	-16.1	1 0.25 2 0.5 3 0.75 4 1
16	All	4	-13.9	1 0.25 2 0.5 3 0.75 4 1
17	All	4	-10.9	1 0.25 2 0.5 3 0.75 4 1
18	All	4	-9.1	1 0.25 2 0.5 3 0.75 4 1
19	All	4	-8	1 0.25 2 0.5 3 0.75 4 1

Figure 4.11: HSUPA Bearer SelectionTable

9955 rejects the user if the terminal power required to obtain the lowest compatible HSUPA bearer ($P_{term-HSUPA}^{req}$) exceeds the maximum terminal power (his connection status is "HSUPA Admission Rejection").

At the end of this step, the number of non-rejected HSUPA bearer users is n_{HSUPA}. All of them will be connected to an HSUPA bearer at the end.

4.4.2.4.2 HSUPA Bearer Allocation Process

The HSUPA bearer allocation process depends on the type of service requested by the user. As explained before, packet (HSPA - Constant Bit Rate) service users have the highest priority and are processed first, in the order established during the generation of the user distribution. After the admission control on packet (HSPA - Constant Bit Rate) service users, **9955** performs a noise rise scheduling, followed by a radio resource control. Then, it repeats the same steps on packet (HSPA - Variable Bit Rate) service users first, and lastly on packet (HSPA - Best Effort) service users, in the order established during the generation of the user distribution.

Packet (HSPA - Constant Bit Rate) Service Users

Let us focus on the three packet (HSPA - Constant Bit Rate) service users mentioned in the example of the previous paragraph "HSUPA Part of the Algorithm" on page 225. We assume that all of them have been admitted. Noise rise scheduling and radio resource control are carried out on each user in order to determine the best HSUPA bearer that the user can obtain. Several Packet (HSPA - Constant Bit Rate) service users can share the same HSUPA bearer. Then, **9955** calculates the HSUPA bearer consumption (C in %) for each user and takes into account this parameter when it determines the resources consumed by the user (i.e., the terminal power used, the number of channel elements and the Iub backhaul throughput).

In the bearer allocation process shown below, the 3 packet (HSPA - Constant Bit Rate) service users are represented by M_j, with j = 1 to 3.

For the user, M_j, with j varying from 1 to 3:

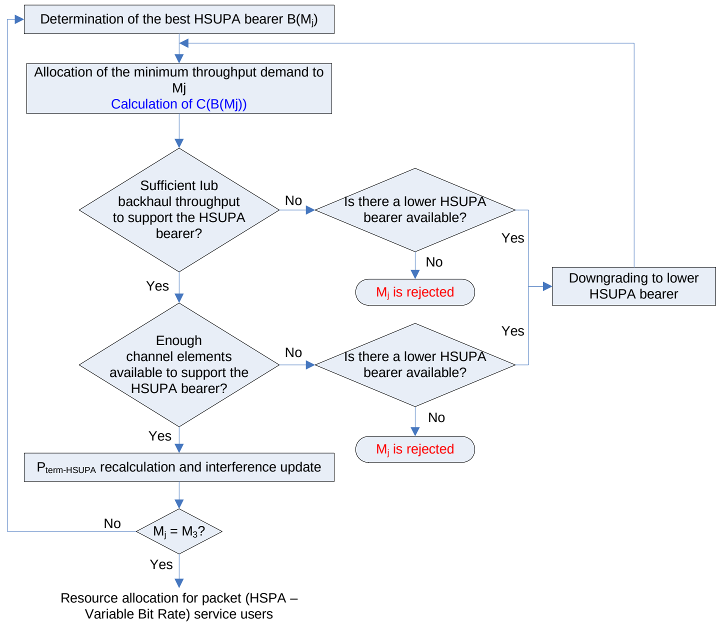


Figure 4.12: HSUPA Bearer Allocation Process for Packet (HSPA - Constant Bit Rate) Service Users

Packet (HSPA - Variable Bit Rate) Service Users

Let us focus on the two packet (HSPA - Variable Bit Rate) service users mentioned in the example of the previous paragraph "HSUPA Part of the Algorithm" on page 225. We assume that all of them have been admitted. Noise rise scheduling and radio resource control are carried out on each user in order to determine the best HSUPA bearer that the user can obtain.

In the bearer allocation process shown below, the 2 packet (HSPA - Variable Bit Rate) service users are represented by M_j, with j = 1 to 2.

For the user, M_j, with j varying from 1 to 2:

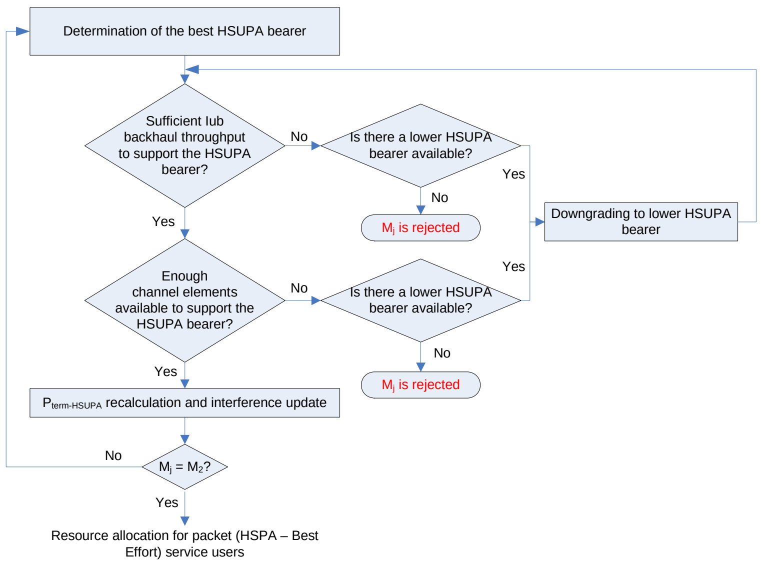


Figure 4.13: HSUPA Bearer Allocation Process for Packet (HSPA - Variable Bit Rate) Service Users

Packet (HSPA - Best Effort) Service Users

Let us focus on the five packet (HSPA - Best Effort) service users mentioned in the example of the previous paragraph "HSUPA Part of the Algorithm" on page 225. We assume that all of them have been admitted. Noise rise scheduling and radio resource control are carried out on each user in order to determine the best HSUPA bearer that the user can obtain.

In the bearer allocation process shown below, the 5 packet (HSPA - Best Effort) service users are represented by M_j, with j = 1 to 5.

For the user, M_j, with j varying from 1 to 5:

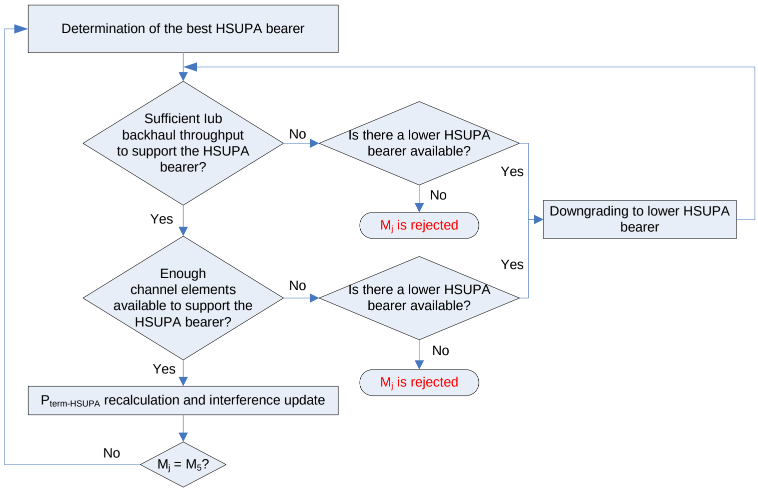


Figure 4.14: HSUPA Bearer Allocation Process for Packet (HSPA - Best Effort) Service Users

4.4.2.4.3 Noise Rise Scheduling

Determination of the Obtained HSUPA Bearer

The obtained HSUPA radio bearer is the bearer that the user obtains after noise rise scheduling and radio resource control.

Packet (HSPA - Constant Bit Rate) service users have the highest priority and are processed first. Therefore, after the admission control, the noise rise scheduling algorithm attempts to evenly share the remaining cell load between the packet (HSPA - Constant Bit Rate) service users admitted in admission control; in terms of HSUPA, each user is allocated a right to produce interference. The remaining cell load factor on uplink ($\Delta X^{UL}_{HSPA-CBR}(txi, ic)$) depends on the maximum load factor allowed on uplink and how much uplink load is produced by the served R99 traffic. It can be expressed as follows:

$$\Delta X^{UL}_{HSPA-CBR}(txi, ic) = X^{UL}_{max}(txi, ic) - X^{UL}_{R99}(txi, ic)$$

Then, **9955** evenly shares the remaining cell load factor between the packet (HSPA - Constant Bit Rate) service users admitted during the previous step ($n_{HSPA-CBR}$).

$$\Delta X^{UL}_{user}(txi, ic) = \frac{\Delta X^{UL}_{HSPA-CBR}(txi, ic)}{n_{HSPA-CBR}}$$

From this value, **9955** calculates the maximum E-DPDCH Ec/Nt allowed ($\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}$) for each packet (HSPA - Constant Bit Rate) service user. For further information on the calculation, see "Uplink Load Factor Due to One User" on page 248.

$$\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \frac{1}{\frac{F^{UL}(txi, ic)}{\Delta X^{UL}_{user}(txi, ic)} - 1}$$ for the Without useful signal option

$$\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \frac{\Delta X^{UL}_{user}}{F^{UL}}$$ for the Total noise option

Then, it selects an HSUPA bearer. The allocation depends on the maximum E-DPDCH Ec/Nt allowed and on UE and cell capabilities. **9955** selects the best HSUPA bearer from the HSUPA compatible bearers. This is the HSUPA bearer ($Index_{HSUPABearer}$) with the highest potential throughput ($\frac{R^{UL}_{RLC-peak}(Index_{HSUPABearer})}{N_{Rtx}(Index_{HSUPABearer})}$) where:

- $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH} \le \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}$
- And $P^{req}_{term-HSUPA} \le P^{max}_{term}$

When several HSUPA bearers are available, **9955** selects the one with the lowest $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH}$.

After the noise rise scheduling, **9955** carries out radio resource control, verifying if enough channel elements and Iub backhaul throughput are available for the HSUPA bearer assigned to the user. For information on radio resource control, see "Radio Resource Control" on page 234.

After processing all packet (HSPA - Constant bit rate) service users, **9955** carries out noise rise scheduling and radio resource control on packet (HSPA - Variable bit rate) service users. During the noise rise scheduling, **9955** distributes the remaining cell load factor available after all packet (HSPA - Constant Bit Rate) service users have been served. It can be expressed as follows:

$$\Delta X_{HSPA-VBR}^{UL}(txi, ic) = X_{max}^{UL}(txi, ic) - X_{R99}^{UL}(txi, ic) - X_{HSPA-CBR}^{UL}(txi, ic)$$

The remaining cell load factor is shared equally between the admitted packet (HSPA - Variable Bit Rate) service users ($n_{HSPA-VBR}$).

$$\Delta X_{user}^{UL}(txi, ic) = \frac{\Delta X_{HSPA-VBR}^{UL}(txi, ic)}{n_{HSPA-VBR}}$$

From this value, **9955** calculates the maximum E-DPDCH Ec/Nt allowed ($\left(\frac{Ec}{Nt}\right)_{E-DPDCH}^{max}$) as explained above and selects an HSUPA bearer for each packet (HSPA - Variable Bit Rate) service user. After the noise rise scheduling, **9955** carries out radio resource control on packet (HSPA - Variable Bit Rate) service users. For information on radio resource control, see "Radio Resource Control" on page 234.

After processing packet (HSPA - Variable bit rate) service users, **9955** carries out noise rise scheduling and radio resource control on packet (HSPA - Best Effort) service users. During the noise rise scheduling, **9955** distributes the remaining cell load factor available after all packet (HSPA - Constant Bit Rate) and packet (HSPA - Variable Bit Rate) service users have been served. It can be expressed as follows:

$$\Delta X_{HSPA}^{UL}(txi, ic) = X_{max}^{UL}(txi, ic) - X_{R99}^{UL}(txi, ic) - X_{HSPA-CBR}^{UL}(txi, ic) - \Delta X_{HSPA-VBR}^{UL}(txi, ic)$$

The remaining cell load factor is shared equally between the admitted packet (HSPA - Best Effort) service users (n_{HSPA}).

$$\Delta X_{user}^{UL}(txi, ic) = \frac{\Delta X_{HSPA}^{UL}(txi, ic)}{n_{HSPA}}$$

From this value, **9955** calculates the maximum E-DPDCH Ec/Nt allowed ($\left(\frac{Ec}{Nt}\right)_{E-DPDCH}^{max}$) as explained above and selects an HSUPA bearer for each packet (HSPA - Best Effort) service user. After the noise rise scheduling, **9955** carries out radio resource control on packet (HSPA - Best Effort) service users. For information on radio resource control, see "Radio Resource Control" on page 234.

Example: We have a cell with six packet (HSPA - Best Effort) service users, and neither packet (HSPA - Constant Bit Rate) user nor packet (HSPA - Variable Bit Rate) user. All packet (HSPA - Best Effort) service users have been admitted.

The remaining cell load factor equal to 0.6 is shared between the packet (HSPA - Best Effort) service users. Therefore, the UL load factor allotted to each user is 0.1. Let's take the cell UL reuse factor equal to 1.5. **9955** calculates the maximum E-DPDCH Ec/Nt allowed (the Without useful signal option is selected).

We have: $\left(\frac{Ec}{Nt}\right)_{E-DPDCH}^{max} = -11.5\ dB$

Here, the obtained HSUPA bearer is the index 5 HSUPA bearer. It provides a potential throughput of 128 kbps and requires E-DPDCH Ec/Nt of -13 dB (lower than -11.5 dB) and a terminal power lower than the maximum terminal power allowed.

HSUPA Bearers Index	Required Ec/Nt Threshold (dB)	Nb of Retransmissions	RLC Peak Rate (kbps)	Potential Throughput (kbps)
1	-21.7	2	32	16
2	-19	2	64	32
3	-16.1	2	128	64
4	-13.9	2	192	96
5	-13	2	256	128
6	-10.1	2	512	256
7	-8	2	768	384
8	-7	2	1024	512

Noise Rise Scheduling in Soft Handover

With HSUPA, uplink soft handover impacts the scheduling operation. While HSDPA sends data from one cell only, with HSUPA all cells in the active set receive the transmission from the terminal. Therefore, all the cells are impacted by the transmission in terms of noise rise.

For each HSUPA capable cell of the active set (tx_k, ic), **9955** calculates the maximum E-DPDCH Ec⁄Nt allowed ($\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)$) as explained in "HSUPA Bearer Allocation Process" on page 228.

For each cell of the active set (tx_k, ic), **9955** calculates the maximum terminal power allowed to obtain an HSUPA radio bearer ($P^{max}_{term-HSUPA}(tx_k, ic)$).

$$P^{max}_{term-HSUPA}(tx_k, ic) = min\left(\left(\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic) \times L_T \times N^{UL}_{tot}\right), P^{max}_{term}\right)$$

With

$$N^{UL}_{tot}(ic) = (1 - F^{tx}_{MUD} \times \rho_{term}) \times I^{UL_{intra}}_{tot}(ic) + I^{UL_{extra}}_{tot}(ic) + I^{UL}_{inter-carrier}(ic) + N^{tx}_0$$

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}} \quad ([9])$$

ρ_{term}, F^{tx}_{MUD}, $I^{UL_{intra}}_{tot}$, $I^{UL_{extra}}_{tot}$, $I^{UL}_{inter-carrier}$ and N^{tx}_0 are defined in "Inputs" on page 182.

As HSUPA bearer users in soft handover use the lowest granted noise rise, **9955** chooses the lowest of maximum terminal power allowed for each cell of the active set (tx_k, ic).

$$P^{max}_{term-HSUPA} = \min_{tx_k \in AS} (P^{max}_{term-HSUPA}(tx_k, ic))$$

Once **9955** knows the selected maximum terminal power ($P^{max}_{term-HSUPA}$), it recalculates the maximum E-DPDCH Ec⁄Nt allowed ($\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)$) for each HSUPA capable cell of the active set.

$$\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic) = \frac{P^{max}_{term-HSUPA}}{L_T \times N^{UL}_{tot}}$$

Then, **9955** calculates the maximum E-DPDCH Ec⁄Nt allowed ($\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}$) after signal recombination of all HSUPA capable cells of the active set [10].

---

9. *In the HSUPA coverage prediction,* L_T *is calculated as follows:*

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}})$$

For softer (1/2) and softer-softer (1/3) handovers, we have:

$$\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = f^{UL}_{rake\ efficiency} \times \sum_{\substack{tx_k \in ActiveSet \\ (samesite)}} \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)$$

For soft (2/2) and soft-soft (3/3) handovers, we have: $\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \underset{tx_k \in ActiveSet}{Max}\left(\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)\right)$

For softer-soft handover (2/3), it depends on if the MRC option is selected (option available in Global parameters). If selected, we have:

$$\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \underset{\substack{tx_k, tx_l \in ActiveSet \\ tx_k \in samesite \\ tx_l \in othersite}}{Max}\left(f^{UL}_{rake\ efficiency} \times \sum_{tx_k} \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic), \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_l, ic)\right)$$

Else, we have: $\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \underset{tx_k \in ActiveSet}{Max}\left(\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)\right)$

---

10. *In HSUPA coverage predictions, we have the following:*

For softer (1/2) and softer-softer (1/3) handovers: $\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = f^{UL}_{rake\ efficiency} \times \sum_{\substack{tx_k \in ActiveSet \\ (samesite)}} \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)$

For soft handover (2/2): $\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \underset{tx_k \in ActiveSet}{Max}\left(\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)\right) \times (G^{UL}_{macro-diversity})_{2links}$

For soft-soft handover (3/3): $\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \underset{tx_k \in ActiveSet}{Max}\left(\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)\right) \times (G^{UL}_{macro-diversity})_{3links}$

For softer-soft handover (2/3), it depends on if the MRC option is selected (option available in Global parameters). If selected, we have:

$$\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \underset{\substack{tx_k, tx_l \in ActiveSet \\ tx_k \in samesite \\ tx_l \in othersite}}{Max}\left(f^{UL}_{rake\ efficiency} \times \sum_{tx_k} \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic), \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_l, ic)\right)$$

$$\times (G^{UL}_{macro-diversity})_{2links}$$

Else, we have: $\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH} = \underset{tx_k \in ActiveSet}{Max}\left(\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}(tx_k, ic)\right) \times (G^{UL}_{macro-diversity})_{2links}$

Then, **9955** selects an HSUPA bearer as previously explained in "HSUPA Bearer Allocation Process" on page 228. The allocation depends on the maximum E-DPDCH Ec⁄Nt allowed and on UE and cell capabilities. **9955** selects the best HSUPA bearer from the HSUPA compatible bearers. This is the HSUPA bearer ($Index_{HSUPABearer}$) with the highest potential throughput ($\frac{R^{UL}_{RLC-peak}(Index_{HSUPABearer})}{N_{Rtx}(Index_{HSUPABearer})}$) where:

- $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH} \leq \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}$

When several HSUPA bearers are available, **9955** selects the one with the lowest $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH}$.

Determination of the Requested HSUPA Bearer

The requested HSUPA radio bearer is selected from the HSUPA bearers compatible with the user equipment. **9955** determines the HSUPA bearer the user would obtain by considering the entire remaining load of the cell. The user is treated as if he is the only user in the cell. Therefore, if we go on with the previous example, the maximum E-DPDCH Ec⁄Nt allowed is equal to -1.8 dB and the requested HSUPA bearer is the index 7 HSUPA bearer. It requires E-DPDCH Ec⁄Nt of -8 dB (lower than -1.8 dB) and a terminal power lower than the maximum terminal power allowed.

4.4.2.4.4 Radio Resource Control

9955 checks to see if enough channel elements are available and if the Iub backhaul throughput is sufficient for the HSUPA bearer assigned to the user (taking into account the maximum number of channel elements defined for the site and the maximum Iub backhaul throughput allowed on the site in the uplink). If not, **9955** allocates a lower HSUPA bearer ("downgrading") which needs fewer channel elements and consumes lower Iub backhaul throughput. If no channel elements are available, the user is rejected. On the same hand, if the maximum Iub backhaul throughput allowed on the site in the uplink is still exceeded even by using the lowest HSDPA bearer, the user is rejected.

4.4.2.5 Convergence Criteria

The convergence criteria are evaluated for each iteration, and can be written as follow:

$$\Delta_{DL} = max\left(int\left(\frac{\underset{Stations}{max}\left|P_{tx}(ic)_k - P_{tx}(ic)_{k-1}\right|}{P_{tx}(ic)_k} \times 100\right), int\left(\frac{\underset{Stations}{max}\left|N^{DL}_{user}(ic)_k - N^{DL}_{user}(ic)_{k-1}\right|}{N^{DL}_{user}(ic)_k} \times 100\right)\right)$$

$$\Delta_{UL} = max\left(int\left(\frac{\underset{Stations}{max}\left|I^{UL}_{tot}(ic)_k - I^{UL}_{tot}(ic)_{k-1}\right|}{I^{UL}_{tot}(ic)_k} \times 100\right), int\left(\frac{\underset{Stations}{max}\left|N^{UL}_{user}(ic)_k - N^{UL}_{user}(ic)_{k-1}\right|}{N^{UL}_{user}(ic)_k} \times 100\right)\right)$$

9955 stops the algorithm if:

1st case: Between two successive iterations, Δ_{UL} and Δ_{DL} are lower than their respective thresholds (defined when creating a simulation).

The simulation has reached convergence.

Example: Let us assume that the maximum number of iterations is 100, UL and DL convergence thresholds are set to 5. If $\Delta_{UL} \leq 5$ and $\Delta_{DL} \leq 5$ between the 4th and the 5th iteration, **9955** stops the algorithm after the 5th iteration. Convergence has been reached.

2nd case: After 30 iterations, Δ_{UL} and/or Δ_{DL} are still higher than their respective thresholds and from the 30th iteration, Δ_{UL} and/or Δ_{DL} do not decrease during the next 15 successive iterations.

The simulation has not reached convergence (specific divergence symbol).

Examples: Let us assume that the maximum number of iterations is 100, UL and DL convergence thresholds are set to 5.

1. After the 30th iteration, Δ_{UL} and/or Δ_{DL} equal 100 and do not decrease during the next 15 successive iterations: **9955** stops the algorithm at the 46th iteration. Convergence has not been reached.
2. After the 30th iteration, Δ_{UL} and/or Δ_{DL} equal 80, they start decreasing slowly until the 40th iteration (without going under the thresholds) and then, do not change during 15 successive iterations: **9955** stops the algorithm at the 56th iteration without reaching convergence.

3rd case: After the last iteration.

If Δ_{UL} and/or Δ_{DL} are still strictly higher than their respective thresholds, the simulation has not reached convergence (specific divergence symbol).

If Δ_{UL} and Δ_{DL} are lower than their respective thresholds, the simulation has reached convergence.

4.4.3 Results

4.4.3.1 R99 Related Results

This table contains some R99 specific simulation results provided in the Cells and Mobiles tabs of the simulation property dialogue.

Name	Value	Unit	Description
$Nb_{E1/T1/Ethernet}$	$RoundUp(Max(T^{DL}_{Iub}(N_I)/T_{E1/T1/Ethernet}, T^{UL}_{Iub}(N_I)/T_{E1/T1/Ethernet}))$	None	Number of E1/T1/Ethernet links required by the site
$I^{DL}_{intra}(txi, ic)$	$P^{DL}_{tot}(txi, ic) - F_{ortho} \times \rho_{BTS} \times \left(\frac{P^{DL}_{tot}(txi, ic)}{txi} - \frac{P_{SCH}(txi, ic)}{L_T}\right)$ $-(1 - F_{ortho}) \times \rho_{BTS} \times P^{DL}_b(txi, ic)$	None	Downlink intra-cell interference at terminal on carrier ic
$I^{DL}_{extra}(ic)$	$\sum_{txj, j \neq i} P^{DL}_{tot}(txj, ic)$	W	Downlink extra-cell interference at terminal on carrier ic
$I^{DL}_{inter-carrier}(ic)$	$\frac{\sum_{txj, \forall j} P^{DL}_{tot}(txj, ic_{adj})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference at terminal on carrier ic
$I^{DL}_{inter-technology}(ic)$	$\sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{n_i, ic}}$	W	Downlink inter-technology interference at terminal on carrier ic [a]
$I^{DL}_{tot}(ic)$	$I^{DL}_{intra}(ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic)$	W	Total effective interference at terminal on carrier ic (after unscrambling)
$N^{DL}_{tot}(ic)$	$I^{DL}_{tot}(ic) + N^{Term}_0$	W	Total received noise at terminal on carrier ic
$I^{UL_{intra}}_{tot}(txi, ic)$	$\sum_{\substack{term \\ txi}} P^{UL}_b(ic)$	W	Total power received at transmitter from intra-cell terminals using carrier ic
$I^{UL_{extra}}_{tot}(txi, ic)$	$\sum_{\substack{term \\ txj, j \neq i}} P^{UL}_b(ic)$	W	Total power received at transmitter from extra-cell terminals using carrier ic
$I^{UL}_{inter-carrier}(txi, ic)$	$\frac{\sum_{\substack{term \\ txj, \forall j}} P^{UL}_b(ic_{adj})}{RF(ic, ic_{adj})}$	W	Uplink inter-carrier interference at terminal on carrier ic
$I^{UL}_{tot}(txi, ic)$	$I^{UL_{extra}}_{tot}(txi, ic) + (1 - F^{Tx}_{MUD} \times \rho_{term}) \times I^{UL_{intra}}_{tot}(txi, ic) + I^{UL}_{inter-carrier}(txi, ic)$	W	Total received interference at transmitter on carrier ic
$N^{UL}_{tot}(txi, ic)$	$I^{UL}_{tot}(txi, ic) + N^{tx}_0$	W	Total noise at transmitter on carrier ic (Uplink interference)
$X^{UL}(txi, ic)$	$\frac{I^{UL}_{tot}(txi, ic)}{N^{UL}_{tot}(txi, ic)}$	None	Cell uplink load factor on carrier ic

Name	Value	Unit	Description
$F^{UL}(txi, ic)$	$\frac{I_{tot}^{UL}(txi, ic)}{I_{tot}^{UL_{intra}}(txi, ic) \times (1 - F_{MUD}^{Tx} \times \rho_{term})}$	None	Cell uplink reuse factor on carrier *ic*
$E^{UL}(txi, ic)$	$\frac{1}{F^{UL}(txi, ic)}$	None	Cell uplink reuse efficiency factor on carrier *ic*
$X^{DL}(txi, ic)$	Simulation result available per cell $\sum_{tch} \frac{\frac{(I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic)) \times L_T}{P_{Tx}^{DL}(txi, ic)} + 1 - F_{ortho} \times \rho_{BTS}}{\frac{1}{CI_{req}^{DL}} + (1 - F_{ortho} \times \rho_{BTS})}$ with $CI_{req}^{DL} = \frac{Q_{req}^{DL}}{G_p^{DL}}$ Simulation result available per mobile $\frac{I_{tot}^{DL}(ic)}{N_{tot}^{DL}(ic)}$	None	Downlink load factor on carrier *ic*
$F^{DL}(txi, ic)$	$\frac{I_{tot}^{DL}(ic)}{I_{intra}^{DL}(txi, ic)}$	None	Downlink reuse factor on a carrier *ic*
$NR^{DL}(txi, ic)$	$-10\log(1 - X^{DL}(txi, ic))$	dB	Noise rise on downlink
$NR^{UL}(txi, ic)$	$-10\log(1 - X^{UL}(txi, ic))$	dB	Noise rise on uplink

a. In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.

4.4.3.2 HSPA Related Results

At the end of the R99 part, Constant Bit Rate, Variable Bit Rate and Best Effort service users can be:

- Either connected and in this case, they obtain the requested R99 bearer,
- Or rejected exactly for the same reasons as R99 users.

Only connected Constant Bit Rate, Variable Bit Rate and Best Effort service users are considered in the HSDPA part. At the end of the HSDPA part, Best Effort service users can be:

- Either connected if they obtain an HSDPA bearer,
- Or rejected if the maximum number of HSDPA users per cell is exceeded,
- Or delayed in case of lack of resources (HSDPA power, HS-SCCH power, HS-SCCH channels, OVSF codes).

Variable Bit Rate service users can be:

- Either connected if they obtain an HSDPA bearer,
- Or rejected for the following reasons: the maximum number of HSDPA users per cell is exceeded, the lowest HSDPA bearer the user can obtain does not provide a RLC peak rate higher than the minimum throughput demand, the HS-SCCH signal quality is not sufficient, there are no more OVSF codes available, the maximum Iub backhaul throughput allowed on the site in the downlink is exceeded.

Constant Bit Rate service users can be:

- Either connected if they obtain an HSDPA bearer,
- Or rejected for the following reasons: the maximum number of HSDPA users per cell is exceeded, the lowest HSDPA bearer the user can obtain does not provide a RLC peak rate higher than the minimum throughput demand, the HS-SCCH signal quality is not sufficient, there are no more OVSF codes available, the maximum Iub backhaul throughput allowed on the site in the downlink is exceeded.

In the HSUPA part, **9955** processes HSPA Constant Bit Rate, Variable Bit Rate and Best Effort service users who are connected to an HSDPA bearer or were delayed in the previous step. At the end, they can be:

- Either connected if they obtain an HSUPA bearer,
- Or rejected for the following reasons: the maximum number of HSUPA users per cell is exceeded, the terminal power required to obtain the lowest compatible HSUPA bearer exceeds the maximum terminal power, there are no more channel elements available, the maximum Iub backhaul throughput allowed on the site in the uplink is exceeded, the lowest compatible HSUPA bearer they can obtain does not provide a RLC peak rate higher than the minimum throughput demand (only for Constant Bit Rate and Variable Bit Rate service users).

In the following parts, a *dual-cell HSDPA user* refers to a user which has a dual-cell HSDPA-capable terminal and which is simultaneously connected to two HSDPA cells of a transmitter supporting dual-cell HSDPA mode.

4.4.3.2.1 Statistics Tab

In the Statistics tab, **9955** displays as results:

- The number of rejected users.
- The number of delayed users.
- The number of R99 bearer users connected to a cell (result of the R99 part). This figure includes R99 users as well as HSDPA and HSUPA bearer users since all of them request an R99 bearer.
  - The number of R99 bearer users per frequency band.
  - The number of R99 bearer users per activity status.
  - The downlink and uplink rates (R^{DL}_{R99} and R^{UL}_{R99}) generated by their connection to R99 bearers. Only active users are considered.

$$R^{DL}_{R99} = \sum_{\substack{Active\\users}} R^{DL}_{nominal}(R99\ Bearer) \text{ and } R^{UL}_{R99} = \sum_{\substack{Active\\users}} R^{UL}_{nominal}(R99\ Bearer)$$

$R^{DL}_{nominal}(R99\ Bearer)$ is the downlink nominal rate of the user R99 radio bearer and $R^{UL}_{nominal}(R99\ Bearer)$ is the uplink nominal rate of the user R99 radio bearer.

- The number of connected users with an HSDPA bearer (result of the HSDPA part) and the downlink rate they generate. Packet (HSDPA - Best Effort), packet (HSPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) service users are considered since they all request an HSDPA bearer.

  On the other hand, only active users are taken into consideration in the downlink rate calculation (R^{DL}_{HSDPA}).

$$R^{DL}_{HSDPA} = \sum_{\substack{Active\\users}} R^{DL}_{RLC-peak}$$

$R^{DL}_{RLC-peak}$ is the RLC peak rate provided in the downlink.

- The number of connected HSUPA bearer users (result of the HSUPA part). Only packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) service users are considered.

  In addition, **9955** indicates the uplink data rate generated by active users connected with an HSUPA bearer (R^{UL}_{HSUPA}):

$$R^{UL}_{HSUPA} = \sum_{\substack{Active\\users}} R^{UL}_{RLC-peak}$$

  $R^{UL}_{RLC-peak}$ is the RLC peak rate provided in the uplink.

4.4.3.2.2 Mobiles Tab

In the Mobiles tab, **9955** indicates for each user:

- The uplink and downlink total requested rates in kbps (respectively, $R^{UL}_{requested}(M_b)$ and $R^{DL}_{requested}(M_b)$)

For circuit and packet (R99) service users, the DL and UL total requested rates correspond to the DL and UL nominal rates of the R99 bearer associated to the service.

$$R^{DL}_{requested}(M_b) = R^{DL}_{nominal}(R99\ Bearer)$$

$$R^{UL}_{requested}(M_b) = R^{UL}_{nominal}(R99\ Bearer)$$

For packet (HSDPA) service users, the uplink requested rate corresponds to the nominal rate of ADPCH R99 radio bearer and the downlink requested rate is the sum of the ADPCH radio bearer nominal rate and the RLC peak rate(s) that the selected HSDPA radio bearer(s) can provide. Here, the user is treated as if he is the only user in the cell and then, **9955** determines the HSDPA bearer the user would obtain by considering the entire HSDPA power available of the cell.

$$R^{DL}_{requested}(M_b) = R^{DL}_{nominal}(ADPCH\ R99\ Bearer) + R^{DL}_{RLC-peak} \text{ for single-carrier users}$$

$$R^{DL}_{requested}(M_b) = R^{DL}_{nominal}(ADPCH\ R99\ Bearer)_{AnchorCell} + \sum_{c \in Serving\ Cells} R^{DL}_{RLC-peak}(c) \text{ for dual-carrier users}$$

$$R^{UL}_{requested}(M_b) = R^{UL}_{nominal}(ADPCH\ R99\ Bearer)$$

For HSUPA bearer users (i.e., packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) service users), the uplink requested rate is equal to the sum of the ADPCH-EDPCCH radio bearer nominal rate and the RLC peak rate of the requested HSUPA radio bearer. The requested HSUPA radio bearer is selected from the HSUPA bearers compatible with the user equipment. Here, the user is treated as if he is the only user in the cell and then, **9955** determines the HSUPA bearer the user would obtain by considering the entire remaining load of the cell. The downlink requested rate is the sum of the ADPCH-EDPCCH radio bearer nominal rate and the RLC peak rate(s) that the requested HSDPA radio bearer(s) can provide. The requested HSDPA radio bearer is determined as explained in the previous paragraph.

$$R^{DL}_{requested}(M_b) = R^{DL}_{nominal}(ADPCH - EDPCCH\ R99\ Bearer) + R^{DL}_{RLC-peak} \text{ for single-carrier users}$$

$$R^{DL}_{requested}(M_b) = R^{DL}_{nominal}(ADPCH - EDPCCH\ R99\ Bearer)_{AnchorCell} + \sum_{c \in Serving\ cells} R^{DL}_{RLC-peak}(c) \text{ for dual-carrier users}$$

$$R^{UL}_{requested}(M_b) = R^{UL}_{nominal}(ADPCH - EDPCCH\ R99\ Bearer) + R^{UL}_{RLC-peak}$$

- The uplink and downlink total obtained rates in kbps (respectively, $R^{UL}_{obtained}(M_b)$ and $R^{DL}_{obtained}(M_b)$)

For circuit and packet (R99) service users, the obtained rate is the same as the requested rate if he is connected without being downgraded. Otherwise, the obtained rate is lower (it corresponds to the nominal rate of the selected R99 bearer). If the user is rejected, the obtained rate is zero.

In the downlink, HSDPA bearer users can be connected to a single cell or to two cells of the same transmitter when the user has a dual-cell HSDPA-capable terminal and when the transmitter supports the dual-cell HSDPA mode.

For a single-carrier packet (HSDPA) service user connected to an HSDPA bearer, the downlink obtained rate corresponds to the instantaneous rate; this is the sum of the A-DPCH radio bearer nominal rate and the RLC peak rate provided by the selected HSDPA radio bearer after scheduling and radio resource control. If the user is delayed (he is only connected to an R99 radio bearer), downlink obtained rate corresponds to the downlink nominal rate of the ADPCH radio bearer. Finally, if the user is rejected either in the R99 part or in the HSDPA part (i.e., because the HSDPA scheduler is saturated), the downlink obtained rate is zero.

For a dual-carrier packet (HSDPA) service user connected to two HSDPA bearers, the downlink obtained rate corresponds to the instantaneous rate; this is the sum of the nominal rate provided by the A-DPCH radio bearer in the anchor cell and the RLC peak rates provided by the selected HSDPA radio bearers after scheduling and radio resource control. If the user is connected to one cell and delayed in the other cell, the downlink obtained rate is the sum of the nominal rate provided by the A-DPCH radio bearer in the anchor cell and the RLC peak rate provided by the selected HSDPA radio bearer after scheduling and radio resource control. If the user is delayed in the two cells (he is only connected to an R99 radio bearer in the anchor cell), the downlink obtained rate corresponds to the downlink nominal rate of the ADPCH radio bearer in the anchor cell. Finally, if the user is rejected either in the R99 part or in the HSDPA part (i.e., because the HSDPA scheduler is saturated), the downlink obtained rate is zero.

In the uplink, packet (HSDPA) service users can only have a single-carrier connection. When the user is either connected or delayed, the uplink obtained rate corresponds to the uplink nominal rate of the ADPCH radio bearer. If the user is rejected either in the R99 part or in the HSDPA part (i.e., because the HSDPA scheduler is saturated), the uplink obtained rate is zero.

For single-carrier packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users, on downlink, if the user is connected to an HSDPA bearer, the downlink obtained rate corresponds to the instantaneous rate. The instantaneous rate is the sum of the ADPCH-EDPCCH radio bearer nominal rate and the RLC peak rate provided by the selected HSDPA radio bearer after scheduling and radio resource control. If the user is delayed, the downlink obtained rate corresponds to the downlink nominal rate of ADPCH-EDPCCH radio bearer. If the user is rejected, the downlink obtained rate is "0."

For dual-carrier packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users connected to two HSDPA bearers, the downlink obtained rate corresponds to the instantaneous rate; this is the sum of the nominal rate provided by the ADPCH-EDPCCH radio bearer in the anchor cell and the RLC peak rates provided by the selected HSDPA radio bearers after scheduling and radio resource control. If the user is connected to one cell and delayed in the other cell, the downlink obtained rate is the sum of the nominal rate provided by the ADPCH-EDPCCH radio bearer in the anchor cell and the RLC peak rate provided by the selected HSDPA radio bearer after scheduling and radio resource control. If the user is delayed in the two cells (he is only connected to an R99 radio bearer in the anchor cell), the downlink obtained rate corresponds to the downlink nominal rate of the ADPCH-EDPCCH radio bearer in the anchor cell. Finally, if the user is rejected, the downlink obtained rate is zero.

In uplink, packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users can only have a single-carrier connection. When the user is connected to an HSUPA bearer, the uplink obtained rate is the sum of the ADPCH-EDPCCH radio bearer nominal rate and the RLC peak rate provided by the selected HSUPA radio bearer after noise rise scheduling. If the user is rejected, the uplink obtained rate is zero.

For a connected packet (HSPA - Constant Bit Rate) service user, the uplink and downlink total obtained rates are the sum of the ADPCH-EDPCCH radio bearer nominal rate and the minimum throughput demand defined for the service. If the user is rejected, the uplink and downlink total obtained rates are "0".

- The mobile total power (P_{term})

$P_{term} = P_{term-R99} \times f_{act-EDPCCH}^{UL} + P_{term-HSUPA}$ for packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users.

$P_{term} = P_{term-R99} \times f_{act-EDPCCH}^{UL} + P_{term-HSUPA} \times C_{HSDPABearer}$ for packet (HSPA - Constant Bit Rate) service users.

For packet (HSPA - Constant Bit Rate) service users, $f_{act-EDPCCH}^{UL} = 0.1$.

And

$P_{term} = P_{term-R99}$ for circuit and packet (R99) service users, packet (HSDPA - Best Effort) and packet (HSDPA - Variable Bit Rate) service users

- The HSDPA application throughput in kbps ($T_{application}^{DL}(M_b)$)

This is the net HSDPA throughput without coding (redundancy, overhead, addressing, etc.).

$$T_{application}^{DL}(M_b) = \frac{\sum_{c \in Serving\ cells} R_{RLC-peak}^{DL}(c) \times (1 - BLER_{HSDPA})}{\Delta TTI} \times SF_{Rate} - \Delta R$$

Where:

$R_{RLC-peak}^{DL}$ is the RLC peak rate provided to the user by the selected HSDPA radio bearer after scheduling and radio resource control.

$BLER_{HSDPA}$ is read in the quality graph defined for the triplet “reception equipment-selected bearer-mobility” (HSDPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (HS-PDSCH Ec/Nt). Knowing the HS-PDSCH Ec/Nt, **9955** calculates the corresponding BLER.

SF_{Rate} and ΔR represent the scaling factor between the application throughput and the RLC (Radio Link Control) throughput and the throughput offset respectively. These two parameters model the header information and other supplementary data that does not appear at the application level. They are defined in the service properties.

ΔTTI is the minimum number of TTI (Transmission Time Interval) between two TTI used; it is defined in the terminal user equipment category properties.

- The number of OVSF codes

This is the number of 512-bit length OVSF codes consumed by the user.

- The required HSDPA power in dBm ($(P_{HSDPA})_{required}$)

It corresponds to the HSDPA power required to provide the HSDPA bearer user with the downlink requested rate. The downlink requested rate is the data rate the user would obtain if he was the only user in the cell. In this case, **9955** determines the HSDPA bearer the user would obtain by considering the entire HSDPA power available of the cell.

$(P_{HSDPA})_{required} = (P_{HS-PDSCH})_{used} + n_{HS-SCCH} \times P_{HS-SCCH}$

$(P_{HS-PDSCH})_{used}$ is the HS-PDSCH power required to obtain the selected HSDPA bearer (in dBm). If the HSDPA bearer allocated to the user is the best one, $(P_{HS-PDSCH})_{used}$ corresponds to the available HS-PDSCH power of the cell. On the other hand, if the HSDPA bearer has been downgraded in order to be compliant with cell and UE capabilities or for another reason, $(P_{HS-PDSCH})_{used}$ will be lower than the available HS-PDSCH power of the cell.

- The served HSDPA power in dBm ($(P_{HSDPA})_{served}$)

This is the HSDPA power required to provide the HSDPA bearer user with the downlink obtained rate. The downlink obtained rateis the data rate experienced by the user after scheduling and radio resource control.

$(P_{HSDPA})_{served} = (P_{HS-PDSCH})_{used} + n_{HS-SCCH} \times P_{HS-SCCH}$ for packet (HSDPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users

And

$(P_{HSDPA})_{served} = (P_{HS-PDSCH})_{used} \times C_{HSDPABearer}$ for packet (HSPA - Constant Bit Rate) service users

Where

$(P_{HS-PDSCH})_{used}$ is the HS-PDSCH power required to obtain the selected HSDPA bearer.

- The No. of HSUPA Retransmissions (Required)

The maximum number of retransmissions in order to have the requested HSUPA radio bearer with a given BLER.

- The No. of HSUPA Retransmissions (Obtained)

The maximum number of retransmissions in order to have the obtained HSUPA radio bearer with a given BLER.

- The HSUPA application throughput in kbps ($T^{UL}_{application}(M_b)$)

This is the net HSUPA throughput without coding (redundancy, overhead, addressing, etc.).

$$T^{UL}_{application}(M_b) = \frac{R^{UL}_{RLC-peak}(M_b) \times (1 - BLER_{HSUPA}) \times SF_{Rate} - \Delta R}{N_{Rtx}}$$

Where:

$R^{UL}_{RLC-peak}$ is the RLC peak rate provided by the selected HSUPA radio bearer after noise rise scheduling.

$BLER_{HSUPA}$ is the residual BLER after N_{Rtx} retransmissions. It is read in the quality graph defined for the quartet "reception equipment-selected bearer-number of retransmissions-mobility" (HSUPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (E-DPDCH Ec/Nt). Knowing the E-DPDCH Ec/Nt, **9955** calculates the corresponding BLER.

SF_{Rate} and ΔR respectively represent the scaling factor between the application throughput and the RLC (Radio Link Control) throughput and the throughput offset. These two parameters model the header information and other supplementary data that does not appear at the application level. They are defined in the service properties.

N_{Rtx} is the maximum number of retransmissions for the obtained HSUPA bearer. This figure is read in the HSUPA Bearer Selection table.

The following columns appear if, when creating the simulation, you select "Detailed information about mobiles":

- The uplink and downlink requested RLC peak rates (kbps)

Downlink and uplink requested RLC peak rates are not calculated for circuit and packet (R99) service users.

For packet (HSDPA - Best Effort) and packet (HSDPA - Variable Bit Rate) service users, the uplink RLC peak rate is not calculated and the downlink requested RLC peak rate is the data rate that the selected HSDPA radio bearer(s) can provide. Here, the user is treated as if he is the only user in the cell and then, **9955** determines the HSDPA bearer he would obtain by considering the entire HSDPA power available of the cell.

For HSUPA bearer users (i.e., packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) service users), the requested uplink RLC peak rate is the data rate of the requested HSUPA radio bearer. The requested HSUPA radio bearer is selected from the HSUPA bearers compatible with the user equipment. Here, the user is treated as if he is the only user in the cell and then, **9955** determines the HSUPA bearer the user would obtain by considering the entire remaining load of the cell. If the user is connected to one or two HSDPA bearers in the downlink, the downlink requested RLC peak rate is the rate that the requested HSDPA radio bearer(s) can provide. The requested HSDPA radio bearer is determined as explained in the previous paragraph.

- The uplink and downlink obtained RLC peak rate (kbps)

Downlink and uplink obtained RLC peak rates are not calculated for circuit and packet (R99) service users.

For packet (HSDPA - Best Effort) and packet (HSDPA - Variable Bit Rate) service users connected to one or two HSDPA bearers, the uplink obtained RLC peak rate is not calculated, and the downlink obtained RLC peak rate is the data rate provided by the selected HSDPA radio bearer(s) after scheduling and radio resource control.

For connected packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users, on uplink, if the user is connected to an HSUPA bearer, the obtained uplink RLC peak rate is the rate provided by the selected HSUPA radio bearer after noise rise scheduling. On downlink, if the user is connected to one or two HSDPA bearers, the downlink obtained RLC peak rate is the rate provided by the selected HSDPA radio bearer(s) after scheduling and radio resource control.

For a connected packet (HSPA - Constant Bit Rate) service user, the uplink and downlink obtained RLC peak rates are the uplink and downlink minimum throughput demands defined for the service.

4.4.3.2.3 Cells Tab

In the Cells tab, **9955** gives:

- The available HSDPA power in the cell, *c*, in dBm ($P_{HSDPA}(c)$):

This is:

- Either a fixed value in case of a static HSDPA power allocation strategy,
- Or a simulation result when the option "HSDPA Power Dynamic Allocation" is selected. We have:

$$P_{HSDPA}(c) = P_{max}(c) - P_{Headroom}(c) - P_{tx-R99}(c) - P_{HSUPA}(c)$$

with $P_{tx-R99}(c) = P_{pilot}(c) + P_{SCH}(c) + P_{OtherCCH}(c) + \sum_{\substack{tch\ used\ for\\ R99\ users}} P_{tch}(c) + \sum_{\substack{tch\ used\ for\\ HSPA\ users}} P_{tch}(c) \times f_{act-ADPCH}^{DL}$

- The transmitted HSDPA power in the cell, *c*, in dBm ($P_{tx-HSDPA}(c)$):

It corresponds to the HSDPA power used to serve HSDPA bearer users.

$$P_{tx-HSDPA}(c) = \sum_{M_b \in c} (P_{HSDPA}(M_b))_{served}$$

- The number of HSDPA users in the cell

They are the connected and delayed HSDPA bearer users. This figure includes packet (HSDPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) users. Dual-carrier HSDPA bearer users are accounted for once in each serving cell.

- The number of simultaneous HSDPA users in the cell (n_{M_b})

It corresponds to the number of connected HSDPA bearer users that the cell supports at a time, i.e. within one transmission time interval. All these users are connected to the cell at the end of the HSDPA part of the simulation; they have a connection with the R99 bearer and an HSDPA bearer. Dual-carrier HSDPA bearer users are accounted for once in each serving cell.

- The instantaneous HSDPA rate in the cell, *c*, in kbps ($R_{Inst}^{DL}(c)$)

This is the number of kilobits per second that the cell supports on downlink to provide simultaneous connected HSDPA bearer users with an HSDPA bearer. We will differentiate single-carrier users (M_s) from dual-cell users ($M_{d-HSDPA}$ stands for HSDPA Best Effort and Variable Bit Rate users, M_{d-HSPA} refers to HSPA Best Effort and Variable Bit Rate service users, and $M_{d-HSPA-CBR}$ stands for HSPA Constant Bit Rate service users).

$$R_{Inst}^{DL}(cell) = \begin{aligned} &\sum_{M_s \in c} R_{obtained}^{DL}(M_s) + \sum_{\substack{M_{d-HSDPA} \in c\\ c\ is\ the\ anchor\ cell}} (R_{nominal}^{DL}(R99\ Bearer) + R_{RLC-peak}^{DL}(M_{d-HSDPA})) \\ &+ \sum_{\substack{M_{d-HSDPA} \in c\\ c\ is\ the\ secondary\ cell}} R_{RLC-peak}^{DL}(M_{d-HSDPA}) + \\ &\sum_{\substack{M_{d-HSPA} \in c\\ c\ is\ the\ anchor\ cell}} (R_{nominal}^{DL}(R99\ Bearer) + R_{RLC-peak}^{DL}(M_{d-HSPA})) \\ &\sum_{\substack{M_{d-HSPA} \in c\\ c\ is\ the\ secondary\ cell}} R_{RLC-peak}^{DL}(M_{d-HSPA}) + \sum_{\substack{M_{d-HSPA-CBR} \in c\\ c is\ the\ secondary\ cell}} T_{min}^{DL}(M_{d-HSPA-CBR}) \\ &+ \sum_{\substack{M_{d-HSPA-CBR} \in c\\ c\ is\ the\ anchor\ cell}} (R_{nominal}^{DL}(R99\ Bearer) + T_{min}^{DL}(M_{d-HSPA-CBR})) \end{aligned}$$

$R_{RLC-peak}^{DL}$ is the RLC peak rate provided by the selected HSDPA radio bearer after scheduling and radio resource control.

$R^{DL}_{nominal}(R99\ Bearer)$ is the nominal rate of the ADPCH radio bearer if the user is a packet (HSDPA - Best Effort) or a packet (HSDPA - Variable Bit Rate) service user. For packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) service users, it corresponds to the ADPCH-EDPCCH radio bearer.

- The instantaneous HSDPA MAC Throughput in the cell, *c*, in kbps ($T^{DL}_{MAC}(c)$)

$$T^{DL}_{MAC}(c) = \sum_{M_b \in c} \frac{S_{block}(M_b)}{T_{TTI} \times \Delta TTI(M_b)}$$

Where,

$S_{block}(M_b)$ is the transport block size (in kbits) of the HSDPA bearer selected by the user; it is defined for each HSDPA bearer in the HSDPA Radio Bearers table.

$\Delta TTI(M_b)$ is the minimum number of TTI (Transmission Time Interval) between two TTI used; it is defined in the terminal user equipment category properties.

T_{TTI} is the TTI duration, i.e. $2 \times 10^{-3} s$ (2000 TTI in one second). This value is specified by the 3GPP.

- The average instantaneous HSDPA rate in the cell, *c*, in kbps ($R^{DL}_{Av-Inst}(c)$)

$$R^{DL}_{Av-Inst}(c) = \frac{R^{DL}_{Inst}(c)}{n_{M_b}}$$

- The HSDPA application throughput in the cell, *c*, in kbps ($T^{DL}_{application}(c)$)

Either $T^{DL}_{application}(c) = \sum_{M_b \in c} \frac{R^{DL}_{RLC-peak}(M_b) \times (1 - BLER_{HSDPA}) \times SF_{Rate} - \Delta R}{\Delta TTI}$ if the scheduling algorithm is Round Robin or Proportional Fair,

Or $T^{DL}_{application}(c) = \frac{R^{DL}_{RLC-peak}(M_b(maxC/I)) \times (1 - BLER_{HSDPA}) \times SF_{Rate} - \Delta R}{\Delta TTI}$ if the scheduling algorithm is Max C/I.

$M_b(maxC/I)$ is the user with the highest C/I in the cell.

$R^{DL}_{RLC-peak}$ is the RLC peak rate provided by the selected HSDPA radio bearer after scheduling and radio resource control.

$BLER_{HSDPA}$ is read in the quality graph defined for the triplet “reception equipment-selected bearer-mobility” (HSDPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (HS-PDSCH Ec/Nt). Knowing the HS-PDSCH Ec/Nt, **9955** calculates the corresponding BLER.

SF_{Rate} and ΔR respectively represent the scaling factor between the application throughput and the RLC (Radio Link Control) throughput and the throughput offset. These two parameters model the header information and other supplementary data that does not appear at the application level. They are defined in the service properties.

ΔTTI is the minimum number of TTI (Transmission Time Interval) between two TTI used; it is defined in the terminal user equipment category properties.

- The minimum HSDPA RLC peak rate in kbps ($\min_{M_b \in cell}(R^{DL}_{RLC-peak}(M_b))$)

It corresponds to the lowest of RLC peak rates obtained by HSDPA bearer users connected to the cell.

- The maximum HSDPA RLC peak rate in kbps ($\max_{M_b \in cell}(R^{DL}_{RLC-peak}(M_b))$)

It corresponds to the highest of RLC peak rates obtained by HSDPA bearer users connected to the cell.

- The number of HSUPA users in the cell (n_{M_c}):

They are the HSDPA bearer users connected to the cell.

- The HSUPA application throughput in the cell, *c*, in kbps ($T^{UL}_{application}(c)$)

$$T^{UL}_{application}(c) = \sum_{M_b \in c} T^{UL}_{application}(M_b)$$

- The uplink cell load factor due to HSUPA traffic ($X^{UL}_{HSUPA}(c)$):

$$X^{UL}_{HSUPA}(c) = \frac{(I^{UL}_{tot}(c))_{HSUPA}}{N^{UL}_{tot}(c)}$$

Where

$(I^{UL}_{tot}(c))_{HSUPA}$ is the total interference at transmitter received from HSUPA bearer users.

4.4.3.2.4 Sites Tab

In the Sites tab, **9955** displays:

- The instantaneous HSDPA rate carried by the site in kbps ($R^{DL}_{Inst}(site)$)

$$R^{DL}_{Inst}(site) = \sum_{c \in site} R^{DL}_{Inst}(c)$$

- The instantaneous HSDPA MAC Throughput carried by the site in kbps ($T^{DL}_{MAC}(site)$ in kbps)

$$T^{DL}_{MAC}(site) = \sum_{c \in site} T^{DL}_{MAC}(c)$$

- The HSUPA rate carried by the site in kbps ($R^{UL}(site)$)

$$R^{UL}(site) = \sum_{M_c \in site} R^{UL}_{obtained}(M_c)$$

4.4.4 Appendices

4.4.4.1 Admission Control in the R99 Part

During admission control in the R99 part of the simulation, **9955** calculates the uplink load factor of a considered cell assuming the mobile concerned is connected to it. Here, activity status assigned to users is not taken into account. So even if the mobile is not active on UL, it can be rejected due to cell load saturation. To calculate the cell UL load factor, either **9955** takes into account the mobile power determined during power control if mobile was connected in previous iteration, or it estimates a load rise due to the mobile and adds it to the current load. The load rise (ΔX^{UL}) is calculated as follows:

$$\Delta X^{UL} = \frac{1}{1 + \frac{W}{Q^{UL}_{req} \times R^{UL}_{nominal}}}$$

4.4.4.2 Resources Management

4.4.4.2.1 OVSF Codes Management

OVSF codes are managed in the downlink during the simulation since this resource is downlink limited only. **9955** checks the availability of this resource during the simulation, first in the R99 part and then in the HSDPA part. It determines the number of codes that will be consumed by each cell.

OVSF codes form a binary tree. Codes of longer lengths are generated from codes of a shorter length. Length-k OVSF codes are generated from length-k/2 OVSF codes. Therefore, if one channel needs 1 length-k/2 OVSF code, it is equivalent to use 2 length-k OVSF codes, or 4 length-2k OVSF codes and so on.

512 512-bit-length codes per cell are available in UMTS HSPA projects.

In the R99 part, during the resource control, **9955** determines the number of 512 bit-length codes that will be consumed for each cell.

If the cell supports HSUPA, **9955** allocates codes for the DL channels used for HSUPA:

- A 128 bit-length code for the E-HICH and E-RGCH channels (i.e. four 512 bit-length OVSF codes), for each cell. Therefore, **9955** will take four 512-bit-length codes,
- A 256 bit-length code for the E-AGCH channel (i.e. two 512 bit-length OVSF codes), for each cell. Therefore, **9955** will take two 512-bit-length codes,

If the cell supports HSDPA, **9955** reserves for potential HSDPA bearer users:

- The minimum number of HS-PDSCH codes defined for the cell, $N_{min}^{Codes-HS-PDSCH}$. They are 16-bit length OVSF codes (i.e. thirty-two 512 bit-length OVSF codes). Therefore, **9955** will take $32 \times N_{min}^{Codes-HS-PDSCH}$ 512-bit-length codes,
- A 128 bit-length code per HS-SCCH channel (i.e. four 512 bit-length OVSF codes), for each cell. Therefore, **9955** will take $4 \times n_{HS-SCCH}$ 512-bit-length codes,

Then, it allocates to the cell OVSF codes to support R99 bearers required by users:

- A 256 bit-length code per common channel (i.e. two 512 bit-length OVSF codes), for each cell. Therefore, **9955** will take $2 \times N^{Overhead-Codes}$ 512-bit-length codes,
- A code per cell-receiver link, for TCH (traffic channels). The length of code to be allocated, *Code_Length*, depends on the user activity. We have:

  Either $Code\_Length = F_{spreading}^{DL}(Active\ user)$ when the user is active,

  Or $Code\_Length = F_{spreading}^{DL}(Inactive\ user)$ if the user is inactive.

The number of 512 bit-length OVSF codes needed $N^{Codes\text{-}TCH}$ is calculated from the length of the code to be allocated as follows:

$$N^{Codes\text{-}TCH} = \frac{512}{Code\_Length}$$

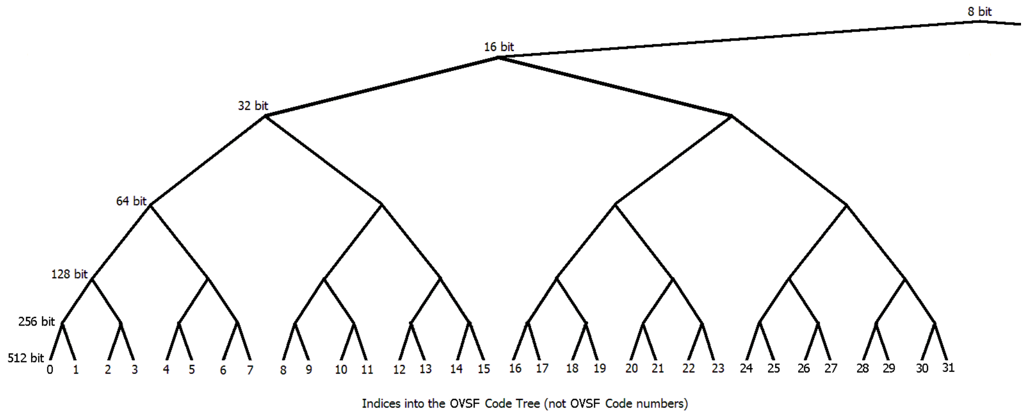


Figure 4.15: OVSF Code Tree Indices (Not OVSF Code Numbers)

The OVSF code allocation follows the "Buddy" algorithm, which guarantees that:

- If a k-length OVSF code is used, all of its children with lengths 2k, 4k, …, cannot be used as they will not be orthogonal.
- If a k-length OVSF code is used, all of its ancestors with lengths k/2, k/4, …, cannot be used as they will not be orthogonal.

Example: We consider a user with a service requiring the UDD64 R99 radio bearer. This user is active on DL while connected to a cell (which does not support HSDPA). The spreading factor for active users has been set to 64 and site equipment requires four overhead downlink channel elements per cell. **9955** will consume four 256 bit-length OVSF codes for common channels (i.e. eight 512 bit-length OVSF codes) and a 64 bit-length OVSF code for traffic channels (i.e. eight additional 512 bit-length OVSF codes).

- In the R99 part, the OVSF code allocation follows the mobile connection order (mobile order in the Mobiles tab).
- In dual-cell HSDPA, A-DPCH is only transmitted in the anchor carrier. Therefore, a dual-cell HSDPA user requires R99 resources in the best serving cell only and consumes the same amount of R99 resources as a single-cell HSDPA user.
- The OVSF code and channel element management is differently dealt with in case of "softer" handover. **9955** allocates OVSF codes for each cell-mobile link while it globally assigns channel elements to a site.

In the HSDPA part, packet (HSDPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) and packet (HSPA - Constant Bit Rate) service users are assigned an HSDPA bearer (Fast link adaptation).

Therefore, **9955** allocates to the cell:

- 16-bit length OVSF codes per cell-HSDPA receiver, for HS-PDSCH. This figure depends on the HSDPA bearer assigned to the user and on the type of service.

  For packet (HSDPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Best Effort), packet (HSPA - Variable Bit Rate) service users, **9955** needs $32 \times N^{Codes-HS-PDSCH}$ 512-bit-length codes for each user connected to the cell. $N^{Codes-HS-PDSCH}$ is the number of HS-PDSCH channels required by the HSDPA bearer.

  For packet (HSPA - Constant Bit Rate) service users, **9955** needs $32 \times N^{Codes-HS-PDSCH} \times C_{HSDPABearer}$ 512-bit-length codes for each user connected to the cell. $N^{Codes-HS-PDSCH}$ is the number of HS-PDSCH channels required by the HSDPA bearer.

  Dual-cell HSDPA users have two HSDPA bearers, one for each serving cell. Therefore, one dual-cell HSDPA user consumes OVSF codes in both cells.

> When HSDPA bearer users (at least one) are connected to the cell, **9955** gives the cell back the minimum number of OVSF codes reserved for HS-PDSCH ($N_{min}^{Codes-HS-PDSCH}$). On the other hand, if no HSDPA bearer user is connected, **9955** still keeps these codes and the codes for HS-SCCH too. This is the same with HSUPA bearer users. Even if no HSUPA bearer user is connected to the cell, **9955** still keeps the codes for E-HICH, E-RGCH and E-AGCH channels.

4.4.4.2.2 Channel Elements Management

Channel elements are controlled in the R99 and the HSUPA parts of the simulation. **9955** checks the availability of this resource in the uplink and downlink.

In the R99 part, during the resource control, **9955** determines the number of channel elements required by each site for R99 bearer users in the uplink and downlink. Then, in the HSUPA part, **9955** carries out another resource control after allocating HSUPA bearers. It takes into account the channel elements consumed by HSUPA bearer users in the uplink and recalculates the number of channel elements required by each site in the uplink.

In the uplink, **9955** consumes $N^{CE-UL}(j)$ channel elements for each cell *j* on a site N_l. This figure includes:

- Channel elements for R99 bearers:
  - $N^{Overhead-CE-UL}$ channel elements for control channels,
  - $N^{R99-TCH-CE-UL}$ per cell-receiver link, for R99 TCH (traffic channels).
- Channel elements for HSUPA bearers:
  - $N^{HSUPA-CE}$ per cell-receiver link, for packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users.
  - $N^{HSUPA-CE} \times C_{HSUPABearer}$ per cell-receiver link, for packet (HSPA - Constant Bit Rate) service users.

Therefore, the number of channel elements required in the uplink at the site level, $N^{CE-UL}(N_l)$, is:

$$N^{CE-UL}(N_l) = \sum_{j \in N_l} N^{CE-UL}(j)$$

In the downlink, **9955** consumes $N^{CE-DL}(j)$ channel elements for each cell *j* on a site N_l. This figure includes:

- Channel elements for R99 bearers
  - $N^{Overhead-CE-DL}$ channel elements for control channels (Pilot channel, Synchronisation channel, common channels),
  - $N^{R99-TCH-CE-DL}$ per cell-receiver link, for R99 TCH (traffic channels).

Therefore, the number of channel elements required in the downlink at the site level, $N^{CE-DL}(N_l)$, is:

$$N^{CE-DL}(N_l) = \sum_{j \in N_l} N^{CE-DL}(j)$$

- In dual-cell HSDPA, A-DPCH is only transmitted on the anchor carrier. Therefore, a dual-cell HSDPA user requires R99 resources in the best serving cell only and consumes the same amount of R99 resources as a single-cell HSDPA user.
- In case of "softer" handover (the mobile has several links with co-site cells), **9955** allocates channel elements for the best serving cell-mobile link only.

4.4.4.2.3 Iub Backhaul Throughput

The Iub backhaul throughput is controlled in the R99, the HSDPA and the HSUPA parts of the simulation. **9955** checks the availability of this resource in the uplink and downlink.

In the R99 part, during the resource control, **9955** determines the Iub throughput required by each site for R99 bearer users in the uplink and downlink. Then, in the HSDPA part, **9955** performs a resource control in the downlink after allocating HSDPA bearers. It takes into account the Iub backhaul throughput consumed by HSDPA bearer users in the downlink and recalculates the Iub backhaul throughput required by each site in the downlink. Finally, in the HSUPA part, **9955** carries out a resource control in the uplink after allocating HSUPA bearers. It takes into account the Iub backhaul throughput consumed by HSUPA bearer users in the uplink and updates the Iub backhaul throughput required by each site in the uplink.

In the uplink, the Iub backhaul throughput consumed by each cell *j* on a site N_l, $T_{Iub}^{UL}(j)$, includes:

- The Iub backhaul throughput required for R99 bearers:
  - $T_{Iub}^{R99-TCH-UL}$ per cell-receiver link, for R99 TCH (traffic channels).
- The Iub backhaul throughput required for HSUPA bearers:
  - T_{Iub}^{HSUPA} per cell-receiver link, for packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users.
  - $T_{Iub}^{HSUPA} \times C_{HSUPABearer}$ per cell-receiver link, for packet (HSPA - Constant Bit Rate) service users.

Therefore, the Iub backhaul throughput required on uplink at the site level, $T_{Iub}^{UL}(N_l)$, is:

$$T_{Iub}^{UL}(N_l) = \sum_{j \in N_l} T_{Iub}^{UL}(j)$$

In the downlink, the Iub backhaul throughput consumed by each cell *j* on a site N_l, $T_{Iub}^{DL}(j)$, includes:

- The Iub backhaul throughput required for R99 bearers:
  - $T_{Iub}^{Overhead-DL}$ for R99 control channels (Pilot channel, Synchronisation channel, common channels).
  - $T_{Iub}^{R99-TCH-DL}$ per cell-receiver link, for R99 TCH (traffic channels).
- The Iub backhaul throughput required for HSDPA bearers:
  - T_{Iub}^{HSDPA} per cell-receiver link, for packet (HSDPA - Best Effort), packet (HSDPA - Variable Bit Rate), packet (HSPA - Best Effort) and packet (HSPA - Variable Bit Rate) service users.
  - $T_{Iub}^{HSDPA} \times C_{HSDPABearer}$ per cell-receiver link, for packet (HSPA - Constant Bit Rate) service users.

  With $T_{Iub}^{HSDPA} = R_{RLC-peak}^{DL} + Overhead_{Iub}^{HSDPA} \times R_{RLC-peak}^{DL}$

Therefore, the Iub backhaul throughput required on downlink at the site level, $T_{Iub}^{DL}(N_l)$, is:

$$T_{Iub}^{DL}(N_l) = \sum_{j \in N_l} T_{Iub}^{DL}(j)$$

- In dual-cell HSDPA, A-DPCH is only transmitted on the anchor carrier. Therefore, a dual-cell HSDPA user requires R99 resources in the best serving cell only and consumes the same amount of R99 resources as a single-cell HSDPA user. On the other hand, the dual-cell HSDPA user has two HSDPA bearers (one for each serving cell) and consumes HSDPA resources in both cells.
- In case of "softer" handover (the mobile has several links with co-site cells), Iub backhaul throughput is consumed by the best serving cell-mobile link only.

4.4.4.3 Downlink Load Factor Calculation

9955 calculates a downlink load factor for each cell (available in the Cells tab of any simulation result) and each connected mobile (available in the Mobiles tab of any given simulation result).

4.4.4.3.1 Downlink Load Factor per Cell

Approach for downlink load factor evaluation is highly inspired by the downlink load factor defined in the book “WCDMA for UMTS by Harry Holma and Antti Toskala”.

Let $CI_{req} = \frac{Q_{req}^{DL}}{G_p^{DL}}$ be the required quality.

G_p^{DL} and Q_{req}^{DL} are the processing gain on downlink and the Eb/Nt target on downlink respectively.

In case of soft-handoff, required quality is limited to the effective contribution of the transmitter.

$$P_{tx}^{DL}(c) = P_{pilot}(c) + P_{SCH}(c) + P_{otherCCH}(c) + \sum_{tch} P_{tch}(c)$$

$$P_{tx}^{DL}(c) = P_{CCH}^{ortho}(c) + P_{CCH}^{nonOrtho}(c) + \sum_{tch} P_{tch}(c)$$

where

$$P_{CCH}^{ortho}(c) = P_{pilot}(c) + P_{otherCCH}(c)$$

$$P_{CCH}^{nonOrtho}(c) = P_{SCH}(c)$$

At mobile level, we have a required power, P_{tch}:

$$P_{tch}(c) = CI_{req} \times (I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c) + I_{intra}(c) + N_0^{term}) \times L_T \times r$$

With $r = 1$ when the user is active on the downlink and $r = r_c^{DL}$ when the user is inactive. In case of an HSDPA bearer user, $r = f_{act-ADPCH}^{DL}$.

$$P_{tch}(c) = CI_{req} \times \begin{pmatrix} I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c) \\ + (1 - F_{ortho} \times \rho_{BTS}) \times \frac{(P_{tx}^{DL}(c) - P_{CCH}^{nonOrtho}(c) - P_{tch}(c))}{L_T} + \frac{P_{CCH}^{nonOrtho}(c)}{L_T} + N_0^{term} \end{pmatrix} \times L_T \times r$$

$$P_{tch}(ic) = \frac{\begin{matrix}(I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c)) \times L_T \times r + (1 - F_{ortho} \times \rho_{BTS}) \times P_{tx}^{DL}(c) \times r \; + \\ F_{ortho} \times \rho_{BTS} \times P_{CCH}^{nonOrtho}(c) \times r + N_0^{term} \times L_T \times r\end{matrix}}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})}$$

$I_{intra}(c)$ is the total power received at the receiver from the cell with which it is connected.

$I_{extra}(c)$ is the total power received at the receiver from other cells.

$I_{inter-carrier}(c)$ is the inter-carrier interference received at the terminal.

$I_{inter-technology}(c)$ is the inter-technology interference received at the terminal from an external transmitter.

We have:

$$P_{tx}^{DL}(c) = \begin{matrix} P_{CCH}^{ortho}(c) + P_{CCH}^{nonOrtho}(c) \\ + \sum_{tch} \left(\frac{\left(\begin{matrix} (I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c)) \times L_T \times r \\ + (1 - F_{ortho} \times \rho_{BTS}) \times P_{tx}^{DL}(c) \times r + F_{ortho} \times \rho_{BTS} \times P_{CCH}^{nonOrtho}(c) \times r + N_0^{term} \times L_T \times r \end{matrix} \right)}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})} \right) \end{matrix}$$

$$P_{tx}^{DL}(c) = P_{CCH}^{ortho}(c) + P_{CCH}^{nonOrtho}(c) + \sum_{tch} \frac{\frac{(I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c)) \times L_T \times r}{P_{tx}^{DL}(c)} \times P_{tx}^{DL}(c)}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})} +$$

$$\sum_{tch} \frac{(1 - F_{ortho} \times \rho_{BTS}) \times P_{tx}^{DL}(c) \times r}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})} + \sum_{tch} \frac{F_{ortho} \times \rho_{BTS} \times P_{CCH}^{nonOrtho}(c) \times r + N_0^{term} \times L_T \times r}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})}$$

$$P_{tx}^{DL}(c) - \sum_{tch} \left(\frac{\frac{(I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c)) \times L_T \times r}{P_{tx}^{DL}(c)} + 1 - F_{ortho} \times \rho_{BTS} \times r}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})} \right) \cdot P_{tx}^{DL}(ic)$$

$$= P_{CCH}^{ortho}(c) + P_{CCH}^{nonOrtho}(c) + \sum_{tch} \frac{F_{ortho} \times \rho_{BTS} \times P_{CCH}^{nonOrtho}(c) \times r + N_0^{term} \times L_T \times r}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})}$$

$$P_{tx}^{DL}(c) = \frac{P_{CCH}^{ortho}(c) + P_{CCH}^{nonOrtho}(c) + \sum_{tch} \frac{F_{ortho} \times \rho_{BTS} \times P_{CCH}^{nonOrtho}(c) \times r + N_0^{term} \times L_T \times r}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})}}{1 - \sum_{tch} \left(\frac{\frac{(I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c)) \times L_T \times r}{P_{tx}^{DL}(c)} + 1 - F_{ortho} \times \rho_{BTS} \times r}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})} \right)}$$

Therefore, the downlink load factor can be expressed as:

$$X^{DL} = \sum_{tch} \frac{\frac{(I_{extra}(c) + I_{inter-carrier}(c) + I_{inter-technology}(c)) \times L_T \times r}{P_{tx}^{DL}(c)} + 1 - F_{ortho} \times \rho_{BTS} \times r}{\frac{1}{CI_{req} \times r} + (1 - F_{ortho} \times \rho_{BTS})}$$

The downlink load factor represents the signal degradation in relation to the reference interference (thermal noise plus synchronisation channel power).

4.4.4.3.2 Downlink Load Factor per Mobile

9955 evaluates the downlink load factor for any connected mobile as follows:

$$X^{DL} = \frac{I_{tot}^{DL}(c)}{N_{tot}^{DL}(c)}$$

4.4.4.4 Uplink Load Factor Due to One User

This part details how **9955** calculates the contribution of one user to the UL load factor (ΔX_k^{UL}).

In this calculation, we assume that the cell UL reuse factor ($F^{UL}(txi, ic)$) is constant.

The result depends on the option used to calculate Nt (Without useful signal or Total noise that you may select in Global parameters).

Without Useful Signal Option

$$Q_{req}^{UL}(k) = \frac{W}{R_{nominal}^{UL}(k)} \times \frac{(P_b^{UL}(k))_{req}}{I_{intra} - (P_b^{UL}(k))_{req} + I_{extra} + I_{inter-carrier} + N_0^{tx}}$$

$$Q_{req}^{UL}(k) = \frac{W}{R_{nominal}^{UL}(k)} \times \frac{(P_b^{UL}(k))_{req}}{I_{intra} \times F^{UL} - (P_b^{UL}(k))_{req} + N_0^{tx}}$$

$$(P_b^{UL}(k))_{req} \times \left(1 + Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W}\right) = Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W} \times (I_{intra} \times F^{UL} + N_0^{tx})$$

$$(P_b^{UL}(k))_{req} = \frac{Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W} \times I_{intra} \times F^{UL}}{1 + Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W}} + \frac{Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W} \times N_0^{tx}}{1 + Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W}}$$

We note $\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req} = Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W}$

$$(P_b^{UL}(k))_{req} = \frac{I_{intra} \times F^{UL}}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req}} + 1\right)} + \frac{N_0^{tx}}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req}} + 1\right)}$$

As $I_{intra} = \sum_K (P_b^{UL}(k))_{req}$, we have:

$$I_{intra} = I_{intra} \times F^{UL} \times \sum_K \frac{1}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req}} + 1\right)} + N_0^{tx} \times \sum_K \frac{1}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req}} + 1\right)}$$

$$I_{intra} = \frac{N_0^{tx} \times \sum_K \frac{1}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req}} + 1\right)}}{1 - F^{UL} \times \sum_K \frac{1}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req}} + 1\right)}}$$

$$I_{intra} = \frac{N_0^{tx} / F^{UL}}{\frac{1}{F^{UL} \times \sum_K \frac{1}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)_{E-DPDCH}^{req}} + 1\right)}} - 1}$$

$$X^{UL} = \frac{I_{intra} + I_{extra} + I_{inter-carrier}}{I_{intra} + I_{extra} + I_{inter-carrier} + N_0^{tx}} = \frac{I_{intra} \times F^{UL}}{I_{intra} \times F^{UL} + N_0^{tx}} = \frac{1}{1 + \frac{N_0^{tx}}{I_{intra} \times F^{UL}}}$$

Therefore, we have:

$$X^{UL} = F^{UL} \times \sum_{K} \frac{1}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH}} + 1\right)}$$

So, we can conclude that the contribution of one user to the UL load is defined as:

$$\Delta X_k^{UL} = F^{UL} \times \frac{1}{\left(\frac{1}{\left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH}} + 1\right)}$$

Total Noise Option

$$Q_{req}^{UL}(k) = \frac{W}{R_{nominal}^{UL}(k)} \times \frac{(P_b^{UL}(k))_{req}}{I_{intra} + I_{extra} + I_{inter-carrier} + N_0^{tx}}$$

$$Q_{req}^{UL}(k) = \frac{W}{R_{nominal}^{UL}(k)} \times \frac{(P_b^{UL}(k))_{req}}{I_{intra} \times F^{UL} + N_0^{tx}}$$

$$(P_b^{UL}(k))_{req} = Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W} \times (I_{intra} \times F^{UL} + N_0^{tx})$$

We note $\left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH} = Q_{req}^{UL}(k) \times \frac{R_{nominal}^{UL}(k)}{W}$

$$(P_b^{UL}(k))_{req} = \left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH} \times (I_{intra} \times F^{UL} + N_0^{tx})$$

As $I_{intra} = \sum_{K} (P_b^{UL}(k))_{req}$, we have:

$$I_{intra} = (I_{intra} \times F^{UL} + N_0^{tx}) \times \sum_{K} \left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH}$$

$$I_{intra} = \frac{N_0^{tx} \times \sum_{K} \left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH}}{1 - F^{UL}}$$

$$X^{UL} = \frac{I_{intra} + I_{extra} + I_{inter-carrier}}{I_{intra} + I_{extra} + I_{inter-carrier} + N_0^{tx}} = \frac{I_{intra} \times F^{UL}}{I_{intra} \times F^{UL} + N_0^{tx}} = \frac{1}{1 + \frac{N_0^{tx}}{I_{intra} \times F^{UL}}}$$

Therefore, we have:

$$X^{UL} = F^{UL} \times \sum_{K} \left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH}$$

So, we can conclude that the contribution of one user to the UL load is defined as:

$$\Delta X_k^{UL} = F^{UL} \times \left(\frac{Ec}{Nt}(k)\right)^{req}_{E-DPDCH}$$

4.4.4.5 Inter-carrier Power Sharing Modelling

Inter-carrier power sharing enables the network to dynamically allocate available power from R99-only and HSDPA carriers among HSDPA carriers.

In this part, we will consider the most common scenario, a network consisting of an R99-only carrier (c_1) and an HSDPA carrier with dynamic power allocation (c_2) (c_2 does not support HSUPA).

As explained in *The User Manual*, the maximum power of the HSDPA cell must be set to the same value as the maximum shared power in order to use power sharing efficiently. In this case, the HSDPA cell can use 100% of the available power, i.e, all of the R99-only cell's unused power can be allocated to the HSDPA cell.

Let's take the following example to measure the impact of the inter-carrier power sharing.

- 1st case: Inter-carrier power sharing is not activated

On c_1, we have: $P_{max}(Tx, c_1) = 43dBm$ and $P_{tx-R99}(Tx, c_1) = 39.1dBm$.

On c_2, we have: $P_{max}(Tx, c_2) = 43dBm$, $P_{tx-R99}(Tx, c_2) = 36.1dBm$ and $P_{Headroom}(Tx, c_2) = 0dB$.

Therefore, $P_{HSDPA}(Tx, c_2) = P_{max}(Tx, c_2) - P_{tx-R99}(Tx, c_2) - P_{Headroom}(Tx, c_2) = 42dBm$

- 2nd case: Inter-carrier power sharing is activated and $P_{max}(Tx) = 46dBm$

On c_1, we have: $P_{max}(Tx, c_1) = 43dBm$ and $P_{tx-R99}(Tx, c_1) = 39.1dBm$.

On c_2, we have: $P_{max}(Tx, c_2) = 46dBm$, $P_{tx-R99}(Tx, c_2) = 36.1dBm$ and $P_{Headroom}(Tx, c_2) = 0dB$.

Therefore, $P_{HSDPA}(Tx, c_2) = P_{max}(Tx) - P_{tx-R99}(Tx, c_1) - P_{tx-R99}(Tx, c_2) - P_{Headroom}(Tx, c_2) = 44.4dBm$

4.4.4.6 Best Server Determination in Monte Carlo Simulations - Old Method

Before **9955** V6.8, best server determination used to be performed by selecting the best carrier within transmitters according to the selected method (site equipment) and then the best transmitter using the best carrier. To switch back to this method, add the following lines in the Atoll.ini file:

```
[CDMA]
MultiBandSimu = 0
```

The method is described below:

For each station *txi* containing M_b in its calculation area and using the main frequency band supported by the M_b's terminal (i.e. either *f1* for a single frequency band network, or *f1* or *f2* for a dual-band terminal without any priority on frequency bands, or *f1* for a dual-band terminal with *f1* as main frequency band).

Determination of $BestCarrier_k(txi, M_b)$.

If a given carrier is specified for the service requested by M_b and if it is used by *txi*

$BestCarrier_k(txi, M_b)$ is the carrier specified for the service.

Else the carrier selection mode defined for *txi* is considered.

If carrier selection mode is "Min. UL Load Factor"

For each carrier *ic* used by *txi*, we calculate current loading factor:

$$X_k^{UL}(txi, ic) = \frac{I_{tot}^{UL}(txi, ic)}{N_{tot}^{UL}(txi, ic)} + \Delta X^{UL}$$

EndFor

$BestCarrier_k(txi, M_b)$ is the carrier with the lowest $X_k^{UL}(txi, ic)$

Else if carrier selection mode is "Min. DL Total Power"

$BestCarrier_k(txi, M_b)$ is the carrier with the lowest $P_{tx}(txi, ic)_k$

Else if carrier selection mode is "Random"

$BestCarrier_k(txi, M_b)$ is randomly selected

Else if carrier selection mode is "Sequential"

$BestCarrier_k(txi, M_b)$ is the first carrier so that $X_k^{UL}(txi, ic) \le X_{max}^{UL}$

Calculation of

$$Q_{pilot_k}(txi, BestCarrier) = \frac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, BestCarrier)}{\left(\begin{matrix} P_{tot}^{DL}(txi, BestCarrier_k(txi, M_b)) + I_{extra}^{DL}(BestCarrier_k(txi, M_b)) + \\ I_{inter-carrier}^{DL}(BestCarrier_k(txi, M_b)) + I_{inter-technology}^{DL}(BestCarrier_k(txi, M_b)) + N_0^{Term} \end{matrix}\right)}$$

If user selects “without Pilot”

$$Q_{pilot_k}(txi, BestCarrier) = \frac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, BestCarrier)}{\left(\begin{matrix} P_{tot}^{DL}(txi, BestCarrier_k(txi, M_b)) + I_{extra}^{DL}(BestCarrier_k(txi, M_b)) \\ + I_{inter-carrier}^{DL}(BestCarrier_k(txi, M_b)) + I_{inter-technology}^{DL}(BestCarrier_k(txi, M_b)) \\ + N_0^{Term} - (1-\alpha) \times \rho_{BTS} \times P_c(txi, M_b, BestCarrier) \end{matrix}\right)}$$

Rejection of station *txi* if the pilot is not received

If $Q_{pilot_k}(txi, M_b, BestCarrier) < Q_{req}^{pilot}(Mobility(M_b))$ then *txi* is rejected by M_b

If $Q_{pilot_k}(txi, M_b, BestCarrier) > Q_{pilot_k}^{max}(M_b)$

Admission control (If simulation respects a loading factor constraint and M_b was not connected in previous iteration).

If $X_k^{UL}(txi, BestCarrier(txi, M_b)) > X_{max}^{UL}$, then *txi* is rejected by M_b

Else

$$Q_{pilot_k}^{max}(M_b) = Q_{pilot_k}(txi, M_b, BestCarrier)$$

$$Tx_{BS}(M_b) = txi$$

Endif

EndFor

If no Tx_{BS} has been selected and M_b’s terminal can work on one frequency band only, M_b has failed to be connected to the network and is rejected.

If no Tx_{BS} has been selected and M_b’s terminal can work on another frequency band.

Determination of $BestCarrier_k(txi, M_b)$ for each station *txi* containing M_b in its calculation area and using another frequency band supported by the M_b’s terminal (i.e. *f1* or *f2* for a dual-band terminal without any priority on frequency bands, or *f2* for a dual-band terminal with *f2* as secondary frequency band)

If a given carrier is specified for the service requested by M_b and if it is used by *txi*

$BestCarrier_k(txi, M_b)$ is the carrier specified for the service.

Else the carrier selection mode defined for *txi* is considered.

If carrier selection mode for *txi* is “Min. UL Load Factor”

For each carrier *ic* used by *txi*, we calculate current loading factor:

$$X_k^{UL}(txi, ic) = \frac{I_{tot}^{UL}(txi, ic)}{N_{tot}^{UL}(txi, ic)} + \Delta X^{UL}$$

EndFor

$BestCarrier_k(txi, M_b)$ is the carrier with the lowest $X_k^{UL}(txi, ic)$

Else if carrier selection mode is “Min. DL Total Power”

$BestCarrier_k(txi, M_b)$ is the carrier with the lowest $P_{tx}(txi, ic)_k$

Else if carrier selection mode is “Random”

$BestCarrier_k(txi, M_b)$ is randomly selected

Else if carrier selection mode is "Sequential"

$BestCarrier_k(txi, M_b)$ is the first carrier so that $X_k^{UL}(txi, ic) \le X_{max}^{UL}$

Calculation of

$$Q_{pilot_k}(txi, BestCarrier) = \frac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, BestCarrier)}{\left(\begin{array}{c} P_{tot}^{DL}(txi, BestCarrier_k(txi, M_b)) + I_{extra}^{DL}(BestCarrier_k(txi, M_b)) + \\ I_{inter-carrier}^{DL}(BestCarrier_k(txi, M_b)) + I_{inter-technology}^{DL}(BestCarrier_k(txi, M_b)) + N_0^{Term} \end{array}\right)}$$

If user selects "without Pilot"

$$Q_{pilot_k}(txi, BestCarrier) = \frac{\alpha \times \rho_{BTS} \times P_c(txi, M_b, BestCarrier)}{\left(\begin{array}{c} P_{tot}^{DL}(txi, BestCarrier_k(txi, M_b)) + I_{extra}^{DL}(BestCarrier_k(txi, M_b)) \\ + I_{inter-carrier}^{DL}(BestCarrier_k(txi, M_b)) + I_{inter-technology}^{DL}(BestCarrier_k(txi, M_b)) \\ + N_0^{Term} - (1-\alpha) \times \rho_{BTS} \times P_c(txi, M_b, BestCarrier) \end{array}\right)}$$

Rejection of station *txi* if the pilot is not received

If $Q_{pilot_k}(txi, M_b, BestCarrier) < Q_{req}^{pilot}(Mobility(M_b))$ then *txi* is rejected by M_b

If $Q_{pilot_k}(txi, M_b, BestCarrier) > Q_{pilot_k}^{max}(M_b)$

Admission control (If simulation respects a loading factor constraint and M_b was not connected in previous iteration).

If $X_k^{UL}(txi, BestCarrier(txi, M_b)) > X_{max}^{UL}$, then *txi* is rejected by M_b

Else

$$Q_{pilot_k}^{max}(M_b) = Q_{pilot_k}(txi, M_b, BestCarrier)$$

$$Tx_{BS}(M_b) = txi$$

Endif

EndFor

If no Tx_{BS} has been selected, M_b has failed to be connected to the network and is rejected.

4.5 UMTS HSPA Prediction Studies

4.5.1 Point Analysis

4.5.1.1 AS Analysis Tab

Let us suppose a receiver with a terminal, a service and a mobility type. This receiver does not create any interference. You can make the prediction for a specific carrier or for the best carrier. If you have selected a dual-cell HSDPA user, the analysis must be made on the best carrier.

The analysis is based on the following parameters:

- The uplink load factor and the downlink total power of cells,
- The available HSDPA power of the cell in case of an HSDPA bearer user,
- The cell UL reuse factor, the cell UL load factor due to HSUPA and the maximum cell UL load factor for HSUPA bearer users.

These parameters can be results of a given simulation, average values calculated from a group of simulations, or user-defined cell inputs. In the last case, when no value is defined in the Cells table, **9955** uses the following default values:

- Total transmitted power = 50% of the maximum power (i.e, 40 dBm if the maximum power is set to 43 dBm)
- Uplink load factor = 50%.
- Uplink reuse factor = 1
- Uplink load factor due to HSUPA = 0%
- Maximum uplink load factor = 75%

On the other hand, no default value is used for the HSDPA power; this parameter must be defined by the user.

4.5.1.1.1 Bar Graph and Pilot Sub-Menu

We can consider the following cases:

1st case: Analysis based on a specific carrier

The carrier that can be used by transmitters is fixed. In this case, for each transmitter *i* containing the receiver in its calculation area and using the selected carrier, **9955** calculates the pilot quality at the receiver on this carrier. Then, it determines the best serving transmitter using the selected carrier *ic*.

2nd case: Analysis based on the best carrier

9955 determines the best carrier for each transmitter *i* which contains the receiver in its calculation area and uses a frequency band supported by the receiver's terminal. The best carrier selection depends on the option selected for the site equipment (UL minimum noise, DL minimum power, random, sequential). Then, **9955** calculates the pilot quality at the receiver from these transmitters on their best carriers (*ic)* and defines the best server (on its best carrier).

3rd case: Analysis based on the best carrier of any frequency band (for dual-band terminals with priority defined on frequency bands only)

The frequency band that can be used is fixed. **9955** determines the best carrier for each transmitter *i* containing the receiver in its calculation area and using the selected frequency band. The best carrier selection depends on the option selected for the site equipment (UL minimum noise, DL minimum power, random, sequential). Then, **9955** calculates the pilot quality at the receiver from these transmitters on their best carriers (*ic)* and defines the best server (on its best carrier).

Ec/I0 (or $Q_{pilot}(ic)$) Evaluation

Let us assume that *ic* is either the best carrier or the selected carrier of a transmitter *i* containing the receiver in its radius calculation and ic_{adj} is another carrier adjacent to *ic*. An interference reduction factor, $RF(ic, ic_{adj})$, is defined between *ic* and ic_{adj} and set to a value different from 0.

Two ways may be used to calculate I0.

Option <u>Total noise</u>: **9955** considers the noise generated by all the transmitters and the thermal noise.

Option <u>Without pilot</u>: **9955** considers the total noise deducting the pilot signal.

Calculation option may be selected in Global parameters.

Therefore, we have:

$$Q_{pilot}(i, ic) = \frac{\rho_{BTS} \times \alpha \times P_c(i, ic)}{I_0^{DL}(ic)}$$

With,

$$I_0^{DL}(ic) = P_{tot}^{DL}(i, ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term}$$ for the total noise option,

And

$$I_0^{DL}(ic) = I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term} - (1-\alpha) \times \rho_{BTS} \times P_c(i, ic)$$ for the without pilot option.

<u>1st step</u>: $P_c(i, ic)$ calculation for each cell (i,*ic*)

$P_c(i, ic)$ is the pilot power of a transmitter *i* on carrier *ic* at the receiver.

$$P_c(i, ic) = \frac{P_{pilot}(i, ic)}{L_{T_i}}$$

L_{T_i} is the total loss between transmitter *i* and receiver.

$$L_{T_i} = \frac{L_{Tx} \times L_{path} \times L_{term} \times L_{body} \times L_{Indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}}$$

<u>2nd step</u>: $P_{tot}^{DL}(j, ic)$, $P_{tot}^{DL}(i, ic)$ and $P_{tot}^{DL}(j, ic_{adj})$ calculations

We have:

$$I_{extra}^{DL}(ic) = \sum_{txj, j \neq i} P_{tot}^{DL}(j, ic)$$

$$I_{intra}^{DL}(ic) = P_{tot}^{DL}(i, ic) - \rho_{BTS} \times \alpha \times \left(P_{tot}^{DL}(i, ic) - \frac{P_{SCH}(ic)}{L_T}\right)$$

$$I_{inter-carrier}^{DL}(ic) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(j, ic_{adj})}{RF(ic, ic_{adj})}$$

and

$$I_{inter-technology}^{DL}(ic) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic}^{Tx, m}}$$

For each transmitter of the network, $P_{tot}^{DL}(ic)$ is the total power received at the receiver from the transmitter on the best carrier *ic* of the transmitter *i*.

$$P_{tot}^{DL}(ic) = \frac{P_{Tx}(ic)}{L_T}$$

$P_{Tx}(ic)$ is the total power transmitted by the transmitter on the best carrier. Total power transmitted by each cell is either a simulation result (provided in **Simulation properties** (Cells tab)) or a value user-defined in Cell properties.

For each transmitter of the network, $P_{tot}^{DL}(ic_{adj})$ is the total power received at the receiver from the transmitter on the carrier ic_{adj}. This carrier is adjacent to *ic*.

$$P_{tot}^{DL}(ic_{adj}) = \frac{P_{Tx}(ic_{adj})}{L_T}$$

$P_{Tx}(ic_{adj})$ is the total power transmitted by the transmitter on the carrier ic_{adj}. Total power transmitted by each cell is either a simulation result (provided in **Simulation properties** (Cells tab)) or a value user-defined in Cell properties.

3rd step: N_0^{term} calculation

$$N_0^{term} = NF_{Term} \times K \times T \times W \times NR_{inter-technology}^{Tx, DL}$$

4th step: $I_0^{DL}(ic)$ and $Q_{pilot}(i, ic)$ evaluation using formulas described above

5th step: $G_{macro-diversity}^{DL}$ calculation

The macro-diversity gain, $G_{macro-diversity}^{DL}$, models the decrease in shadowing margin due to the fact there are several available pilot signals at the mobile.

$$G_{macro-diversity}^{DL} = M_{Shadowing-Ec/Io}^{npaths} - M_{Shadowing-Ec/Io}$$

$M_{Shadowing-Ec/Io}^{npaths}$ is the shadowing margin when the mobile receives n pilot signals (not necessarily from transmitters belonging to the mobile active set).

> This parameter is determined from cell edge coverage probability and Ec/I0 standard deviation. When the Ec/I0 standard deviation is set to 0, the macro-diversity gain equals 0.

6th step: Determination of active-set

9955 takes the transmitter *i* with the highest $Q_{pilot}(i, ic)$ and calculates the best pilot quality received with a fixed cell edge coverage probability, $Q_{pilot}^{Resulting}(ic)$.

$$Q_{pilot}^{Resulting}(ic) = G_{macro-diversity}^{DL} \times max(Q_{pilot}(i, ic))$$

If $Q_{pilot}^{Resulting} \geq Q_{pilot}^{req}$, it means pilot quality at the receiver exceeds $Q_{pilot}^{Resulting}(ic)$ x% of time (x is the fixed cell edge coverage probability). The cell whose $Q_{pilot}(i, ic)$ is the highest one enters the active set as best server ($Q_{pilot}(BS, ic)$) and the best carrier (ic_{BS}) of the best server, *BS*, will be the carrier used by other transmitters of the active set (when active set size is greater than 1). Pilot is available.

If $Q_{pilot}^{Resulting} < Q_{pilot}^{req}$, no cell *(i,ic)* can enter the active set. Pilot is unavailable.

Then, pilot qualities at the receiver from transmitters *i* (except the best server) on the best carrier of the best server, ic_{BS}, are recalculated to determine the entire receiver active set (when active set size is greater than 1). Same formulas and calculation method are used to update $I_0^{DL}(ic_{BS})$ value and determine $Q_{pilot}(i, ic_{BS})$.

We have:

$$Q_{pilot}(i, ic) = \frac{\rho_{BTS} \times \alpha \times P_c(i, ic)}{I_0^{DL}(ic)}$$

With,

$I_0^{DL}(ic) = P_{tot}^{DL}(i, ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term}$ for the total noise option,

And

$I_0^{DL}(ic) = I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term} - (1-\alpha) \times \rho_{BTS} \times P_c(i, ic)$ for the without pilot option.

Other cells *(i,*ic_{BS}*)* in the active set must satisfy the following criteria:

$$|Q_{pilot}(i, ic_{BS}) - Q_{pilot}(BS, ic_{BS})| \geq AS\_threshold(i_{BS}, ic_{BS})$$

$(i, ic_{BS}) \in$ *neighbour list*(i_{BS}, ic_{BS}) (optionally)

Number of Cells in Active Set

This is a user-specified input in the **Terminal properties**. It corresponds to the active set size.

Thermal Noise

This parameter is calculated as described above (3rd step).

I0 (Best Server)

I0 (Best server) is the total noise received at the receiver on ic_{BS}. The notation "Best server" refers to the best server of active set. This is relevant when using the calculation option "Without pilot". In this case, it informs that the pilot signal of the best server *(BS,*ic_{BS}*)* is deducted from the total noise.

Downlink Macro-Diversity Gain

This parameter is calculated as described above (5th step).

4.5.1.1.2 Downlink Sub-Menu

The Downlink sub-menu may contain R99-related results and HSDPA-related results when an HSPA bearer user is modelled and the HS-SCCH quality is sufficient.

For dual-cell HSDPA users with an R99 connection to a transmitter that supports the dual-cell HSDPA mode, **9955** determines the best HSDPA bearers obtained in the two serving cellsResult is available for a single carrier when the HS-SCCH quality in one cell is not sufficient.

- **R99-related Results**

9955 calculates the traffic channel quality from each cell (*k,*ic_{BS}*)* of the receiver's active set at the receiver. No power control is performed as in simulations. Here, **9955** determines the downlink traffic channel quality at the receiver for the maximum allowed traffic channel power per transmitter. Then, after combination, the total downlink traffic channel quality is evaluated and compared with the specified target quality.

Eb/Nt Target

Eb/Nt target (Q_{req}^{DL}) is defined for a given R99 bearer, a mobility type and a reception equipment. This parameter is available in the R99 Bearer Selection table.

Compressed mode is operated when amobile supporting compressed mode is connected to a cell located on a site with a compressed-mode-capable equipment, and

- Either the received Ec/I0 is lower than the Ec/I0 activation threshold (Global parameters): $Q_{pilot}^{Resulting} \le Q_{pilot}^{CM-activation}$,
- Or the pilot RSCP is lower than the pilot RSCP activation threshold (Global parameters): $P_c \le RSCP_{pilot}^{CM-activation}$.

When compressed mode is activated, the downlink Eb/Nt target is increased by the value user-defined for the DL Eb/Nt target increase field (Global parameters), ΔQ_{req}^{DL}.

Required transmitter power on traffic channels

The calculation of the required transmitter power on traffic channels (P_{tch}^{req}) may be divided into three steps.

1st step: $Q_{max}^{DL}(k, ic_{BS})$ evaluation for each cell

Let us assume the following notation: Eb/Nt max corresponds to Q_{max}^{DL}

Therefore, for each cell (k,ic_{BS}), we have:

$$Q_{max}^{DL}(k, ic_{BS}) = \frac{\rho_{BTS} \times P_{b-max}^{DL}(k, ic_{BS})}{N_{tot}^{DL}(ic_{BS})} \times G_p^{DL} \times G_{Div}^{DL}$$

With $P_{b-max}^{DL}(k, ic_{BS}) = \frac{P_{tch}^{max}}{L_{T_k}}$

and $N_{tot}^{DL}(ic_{BS}) = I_{intra}^{DL}(ic_{BS}) + I_{extra}^{DL}(ic_{BS}) + I_{inter-carrier}^{DL}(ic_{BS}) + I_{inter-technology}^{DL}(ic_{BS}) + N_0^{term}$

Where

P_{tch}^{max} is the maximum power allowed on traffic channels. This parameter is user-defined in the R99 Radio Bearers table.

$N_{tot}^{DL}(ic_{BS})$ is the total noise at the receiver on the best carrier of the best server.

$I_{intra}^{DL}(ic_{BS})$ is the intra-cell interference at the receiver on the best carrier of the best server.

$$I_{intra}^{DL}(ic_{BS}) = P_{tot}^{DL}(k, ic_{BS}) - \rho_{BTS} \times F_{ortho} \times \left(P_{tot}^{DL}(k, ic_{BS}) - \frac{P_{SCH}(k, ic_{BS})}{L_T} \right)$$

$I_{extra}^{DL}(ic_{BS})$ is the extra-cell interference at the receiver on the best carrier of the best server.

$$I_{extra}^{DL}(ic_{BS}) = \sum_{j, j \ne k} P_{tot}^{DL}(j, ic_{BS})$$

$I_{inter-carrier}^{DL}(ic_{BS})$ is the inter-carrier interference at the receiver on the best carrier of the best server.

$$I_{inter-carrier}^{DL}(ic_{BS}) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(j, ic_{adj})}{RF(ic_{BS}, ic_{adj})}$$

ic_{adj} is a carrier adjacent to ic_{BS}.

$RF(ic_{BS}, ic_{adj})$ is the interference reduction factor, defined between ic and ic_{adj} and set to a value different from 0.

$I_{inter-technology}^{DL}(ic_{BS})$ is the inter-technology interference at the receiver on the best carrier of the best server.

$$I_{inter-technology}^{DL}(ic_{BS}) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic_{BS}}^{Tx, m}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP_{ic_i, ic_{BS}}^{Tx, m}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic_{BS}.

2nd step: Calculation of the total traffic channel quality

Q_{MAX}^{DL} is the traffic channel quality at the receiver on ic_{BS} after signal combination of all the transmitters *k* of the active set.

On downlink, if there is no handoff, we have:

$$Q_{MAX}^{DL}(ic_{BS}) = Q_{max}^{DL}(k, ic_{BS})$$

For any other handoff status, we have:

$$Q_{MAX}^{DL}(ic_{BS}) = f_{rake\ efficiency}^{DL} \times \sum_k Q_{max}^{DL}(k, ic_{BS})$$

Where

$f_{rake\ efficiency}^{DL}$ is the downlink rake efficiency factor defined in Terminal properties.

3rd step: P_{tch}^{req} calculation

$$P_{tch}^{req} = \frac{Q_{req}^{DL}}{Q_{MAX}^{DL}(ic_{BS})} \times P_{tch}^{max}$$

> Compressed mode is operated when a mobile supporting compressed mode is connected to a cell located on a site with a compressed-mode-capable equipment, and
>
> - Either the received Ec/I0 is lower than the Ec/I0 activation threshold (Global parameters): $Q_{pilot}^{Resulting} \le Q_{pilot}^{CM-activation}$.
> - Or the pilot RSCP is lower than the pilot RSCP activation threshold (Global parameters): $P_c \le RSCP_{pilot}^{CM-activation}$
>
> When compressed mode is activated, the downlink Eb/Nt target is increased by the value user-defined for the DL Eb/Nt target increase field (Global parameters), ΔQ_{req}^{DL}. In this case, we have: $P_{tch}^{req} = \frac{Q_{req}^{DL} \times \Delta Q_{req}^{DL}}{Q_{MAX}^{DL}(ic_{BS})} \times P_{tch}^{max}$

Eb/Nt Max for Each Cell of Active Set

For each cell (k, ic_{BS}), we have:

$$Q_{max}^{DL}(k, ic_{BS}) = \frac{\rho_{BTS} \times P_{b-max}^{DL}(k, ic_{BS})}{N_{tot}^{DL}(ic_{BS})} \times G_p^{DL} \times G_{Div}^{DL}$$

With $P_{b-max}^{DL}(k, ic_{BS}) = \frac{P_{tch}^{max}}{L_{T_k}}$

$$N_{tot}^{DL}(ic_{BS}) = I_{intra}^{DL}(ic_{BS}) + I_{extra}^{DL}(ic_{BS}) + I_{inter-carrier}^{DL}(ic_{BS}) + I_{inter-technology}^{DL}(ic_{BS}) + N_0^{term}$$

$$I_{intra}^{DL}(ic_{BS}) = P_{tot}^{DL}(k, ic_{BS}) - \rho_{BTS} \times F_{ortho} \times \left(P_{tot}^{DL}(k, ic_{BS}) - \frac{P_{SCH}(k, ic_{BS})}{L_T} \right) - (1 - \rho_{BTS}) \times max\left(\frac{P_{tch}^{max} - P_{tch}^{req}}{L_{T_k}}, 0\right)$$

$$I_{extra}^{DL}(ic_{BS}) = \sum_{j, j \ne k} P_{tot}^{DL}(j, ic_{BS})$$

$$I^{DL}_{inter-carrier}(ic_{BS}) = \frac{\sum_{txj,\forall j} P^{DL}_{tot}(j, ic_{adj})}{RF(ic_{BS}, ic_{adj})}$$

$$I^{DL}_{inter-technology}(ic_{BS}) = \sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx,m}_{ic_i, ic_{BS}}}$$

Where

P^{req}_{tch} is the required transmitter power on traffic channels.

Eb/Nt Max

Q^{DL}_{MAX} is the traffic channel quality at the receiver on ic_{BS} after signal combination of all the transmitters k of the active set.

On downlink, if there is no handoff, we have:

$$Q^{DL}_{MAX}(ic_{BS}) = Q^{DL}_{max}(k, ic_{BS})$$

For any other handoff status, we have:

$$Q^{DL}_{MAX}(ic_{BS}) = f^{DL}_{rake\ efficiency} \times \sum_k Q^{DL}_{max}(k, ic_{BS})$$

Where

$f^{DL}_{rake\ efficiency}$ is the downlink rake efficiency factor defined in Terminal properties.

Therefore, the service on the downlink traffic channel is available if $Q^{DL}_{MAX}(ic_{BS}) \geq Q^{DL}_{req}$ (or $Q^{DL}_{MAX}(ic_{BS}) \geq Q^{DL}_{req} \times \Delta Q^{DL}_{req}$ when compressed mode is activated).

Effective Eb/Nt

Q^{DL}_{eff} is the effective traffic channel quality at the receiver on ic_{BS}.

$Q^{DL}_{eff} = min(Q^{DL}_{MAX}, Q^{DL}_{req})$ (or $Q^{DL}_{eff} = min(Q^{DL}_{MAX}, Q^{DL}_{req} \times \Delta Q^{DL}_{req})$ when compressed mode is activated).

Downlink Soft Handover Gain

G^{DL}_{SHO} corresponds to the DL soft handover gain.

$$G^{DL}_{SHO} = \frac{Q^{DL}_{MAX}(ic_{BS})}{max(Q^{DL}_{max}(k, ic_{BS}))}$$

$max(Q^{DL}_{max}(k, ic_{BS}))$ corresponds to the highest $Q^{DL}_{max}(k, ic_{BS})$ value.

- **HSDPA-related Results**

9955 determines the best HSDPA bearer that the user can obtain. The HSDPA bearer user is processed as if he is the only user in the cell i.e. he uses the entire HSDPA power available in the cell.

For dual-cell HSDPA users with an R99 connection to a dual-cell HSDPA transmitter, **9955** determines the best HSDPA bearers that the user can obtain in the anchor and secondary cells. In each cell, the user is processed as if he is the only user in the cell.

For further information on the fast link adaptation modelling, see "Fast Link Adaptation Modelling" on page 209.

HS-PDSCH Ec/Nt

9955 calculates the best HS-PDSCH quality (HS-PDSCH Ec/Nt). The way of calculating it depends on the selected option in the transmitters global parameters (HSDPA part): CQI based on CPICH quality or CQI based on HS-PDSCH quality.

For dual-cell HSDPA users, **9955** determines the best HS-SCCH quality (HS-PDSCH Ec/Nt) for each serving cell (i.e., the anchor and the secondary cells).

For further details on the HS-PDSCH quality calculation, see either "HS-PDSCH Quality Calculation" on page 211 if the selected option is "CQI based on CPICH quality" or "HS-PDSCH Quality Calculation" on page 216 if the selected option is "CQI based on HS-PDSCH quality".

HS-SCCH Ec/Nt

9955 displays the obtained HS-SCCH quality. For dual-cell HSDPA users, it provides the HS-SCCH quality for each serving cell (i.e., the anchor and the secondary cells).

When the HS-SCCH power allocation strategy is dynamic, this parameter corresponds to the HS-SCCH Ec/Nt threshold defined for the selected mobility type.

When the HS-SCCH power allocation strategy is static, the HS-SCCH Ec/Nt is calculated from the fixed HS-SCCH power.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N_{tot}^{DL}(ic)} \text{ for the total noise option,}$$

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times P_{c_i}(ic)}{N_{tot}^{DL}(ic) - (1-F_{ortho}) \times (1-F_{MUD}^{term}) \times \rho_{BTS} \times P_{c_i}(ic)} \text{ for the without useful signal option.}$$

With

$$N_{tot}^{DL}(ic) = I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term}$$

$$I_{intra}^{DL}(ic) = \underset{txi}{P_{tot}^{DL}(ic)} + \rho_{BTS} \times (1-F_{MUD}^{term}) \times (1-F_{ortho}) \times \left(\underset{txi}{P_{tot}^{DL}(ic)} - \frac{P_{SCH}(ic)}{L_T}\right) - \rho_{BTS} \times \left(\underset{txi}{P_{tot}^{DL}(ic)} - \frac{P_{SCH}(ic)}{L_T}\right)$$

$$I_{extra}^{DL}(ic) = \sum_{txj, j \neq i} P_{tot}^{DL}(ic)$$

$$I_{inter-carrier}^{DL}(ic) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(ic_{adj})}{RF(ic, ic_{adj})}$$

ic_{adj} is a carrier adjacent to *ic*.

$RF(ic, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I_{inter-technology}^{DL}(ic)$ is the inter-technology interference at the receiver on *ic*.

$$I_{inter-technology}^{DL}(ic) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic}^{Tx, m}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP_{ic_i, ic}^{Tx, m}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic.

$$P_{c_i}(ic) = \frac{P_{HS-SCCH}(ic)}{L_{T_i}}$$

And

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}}$$

ρ_{BTS}, F_{ortho}, F_{MUD}^{term} and N_0^{term} are defined in "Inputs" on page 182.

CQI

It corresponds to the HS-PDSCH CQI. For dual-cell HSDPA users, **9955** determines the HS-PDSCH CQI for each serving cell (i.e., the anchor and the secondary cells).

The way of calculating it depends on the selected option in the transmitters global parameters (HSDPA part): CQI based on CPICH quality or CQI based on HS-PDSCH quality.

For further details on the HS-PDSCH quality calculation, see either "HS-PDSCH CQI Determination" on page 213 if the selected option is "CQI based on CPICH quality" or "HS-PDSCH CQI Determination" on page 219 if the selected option is "CQI based on HS-PDSCH quality".

RLC Peak Rate

Knowing the HS-PDSCH CQI, **9955** calculates the best HSDPA bearer that can be used and selects a bearer compatible with cell and terminal user equipment HSDPA capabilities. Once the bearer selected, **9955** determines the RLC peak rate that can be provided to the user $R^{DL}_{RLC-peak}$.

For dual-cell HSDPA users, **9955** determines the HSDPA bearers obtained in the two cells and displays the total data rate that can be provided.

$$R^{DL}_{RLC-peak} = \sum_{ic \in Txi} R^{DL}_{RLC-peak}(Txi, ic)$$

For further details on the HSDPA bearer selection, see "HSDPA Bearer Selection" on page 214.

Bearer Consumption

9955 provides this result for packet (HSPA - Constant Bit Rate) service users only. The minimum throughput demand required by the service is allocated to these users. Therefore, they partly consume the HSDPA bearer. The bearer consumption expressed in %, $C_{HSDPABearer}$, is calculated as follows:

$$C_{HSDPABearer} = \frac{R^{DL}_{Guaranteed}}{R^{DL}_{RLC-peak}(I_{HSDPABearer})}$$

4.5.1.1.3 Uplink Sub-Menu

The Uplink sub-menu may contain R99-related results and HSUPA-related results when an HSPA bearer user is modelled.

- **R99-related Results**

For each cell (*k,ic_{BS}*) in the receiver's active set, **9955** calculates uplink traffic channel quality from receiver. No power control is performed as in simulations. Here, **9955** determines the uplink traffic channel quality at the cell for the maximum terminal power allowed. Then, the total uplink traffic channel quality is evaluated with respect to the receiver handover status. From this value, **9955** calculates the terminal power required to obtain the R99 bearer and compares it to the maximum terminal power allowed.

Max Terminal Power

Max terminal power (P^{max}_{term}) is an input user-defined for each terminal. It corresponds to the terminal's maximum power.

Required Terminal Power

The calculation of the terminal power required to obtain an R99 bearer ($P^{req}_{term-R99}$) may be divided into three steps.

<u>1st step:</u> $Q^{UL}_{max}(k, ic_{BS})$ evaluation for each cell

For each cell (k, ic_{BS}) in the receiver's active set, we have:

$$Q^{UL}_{max}(k, ic_{BS}) = \frac{\rho_{term} \times P^{UL}_{b-max}(k, ic_{BS})}{N^{UL}_{tot}(k, ic_{BS})} \times G^{UL}_{p} \times G^{UL}_{Div}$$

With $P^{UL}_{b-max}(k, ic_{BS}) = \frac{P^{max}_{term} \times (1 - r^{UL}_{c})}{L_{T_k}}$

$N^{UL}_{tot}(k, ic_{BS})$ is the total noise at the transmitter on the best carrier of the best server. This value is calculated from the cell uplink load factor $X^{UL}(k, ic_{BS})$.

$$N^{UL}_{tot}(k, ic_{BS}) = \frac{N^{tx}_{0}}{1 - X^{UL}(k, ic_{BS})}$$

N_0^{tx} is the transmitter thermal noise.

2nd step: Calculation of the total traffic channel quality

$Q_{MAX}^{UL}(ic_{BS})$ is the traffic channel quality at the transmitter on ic_{BS} after signal combination of all the transmitters k of the active set.

If there is no handoff (1/1): $Q_{MAX}^{UL}(ic_{BS}) = Q_{max}^{UL}(k, ic_{BS})$

For soft handoff (2/2):

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times max(Q_{max}^{UL}(k, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{2\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

$max(Q_{max}^{UL}(k, ic_{BS}))$ corresponds to the highest $Q_{max}^{UL}(k, ic_{BS})$ value.

For soft-soft handoffs (3/3):

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{3\ links} \times max(Q_{max}^{UL}(k, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{3\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

For softer and softer-softer handoffs (1/2 and 1/3):

$$Q_{MAX}^{UL}(ic_{BS}) = f_{rake\ efficiency}^{UL} \times \sum_{k}(Q_{max}^{UL}(k, ic_{BS}))$$

For softer-soft handoffs (2/3), there are two possibilities. If the MRC option is selected (option available in Global parameters), we have:

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times max\left(f_{rake\ efficiency}^{UL} \times \sum_{k\ on\ the\ same\ site}(Q_{max}^{UL}(k, ic_{BS})), Q_{max_{k\ on\ the\ same\ site}}^{UL}(k, ic_{BS})\right)$$

Else,

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times max(Q_{max}^{UL}(k, ic_{BS}))$$

3rd step: $P_{term-R99}^{req}$ calculation

$P_{term-R99}^{req}$ is the required terminal power.

$$P_{term-R99}^{req} = \frac{Q_{req}^{UL}}{Q_{MAX}^{UL}(ic_{BS})} \times P_{term}^{max}$$

Q_{req}^{UL} is the uplink traffic quality target defined by the user for a given reception equipment, a given R99 bearer and a given mobility type. This parameter is available in the R99 Bearer Selection table.

Compressed mode is operated when a mobile supporting compressed mode is connected to a cell located on a site with a compressed-mode-capable equipment, and

- The received Ec/I0 is lower than the Ec/I0 activation threshold (Global parameters): $Q_{pilot}^{Resulting} \le Q_{pilot}^{CM-activation}$.
- The pilot RSCP is lower than the pilot RSCP activation threshold (Global parameters): $P_c \le RSCP_{pilot}^{CM-activation}$

When compressed mode is activated, the uplink Eb/Nt target is increased by the value user-defined for the UL Eb/Nt target increase field (Global parameters), ΔQ_{req}^{UL}. In this case, we have: $P_{term-R99}^{req} = \frac{Q_{req}^{UL} \times \Delta Q_{req}^{UL}}{Q_{MAX}^{UL}(ic_{BS})} \times P_{term}^{max}$

Therefore, the service on the uplink traffic channel is available if $P_{term-R99}^{req} \le P_{term}^{max}$.

Eb/Nt Max

For each cell (k, ic_{BS}) in the receiver's active set, we have:

$$Q_{max}^{UL}(k, ic_{BS}) = \frac{\rho_{term} \times P_{b-max}^{UL}(k, ic_{BS})}{N_{tot}^{UL}(k, ic_{BS})} \times G_p^{UL} \times G_{Div}^{UL}$$

With $P_{b-max}^{UL}(k, ic_{BS}) = \frac{P_{term}^{max} \times (1 - r_c^{UL})}{L_{T_k}}$

$N_{tot}^{UL}(k, ic_{BS})$ is the total noise at the transmitter on the best carrier of the best server. This value is calculated from the cell uplink load factor $X^{UL}(k, ic_{BS})$.

$$N_{tot}^{UL}(k, ic_{BS}) = \frac{N_0^{tx}}{1 - X^{UL}(k, ic_{BS})} + (1 - \rho_{term}) \times max(\frac{P_{term}^{max} - P_{term-R99}^{req}}{L_{T_k}}, 0)$$

N_0^{tx} is the transmitter thermal noise.

$Q_{MAX}^{UL}(ic_{BS})$ is the traffic channel quality at the transmitter on ic_{BS} after signal combination of all the transmitters k of the active set.

If there is no handoff (1/1): $Q_{MAX}^{UL}(ic_{BS}) = Q_{max}^{UL}(k, ic_{BS})$

For soft handoff (2/2):

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\,links} \times max(Q_{max}^{UL}(k, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{2\,links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

$max(Q_{max}^{UL}(k, ic_{BS}))$ corresponds to the highest $Q_{max}^{UL}(k, ic_{BS})$ value.

For soft-soft handoffs (3/3):

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{3\,links} \times max(Q_{max}^{UL}(k, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{3\,links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

For softer and softer-softer handoffs (1/2 and 1/3):

$$Q^{UL}_{MAX}(ic_{BS}) = f^{UL}_{rake\ efficiency} \times \sum_{k}(Q^{UL}_{max}(k, ic_{BS}))$$

For softer-soft handoffs (2/3), there are two possibilities. If the MRC option is selected (option available in Global parameters), we have:

$$Q^{UL}_{MAX}(ic_{BS}) = (G^{UL}_{macro-diversity})_{2\ links} \times max\left(f^{UL}_{rake\ efficiency} \times \sum_{k\ on\ the\ same\ site}(Q^{UL}_{max}(k, ic_{BS})), Q^{UL}_{max_{k\ on\ the\ same\ site}}(k, ic_{BS})\right)$$

Else,

$$Q^{UL}_{MAX}(ic_{BS}) = (G^{UL}_{macro-diversity})_{2\ links} \times max(Q^{UL}_{max}(k, ic_{BS}))$$

Effective Eb/Nt

Q^{UL}_{eff} is the effective traffic channel quality at the transmitter on ic_{BS}.

$Q^{UL}_{eff} = min(Q^{UL}_{MAX}, Q^{UL}_{req})$ (or $Q^{UL}_{eff} = min(Q^{UL}_{MAX}, Q^{UL}_{req} \times \Delta Q^{UL}_{req})$ when compressed mode is activated).

Uplink Soft Handover Gain

G^{UL}_{SHO} corresponds to the uplink soft handover gain.

$$G^{UL}_{SHO} = \frac{Q^{UL}_{MAX}(ic_{BS})}{max(Q^{UL}_{max}(k, ic_{BS}))}$$

$max(Q^{UL}_{max}(k, ic_{BS}))$ corresponds to the highest $Q^{UL}_{max}(k, ic_{BS})$ value.

- **HSUPA-related Results**

9955 determines the best HSUPA bearer that the user can obtain. The HSUPA bearer user is processed as if he is the only user in the cell i.e. he uses the entire remaining load of the cell.

For further information on the HSUPA bearer selection, see "HSUPA Bearer Allocation Process" on page 228.

Required E-DPDCH Ec/Nt

It corresponds to the E-DPDCH Ec/Nt required to obtain the HSUPA bearer ($\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH}$). This value is defined for an HSUPA bearer ($Index_{HSUPABearer}$) and a number of retransmissions (N_{Rtx}) in the HSUPA Bearer Selection table.

Required Terminal Power

From $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH}$, **9955** calculates the terminal power required to obtain the HSUPA bearer, $P^{req}_{term-HSUPA}$.

$$P^{req}_{term-HSUPA} = \left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH} \times L_T \times N^{UL}_{tot}$$

With

$$N^{UL}_{tot}(ic) = (1 - F^{tx}_{MUD} \times \rho_{term}) \times I^{UL_{intra}}_{tot}(ic) + I^{UL_{extra}}_{tot}(ic) + I^{UL}_{inter-carrier}(ic) + N^{tx}_{0}$$

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$$

ρ_{term}, F^{tx}_{MUD}, $I^{UL_{intra}}_{tot}$, $I^{UL_{extra}}_{tot}$, $I^{UL}_{inter-carrier}$ and N^{tx}_{0} are defined in "Inputs" on page 182.

RLC Peak Rate

9955 selects the best HSUPA bearer from the HSUPA compatible bearers. This is the HSUPA bearer with the highest potential throughput ($\frac{R^{UL}_{RLC-peak}(Index_{HSUPABearer})}{N_{Rtx}(Index_{HSUPABearer})}$) where:

- $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH} \le \left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}$
- And $P^{req}_{term-HSUPA} \le P^{max}_{term}$

With

$\left(\frac{Ec}{Nt}\right)^{max}_{E-DPDCH}$: the maximum E-DPDCH Ec⁄Nt allowed.

P^{max}_{term} : the maximum terminal power allowed.

After selecting the HSUPA bearer, **9955** determines the corresponding RLC peak rate, $R^{UL}_{RLC-peak}$.

Application Throughput

9955 displays the provided application throughput ($T^{UL}_{application}$). The application throughput represents the net throughput after deduction of coding (redundancy, overhead, addressing, etc.). This one is calculated as follows:

$$T^{UL}_{application}(M_b) = \frac{R^{UL}_{RLC-peak} \times (1 - BLER_{HSUPA}) \times SF_{Rate} - \Delta R}{N_{Rtx}}$$

Where:

$BLER_{HSUPA}$ is the residual BLER after N_{Rtx} retransmissions. It is read in the quality graph defined for the quartet “reception equipment-selected bearer-number of retransmissions-mobility” (HSUPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (E-DPDCH Ec/Nt). Knowing the E-DPDCH Ec/Nt, **9955** finds the corresponding BLER.

SF_{Rate} and ΔR respectively represent the scaling factor between the application throughput and the RLC (Radio Link Control) throughput and the throughput offset. These two parameters model the header information and other supplementary data that does not appear at the application level. They are defined in the service properties.

Bearer Consumption

9955 provides this result for packet (HSPA - Constant Bit Rate) service users only. The minimum bit rate required by the service is allocated to these users. Therefore, they parly consume the HSUPA bearer. The bearer consumption expressed in %, $C_{HSUPABearer}$, is calculated as follows:

$$C_{HSUPABearer} = \frac{R^{UL}_{Guaranteed}}{R^{UL}_{RLC-peak}(I_{HSUPABearer})}$$

4.5.2 Coverage Studies

Let us assume each pixel on the map corresponds to a probe receiver with a terminal, a mobility type and a service. This receiver does not create any interference. You can make the coverage prediction for a specific carrier or for the best carrier Coverage predictions are based on parameters that can be either simulation results, or user-defined cell inputs.

4.5.2.1 Pilot Quality Analysis

For further details of calculation formulas and methods, please refer to **Definitions and formulas** part, and **Point analysis – AS analysis tab – Pilot sub-menu** part.

We consider the following cases:

1st case: Analysis based on a specific carrier

The carrier that can be used by transmitters is fixed. In this case, for each transmitter *i* containing the receiver in its calculation area and using the selected carrier, **9955** calculates the pilot quality at the receiver on this carrier ic_{given}. Then, it determines the best serving transmitter *BS* using the carrier ic_{given} ($Q_{pilot_{BS}}(ic_{given})$) and calculates the best pilot quality received with a fixed cell edge coverage probability, $Q^{Resulting}_{pilot}(ic_{given})$.

9955 displays the best pilot quality received with a fixed cell edge coverage probability.

2nd case: Analysis based on the best carrier

9955 proceeds as in point predictions. It determines the best carrier of each transmitter *i* containing the receiver in its calculation area and using a frequency band supported by the receiver's terminal. The best carrier selection depends on the option selected for the site equipment (UL minimum noise, DL minimum power, random, sequential) and is based on the UL load percentage and the downlink total power of cells (simulation results or cell properties). **9955** calculates the pilot quality at the receiver from these transmitters on their best carriers and determines the best serving transmitter *BS* on its best carrier ic_{BS} ($Q_{pilot_{BS}}(ic_{BS})$). Then, it calculates the best pilot quality received with a fixed cell edge coverage probability, $Q_{pilot}^{Resulting}(ic_{BS})$.

9955 displays the best pilot quality received with a fixed cell edge coverage probability.

3rd case: Analysis based on the best carrier of any frequency band (for dual-band terminals with priority defined on frequency bands only)

The frequency band that can be used is fixed. **9955** determines the best carrier of each transmitter *i* containing the receiver in its calculation area and using the selected frequency band. The best carrier selection depends on the option selected for the site equipment (UL minimum noise, DL minimum power, random, sequential) and is based on the UL load percentage and the downlink total power of cells (simulation results or cell properties). Then, **9955** calculates the pilot quality at the receiver from these transmitters on their best carriers and determines the best serving transmitter *BS* on its best carrier ic_{BS} ($Q_{pilot_{BS}}(ic_{BS})$). Then, it calculates the best pilot quality received with a fixed cell edge coverage probability, $Q_{pilot}^{Resulting}(ic_{BS})$.

9955 displays the best pilot quality received with a fixed cell edge coverage probability.

4.5.2.1.1 Prediction Study Inputs

The Pilot Quality Analysis depends on the downlink total transmitted power of cells. This parameter can be either a simulation output, or a user-defined cell input. In the last case, when no value is defined in the Cells table for the total transmitted power, **9955** considers 50% of the maximum power as default value (i.e. 40 dBm if the maximum power is set to 43 dBm).

4.5.2.1.2 Study Display Options

Single colour

9955 displays a coverage if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$. Coverage consists of a single layer with a unique colour ($ic = ic_{BS}$ or ic_{given}). Q_{pilot}^{req} is a target value defined in the Mobility table by the user.

Colour per transmitter

9955 displays a coverage if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}). Coverage consists of several layers with associated colours. There is a layer per transmitter with no intersection between layers. Layer colour is the colour assigned to the best serving transmitter *BS*.

Colour per mobility

In this case, receiver is not completely defined and no mobility is assigned.

Coverage consists of several layers with a layer per user-defined mobility defined in Mobility sub-folder. For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

Colour per probability

This display option is available only if analysis is based on all simulations in a group (i.e. if you select a group of simulations and the "All" option in the Condition tab of prediction properties). Coverage consists of several layers with a layer per user-defined probability level defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}) in the required number of simulations. Each layer is assigned a colour and displayed with intersections between layers.

Colour per cell edge coverage probability

Coverage consists of several layers with a layer per user-defined cell edge coverage probability, *p*, defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic, p) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

Colour per quality level (Ec/I0)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq (Q_{pilot})_{threshold}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

Colour per quality margin (Ec/I0 margin)

Coverage consists of several layers with a layer per user-defined quality margin defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) - Q_{pilot}^{req} \geq (Q_{pilot})_{margin}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

Colour per pilot signal level (Ec)

Coverage consists of several layers with a layer per user-defined pilot signal level defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq (Q_{pilot})_{threshold}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

4.5.2.2 Downlink Service Area Analysis

As in point predictions, **9955** calculates traffic channel quality at the receiver for each cell *(k,ic)* (with $ic=ic_{BS}$ or ic_{given}) in the receiver's active set. No power control is performed as in simulations. Here, **9955** determines downlink traffic channel quality at the receiver for a maximum allowed traffic channel power for transmitters. Then, the total downlink traffic channel quality ($Q_{MAX}^{DL}(ic)$) is evaluated after recombination.

> Best server and active set determination is performed as in point prediction (AS analysis).

9955 displays traffic channel quality at the receiver for transmitters in active set on the carrier *ic* (ic_{BS} or ic_{given}).

For further details of calculation formulas and methods, see "Downlink Sub-Menu" on page 256.

4.5.2.2.1 Prediction Study Inputs

The Downlink Service Area Analysis depends on the downlink total transmitted power of cells. This parameter can be either a simulation output, or a user-defined cell input. In the last case, when no value is defined in the Cells table for the total transmitted power, **9955** considers 50% of the maximum power as default value (i.e. 40 dBm if the maximum power is set to 43 dBm).

4.5.2.2.2 Study Display Options

Single colour

9955 displays a coverage with a unique colour if $Q_{MAX}^{DL}(ic) \geq Q_{req}^{DL}$ (or $Q_{MAX}^{DL}(ic) \geq Q_{req}^{DL} \times \Delta Q_{req}^{DL}$ if compressed mode is activated).

Q_{req}^{DL} is the downlink traffic quality target defined by the user for a given reception equipment, a given R99 bearer and a given mobility type. This parameter is available in the R99 Bearer Selection table.

ΔQ_{req}^{DL} is the DL Eb/Nt target increase; this parameter is user-defined in the Global parameters.

Colour per transmitter

9955 displays a coverage if $Q_{MAX}^{DL}(ic) \geq Q_{req}^{DL}$ (or $Q_{MAX}^{DL}(ic) \geq Q_{req}^{DL} \times \Delta Q_{req}^{DL}$ if compressed mode is activated). Coverage consists of several layers with associated colours. There is a layer per transmitter with no intersection between layers. Layer colour is the colour assigned to best serving transmitter.

Colour per mobility

In this case, receiver is not completely defined and no mobility is assigned. Coverage consists of several layers with a layer per user-defined mobility defined in Mobility sub-folder. For each layer, area is covered if $Q_{MAX}^{DL}(ic) \geq Q_{req}^{DL}$ (or

$Q^{DL}_{MAX}(ic) \geq Q^{DL}_{req} \times \Delta Q^{DL}_{req}$ if compressed mode is activated). Each layer is assigned a colour and displayed with intersections between layers.

Colour per service

In this case, receiver is not completely defined and no service is assigned. Coverage consists of several layers with a layer per user-defined service defined in Services sub-folder. For each layer, area is covered if $Q^{DL}_{MAX}(ic) \geq Q^{DL}_{req}$ (or $Q^{DL}_{MAX}(ic) \geq Q^{DL}_{req} \times \Delta Q^{DL}_{req}$ if compressed mode is activated). Each layer is assigned a colour and displayed with intersections between layers.

Colour per probability

This display option is available only if analysis is based on all simulations in a group (i.e. if you select a group of simulations and the "All" option in the Condition tab of prediction properties). Coverage consists of several layers with a layer per user-defined probability level defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{DL}_{MAX}(ic) \geq Q^{DL}_{req}$ in the required number of simulations. Each layer is assigned a colour and displayed with intersections between layers.

Colour per cell edge coverage probability

Coverage consists of several layers with a layer per user-defined cell edge coverage probability, *p*, defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{DL}_{MAX}(ic, p) \geq Q^{DL}_{req}$ (or $Q^{DL}_{MAX}(ic) \geq Q^{DL}_{req} \times \Delta Q^{DL}_{req}$ if compressed mode is activated). Each layer is assigned a colour and displayed with intersections between layers.

Colour per maximum quality level (max Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{DL}_{MAX}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per effective quality level (Effective Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{DL}_{eff}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers. $Q^{DL}_{eff}(ic) = min(Q^{DL}_{MAX}(ic), Q^{DL}_{req})$ (or $Q^{DL}_{eff}(ic) = min(Q^{DL}_{MAX}(ic), Q^{DL}_{req} \times \Delta Q^{DL}_{req})$ when compressed mode is activated).

Colour per quality margin (Eb/Nt margin)

Coverage consists of several layers with a layer per user-defined quality margin defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{DL}_{MAX}(ic) - Q^{DL}_{req} \geq Margin$ (or $Q^{DL}_{MAX}(ic) - Q^{DL}_{req} \times \Delta Q^{DL}_{req} \geq Margin$ when compressed mode is activated). Each layer is assigned a colour and displayed with intersections between layers.

Colour per required power

9955 calculates the downlink required power, $P^{req}_{tch}(ic)$, as follows:

$$P^{req}_{tch}(ic) = \frac{Q^{DL}_{req}}{Q^{DL}_{MAX}(ic)} \times P^{max}_{tch}$$

Where

Q^{DL}_{req} is the Eb/Nt target on downlink. This parameter, available in the R99 Bearer Selection table, is user-defined for a given R99 bearer, a given reception equipment and a mobility type.

P^{max}_{tch} is a user-defined input for each bearer related to a service. It corresponds to the maximum allowable traffic channel power for a transmitter.

When compressed mode is activated, we have: $P^{req}_{tch}(ic) = \frac{Q^{DL}_{req} \times \Delta Q^{DL}_{req}}{Q^{DL}_{MAX}(ic)} \times P^{max}_{tch}$.

Coverage consists of several layers with a layer per user-defined required power threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{tch}^{req}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per required power margin

Coverage consists of several layers with a layer per user-defined power margin defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{tch}^{req}(ic) - P_{tch}^{max} \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

4.5.2.3 Uplink Service Area Analysis

As in point prediction, **9955** calculates uplink traffic channel quality from receiver for each cell *(k,ic)* (with *ic=*ic_{BS} *or* ic_{given}) in receiver active set. No power control simulation is performed. **9955** determines uplink traffic channel quality at the transmitter for the maximum terminal power allowed. Then, the total uplink traffic channel quality ($Q_{MAX}^{UL}(ic)$) is evaluated with respect to receiver handover status.

> Best server and active set determination is performed as in point prediction (AS analysis).

9955 displays traffic channel quality at transmitters in active set on the carrier *ic* (ic_{BS} or ic_{given}) received from the receiver.

For further details of calculations formulas and methods, see "Uplink Sub-Menu" on page 261.

4.5.2.3.1 Prediction Study Inputs

The Uplink Service Area Analysis depends on the UL load factor of cells. This parameter can be either a simulation output, or a user-defined cell input. In the last case, when no value is defined in the Cells table for the uplink load factor, **9955** uses 50% as default value.

4.5.2.3.2 Study Display Options

Single colour

9955 displays a coverage if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$ (or $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL} \times \Delta Q_{req}^{UL}$ if compressed mode is activated). Coverage colour is unique.

Q_{req}^{UL} is defined for a reception equipment, a R99 bearer and a mobility type. This parameter is available in the R99 Bearer Selection table.

ΔQ_{req}^{UL} is the UL Eb/Nt target increase; this parameter is user-defined in the Global parameters.

Colour per transmitter

9955 displays a coverage if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$ (or $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL} \times \Delta Q_{req}^{UL}$ if compressed mode is activated). Coverage consists of several layers with associated colours. There is a layer per transmitter with no intersection between layers. Layer colour is the colour assigned to best server transmitter.

Colour per mobility

In this case, receiver is not completely defined and no mobility is assigned. Coverage consists of several layers with a layer per user-defined mobility defined in Mobility sub-folder. For each layer, area is covered if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$ (or $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL} \times \Delta Q_{req}^{UL}$ if compressed mode is activated). Each layer is assigned a colour and displayed with intersections between layers.

Colour per service

In this case, receiver is not completely defined and no service is assigned. Coverage consists of several layers with a layer per user-defined service defined in Services sub-folder. For each layer, area is covered if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$ (or

$Q^{UL}_{MAX}(ic) \geq Q^{UL}_{req} \times \Delta Q^{UL}_{req}$ if compressed mode is activated). Each layer is assigned a colour and displayed with intersections between layers.

Colour per probability

This display option is available only if analysis is based on all simulations in a group (i.e. if you select a group of simulations and the "All" option in the Condition tab of prediction properties). Coverage consists of several layers with a layer per user-defined probability level defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{UL}_{MAX}(ic) \geq Q^{UL}_{req}$ (or $Q^{UL}_{MAX}(ic) \geq Q^{UL}_{req} \times \Delta Q^{UL}_{req}$ if compressed mode is activated) in the required number of simulations. Each layer is assigned a colour and displayed with intersections between layers.

Colour per maximum quality level (Max Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{UL}_{MAX}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per effective quality level (Effective Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{UL}_{effective}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

$Q^{UL}_{eff}(ic) = min(Q^{UL}_{MAX}(ic), Q^{UL}_{req})$ (or $Q^{UL}_{eff}(ic) = min(Q^{UL}_{MAX}(ic), Q^{UL}_{req} \times \Delta Q^{UL}_{req})$ when compressed mode is activated).

Colour per quality margin (Eb/Nt margin)

Coverage consists of several layers with a layer per user-defined quality margin defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{UL}_{MAX}(ic) - Q^{UL}_{req} \geq Margin$ (or $Q^{UL}_{MAX}(ic) - Q^{UL}_{req} \times \Delta Q^{UL}_{req} \geq Margin$ if compressed mode is activated). Each layer is assigned a colour and displayed with intersections between layers.

Colour per required power

Coverage consists of several layers with a layer per user-defined power threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $P^{req}_{term-R99}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per required power margin

Coverage consists of several layers with a layer per user-defined power margin defined in the Display tab (Prediction properties). For each layer, area is covered if $P^{req}_{term-R99}(ic) - P^{max}_{term} \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per soft handover gain

Coverage consists of several layers with a layer per soft handover gain value defined in the Display tab (Prediction properties). For each layer, area is covered if $G^{UL}_{SHO} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

4.5.2.4 Downlink Total Noise Analysis

9955 determines the downlink total noise generated by cells.

$$N^{DL}_{tot}(ic) = \sum_{txj, \forall j} P^{DL}_{tot}(ic) + \frac{\sum_{txj, \forall j} P^{DL}_{tot}(ic_{adj})}{RF(ic, ic_{adj})} + \sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic}} + N^{term}_0$$

Downlink noise rise, $NR_{DL}(ic)$, is calculated from the downlink total noise, N^{DL}_{tot}, as follows:

$$NR_{DL}(ic) = -10log\left(\frac{N_0^{term}}{N_{tot}^{DL}}\right)$$

4.5.2.4.1 Study Inputs

The Downlink Total Noise Analysis depends on the downlink total transmitted power of cells. This parameter can be either a simulation output, or a user-defined cell input. In the last case, when no value is defined in the Cells table for the total transmitted power, **9955** considers 50% of the maximum power as default value (i.e. 40 dBm if the maximum power is set to 43 dBm).

4.5.2.4.2 Analysis on the Best Carrier

If the best carrier is selected, **9955** determines DL total noise for the best carrier. Then, allows the user to choose different colours.

Colour per minimum noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $\min_{ic} N_{tot}^{DL}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per maximum noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $\max_{ic} N_{tot}^{DL}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per average noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $\underset{ic}{average} N_{tot}^{DL}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per minimum noise rise

9955 displays bins where $\min_{ic} NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

Colour per maximum noise rise

9955 displays bins where $\max_{ic} NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

Colour per average noise rise

9955 displays bins where $\underset{ic}{average} NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

4.5.2.4.3 Analysis on a Specific Carrier

When only one carrier is analysed, **9955** determines DL total noise or DL noise rise on this carrier. In this case, the displayed coverage is the same for any selected display per noise level (average, minimum, maximum) or any display per noise rise (average, minimum, maximum).

Colour per noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $N_{tot}^{DL}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per noise rise

9955 displays bins where $NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

4.5.2.5 HSDPA Prediction Study

When calculating the HSDPA coverage prediction, either you can take all the possible HSDPA radio bearers into consideration, or you can study a certain HSDPA radio bearer. Then, available display options depend on what you have selected.

When considering all the HSDPA radio bearers, you can set display parameters:

- To analyse the uplink and downlink A-DPCH qualities on the map,
- To analyse the HS-SCCH quality/power,
- To model fast link adaptation for a single HSDPA bearer user or for a defined number of HSDPA bearer users.

When studying a certain HSDPA radio bearer, you can display areas where a certain RLC peak rate is available with different cell edge coverage probabilities (i.e. the probability of having a certain RLC peak rate). This type of analysis is not relevant when modelling a dual-cell HSDPA user.

Let us assume each pixel on the map corresponds to one or several users with HSDPA capable terminal, mobility and HSDPA service.The user does not create any interference. Each user may be using a specific carrier or the best carrier. If you are modelling a dual-cell HSDPA user, you have to make the analysis on the best carriers. In this case, **9955** determines the best and the secondary carriers of dual-cell HSDPA transmitters according to the carrier selection criterion defined in the site equipment.

Note that the HSDPA service area is limited by the pilot quality, the A-DPCH quality and the HS-SCCH quality.

4.5.2.5.1 Prediction Study Inputs

Parameters used as input for the HSDPA prediction study are:

- The available HSDPA power of the cell,
- The downlink total transmitted power of the cell,
- The number of HSDPA users within the cell if the study is calculated for several users.

These parameters can be either simulation outputs, or user-defined cell inputs. In the last case, when no value is defined in the Cells table for the total transmitted power and the number of HSDPA users, **9955** uses the following default values:

- Total transmitted power = 50% of the maximum power (i.e, 40 dBm if the maximum power is set to 43 dBm)
- Number of HSDPA users = 1

On the other hand, no default value is used for the available HSDPA power; this parameter must be defined by the user.

4.5.2.5.2 Study Display Options

When considering all the HSDPA radio bearers, several display options are available in the study properties dialogue. They can be regrouped in four categories according to the objective of the study:

- To analyse the uplink and downlink A-DPCH qualities on the map,
- To analyse the HS-SCCH quality/power,
- To model fast link adaptation for a single HSDPA bearer user,
- To model fast link adaptation for a defined number of HSDPA bearer users.

When studying a certain HSDPA radio bearer, only one display option is available. It allows you to display where a certain RLC peak rate is available with different cell edge coverage probabilities.

Analysis of UL And DL A-DPCH Qualities

- Colour per Max A-DPCH Eb/Nt DL

9955 displays the A-DPCH quality at the receiver ($Q_{MAX}^{DL}(ic)$) for the best server on the carrier *ic* (ic_{BS} or ic_{given}). No power control is performed as in simulations. Here, **9955** determines downlink traffic channel quality at the receiver for a maximum traffic channel power allowed for the best server.

For further details of calculation formulas and methods, please refer to Prediction studies: Point analysis – AS analysis tab – Downlink sub-menu part.

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{MAX}^{DL}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per Max A-DPCH Eb/Nt UL

9955 displays the A-DPCH quality at the best server ($Q^{UL}_{MAX}(ic)$) on the carrier *ic* (ic_{BS} or ic_{given}). No power control is performed as in simulations. Here, **9955** determines uplink traffic channel quality at the receiver for a maximum terminal power allowed.

For further details of calculations formulas and methods, please refer to Point analysis – AS analysis tab – Uplink sub-menu part.

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q^{UL}_{MAX}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Analysis of The HS-SCCH Quality/Power

- Colour per HS-SCCH Power

This display option is relevant in case of dynamic HS-SCCH power allocation only. In this case, **9955** displays on each pixel the HS-SCCH power per HS-SCCH channel. Coverage consists of several layers with a layer per threshold. For each layer, area is covered if $P_{HS-SCCH}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per HS-SCCH Ec/Nt

This display option is relevant in case of static HS-SCCH power allocation only. In this case, **9955** displays on each pixel the HS-SCCH quality per HS-SCCH channel. Coverage consists of several layers with a layer per threshold. For each layer, area is covered if $\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Fast Link Adaptation Modelling For A Single User

When you calculate the study with the following display options, **9955** considers one user on each pixel and determines the best HSDPA bearer that the user can obtain. For dual-cell HSDPA users, **9955** determines the best HSDPA bearers that the user can obtain in the two cells. On each pixel, the user is processed as if he is the only user in the cell i.e. he uses the entire HSDPA power available in the cell.

For further information on the fast link adaptation modelling, see "Fast Link Adaptation Modelling" on page 209.

- Colour per HS-PDSCH Ec/Nt

9955 displays on each pixel the HS-PDSCH quality. For a dual-cell HSDPA user, it corresponds to the HS-PDSCH Ec/Nt of the best serving cell. Coverage consists of several layers with a layer per threshold. For each layer, area is covered if $\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per CQI

9955 displays either the CPICH CQI (see the calculation detail in "CPICH CQI Determination" on page 211) when the selected option in Global parameters (HSDPA part) is CQI based on CPICH quality, or the HS-PDSCH CQI (see the calculation detail in the section 10.7.1.2.2) when considering the CQI based on HS-PDSCH quality option.

For a dual-cell HSDPA user, it corresponds to the CQI of the best serving cell.

Coverage consists of several layers with a layer per CQI threshold ($(CQI)_{threshold}$). For each layer, area is covered if $CQI \geq (CQI)_{threshold}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per MAC Rate

9955 displays the MAC rate (R^{DL}_{MAC}) provided on each pixel. The MAC rate is calculated as follows:

$$R^{DL}_{MAC} = \sum_{c \in Serving\ cells} \frac{S_{block}(c)}{T_{TTI}}$$

Where,

$S_{block}(c)$ is the transport block size (in kbits) of the HSDPA bearer selected in the cell, *c*, for the user; it is defined for each HSDPA bearer in the HSDPA Radio Bearers table.

T_{TTI} is the TTI duration, i.e. $2 \times 10^{-3} s$ (2000 TTI in one second). This value is specified by the 3GPP.

Coverage consists of several layers with a layer per possible MAC rate (R^{DL}_{MAC}). For each layer, area is covered if the MAC rate exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per MAC Throughput

9955 displays the MAC throughput (T_{MAC}^{DL}) provided on each pixel. The MAC throughput is calculated as follows:

$$T_{MAC}^{DL} = \sum_{c \in \text{Serving cells}} \frac{S_{block}(c)}{T_{TTI} \times \Delta TTI}$$

Where,

$S_{block}(c)$ is the transport block size (in kbits) of the selected HSDPA bearer in the cell, *c*; it is defined for each HSDPA bearer in the HSDPA Radio Bearers table.

ΔTTI is the minimum number of TTI (Transmission Time Interval) between two TTI used; it is defined in the terminal user equipment category properties.

T_{TTI} is the TTI duration, i.e. $2 \times 10^{-3} s$ (2000 TTI in one second). This value is specified by the 3GPP.

Coverage consists of several layers with a layer per possible MAC throughput (T_{MAC}^{DL}). For each layer, area is covered if the MAC throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per RLC Peak Rate

After selecting the bearer (two bearers can be selected in case of dual-cell HSDPA), **9955** reads the corresponding RLC peak rate ($R_{RLC-peak}^{DL}(I_{HSDPABearer})$). This is the highest rate that the bearer can provide on each pixel. Then, it determines the RLC peak rate provided by the serving cell, *c*, in the downlink, $R_{RLC-peak}^{DL}(c)$.

For a single-carrier HSDPA user,we have: $R_{RLC-peak}^{DL} = R_{RLC-peak}^{DL}(c)$

For dual-cell HSDPA users, the RLC peak rate provided to the user is calculated as follows:

$$R_{RLC-peak}^{DL} = \sum_{c \in \text{Serving cell}} R_{RLC-peak}^{DL}(c)$$

Coverage consists of several layers with a layer per possible RLC peak rate ($R_{RLC-peak}^{DL}$). For each layer, area is covered if the RLC peak rate can be provided. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per RLC Peak Throughput

9955 displays the RLC peak throughput ($T_{RLC-peak}^{DL}$) provided on each pixel. The RLC peak throughput is calculated as follows:

$$T_{RLC-peak}^{DL} = \frac{R_{RLC-peak}^{DL}}{\Delta TTI}$$

Where ΔTTI is the minimum number of TTI (Transmission Time Interval) between two TTI used; it is defined in the terminal user equipment category properties.

Coverage consists of several layers with a layer per possible RLC peak throughput ($T_{RLC-peak}^{DL}$). For each layer, area is covered if the RLC peak throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per Average RLC Throughput

9955 displays the average RLC throughput (T_{RLC-Av}^{DL}) provided on each pixel.

For a single-carrier HSDPA user, we have:

$$T_{RLC-Av}^{DL} = \frac{R_{RLC-peak}^{DL}(c) \times (1 - BLER_{HSDPA})}{\Delta TTI}$$

For a dual-cell HSDPA user, we have:

$$T_{RLC-Av}^{DL} = \frac{\sum_{c \in \text{Serving cells}} (R_{RLC-peak}^{DL}(c) \times (1 - BLER_{HSDPA}))}{\Delta TTI}$$

Where,

$BLER_{HSDPA}$ is read in the quality graph defined for the triplet “reception equipment-selected bearer-mobility” (HSDPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (HS-PDSCH Ec/Nt). Knowing the HS-PDSCH Ec/Nt, **9955** finds the corresponding BLER.

ΔTTI is the minimum number of TTI (Transmission Time Interval) between two TTI used; it is defined in the terminal user equipment category properties.

Coverage consists of several layers with a layer per possible average RLC throughput (T^{DL}_{RLC-Av}). For each layer, area is covered if the average RLC throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per Application Throughput

9955 displays the application throughput ($T^{DL}_{application}$) provided on each pixel. The application throughput represents the net throughput after deduction of coding (redundancy, overhead, addressing, etc.).

It is calculated as follows:

$$T^{DL}_{application} = T^{DL}_{RLC-Av} \times SF_{Rate} - \Delta R$$

Where:

T^{DL}_{RLC-Av} is the average RLC throughput.

$BLER_{HSDPA}$ is read in the quality graph defined for the triplet “reception equipment-selected bearer-mobility” (HSDPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (HS-PDSCH Ec/Nt). Knowing the HS-PDSCH Ec/Nt, **9955** finds the corresponding BLER.

SF_{Rate} and ΔR respectively represent the scaling factor between the application throughput and the RLC (Radio Link Control) throughput and the throughput offset. These two parameters model the header information and other supplementary data that does not appear at the application level. They are defined in the service properties.

ΔTTI is the minimum number of TTI (Transmission Time Interval) between two TTI used; it is defined in the terminal user equipment category properties.

Coverage consists of several layers with a layer per possible application throughput ($T^{DL}_{application}$). For each layer, area is covered if the application throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

Fast Link Adaptation Modelling For Several Users

When you calculate the study with the following display options, **9955** considers several users per pixel and determines the best HSDPA bearer that each user can obtain. In this case, the cell available HSDPA power is shared between HSDPA bearer users. When the coverage prediction is not based on a simulation, the number of HSDPA bearer users is taken from the cell properties. The displayed results of the coverage prediction will be an average result for one user.

For further information on the HSDPA bearer allocation process when there are several users, see "HSDPA Bearer Allocation Process" on page 206 For further information on the fast link adaptation modelling, see "Fast Link Adaptation Modelling" on page 209.

- Colour per MAC Throughput Per Mobile

9955 displays the average MAC throughput per mobile ($(T^{DL}_{MAC})_{average}$) provided on each pixel. The average MAC throughput per mobile is calculated as follows:

$$(T^{DL}_{MAC})_{average} = \frac{\sum_{x=1}^{n_{HSDPA}} T^{DL}_{MAC}(x)}{\underset{c \in Serving\ cells(x)}{Max}(n_{HSDPA}(c))}$$

Where,

$Serving\ cells(x)$ represents the set of serving cells for a user x. For a dual-cell HSDPA user, there are two serving cells.

$n_{HSDPA}(c)$ is the number of HSDPA users within the cell, *c*.

$T^{DL}_{MAC}(x)$ is the MAC throughput of each HSDPA bearer user. For further information on the calculation of the MAC throughput, see "Colour per MAC Throughput" on page 273.

Coverage consists of several layers with a layer per possible average MAC throughput per mobile ($(T^{DL}_{MAC})_{average}$). For each layer, area is covered if the average MAC throughput per mobile exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per RLC Throughput Per Mobile

9955 displays the average RLC throughput per mobile ($(T^{DL}_{RLC})_{average}$) provided on each pixel. The average RLC throughput per mobile is calculated as follows:

$$(T^{DL}_{RLC})_{average} = \frac{\sum_{x=1}^{n_{HSDPA}} T^{DL}_{RLC-peak}(x)}{n_{HSDPA}}$$

Where,

n_{HSDPA} is the number of HSDPA users within the cell.

$T^{DL}_{RLC-peak}(x)$ is the RLC peak throughput of each HSDPA bearer user. For further information on the calculation of the RLC peak throughput, see "Colour per RLC Peak Throughput" on page 274.

Coverage consists of several layers with a layer per possible average RLC throughput per mobile ($(T^{DL}_{RLC})_{average}$). For each layer, area is covered if the average RLC throughput per mobile exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per ApplicationThroughput Per Mobile

9955 displays the average application throughput per mobile ($(T^{DL}_{application})_{average}$) provided on each pixel. The average application throughput per mobile is calculated as follows:

$$(T^{DL}_{application})_{average} = \frac{\sum_{x=1}^{n_{HSDPA}} T^{DL}_{application}(x)}{n_{HSDPA}}$$

Where,

n_{HSDPA} is the number of HSDPA users within the cell.

$T^{DL}_{application}(x)$ is the application throughput of each HSDPA bearer user. For further information on the calculation of the application throughput, see "Colour per Application Throughput" on page 275.

Coverage consists of several layers with a layer per possible average application throughput per mobile ($(T^{DL}_{application})_{average}$). For each layer, area is covered if the average application throughput per mobile exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

Probability of Having a Certain RLC Peak Rate

This result can be obtained only if you have selected an HSDPA radio bearer in the Condition tab.

- Colour per Cell Edge Coverage Probability

9955 shows areas where the selected HSDPA radio bearer is available with different cell edge coverage probabilities. Coverage consists of several layers with a layer per cell edge coverage probability defined in the Display tab. For each layer, area is covered if the selected HSDPA radio bearer is available. Each layer is assigned a colour and displayed with intersections between layers.

4.5.2.6 HSUPA Prediction Study

A dedicated HSUPA study is available with different calculation and display options. **9955** determines on each pixel the best HSUPA bearer that can be obtained; it can consider either a single HSUPA bearer user or several ones on each pixel. For further information on the HSUPA bearer selection, see "HSUPA Bearer Allocation Process" on page 228. By caclulating this study with suitable display options, it is possible:

- To analyse the power required by the selected terminal,
- To analyse the required E-DPDCH quality,
- To analyse rates and throughputs.

Let us assume each pixel on the map corresponds to one or several users with HSUPA capable terminal, mobility and HSUPA service. Each user may be using a specific carrier or the best carrier. Moreover, he does not create any interference.

Note that the HSUPA service area is limited by the pilot quality and the A-DPCH-EDPCCH quality.

4.5.2.6.1 Prediction Study Inputs

Parameters used as input for the HSUPA prediction study are:

- The cell UL load factor,
- The cell UL reuse factor,
- The cell UL load factor due to HSUPA,
- The maximum cell UL load factor,
- The number of HSUPA users within the cell if the study is calculated for several users.

These parameters can be either simulation outputs, or user-defined cell inputs. In the last case, When no value is defined in the Cells table, **9955** uses the following default values:

- Uplink load factor = 50%
- Uplink reuse factor = 1
- Uplink load factor due to HSUPA = 0%
- Maximum uplink load factor = 75%
- Number of HSUPA users = 1

4.5.2.6.2 Calculation Options

9955 can calculate the HSUPA coverage prediction in one of two ways:

- **HSUPA resources can be dedictated to a single user**: On each pixel, the user is processed as if he is the only user in the cell i.e he will use the entire remaining load after allocating capacity to all R99 users.
- **HSUPA resources can be shared by HSUPA users defined or calculated per cell: 9955** considers several HSUPA bearer users per pixel. After allocating capacity to all R99 users, the remaining load of the cell will be shared equally between all the HSUPA bearer users. When the coverage prediction is not based on a simulation, the number of HSUPA users is taken from the cell properties. The displayed results of the coverage prediction will be an average result for one user.

4.5.2.6.3 Display Options

The following display options are available in the prediction property dialogue.

Colour per Required E-DPDCH Ec/Nt

9955 displays on each pixel the E-DPDCH Ec/Nt required to obtain the selected HSUPA bearer. Coverage consists of several layers with a layer per threshold. For each layer, area is covered if $\left(\frac{Ec}{Nt}\right)^{req}_{E-DPDCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per Required Terminal Power

9955 displays on each pixel the terminal power required to obtain the selected HSUPA bearer. The required terminal power is calculated from the required E-DPDCH Ec/Nt. Coverage consists of several layers with a layer per threshold. For each layer, area is covered if $P^{req}_{term} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

Colour per MAC Rate

9955 displays the MAC rate (R^{UL}_{MAC}) provided on each pixel. The MAC rate is calculated as follows:

$$R^{UL}_{MAC} = \frac{S^{UL}_{block}}{T_{TTI}}$$

Where,

S^{UL}_{block} is the transport block size (in kbits) for the selected HSUPA bearer; it is defined for each HSUPA bearer in the HSUPA Radio Bearers table.

T_{TTI} is the duration of one TTI for the selected HSUPA bearer; it is defined for each HSUPA bearer in the HSUPA Radio Bearers table.

Coverage consists of several layers with a layer per possible MAC rate (R^{UL}_{MAC}). For each layer, area is covered if the MAC rate exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

Colour per RLC Peak Rate

After selecting the HSUPA bearer, **9955** reads the corresponding RLC peak rate. This is the highest rate that the selected HSUPA bearer can provide on each pixel.

Coverage consists of several layers with a layer per possible RLC peak rate ($R^{UL}_{RLC-peak}$). For each layer, area is covered if the RLC peak rate can be provided. Each layer is assigned a colour and displayed with intersections between layers.

Colour per Minimum RLC Throughput

9955 displays the minimum RLC throughput ($T^{UL}_{RLC-Min}$) provided on each pixel. The minimum RLC throughput corresponds to the RLC throughput obtained for a given BLER and the maximum number of retransmissions. It is calculated as follows:

$$T^{UL}_{RLC-Min} = \frac{R^{UL}_{RLC-peak} \times (1 - BLER_{HSUPA})}{N_{Rtx}}$$

Where,

$BLER_{HSUPA}$ is the residual BLER for the selected uplink transmission format (HSUPA bearer with N_{Rtx} retransmissions). It is read in the quality graph defined for the quartet “reception equipment-selected bearer-number of retransmissions-mobility” (HSUPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (E-DPDCH Ec/Nt). Knowing the E-DPDCH Ec/Nt, **9955** finds the corresponding BLER.

N_{Rtx} is the maximum number of retransmissions for the selected HSUPA bearer. This figure is read in the HSUPA Bearer Selection table.

Coverage consists of several layers with a layer per possible minimum RLC throughput ($T^{DL}_{RLC-Min}$). For each layer, area is covered if the minimum RLC throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

Colour per Average RLC Throughput

When HARQ (Hybrid Automatic Repeat Request) is used, the required average number of retransmissions is smaller and the RLC throughput is an average RLC throughput (T^{UL}_{RLC-Av}). This is the RLC throughput obtained for a given BLER and the average number of retransmissions. It is calculated as follows:

$$T^{UL}_{RLC-Av} = \frac{R^{UL}_{RLC-peak} \times (1 - BLER_{HSUPA})}{(N_{Rtx})_{av}}$$

$BLER_{HSUPA}$ is the residual BLER for the selected uplink transmission format (HSUPA bearer with N_{Rtx} retransmissions). It is read in the quality graph defined for the quartet “reception equipment-selected bearer-number of retransmissions-mobility” (HSUPA Quality Graphs tab in the Reception equipment properties). This graph describes the variation of BLER as a function of the measured quality (E-DPDCH Ec/Nt). Knowing the E-DPDCH Ec/Nt, **9955** finds the corresponding BLER.

The average number of retransmissions ($(N_{Rtx})_{av}$) is determined from early termination probabilities defined for the selected HSUPA bearer (in the HSUPA Bearer Selection table). The Early Termination Probability graph shows the probability of early termination (p) as a function of the number of retransmissions (N_{Rtx}). **9955** calculates the average number of retransmissions ($(N_{Rtx})_{av}$) as follows:

$$(N_{Rtx})_{av} = \frac{\sum_{N_{Rtx} = 1}^{(N_{Rtx})_{max}} (p(N_{Rtx}) - p(N_{Rtx} - 1)) \times N_{Rtx}}{p((N_{Rtx})_{max})}$$

Coverage consists of several layers with a layer per possible average RLC throughput (T^{DL}_{RLC-Av}). For each layer, area is covered if the minimum RLC throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

Colour per Application Throughput

9955 displays the application throughput ($T^{UL}_{application}$) provided on each pixel. The application throughput represents the net throughput after deduction of coding (redundancy, overhead, addressing, etc.). This one is calculated as follows:

$$T_{application}^{UL}(M_b) = T_{RLC-Min}^{UL} \times SF_{Rate} - \Delta R$$

Where:

SF_{Rate} and ΔR respectively represent the scaling factor between the application throughput and the minimum RLC (Radio Link Control) throughput and the throughput offset. These two parameters model the header information and other supplementary data that does not appear at the application level. They are defined in the service properties.

Coverage consists of several layers with a layer per possible application throughput ($T_{application}^{UL}$). For each layer, area is covered if the application throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

Colour per Average Application Throughput

9955 displays the average application throughput ($T_{application-Av}^{UL}$) provided on each pixel. It is calculated as follows:

$$T_{application-Av}^{UL}(M_b) = T_{RLC-Av}^{UL} \times SF_{Rate} - \Delta R$$

Where:

SF_{Rate} and ΔR respectively represent the scaling factor between the average application throughput and the average RLC (Radio Link Control) throughput and the throughput offset. These two parameters model the header information and other supplementary data that does not appear at the application level. They are defined in the service properties.

Coverage consists of several layers with a layer per possible average application throughput ($T_{application-Av}^{UL}$). For each layer, area is covered if the average application throughput exceeds the user-defined thresholds. Each layer is assigned a colour and displayed with intersections between layers.

4.6 Automatic Neighbour Allocation

9955 permits the automatic allocation of intra-technology neighbours in the current network. Two allocation algorithms are available, one dedicated to intra-carrier neighbours and the other for inter-carrier neighbours.

The intra-technology neighbour allocation algorithms take into account all the cells of TBC transmitters. It means that all the cells of TBC transmitters of your .atl document are potential neighbours.

The cells to be allocated will be called TBA cells. They must fulfil following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters or a single transmitter.

Only TBA cells may be assigned neighbours.

> If no focus zone exists in the .atl document, **9955** takes into account the computation zone.

In this section, the following are explained:

- "Neighbour Allocation for All Transmitters" on page 279.
- "Neighbour Allocation for a Group of Transmitters or One Transmitter" on page 283.
- "Importance Calculation" on page 283.

4.6.1 Neighbour Allocation for All Transmitters

We assume that we have a reference, cell A, and a candidate neighbour, cell B. When the automatic neighbour allocation starts, **9955** checks the following conditions:

- The distance between both cells must be less than the user-definable maximum inter-site distance. If the distance between the reference cell and the candidate neighbour is greater than this value, then the candidate neighbour is discarded.

9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 286.

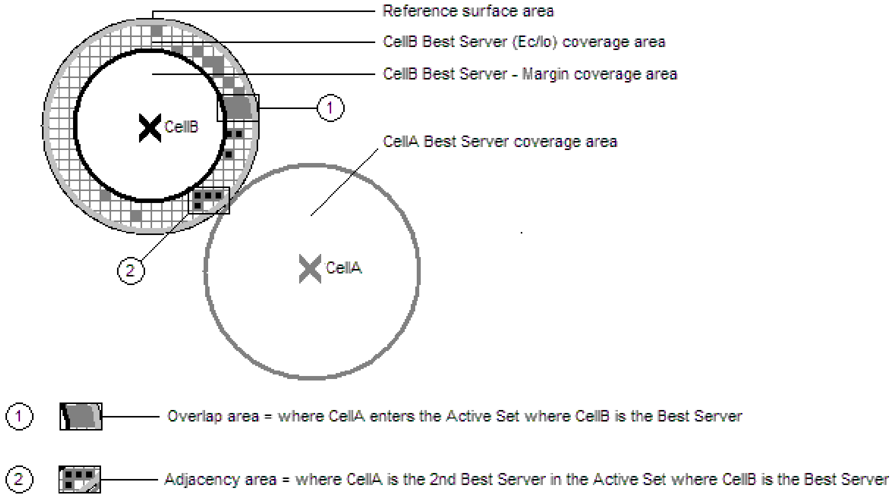
- The calculation options,

Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

Force co-site cells as neighbours: This option enables you to force cells located on the reference cell site in the candidate neighbour list. This constraint can be weighted among the others and ranks the neighbours through the importance field (see after).

Force adjacent cells as neighbours (only for intra-carrier neighbours): This option enables you to force cells geographically adjacent to the reference cell in the candidate neighbour list.This constraint can be weighted among the others and ranks the neighbours through the importance field (see after).

- **Adjacence criterion:** Let CellA be a candidate neighbour cell of CellB. CellA is considered adjacent to CellB if there exists at least one pixel in the CellB Best Server coverage area where CellA is Best Server (if several cells have the same best server value) or CellA is the second best server that enters the Active Set (respecting the HO margin of the allocation).



- When this option is checked, adjacent cells are sorted and listed from the most adjacent to the least, depending on the above criterion. Adjacence is relative to the number of pixels satisfying the criterion.

Force neighbour symmetry: This option enables user to force the reciprocity of a neighbourhood link. Therefore, if the reference cell is a candidate neighbour of another cell, this one will be considered as candidate neighbour of the reference cell.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a cell to be candidate neighbour of the reference cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept.

- There must be an overlapping zone ($S_A \cap S_B$) with a given cell edge coverage probability:
- Intra-carrier neighbours: intra-carrier handover is a soft handover.

The reference cell A and the candidate cell B are located inside a continuous layer of cells with carrier c1 (c1 is the selected carrier on which you run the allocation).

S_A is the area where the cell A is the best serving cell. It means that the cell A is the first one in the active set.

- The pilot signal received from the cell A is greater than the minimum pilot signal level.
- The pilot quality from A exceeds a user-definable minimum value (minimum Ec/I_0).
- The pilot quality from A is the best.

S_B is the area where the cell B can enter the active set.

- The pilot signal received from the cell B is greater than the minimum pilot signal level.
- The pilot quality from B is greater than the pilot quality from A minus the Ec/I_0 margin. The Ec/I_0 margin has the same meaning as the AS-threshold defined in the Cell properties. So, it should logically have the same value.

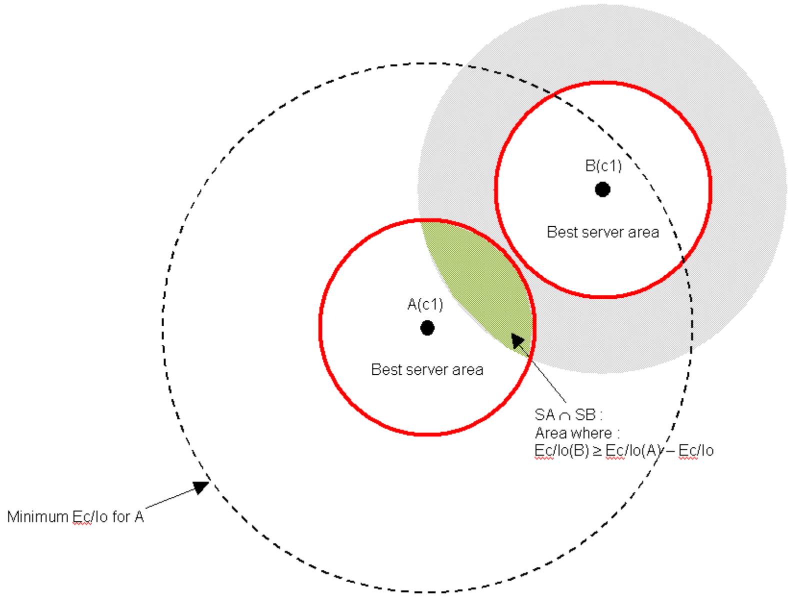


Figure 4.16: Overlapping Zone for Intra-carrier Neighbours

- Inter-carrier neighbours: inter-frequency handover is a hard handover. It is needed in a multi-carrier W-CDMA network:
  - To balance loading between carriers and layers (1^{st} case),
  - To make a coverage reason handover from micro cell frequency to macro cells (2^{nd} case).

1^{st} case: the reference cell A is located inside a continuous layer of cells with carrier c1 (c1 is the selected carrier on which you run the allocation) and the candidate cell B belongs to a layer of cells with carrier c2.

S_A is the area where the cell A is not the best serving cell of its layer but can enter the active set.

- The pilot signal received from the cell A is greater than the minimum pilot signal level.
- The pilot quality from A exceeds a user-definable minimum value (minimum Ec/I_0).
- The pilot quality from A is not the highest one. It is strictly lower than the best pilot quality received and greater than the best pilot quality minus the Ec/I_0 margin.

S_B is the area where the cell B is the best serving cell of its layer.

- The pilot signal received from the cell B is greater than the minimum pilot signal level.
- The pilot quality from B exceeds a user-definable minimum value (minimum Ec/I_0).
- The pilot quality from B is the highest one.

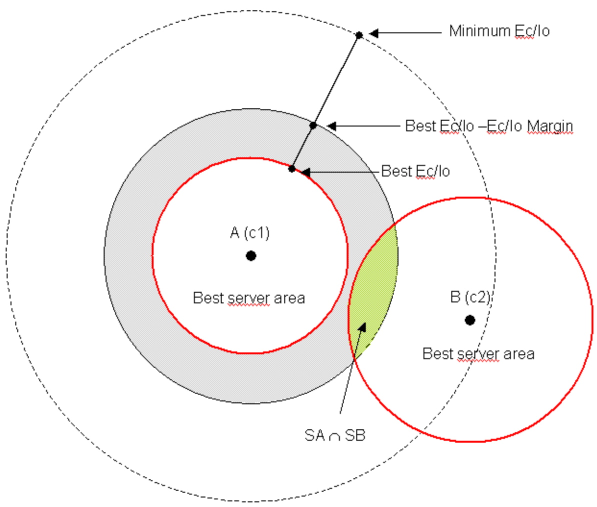


Figure 4.17: Overlapping Zone for Inter-carrier Neighbours - 1^{st} Case

2^{nd} case: the reference cell A is located on the border of a layer with carrier c1 (c1 is the selected carrier on which you run the allocation) and the candidate cell B belongs to a layer of cells with carrier c2.

S_A is the area where the pilot quality from the cell A starts significantly decreasing but the cell A is still the best serving cell of its layer (since it is on the border).

- The pilot signal received from the cell A is greater than the minimum pilot signal level.
- The pilot quality from A is the highest one
- The pilot quality from A is lower than a user-definable minimum value (minimum Ec/I_0) plus the Ec/I_0 margin.

S_B is the area where the cell B is the best serving cell of its layer.

- The pilot signal received from the cell B is greater than the minimum pilot signal level.
- The pilot quality from B exceeds a user-definable minimum value (minimum Ec/I_0).
- The pilot quality from B is the highest one.

Two ways enable you to determine the I_0 value:

1. **Global Value**: A percentage of the cell maximum power is considered. If the % of maximum power is too low, i.e. if $\% \times P_{max} < P_{pilot}$, **9955** takes into account the pilot power of the cell. Then, I_0 represents the sum of values calculated for each cell.
2. **Defined per Cell**: **9955** takes into account the total downlink power defined per cell. I_0 represents the sum of total transmitted powers.

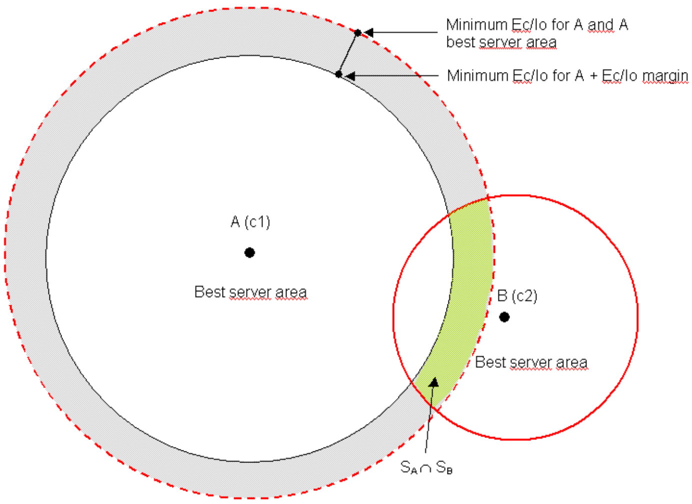


Figure 4.18: Overlapping Zone for Inter-carrier Neighbours - 2nd Case

9955 calculates the percentage of covered area ($\frac{S_A \cap S_B}{S_A} \times 100$) and compares this value to the % minimum covered area. If this percentage is not exceeded, the candidate neighbour B is discarded.

- The importance of neighbours.

For information on the importance calculation, see "Importance Calculation" on page 283.

Importance values are used by the allocation algorithm to rank the neighbours according to the allocation reason. **9955** lists all neighbours and sorts them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each transmitter is exceeded. If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference cell is 8. Among these 15 candidate neighbours, only 8 (having the highest importance values) will be allocated to the reference cell. Note that specific maximum numbers of neighbours (maximum number of intra-carrier neighbours, maximum number of inter-carrier neighbours) can be defined at the cell level (property dialogue or cell table). If defined there, this value is taken into account instead of the default one available in the **Neighbour Allocation** dialogue.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site, adjacent, coverage or symmetric. For neighbours accepted for co-site, adjacency and coverage reasons, **9955** displays the percentage of area meeting the coverage conditions and the corresponding surface area (km^2), the percentage of area meeting the adjacency conditions and the corresponding surface area (km^2). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

- No simulation or prediction study is needed to perform an automatic neighbour allocation. When starting an automatic neighbour allocation, **9955** automatically calculates the path loss matrices if not found.
- Even if no specific terminal, mobility or service is selected in the automatic allocation, it is interesting to know that the algorithm works such as finding the maximum number of neighbours by selection the multi-service traffic data as follows:
- Service: selection of the one with the lowest body loss.
- Mobility: no impact on the allocation, no specific selection.
- Terminal: selection of the one with the greatest (Gain - Loss) value, and, if equal, the one with the lowest noise figure.
- The neighbour lists may be optionally used in the power control simulations to determine the mobile's active set.
- A forbidden neighbour must not be listed as neighbour except if the neighbourhood relationship already exists and the Delete existing neighbours option is unchecked when you start the new allocation. In this case, **9955** displays a warning in the Event viewer indicating that the constraint on the forbidden neighbour will be ignored by algorithm because the neighbour already exists.
- The force neighbour symmetry option enables the users to consider the reciprocity of a neighbourhood link. This reciprocity is allowed only if the neighbour list is not already full. Thus, if the cell B is a neighbour of the cell A while the cell A is not a neighbour of the cell B, two cases are possible:
- 1st case: There is space in the cell B neighbour list: the cell A will be added to the list. It will be the last one.
- 2nd case: The cell B neighbour list is full: **9955** will not include cell A in the list and will cancel the link by deleting cell B from the cell A neighbour list.
- When the options "Force exceptional pairs" and "Force symmetry" are selected, **9955** considers the constraints between exceptional pairs in both directions so as to respect symmetry condition. On the other hand, if neighbourhood relationship is forced in one direction and forbidden in the other one, symmetry cannot be respected. In this case, **9955** displays a warning in the Event viewer.
- In the Results, **9955** displays only the cells for which it finds new neighbours. Therefore, if a TBA cell has already reached its maximum number of neighbours before starting the new allocation, it will not appear in the Results table.

4.6.2 Neighbour Allocation for a Group of Transmitters or One Transmitter

9955 allocates neighbours to:

- TBA cells,
- Neighbours of TBA cells marked as exceptional pair, adjacent and symmetric,
- Neighbours of TBA cells that satisfy coverage conditions.

Automatic neighbour allocation parameters are described in "Neighbour Allocation for All Transmitters" on page 279.

4.6.3 Importance Calculation

Importance values are used by the allocation algorithm to rank the neighbours according to the allocation reason and the distance, and to quantify the neighbour importance.

4.6.3.1 Importance of Intra-carrier Neighbours

The neighbour importance depends on the distance from the reference transmitter and on the neighbourhood cause (cf. table below); this value varies between 0 and 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	Only if the Delete existing neighbours option is not selected and in case of a new allocation	Existing importance
Exceptional pair	Only if the Force exceptional pairs option is selected	100 %
Co-site cell	Only if the Force co-site cells as neighbours option is selected	Importance Function (IF)
Adjacent cell	Only if the Force adjacent cells as neighbours option is selected	Importance Function (IF)

Neighbourhood cause	When	Importance value
Neighbourhood relationship that fulfils coverage conditions	Only if the % minimum covered area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	Only if the Force neighbour symmetry option is selected	Importance Function (IF)

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers four factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

$$(Di) = 1 - \frac{d}{d_{max}}$$

d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 286.

d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The adjacency factor (A): the percentage of adjacency,
- The overlapping factor (O): the percentage of overlapping.

The minimum and maximum importance assigned to each of the above factors can be defined.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	30%
Adjacency factor (A)	Min(A)	30%	Max(A)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The Importance Function is evaluated as follows:

Neighbourhood cause		Importance Function	Resulting IF using the default values from the table above
Co-site	Adjacent		
No	No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+20%{10%(Di)+90%(O)}
No	Yes	Min(A)+Delta(A){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	30%+30%{10%(Di)+30%(O) +60%(A)}
Yes	Yes	Min(C)+Delta(C){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	60%+40%{10%(Di)+30%(O) +60%(A)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours, adjacent neighbours, and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.

4.6.3.2 Importance of Inter-carrier Neighbours

As indicated in the table below, the neighbour importance depends on the distance and on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site cell	If the Force co-site cells as neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	If the % minimum covered area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	If the Force neighbour symmetry option is selected	Importance Function (IF)

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers three factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 286.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The overlapping factor (O): the percentage of overlapping.

The IF is user-definable using the Min importance and Max importance fields.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The IF evaluates importance as follows:

Co-site Neighbourhood cause	IF	Resulting IF using the default values from the table above
No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+50%{10%(Di)+90%(O)}
Yes	Min(C)+Delta(C){Max(Di)(Di)/(Max(Di)+Max(O))+ Max(O)(O)/(Max(Di)+Max(O))}	60%+40%{1/7%(Di)+6/7%(O)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.

4.6.4 Appendices

4.6.4.1 Calculation of the Inter-Transmitter Distance

9955 takes into account the real distance (D in m) and azimuths of antennas in order to calculate the effective inter-transmitter distance (d in m).

$$d = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

where x = 0.3% so that the maximum D variation does not exceed 1%.

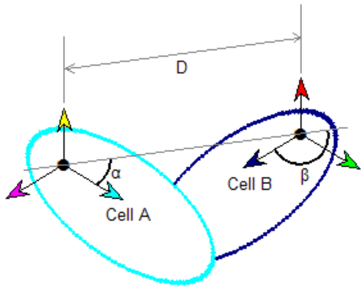


Figure 4.19: Inter-Transmitter Distance Computation

The formula above implies that two cells facing each other will have a smaller effective distance than the real physical distance. It is this effective distance that will be taken into account rather than the real distance.

4.7 Primary Scrambling Code Allocation

Downlink primary scrambling codes enable you to distinguish cells from one another (cell identification).

By default, there are 512 primary scrambling codes numbered (0...511).

The cells to which **9955** allocates scrambling codes are referred to as the *TBA cells* (cells to be allocated). TBA cells fulfil following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters or a single transmitter.

> If no focus zone exists in the .atl document, **9955** takes into account the computation zone.

4.7.1 Automatic Allocation Description

4.7.1.1 Options and Constraints

The scrambling code allocation algorithm can take into account following constraints and options:

- Neighbourhood between cells,

You may consider:

- First order neighbours: The neighbours of TBA cells listed in the Intra-technology neighbours table,
- Second order neighbours: The neighbours of neighbours,
- Third order neighbours: The neighbour’s neighbour’s neighbours.

- In the context of the primary scrambling code allocation, the term "neighbours" refers to intra-carrier neighbours.
- **9955** can take into account inter-technology neighbour relations as constraints to allocate different scrambling codes to the UMTS neighbours of a GSM transmitter. In order to consider inter-technology neighbour relations in the scrambling code allocation, you must make the Transmitters folder of the GSM .atl document accessible in the UMTS .atl document. For information on making links between GSM and UMTS .atl documents, see the *User Manual*.
- **9955** considers symmetry relationship between a cell, its first order neighbours, its second order neighbours and its third order neighbours.

- Cells fulfilling a criterion on Ec/I0 (option “Additional Overlapping Conditions”),

For a reference cell “A”, **9955** considers all the cells “B” that can enter the active set on the area where the reference cell is the best server (area where $(Ec/I0)_A$ exceeds the minimum Ec/I0 and is the highest one and $(Ec/I0)_B$ is within a Ec/I0 margin of $(Ec/I0)_A$).

- **9955** considers either a percentage of the cell maximum powers or the total downlink power used by the cells in order to evaluate I0. In this case, I0 equals the sum of total transmitted powers. When this parameter is not specified in the cell properties, **9955** uses 50% of the maximum power.

- Reuse distance,

- Reuse distance is a constraint on the allocation of scrambling codes. A code cannot be reused at a cell that is not at least as far away as the reuse distance from the cell allocated with the particular code.
- Scrambling code reuse distance can be defined at cell level. If this value is not defined, then **9955** will use the default reuse distance defined in the **Scrambling Code Automatic Allocation** dialogue.

- Exceptional pairs,
- Domains of scrambling codes,

When no domain is assigned to cells, **9955** considers the 512 primary scrambling codes available.

- The number of primary scrambling codes per cluster. In **9955**, we call "cluster", a group of scrambling codes as defined in 3GPP specifications. 3GPP specifications define 64 clusters consisting of 8 scrambling codes (in this case, clusters are numbererd from 0 to 63). However, you can define another value (e.g. if you set the number of codes per cluster to 4, scrambling codes will be distributed in 128 clusters).

  When the allocation is based on a Distributed strategy (Distributed per Cell or Distributed per Site), this parameter can also be used to define the interval between the primary scrambling codes assigned to cells on a same site. The defined interval is applied by adding the following lines in the Atoll.ini file:

```
[PSC]
ConstantStep = 1
```

  For more information about setting options in the atoll.ini file, see the *Administrator Manual*.

- The carrier on which the allocation is run: It can be a given carrier or all of them. In this case, either **9955** independently plans scrambling codes for the different carriers, or it allocates the same primary scrambling code to each carrier of a transmitter if the option "Allocate carriers identically" is selected.
- The possibility to use a maximum of codes from the defined domains (option "Use a Maximum of Codes"): **9955** will try to spread the scrambling code spectrum the most.
- The "Delete All Codes" option: When selecting this option, **9955** deletes all the current scrambling codes and carries out a new scrambling code allocation. If not selected, the existing scrambling codes are kept.

In addition, it depends on the selected allocation strategy. Allocation strategies can be:

- Clustered allocation: The purpose of this strategy is to choose for a group of mutually constrained cells, scrambling codes among a minimum number of clusters. In this case, **9955** will preferentially allocate all the codes within the same cluster.
- Distributed per cell allocation: This strategy consists in using as many clusters as possible. **9955** will preferentially allocate codes from different clusters.
- One cluster per site allocation: This strategy allocates one cluster to each site, then, one code from the cluster to each cell of each site. When all the clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the clusters as far as possible at another site.
- Distributed per site allocation: This strategy allocates a group of adjacent clusters to each site, then, one cluster to each transmitter on the site according to its azimuth and finally, one code from the cluster to each cell of each transmitter. The number of adjacent clusters per group depends on the number of transmitters per site you have in your network; this information is required to start allocation based on this strategy. When all the groups of adjacent clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the groups of adjacent clusters as far as possible at another site.

In the Results table, **9955** only displays scrambling codes allocated to TBA cells.

4.7.1.2 Allocation Process

For each TBA cell, **9955** lists all cells which have constraints with the cell. They are referred to as *near cells*. The near cells of a TBA cell may be:

- Its neighbour cells: the neighbours listed in the Intra-technology neighbours table (options “Existing neighbours” and "First Order"),
- The neighbours of its neighbours (options “Existing neighbours” and “Second Order”),
- The third order neighbours (options “Existing neighbours” and “Third Order”),
- The cells that fulfil Ec/I0 condition (option “Additional Overlapping Conditions”),
- The cells with distance from the TBA cell less than the reuse distance,
- The cells that make exceptional pairs with the TBA cell.

Additional constraints are considered when:

- The cell and its near cells are neighbours of a same GSM transmitter (only if the Transmitters folder of the GSM .atl document is accessible in the UMTS .atl document),
- The neighbour cells cannot share the same cluster (for the "Distributed per site" allocation strategy only).

These constraints have a certain weight taken into account to determine the TBA cell priority during the allocation process and the cost of the scrambling code plan. During the allocation, **9955** tries to assign different scrambling codes to the TBA cell and its near cells. If it respects all the constraints, the cost of the scrambling code plan is 0. When a cell has too many constraints and there are not anymore scrambling codes available, **9955** breaks the constraint with the lowest cost so as to generate the scrambling code plan with the lowest cost. For information on the cost generated by each constraint, see "Cell Priority" on page 290.

4.7.1.2.1 Single Carrier Network

The allocation process depends on the selected strategy. Algorithm works as follows:

Strategies: Clustered and Distributed per Cell

9955 processes TBA cells according to their priority. It allocates scrambling codes starting with the highest priority cell and its near cells, and continuing with the lowest priority cells not allocated yet and their near cells. For information on calculating cell priority, see "Cell Priority" on page 290.

Strategy: One Cluster per Site

All sites which have constraints with the studied site are referred to as *near sites.*

9955 assigns a cluster to each site, starting with the highest priority site and its near sites, and continuing with the lowest priority sites not allocated yet and their near sites. When all the clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the clusters at another site. When the Reuse Distance option is selected, the algorithm reuses the clusters as soon as the reuse distance is exceeded. Otherwise, when the option is not selected, the algorithm tries to assign reused clusters as spaced out as possible.

Then, **9955** allocates a primary scrambling code from the cluster to each cell located on the sites (codes belong to the assigned clusters). It starts with the highest priority cell and its near cells and goes on with the lowest priority cells not allocated yet and their near cells.

For information on calculating site priority, see "Site Priority" on page 292. For information on calculating cell priority, see "Cell Priority" on page 290.

Strategy: Distributed per Site

All sites which have constraints with the studied site are referred to as *near sites.*

9955 assigns a group of adjacent clusters to each site, starting with the highest priority site and its near sites, and continuing with the lowest priority sites not allocated yet and their near sites. When all the groups of adjacent clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the groups of adjacent clusters at another site. When the Reuse Distance option is selected, the algorithm reuses the groups of adjacent clusters as soon as the reuse distance is exceeded. Otherwise, when the option is not selected, the algorithm tries to assign reused groups of adjacent clusters as spaced out as possible. Then, **9955** assigns each cluster of the group to each transmitter of the site according to the transmitter azimuth and selected neighbourhood constraints (options "Neighbours in Other Clusters" and "Secondary Neighbours in Other Clusters"). Then, **9955** allocates a primary scrambling code to each cell located on the transmitters (codes belong to the assigned clusters). It starts with the highest priority cell and its near cells and goes on with the lowest priority cells not allocated yet and their near cells.

For information on calculating site priority, see "Site Priority" on page 292. For information on calculating cell priority, see "Cell Priority" on page 290.

Determination of Groups of Adjacent Clusters

In order to determine the groups of adjacent clusters to be used, **9955** proceeds as follows: It defines theoretical groups of adjacent clusters, independently of the defined domain, considering the 512 primary scrambling codes available and the specified number of codes per cluster (if this one is set to 8, 64 clusters are supposed to be available). It starts the division in group from the cluster 0 (hard coded) and takes into account the maximum number of transmitters per site user-specified in order to determine the number of clusters in each group and then, the number of possible groups.

Let us assume that the number of codes per cluster is set to 8 and the maximum number of transmitters per site in the network is 3. In this case, we have the following theoretical groups:

Group 1	Group 2	Group 3	Group 4	...	Group 21
Cluster 0 Cluster 1 Cluster 2	Cluster 3 Cluster 4 Cluster 5	Cluster 6 Cluster 7 Cluster 8	Cluster 9 Cluster 10 Cluster 11	...	Cluster 61 Cluster 62 Cluster 63

If no domain is assigned to cells, **9955** can use all these groups for the allocation. On the other hand, if a domain is used, the tool compares adjacent clusters really available in the assigned domain to the theoretical groups and only keeps adjacent clusters mapping the theoretical groups.

Let us assume that we have a domain consisted of 12 clusters: clusters 1 to 8 and clusters 12 to 15.

Therefore, **9955** will be able to use the following groups of adjacent clusters:

- Group 2 with cluster 3, 4 and 5,
- Group 3 with cluster 6, 7 and 8,
- Group 6 with cluster 12, 13 and 14.
- The clusters 1, 2 and 15 will not be used.

If a domain does not contain any adjacent clusters, the user is warned through the 'Event Viewer'.

4.7.1.2.2 Multi-Carrier Network

In case you have a multi-carrier network and you run the scrambling code allocation on all the carriers, the allocation process depends on the allocation strategy as detailed above and in addition, wether the option "Allocate Carriers Identically" is selected or not.

When the option is not selected, algorithm works for each strategy, as explained above. On the other hand, when the option is selected, allocation order changes. It is no longer based on the cell priority but depends on the transmitter priority. All transmitters which have constraints with the studied transmitter will be referred to as *near transmitters*.

In case of a "Per cell" strategy (Clustered and Distributed per cell), **9955** starts scrambling code allocation with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same scrambling code is assigned to each cell of the transmitter.

In case of the "One cluster per site" strategy, **9955** assigns a cluster to each site and then, allocates a scrambling code to each transmitter. It starts with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same scrambling code is assigned to each cell of the transmitter.

In case of the "Distributed per site" strategy, **9955** assigns a group of adjacent clusters to each site, then a cluster to each transmitter and finally, allocates a scrambling code to each transmitter. It starts with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same scrambling code is assigned to each cell of the transmitter.

For information on calculating transmitter priority, see "Transmitter Priority" on page 292.

When cells, transmitters or sites have the same priority, processing is based on an alphanumeric order.

4.7.1.3 Priority Determination

4.7.1.3.1 Cell Priority

Scrambling code allocation algorithm in **9955** allots priorities to cells before performing the actual allocation. Priorities assigned to cells depend upon how much constrained each cell is and the cost defined for each constraint. A cell without any constraint has a default cost, C, equal to 0. The higher the cost on a cell, the higher the priority it has for the scrambling code allocation process.

There are six criteria employed to determine the cell priority:

- Scrambling Code Domain Criterion

The cost due to the domain constraint, $C_i(Dom)$, depends on the number of scrambling codes available for the allocation. The domain constraint is mandatory and cannot be broken.

When no domain is assigned to cells, 512 scrambling codes are available and we have:

$$C_i(Dom) = 0$$

When domains of scrambling codes are assigned to cells, each unavailable scrambling code generates a cost. The higher the number of codes available in the domain, the less will be the cost due to this criterion. The cost is given as:

$$C_i(Dom) = 512 - \textit{Number of scrambling codes in the domain}$$

- Distance Criterion

The constraint level of any cell *i* depends on the number of cells (*j*) present within a radius of "reuse distance" from its centre. The total cost due to the distance constraint is given as:

$$C_i(Dist) = \sum_j C_j(Dist(i))$$

Each cell *j* within the reuse distance generates a cost given as:

$$C_j(Dist(i)) = w(d_{ij}) \times c_{distance}$$

Where

$w(d_{ij})$ is a weight depending on the distance between *i* and *j*. This weight is inversely proportional to the inter-cell distance. For a reuse distance of 2000m, the weight for an inter-cell distance of 1500m is 0.25, the weight for co-site cells is 1 and the weight for two cells spaced out 2100m apart is 0.

$c_{distance}$ is the cost of the distance constraint. This value can be defined in the **Constraint Cost** dialogue.

- Exceptional Pair Criterion

The constraint level of any cell *i* depends on the number of exceptional pairs (*j*) for that cell. The total cost due to exceptional pair constraint is given as:

$$C_i(EP) = \sum_j c_{EP}(i-j)$$

Where

c_{EP} is the cost of the exceptional pair constraint. This value can be defined in the **Constraint Cost** dialogue.

- Neighbourhood Criterion

The constraint level of any cell *i* depends on the number of its neighbour cells *j*, the number of second order neighbours *k* and the number of third order neighbours *l*.

Let's consider the following neighbour schema:

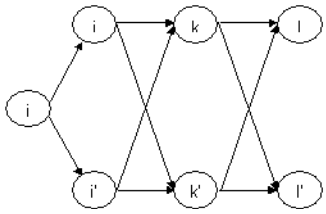


Figure 4.20: Neighbourhood Constraints

The total cost due to the neighbour constraint is given as:

$$C_i(N) = \left(\sum_j C_j(N1(i)) + \sum_{j'} C_{j-j'}(N1(i))\right) + \left(\sum_k C_k(N2(i)) + \sum_{k'} C_{k-k'}(N2(i))\right) + \left(\sum_l C_l(N3(i)) + \sum_{l'} C_{l-l'}(N3(i))\right)$$

Each first order neighbour cell *j* generates a cost given as:

$$C_j(N1(i)) = I_j \times c_{N1}$$

Where

I_j is the importance of the neighbour cell *j*.

c_{N1} is the cost of the first order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two first order neighbours must not have the same scrambling code, **9955** considers the cost created by two first order neighbours to be each other.

$$C_{j-j'}(N1(i)) = \frac{C_j(N1(i)) + C_{j'}(N1(i))}{2}$$

Each second order neighbour cell *k* generates a cost given as:

$$C_k(N2(i)) = Max((C_j(N1(i)) \times C_k(N1(j))),(C_{j'}(N1(i)) \times C_k(N1(j')))) \times c_{N2}$$

Where

c_{N2} is the cost of the second order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two second order neighbours must not have the same scrambling code, **9955** considers the cost created by two second order neighbours to be each other.

$$C_{k-k'}(N2(i)) = \frac{C_k(N2(i)) + C_{k'}(N2(i))}{2}$$

Each third order neighbour cell *l* generates a cost given as:

$$C_l(N3(i)) = Max\begin{pmatrix} C_j(N1(i)) \times C_k(N1(j)) \times C_l(N1(k)), C_{j'}(N1(i)) \times C_k(N1(j')) \times C_l N1(k), \\ (C_j(N1(i)) \times C_{k'}(N1(j))) \times C_l N1(k'), C_{j'}(N1(i)) \times C_{k'}(N1(j')) \times C_l N1(k') \end{pmatrix} \times c_{N3}$$

Where

c_{N3} is the cost of the third order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two third order neighbours must not have the same scrambling code, **9955** considers the cost created by two third order neighbours to be each other.

$$C_{l-l'}(N3(i)) = \frac{C_l(N3(i)) + C_{l'}(N3(i))}{2}$$

> **9955** considers the highest cost of both links when a neighbour relation is symmetric and the importance value is different.
>
> 
>
>
> In this case, we have:
>
> $$C_j(N1(i)) = Max(I_{i-j}, I_{j-i}) \times c_{N1}$$
>
> And
>
> $$C_k(N2(i)) = Max(C_j(N1(i)) \times C_k(N1(j)), C_j(N1(k)) \times C_i(N1(j))) \times c_{N2}$$

- GSM Neighbour Criterion

This criterion is considered when the co-planning mode is activated (i.e. the Transmitters folder of the GSM .atl document is made accessible in the UMTS .atl document) and inter-technology neighbours have been allocated. If the cell *i* is neighbour of a GSM transmitter, the cell constraint level depends on how many cells *j* are neighbours of the same GSM transmitter. The total cost due to GSM neighbour constraint is given as:

$$C_i(N_{2G}) = \sum_j c_{N_{2G}}(j - Tx_{2G})$$

Where

$c_{N_{2G}}$ is the cost of the GSM neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

- Cluster Criterion

When the "Distributed per Site" allocation strategy is used, you can consider additional constraints on allocated clusters (one cell, its first order neighbours and its second order neighbours must be assigned scrambling codes from different clusters). In this case, the constraint level of any cell *i* depends on the number of first and second order neighbours, *j* and *k*. The total cost due to the cluster constraint is given as:

$$C_i(Cluster) = \sum_j C_j(N1(i)) \times c_{Cluster} + \sum_k C_k(N2(i)) \times c_{Cluster}$$

Where

$c_{Cluster}$ is the cost of the cluster constraint. This value can be defined in the **Constraint Cost** dialogue.

Therefore, the total cost due to constraints on any cell *i* is defined as:

$$C_i = C_i(Dom) + C_i(U)$$

With

$$C_i(U) = C_i(Dist) + C_i(EP) + C_i(N) + C_i(N_{2G}) + C_i(Cluster)$$

4.7.1.3.2 Transmitter Priority

In case you have a multi-carrier network and you run scrambling code allocation on "all" the carriers with the option "allocate carriers identically", algorithm in **9955** allots priorities to transmitters. Priorities assigned to transmitters depend on how much constrained each transmitter is and the cost defined for each constraint. The higher the cost on a transmitter, the higher the priority it has for the scrambling code allocation process.

Let us consider a transmitter Tx with two cells using carriers 0 and 1. The cost due to constraints on the transmitter is given as:

$$C_{Tx} = C_{Tx}(Dom) + C_{Tx}(U)$$

With $C_{Tx}(U) = \underset{i \in Tx}{Max}(C_i(U))$ and $C_{Tx}(Dom) = 512 - \text{Number of scrambling codes in the domain}$

Here, the domain available for the transmitter is the intersection of domains assigned to cells of the transmitter. The domain constraint is mandatory and cannot be broken.

4.7.1.3.3 Site Priority

In case of "Per Site" allocation strategies (One cluster per site and Distributed per site), algorithm in **9955** allots priorities to sites. Priorities assigned to sites depend on how much constrained each site is and the cost defined for each constraint. The higher the cost on a site, the higher the priority it has for the scrambling code allocation process.

Let us consider a site S with three transmitters; each of them has two cells using carriers 0 and 1. The cost due to constraints on the site is given as:

$$C_S = C_S(U) + C_S(Dom)$$

With $C_S(U) = \underset{Tx \in S}{Max}(C_{Tx}(U))$ and $C_S(Dom) = 512 - \textit{Number of scrambling codes in the domain}$

Here, the domain considered for the site is the intersection of domains available for transmitters of the site. The domain constraint is mandatory and cannot be broken.

4.7.2 Allocation Examples

4.7.2.1 Allocation Strategies and Use a Maximum of Codes

In order to understand the differences between the different allocation strategies and the behaviour of algorithm when using a maximum of codes or not, let us consider the following sample scenario:

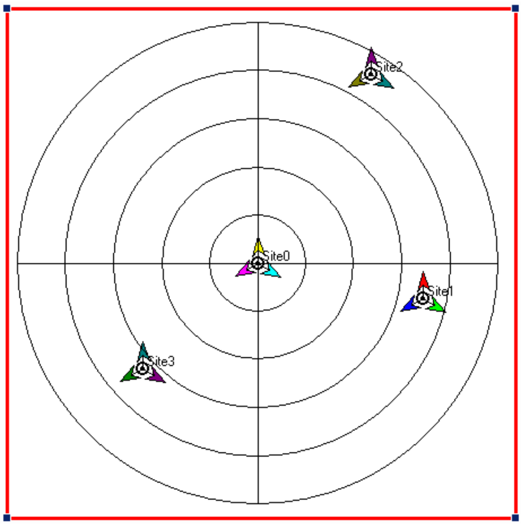


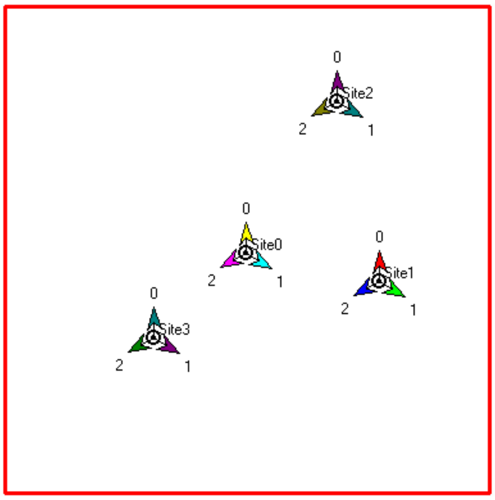
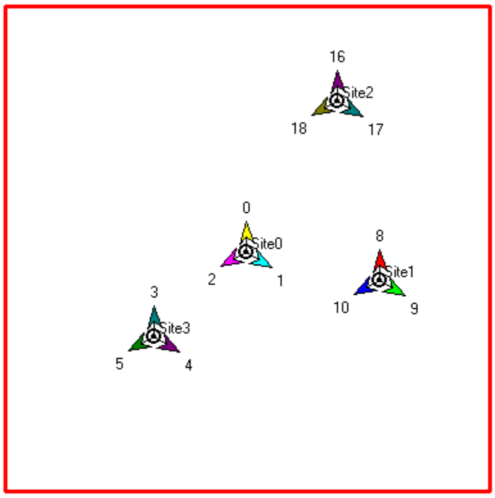
Figure 4.21: Primary Scrambling Codes Allocation

Let Site0, Site1, Site2 and Site3 be four sites with 3 cells using carrier 0 whom scrambling codes have to be allocated out of three clusters consisted of 8 primary scrambling codes. This implies that the domain of scrambling codes for the four sites is from 0 to 23 (cluster 0 to cluster 2). The reuse distance is supposed to be less than the inter-site distance. Only co-site neighbours exist.

The following section lists the results of each combination of options with explanation where necessary.

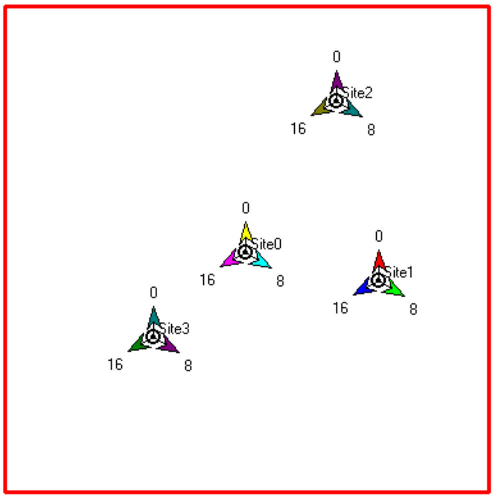
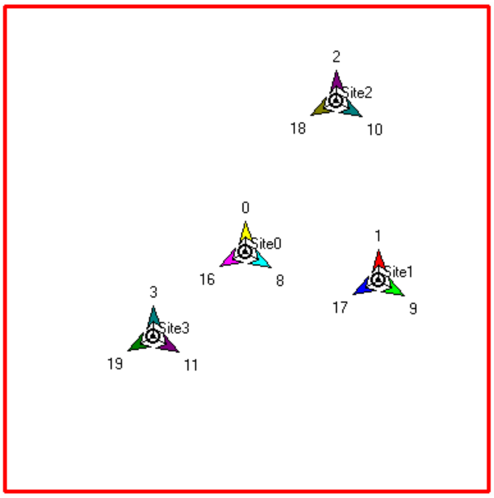
4.7.2.1.1 Strategy: Clustered

Since the restrictions of neighbourhood only apply to co-sites with the same importance and sites distances are greater than reuse distances, every cell has the same priority. Then, scrambling code allocation to cells is performed in an alphanumeric order.

Without 'Use a Maximum of Codes'	With 'Use a Maximum of Codes'
	
9955 starts allocating the codes from the start of cluster 0 at each site.	As it is possible to use a maximum of codes, **9955** starts allocation at the start of a different cluster at each site. When a cluster is reused, and there are non allocated codes left in the cluster, **9955** first allocates those codes before reusing the already used ones.

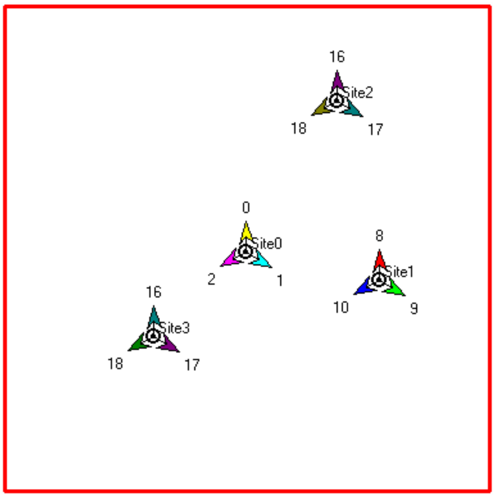
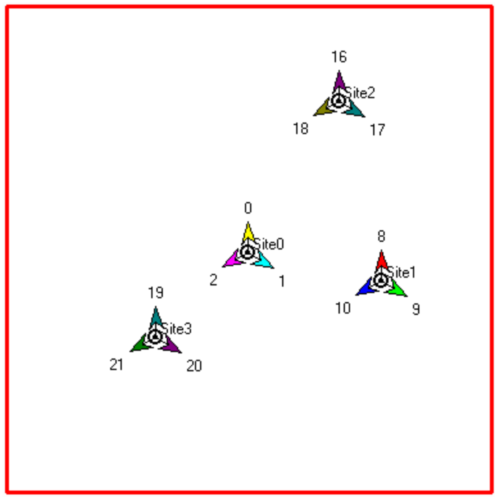
4.7.2.1.2 Strategy: Distributed

Since the restrictions of neighbourhood only apply to co-sites with the same importance and sites distances are greater than reuse distances, every cell has the same priority. Then, scrambling code allocation to cells is performed in an alphanumeric order.

Without 'Use a Maximum of Codes'	With 'Use a Maximum of Codes'
	
9955 allocates codes from different clusters to each cell of the same site. Under given constraints of neighbourhood and reuse distance, same codes can be allocated to each site's cells.	**9955** allocates codes from different clusters to each site's cells. As it is possible to use a maximum of codes, **9955** allocates the codes so that there is least repetition of codes.

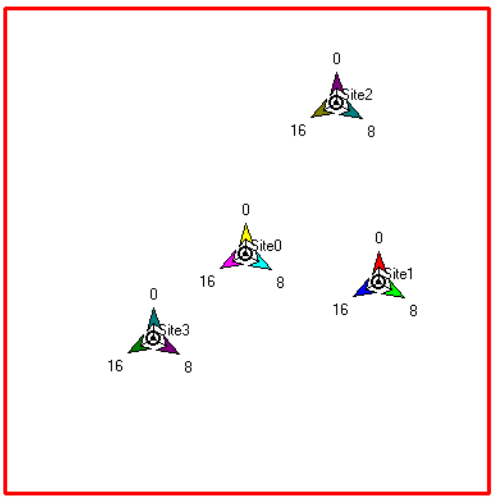
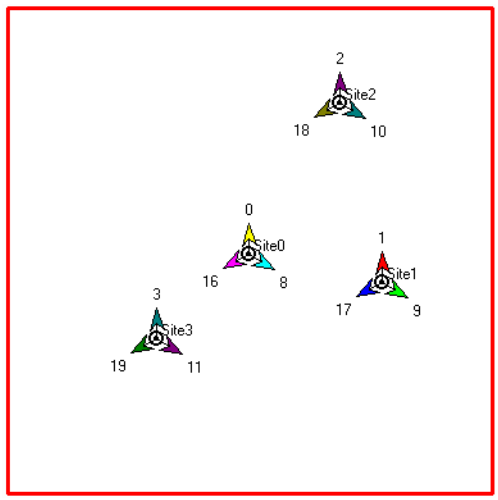
4.7.2.1.3 Strategy: 'One Cluster per Site

Since the restrictions of neighbourhood only apply to co-sites with the same importance and sites distances are greater than reuse distances, every site has the same priority. Then, cluster allocation to sites is performed in an alphanumeric order.

<table>
<tr><th>Without 'Use a Maximum of Codes'</th><th>With 'Use a Maximum of Codes'</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>In this strategy, a cluster of codes is limited to be used at just one site at a time unless all codes and clusters have been allocated and there are still sites remaining to be allocated. In this case 9955 reuses the clusters as far as possible at another site.</td><td>When it is possible to use a maximum of codes, 9955 can allocate different codes from a reused cluster at another site.</td></tr>
</table>

4.7.2.1.4 Strategy: 'Distributed per Site

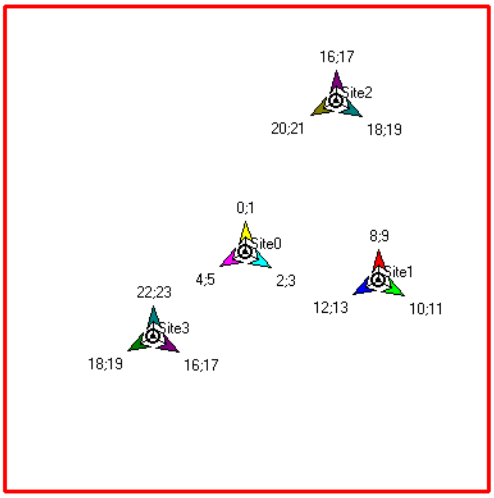
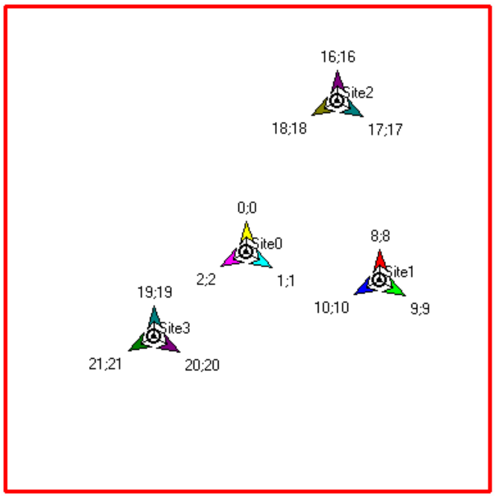
Since the restrictions of neighbourhood only apply to co-sites with the same importance and sites distances are greater than reuse distances, every site has the same priority. Then, the group of adjacent clusters allocation to sites is performed in an alphanumeric order.

<table>
<tr><th>Without 'Use a Maximum of Codes'</th><th>With 'Use a Maximum of Codes'</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>In this strategy, a group of adjacent clusters is limited to be used at just one site at a time unless all codes and groups of adjacent clusters have been allocated and there are still sites remaining to be allocated. In this case (here only one group of adjacent clusters (clusters 0, 1 and 2) is available), 9955 reuses the group at another site.</td><td>When it is possible to use a maximum of codes, 9955 can allocate different codes from a reused group of adjacent cluster at another site.</td></tr>
</table>

4.7.2.2 Allocate Carriers Identically

In order to understand the behaviour of algorithm when using the option "Allocate Carriers Identically" or not, let us consider the following sample scenario:

Let Site0, Site1, Site2 and Site3 be four sites with 3 cells using carrier 0 and 3 cells using carrier 1. Scrambling codes have to be allocated out of 3 clusters consisted of 8 primary scrambling codes. This implies that the domain of scrambling codes for the five sites is from 0 to 23 (cluster 0 to cluster 2). The reuse distance is supposed to be less than the inter-site distance. Only co-site neighbours exist. Allocation algorithm will be based on the "One Cluster per Site" strategy and the option "Use a Maximum of Codes" is selected.

Without 'Allocate Carriers Identically'	With 'Allocate Carriers Identically'
	
9955 allocates one cluster at each site as detailed in the previous section. Then, it allocates a code from the cluster to each cell of the site so as to use a maximum of codes.	In this case, **9955** allocates one cluster at each site and then, one code to each transmitter so as to use a maximum of codes. Then, the same code is given to each cell of the transmitter.

In both cases (with and without 'Allocate Carriers Identically'), every site has the same priority. Then, cluster allocation to sites is performed in an alphanumeric order.

4.8 Automatic GSM-UMTS Neighbour Allocation

4.8.1 Overview

You can automatically calculate and allocate neighbours between GSM and UMTS networks. In **9955**, it is called inter-technology neighbour allocation.

Inter-technology handover is used in two cases:

- When the UMTS coverage is not continuous. In this case, the UMTS coverage is extended by UMTS-GSM handover into the GSM network,
- And in order to balance traffic and service distribution between both networks.

Note that the automatic inter-technology neighbour allocation algorithm takes into account both cases.

In order to be able to use the inter-technology neighbour allocation algorithm, you must have:

- An .atl document containing the GSM network, GSM.atl, and another one describing the UMTS network, UMTS.atl,
- An existing link on the Transmitters folder of GSM.atl into UMTS.atl.

The external neighbour allocation algorithm takes into account all the GSM TBC transmitters. It means that all the TBC transmitters of GSM.atl are potential neighbours. The cells to be allocated will be called TBA cells which, being cells of UMTS.atl, satisfy following conditions:

- They are active,
- They satisfy the filter criteria applied to Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder for which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters subfolder.

Only UMTS TBA cells may be assigned neighbours.

4.8.2 Automatic Allocation Description

The allocation algorithm takes into account criteria listed below:

- The inter-transmitter distance,
- The maximum number of neighbours fixed,
- Allocation options,
- The selected allocation strategy,

Two allocation strategies are available: the first one is based on distance and the second one on coverage overlapping.

We assume we have a UMTS reference cell, A, and a GSM candidate neighbour, transmitter B.

4.8.2.1 Algorithm Based on Distance

When the automatic allocation starts, **9955** checks the following conditions:

- The distance between the UMTS reference cell and the GSM neighbour must be less than the user-definable maximum inter-site distance. If the distance between the UMTS reference cell and the GSM neighbour is greater than this value, then the candidate neighbour is discarded.

  9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 286.

- The calculation options,

Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

Force co-site cells as neighbours: It enables you to automatically include GSM transmitters located on the same site as the reference UMTS cell in the candidate neighbour list. This option is automatically selected.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a GSM transmitter to be candidate neighbour of the reference UMTS cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, existing neighbours are kept.

- The importance of neighbours.

Importance values are used by the allocation algorithm to rank the neighbours. **9955** lists all neighbours and sorts them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each cell is exceeded. If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference cell is 8. Among these 15 candidate neighbours, only 8 (having the highest importance values) will be allocated to the reference cell. Note that the maximum number of inter-technology neighbours can be defined at the cell level (property dialogue or cell table). If defined there, this value is taken into account instead of the default one available in the **Neighbour Allocation** dialogue.

As indicated in the table below, the neighbour importance depends on the distance and on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter	If the Force co-site cells as neighbours option is selected	100 %
Neighbourhood relationship that fulfils distance conditions	If the maximum distance is not exceeded	$1-\frac{d}{d_{max}}$

Where d is the effective distance between the UMTS reference cell and the GSM neighbour and d_{max} is the maximum inter-site distance.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site, or distance. For neighbours accepted for distance reasons, **9955** displays the distance from the reference cell (m). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

4.8.2.2 Algorithm Based on Coverage Overlapping

When automatic allocation starts, **9955** checks following conditions:

- The distance between the UMTS reference cell and the GSM neighbour must be less than the user-definable maximum inter-site distance. If the distance between the UMTS reference cell and the GSM neighbour is greater than this value, then the candidate neighbour is discarded.

  9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 286.

- The calculation options,

Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

Force co-site cells as neighbours: It enables you to automatically include GSM transmitters located on the same site as the reference UMTS cell in the candidate neighbour list. This option is automatically selected.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a GSM transmitter to be candidate neighbour of the reference UMTS cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, existing neighbours are kept.

- There must be an overlapping zone ($S_A \cap S_B$) with a given cell edge coverage probability.

Four different cases may be considered for S_A:

- 1st case: S_A is the area where the cell A is the best serving cell of the UMTS network.
  - The pilot signal received from A is greater than the minimum pilot signal level,
  - The pilot quality from A exceeds a user-definable minimum value (minimum Ec/I_0) and is the highest one.

  In this case, the Ec/I_0 margin must be equal to 0dB and the max Ec/I0 option disabled.

- 2nd case: S_A represents the area where the pilot quality from the cell A strats decreasing but the cell A is still the best serving cell of the UMTS network.

  The Ec/I_0 margin must be equal to 0dB, the max Ec/I0 option selected and a maximum Ec/I0 user-defined.

  - The pilot signal received from A is greater than the minimum pilot signal level,
  - The pilot quality from A exceeds the minimum Ec/I_0 but is lower than the maximum Ec/I0.
  - The pilot quality from A is the highest one.
- 3rd case: S_A represents the area where the cell A is not the best serving cell but can enter the active set.

  Here, the Ec/I_0 margin has to be different from 0dB and the max Ec/I0 option disabled.

  - The pilot signal received from A is greater than the minimum pilot signal level,
  - The pilot quality from A is within a margin from the best Ec/I0, where the best Ec/I0 exceeds the minimum Ec/I0.
- 4th case: S_A represents the area where:
  - The pilot signal received from A is greater than the minimum pilot signal level,
  - The pilot quality from A is within a margin from the best Ec/I0 (where the best Ec/I0 exceeds the minimum Ec/I0) and lower than the maximum Ec/I0.

  In this case, the margin must be different from 0dB, the max Ec/I0 option selected and a maximum Ec/I0 user-defined.

Two different cases may be considered for S_B:

- 1st case: S_B is the area where the cell B is the best serving cell of the GSM network.

  In this case, the margin must be set to 0dB.

  - The signal level received from B on the BCCH TRX type exceeds the user-defined minimum threshold and is the highest one.
- 2nd case: The margin is different from 0dB and S_B is the area where:
  - The signal level received from B on the BCCH TRX type exceeds the user-defined minimum threshold and is within a margin from the best BCCH signal level.

9955 calculates the percentage of covered area ($\frac{S_A \cap S_B}{S_A} \times 100$) and compares this value to the % minimum covered area. If this percentage is not exceeded, the candidate neighbour B is discarded.

Candidate neighbours fulfilling coverage conditions are sorted in descending order with respect to % of covered area.

When the automatic allocation is based on coverage overlapping, we recommend you to perform two successive automatic allocations:

- A first allocation in order to find handovers due to non-continuous UMTS coverage. In this case, you have to select the max Ec/I_0 option and define a high enough value.
- A second allocation in order to complete the previous list with handovers motivated for reasons of traffic and service distribution. Here, the max Ec/I_0 option must be disabled.

- The importance of neighbours.

Importance values are used by the allocation algorithm to rank the neighbours according to the distance and the allocation reason. **9955** lists all neighbours and sorts them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each cell is exceeded. If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference cell is 8. Among these 15 candidate neighbours, only 8 (having the highest importance values) will be allocated to the reference cell. Note that the maximum number of inter-technology neighbours can be defined at the cell level (property dialogue or cell table). If defined there, this value is taken into account instead of the default one available in the **Neighbour Allocation** dialogue.

As indicated in the table below, the neighbour importance depends on the distance and on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood reason	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter	If the Force co-site cells as neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	If the % minimum covered area is exceeded	Importance Function (IF)

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers three factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 286.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The overlapping factor (O): the percentage of overlapping.

The IF is user-definable using the Min importance and Max importance fields.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The IF evaluates importance as follows:

Co-site Neighbourhood cause	IF	Resulting IF using the default values from the table above
No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+50%{10%(Di)+90%(O)}
Yes	Min(C)+Delta(C){Max(Di)(Di)/(Max(Di)+Max(O))+ Max(O)(O)/(Max(Di)+Max(O))}	60%+40%{1/7%(Di)+6/7%(O)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site or coverage. For neighbours accepted for co-site and coverage reasons, **9955** displays the percentage of area meeting the coverage conditions and the corresponding surface area (km^2). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

- No prediction study is needed to perform an automatic neighbour allocation. When starting an automatic neighbour allocation, **9955** automatically calculates the path loss matrices if not found.
- A forbidden neighbour must not be listed as neighbour except if the neighbourhood relationship already exists and the Delete existing neighbours option is unchecked when you start the new allocation. In this case, **9955** displays a warning in the Event viewer indicating that the constraint on the forbidden neighbour will be ignored by algorithm because the neighbour already exists.
- In the Results, **9955** displays only the cells for which it finds new neighbours. Therefore, if a TBA cell has already reached its maximum number of neighbours before starting the new allocation, it will not appear in the Results table.

4.8.2.3 Appendices

4.8.2.3.1 Delete Existing Neighbours Option

As explained above, **9955** keeps the existing inter-technology neighbours when the Delete existing neighbours option is not checked. We assume that we have an existing allocation of inter-technology neighbours.

A new TBA cell *i* is created in UMTS.atl. Therefore, if you start a new allocation without selecting the Delete existing neighbours option, **9955** determines the neighbour list of the cell *i*.

If you change some allocation criteria (e.g. increase the maximum number of neighbours or create a new GSM TBC transmitter) and start a new allocation without selecting the Delete existing neighbours option, it examines the neighbour list of TBA cells and checks allocation criteria if there is space in their neighbour lists. A new GSM TBC transmitter can enter the TBA cell neighbour list if allocation criteria are satisfied. It will be the first one in the neighbour list.

Chapter 5

LTE Networks

This chapter describes LTE calculations.

In this chapter, the following are explained:

- "Definitions" on page 303
- "Calculation Quick Reference" on page 307
- "Available Calculations" on page 327
- "Calculation Details" on page 340
- "Automatic Planning Algorithms" on page 405

Chapter 5

5 LTE Networks

This chapter describes all the calculations performed in **9955** LTE documents. The first part of this chapter lists all the input parameters in the LTE documents, their significance, location in the **9955** GUI, and their usage. It also contains the lists of the formulas used for the calculations.

The second part describes all the calculation processes, i.e., signal level coverage predictions, point analysis calculations, signal quality coverage predictions, calculations on subscriber lists, and Monte Carlo simulations. The calculation algorithms used by these calculation processes are available in the next part.

The third part describes all the calculation algorithms used in all the calculations. These algorithms include the calculation of signal levels, noise, and interference for downlink and uplink considering power control, MIMO, smart antennas, and the radio resource management algorithms used by the different available schedulers.

If you are new to LTE, you can also see the *Glossary of LTE Terms* in the *User Manual* for information on LTE terms and concepts, especially in the context of their user in **9955**.

- All the calculations are performed on TBC (to be calculated) transmitters. For the definition of TBC transmitters please refer to "Path Loss Matrices" on page 98.
- A cell refers to a transmitter-carrier (TX-c) pair. The cell being studied during a calculation is referred to as $TX_i(ic)$ in this chapter.
- All the calculation algorithms in this section are described for two types of cells:
  - A *studied cell* (represented by the subscript "*i*") comprising the studied transmitter TX_i and its carrier *ic*. It is the cell which is currently the focus of the calculation. For example, a victim cell when calculating the interference it is receiving from other cells.
  - *Other cells* (represented by the subscript "*j*") comprising the other transmitter TX_j and its carrier *jc*. The other cells in the network can be interfering cells (downlink) or the serving cells of interfering mobiles (uplink).
- All the calculation algorithms in this section are described for two types of receivers:
  - M_i: A pixel (coverage predictions), subscriber (calculations on subscriber lists), or mobile (Monte Carlo simulations) covered/served by the studied cell $TX_i(ic)$.
  - M_j: A mobile (Monte Carlo simulations) covered/served by any other cell $TX_j(jc)$.
- Logarithms used in this chapter (Log function) are base-10 unless stated otherwise.

5.1 Definitions

This table lists the input to calculations, coverage predictions, and simulations.

Name	Value	Unit	Description
D_{Frame}	3GPP parameter (Fixed to 10 ms in **9955**)	ms	Frame duration
W_{FB}	3GPP parameter (Fixed to 180 kHz in **9955**)	kHz	Width of a resource/frequency block
ΔF	3GPP parameter (Fixed to 15 kHz in **9955**)	kHz	Subcarrier width
$N_{FB-SS, PBCH}$	3GPP parameter (Fixed to 6 in **9955**)	None	Number of frequency blocks for SS and PBCH transmission
$N_{SF/Frame}$	3GPP parameter (Fixed to 10 in **9955**)	None	Number of subframes per frame
$N_{Slots/SF}$	3GPP parameter (Fixed to 2 in **9955**)	None	Number of slots per subframe
K	1.38×10^{-23}	J/K	Boltzmann's constant
T	290	K	Ambient temperature
n_0	Calculation result ($10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$)	dBm/Hz	Power spectral density of thermal noise
D_{CP}	Global parameter	None	Default cyclic prefix duration
$N_{SD-PDCCH}$	Global parameter	SD	Number of PDCCH symbol durations per subframe
$N_{FB-PUCCH}$	Global parameter	RB	Average number of PUCCH frequency blocks per frame

Name	Value	Unit	Description
τ_{TDD}	Global parameter	None	Switching point periodicity for TDD frames
M_{PC}	Global parameter	dB	Uplink power control adjustment margin
CNR_{Min}	Global parameter[a]	dB	Minimum signal to thermal noise threshold (interferer cutoff)
$W_{Channel}$	Frequency band parameter	MHz	Channel bandwidth
$N_{Channel}^{First}$	Frequency band parameter	None	First channel number of the frequency band
$N_{Channel}^{Last}$	Frequency band parameter	None	Last channel number of the frequency band
$F_{Start-TDD}$	Frequency band parameter	MHz	Start frequency of the TDD frequency band
$F_{Start-FDD-DL}$	Frequency band parameter	MHz	DL start frequency of the FDD frequency band
$F_{Start-FDD-UL}$	Frequency band parameter	MHz	UL start frequency of the FDD frequency band
$F_{Sampling}$	Frequency band parameter	MHz	Sampling frequency
f_{ACS}	Frequency band parameter	dB	Adjacent channel suppression factor
N_{FB}	Frequency band parameter	None	Number of frequency blocks per channel bandwidth
$N_{SCa-Total}$	Calculation result ($N_{SCa-Total} = \frac{F_{Sampling}}{\Delta F}$)	None	Total number of subcarriers
$N_{SCa-Used}$	Calculation result ($N_{SCa-Used} = \frac{N_{FB} \times W_{FB}}{\Delta F}$)	None	Number of used subcarriers
N_{SCa-DC}	Hard-coded parameter ($N_{SCa-DC} = 1$)	None	Number of DC subcarriers
$N_{SCa-Guard}$	Calculation result ($N_{SCa-Guard} = N_{SCa-Total} - N_{SCa-Used} - N_{SCa-DC}$)	None	Number of guard subcarriers
B	Bearer parameter	None	Bearer index
Mod_B	Bearer parameter	None	Modulation used by the bearer
CR_B	Bearer parameter	None	Coding rate of the bearer
η_B	Bearer parameter	bits/ symbol	Bearer efficiency
T_B	Bearer parameter	dB	Bearer selection threshold
nf^{TX}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	dB	Transmitter noise figure
N_{Ant-TX}	Transmitter parameter	None	Number of antenna ports used for transmission
N_{Ant-RX}	Transmitter parameter	None	Number of antenna ports used for reception
G^{TX}	Transmitter antenna parameter	dB	Antenna gain
L^{TX}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	dB	Transmitter loss
E_{SA}^{TX}	Smart antenna parameter	None	Number of smart antenna elements
ΔG_{SA}^{Array}	Smart antenna parameter	dB	Array gain offset
$\Delta G_{SA}^{Combining}$	Smart antenna parameter	dB	Power combining gain offset

Name	Value	Unit	Description
G_{SA}^{Div}	Smart antenna parameter	dB	Diversity gain (cross-polarisation)
$N_{Channel}$	Cell parameter	None	Cell's channel number
ID_{φ}	Cell parameter	None	Cell's physical ID
ID_{SSS}	Cell parameter: $Floor\left(\frac{ID_{\varphi}}{3}\right)$	None	Cell's SSS ID (one of 168 pseudo-random sequences)
ID_{PSS}	Cell parameter: $ID_{\varphi}\ Mod\ 3$	None	Cell's PSS ID (one of 3 cyclic shifts of the sequence given by the SSS ID)
ν_{Shift}	Cell parameter: $ID_{\varphi}\ Mod\ 6$	None	Cell's v shift (also known as the reference signal hopping index)
P_{Max}	Cell parameter	dBm	Maximum cell transmission power
$EPRE_{DLRS}$	Cell parameter	dBm	Energy per resource element for the downlink reference signals (User-defined or calculated)
$\Delta EPRE_{SS}$	Cell parameter	dB	Energy per resource element offset for the SS with respect to the downlink reference signal EPRE
$\Delta EPRE_{PBCH}$	Cell parameter	dB	Energy per resource element offset for the PBCH with respect to the downlink reference signal EPRE
$\Delta EPRE_{PDCCH}$	Cell parameter	dB	Energy per resource element offset for the PDCCH with respect to the downlink reference signal EPRE
$\Delta EPRE_{PDSCH}$	Cell parameter	dB	Energy per resource element offset for the PDSCH with respect to the downlink reference signal EPRE
T_{RSRP}	Cell parameter	dB	Minimum Required RSRP
TL_{DL}	Cell parameter	%	Downlink traffic load
$r_{DL-ICIC}$	Cell parameter	%	Downlink ICIC ratio
TL_{UL}	Cell parameter	%	Uplink traffic load
TL_{DL-Max}	Cell parameter	%	Maximum downlink traffic load
TL_{UL-Max}	Cell parameter	%	Maximum uplink traffic load
NR_{UL}	Cell parameter	dB	Uplink noise rise
$NR_{UL-ICIC}$	Cell parameter	dB	ICIC uplink noise rise
NR_{UL-Max}	Cell parameter	dB	Maximum uplink noise rise
$N_{Users-Max}$	Cell parameter	None	Maximum number of users per cell
$N_{Users-DL}$	Cell parameter	None	Number of users connected to the cell in downlink
$N_{Users-UL}$	Cell parameter	None	Number of users connected to the cell in uplink
T_{AMS}	Cell parameter	dB	Adaptive MIMO switch threshold
$T_{MU-MIMO}$	Cell parameter	dB	Multi-user MIMO threshold
ΔL_{Path}	Cell parameter	dB	Delta path loss threshold
N_{SF-DL}	Cell parameter	None	Number of downlink subframes per frame
N_{SF-UL}	Cell parameter	None	Number of uplink subframes per frame

Name	Value	Unit	Description
$N_{TDD-SSF}^{TX_i(ic)}$	Cell parameter	None	Number of TDD special subframes per frame
D_{Reuse}	Cell parameter	m	Channel and physical cell ID reuse distance
$G_{MU-MIMO}$	Cell parameter	None	Uplink MU-MIMO gain
α_{FPC}	Cell parameter	None	Fractional power control factor
$CINR_{PUSCH-Max}$	Cell parameter	dB	Maximum PUSCH C/(I+N)
$NR_{DL}^{Inter-Tech}$	Cell parameter	dB	Inter-technology downlink noise rise
$NR_{UL}^{Inter-Tech}$	Cell parameter	dB	Inter-technology uplink noise rise
AU_{DL}	Cell parameter	%	Downlink AAS usage ratio
$G_{MUG-DL}^{TX_i(ic)}$	Proportional Fair scheduler parameter	None	Downlink multi-user diversity gain (MUG)
$G_{MUG-UL}^{TX_i(ic)}$	Proportional Fair scheduler parameter	None	Uplink multi-user diversity gain (MUG)
$CINR_{MUG}^{Max}$	Proportional Fair scheduler parameter	dB	Maximum C/(I+N) above which no MUG gain is applied
$G_{SU-MIMO}^{Max}$	Cell LTE equipment parameter	None	Maximum uplink SU-MIMO gain
G_{Div}^{UL}	Cell LTE equipment parameter	dB	Uplink diversity gain
p	Service parameter	None	Service priority
$B_{DL-Highest}$	Service parameter	None	Highest bearer used by a service in the downlink
$B_{UL-Highest}$	Service parameter	None	Highest bearer used by a service in the uplink
$B_{DL-Lowest}$	Service parameter	None	Lowest bearer used by a service in the downlink
$B_{UL-Lowest}$	Service parameter	None	Lowest bearer used by a service in the uplink
f_{Act}^{UL}	Service parameter	%	Uplink activity factor
f_{Act}^{DL}	Service parameter	%	Downlink activity factor
TPD_{Min-UL}	Service parameter	kbps	Minimum throughput demand in the uplink (Guaranteed Bit Rate, GBR)
TPD_{Min-DL}	Service parameter	kbps	Minimum throughput demand in the downlink (Guaranteed Bit Rate, GBR)
TPD_{Max-UL}	Service parameter	kbps	Maximum throughput demand in the uplink (Maximum Bit Rate, MBR)
TPD_{Max-DL}	Service parameter	kbps	Maximum throughput demand in the downlink (Maximum Bit Rate, MBR)
$TP_{Average}^{UL}$	Service parameter	kbps	Average requested throughput in the uplink
$TP_{Average}^{DL}$	Service parameter	kbps	Average requested throughput in the downlink
TP_{Offset}	Service parameter	kbps	Throughput offset
$f_{TP-Scaling}$	Service parameter	%	Scaling factor
L_{Body}	Service parameter	dB	Body loss
P_{Min}	Terminal parameter	dBm	Minimum terminal power

Name	Value	Unit	Description
P_{Max}	Terminal parameter	dBm	Maximum terminal power
nf	Terminal parameter	dB	Terminal noise figure
G	Terminal parameter	dB	Terminal antenna gain
L	Terminal parameter	dB	Terminal loss
N_{Ant-TX}	Terminal parameter	None	Number of antenna ports for transmission
N_{Ant-RX}	Terminal parameter	None	Number of antenna ports for reception
$N_{TBB/TTI}^{Max-DL}$	UE category parameter	Bits	Maximum number of transport block bits per TTI (subframe) in downlink
$N_{TBB/TTI}^{Max-UL}$	UE category parameter	Bits	Maximum number of transport block bits per TTI (subframe) in uplink
Mod_{UE}^{Max-UL}	UE category parameter	None	Highest modulation supported in uplink
N_{Ant-UE}^{Max-DL}	UE category parameter	None	Maximum number of reception antenna ports supported in downlink
$G_{SU-MIMO}^{Max}$	Terminal LTE equipment parameter	None	Maximum downlink SU-MIMO gain
G_{Div}^{DL}	Terminal LTE equipment parameter	dB	Downlink diversity gain
ΔG_{Div}^{UL}	Clutter parameter	dB	Additional uplink diversity gain
ΔG_{Div}^{DL}	Clutter parameter	dB	Additional downlink diversity gain
$f_{SU-MIMO}$	Clutter parameter	None	SU-MIMO gain factor
L_{Indoor}	Clutter parameter	dB	Indoor loss
L_{Path}	Propagation model result	dB	Path loss
$M_{Shadowing-Model}$	Monte Carlo simulations: Random result calculated from model standard deviation Coverage Predictions: Result calculated from cell edge coverage probability and model standard deviation	dB	Model shadowing margin
$M_{Shadowing-C/I}$	Coverage Predictions: Result calculated from cell edge coverage probability and C/I standard deviation	dB	C/I shadowing margin

a. *Any interfering cell whose signal to thermal noise ratio is less than* CNR_{Min} *will be discarded.*

5.2 Calculation Quick Reference

The following tables list the formulas used in calculations.

5.2.1 Downlink Transmission Powers Calculation

Name	Value	Unit	Description
$N_{Sym/SRB}$	$N_{SCa-FB} \times N_{SD/Slot} \times N_{Slot/SF}$	None	Number of symbols per scheduler resource block
$N_{Sym/SSF}^{DwPTS}$	$N_{SCa-FB} \times N_{SD/SSF}^{DwPTS}$	None	Number of DwPTS modulation symbols per scheduler resource block in the TDD special subframes
N_{SCa-FB}	$\frac{W_{FB}}{\Delta F}$	None	Number of subcarriers per frequency block
$N_{Sym-DL}^{TX_i(ic)}$	$N_{FB}^{TX_i(ic)} \times N_{Sym/SRB} \times N_{SF-DL}^{TX_i(ic)} + N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)} \times N_{Sym/SSF}^{DwPTS}$	None	Total number of symbols in downlink

Name	Value	Unit	Description
$N_{Res/SRB}^{TX_i(ic)}$	$\begin{cases} 8 & if\ \left(N_{Ant-TX}^{TX_i(ic)} = 1\right) \\ 16 & if\ \left(N_{Ant-TX}^{TX_i(ic)} = 2\right) \\ 24 & if\ \left(N_{Ant-TX}^{TX_i(ic)} = 4\ or\ 8\right) \end{cases}$	None	Number of symbols reserved for downlink reference signals in one scheduler resource block
$N_{Res/DwPTS}^{TX_i(ic)}$	See "Downlink Transmission Power Calculation" on page 340	None	Number of symbols reserved for downlink reference signals in DwPTS of one TDD special subframe
$N_{Sym-Res}^{TX_i(ic)}$	$N_{SF-DL}^{TX_i(ic)} \times N_{FB}^{TX_i(ic)} \times N_{Res/SRB}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)} \times N_{FB}^{TX_i(ic)} \times N_{Res/DwPTS}^{TX_i(ic)}$	None	Number of symbols reserved for downlink reference signals in one frame
$N_{DLRS/SRB}^{TX_i(ic)}$	$\begin{cases} 8 & if\ \left(N_{Ant-TX}^{TX_i(ic)} = 1\right) \\ 8 & if\ \left(N_{Ant-TX}^{TX_i(ic)} = 2\right) \\ 6 & if\ \left(N_{Ant-TX}^{TX_i(ic)} = 4\ or\ 8\right) \end{cases}$	None	Number of symbols for downlink reference signals in one scheduler resource block
$N_{DLRS/DwPTS}^{TX_i(ic)}$	See "Downlink Transmission Power Calculation" on page 340	None	Number of symbols for downlink reference signals in DwPTS of one TDD special subframe
$N_{Sym-DLRS}^{TX_i(ic)}$	$N_{SF-DL}^{TX_i(ic)} \times N_{FB}^{TX_i(ic)} \times N_{DLRS/SRB}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)} \times N_{FB}^{TX_i(ic)} \times N_{DLRS/DwPTS}^{TX_i(ic)}$	None	Number of symbols for downlink reference signals in one frame
N_{Sym-SS}	$N_{Sym-PSS} + N_{Sym-SSS} = 288$ Where $N_{Sym-PSS} = 2 \times N_{FB-SS,\ PBCH} \times N_{SCa-FB} = 144$ $N_{Sym-SSS} = 2 \times N_{FB-SS,\ PBCH} \times N_{SCa-FB} = 144$	None	Number of symbols for the PSS and the SSS
$N_{Sym-PBCH}^{TX_i(ic)}$	Extended CP: $\left(4 \times N_{SCa-FB} - \frac{N_{Res/SRB}^{TX_i(ic)}}{2}\right) \times N_{FB-SS,\ PBCH}$ Normal CP: $\left(4 \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB-SS,\ PBCH}$	None	Number of symbols for the PBCH
$N_{Sym-PDCCH}^{TX_i(ic)}$	$if\ \ (N_{SD-PDCCH} = 0) : 0$ $if\ \ (N_{SD-PDCCH} = 1)\ AND \left(N_{Ant-TX}^{TX_i(ic)} = 4\ or\ 8\right) :$ $\left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)}$ $+ \left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$ Otherwise: $\left(N_{SD-PDCCH} \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)}$ $+ \left(Min(2, N_{SD-PDCCH}) \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$	None	Number of symbols for the PDCCH
$N_{Sym-PDSCH}^{TX_i(ic)}$	$N_{Sym-DL}^{TX_i(ic)} - N_{Sym-Res}^{TX_i(ic)} - N_{Sym-SS} - N_{Sym-PBCH}^{TX_i(ic)} - N_{Sym-PDCCH}^{TX_i(ic)}$	None	Number of symbols for the PDSCH

Name	Value	Unit	Description
$EPRE_{DLRS}^{TX_i(ic)}$	$10\times Log\left(10^{\frac{P_{Max}^{TX_i(ic)}}{10}}\times N_{SD/Slot}\times N_{Slot/SF}\times N_{SF-DL}^{TX_i(ic)}\right) - 10\times Log\left(N_{Sym-DLRS}^{TX_i(ic)}+N_{Sym-SS}\times 10^{\frac{\Delta EPRE_{SS}^{TX_i(ic)}}{10}}+N_{Sym-PBCH}\times 10^{\frac{\Delta EPRE_{PBCH}^{TX_i(ic)}}{10}}+N_{Sym-PDCCH}\times 10^{\frac{\Delta EPRE_{PDCCH}^{TX_i(ic)}}{10}}+N_{Sym-PDSCH}\times 10^{\frac{\Delta EPRE_{PDSCH}^{TX_i(ic)}}{10}}\right)$	dBm/Sym	Energy per resource element for 1 modulation symbol (dBm/Sym) of the downlink reference signals With reference signal EPRE calculation method is set to Calculated (equal distribution of unused EPRE)
$EPRE_{DLRS}^{TX_i(ic)}$	$10\times Log\left(10^{\frac{P_{Max}^{TX_i(ic)}}{10}}\times N_{SD/Slot}\times N_{Slot/SF}\times N_{SF-DL}^{TX_i(ic)}\right) - 10\times Log\left(N_{Sym-Res}^{TX_i(ic)}+N_{Sym-SS}\times 10^{\frac{\Delta EPRE_{SS}^{TX_i(ic)}}{10}}+N_{Sym-PBCH}\times 10^{\frac{\Delta EPRE_{PBCH}^{TX_i(ic)}}{10}}+N_{Sym-PDCCH}\times 10^{\frac{\Delta EPRE_{PDCCH}^{TX_i(ic)}}{10}}+N_{Sym-PDSCH}\times 10^{\frac{\Delta EPRE_{PDSCH}^{TX_i(ic)}}{10}}\right)$	dBm/Sym	Energy per resource element for 1 modulation symbol (dBm/Sym) of the downlink reference signals With reference signal EPRE calculation method is set to Calculated (with boost) or Calculated (without boost)
$EPRE_{SS}^{TX_i(ic)}$	$EPRE_{DLRS}^{TX_i(ic)}+\Delta EPRE_{SS}^{TX_i(ic)}$	dBm/Sym	Energy per resource element for 1 modulation symbol (dBm/Sym) of the SS
$EPRE_{PBCH}^{TX_i(ic)}$	$EPRE_{DLRS}^{TX_i(ic)}+\Delta EPRE_{PBCH}^{TX_i(ic)}$	dBm/Sym	Energy per resource element for 1 modulation symbol (dBm/Sym) of the PBCH
$EPRE_{PDCCH}^{TX_i(ic)}$	$EPRE_{DLRS}^{TX_i(ic)}+\Delta EPRE_{PDCCH}^{TX_i(ic)}$	dBm/Sym	Energy per resource element for 1 modulation symbol (dBm/Sym) of the PDCCH
$EPRE_{PDSCH}^{TX_i(ic)}$	$EPRE_{DLRS}^{TX_i(ic)}+\Delta EPRE_{PDSCH}^{TX_i(ic)}$	dBm/Sym	Energy per resource element for 1 modulation symbol (dBm/Sym) of the PDSCH
$EPRE_{DLRS}^{TX_i(ic)}$	$EPRE_{DLRS}^{TX_i(ic)}+10\times Log\left(\frac{N_{Sym-Res}^{TX_i(ic)}}{N_{Sym-DLRS}^{TX_i(ic)}}\right)$	dbm/Sym	"Boosted" energy per resource element for 1 modulation symbol (dBm/Sym) of downlink reference signals when the reference signal EPRE calculation method is set to Calculated (with boost)
$P_{DLRS}^{TX_i(ic)}$	$EPRE_{DLRS}^{TX_i(ic)}+10\times Log\left(2\times N_{FB}^{TX_i(ic)}\right)$	dBm	Instantaneous transmission power of the downlink reference signals
$P_{SS}^{TX_i(ic)}$	$EPRE_{SS}^{TX_i(ic)}+10\times Log(N_{SCa-FB}\times N_{FB-SS,PBCH})$	dBm	Instantaneous transmission power of the SS
$P_{PBCH}^{TX_i(ic)}$	$EPRE_{PBCH}^{TX_i(ic)}+10\times Log(N_{SCa-FB}\times N_{FB-SS,PBCH})$	dBm	Instantaneous transmission power of the PBCH
$P_{PDCCH}^{TX_i(ic)}$	$EPRE_{PDCCH}^{TX_i(ic)}+10\times Log\left(\frac{N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SD-PDCCH}\times N_{SF-DL}^{TX_i(ic)}}\right)$	dBm	Average transmission power of the PDCCH

Name	Value	Unit	Description
$P_{PDSCH}^{TX_i(ic)}$	$EPRE_{PDSCH}^{TX_i(ic)} + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)}}{(N_{SD/Slot} \times N_{Slot/SF} - N_{SD-PDCCH}) \times N_{SF-DL}^{TX_i(ic)}}\right)$	dBm	Average transmission power of the PDSCH

5.2.2 Co- and Adjacent Channel Overlaps Calculation

Name	Value	Unit	Description
$F_{Start}^{TX_i(ic)}$	$F_{Start-Band}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First}\right)$	MHz	Start frequency for the channel number assigned to a cell
$F_{End}^{TX_i(ic)}$	$F_{Start-Band}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First} + 1\right)$	MHz	End frequency for the channel number assigned to a cell
$W_{CCO}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right)$	MHz	Co-channel overlap bandwidth
$r_{CCO}^{TX_i(ic)-TX_j(jc)}$	$\frac{W_{CCO}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Co-channel overlap ratio
$W_{ACO_L}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)}\right)$	MHz	Bandwidth of the lower-frequency adjacent channel overlap
$r_{ACO_L}^{TX_i(ic)-TX_j(jc)}$	$\frac{W_{ACO_L}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Lower-frequency adjacent channel overlap ratio
$W_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right)$	MHz	Bandwidth of the higher-frequency adjacent channel overlap
$r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	$\frac{W_{ACO_H}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Higher-frequency adjacent channel overlap ratio
$r_{ACO}^{TX_i(ic)-TX_j(jc)}$	$r_{ACO_L}^{TX_i(ic)-TX_j(jc)} + r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	None	Adjacent channel overlap ratio
$r_O^{TX_i(ic)-TX_j(jc)}$	$\left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS}^{TX_i(ic)}}{10}}\right)$ if $W_{Channel}^{TX_i(ic)} \ge W_{Channel}^{TX_j(jc)}$ $\left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS}^{TX_i(ic)}}{10}}\right) \times \frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ if $W_{Channel}^{TX_i(ic)} < W_{Channel}^{TX_j(jc)}$	None	Total overlap ratio

5.2.3 Signal Level Calculation (DL)

The received signal levels (dBm) from any cell $TX_i(ic)$ are calculated for a pixel, subscriber, or mobile M_i as follows:

Name	Value	Unit	Description
$C_{Max}^{TX_i(ic)}$	$EIRP_{Max}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm	Received max cell power
$EIRP_{Max}^{TX_i(ic)}$	Without smart antennas: $P_{Max}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $P_{Max}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dbm	Downlink max EIRP
$C_{DLRS}^{TX_i(ic)}$	$EIRP1_{DLRS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm	Received downlink reference signal level
$EIRP1_{DLRS}^{TX_i(ic)}$	Without smart antennas: $P_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $P_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining}$	dBm	RS EIRP
$C_{SS}^{TX_i(ic)}$	$EIRP1_{SS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm	Received SS signal level
$EIRP1_{SS}^{TX_i(ic)}$	Without smart antennas: $P_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $P_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dBm	SS EIRP
$C_{PBCH}^{TX_i(ic)}$	$EIRP1_{PBCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm	Received PBCH signal level
$EIRP1_{PBCH}^{TX_i(ic)}$	Without smart antennas: $P_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $P_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dBm	PBCH EIRP
$C_{PDCCH}^{TX_i(ic)}$	$EIRP1_{PDCCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm	Received PDCCH signal level
$EIRP1_{PDCCH}^{TX_i(ic)}$	Without smart antennas: $P_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $P_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dBm	PDCCH EIRP
$C_{PDSCH}^{TX_i(ic)}$	$EIRP1_{PDSCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm	Received PDSCH signal level
$EIRP1_{PDSCH}^{TX_i(ic)}$	Without smart antennas: $P_{PDSCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $P_{PDSCH}^{TX_i(ic)} + G_{SA}^{TX_i}(\theta) + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$	dBm	PDSCH EIRP
$E_{DLRS}^{TX_i(ic)}$	$EIRP2_{DLRS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm/Sym	Received downlink reference signal energy per resource element (RSRP)

Name	Value	Unit	Description
$EIRP2_{DLRS}^{TX_i(ic)}$	Without smart antennas: $EPRE_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $EPRE_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining}$	dBm/Sym	RS EIRP
$E_{SS}^{TX_i(ic)}$	$EIRP2_{SS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model}$ $- L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm/Sym	Received SS energy per resource element
$EIRP2_{SS}^{TX_i(ic)}$	Without smart antennas: $EPRE_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $EPRE_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dBm/Sym	SS EIRP
$E_{PBCH}^{TX_i(ic)}$	$EIRP2_{PBCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model}$ $- L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm/Sym	Received PBCH energy per resource element
$EIRP2_{PBCH}^{TX_i(ic)}$	Without smart antennas: $EPRE_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $EPRE_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dBm/Sym	PBCH EIRP
$E_{PDCCH}^{TX_i(ic)}$	$EIRP2_{PDCCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model}$ $- L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm/Sym	Received PDCCH energy per resource element
$EIRP2_{PDCCH}^{TX_i(ic)}$	Without smart antennas: $EPRE_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $EPRE_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dBm/Sym	PDCCH EIRP
$E_{PDSCH}^{TX_i(ic)}$	$EIRP2_{PDSCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model}$ $- L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm/Sym	Received PDSCH energy per resource element
$EIRP2_{PDSCH}^{TX_i(ic)}$	Without smart antennas: $EPRE_{PDSCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$ With smart antennas: $EPRE_{PDSCH}^{TX_i(ic)} + G_{SA}^{TX_i}(\theta) + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$	dBm/Sym	PDSCH EIRP
L_{Path}	$L_{Model} + L_{Ant}^{TX_i}$	dB	Path loss
L_{Total}	$L_{Path} + L^{TX_i} + L_{Indoor} + M_{Shadowing-Model} - G^{TX_i}$ $+ L^{M_i} - G^{M_i} + L_{Ant}^{M_i} + L_{Body}^{M_i}$	dB	Total losses
f_{CP}	$10 \times Log(7/7.5)$ If $D_{CP} = Normal$ $10 \times Log(6/7.5)$ If $D_{CP} = Extended$ 0 If $TX_i(ic)$ is an interferer	dB	Cyclic prefix factor, i.e., the ratio of the useful symbol energy to the total symbol energy

5.2.4 Noise Calculation (DL)

Name	Value	Unit	Description
$n_{0-Sym}^{TX_i(ic)}$	$n_0 + 10 \times Log(\Delta F)$	dBm	Thermal noise for one resource element

Name	Value	Unit	Description
$n_{Sym}^{TX_i(ic)}$	$n_{0-Sym}^{TX_i(ic)} + nf^{M_i}$	dBm	Downlink noise for one resource element

5.2.5 Interference Calculation (DL)

Name	Value	Unit	Description
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)}}{N_{Ant-TX}^{TX_j(jc)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 1: synchronised transmission and reception) Case: RS of the interfered cell collide only with RS of the interfering cell
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(\frac{N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)} + 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)} - N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times \frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} + 3 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}}{4}\right)$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 1: synchronised transmission and reception) Case: RS of the interfered cell collide with RS, PDCCH, and PDSCH of the interfering cell With 1 or 2 antenna ports
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(\frac{N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)} + 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)} - N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times \frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} + 5 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}}{6}\right)$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 1: synchronised transmission and reception) Case: RS of the interfered cell collide with RS, PDCCH, and PDSCH of the interfering cell With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} = 1$
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(\frac{N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)} + 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)} - N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times \frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} + 2 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}}{3}\right)$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 1: synchronised transmission and reception) Case: RS of the interfered cell collide with RS, PDCCH, and PDSCH of the interfering cell With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} > 1$
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(\frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} + 3 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}}{4}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 1: synchronised transmission and reception) Case: RS of the interfered cell collide with PDCCH and PDSCH of the interfering cell With 1 or 2 antenna ports

Name	Value	Unit	Description
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(\frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} + 5 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}}{6}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 1: synchronised transmission and reception) Case: RS of the interfered cell collide with PDCCH and PDSCH of the interfering cell With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} = 1$
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(\frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} + 2 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}}{3}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 1: synchronised transmission and reception) Case: RS of the interfered cell collide with PDCCH and PDSCH of the interfering cell With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} > 1$
$\varepsilon_{SS,\,PBCH}^{TX_j(jc)}$	$10 \times Log\left(\frac{10^{\frac{E_{SS}^{TX_j(jc)}}{10}} \times N_{Sym-SS} + 10^{\frac{E_{PBCH}^{TX_j(jc)}}{10}} \times N_{Sym-PBCH}^{TX_j(jc)}}{N_{Sym-SS} + N_{Sym-PBCH}^{TX_j(jc)}}\right) + f_O^{TX_i(ic)-TX_j(jc)} + f_{MIMO}^{TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the SS and the PBCH (Method 1: synchronised transmission and reception)
$\varepsilon_{PDCCH}^{TX_j(jc)}$	$10 \times Log\left(\frac{1}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDCCH}^{TX_j(jc)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$ $+ 10 \times Log\left(\frac{N_{Sym-PDCCH}^{TX_i(ic)} - N_{Sym-DLRS\ in\ PDCCH}^{TX_j(jc)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right)$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDCCH (Method 1: synchronised transmission and reception) Case: PDCCH of the interfered cell collides with PDCCH and all the RS of the interfering cell
$\varepsilon_{PDCCH}^{TX_j(jc)}$	$10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)}}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDCCH}^{TX_j(jc)} - N_{Sym-DLRS\ in\ PDCCH}^{TX_i(ic)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right)$ $+ 10 \times Log\left(\frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDCCH (Method 1: synchronised transmission and reception) Case: PDCCH of the interfered cell collides with PDCCH and some RS of the interfering cell
$\varepsilon_{PDCCH}^{TX_j(jc)}$	$E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDCCH (Method 1: synchronised transmission and reception) Case: PDCCH of the interfered cell collides only with PDCCH of the interfering cell

Name	Value	Unit	Description
$\varepsilon_{PDSCH}^{TX_j(jc)}$	$10 \times Log\left(\frac{1}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$ $+ 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)} - N_{Sym-DLRS\ in\ PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right)$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDSCH (Method 1: synchronised transmission and reception) Case: PDSCH of the interfered cell collides with PDSCH and all the RS of the interfering cell
$\varepsilon_{PDSCH}^{TX_j(jc)}$	$10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)}}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDSCH}^{TX_j(jc)} - N_{Sym-DLRS\ in\ PDSCH}^{TX_i(ic)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right)$ $+ 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDSCH (Method 1: synchronised transmission and reception) Case: PDSCH of the interfered cell collides with PDSCH and some RS of the interfering cell
$\varepsilon_{PDSCH}^{TX_j(jc)}$	$E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDSCH (Method 1: synchronised transmission and reception) Case: PDSCH of the interfered cell collides only with PDSCH of the interfering cell
$\varepsilon_{DLRS}^{TX_j(jc)}$	$10 \times Log\left(10^{\frac{E_{DLRS}^{TX_j(jc)} + G_{RS\_Ant\_Div}^{TX_j(jc)}}{10}} \times \frac{N_{Sym-DLRS}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}}\right.$ $\left. + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over downlink reference signals (Method 2: non-synchronised transmission and reception)
$\varepsilon_{SS,\ PBCH}^{TX_j(jc)}$	$10 \times Log\left(\frac{10^{\frac{E_{SS}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times N_{Sym-SS} + 10^{\frac{E_{PBCH}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times N_{Sym-PBCH}^{TX_j(jc)}}{N_{Sym-SS} + N_{Sym-PBCH}^{TX_j(jc)}} \times \left(1 - f_{DC-SCa-Shift}^{TX_i(ic)-TX_j(jc)}\right)\right.$ $\left. + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times f_{DC-SCa-Shift}^{TX_i(ic)-TX_j(jc)}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the SS and the PBCH (Method 2: non-synchronised transmission and reception)
$\varepsilon_{PDCCH}^{TX_j(jc)}$	$10 \times Log\left(10^{\frac{E_{DLRS}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times \frac{N_{Sym-DLRS}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}}\right.$ $\left. + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDCCH (Method 2: non-synchronised transmission and reception)

Name	Value	Unit	Description
$\varepsilon_{PDSCH}^{TX_j(jc)}$	$10 \times Log\left(10^{\frac{E_{DLRS}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times \frac{N_{Sym-DLRS}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/Sym	Interfering energy per resource element (dBm/Sym) received over the PDSCH (Method 2: non-synchronised transmission and reception)
$\varepsilon_{RSSI}^{TX_j(jc)}$	$10 \times Log\left(10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_j(jc)} + N_{Sym-PDCCH}^{TX_j(jc)}} \times 10 + 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_j(jc)} + N_{Sym-PDCCH}^{TX_j(jc)}} \times 10 + 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}} \times N_{Ant-TX}^{TX_j(jc)} \times 2\right) + f_O^{TX_i(ic)-TX_j(jc)}$	dBm/RB	Interfering energy per frequency block (dBm/RB) received over 1 frequency block during an OFDM symbol carrying reference signals For number of antenna ports > 1, 8 is used instead of encircled 10
$f_{PDCCH}^{TX_i(ic)-TX_j(jc)}$	$\left\{\left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{RS\_Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}}\right\}$	dB	PDCCH interference weighting factor for calculating $\varepsilon_{DLRS}^{TX_j(jc)}$
$f_{PDSCH}^{TX_i(ic)-TX_j(jc)}$	$\left\{\left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{RS\_Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{\left(G_{SA}^{TX_j}(\varphi) - G_{SA}^{TX_j}(\theta)\right) + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}}\right\}$	dB	PDSCH interference weighting factor for calculating $\varepsilon_{DLRS}^{TX_j(jc)}$
$f_{PDCCH}^{TX_i(ic)-TX_j(jc)}$	$\left\{\left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}}\right\}$	dB	PDCCH interference weighting factor for calculating $\varepsilon_{SS,PBCH}^{TX_j(jc)}$, $\varepsilon_{PDCCH}^{TX_j(jc)}$, and $\varepsilon_{PDSCH}^{TX_j(jc)}$
$f_{PDSCH}^{TX_i(ic)-TX_j(jc)}$	$\left\{\left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{\left(G_{SA}^{TX_j}(\varphi) - G_{SA}^{TX_j}(\theta)\right) + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}}\right\}$	dB	PDSCH interference weighting factor for calculating $\varepsilon_{SS,PBCH}^{TX_j(jc)}$, $\varepsilon_{PDCCH}^{TX_j(jc)}$, and $\varepsilon_{PDSCH}^{TX_j(jc)}$
$f_{PDCCH}^{TX_i(ic)-TX_j(jc)}$	$\left\{\left(1 - AU_{DL}^{TX_j(jc)}\right) \times N_{Ant-TX}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}}\right\}$	dB	PDCCH interference weighting factor for calculating $\varepsilon_{RSSI}^{TX_j(jc)}$
$f_{PDSCH}^{TX_i(ic)-TX_j(jc)}$	$\left\{\left(1 - AU_{DL}^{TX_j(jc)}\right) \times N_{Ant-TX}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{\left(G_{SA}^{TX_j}(\varphi) - G_{SA}^{TX_j}(\theta)\right) + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}}\right\}$	dB	PDSCH interference weighting factor for calculating $\varepsilon_{RSSI}^{TX_j(jc)}$

Name	Value	Unit	Description
$f_{DC-SCa-Shift}^{TX_i(ic)-TX_j(jc)}$	$Min\left(1, \left\lvert\frac{F_{Centre}^{TX_i(ic)} - F_{Centre}^{TX_j(jc)}}{N_{FB-SS,PBCH} \times W_{FB}}\right\rvert\right)$	None	DC subcarrier shift factor
$F_{Centre}^{TX_i(ic)}$	$F_{Start-Band}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)} + \frac{1}{2}\right)$	MHz	Centre frequency of the channel used by $TX_i(ic)$
$f_O^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to channel overlap
$f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(p_{Collision}^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to static downlink ICIC using fractional frequency reuse
$f_{TL}^{TX_j(jc)}$	$10 \times Log\left(TL_{DL}^{TX_j(jc)}\right)$	dB	Interference reduction factor due to the downlink traffic load
$G_{RS\_Ant\_Div}^{TX_j(jc)}$	$10 \times Log\left(N_{Ant-TX}^{TX_j(jc)}\right)$	dB	Diversity gain due to more than one transmission antenna port applied on interfering signals received by RS
$G_{Ant\_Div}^{TX_j(jc)}$	$10 \times Log\left(N_{Ant-TX}^{TX_j(jc)}\right)$	dB	Interference increment due to more than one transmission antenna port

5.2.6 C/N Calculation (DL)

Name	Value	Unit	Description
$CNR_{DLRS}^{TX_i(ic)}$	$E_{DLRS}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$	dB	Downlink reference signals C/N
$CNR_{SS}^{TX_i(ic)}$	$E_{SS}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$	dB	SS C/N
$CNR_{PBCH}^{TX_i(ic)}$	$E_{PBCH}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$	dB	PBCH C/N
$CNR_{PDCCH}^{TX_i(ic)}$	$E_{PDCCH}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$	dB	PDCCH C/N
$CNR_{PDSCH}^{TX_i(ic)}$	$E_{PDSCH}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$ With Transmit Diversity: $CNR_{PDSCH}^{TX_i(ic)} = CNR_{PDSCH}^{TX_i(ic)} + G_{Div}^{DL} + \Delta G_{Div}^{DL}$ With AMS *if* $CNR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CNR_{PDSCH}^{TX_i(ic)} = CNR_{PDSCH}^{TX_i(ic)} + G_{Div}^{DL} + \Delta G_{Div}^{DL}$	dB	PDSCH C/N

5.2.7 C/(I+N) Calculation (DL)

Name	Value	Unit	Description
$CINR_{DLRS}^{TX_i(ic)}$	$E_{DLRS}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{DLRS}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$	dB	Downlink reference signals C/(I+N)
$CINR_{SS}^{TX_i(ic)}$	$E_{SS}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{SS,PBCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$	dB	SS C/(I+N)

Name	Value	Unit	Description
$CINR_{PBCH}^{TX_i(ic)}$	$E_{PBCH}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{SS,\ PBCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$	dB	PBCH C/(I+N)
$CINR_{PDCCH}^{TX_i(ic)}$	$E_{PDCCH}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDCCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$	dB	PDCCH C/(I+N)
$CINR_{PDSCH}^{TX_i(ic)}$	$E_{PDSCH}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDSCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$ With Transmit Diversity: $CINR_{PDSCH}^{TX_i(ic)} = CINR_{PDSCH}^{TX_i(ic)} + G_{Div}^{DL} + \Delta G_{Div}^{DL}$ With AMS *if* $CNR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CINR_{PDSCH}^{TX_i(ic)} = CINR_{PDSCH}^{TX_i(ic)} + G_{Div}^{DL} + \Delta G_{Div}^{DL}$	dB	PDSCH C/(I+N)
$G_{Useful\_Ant\_Div}^{TX_i(ic)}$	$10 \times Log\left(N_{Ant-TX}^{TX_i(ic)}\right)$	dB	Diversity gain due to more than one transmission antenna port applied on desired signal
$RSRQ^{TX_i(ic)}$	$10 \times Log\left(N_{FB}^{TX_i(ic)}\right) + E_{DLRS}^{TX_i(ic)} - RSSI^{TX_i(ic)}$	dB	Reference signal received quality (RSRQ)
$RSSI^{TX_i(ic)}$	$10 \times Log\left(\varepsilon_{RSSI}^{TX_i(ic)} + \sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{RSSI}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) +$ $NR_{DL}^{Inter-Tech} + 10 \times Log\left(N_{FB}^{TX_i(ic)}\right)$	dBm	Received signal strength indicator (RSSI)
$(I+N)_{DLRS}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{DLRS}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right)$ $+ NR_{DL}^{Inter-Tech} + 10 \times Log\left(2 \times N_{FB}^{TX_i(ic)}\right)$	dBm	Downlink reference signals total noise (I+N)
$(I+N)_{SS,\ PBCH}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{SS,\ PBCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right)$ $+ NR_{DL}^{Inter-Tech} + 10 \times Log(N_{SCa-FB} \times N_{FB-SS,\ PBCH})$	dBm	SS and PBCH total noise (I+N)

Name	Value	Unit	Description
$(I+N)_{PDCCH}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{\varepsilon_{PDCCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + 10 \times Log\left(\frac{N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SF-DL}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)}}\right) + NR_{DL}^{Inter-Tech}$	dBm	PDCCH total noise (I+N) (Method 1: synchronised transmission and reception)
$(I+N)_{PDCCH}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{\varepsilon_{PDCCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)} + N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SD/Slot} \times N_{Slot/SF} \times N_{SF-DL}^{TX_i(ic)}}\right) + NR_{DL}^{Inter-Tech}$	dBm	PDCCH total noise (I+N) (Method 2: non-synchronised transmission and reception)
$(I+N)_{PDSCH}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{\varepsilon_{PDSCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)}}{N_{SF-DL}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)}}\right) + NR_{DL}^{Inter-Tech}$	dBm	PDSCH total noise (I+N) (Method 1: synchronised transmission and reception)
$(I+N)_{PDSCH}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{\varepsilon_{PDSCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)} + N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SD/Slot} \times N_{Slot/SF} \times N_{SF-DL}^{TX_i(ic)}}\right) + NR_{DL}^{Inter-Tech}$	dBm	PDSCH total noise (I+N) (Method 2: non-synchronised transmission and reception)

5.2.8 Signal Level Calculation (UL)

Name	Value	Unit	Description
$P_{O\_PUSCH}^{TX_i(ic)}$	$CINR_{PUSCH-Max}^{TX_i(ic)} + NR_{UL}^{TX_i(ic)} + n_{PUSCH,\ PUCCH}^{TX_i(ic)} - 10 \times Log\left(N_{FB}^{TX_i(ic)}\right)$	dBm	Nominal PUSCH power
$P_{Allowed}^{M_i}$	$Min\left\{P_{Max}^{M_i},\ 10 \times Log\left(N_{FB}^{TX_i(ic)}\right) + P_{O\_PUSCH}^{TX_i(ic)} + \alpha_{FPC}^{TX_i(ic)} \times L_{Total}\right\}$	dBm	Maximum allowed transmission power of a user equipment
$C_{PUSCH,\ PUCCH}^{M_i}$	$EIRP_{PUSCH,\ PUCCH}^{M_i} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G_{Ant}^{TX_i}$ $- L^{TX_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$	dBm	Received PUSCH and PUCCH signal level
$EIRP_{PUSCH,\ PUCCH}^{M_i}$	$P^{M_i} + G^{M_i} - L^{M_i}$ With $P^{M_i} = P_{Allowed}^{M_i}$ without power control adjustment and $P^{M_i} = P_{Eff}^{M_i}$ after power control adjustment	dBm	PUSCH and PUCCH EIRP of a user equipment

Name	Value	Unit	Description
f_{CP}	$10 \times Log(7/7.5)$ If $D_{CP} = Normal$ $10 \times Log(6/7.5)$ If $D_{CP} = Extended$ 0 If M_i is an interferer	dB	Cyclic prefix factor, i.e., the ratio of the useful symbol energy to the total symbol energy

5.2.9 Noise Calculation (UL)

Name	Value	Unit	Description
$n_{0-PUSCH,\,PUCCH}^{TX_i(ic)}$	$n_0 + 10 \times Log\left(N_{FB}^{TX_i(ic)} \times W_{FB} \times 1000\right)$	dBm	PUSCH and PUCCH thermal noise
$n_{PUSCH,\,PUCCH}^{TX_i(ic)}$	$n_{0-PUSCH,\,PUCCH}^{TX_i(ic)} + nf^{TX_i(ic)}$	dBm	PUSCH and PUCCH noise

5.2.10 Interference Calculation (UL)

Name	Value	Unit	Description
$I_{PUSCH,\,PUCCH}^{M_j}$	$C_{PUSCH,\,PUCCH}^{M_j} + f_O^{TX_i(ic)-TX_j(jc)} + f_{TL-UL}^{M_j} + f_{ICIC-UL}^{TX_i(ic)-TX_j(jc)}$	dBm	Received PUSCH and PUCCH interference
$f_O^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to the co- and adjacent channel overlap
$f_{TL-UL}^{M_j}$	$10 \times Log\left(TL_{UL}^{M_j}\right)$	dB	Interference reduction factor due to the interfering mobile's uplink traffic load
$f_{ICIC-UL}^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(p_{Collision}^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to static uplink ICIC using fractional frequency reuse

5.2.11 Noise Rise Calculation (UL)

Name	Value	Unit	Description
$NR_{UL}^{TX_i(ic)}$	$10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}}\left(10^{\frac{I_{PUSCH,\,PUCCH}^{M_j}\big\|_{\forall\ non\text{-}ICIC\ M_i}}{10}}\right) + 10^{\frac{n_{PUSCH,\,PUCCH}^{TX_i(ic)}}{10}}\right) + NR_{UL}^{Inter-Tech} - n_{PUSCH,\,PUCCH}^{TX_i(ic)}$	dB	Uplink noise rise for any mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$
$NR_{UL-ICIC}^{TX_i(ic)}$	$10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}}\left(10^{\frac{I_{PUSCH,\,PUCCH}^{M_j}\big\|_{\forall\ ICIC\ M_i}}{10}}\right) + 10^{\frac{n_{PUSCH,\,PUCCH}^{TX_i(ic)}}{10}}\right) + NR_{UL}^{Inter-Tech} - n_{PUSCH,\,PUCCH}^{TX_i(ic)}$	dB	Uplink noise rise for any mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$

Name	Value	Unit	Description
$(I+N)^{TX_i(ic)}_{PUSCH, PUCCH}$	For any mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$: $NR^{TX_i(ic)}_{UL} + n^{TX_i(ic)}_{PUSCH, PUCCH}$ For any mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$: $NR^{TX_i(ic)}_{UL-ICIC} + n^{TX_i(ic)}_{PUSCH, PUCCH}$	dBm	PUSCH and PUCCH total noise (I+N)

5.2.12 C/N Calculation (UL)

Name	Value	Unit	Description
$CNR^{M_i}_{PUSCH, PUCCH}$	$C^{M_i}_{PUSCH, PUCCH} - n^{TX_i(ic)}_{PUSCH, PUCCH}$ With Receive Diversity: $CNR^{M_i}_{PUSCH, PUCCH} = CNR^{M_i}_{PUSCH, PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div}$ With AMS *if* $CNR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$ or $CINR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$: $CNR^{M_i}_{PUSCH, PUCCH} = CNR^{M_i}_{PUSCH, PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div}$	dB	PUSCH and PUCCH C/N

5.2.13 C/(I+N) Calculation (UL)

Name	Value	Unit	Description
$CINR^{M_i}_{PUSCH, PUCCH}$	For any mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$: $CNR^{M_i}_{PUSCH, PUCCH} - NR^{TX_i(ic)}_{UL}$ For any mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$: $CNR^{M_i}_{PUSCH, PUCCH} - NR^{TX_i(ic)}_{ICIC-UL}$ With Receive Diversity: $CINR^{M_i}_{PUSCH, PUCCH} = CINR^{M_i}_{PUSCH, PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div}$ With AMS *if* $CNR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$ or $CINR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$: $CINR^{M_i}_{PUSCH, PUCCH} = CINR^{M_i}_{PUSCH, PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div}$	dB	PUSCH and PUCCH C/(I+N)
$P^{M_i}_{Eff}$	$Max\left(P^{M_i}_{Allowed} - \left(CINR^{M_i}_{PUSCH, PUCCH} - \left(T^{TX_i(ic)}_{B^{M_i}_{UL}} + M_{PC}\right)\right), P^{M_i}_{Min}\right)$	dBm	Effective transmission power of a user equipment after power control adjustment

5.2.14 Calculation of Downlink Cell Resources

Name	Value	Unit	Description
$N_{Sym/SRB}$	$N_{SCa-FB} \times N_{SD/Slot} \times N_{Slot/SF}$	None	Number of modulation symbols per scheduler resource block
$N^{DwPTS}_{Sym/SSF}$	$N_{SCa-FB} \times N^{DwPTS}_{SD/SSF}$	None	Number of DwPTS modulation symbols per scheduler resource block in the TDD special subframes
N_{SCa-FB}	$\frac{W_{FB}}{\Delta F}$	None	Number of subcarriers per frequency block
$N^{TX_i(ic)}_{Sym-DL}$	$N^{TX_i(ic)}_{FB} \times N_{Sym/SRB} \times N^{TX_i(ic)}_{SF-DL} + N^{TX_i(ic)}_{FB} \times N^{TX_i(ic)}_{TDD-SSF} \times N^{DwPTS}_{Sym/SSF}$	None	Total number of modulation symbols in downlink
$R^{TX_i(ic)}_{DL}$	$N^{TX_i(ic)}_{Sym-DL} - O^{TX_i(ic)}_{DLRS} - O_{PSS} - O_{SSS} - O^{TX_i(ic)}_{PBCH} - O^{TX_i(ic)}_{PDCCH} - O^{TX_i(ic)}_{UERS}$	None	Number of PDSCH modulation symbols

Name	Value	Unit	Description
$O_{DLRS}^{TX_i(ic)}$	$N_{FB}^{TX_i(ic)} \times N_{DLRS/SRB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)} + N_{FB}^{TX_i(ic)} \times N_{DLRS/DwPTS}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$	None	Downlink reference signals overhead
$N_{DLRS/SRB}^{TX_i(ic)}$	$\begin{cases} 8 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 1\right) \\ 16 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 2\right) \\ 24 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 4 \text{ or } 8\right) \end{cases}$	None	Number of symbols reserved for downlink reference signals in one scheduler resource block
$N_{DLRS/DwPTS}^{TX_i(ic)}$	See "Calculation of Downlink Cell Resources" on page 386	None	Number of symbols reserved for downlink reference signals in DwPTS of one TDD special subframe
O_{PSS}	$2 \times N_{FB-SS,\,PBCH} \times N_{SCa-FB} = 144$	None	PSS overhead
O_{SSS}	$2 \times N_{FB-SS,\,PBCH} \times N_{SCa-FB} = 144$	None	SSS overhead
$O_{PBCH}^{TX_i(ic)}$	Extended CP: $\left(4 \times N_{SCa-FB} - \frac{N_{Res/SRB}^{TX_i(ic)}}{2}\right) \times N_{FB-SS,\,PBCH}$ Normal CP: $\left(4 \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB-SS,\,PBCH}$	None	PBCH overhead
$O_{PDCCH}^{TX_i(ic)}$	$if \quad (N_{SD-PDCCH} = 0) : 0$ $if \quad (N_{SD-PDCCH} = 1)\ AND \left(N_{Ant-TX}^{TX_i(ic)} = 4 \text{ or } 8\right) :$ $\left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)}$ $+\left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$ Otherwise: $\left(N_{SD-PDCCH} \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)}$ $+\left(Min(2, N_{SD-PDCCH}) \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$	None	PDCCH overhead
$O_{UERS}^{TX_i(ic)}$	With smart antennas: $12 \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)}$ Without smart antennas: 0	None	UE-specific reference signals overhead

5.2.15 Calculation of Uplink Cell Resources

Name	Value	Unit	Description
$N_{Sym/SRB}$	$N_{SCa-FB} \times N_{SD/Slot} \times N_{Slot/SF}$	None	Number of modulation symbols per scheduler resource block
N_{SCa-FB}	$\frac{W_{FB}}{\Delta F}$	None	Number of subcarriers per frequency block
$N_{Sym-UL}^{TX_i(ic)}$	$\left(N_{FB}^{TX_i(ic)} - N_{FB-PUCCH}\right) \times N_{Sym/SRB} \times N_{SF-UL}^{TX_i(ic)}$	None	Total number of modulation symbols in uplink
$R_{UL}^{TX_i(ic)}$	$N_{Sym-UL}^{TX_i(ic)} - O_{ULSRS}^{TX_i(ic)} - O_{ULDRS}^{TX_i(ic)}$	None	Nnumber of PUSCH modulation symbols
$O_{ULSRS}^{TX_i(ic)}$	$\frac{N_{SCa-FB}}{N_{Sym/SRB}} \times N_{Sym-UL}^{TX_i(ic)}$	None	Uplink sounding reference signal overhead

Name	Value	Unit	Description
$O_{ULDRS}^{TX_i(ic)}$	$2 \times \frac{N_{SCa-FB}}{N_{Sym/SRB}} \times N_{Sym-UL}^{TX_i(ic)}$	None	Uplink demodulation reference signal overhead

5.2.16 Calculation of Downlink UE Capacity

Name	Value	Unit	Description
TP_{UE-DL}^{Max}	$N_{TBB/TTI}^{Max-DL} \times \frac{\left(N_{SF-DL}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)}\right)}{D_{Frame}}$	bps	Maximum downlink throughput capacity of a UE category

5.2.17 Calculation of Uplink UE Capacity

Name	Value	Unit	Description
TP_{UE-UL}^{Max}	$N_{TBB/TTI}^{Max-UL} \times \frac{N_{SF-UL}^{TX_i(ic)}}{D_{Frame}}$	bps	Maximum uplink throughput capacity of a UE category

5.2.18 Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation

Name	Value	Unit	Description
$CTP_{P-DL}^{M_i}$	Without static downlink ICIC using FFR: $\frac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}}^{M_i}}{D_{Frame}}$ With static downlink ICIC using FFR: $\frac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}}^{M_i}}{D_{Frame}} \times \frac{N_{FB-CE}^{TX_i(ic)}}{N_{FB}^{TX_i(ic)}}$ With MIMO (SU-MIMO): $\eta_{B_{DL}}^{M_i} = \eta_{B_{DL}}^{M_i} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ With MIMO (AMS): $\eta_{B_{DL}}^{M_i} = \eta_{B_{DL}}^{M_i} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ if $CNR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ or $CINR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$	kbps	Downlink peak RLC channel throughput
$CTP_{E-DL}^{M_i}$	$CTP_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$	kbps	Downlink effective RLC channel throughput
$CTP_{A-DL}^{M_i}$	$CTP_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Downlink application channel throughput
$Cap_{P-DL}^{M_i}$	$CTP_{P-DL}^{M_i} \times TL_{DL-Max}^{TX_i(ic)}$	kbps	Downlink peak RLC cell capacity
$Cap_{E-DL}^{M_i}$	$Cap_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$	kbps	Downlink effective RLC cell capacity
$Cap_{A-DL}^{M_i}$	$Cap_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Downlink application cell capacity

Name	Value	Unit	Description
$AUTP_{P-DL}^{M_i}$	$\frac{Cap_{P-DL}^{M_i}}{N_{Users-DL}^{TX_i(ic)}}$	kbps	Downlink peak RLC throughput averaged per user
$AUTP_{E-DL}^{M_i}$	$\frac{Cap_{E-DL}^{M_i}}{N_{Users-DL}^{TX_i(ic)}}$	kbps	Downlink effective RLC throughput averaged per user
$AUTP_{A-DL}^{M_i}$	$AUTP_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Downlink application throughput averaged per user
$CTP_{P-UL}^{M_i}$	$\frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}}$ With MIMO (SU-MIMO): $\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ With MIMO (AMS): $\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ if $CNR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ or $CINR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ With MIMO (MU-MIMO) in uplink throughput coverage predictions: $\frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}} \times G_{MU-MIMO}^{TX_i(ic)}$	kbps	Uplink peak RLC channel throughput
$CTP_{E-UL}^{M_i}$	$CTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$	kbps	Uplink effective RLC channel throughput
$CTP_{A-UL}^{M_i}$	$CTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Uplink application channel throughput
$Cap_{P-UL}^{M_i}$	$CTP_{P-UL}^{M_i} \times TL_{UL-Max}^{TX_i(ic)}$	kbps	Uplink peak RLC cell capacity
$Cap_{E-UL}^{M_i}$	$Cap_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$	kbps	Uplink effective RLC cell capacity
$Cap_{A-UL}^{M_i}$	$Cap_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Uplink application cell capacity
$ABTP_{P-UL}^{M_i}$	$CTP_{P-UL}^{M_i} \times \frac{N_{FB-UL}^{M_i}}{N_{FB}^{TX_i(ic)}}$	kbps	Uplink peak RLC allocated bandwidth throughput
$ABTP_{E-UL}^{M_i}$	$ABTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$	kbps	Uplink effective RLC allocated bandwidth throughput
$ABTP_{A-UL}^{M_i}$	$ABTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Uplink application allocated bandwidth throughput
$AUTP_{P-DL}^{M_i}$	$Min\left(\frac{Cap_{P-UL}^{M_i}}{N_{Users-UL}^{TX_i(ic)}}, ABTP_{P-UL}^{M_i}\right)$	kbps	Downlink peak RLC throughput averaged per user
$AUTP_{E-UL}^{M_i}$	$Min\left(\frac{Cap_{E-UL}^{M_i}}{N_{Users-UL}^{TX_i(ic)}}, ABTP_{E-UL}^{M_i}\right)$	kbps	Downlink effective RLC throughput averaged per user

Name	Value	Unit	Description
$AUTP_{A-UL}^{M_i}$	$AUTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Downlink application throughput averaged per user

5.2.19 Scheduling and Radio Resource Management

Name	Value	Unit	Description
$R_{Min-DL}^{M_i^{Sel}}$	$\frac{TPD_{Min-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}}$	None	Resources allocated to a mobile to satisfy its minimum throughput demand in downlink
$R_{Min-UL}^{M_i^{Sel}}$	$\frac{TPD_{Min-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$	None	Resources allocated to a mobile to satisfy its minimum throughput demand in uplink
$R_{Rem-DL}^{TX_i(ic)}$	$TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}}$	None	Remaining downlink cell resources after allocation for minimum throughput demands
$R_{Rem-UL}^{TX_i(ic)}$	$TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}}$	None	Remaining uplink cell resources after allocation for minimum throughput demands
$TPD_{Rem-DL}^{M_i^{Sel}}$	$Min\left(TPD_{Max-DL}^{M_i^{Sel}} - TPD_{Min-DL}^{M_i^{Sel}}, TP_{UE-DL}^{Max}\right)$	kbps	Remaining throughput demand for a mobile in downlink
$TPD_{Rem-UL}^{M_i^{Sel}}$	$Min\left(TPD_{Max-UL}^{M_i^{Sel}} - TPD_{Min-UL}^{M_i^{Sel}}, TP_{UE-UL}^{Max}\right)$	kbps	Remaining throughput demand for a mobile in uplink
$CTP_{P-DL}^{M_i^{Sel}}$	$CTP_{P-DL}^{M_i^{Sel}}\Big\vert_{Without\ MUG} \times G_{MUG-DL}^{TX_i(ic)}$	kbps	Downlink peak channel throughput with multi-user diversity gain (Proportional Fair)
$CTP_{P-UL}^{M_i^{Sel}}$	$CTP_{P-UL}^{M_i^{Sel}}\Big\vert_{Without\ MUG} \times G_{MUG-UL}^{TX_i(ic)}$	kbps	Uplink peak channel throughput with multi-user diversity gain (Proportional Fair)
$RD_{Rem-DL}^{M_i^{Sel}}$	$\frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}}$	None	Remaining resource demand for a mobile in downlink
$RD_{Rem-UL}^{M_i^{Sel}}$	$\frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$	None	Remaining resource demand for a mobile in uplink

Name	Value	Unit	Description
$R_{Max-DL}^{M_i^{Sel}}$	Proportional Fair: $Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right)$ Round Robin: $Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right)$ Proportional Demand: $R_{Eff-Rem-DL}^{TX_i(ic)} \times \frac{RD_{Rem-DL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}}$ Max C/I: $\frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}}$	None	Resources allocated to a mobile to satisfy its maximum throughput demand in downlink
$R_{Max-UL}^{M_i^{Sel}}$	Proportional Fair: $Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$ Round Robin: $Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right)$ Proportional Demand: $R_{Eff-Rem-UL}^{TX_i(ic)} \times \frac{RD_{Rem-UL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}}$ Max C/I: $\frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$	None	Resources allocated to a mobile to satisfy its maximum throughput demand in uplink
$R_{Eff-Rem-DL}^{TX_i(ic)}$	$Min\left(R_{Rem-DL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}\right)$	None	Effective remaining downlink resources in a cell (Proportional Demand)
$R_{Eff-Rem-UL}^{TX_i(ic)}$	$Min\left(R_{Rem-UL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}\right)$	None	Effective remaining uplink resources in a cell (Proportional Demand)
$TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}}$	$R_{Min-DL}^{M_i^{Sel}} + R_{Max-DL}^{M_i^{Sel}}$	None	Total resources assigned to a mobile in downlink (Downlink traffic load of the mobile)
$TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}}$	$R_{Min-UL}^{M_i^{Sel}} + R_{Max-UL}^{M_i^{Sel}}$	None	Total resources assigned to a mobile in uplink (Uplink traffic load of the mobile)

5.2.20 User Throughput Calculation

Name	Value	Unit	Description
$UTP_{P-DL}^{M_i^{Sel}}$	$R_{DL}^{M_i^{Sel}} \times CTP_{P-DL}^{M_i^{Sel}}$	kbps	Downlink peak RLC user throughput
$UTP_{E-DL}^{M_i^{Sel}}$	$UTP_{P-DL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)$	kbps	Downlink effective RLC user throughput

Name	Value	Unit	Description
$UTP_{A-DL}^{M_i^{Sel}}$	$UTP_{E-DL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$	kbps	Downlink application user throughput
$UTP_{P-UL}^{M_i^{Sel}}$	$R_{UL}^{M_i^{Sel}} \times CTP_{P-UL}^{M_i^{Sel}}$	kbps	Uplink peak RLC user throughput
$UTP_{E-UL}^{M_i^{Sel}}$	$UTP_{P-UL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)$	kbps	Uplink effective RLC user throughput
$UTP_{A-UL}^{M_i^{Sel}}$	$UTP_{E-UL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$	kbps	Uplink application user throughput

5.3 Available Calculations

5.3.1 Point Analysis

5.3.1.1 Profile View

The point analysis profile view displays the following calculation results for the selected transmitter based on the calculation algorithm described in "Signal Level Calculation (DL)" on page 351.

- Downlink reference signal level $C_{DLRS}^{TX_i(ic)}$
- Path loss L_{Path}
- Total losses L_{Total}

L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, $L_{Body}^{M_i}$, and f_{CP} are not used in the calculations performed for the profile view.

5.3.1.2 Reception View

Analysis provided in the reception view is based on path loss matrices. So, you can display received downlink reference signal levels from the cells for which calculated path loss matrices are available. For each cell, **9955** displays the received RSRP or reference signal, SS, or PDSCH signal levels.

Reception level bar graphs show the RSRP or signal levels in decreasing order. The maximum number of bars in the graph depends on the downlink reference signal level of the best server. The bar graph displays cells whose received RSRP are higher than their minimum RSRP thresholds and are within a 30 dB margin from the highest RSRP.

You can use a value other than 30 dB for the margin from the highest downlink reference signal level, for example a smaller value for improving the calculation speed. For more information on defining a different value for this margin, see the *Administrator Manual*.

The reception view calculates:

- The RSRP and RS, SS, PBCH, PDCCH, and PDSCH signal levels from cells as explained in "Signal Level Calculation (DL)" on page 351.
- The RSSI, RSRQ, RS C/(I+N), SS C/(I+N), and PDSCH C/(I+N), and the RS, SS & PBCH, and PDCCH & PDSCH total noise (I+N) as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- The best server as explained in "Best Server Determination" on page 384.
- The service availability as explained in "Service Area Calculation" on page 385.
- The PUSCH and PUCCH signal level as explained in "Signal Level Calculation (UL)" on page 372.
- The PUSCH and PUCCH C/(I+N) and total noise (I+N) as explained in "C/(I+N) and Bearer Calculation (UL)" on page 381.
- The downlink and uplink bearers as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367 and "C/(I+N) and Bearer Calculation (UL)" on page 381.
- The different throughputs as explained in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

5.3.1.3 Interference View

Analysis provided in the interference view is based on path loss matrices. So, you can display the received signal level from the best server and interfering signal levels from other cells for which calculated path loss matrices are available. For each cell, **9955** displays the best server RS, SS, or PDSCH signal level, and interference from other cells.

Ten interferer bar graphs are displayed by default. This number can be changed through the Atoll.ini file. For more information on defining a different number of interferers, see the *Administrator Manual*.

The interference view calculates:

- The RS, SS, PBCH, PDCCH, and PDSCH signal levels as explained in "Signal Level Calculation (DL)" on page 351.
- The RS, SS, PBCH, PDCCH, and PDSCH C/(I+N) as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- The RS, SS & PBCH, and PDCCH & PDSCH total noise (I+N) as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- The best server as explained in "Best Server Determination" on page 384.
- The service availability as explained in "Service Area Calculation" on page 385.
- The channel overlap as explained in "Co- and Adjacent Channel Overlaps Calculation" on page 310.
- The collision probability due to ICIC as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- The interference reduction due to the downlink traffic load as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367.

5.3.2 Coverage Predictions

5.3.2.1 Downlink Signal Level Coverage Predictions

The following coverage predictions are based on the received downlink reference signal levels:

- Coverage by Transmitter
- Coverage by Signal Level
- Overlapping Zones

For these calculations, **9955** calculates the received downlink reference signal level. Then, **9955** determines the selected display parameter on each pixel inside the cell's calculation area. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver.

These coverage predictions do not depend on the traffic input. Therefore, these calculations are of special interest before and during the deployment stage of the network to study the coverage footprint of the system.

L^{M_i}, G^{M_i}, $L^{M_i}_{Ant}$, and $L^{M_i}_{Body}$ are not considered in the calculations performed for the downlink signal level based coverage predictions.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on downlink reference signal level calculations, see "Signal Level Calculation (DL)" on page 351.

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 328.
- "Coverage Display Types" on page 329.

Coverage Area Determination

9955 uses parameters entered in the Condition tab of the coverage prediction properties dialogue to determine coverage areas to display. There are three possibilities.

- All Servers

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C^{TX_i(ic)}_{DLRS}\left(or\ L^{TX_i(ic)}_{Total}\ \ or\ L^{TX_i(ic)}_{Path}\right) < MaximumThreshold$$

- Best Signal Level and a Margin

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C^{TX_i(ic)}_{DLRS}\left(or\ L^{TX_i(ic)}_{Total}\ \ or\ L^{TX_i(ic)}_{Path}\right) < MaximumThreshold$$

AND

$$C_{DLRS}^{TX_i(ic)} \geq \underset{j \neq i}{Best}\left(C_{DLRS}^{TX_j(jc)}\right) - M$$

Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received downlink reference signal level from $TX_i(ic)$ is the highest.
- If *M* = 2 dB, **9955** considers pixels where the received downlink reference signal level from $TX_i(ic)$ is either the highest or within a 2 dB margin from the highest
- If *M* = -2 dB, **9955** considers pixels where the received downlink reference signal level from $TX_i(ic)$ is 2 dB higher than the received downlink reference signal levels from the cells which are 2nd best servers

- Second Best Signal Level and a Margin

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \leq C_{DLRS}^{TX_i(ic)}\left(or\ L_{Total}^{TX_i(ic)}\ or\ L_{Path}^{TX_i(ic)}\right) < MaximumThreshold$$

AND

$$C_{DLRS}^{TX_i(ic)} \geq \underset{j \neq i}{2^{nd}Best}\left(C_{DLRS}^{TX_j(jc)}\right) - M$$

Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

- If *M* = 0 dB, **9955** considers pixels where the received downlink reference signal level from $TX_i(ic)$ is the second highest.
- If *M* = 2 dB, **9955** considers pixels where the received downlink reference signal level from $TX_i(ic)$ is either the second highest or within a 2 dB margin from the second highest.
- If *M* = -2 dB, **9955** considers pixels where the received downlink reference signal level from $TX_i(ic)$ is 2 dB higher than the received downlink reference signal levels from the cells which are 3rd best servers.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the coverage predictions with colours depending on any transmitter or cell attribute, and other criteria such as:

- Signal Level (dBm, dBµV, dBµV/m)
- Best Signal Level (dBm, dBµV, dBµV/m): Where cell coverage areas overlap, 9955 keeps the highest value of the signal level.
- Path Loss (dB)
- Total Losses (dB)
- Best Server Path Loss (dB): Where cell coverage areas overlap, 9955 determines the best cell (i.e., the cell with the highest downlink reference signal level) and evaluates the path loss from this cell.
- Best Server Total Losses (dB): Where cell coverage areas overlap, 9955 determines the best cell (i.e., the cell with the highest downlink reference signal level) and evaluates the total losses from this cell.
- Number of Servers: 9955 evaluates the number of cells that cover a pixel (i.e., the pixel falls within the coverage areas of these cells).

5.3.2.2 Effective Signal Analysis Coverage Predictions

The following coverage predictions are based on the received downlink reference signal, SS, PDSCH, and PUSCH and PUCCH signal levels and noise, and take into account the receiver characteristics (L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$) when calculating the required parameter:

- Effective Signal Analysis (DL)
- Effective Signal Analysis (UL)

For these calculations, **9955** calculates the received signal level or C/N level at each pixel for the channel type being studied, i.e., RS, SS, PBCH, PDCCH, PDSCH, PUSCH and PUCCH. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver. The properties of the non-interfering probe receiver are set by selecting a terminal, a mobility type, and a service.

These coverage predictions do not depend on the traffic input. Therefore, these calculations are of special interest before and during the deployment stage of the network to study the coverage footprint of the system.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on signal level calculations, see:

- "Signal Level Calculation (DL)" on page 351.
- "Signal Level Calculation (UL)" on page 372.

For more information on C/N level calculations, see:

- "C/N Calculation (DL)" on page 365.
- "C/N Calculation (UL)" on page 378.

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 330.
- "Coverage Display Types" on page 330.

Coverage Area Determination

These coverage predictions are best server coverage predictions, i.e., the coverage area of each cell comprises the pixels where the cell is the best server. Best server for each pixel is calculated as explained in "Best Server Determination" on page 384.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display type parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the Effective Signal Analysis (DL) coverage prediction with colours depending on the following display options:

- RSRP (RS EPRE) Level (DL) (dBm)
- RS Signal Level (DL) (dBm)
- SS Signal Level (DL) (dBm)
- PBCH Signal Level (DL) (dBm)
- PDCCH Signal Level (DL) (dBm)
- PDSCH Signal Level (DL) (dBm)
- RS C/N Level (DL) (dB)
- SS C/N Level (DL) (dB)
- PBCH C/N Level (DL) (dB)
- PDCCH C/N Level (DL) (dB)
- PDSCH C/N Level (DL) (dB)
- Delta Path Loss (dB): 9955 calculates the difference of the total losses from the second best serving cells ($L_{Total}^{TX_j(jc)}$) and the total losses from the best serving cells ($L_{Total}^{TX_i(ic)}$) on each pixel of their coverage areas ($L_{Total}^{TX_j(jc)} - L_{Total}^{TX_i(ic)}$). Total losses are calculated as explained in "Signal Level Calculation (DL)" on page 310.

It is possible to display the Effective Signal Analysis (UL) coverage prediction with colours depending on the following display options:

- PUSCH & PUCCH Signal Level (UL) (dBm)
- PUSCH & PUCCH C/N Level (UL) (dB)

5.3.2.3 C/(I+N)-based Coverage Predictions

The following coverage predictions are based on the received signal levels, total noise, and interference.

- Coverage by C/(I+N) Level (DL)
- Service Area Analysis (DL)
- Coverage by Throughput (DL)
- Coverage by Quality Indicator (DL)
- Coverage by C/(I+N) Level (UL)
- Service Area Analysis (UL)
- Coverage by Throughput (UL)
- Coverage by Quality Indicator (UL)

These coverage predictions take into account the receiver characteristics (L^{M_i}, G^{M_i}, $L^{M_i}_{Ant}$, and $L^{M_i}_{Body}$) when calculating the required parameter. For these calculations, **9955** calculates the received signal level, noise, and interference at each pixel. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver. The properties of the non-interfering probe receiver are set by selecting a terminal, a mobility type, and a service.

The downlink coverage predictions are based on the downlink traffic loads of the cells, and the uplink coverage predictions are based on the uplink noise rise values. These parameters can either be calculated by **9955** during the Monte Carlo simulations, or set manually by the user for all the cells.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on RSRQ, RSSI, C/(I+N), (I+N), and bearer calculations, see:

- "C/(I+N) and Bearer Calculation (DL)" on page 367.
- "C/(I+N) and Bearer Calculation (UL)" on page 381.

For more information on thoughput calculations, see:

- "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 331.
- "Coverage Display Types" on page 331.

Coverage Area Determination

These coverage predictions are all best server coverage predictions, i.e., the coverage area of each cell comprises the pixels where the cell is the best server. Best server for each pixel is calculated as explained in "Best Server Determination" on page 384.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display type parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the Coverage by C/(I+N) Level (DL) coverage prediction with colours depending on the following display options:

- RSRQ Level (DL) (dB)
- RSSI Level (DL) (dBm)
- RS C/(I+N) Level (DL) (dB)
- SS C/(I+N) Level (DL) (dB)
- PBCH C/(I+N) Level (DL) (dB)
- PDCCH C/(I+N) Level (DL) (dB)
- SS & PBCH Total Noise (I+N) (DL) (dBm)
- PDSCH C/(I+N) Level (DL) (dB)
- PDSCH & PDCCH Total Noise (I+N) (DL) (dBm)

It is possible to display the Service Area Analysis (DL) coverage prediction with colours depending on the following display options:

- Bearer (DL)
- Modulation (DL): Modulation used by the bearer
- Service

It is possible to display the Coverage by Throughput (DL) coverage prediction with colours depending on the following display options:

- Peak RLC Channel Throughput (DL) (kbps)
- Effective RLC Channel Throughput (DL) (kbps)
- Application Channel Throughput (DL) (kbps)
- Peak RLC Cell Capacity (DL) (kbps)
- Effective RLC Cell Capacity (DL) (kbps)
- Application Cell Capacity (DL) (kbps)
- Peak RLC Throughput Averaged per User (DL) (kbps)
- Effective RLC Throughput Averaged per User (DL) (kbps)
- Application Throughput Averaged per User (DL) (kbps)

It is possible to display the Coverage by Quality Indicator (DL) coverage prediction with colours depending on the following display options:

- Quality indicators available in the document (Quality Indicators table): 9955 calculates the PDSCH C/(I+N) levels received from the best serving cells at each pixel of their coverage areas. From the C/(I+N), 9955 determines the best bearer available on each pixel. Then, for the calculated C/(I+N) and bearer, it determines the value of the selected quality indicator from the quality graphs defined in the LTE equipment of the selected terminal.

It is possible to display the Coverage by C/(I+N) Level (UL) coverage prediction with colours depending on the following display options:

- PUSCH & PUCCH C/(I+N) Level (UL) (dB)
- PUSCH & PUCCH Total Noise (I+N) (UL) (dBm)
- Allocated Bandwidth (UL) (No. of Frequency Blocks)
- PUSCH & PUCCH C/(I+N) Level for 1 Frequency Block (UL) (dB): PUSCH & PUCCH C/(I+N) level with $N_{FB-UL}^{M_i} = 1$
- Transmission Power (UL) (dBm)

It is possible to display the Service Area Analysis (UL) coverage prediction with colours depending on the following display options:

- Bearer (UL)
- Modulation (UL): Modulation used by the bearer
- Service

It is possible to display the Coverage by Throughput (UL) coverage prediction with colours depending on the following display options:

- Peak RLC Channel Throughput (UL) (kbps)
- Effective RLC Channel Throughput (UL) (kbps)
- Application Channel Throughput (UL) (kbps)
- Peak RLC Cell Capacity (UL) (kbps)
- Effective RLC Cell Capacity (UL) (kbps)
- Application Cell Capacity (UL) (kbps)
- Peak RLC Allocated Bandwidth Throughput (UL) (kbps)
- Effective RLC Allocated Bandwidth Throughput (UL) (kbps)
- Application Allocated Bandwidth Throughput (UL) (kbps)
- Peak RLC Throughput Averaged per User (UL) (kbps)
- Effective RLC Throughput Averaged per User (UL) (kbps)
- Application Throughput Averaged per User (UL) (kbps)

It is possible to display the Coverage by Quality Indicator (UL) coverage prediction with colours depending on the following display options:

- Quality indicators available in the document (Quality Indicators table): **9955** calculates the PUSCH and PUCCH C/(I+N) levels received at the best serving cells from each pixel of their coverage areas. From the C/(I+N), **9955** determines the best bearer available on each pixel. Then, for the calculated C/(I+N) and bearer, it determines the value of the selected quality indicator from the quality graphs defined in the LTE equipment of the best serving cell.

5.3.3 Calculations on Subscriber Lists

When calculations are performed on a list of subscribers by running the Automatic Server Allocation, **9955** calculates the path loss again for the subscriber locations and heights because the subscriber heights can be different from the default receiver height used for calculating the path loss matrices.

9955 calculates the following parameters for each subscriber in the list whose **Lock Status** is set to **None**.

- **Serving Base Station** and **Reference Cell** as described in "Best Server Determination" on page 384.

9955 calculates the following parameters for each subscriber in the list that has a serving base station assigned and whose **Lock Status** is set to **None** or **Server**.

- **Azimuth (°)**: Angle with respect to the north for pointing the subscriber terminal antenna towards its serving base station.
- **Mechanical Downtilt (°)**: Angle with respect to the horizontal for pointing the subscriber terminal antenna towards its serving base station.

9955 calculates the remaining parameters for each subscriber in the list that has a serving base station assigned, using the properties of the default terminal and service. For more information, see:

- "Signal Level Calculation (DL)" on page 351.
- "Signal Level Calculation (UL)" on page 372.
- "C/(I+N) and Bearer Calculation (DL)" on page 367.
- "C/(I+N) and Bearer Calculation (UL)" on page 381.

• "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

5.3.4 Monte Carlo Simulations

The simulation process is divided into two steps.

- Generating a realistic user distribution as explained in "User Distribution" on page 333.

  9955 generates user distributions as part of the Monte Carlo algorithm based on traffic data. The resulting user distribution complies with the traffic database and maps selected when creating simulations.

- Scheduling and Radio Resource Management as explained under "Simulation Process" on page 336.

5.3.4.1 User Distribution

During each simulation, **9955** performs two random trials. The first random trial generates the number of users and their activity status as explained in the following sections depending on the type of traffic input.

- "Simulations Based on User Profile Traffic Maps and Subscriber Lists" on page 333.
- "Simulations Based on Sector Traffic Maps" on page 335.

Once all the user characteristics have been determined, a second random trial is performed to obtain their geographical locations weighted according to the clutter classes, and whether they are indoor or outdoor according to the percentage of indoor users per clutter class.

> **9955** determines the total number of users attempting connection in each simulation based on the Poisson distribution. This may lead to slight variations in the total numbers of users in different simulations. To have the same total number of users in each simulation of a group, add the following lines in the Atoll.ini file:
> [Simulation]
> RandomTotalUsers=0

5.3.4.1.1 Simulations Based on User Profile Traffic Maps and Subscriber Lists

User profile environment based traffic maps: Each pixel of the map is assigned an environment class which contains a list of user profiles with an associated mobility type and a given density, i.e., number of users of a user profile per km².

User profile traffic maps: Each polygon or line of the map is assigned a density of users with a given user profile and mobility type. If the map is composed of points, each point is assigned a number of users with given user profile and mobility type.

Fixed subscribers listed in subscriber lists have a user profile assigned to each of them.

User profiles model the behaviour of the different user categories. Each user profile contains a list of services and parameters describing how these services are accessed by the user.

The number of users of each user profile is calculated from the surface area (S_{Env}) of each environment class map (or each polygon) and the user profile density (D_{UP}).

$$N_{Users} = S_{Env} \times D_{UP}$$

> - In case of user profile traffic maps composed of lines, the number of users of each user profile is calculated from the line length (L) and the user profile density (D_{UP}) (users per km): $N_{Users} = L \times D_{UP}$
> - The number of users is a direct input when a user profile traffic map is composed of points.

9955 calculates the probability for a user being active at a given instant in the uplink and in the downlink according to the service usage characteristics described in the user profiles, i.e., the number of voice calls or data sessions, the average duration of each voice call, or the volume of the data transfer in the uplink and the downlink in each data session.

Voice Service (*v*)

User profile parameters for voice type services are:

- The user terminal equipment used for the service (from the Terminals table).
- The average number of calls per hour N_{Call}.
- The average duration of a call (seconds) D_{Call}.

Calculation of the service usage duration per hour (p_0 : probability of an active call): $p_0 = \frac{N_{Call} \times D_{Call}}{3600}$

Calculation of the number of users trying to access the service *v* (n_v): $n_v = N_{Users} \times p_0$

The activity status of each user depends on the activity periods during the call, i.e., the uplink and downlink activity factors defined for the voice type service *v*, f_{Act}^{UL} and f_{Act}^{DL}.

Calculation of activity probabilities:

Probability of being inactive: $p_{Inactive} = (1 - f_{Act}^{UL}) \times (1 - f_{Act}^{DL})$

Probability of being active in the uplink: $p_{Active}^{UL} = f_{Act}^{UL} \times (1 - f_{Act}^{DL})$

Probability of being active in the downlink: $p_{Active}^{DL} = f_{Act}^{DL} \times (1 - f_{Act}^{UL})$

Probability of being active in the uplink and downlink both: $p_{Active}^{UL+DL} = f_{Act}^{UL} \times f_{Act}^{DL}$

Calculation of number of users per activity status:

Number of inactive users: $n_{v-Inactive} = n_v \times p_{Inactive}$

Number of users active in the uplink: $n_{v-Active}^{UL} = n_v \times p_{Active}^{UL}$

Number of users active in the downlink: $n_{v-Active}^{DL} = n_v \times p_{Active}^{DL}$

Number of users active in the uplink and downlink both: $n_{v-Active}^{UL+DL} = n_v \times p_{Active}^{UL+DL}$

Therefore, a connected user can be either active on both links, inactive on both links, active on UL only, or active on DL only.

Data Service (*d*)

User profile parameters for data type services are:

- The user terminal equipment used for the service (from the Terminals table).
- The average number of data sessions per hour $N_{Session}$.
- The average data volume (in kBytes) transferred in the downlink V^{DL} and the uplink V^{UL} during a session.
- The average throughputs in the downlink $TP_{Average}^{DL}$ and the uplink $TP_{Average}^{UL}$ for the service *d*.

Calculation of activity probabilities: $f^{UL} = \frac{N_{Session} \times V^{UL} \times 8}{TP_{Average}^{UL} \times 3600}$ and $f^{DL} = \frac{N_{Session} \times V^{DL} \times 8}{TP_{Average}^{DL} \times 3600}$

Probability of being inactive: $p_{Inactive} = (1 - f^{UL}) \times (1 - f^{DL})$

Probability of being active in the uplink: $p_{Active}^{UL} = f^{UL} \times (1 - f^{DL})$

Probability of being active in the downlink: $p_{Active}^{DL} = f^{DL} \times (1 - f^{UL})$

Probability of being active in the uplink and downlink both: $p_{Active}^{UL+DL} = f^{UL} \times f^{DL}$

Calculation of number of users:

Number of inactive users: $n_{d-Inactive} = N_{Users} \times p_{Inactive}$

Number of users active in the uplink: $n_{d-Active}^{UL} = N_{Users} \times p_{Active}^{UL}$

Number of users active in the downlink: $n_{d-Active}^{DL} = N_{Users} \times p_{Active}^{DL}$

Number of users active in the uplink and downlink both: $n_{d-Active}^{UL+DL} = N_{Users} \times p_{Active}^{UL+DL}$

Calculation of the number of active users trying to access the service *d* (n_d):

$$n_d = n^{UL}_{d-Active} + n^{DL}_{d-Active} + n^{UL+DL}_{d-Active}$$

The user distribution per service and the activity status distribution between the users are average distributions. The service and the activity status of each user are randomly drawn in each simulation. Therefore, if you calculate several simulations at once, the average number of users per service and average numbers of inactive, active on UL, active on DL and active on UL and DL users, respectively, will correspond to calculated distributions. But if you check each simulation, the user distribution between services as well as the activity status distribution between users can be different in each of them.

5.3.4.1.2 Simulations Based on Sector Traffic Maps

Sector traffic maps are also referred to as live traffic maps. Live traffic data from the O&M is spread over the best server coverage areas of the transmitters included in the traffic map. Either throughput demands per service or the number of active users per service are assigned to the coverage areas of each transmitter.

For each transmitter TX_i and each service *s*,

- **Sector Traffic Maps (Throughputs)**

  9955 calculates the number of active users of each service *s* on UL and DL in the coverage area of TX_i as follows:

  $$N^{UL} = \frac{TP^{UL}_{Cell}}{TP^{UL}_{Average}} \text{ and } N^{DL} = \frac{TP^{DL}_{Cell}}{TP^{DL}_{Average}}$$

  Where TP^{UL}_{Cell} is the total uplink throughput demand defined in the map for any service *s* for the coverage area of the transmitter, TP^{DL}_{Cell} is the total downlink throughput demand defined in the map for any service *s* for the coverage area of the transmitter, $TP^{UL}_{Average}$ is the average uplink requested throughput of the service *s*, and $TP^{DL}_{Average}$ is the average downlink requested throughput of the service *s*.

- **Sector Traffic Maps (# Active Users)**

  9955 directly uses the defined N^{UL} and N^{DL} values, i.e., the number of active users on UL and DL in the transmitter coverage area using the service *s*.

At any given instant, **9955** calculates the probability for a user being active in the uplink and in the downlink as follows:

Users active in the uplink and downlink both are included in the N^{UL} and N^{DL} values. Therefore, it is necessary to accurately determine the number of active users in the uplink (n^{UL}_{Active}), in the downlink (n^{DL}_{Active}), and both (n^{UL+DL}_{Active}). As for the other types of traffic maps, **9955** considers both active and inactive users.

The activity status of each user depends on the activity periods during the call, i.e., the uplink and downlink activity factors defined for the service, f^{UL}_{Act} and f^{DL}_{Act}.

Calculation of activity probabilities:

Probability of being inactive: $p_{Inactive} = (1 - f^{UL}_{Act}) \times (1 - f^{DL}_{Act})$

Probability of being active in the uplink: $p^{UL}_{Active} = f^{UL}_{Act} \times (1 - f^{DL}_{Act})$

Probability of being active in the downlink: $p^{DL}_{Active} = f^{DL}_{Act} \times (1 - f^{UL}_{Act})$

Probability of being active in the uplink and downlink both: $p^{UL+DL}_{Active} = f^{UL}_{Act} \times f^{DL}_{Act}$

Calculation of the number of active users trying to access the service:

We have: $N^{UL} = (p^{UL}_{Active} + p^{UL+DL}_{Active}) \times n$ and $N^{DL} = (p^{DL}_{Active} + p^{UL+DL}_{Active}) \times n$

Where, *n* is the total number of active users in the transmitter coverage area using the service.

Calculation of number of users per activity status:

Number of users active in the uplink and downlink both: $n_{Active}^{UL+DL} = Min\left(\frac{N^{UL} \times p_{Active}^{UL+DL}}{p_{Active}^{UL} + p_{Active}^{UL+DL}}, \frac{N^{DL} \times p_{Active}^{UL+DL}}{p_{Active}^{DL} + p_{Active}^{UL+DL}}\right)$ or

simply, $n_{Active}^{UL+DL} = Min(N^{UL} \times f_{Act}^{DL}, N^{DL} \times f_{Act}^{UL})$

Number of users active in the uplink: $n_{Active}^{UL} = N^{UL} - n_{Active}^{UL+DL}$

Number of users active in the downlink: $n_{Active}^{DL} = N^{DL} - n_{Active}^{UL+DL}$

And, $n = n_{Active}^{UL} + n_{Active}^{DL} + n_{Active}^{UL+DL}$

Calculation of the number of inactive users attempting to access the service:

Number of inactive users: $n_{Inactive} = \frac{n_v}{1 - p_{Inactive}} \times p_{Inactive}$

> The activity status distribution between users is an average distribution. In fact, in each simulation, the activity status of each user is randomly drawn. Therefore, if you calculate several simulations at once, average numbers of inactive, active on UL, active on DL and active on UL and DL users correspond to the calculated distribution. But if you check each simulation, the activity status distribution between users can be different in each of them.

5.3.4.2 Simulation Process

LTE cells include intelligent schedulers and radio resource management features for regulating network traffic loads, optimising spectral efficiency, and satisfying the QoS demands of the users. Each Monte Carlo simulation in the **9955** LTE module is a snap-shot of the network with resource allocation carried out over a duration of *1* second (100 frames). The steps of this algorithm are listed below.

The simulation process can be summed up into the following iterative steps.

For each simulation, the simulation process,

1. Generates mobiles according to the input traffic data as explained in "User Distribution" on page 333.
2. Sets initial values for the following parameters:
   - Cell transmission powers and EPREs are calculated from the maximum power and EPRE offset values defined by the user as explained in "Downlink Transmission Power Calculation" on page 340.
   - Mobile transmission power is set to the maximum mobile power ($P_{Max}^{M_i}$).
   - Cell loads ($TL_{DL}^{TX_i(ic)}$, $TL_{UL}^{TX_i(ic)}$, $NR_{UL}^{TX_i(ic)}$, $NR_{UL-ICIC}^{TX_i(ic)}$, $r_{DL-ICIC}^{TX_i(ic)}$, and $AU_{DL}^{TX_i(ic)}$) are set to their current values in the Cells table.
3. Determines the best servers for all the mobiles generated for the simulation, and determines whether they are covered by the ICIC or the non-ICIC parts of the frame in downlink, as explained in "Best Server Determination" on page 384.
4. Determines the mobiles which are within the service areas of their best serving cells as explained in "Service Area Calculation" on page 385.
5. Sets the maximum PUSCH C/(I+N) of each cell to a value high enough to ensure that it will not cause any power constraints for cell-edge mobiles.

   For all the mobiles M_i served by any cell $TX_i(ic)$ in the uplink, **9955** calculates $CINR_{PUSCH-Max}^{TX_i(ic)}$ as follows to ensure access to the highest bearer using all the frequency blocks.

   From fractional power control (see "Signal Level Calculation (UL)" on page 372), we know that:

   $$P_{Allowed}^{M_i} = CINR_{PUSCH-Max} + NR_{UL} + n_{PUSCH,\,PUCCH} + \alpha_{FPC} \times L_{Total} \quad (1)$$

   Where $CINR_{PUSCH-Max}$ is the maximum PUSCH C/(I+N), NR_{UL} is the noise rise, $n_{PUSCH,\,PUCCH}$ is the uplink thermal noise, α_{FPC} is the fractional power control factor, and L_{Total} are the total losses.

   Transmitting $P_{Allowed}^{M_i}$, a mobile M_i can access the highest bearer if:

$$P_{Allowed}^{M_i} - NR_{UL} - n_{PUSCH,\,PUCCH} - L_{Total} = T_B^{M_i} \quad (2)$$

Where $T_B^{M_i}$ is the bearer selection thresholds of the highest bearer defined in the LTE equipment used by the cell $TX_i(ic)$.

Combining equations (1) and (2), we get the $CINR_{PUSCH-Max}^{M_i}$ for each mobile M_i that ensures access to the highest bearer:

$$CINR_{PUSCH-Max}^{M_i} = T_B^{M_i} + \left(1 - \alpha_{FPC}^{TX_i(ic)}\right) \times L_{Total}$$

For each cell $TX_i(ic)$, the highest value is kept:

$$CINR_{PUSCH-Max}^{TX_i(ic)} = \underset{All\ M_i}{Max}\left(CINR_{PUSCH-Max}^{M_i}\right)$$

For each iteration *k*, the simulation process,

6. Determines the downlink and uplink C/(I+N) and bearers for each of these mobiles as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367 and "C/(I+N) and Bearer Calculation (UL)" on page 381 respectively.
7. Determines the channel throughputs at the mobile as explained in "Throughput Calculation" on page 385.
8. Performs radio resource management and scheduling to determine the amount of resources to allocate to each mobile according to the service priorities and throughput demands of each mobile using the selected scheduler as explained in "Scheduling and Radio Resource Management" on page 397.
9. Calculates the user throughputs after allocating resources to each mobile as explained in "User Throughput Calculation" on page 403.

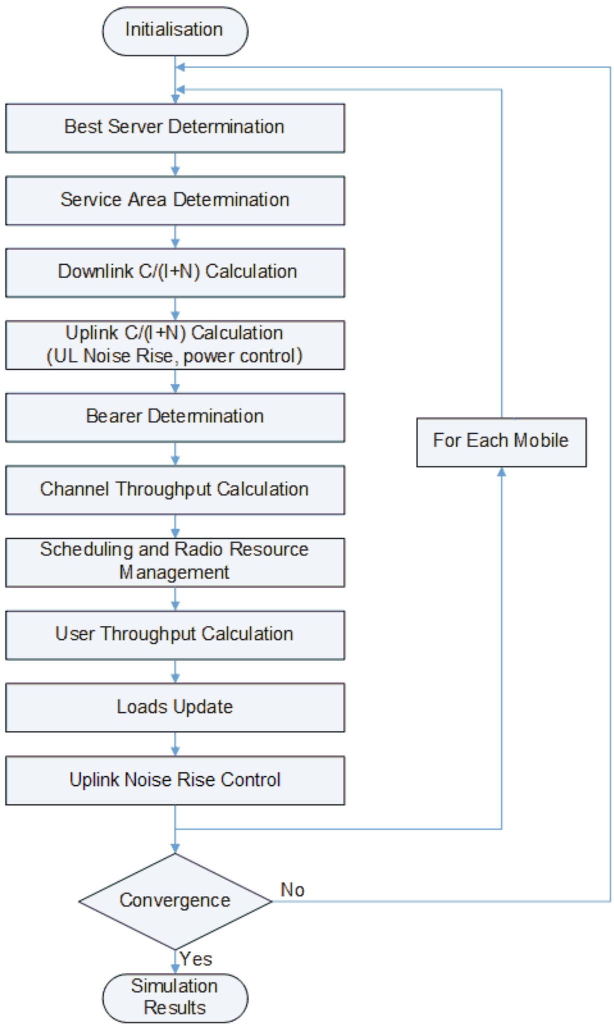


Figure 5.1: LTE Simulation Algorithm

10. Updates the traffic loads, and noise rise values of all the cells according to the resources in use and the total resources as follows:

Calculation of Traffic Loads:

9955 calculates the traffic loads for all the cells $TX_i(ic)$.

$$TL_{DL}^{TX_i(ic)} = \sum_{M_i} R_{DL}^{M_i} \text{ and } TL_{UL}^{TX_i(ic)} = \sum_{M_i} R_{UL}^{M_i}$$

For uplink MU-MIMO, $TL_{UL}^{TX_i(ic)} = \sum_{M_i^{MU-MIMO}} RC_{UL}^{M_i^{MU-MIMO}}$

Calculation of Uplink Noise Rise:

For each victim cell $TX_i(ic)$, the uplink noise rise is calculated and updated by considering each interfering mobile M_j as explained in "Interference Calculation (UL)" on page 375.

Calculation of Downlink ICIC Ratio:

9955 calculates the downlink ICIC ratio for all the cells as follows:

$$r_{DL-ICIC}^{TX_i(ic)} = \frac{\sum_{M_i^{ICIC}} R_{DL}^{M_i^{ICIC}}}{TL_{DL}^{TX_i(ic)}}$$

Where $\sum_{M_i^{ICIC}} R_{DL}^{M_i^{ICIC}}$ is the sum of the percentages of the downlink cell resources allocated to mobiles in the ICIC part of the frame.

Calculation of Downlink AAS Usage:

9955 calculates the downlink AAS usages for all the cells as follows:

$$AU_{DL}^{TX_i(ic)} = \frac{\sum_{M_i|_{AAS}} R_{DL}^{M_i}\Big|_{AAS}}{TL_{DL}^{TX_i(ic)}}$$

Where $\sum_{M_i|_{AAS}} R_{DL}^{M_i}\Big|_{AAS}$ is the sum of the percentages of the downlink cell resources allocated to mobiles served by the smart antennas.

Calculation of Uplink MU-MIMO Gain:

9955 calculates the uplink MU-MIMO gain for all the cells as follows:

$$G_{MU-MIMO}^{TX_i(ic)} = \frac{\sum_{M_i^{MU-MIMO}} R_{UL}^{M_i^{MU-MIMO}}}{\sum_{M_i^{MU-MIMO}} RC_{UL}^{M_i^{MU-MIMO}}}$$

Where $\sum_{M_i^{MU-MIMO}} R_{UL}^{M_i^{MU-MIMO}}$ is the sum of the percentages of the uplink cell resources allocated to MU-MIMO mobiles and $\sum_{M_i^{MU-MIMO}} RC_{UL}^{M_i^{MU-MIMO}}$ is the sum of the real resource consumption of MU-MIMO mobiles.

11. Performs uplink noise rise control as follows:

For each cell $TX_i(ic)$, **9955** calculates the difference between the current and the maximum noise rise values:

$$\Delta NR_{UL}^{TX_i(ic)} = NR_{UL}^{TX_i(ic)} - NR_{UL-Max}^{TX_i(ic)}$$

Here $NR_{UL}^{TX_i(ic)}$ is the uplink noise rise of the cell $TX_i(ic)$ calculated in step 10.

- If $\Delta NR_{UL}^{TX_i(ic)} > 0$, the cell $TX_i(ic)$ requests its neighbouring cells to decrease the uplink transmission powers of the mobiles they serve (mobiles interfering $TX_i(ic)$).
- If $0 > \Delta NR_{UL}^{TX_i(ic)} > M_{NRC}$, the cell $TX_i(ic)$ does not request any change.
- If $\Delta NR_{UL}^{TX_i(ic)} < M_{NRC}$, the cell $TX_i(ic)$ requests its neighbouring cells to increase the uplink transmission powers of the mobiles they serve (mobiles interfering $TX_i(ic)$).

Here M_{NRC} is a noise rise control margin set to -1 dB by default. This value can be changed through Atoll.ini file by adding the following lines and setting it to a value other than "1" (positive values are considered as negative margins):

```
[LTE]
NR_CONTROL_MARGIN_MIN = 1
```

The uplink transmission powers of the mobiles in neighbouring cells of the cell $TX_i(ic)$ are adjusted according to the request in the next iteration by updating the maximum PUSCH C/(I+N) for the neighbouring cells $TX_j(jc)$:

$$CINR_{PUSCH-Max}^{TX_j(jc)}\Big|_k = Min\left(CINR_{PUSCH-Max}^{TX_j(jc)}\Big|_{k-1} - \Delta NR_{UL}^{TX_i(ic)}, CINR_{PUSCH-Limit}, CINR_{PUSCH-Max}^{TX_j(jc)} \right)$$

Here $CINR_{PUSCH-Max}^{TX_j(jc)}\Big|_k$ is the maximum PUSCH C/(I+N) for the neighbouring cell $TX_j(jc)$ in the current iteration k, $CINR_{PUSCH-Max}^{TX_j(jc)}\Big|_{k-1}$ is the maximum PUSCH C/(I+N) for the neighbouring cell $TX_j(jc)$ in the previous iteration k, $CINR_{PUSCH-Limit}$ is an upper limit fixed at 50 dB, and $CINR_{PUSCH-Max}^{TX_j(jc)}$ is the maximum PUSCH C/(I+N) for the neighbouring cell $TX_j(jc)$ as calculated in step 5.

> At most six neighbouring cells are considered in uplink noise rise control. These six neighbouring cells are those whose served mobiles generate the highest interference for the studied cell.

12. Performs the convergence test to see whether the differences between the current and the new loads are within the convergence thresholds.

The convergence criteria are evaluated at the end of each iteration k, and can be written as follows:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(TL_{DL}^{TX_i(ic)}\Big|_k - TL_{DL}^{TX_i(ic)}\Big|_{k-1} \right)$$

$$\Delta TL_{UL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(TL_{UL}^{TX_i(ic)}\Big|_k - TL_{UL}^{TX_i(ic)}\Big|_{k-1} \right)$$

$$\Delta NR_{UL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(NR_{UL}^{TX_i(ic)}\Big|_k - NR_{UL}^{TX_i(ic)}\Big|_{k-1} \right)$$

If $\Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}$, $\Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}$, and $\Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$ are the simulation convergence thresholds defined when creating the simulation, **9955** stops the simulation in the following cases.

Convergence: Simulation has converged between iteration k - 1 and k if:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k \le \Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}\ AND\ \Delta TL_{UL}^{TX_i(ic)}\Big|_k \le \Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}\ AND\ \Delta NR_{UL}^{TX_i(ic)}\Big|_k \le \Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$$

No convergence: Simulation has not converged even after the last iteration, i.e., *k* = Max Number of Iterations defined when creating the simulation, if:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k > \Delta TL_{DL}^{TX_i(ic)}\Big|_{Req} \ OR \ \Delta TL_{UL}^{TX_i(ic)}\Big|_k > \Delta TL_{UL}^{TX_i(ic)}\Big|_{Req} \ OR \ \Delta NR_{UL}^{TX_i(ic)}\Big|_k > \Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$$

13. Repeats the above steps (from step 3.) for the iteration *k+1* using the new calculated loads as the current loads.

Simulation Results

At the end of the simulation process, the main results obtained are:

- Downlink traffic loads
- Uplink traffic loads
- Uplink noise rise
- Downlink ICIC ratio
- Uplink ICIC noise rise
- Downlink AAS usage
- Uplink MU-MIMO capacity gain
- Maximum PUSCH C/(I+N)
- Number of connected users in downlink
- Number of connected users in uplink

These results can be used as input for C/(I+N)-based coverage predictions.

In addition to the above parameters, the simulations also list the connection status of each mobile. Mobiles can be rejected due to:

- **No Coverage:** If the mobile does not have any best serving cell (step 3.) or if the mobile is not within the service area of its best server (step 4.).
- **No Service:** If the mobile is not able to access a bearer in the direction of its activity (step 6.), i.e., UL, DL, or DL+UL, or if the mobile's minimum throughput demand is higher than the UE throughput capacity.
- **Scheduler Saturation:** If the mobile is not in the list of mobiles selected for scheduling (step 8.)
- **Resource Saturation:** If all the cell resources are used up before allocation to the mobile or if, for a user active in uplink, the minimum uplink throughput demand is higher than the uplink allocated bandwidth throughput (step 8.)

Connected mobiles (step 8.) can be:

- **Connected UL:** If a mobile active in UL is allocated resources in UL.
- **Connected DL:** If a mobile active in DL is allocated resources in DL.
- **Connected DL+UL:** If a mobile active in DL+UL is allocated resources in DL+UL.

5.4 Calculation Details

The following sections describe all the calculation algorithms used in point analysis, calculation of coverage predictions, calculations on subscriber lists, and Monte Carlo simulations.

5.4.1 Downlink Transmission Power Calculation

LTE eNode-Bs have a maximum transmission power which is shared by downlink channels. These channels include the downlink reference signals, SSS, PSS, PBCH, PDCCH (which is considered to include the PHICH and PCFICH), and PDSCH. The transmission powers of various channels are determined from the distribution of the total energy over a frame among the resource elements corresponding to these channels. The energy per resource element (EPRE) of the downlink reference signals is considered to be the reference with respect to which the EPRE of other channels is determined. You can either define the reference signal EPRE for each cell, or let **9955** calculate it from the cell's maximum power and the EPRE offsets of other channels. The EPRE offsets of channels other than the downlink reference signals can be positive values meaning a relative boost with respect to the downlink reference signals EPRE, or negative values meaning a reduction with respect to the downlink reference signals EPRE.

9955 first determines the EPRE for each channel in the downlink and then the transmission power corresponding to each channel from the EPRE values.

Input

- ΔF : Subcarrier width (15 kHz).
- W_{FB} : Width of a frequency block (180 kHz).
- $N_{FB-SS,\,PBCH}$: Number of frequency blocks that carry the SS and the PBCH (6).
- $N_{Slot/SF}$: Number of slots per subframe (2).

- D_{CP} : Cyclic prefix duration defined for the network in the Global Parameters.
- $N_{SD/Slot}$: Number of symbol durations per slot (7 is D_{CP} is Normal, 6 if D_{CP} is Extended).
- $N_{SD-PDCCH}$: Number of PDCCH symbol durations per subframe defined in the Global Parameters.
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell *TX_i(ic)*.
- $N_{SF-DL}^{TX_i(ic)}$: Number of downlink subframes in the frame for the cell $TX_i(ic)$. It is equal to 10 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.
- $N_{TDD-SSF}^{TX_i(ic)}$: Number of TDD special subframes (containing DwPTS, GP, and UpPTS) in the frame for the cell $TX_i(ic)$. It is equal to 0 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.

  $N_{SF-DL}^{TX_i(ic)}$ and $N_{TDD-SSF}^{TX_i(ic)}$ are determined as follows:

Configuration	$N_{SF-DL}^{TX_i(ic)}$	$N_{TDD-SSF}^{TX_i(ic)}$
FDD	10	0
DSUUU-DSUUU	2	2
DSUUD-DSUUD	4	2
DSUDD-DSUDD	6	2
DSUUU-DSUUD	3	2
DSUUU-DDDDD	6	1
DSUUD-DDDDD	7	1
DSUDD-DDDDD	8	1

- $N_{Ant-TX}^{TX_i(ic)}$: Number of transmission (downlink) antenna ports defined for the cell $TX_i(ic)$.
- $P_{Max}^{TX_i(ic)}$: Maximum transmission power of the cell $TX_i(ic)$.
- $EPRE_{DLRS}^{TX_i(ic)}$: Downlink reference signal EPRE of the cell $TX_i(ic)$.

  You can either set the $P_{Max}^{TX_i(ic)}$ or $EPRE_{DLRS}^{TX_i(ic)}$ for a cell.

- $\Delta EPRE_{SS}^{TX_i(ic)}$: Energy per resource element offset for the SS with respect to the downlink reference signals EPRE.
- $\Delta EPRE_{PBCH}^{TX_i(ic)}$: Energy per resource element offset for the PBCH with respect to the downlink reference signals EPRE.
- $\Delta EPRE_{PDCCH}^{TX_i(ic)}$: Energy per resource element offset for the PDCCH with respect to the downlink reference signals EPRE.
- $\Delta EPRE_{PDSCH}^{TX_i(ic)}$: Energy per resource element offset for the PDSCH with respect to the downlink reference signals EPRE.

Calculations

If you have directly entered the downlink reference signal EPRE for the cell, you can skip the section "Calculation of Downlink Reference Signal EPRE" on page 341 and go directly to the section "Calculation of Other EPREs and Per-channel Powers" on page 346.

Calculation of Downlink Reference Signal EPRE

In LTE, a resource block (RB) is defined as 1 frequency block by 1 slot. However, schedulers are able to perform resource allocation every subframe (2 slots). 1 frequency block by 1 subframe (2 slots) is called a scheduler resource block (SRB) in the calculations below.

The number of modulation symbols (resource elements) per scheduler resource block is calculated as follows:

$$N_{Sym/SRB} = N_{SCa-FB} \times N_{SD/Slot} \times N_{Slot/SF}$$

Where N_{SCa-FB} is the number of subcarriers per frequency block calculated as follows:

$$N_{SCa-FB} = \frac{W_{FB}}{\Delta F}$$

The number of modulation symbols (resource elements) corresponding to the DwPTS per scheduler resource block in the TDD special subframes is calculated as follows:

$$N_{Sym/SSF}^{DwPTS} = N_{SCa-FB} \times N_{SD/SSF}^{DwPTS}$$

Where $N_{SD/SSF}^{DwPTS}$ is the number of DwPTS symbol durations (OFDM symbols) per special subframe, determined from the TDD special subframe configuration according to the 3GPP specifications as follows:

Special Subframe Configuration	Cyclic Prefix = Normal			Cyclic Prefix = Extended		
	DwPTS $N_{SD/SSF}^{DwPTS}$	GP $N_{SD/SSF}^{GP}$	UpPTS $N_{SD/SSF}^{UpPTS}$	DwPTS $N_{SD/SSF}^{DwPTS}$	GP $N_{SD/SSF}^{GP}$	UpPTS $N_{SD/SSF}^{UpPTS}$
0	3	10	1	3	8	1
1	9	4		8	3	
2	10	3		9	2	
3	11	2		10	1	
4	12	1		3	7	2
5	3	9	2	8	2	
6	9	3		9	1	
7	10	2				
8	11	1				

The total number of modulation symbols (resource elements) in downlink is calculated as follows:

$$N_{Sym-DL}^{TX_i(ic)} = N_{FB}^{TX_i(ic)} \times N_{Sym/SRB} \times N_{SF-DL}^{TX_i(ic)} + N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)} \times N_{Sym/SSF}^{DwPTS}$$

Out of the total number of modulation symbols, **9955** then determines the numbers of modulation symbols corresponding to each control channel as follows:

The number of modulation symbols for the downlink reference signals

The number of modulation symbols reserved for downlink reference signal transmission in one scheduler resource block depends on the number of transmission antenna ports:

For all subframes except the TDD special subframes: $N_{Res/SRB}^{TX_i(ic)} = \begin{cases} 8 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 1\right) \\ 16 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 2\right) \\ 24 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 4 \text{ or } 8\right) \end{cases}$

For TDD special subframes:

Special Subframe Configuration	Cyclic Prefix = Normal			Cyclic Prefix = Extended		
	$N_{SD/SSF}^{DwPTS}$	$N_{Ant-TX}^{TX_i(ic)}$	$N_{Res/DwPTS}^{TX_i(ic)}$	$N_{SD/SSF}^{DwPTS}$	$N_{Ant-TX}^{TX_i(ic)}$	$N_{Res/DwPTS}^{TX_i(ic)}$
0	3	1	2	3	1	2
		2	4		2	4
		4	8		4	8
		8	8		8	8
1	9	1	6	8	1	6
		2	12		2	12
		4	20		4	20
		8	20		8	20

Special Subframe Configuration	Cyclic Prefix = Normal			Cyclic Prefix = Extended		
	$N^{DwPTS}_{SD/SSF}$	$N^{TX_i(ic)}_{Ant-TX}$	$N^{TX_i(ic)}_{Res/DwPTS}$	$N^{DwPTS}_{SD/SSF}$	$N^{TX_i(ic)}_{Ant-TX}$	$N^{TX_i(ic)}_{Res/DwPTS}$
2	10	1	6	9	1	6
		2	12		2	12
		4	20		4	20
		8	20		8	20
3	11	1	6	10	1	8
		2	12		2	16
		4	20		4	24
		8	20		8	24
4	12	1	8	3	1	2
		2	16		2	4
		4	24		4	8
		8	24		8	8
5	3	1	2	8	1	6
		2	4		2	12
		4	8		4	20
		8	8		8	20
6	9	1	6	9	1	6
		2	12		2	12
		4	20		4	20
		8	20		8	20
7	10	1	6			
		2	12			
		4	20			
		8	20			
8	11	1	6			
		2	12			
		4	20			
		8	20			

This gives a number of reserved modulation symbols per frame:

$$N^{TX_i(ic)}_{Sym-Res} = N^{TX_i(ic)}_{SF-DL} \times N^{TX_i(ic)}_{FB} \times N^{TX_i(ic)}_{Res/SRB} + N^{TX_i(ic)}_{TDD-SSF} \times N^{TX_i(ic)}_{FB} \times N^{TX_i(ic)}_{Res/DwPTS}$$

The number of modulation symbols used for downlink reference signal transmission in one scheduler resource block is:

For all subframes except the TDD special subframes: $N^{TX_i(ic)}_{DLRS/SRB} = \begin{cases} 8 & if \left(N^{TX_i(ic)}_{Ant-TX} = 1\right) \\ 8 & if \left(N^{TX_i(ic)}_{Ant-TX} = 2\right) \\ 6 & if \left(N^{TX_i(ic)}_{Ant-TX} = 4 \ or \ 8\right) \end{cases}$

For TDD special subframes:

Special Subframe Configuration	Cyclic Prefix = Normal			Cyclic Prefix = Extended		
	$N_{SD/SSF}^{DwPTS}$	$N_{Ant-TX}^{TX_i(ic)}$	$N_{DLRS/DwPTS}^{TX_i(ic)}$	$N_{SD/SSF}^{DwPTS}$	$N_{Ant-TX}^{TX_i(ic)}$	$N_{DLRS/DwPTS}^{TX_i(ic)}$
0	3	1	2	3	1	2
		2	2		2	2
		4	2		4	2
		8	2		8	2
1	9	1	6	8	1	6
		2	6		2	6
		4	5		4	5
		8	5		8	5
2	10	1	6	9	1	6
		2	6		2	6
		4	5		4	5
		8	5		8	5
3	11	1	6	10	1	8
		2	6		2	8
		4	5		4	6
		8	5		8	6
4	12	1	8	3	1	2
		2	8		2	2
		4	6		4	2
		8	6		8	2
5	3	1	2	8	1	6
		2	2		2	6
		4	2		4	5
		8	2		8	5
6	9	1	6	9	1	6
		2	6		2	6
		4	5		4	5
		8	5		8	5
7	10	1	6			
		2	6			
		4	5			
		8	5			
8	11	1	6			
		2	6			
		4	5			
		8	5			

This gives a number of downlink reference signal modulation symbols per frame:

$$N_{Sym-DLRS}^{TX_i(ic)} = N_{SF-DL}^{TX_i(ic)} \times N_{FB}^{TX_i(ic)} \times N_{DLRS/SRB}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)} \times N_{FB}^{TX_i(ic)} \times N_{DLRS/DwPTS}^{TX_i(ic)}$$

The number of modulation symbols for the SS

The primary and secondary synchonisation signals are transmitted on 1 symbol duration each in the 1st and the 6th downlink subframes, over the center 6 frequency blocks. Therefore,

$$N_{Sym-PSS} = 2 \times N_{FB-SS,\,PBCH} \times N_{SCa-FB} = 144$$

$$N_{Sym-SSS} = 2 \times N_{FB-SS,\,PBCH} \times N_{SCa-FB} = 144$$

And, $N_{Sym-SS} = N_{Sym-PSS} + N_{Sym-SSS} = 288$

The number of modulation symbols for the PBCH

The physical broadcast channel is transmitted on four symbol durations in the 1st downlink subframe over the center 6 frequency blocks. The physical broadcast channel overlaps with the downlink reference signals, therefore, some modulation symbols reserved for downlink reference signals are subtracted:

$$N_{Sym-PBCH}^{TX_i(ic)} = \left(4 \times N_{SCa-FB} - \frac{N_{Res/SRB}^{TX_i(ic)}}{2}\right) \times N_{FB-SS,\,PBCH} \text{ for extended cyclic prefix}$$

$$N_{Sym-PBCH}^{TX_i(ic)} = \left(4 \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB-SS,\,PBCH} \text{ for normal cyclic prefix}$$

The number of modulation symbols for the PDCCH

The physical downlink control channel can be transmitted over up to 3 symbol durations in each subframe. The number of symbol durations for the PDCCH is defined in the global parameters. The physical downlink control channel overlaps with the downlink reference signals, therefore, some modulation symbols reserved for downlink reference signals are subtracted:

$$if \quad (N_{SD-PDCCH} = 0):$$

$$N_{Sym-PDCCH}^{TX_i(ic)} = 0$$

$$if \quad (N_{SD-PDCCH} = 1)\ AND \left(N_{Ant-TX}^{TX_i(ic)} = 4 \text{ or } 8\right):$$

$$N_{Sym-PDCCH}^{TX_i(ic)} = \left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)} + \left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$$

Otherwise:

$$N_{Sym-PDCCH}^{TX_i(ic)} = \left(N_{SD-PDCCH} \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)} + \left(Min(2, N_{SD-PDCCH}) \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$$

The number of modulation symbols for the PDSCH

The total number of modulation symbols in the frame excluding all the control channel modulation symbols gives the number of modulation symbols available for user data, i.e., for the PDSCH:

$$N_{Sym-PDSCH}^{TX_i(ic)} = N_{Sym-DL}^{TX_i(ic)} - N_{Sym-Res}^{TX_i(ic)} - N_{Sym-SS} - N_{Sym-PBCH}^{TX_i(ic)} - N_{Sym-PDCCH}^{TX_i(ic)}$$

The energy per resource element for 1 modulation symbol (dBm/Sym) of the downlink reference signals is calculated as follows:

- If the reference signal EPRE calculation method is set to Calculated (equal distribution of unused EPRE):

$$EPRE_{DLRS}^{TX_i(ic)} = 10 \times Log\left(10^{\frac{P_{Max}^{TX_i(ic)}}{10}} \times N_{SD/Slot} \times N_{Slot/SF} \times N_{SF-DL}^{TX_i(ic)}\right) - 10 \times Log\left(N_{Sym-DLRS}^{TX_i(ic)} + N_{Sym-SS} \times 10^{\frac{\Delta EPRE_{SS}^{TX_i(ic)}}{10}} + N_{Sym-PBCH} \times 10^{\frac{\Delta EPRE_{PBCH}^{TX_i(ic)}}{10}} + N_{Sym-PDCCH} \times 10^{\frac{\Delta EPRE_{PDCCH}^{TX_i(ic)}}{10}} + N_{Sym-PDSCH} \times 10^{\frac{\Delta EPRE_{PDSCH}^{TX_i(ic)}}{10}}\right)$$

- If the reference signal EPRE calculation method is set to Calculated (with boost) or Calculated (without boost):

$$EPRE_{DLRS}^{TX_i(ic)} = 10 \times Log\left(10^{\frac{P_{Max}^{TX_i(ic)}}{10}} \times N_{SD/Slot} \times N_{Slot/SF} \times N_{SF-DL}^{TX_i(ic)}\right) -$$

$$10 \times Log\left(N_{Sym-Res}^{TX_i(ic)} + N_{Sym-SS} \times 10^{\frac{\Delta EPRE_{SS}^{TX_i(ic)}}{10}} + N_{Sym-PBCH} \times 10^{\frac{\Delta EPRE_{PBCH}^{TX_i(ic)}}{10}}\right.$$

$$\left. + N_{Sym-PDCCH} \times 10^{\frac{\Delta EPRE_{PDCCH}^{TX_i(ic)}}{10}} + N_{Sym-PDSCH} \times 10^{\frac{\Delta EPRE_{PDSCH}^{TX_i(ic)}}{10}}\right)$$

Calculation of Other EPREs and Per-channel Powers

The energy per resource element for 1 modulation symbol (dBm/Sym) of the SS is calculated as follows:

$$EPRE_{SS}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + \Delta EPRE_{SS}^{TX_i(ic)}$$

The energy per resource element for 1 modulation symbol (dBm/Sym) of the PBCH is calculated as follows:

$$EPRE_{PBCH}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + \Delta EPRE_{PBCH}^{TX_i(ic)}$$

The energy per resource element for 1 modulation symbol (dBm/Sym) of the PDCCH is calculated as follows:

$$EPRE_{PDCCH}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + \Delta EPRE_{PDCCH}^{TX_i(ic)}$$

The energy per resource element for 1 modulation symbol (dBm/Sym) of the PDSCH is calculated as follows:

$$EPRE_{PDSCH}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + \Delta EPRE_{PDSCH}^{TX_i(ic)}$$

If the reference signal EPRE calculation method is set to Calculated (with boost), the "boosted" RS energy per resource element is calculated as follows:

$$EPRE_{DLRS}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + 10 \times Log\left(\frac{N_{Sym-Res}^{TX_i(ic)}}{N_{Sym-DLRS}^{TX_i(ic)}}\right)$$

The instantaneous downlink reference signal transmission power is calculated as follows:

$$P_{DLRS}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + 10 \times Log\left(2 \times N_{FB}^{TX_i(ic)}\right)$$

Where $2 \times N_{FB}^{TX_i(ic)}$ implies that at the instant when downlink reference signals are transmitted, they are transmitted using 2 subcarriers in each frequency block.

The instantaneous SS transmission power is calculated as follows:

$$P_{SS}^{TX_i(ic)} = EPRE_{SS}^{TX_i(ic)} + 10 \times Log(N_{SCa-FB} \times N_{FB-SS,\,PBCH})$$

The instantaneous PBCH transmission power is calculated as follows:

$$P_{PBCH}^{TX_i(ic)} = EPRE_{PBCH}^{TX_i(ic)} + 10 \times Log(N_{SCa-FB} \times N_{FB-SS,\,PBCH})$$

Where $N_{SCa-FB} \times N_{FB-SS,\,PBCH}$ implies that at the instant when the SS and the PBCH are transmitted, they are transmitted using all the subcarriers in the centre 6 consecutive frequency blocks.

The average PDCCH transmission power is calculated as follows:

$$P_{PDCCH}^{TX_i(ic)} = EPRE_{PDCCH}^{TX_i(ic)} + 10 \times Log\left(\frac{N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SD-PDCCH} \times N_{SF-DL}^{TX_i(ic)}}\right)$$

The average PDSCH transmission power is calculated as follows:

$$P_{PDSCH}^{TX_i(ic)} = EPRE_{PDSCH}^{TX_i(ic)} + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)}}{(N_{SD/Slot} \times N_{Slot/SF} - N_{SD-PDCCH}) \times N_{SF-DL}^{TX_i(ic)}}\right)$$

As the number of subcarriers used for the PDCCH and PDSCH transmission varies over time, i.e., from one symbol duration to the next, the instantaneous powers of the PDCCH and the PDSCH also vary over time. This is why average transmission powers are calculated and used in **9955**.

Output

- $EPRE_{DLRS}^{TX_i(ic)}$: Energy per resource element of the downlink reference signals for cell $TX_i(ic)$.
- $EPRE_{SS}^{TX_i(ic)}$: Energy per resource element of the SS for cell $TX_i(ic)$.
- $EPRE_{PBCH}^{TX_i(ic)}$: Energy per resource element of the PBCH for cell $TX_i(ic)$.
- $EPRE_{PDCCH}^{TX_i(ic)}$: Energy per resource element of the PDCCH for cell $TX_i(ic)$.
- $EPRE_{PDSCH}^{TX_i(ic)}$: Energy per resource element of the PDSCH for cell $TX_i(ic)$.
- $P_{DLRS}^{TX_i(ic)}$: Instantaneous transmission power of the downlink reference signals for cell $TX_i(ic)$.
- $P_{SS}^{TX_i(ic)}$: Instantaneous transmission power of the SS for cell $TX_i(ic)$.
- $P_{PBCH}^{TX_i(ic)}$: Instantaneous transmission power of the PBCH for cell $TX_i(ic)$.
- $P_{PDCCH}^{TX_i(ic)}$: Average transmission power of the PDCCH for cell $TX_i(ic)$.
- $P_{PDSCH}^{TX_i(ic)}$: Average transmission power of the PDSCH for cell $TX_i(ic)$.

5.4.2 Co- and Adjacent Channel Overlaps Calculation

An LTE network can consist of cells that use different channel bandwidths. Therefore, the start and end frequencies of all the channels may not exactly coincide. Channel bandwidths of cells can overlap each other with different ratios.

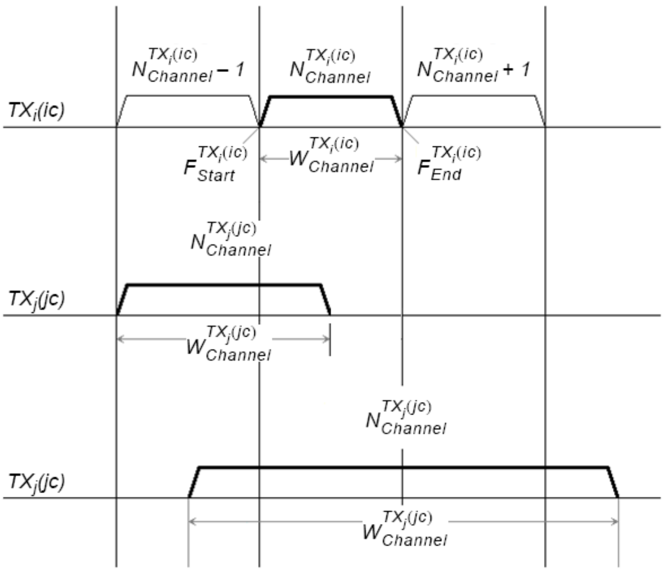


Figure 5.2: Co-Channel and Adjacent Channel Overlaps

The following sections describe how the co- and adjacent channel overlaps are calculated between the channels used by any studied cell $TX_i(ic)$ and any other cell $TX_j(jc)$ of the network. In terms of interference calculation, the studied cell can be considered a victim of interference received from the other cells that might be interfering the studied cell.

If the studied cell is assigned a channel number $N_{Channel}^{TX_i(ic)}$, it receives co-channel interference on the channel bandwidth of $N_{Channel}^{TX_i(ic)}$, and adjacent channel interference on the adjacent channel bandwidths, i.e., corresponding to $N_{Channel}^{TX_i(ic)} - 1$ and $N_{Channel}^{TX_i(ic)} + 1$.

In order to calculate the co- and adjacent channel overlaps between two channels, it is necessary to calculate the start and end frequencies of both channels (explained in "Conversion From Channel Numbers to Start and End Frequencies" on page 348). Once the start and end frequencies are known for the studied and other cells, the co- and adjacent overlaps and the total overlap ratio are calculated as respectively explained in:

- "Co-Channel Overlap Calculation" on page 349.
- "Adjacent Channel Overlap Calculation" on page 349.
- "Total Overlap Ratio Calculation" on page 350.

5.4.2.1 Conversion From Channel Numbers to Start and End Frequencies

Input

- $F_{Start-Band}^{TX_i(ic)}$ and $F_{Start-Band}^{TX_j(jc)}$: Start frequencies of the frequency bands assigned to the cells *$TX_i(ic)$ and $TX_j(jc)$.*

  $F_{Start-Band}$ can be the start frequency of a TDD frequency band ($F_{Start-TDD}$), or the uplink or the downlink start frequency of an FDD frequency band ($F_{Start-FDD-UL}$ or $F_{Start-FDD-DL}$).

- $N_{Channel}^{First-TX_i(ic)}$ and $N_{Channel}^{First-TX_j(jc)}$: First channel numbers the frequency band assigned to the cells *$TX_i(ic)$ and $TX_j(jc)$.*
- $N_{Channel}^{TX_i(ic)}$ and $N_{Channel}^{TX_j(jc)}$: Channel numbers assigned to cells *$TX_i(ic)$ and $TX_j(jc)$.*

  For FDD networks, **9955** considers that the same channel number is assigned to a cell in the downlink and uplink, i.e., the channel number you assign to a cell is considered for uplink and downlink both.

- $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$: Bandwidths of the channels assigned to cells *$TX_i(ic)$* and *$TX_j(jc)$.*

Calculations

Channel numbers are converted into start and end frequencies as follows:

For cell *$TX_i(ic)$*:

$$F_{Start}^{TX_i(ic)} = F_{Start-Band}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)}\right)$$

$$F_{End}^{TX_i(ic)} = F_{Start-Band}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)} + 1\right)$$

For cell *$TX_j(jc)$*:

$$F_{Start}^{TX_j(jc)} = F_{Start-Band}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times \left(N_{Channel}^{TX_j(jc)} - N_{Channel}^{First-TX_j(jc)}\right)$$

$$F_{End}^{TX_j(jc)} = F_{Start-Band}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times \left(N_{Channel}^{TX_j(jc)} - N_{Channel}^{First-TX_j(jc)} + 1\right)$$

Output

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells *$TX_i(ic)$* and *$TX_j(jc)$.*
- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells *$TX_i(ic)$* and *$TX_j(jc)$.*

5.4.2.2 Co-Channel Overlap Calculation

Input

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells *TX$_i$(ic)* and *TX$_j$(jc)* as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 348.
- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells *TX$_i$(ic)* and *TX$_j$(jc)* as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 348.
- $W_{Channel}^{TX_i(ic)}$: Bandwidth of the channel assigned to the studied cell *TX$_i$(ic).*

Calculations

9955 first verifies that co-channel overlap exists between the cells *TX$_i$(ic)* and *TX$_j$(jc)*.

Co-channel overlap exists if:

$$F_{Start}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \quad AND \quad F_{End}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Otherwise there is no co-channel overlap.

9955 calculates the bandwidth of the co-channel overlap as follows:

$$W_{CCO}^{TX_i(ic) - TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right)$$

The co-channel overlap ratio is given by:

$$r_{CCO}^{TX_i(ic) - TX_j(jc)} = \frac{W_{CCO}^{TX_i(ic) - TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

Output

- $r_{CCO}^{TX_i(ic) - TX_j(jc)}$: Co-channel overlap ratio between the cells *TX$_i$(ic)* and *TX$_j$(jc).*

5.4.2.3 Adjacent Channel Overlap Calculation

Input

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells *TX$_i$(ic)* and *TX$_j$(jc)* as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 348.
- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells *TX$_i$(ic)* and *TX$_j$(jc)* as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 348.
- $W_{Channel}^{TX_i(ic)}$: Bandwidth of the channel assigned to the studied cell *TX$_i$(ic).*

Calculations

9955 first verifies that adjacent channel overlaps exist between (the lower-frequency and the higher-frequency adjacent channels of) the cells *TX$_i$(ic)* and *TX$_j$(jc)*.

Adjacent channel overlap exists on the lower-frequency adjacent channel if:

$$F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \quad AND \quad F_{Start}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Adjacent channel overlap exists on the higher-frequency adjacent channel if:

$$F_{End}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \quad AND \quad F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Otherwise there is no adjacent channel overlap.

9955 determines the adjacent channel overlap ratio as follows:

Bandwidth of the lower-frequency adjacent channel overlap:

$$W_{ACO_L}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)}\right)$$

The lower-frequency adjacent channel overlap ratio is given by:

$$r_{ACO_L}^{TX_i(ic)-TX_j(jc)} = \frac{W_{ACO_L}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

Bandwidth of the higher-frequency adjacent channel overlap:

$$W_{ACO_H}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right)$$

The higher-frequency adjacent channel overlap ratio is given by:

$$r_{ACO_H}^{TX_i(ic)-TX_j(jc)} = \frac{W_{ACO_H}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

The adjacent channel overlap ratio is given by:

$$r_{ACO}^{TX_i(ic)-TX_j(jc)} = r_{ACO_L}^{TX_i(ic)-TX_j(jc)} + r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$$

Output

- $r_{ACO}^{TX_i(ic)-TX_j(jc)}$: Adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

5.4.2.4 Total Overlap Ratio Calculation

Input

- $r_{CCO}^{TX_i(ic)-TX_j(jc)}$: Co-channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co-Channel Overlap Calculation" on page 349.
- $r_{ACO}^{TX_i(ic)-TX_j(jc)}$: Adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Adjacent Channel Overlap Calculation" on page 349.
- $f_{ACS}^{TX_i(ic)}$: Adjacent channel suppression factor defined for the frequency band of the cell $TX_i(ic)$.
- $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$: Bandwidths of the channels assigned to the cells $TX_i(ic)$ and $TX_j(jc)$.

Calculations

The total overlap ratio is:

$$r_O^{TX_i(ic)-TX_j(jc)} = \begin{cases} \left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS}^{TX_i(ic)}}{10}}\right) & \text{if } W_{Channel}^{TX_i(ic)} \geq W_{Channel}^{TX_j(jc)} \\ \left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS}^{TX_i(ic)}}{10}}\right) \times \frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}} & \text{if } W_{Channel}^{TX_i(ic)} < W_{Channel}^{TX_j(jc)} \end{cases}$$

The multiplicative factor $\frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ is used to normalise the transmission power of the interfering cell $TX_j(jc)$. This means that if the interfering cell transmits at X dBm over a bandwidth of $W_{Channel}^{TX_j(jc)}$, and it interferes over a bandwidth less than $W_{Channel}^{TX_j(jc)}$, the interference from this cell should not be considered at *X* dBm but less than that. The factor $\frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ converts *X* dBm over $W_{Channel}^{TX_j(jc)}$ to *Y* dBm (which is less than *X* dBm) over less than $W_{Channel}^{TX_j(jc)}$.

Output

- $r_O^{TX_i(ic) - TX_j(jc)}$: Total co- and adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

5.4.3 Signal Level and Signal Quality Calculations

These calculations include the calculation of the received signal levels, and noise and interference. The following sections describe how the received signal levels, the noise and interference, C/N, and C/(I+N) ratios are calculated in **9955**:

- "Signal Level Calculation (DL)" on page 310.
- "Noise Calculation (DL)" on page 354.
- "Interference Calculation (DL)" on page 355.
- "C/N Calculation (DL)" on page 365.
- "C/(I+N) and Bearer Calculation (DL)" on page 367.
- "Signal Level Calculation (UL)" on page 372.
- "Noise Calculation (UL)" on page 374.
- "Interference Calculation (UL)" on page 375.
- "Noise Rise Calculation (UL)" on page 377.
- "C/N Calculation (UL)" on page 378.
- "C/(I+N) and Bearer Calculation (UL)" on page 381.

5.4.3.1 Signal Level Calculation (DL)

Input

- $P_{Max}^{TX_i(ic)}$: Max power of the cell $TX_i(ic)$.
- $P_{DLRS}^{TX_i(ic)}$: Transmission power of the downlink reference signals for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $P_{SS}^{TX_i(ic)}$: Transmission power of the SS for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $P_{PBCH}^{TX_i(ic)}$: Transmission power of the PBCH for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $P_{PDCCH}^{TX_i(ic)}$: Transmission power of the PDCCH for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $P_{PDSCH}^{TX_i(ic)}$: Transmission power of the PDSCH for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $EPRE_{DLRS}^{TX_i(ic)}$: Energy per resource element of the downlink reference signals for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $EPRE_{SS}^{TX_i(ic)}$: Energy per resource element of the SS for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $EPRE_{PBCH}^{TX_i(ic)}$: Energy per resource element of the PBCH for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $EPRE_{PDCCH}^{TX_i(ic)}$: Energy per resource element of the PDCCH for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $EPRE_{PDSCH}^{TX_i(ic)}$: Energy per resource element of the PDSCH for cell $TX_i(ic)$ as calculated in "Downlink Transmission Power Calculation" on page 340.
- $E_{SA}^{TX_i}$: Number of antenna elements defined for the smart antenna equipment used by the transmitter TX_i.

- ΔG_{SA}^{Array} : Smart antenna array gain offset defined per clutter class.
- $\Delta G_{SA}^{Combining}$: Smart power combining gain offset defined per clutter class.
- G_{SA}^{Div} : Smart antenna diversity gain (for cross-polarised smart antennas) defined per clutter class.
- $G_{Ant}^{TX_i}$: Transmitter antenna gain for the antenna used by the transmitter TX_i.
- $G_{SA}^{TX_i}(\theta)$: Smart antenna gain in the direction θ of the served pixel, subscriber, or mobile M_i. For more information on the calculation of $G_{SA}^{TX_i}(\theta)$, see "Beamforming Smart Antenna Models" on page 41.
- L^{TX_i} : Total transmitter losses for the transmitter TX_i ($L^{TX_i} = L_{Total-DL}$).
- L_{Model} : Loss on the transmitter-receiver path (path loss) calculated using a propagation model.
- $L_{Ant}^{TX_i}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_i.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.
- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.
- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.
- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  For calculating the useful signal level from the best serving cell, $L_{Ant}^{M_i}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L_{Ant}^{M_i}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.
- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.

> L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$ are not used in the calculations performed for the point analysis tool's profile tab, delta path loss calculation, and the downlink reference signal level based coverage predictions.

- D_{CP} : Cyclic prefix duration defined for the network in the Global Parameters.

Calculations

The received signal levels (dBm) from any cell $TX_i(ic)$ are calculated for a pixel, subscriber, or mobile M_i as follows:

$$C_{Max}^{TX_i(ic)} = EIRP_{Max}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP_{Max}^{TX_i(ic)} = P_{Max}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP_{Max}^{TX_i(ic)} = P_{Max}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

$$C_{DLRS}^{TX_i(ic)} = EIRP1_{DLRS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP1_{DLRS}^{TX_i(ic)} = P_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP1_{DLRS}^{TX_i(ic)} = P_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining}$

$$C_{SS}^{TX_i(ic)} = EIRP1_{SS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP1_{SS}^{TX_i(ic)} = P_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP1_{SS}^{TX_i(ic)} = P_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

$$C_{PBCH}^{TX_i(ic)} = EIRP1_{PBCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP1_{PBCH}^{TX_i(ic)} = P_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP1_{PBCH}^{TX_i(ic)} = P_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

$$C_{PDCCH}^{TX_i(ic)} = EIRP1_{PDCCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP1_{PDCCH}^{TX_i(ic)} = P_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP1_{PDCCH}^{TX_i(ic)} = P_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

$$C_{PDSCH}^{TX_i(ic)} = EIRP1_{PDSCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP1_{PDSCH}^{TX_i(ic)} = P_{PDSCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP1_{PDSCH}^{TX_i(ic)} = P_{PDSCH}^{TX_i(ic)} + G_{SA}^{TX_i}(\theta) + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$

The energy per resource element (dBm/Sym) received from any cell $TX_i(ic)$ are calculated for a pixel, subscriber, or mobile M_i as follows:

RSRP: $E_{DLRS}^{TX_i(ic)} = EIRP2_{DLRS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$

Without smart antennas: $EIRP2_{DLRS}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP2_{DLRS}^{TX_i(ic)} = EPRE_{DLRS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining}$

$$E_{SS}^{TX_i(ic)} = EIRP2_{SS}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP2_{SS}^{TX_i(ic)} = EPRE_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP2_{SS}^{TX_i(ic)} = EPRE_{SS}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

$$E_{PBCH}^{TX_i(ic)} = EIRP2_{PBCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP2_{PBCH}^{TX_i(ic)} = EPRE_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP2_{PBCH}^{TX_i(ic)} = EPRE_{PBCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

$$E_{PDCCH}^{TX_i(ic)} = EIRP2_{PDCCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP2_{PDCCH}^{TX_i(ic)} = EPRE_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP2_{PDCCH}^{TX_i(ic)} = EPRE_{PDCCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

$$E_{PDSCH}^{TX_i(ic)} = EIRP2_{PDSCH}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Without smart antennas: $EIRP2_{PDSCH}^{TX_i(ic)} = EPRE_{PDSCH}^{TX_i(ic)} + G_{Ant}^{TX_i} - L^{TX_i}$

With smart antennas: $EIRP2_{PDSCH}^{TX_i(ic)} = EPRE_{PDSCH}^{TX_i(ic)} + G_{SA}^{TX_i}(\theta) + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$

In the above, L_{Path} is the path loss (dB) calculated as follows:

$$L_{Path} = L_{Model} + L_{Ant}^{TX_i}$$

Furthermore, the total losses between the cell and the pixel, subscriber, or mobile M_i can be calculated as follows:

$$L_{Total} = L_{Path} + L^{TX_i} + L_{Indoor} + M_{Shadowing-Model} - G^{TX_i} + L^{M_i} - G^{M_i} + L_{Ant}^{M_i} + L_{Body}^{M_i}$$

f_{CP} is the cyclic prefix factor, i.e., the ratio of the useful symbol energy to the total symbol energy.

The total symbol duration of a modulation symbol comprises the useful symbol duration, carrying the actual data bits, and a cyclic prefix, added to the useful data bits as padding against multi-path to avoid inter-symbol interference. Hence, the total energy within a modulation symbol belongs in part to the useful data bits and in part to the cyclic prefix. Once a modulation symbol is received, only the energy of the useful data bits can be used for extracting the data. The energy belonging to the cyclic prefix is lost once it has served its purpose of combatting inter-symbol interference. Therefore, f_{CP} implies that the energy belonging to the cyclic prefix is excluded from the useful signal level.

$$f_{CP} = \begin{cases} 10 \times Log(7/7.5) & If \quad D_{CP} = Normal \\ 10 \times Log(6/7.5) & If \quad D_{CP} = Extended \\ 0 & If \quad TX_i(ic) \text{ is an interferer} \end{cases}$$

The cyclic prefix energy and the useful data bits energy are both taken into account when calculating interfering signal levels.

Output

- $C_{Max}^{TX_i(ic)}$: Received max signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $C_{DLRS}^{TX_i(ic)}$: Received downlink reference signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $C_{SS}^{TX_i(ic)}$: Received SS signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $C_{PBCH}^{TX_i(ic)}$: Received PBCH signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $C_{PDCCH}^{TX_i(ic)}$: Received PDCCH signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $C_{PDSCH}^{TX_i(ic)}$: Received PDSCH signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $E_{DLRS}^{TX_i(ic)}$: Received downlink reference signal energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $E_{SS}^{TX_i(ic)}$: Received SS energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $E_{PBCH}^{TX_i(ic)}$: Received PBCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $E_{PDCCH}^{TX_i(ic)}$: Received PDCCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $E_{PDSCH}^{TX_i(ic)}$: Received PDSCH enerегy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- L_{Path} : Path loss between the cell $TX_i(ic)$ and the pixel, subscriber, or mobile M_i.
- L_{Total} : Total losses between the cell $TX_i(ic)$ and the pixel, subscriber, or mobile M_i.

5.4.3.2 Noise Calculation (DL)

For determining the C/N and C/(I+N), **9955** calculates the downlink noise which comprises thermal noise and the noise figure of the equipment. The thermal noise density depends on the temperature, i.e., it remains constant for a given temperature. However, the value of the thermal noise varies with the used bandwidth.

Input

- K: Boltzmann's constant.
- T: Temperature in Kelvin.
- ΔF : Subcarrier width (15 kHz).
- nf^{M_i} : Noise figure of the terminal used for calculations by the pixel, subscriber, or mobile M_i.

Calculations

The power spectral density of thermal noise is calculated as follows:

$$n_0 = 10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$$

The thermal noise for one resource element, i.e., over one subcarrier, is calculated as follows:

$$n_{0-Sym}^{TX_i(ic)} = n_0 + 10 \times Log(\Delta F)$$

The downlink noise is the sum of the thermal noise and the noise figure of the terminal used for the calculations by the pixel, subscriber, or mobile M_i. The downlink noise for one resource element, i.e., over one subcarrier, is calculated as follows:

$$n_{Sym}^{TX_i(ic)} = n_{0-Sym}^{TX_i(ic)} + nf^{M_i}$$

Output

- $n_{Sym}^{TX_i(ic)}$: Downlink noise for one subcarrier.

5.4.3.3 Interference Calculation (DL)

The interference received by any pixel, subscriber, or mobile, served by a cell $TX_i(ic)$ from other cells $TX_j(jc)$ can be defined as the signal levels received from interfering cells $TX_j(jc)$ depending on the overlap that exists between the channels used by the cells $TX_i(ic)$ and $TX_j(jc)$, on the traffic loads of the interfering cells $TX_j(jc)$, and whether the cells support ICIC or not.

Input

- $E_{DLRS}^{TX_j(jc)}$: Received downlink reference energy per resource element received from any interfering cell $TX_j(jc)$ as calculated in "Signal Level Calculation (DL)" on page 351 at the pixel, subscriber, or mobile M_i covered by the cell $TX_i(ic)$.
- $E_{SS}^{TX_j(jc)}$: Received SS energy per resource element received from any interfering cell $TX_j(jc)$ as calculated in "Signal Level Calculation (DL)" on page 351 at the pixel, subscriber, or mobile M_i covered by the cell $TX_i(ic)$.
- $E_{PBCH}^{TX_j(jc)}$: Received PBCH energy per resource element received from any interfering cell $TX_j(jc)$ as calculated in "Signal Level Calculation (DL)" on page 351 at the pixel, subscriber, or mobile M_i covered by the cell $TX_i(ic)$.
- $E_{PDCCH}^{TX_j(jc)}$: Received PDCCH energy per resource element received from any interfering cell $TX_j(jc)$ as calculated in "Signal Level Calculation (DL)" on page 351 at the pixel, subscriber, or mobile M_i covered by the cell $TX_i(ic)$.
- $E_{PDSCH}^{TX_j(jc)}$: Received PDSCH energy per resource element received from any interfering cell $TX_j(jc)$ as calculated in "Signal Level Calculation (DL)" on page 351 at the pixel, subscriber, or mobile M_i covered by the cell $TX_i(ic)$.
- $G_{SA}^{TX_j}(\theta)$: Smart antenna gain in the direction θ . For more information, see "Beamforming Smart Antenna Models" on page 41.
- $G_{SA}^{TX_j}(\varphi)$: Smart antenna gain in the direction φ calculated from the average array correlation matrix: $G_{SA}(\varphi) = g_n(\varphi) \cdot \vec{S}_\varphi^H \cdot \vec{R}_{Avg} \cdot \vec{S}_\varphi$. For more information, see "Beamforming Smart Antenna Models" on page 41.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.
- $M_{Shadowing-C/I}$: Shadowing margin based on the C/I standard deviation.

  In Monte Carlo simulations, the received energies per resource element from interferers already include $M_{Shadowing-Model}$, as explained in "Signal Level Calculation (DL)" on page 351.

In coverage predictions, the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$ is applied to the interfering signals (for more information, see "Shadow Fading Model" on page 85). As the received energies per resource element from interferers already include $M_{Shadowing-Model}$, $M_{Shadowing-C/I}$ is added to the received energies per resource element from interferers in order to achieve the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$:

$$E^{TX_j(jc)} = E^{TX_j(jc)} + M_{Shadowing-C/I}$$

In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.

- $N^{TX_j(jc)}_{Sym-DLRS}$: Number of downlink reference signal resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.
- N_{Sym-SS}: Number of SS resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.
- $N^{TX_j(jc)}_{Sym-PBCH}$: Number of PBCH resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.
- $N^{TX_j(jc)}_{Sym-PDCCH}$: Number of PDCCH resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.
- $N^{TX_j(jc)}_{Sym-PDSCH}$: Number of PDSCH resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.
- $N^{TX_j(jc)}_{Sym-DL}$: Total number of downlink resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.
- $r_O^{TX_i(ic)-TX_j(jc)}$: Total channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 347.
- $TL_{DL}^{TX_j(jc)}$: Downlink traffic load of the interfering cell $TX_j(jc)$.

  Traffic loads can either be calculated using Monte Carlo simulations, or entered manually for each cell. Calculation of traffic loads is explained in "Simulation Process" on page 336.

- $AU_{DL}^{TX_j(jc)}$: Downlink AAS usage of the interfering cell $TX_j(jc)$.
- W_{FB}: Width of a frequency block in the frequency domain (180 kHz).
- $N_{FB-SS,\,PBCH}$: Number of frequency blocks that carry the SS and the PBCH (6).
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $N_{FB-CE}^{TX_i(ic)}$: Number of cell-edge frequency blocks (used in cell-edge areas in case of ICIC), determined from the list of frequency blocks corresponding to the cell's PSS ID (0, 1, or 2) defined in the ICIC configuration assigned to the cell $TX_i(ic)$. By default (if no ICIC configuration is assigned to the cell), $N_{FB-CE}^{TX_i(ic)} = \frac{N_{FB}^{TX_i(ic)}}{3}$.
- $N_{FB-CE}^{TX_j(jc)}$: Number of cell-edge frequency blocks (used in cell-edge areas in case of ICIC), determined from the list of frequency blocks corresponding to the cell's PSS ID (0, 1, or 2) defined in the ICIC configuration assigned to the cell $TX_j(jc)$. By default (if no ICIC configuration is assigned to the cell), $N_{FB-CE}^{TX_j(jc)} = \frac{N_{FB}^{TX_j(jc)}}{3}$.
- $F_{Start-Band}^{TX_i(ic)}$ and $F_{Start-Band}^{TX_j(jc)}$: Start frequencies of the frequency bands assigned to the cells $TX_i(ic)$ and $TX_j(jc)$.

  $F_{Start-Band}$ can be the start frequency of a TDD frequency band ($F_{Start-TDD}$), or the uplink or the downlink start frequency of an FDD frequency band ($F_{Start-FDD-UL}$ or $F_{Start-FDD-DL}$).

- $N_{Channel}^{First-TX_i(ic)}$ and $N_{Channel}^{First-TX_j(jc)}$: First channel numbers the frequency band assigned to the cells $TX_i(ic)$ and $TX_j(jc)$.
- $N_{Channel}^{TX_i(ic)}$ and $N_{Channel}^{TX_j(jc)}$: Channel numbers assigned to cells $TX_i(ic)$ and $TX_j(jc)$.

For FDD networks, **9955** considers that the same channel number is assigned to a cell in the downlink and uplink, i.e., the channel number you assign to a cell is considered for uplink and downlink both.

- $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$: Bandwidths of the channels assigned to cells *$TX_i(ic)$* and *$TX_j(jc)$.*
- $ID_{\varphi}^{TX_i(ic)}$ and $ID_{\varphi}^{TX_j(jc)}$: Physical cell IDs of the cells *$TX_i(ic)$ and $TX_j(jc)$.*
- $r_{DL-ICIC}^{TX_i(ic)}$ and $r_{DL-ICIC}^{TX_j(jc)}$: ICIC ratios of the cells *$TX_i(ic)$ and $TX_j(jc)$.*
- $N_{Ant-TX}^{TX_i(ic)}$: Number of transmission (downlink) antenna ports defined for the cell *$TX_i(ic)$.*
- $N_{Ant-TX}^{TX_j(jc)}$: Number of transmission (downlink) antenna ports defined for the cell *$TX_j(jc)$.*

Calculations

Method 1: Synchronised Transmission and Reception

9955 calculates the interference between two cells using this method when:

- The frequency channels assigned to the interfered and interfering cells have the same centre frequency, and
- The interfered and interfering cells both have an even number of frequency blocks or both have an odd number of frequency blocks, and
- The Atoll.ini file does not contain the following option:

```
[LTE]
SameItf_PDSCH_RS_PDCCH = 0
```

Synchronised transmission and reception means that the OFDM symbols of the interfered and interfering frames overlap and match each other in time.

> Calculations of $f_{MIMO}^{TX_j(jc)}$, $f_{TL}^{TX_j(jc)}$, $f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}$, $f_{PDCCH}^{TX_i(ic)-TX_j(jc)}$, and $f_{PDSCH}^{TX_i(ic)-TX_j(jc)}$ are explained at the end of this section.

The interfering energy per resource element (dBm/Sym) received over downlink reference signals from any cell *$TX_j(jc)$* at a pixel, subscriber, or mobile M_i is calculated as follows:

- RS of the interfered cell *$TX_i(ic)$* collide only with RS of the interfering cell *$TX_j(jc)$*

  This occurs when $ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $N_{Ant-TX}^{TX_j(jc)} > N_{Ant-TX}^{TX_i(ic)}$

> For the calculation of the probability of collision, here $N_{Ant-TX} = Min(4, N_{Ant-TX})$.

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)}}{N_{Ant-TX}^{TX_j(jc)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$

- RS of the interfered cell *$TX_i(ic)$* collide with RS, PDCCH, and PDSCH of the interfering cell *$TX_j(jc)$*

  This occurs when $ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $N_{Ant-TX}^{TX_j(jc)} \leq N_{Ant-TX}^{TX_i(ic)}$

> For the calculation of the probability of collision, here $N_{Ant-TX} = Min(4, N_{Ant-TX})$.

With 1 or 2 antenna ports:

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(\frac{N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic) - TX_j(jc)}$$

$$+ 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)} - N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times \frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic) - TX_j(jc)}}{10}} + 3 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic) - TX_j(jc)}}{10}}}{4}\right)$$

With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} = 1$:

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(\frac{N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic) - TX_j(jc)}$$

$$+ 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)} - N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times \frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic) - TX_j(jc)}}{10}} + 5 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic) - TX_j(jc)}}{10}}}{6}\right)$$

With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} > 1$:

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(\frac{N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic) - TX_j(jc)}$$

$$+ 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)} - N_{Ant-TX}^{TX_j(jc)}}{N_{Ant-TX}^{TX_i(ic)}} \times \frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic) - TX_j(jc)}}{10}} + 2 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic) - TX_j(jc)}}{10}}}{3}\right)$$

- RS of the interfered cell $TX_i(ic)$ collide only with PDCCH and PDSCH of the interfering cell $TX_j(jc)$

  This occurs when $(ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $\nu_{Shift}^{TX_i(ic)} = \nu_{Shift}^{TX_j(jc)} \pm 3$ and $N_{Ant-TX}^{TX_i(ic)} = N_{Ant-TX}^{TX_j(jc)} = 1)$ OR $ID_{PSS}^{TX_i(ic)} \neq ID_{PSS}^{TX_j(jc)}$

  With 1 or 2 antenna ports:

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(\frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic) - TX_j(jc)}}{10}} + 3 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic) - TX_j(jc)}}{10}}}{4}\right) + f_O^{TX_i(ic) - TX_j(jc)}$$

  With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} = 1$:

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(\frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic) - TX_j(jc)}}{10}} + 5 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic) - TX_j(jc)}}{10}}}{6}\right) + f_O^{TX_i(ic) - TX_j(jc)}$$

  With 4 or 8 antenna ports and $N_{SD-PDCCH}^{TX_i(ic)} > 1$:

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(\frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} + 2 \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}}{3}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$

The interfering energy per resource element (dBm/Sym) received over the SS and the PBCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i is calculated as follows:

$$\varepsilon_{SS,PBCH}^{TX_j(jc)} = 10 \times Log\left(\frac{10^{\frac{E_{SS}^{TX_j(jc)}}{10}} \times N_{Sym-SS} + 10^{\frac{E_{PBCH}^{TX_j(jc)}}{10}} \times N_{Sym-PBCH}^{TX_j(jc)}}{N_{Sym-SS} + N_{Sym-PBCH}^{TX_j(jc)}}\right) + f_O^{TX_i(ic)-TX_j(jc)} + f_{MIMO}^{TX_j(jc)}$$

The interfering energy per resource element (dBm/Sym) received over the PDCCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i is calculated as follows:

- PDCCH of the interfered cell $TX_i(ic)$ collides with PDCCH and all the RS of the interfering cell $TX_j(jc)$

  This occurs when $(ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $v_{Shift}^{TX_i(ic)} = v_{Shift}^{TX_j(jc)} \pm 3$ and $N_{Ant-TX}^{TX_i(ic)} = N_{Ant-TX}^{TX_j(jc)} = 1)$ OR $ID_{PSS}^{TX_i(ic)} \neq ID_{PSS}^{TX_j(jc)}$

  > For the calculation of the probability of collision, here $N_{Ant-TX} = Min(4, N_{Ant-TX})$.

$$\varepsilon_{PDCCH}^{TX_j(jc)} = 10 \times Log\left(\frac{1}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDCCH}^{TX_j(jc)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$

$$+ 10 \times Log\left(\frac{N_{Sym-PDCCH}^{TX_i(ic)} - N_{Sym-DLRS\ in\ PDCCH}^{TX_j(jc)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right)$$

  Here, $N_{Sym-DLRS\ in\ PDCCH}$ is the number of downlink reference signal resource elements that fall within the PDCCH, and $N_{Sym-PDCCH}$ is the number of PDCCH resource elements per frame.

- PDCCH of the interfered cell $TX_i(ic)$ collides with PDCCH and some RS of the interfering cell $TX_j(jc)$

  This occurs when $ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $N_{Ant-TX}^{TX_j(jc)} > N_{Ant-TX}^{TX_i(ic)}$

  > For the calculation of the probability of collision, here $N_{Ant-TX} = Min(4, N_{Ant-TX})$.

$$\varepsilon_{PDCCH}^{TX_j(jc)} = 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)}}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDCCH}^{TX_j(jc)} - N_{Sym-DLRS\ in\ PDCCH}^{TX_i(ic)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$

$$+ 10 \times Log\left(\frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-PDCCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right)$$

Here, $N_{Sym-DLRS\ in\ PDCCH}$ is the number of downlink reference signal resource elements that fall within the PDCCH, and $N_{Sym-PDCCH}$ is the number of PDCCH resource elements per frame.

- PDCCH of the interfered cell $TX_i(ic)$ collides only with PDCCH of the interfering cell $TX_j(jc)$

  This occurs when $ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $N_{Ant-TX}^{TX_j(jc)} \le N_{Ant-TX}^{TX_i(ic)}$

  $$\varepsilon_{PDCCH}^{TX_j(jc)} = E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)}$$

The interfering energy per resource element (dBm/Sym) received over the PDSCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i is calculated as follows:

- PDSCH of the interfered cell $TX_i(ic)$ collides with PDSCH and all the RS of the interfering cell $TX_j(jc)$

  This occurs when $(ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $v_{Shift}^{TX_i(ic)} = v_{Shift}^{TX_j(jc)} \pm 3$ and $N_{Ant-TX}^{TX_i(ic)} = N_{Ant-TX}^{TX_j(jc)} = 1)$ OR $ID_{PSS}^{TX_i(ic)} \ne ID_{PSS}^{TX_j(jc)}$

  For the calculation of the probability of collision, here $N_{Ant-TX} = Min(4, N_{Ant-TX})$.

  $$\varepsilon_{PDSCH}^{TX_j(jc)} = 10 \times Log\left(\frac{1}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$
  $$+ 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)} - N_{Sym-DLRS\ in\ PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right)$$

  Here, $N_{Sym-DLRS\ in\ PDSCH}$ is the number of downlink reference signal resource elements that fall within the PDSCH, and $N_{Sym-PDSCH}$ is the number of PDSCH resource elements per frame.

- PDSCH of the interfered cell $TX_i(ic)$ collides with PDSCH and some RS of the interfering cell $TX_j(jc)$

  This occurs when $ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $N_{Ant-TX}^{TX_j(jc)} > N_{Ant-TX}^{TX_i(ic)}$

  For the calculation of the probability of collision, here $N_{Ant-TX} = Min(4, N_{Ant-TX})$.

  $$\varepsilon_{PDSCH}^{TX_j(jc)} = 10 \times Log\left(\frac{N_{Ant-TX}^{TX_i(ic)}}{N_{Ant-TX}^{TX_j(jc)}} \times \frac{N_{Sym-DLRS\ in\ PDSCH}^{TX_j(jc)} - N_{Sym-DLRS\ in\ PDSCH}^{TX_i(ic)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$
  $$+ 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_i(ic)}} \times 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}}\right)$$

  Here, $N_{Sym-DLRS\ in\ PDSCH}$ is the number of downlink reference signal resource elements that fall within the PDSCH, and $N_{Sym-PDSCH}$ is the number of PDSCH resource elements per frame.

- PDSCH of the interfered cell $TX_i(ic)$ collides only with PDSCH of the interfering cell $TX_j(jc)$

  This occurs when $ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)}$ and $N_{Ant-TX}^{TX_j(jc)} \le N_{Ant-TX}^{TX_i(ic)}$

$$\varepsilon_{PDSCH}^{TX_j(jc)} = E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)}$$

Method 2: Non-synchronised Transmission and Reception

9955 calculates the interference between two cells using this method when:

- The frequency channels assigned to the interfered and interfering cells do not have the same centre frequency, or
- The interfered and interfering cells do not both have an even number of frequency blocks or do not both have an odd number of frequency blocks, or
- The Atoll.ini file contains the following option:

```
[LTE]
SameItf_PDSCH_RS_PDCCH = 1
```

This method is also used for calculating the interference received from LTE cells of an external network in co-planning mode, i.e., inter-technology interference received from LTE cells calculated using the inter-technology IRFs.

The interfering energy per resource element (dBm/Sym) received over downlink reference signals from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i is calculated as follows:

$$\varepsilon_{DLRS}^{TX_j(jc)} = 10 \times Log\left(10^{\frac{E_{DLRS}^{TX_j(jc)} + G_{RS\_Ant\_Div}^{TX_j(jc)}}{10}} \times \frac{N_{Sym-DLRS}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$

The interfering energy per resource element (dBm/Sym) received over the SS and the PBCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i is calculated as follows:

$$\varepsilon_{SS,\,PBCH}^{TX_j(jc)} = 10 \times Log\left(\frac{10^{\frac{E_{SS}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times N_{Sym-SS} + 10^{\frac{E_{PBCH}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times N_{Sym-PBCH}^{TX_j(jc)}}{N_{Sym-SS} + N_{Sym-PBCH}^{TX_j(jc)}} \times \left(1 - f_{DC-SCa-Shift}^{TX_i(ic)-TX_j(jc)}\right) + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times f_{DC-SCa-Shift}^{TX_i(ic)-TX_j(jc)}\right) + f_O^{TX_i(ic)-TX_j(jc)}$$

Where $f_{DC-SCa-Shift}^{TX_i(ic)-TX_j(jc)}$ is the DC subcarrier shift factor. This factor represents the difference in the DC subcarrier frequencies of the interfered and interfering cells with respect to the SS and the PBCH bandwidth. The DC subcarrier shift factor is calculated as follows:

$$f_{DC-SCa-Shift}^{TX_i(ic)-TX_j(jc)} = Min\left(1, \left|\frac{F_{Centre}^{TX_i(ic)} - F_{Centre}^{TX_j(jc)}}{N_{FB-SS,\,PBCH} \times W_{FB}}\right|\right)$$

Where $F_{Centre}^{TX_i(ic)}$ and $F_{Centre}^{TX_j(jc)}$ are the centre frequencies of the channels used by $TX_i(ic)$ and $TX_j(jc)$ respectively. These are the frequencies where the DC subcarrier is located. The centre frequencies are calculated as follows:

For cell $TX_i(ic)$: $F_{Centre}^{TX_i(ic)} = F_{Start-Band}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)} + \frac{1}{2}\right)$

For cell $TX_j(jc)$: $F_{Centre}^{TX_j(jc)} = F_{Start-Band}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times \left(N_{Channel}^{TX_j(jc)} - N_{Channel}^{First-TX_j(jc)} + \frac{1}{2}\right)$

The interfering energy per resource element (dBm/Sym) received over the PDSCH and the PDCCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i is calculated as follows:

$$\varepsilon_{PDSCH}^{TX_j(jc)} = 10 \times Log\left(10^{\frac{E_{DLRS}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times \frac{N_{Sym-DLRS}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} \right) + f_O^{TX_i(ic)-TX_j(jc)}$$

$$\varepsilon_{PDCCH}^{TX_j(jc)} = 10 \times Log\left(10^{\frac{E_{DLRS}^{TX_j(jc)} + G_{Ant\_Div}^{TX_j(jc)}}{10}} \times \frac{N_{Sym-DLRS}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} + 10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times \frac{N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-DL}^{TX_j(jc)}} \right) + f_O^{TX_i(ic)-TX_j(jc)}$$

E-UTRA carrier RSSI is measured on the OFDM symbols that contain reference signals. Therefore, the interfering energy per frequency block (dBm/RB) received from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i over 1 frequency block during an OFDM symbol carrying reference signals, is given as follows:

> For cells using more than 1 antenna port, the encircled 10 in the formulas below is replaced with 8.

$$\varepsilon_{RSSI}^{TX_j(jc)} = 10 \times Log\left(\frac{10^{\frac{E_{PDSCH}^{TX_j(jc)} + f_{PDSCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times N_{Sym-PDSCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_j(jc)} + N_{Sym-PDCCH}^{TX_j(jc)}} \times 10 + \frac{10^{\frac{E_{PDCCH}^{TX_j(jc)} + f_{PDCCH}^{TX_i(ic)-TX_j(jc)}}{10}} \times N_{Sym-PDCCH}^{TX_j(jc)}}{N_{Sym-PDSCH}^{TX_j(jc)} + N_{Sym-PDCCH}^{TX_j(jc)}} \times 10 + 10^{\frac{E_{DLRS}^{TX_j(jc)}}{10}} \times N_{Ant-TX}^{TX_j(jc)} \times 2 \right) + f_O^{TX_i(ic)-TX_j(jc)}$$

Calculation of PDCCH and PDSCH Interference Weighting Factors

The PDCCH and PDSCH interference weighting factors ($f_{PDCCH}^{TX_i(ic)-TX_j(jc)}$ and $f_{PDSCH}^{TX_i(ic)-TX_j(jc)}$) are calculated as follows:

For calculating $\varepsilon_{DLRS}^{TX_j(jc)}$:

$$f_{PDCCH}^{TX_i(ic)-TX_j(jc)} = \left\{ \left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{RS\_Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} \right\}$$

$$f_{PDSCH}^{TX_i(ic)-TX_j(jc)} = \left\{ \left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{RS\_Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{\left(G_{SA}^{TX_j}(\varphi) - G_{SA}^{TX_j}(\theta)\right) + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} \right\}$$

For calculating $\varepsilon_{SS,\,PBCH}^{TX_j(jc)}$, $\varepsilon_{PDCCH}^{TX_j(jc)}$, and $\varepsilon_{PDSCH}^{TX_j(jc)}$:

$$f_{PDCCH}^{TX_i(ic)-TX_j(jc)} = \left\{ \left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} \right\}$$

$$f_{PDSCH}^{TX_i(ic)-TX_j(jc)} = \left\{ \left(1 - AU_{DL}^{TX_j(jc)}\right) \times 10^{\frac{G_{Ant\_Div}^{TX_j(jc)} + f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{\left(G_{SA}^{TX_j}(\varphi) - G_{SA}^{TX_j}(\theta)\right) + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} \right\}$$

For calculating $\varepsilon_{RSSI}^{TX_j(jc)}$:

$$f_{PDCCH}^{TX_i(ic)-TX_j(jc)} = \left\{ \left(1 - AU_{DL}^{TX_j(jc)}\right) \times N_{Ant-TX}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} \right\}$$

$$f_{PDSCH}^{TX_i(ic)-TX_j(jc)} = \left\{ \left(1 - AU_{DL}^{TX_j(jc)}\right) \times N_{Ant-TX}^{TX_j(jc)} \times 10^{\frac{f_{TL}^{TX_j(jc)} + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} + AU_{DL}^{TX_j(jc)} \times 10^{\frac{\left(G_{SA}^{TX_j}(\varphi) - G_{SA}^{TX_j}(\theta)\right) + f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}}{10}} \right\}$$

Calculation of MIMO/Antenna Diversity Interference Factors

$G_{Ant\_Div}^{TX_j(jc)}$ is the interference increment due to more than one transmission antenna port: $G_{Ant\_Div}^{TX_j(jc)} = 10 \times Log\left(N_{Ant-TX}^{TX_j(jc)}\right)$

If you do not wish to apply $G_{Ant\_Div}^{TX_j(jc)}$, add the following lines in the Atoll.ini file:

```
[LTE]
MultiAntennaInterference = 0
```

MultiAntennaInterference is set to 1 by default.

$G_{RS\_Ant\_Div}^{TX_j(jc)}$ is the diversity gain due to more than one transmission antenna port applied on interfering signals received by RS:

$G_{RS\_Ant\_Div}^{TX_j(jc)} = 10 \times Log\left(N_{Ant-TX}^{TX_j(jc)}\right)$

If you do not wish to apply $G_{RS\_Ant\_Div}^{TX_j(jc)}$, add the following lines in the Atoll.ini file:

```
[LTE]
MultiAntennaGainOnRSItf = 0
```

MultiAntennaGainOnRSItf is set to 1 by default.

Calculation of Interference Reduction Factors

Calculations for the interference reduction factors due to traffic load $f_{TL}^{TX_j(jc)}$, channel overlapping ($f_O^{TX_i(ic)-TX_j(jc)}$), and static downlink ICIC using fractional frequency reuse ($f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)}$) are explained below:

Interference reduction due to the traffic loads of the interfering cells:

Interference reduction due to the traffic loads of the interfering cells $TX_j(jc)$ is calculated as follows:

$$f_{TL}^{TX_j(jc)} = 10 \times Log\left(TL_{DL}^{TX_j(jc)}\right)$$

Interference reduction due to the co- and adjacent channel overlap between the studied and the interfering cells:

Interference reduction due to the co- and adjacent channel overlap between the cells $TX_i(ic)$ and $TX_j(jc)$ is calculated as follows:

$$f_O^{TX_i(ic) - TX_j(jc)} = 10 \times Log\left(r_O^{TX_i(ic) - TX_j(jc)}\right)$$

Interference reduction due to static downlink ICIC using fractional frequency reuse:

If the cell supports Static DL ICIC, it means that a part of the LTE frame may use a fraction of the channel bandwidth. This implies that a collision probability must be calculated between the subcarriers used by the fractions of the channels being used by the interfered and interfering cells. The following paragraphs explain how the collision probability is calculated.

The ICIC Ratio ratio is the percentage of the total downlink traffic load present in the ICIC part of the frame. For example, if the downlink traffic load is 80 %, and the ICIC ratio is 50 %, then this means that the downlink traffic load of the ICIC part of the frame is 40 % (i.e., 50 % of 80 %), and the downlink traffic load of the non-ICIC part of the frame is 40 %.

In coverage predictions, **9955** uses the ICIC ratios stored in the cell properties for determining the interference. In simulations, **9955** resets the ICIC ratios for all the cells to 0, and then calculates them according to the traffic loads of the mobiles allocated to the ICIC and non-ICIC parts of the frame.

9955 determines the switching point between the ICIC and the non-ICIC parts of the frame using the ICIC ratio. The switching points between the ICIC and non-ICIC parts of the frame of the victim and interfering cells, $TX_i(ic)$ and $TX_j(jc)$ respectively, are calculated as follows:

$$SP^{TX_i(ic)} = \frac{r_{DL-ICIC}^{TX_i(ic)}}{r_{DL-ICIC}^{TX_i(ic)} + \left(1 - r_{DL-ICIC}^{TX_i(ic)}\right) \times \frac{N_{FB-CE}^{TX_i(ic)}}{N_{FB}^{TX_i(ic)}}} \text{ and } SP^{TX_j(jc)} = \frac{r_{DL-ICIC}^{TX_j(jc)}}{r_{DL-ICIC}^{TX_j(jc)} + \left(1 - r_{DL-ICIC}^{TX_j(jc)}\right) \times \frac{N_{FB-CE}^{TX_j(jc)}}{N_{FB}^{TX_j(jc)}}}$$

Where, *SP* is the switching point between the ICIC and the non-ICIC parts of the frame, and $r_{DL-ICIC}$ is the downlink ICIC ratios of the cells.

If the downlink ICIC ratio is set to 0, it means that the ICIC part of the frame does not exist. Setting it to 0 gives *SP* = 0, and setting it to 1 gives *SP* = 1 (or 100%), which shows how the switching point varies with the ICIC ratio.

The ICIC ratio is used to partition the total downlink traffic load into ICIC and non-ICIC parts of the frame. Therefore, the switching point formula is derived from the equation:

$$\frac{r_{DL-ICIC} \times TL_{DL}}{SP \times W_{Channel} \times \frac{N_{FB-CE}}{N_{FB}}} = \frac{(1 - r_{DL-ICIC}) \times TL_{DL}}{(1 - SP) \times W_{Channel}}$$

With cells using static downlink ICIC, there can be four different interference scenarios.

a. Between the ICIC part of the victim and the ICIC part of the interferer.

b. Between the ICIC part of the victim and the non-ICIC part of the interferer.

c. Between the non-ICIC part of the victim and the ICIC part of the interferer.

d. Between the non-ICIC part of the victim and the non-ICIC part of the interferer.

Therefore, **9955** calculates the probabilities of collision for each scenario and weights the total interference according to the total collision probability. The probability of collision p_{Coll} for each scenario is:

Case	Interfered cell $TX_i(ic)$	Interfering cell $TX_j(jc)$	p_{Coll}
a	ICIC	ICIC	$\frac{N_{FB-CE}^{Common}}{N_{FB-CE}^{TX_i(ic)}}$
b	ICIC	Non ICIC	1
c	Non ICIC	ICIC	$\frac{N_{FB-CE}^{Common}}{N_{FB}^{TX_i(ic)}}$

Case	Interfered cell $TX_i(ic)$	Interfering cell $TX_j(jc)$	p_{Coll}
d	Non ICIC	Non ICIC	1

Where, N_{FB-CE}^{Common} is the number of cell-edge frequency blocks common in $TX_i(ic)$ and $TX_j(jc)$, and $N_{FB-CE}^{TX_i(ic)}$ is the number of cell-edge frequency blocks in the cell $TX_i(ic)$.

There can be 2 cases for calculating the total probability of collision.

- **Case 1:** If the pixel, subscriber, or mobile M_i is covered by the ICIC part of $TX_i(ic)$, the total collision probability for the pixel, subscriber, or mobile M_i is calculated as follows:

$$p_{Collision}^{TX_i(ic)-TX_j(jc)} = \begin{cases} p_{Coll}^{a} & \text{If } SP^{TX_j(jc)} \geq SP^{TX_i(ic)} \\ \dfrac{p_{Coll}^{a} \times SP^{TX_j(jc)} + p_{Coll}^{b} \times \left(SP^{TX_i(ic)} - SP^{TX_j(jc)}\right)}{SP^{TX_i(ic)}} & \text{If } SP^{TX_j(jc)} < SP^{TX_i(ic)} \end{cases}$$

- **Case 2:** If the pixel, subscriber, or mobile M_i is covered by the non-segmented zone of $TX_i(ic)$, the total collision probability for the pixel, subscriber, or mobile M_i is calculated as follows:

$$p_{Collision}^{TX_i(ic)-TX_j(jc)} = \begin{cases} p_{Coll}^{d} & \text{If } SP^{TX_j(jc)} \leq SP^{TX_i(ic)} \\ \dfrac{p_{Coll}^{d} \times \left(1 - SP^{TX_j(jc)}\right) + p_{Coll}^{c} \times \left(SP^{TX_j(jc)} - SP^{TX_i(ic)}\right)}{\left(1 - SP^{TX_i(ic)}\right)} & \text{If } SP^{TX_j(jc)} > SP^{TX_i(ic)} \end{cases}$$

The interference reduction factor due to static downlink ICIC using fractional frequency reuse for the pixel, subscriber, or mobile M_i is calculated as follows:

$$f_{ICIC-DL}^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(p_{Collision}^{TX_i(ic)-TX_j(jc)}\right)$$

Whether a pixel, subscriber, or mobile M_i is covered by the ICIC part of the frame is determined as explained in "Best Server Determination" on page 384.

Output

- $\varepsilon_{DLRS}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over downlink reference signals from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $\varepsilon_{SS,\,PBCH}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over the SS and the PBCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $\varepsilon_{PDSCH}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over the PDSCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $\varepsilon_{PDCCH}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over the PDCCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $\varepsilon_{RSSI}^{TX_j(jc)}$: Interfering energy per frequency block (dBm/RB) received from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i over 1 frequency block during an OFDM symbol carrying reference signals.

5.4.3.4 C/N Calculation (DL)

Input

- $E_{DLRS}^{TX_i(ic)}$: Received downlink reference signal energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.

- $E_{SS}^{TX_i(ic)}$: Received SS energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $E_{PBCH}^{TX_i(ic)}$: Received PBCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $E_{PDCCH}^{TX_i(ic)}$: Received PDCCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $E_{PDSCH}^{TX_i(ic)}$: Received PDSCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $n_{Sym}^{TX_i(ic)}$: Downlink noise for one subcarrier for the cell $TX_i(ic)$ as calculated in "Noise Calculation (DL)" on page 354.
- $CINR_{DLRS}^{TX_i(ic)}$: Downlink reference signal C/(I+N) from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i as calculated in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the LTE equipment used by M_i's terminal.
- $B_{DL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{DL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{TX_i(ic)}$: Number of transmission (downlink) antenna ports defined for the cell $TX_i(ic)$.
- $N_{Ant-RX}^{M_i}$: Number of reception (downlink) antenna ports defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the LTE equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.

Calculations

The C/N for cell $TX_i(ic)$ are calculated as follows for any pixel, subscriber, or mobile M_i:

$$CNR_{DLRS}^{TX_i(ic)} = E_{DLRS}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$$

$$CNR_{SS}^{TX_i(ic)} = E_{SS}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$$

$$CNR_{PBCH}^{TX_i(ic)} = E_{PBCH}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$$

$$CNR_{PDCCH}^{TX_i(ic)} = E_{PDCCH}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$$

$$CNR_{PDSCH}^{TX_i(ic)} = E_{PDSCH}^{TX_i(ic)} - n_{Sym}^{TX_i(ic)}$$

Bearer Determination:

The bearers available for selection in the pixel, subscriber, or mobile M_i's LTE equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the PDSCH C/N at M_i: $T_B^{M_i} < CNR_{PDSCH}^{TX_i(ic)}$

If the cell supports Transmit Diversity or AMS, the transmit diversity gain, G^{DL}_{Div}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the LTE equipment assigned to the pixel, subscriber, or mobile M_i for $N^{TX_i(ic)}_{Ant-TX}$, $N^{M_i}_{Ant-RX}$, $Mobility(M_i)$, $BLER\left(B^{M_i}_{DL}\right)$.

The additional downlink diversity gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG^{DL}_{Div} is also applied. Therefore, the bearers available for selection are all the bearers defined in the LTE equipment for which the following is true:

In case of Transmit Diversity:

$$T^{M_i}_B - G^{DL}_{Div} - \Delta G^{DL}_{Div} < CNR^{TX_i(ic)}_{PDSCH}$$

In case of AMS:

$$T^{M_i}_B - G^{DL}_{Div} - \Delta G^{DL}_{Div} < CNR^{TX_i(ic)}_{PDSCH} \qquad if \quad CNR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$$

The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$.

- Bearer Index

  From among the bearers available for selection, the selected bearer is the one with the highest index.

- Peak RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest downlink peak RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

- Effective RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest downlink effective RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

MIMO – Transmit Diversity Gain:

Once the bearer is known, the PDSCH C/N calculated above become:

In case of Transmit Diversity:

$$CNR^{TX_i(ic)}_{PDSCH} = CNR^{TX_i(ic)}_{PDSCH} + G^{DL}_{Div} + \Delta G^{DL}_{Div}$$

In case of AMS:

$$CNR^{TX_i(ic)}_{PDSCH} = CNR^{TX_i(ic)}_{PDSCH} + G^{DL}_{Div} + \Delta G^{DL}_{Div} \qquad if \quad CNR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS} \quad or \quad CINR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$$

Where G^{DL}_{Div} is the transmit diversity gain corresponding to the selected bearer.

Output

- $CNR^{TX_i(ic)}_{DLRS}$: Downlink reference signal C/N from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CNR^{TX_i(ic)}_{SS}$: SS C/N from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CNR^{TX_i(ic)}_{PBCH}$: PBCH C/N from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CNR^{TX_i(ic)}_{PDCCH}$: PDCCH C/N from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CNR^{TX_i(ic)}_{PDSCH}$: PDSCH C/N from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.

5.4.3.5 C/(I+N) and Bearer Calculation (DL)

The carrier signal to interference and noise ratio is calculated in three steps. First **9955** calculates the received signal level from the studied cell (as explained in "Signal Level Calculation (DL)" on page 351) at the pixel, subscriber, or mobile under study. Next, **9955** calculates the interference received at the same studied pixel, subscriber, or mobile from all the interfering cells (as explained in "Interference Calculation (DL)" on page 355). Interference from each cell is weighted according to the co- and adjacent channel overlap between the studied and the interfering cells, the traffic loads of the interfering cells, and the probability of collision in case ICIC is used by the cells. Finally, **9955** takes the ratio of the signal level and the sum of the total interference from other cells and the downlink noise (as calculated in "Noise Calculation (DL)" on page 354).

The receiver terminal is always considered to be oriented towards its best server, except when the "Lock Status" is set to "Server+Orientation" for a subscriber in a subscriber list and its azimuth and tilt manually edited. In the case of NLOS between the receiver and the best server, **9955** does not try to find the direction of the strongest signal, the receiver is oriented towards the best server just as in the case of LOS.

Input

- ΔF : Subcarrier width (15 kHz).
- W_{FB} : Width of a frequency block (180 kHz).
- $N_{FB-SS,\,PBCH}$: Number of frequency blocks that carry the SS and the PBCH (6).
- $N_{Slot/SF}$: Number of slots per subframe (2).
- D_{CP} : Cyclic prefix duration defined for the network in the Global Parameters.
- $N_{SD/Slot}$: Number of symbol durations per slot (7 is D_{CP} is Normal, 6 if D_{CP} is Extended).
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $N_{SF-DL}^{TX_i(ic)}$: Number of downlink subframes in the frame for the cell $TX_i(ic)$. It is equal to 10 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.
- $N_{TDD-SSF}^{TX_i(ic)}$: Number of TDD special subframes (containing DwPTS, GP, and UpPTS) in the frame for the cell $TX_i(ic)$. It is equal to 0 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.

  $N_{SF-DL}^{TX_i(ic)}$ and $N_{TDD-SSF}^{TX_i(ic)}$ are determined as follows:

Configuration	$N_{SF-DL}^{TX_i(ic)}$	$N_{TDD-SSF}^{TX_i(ic)}$
FDD	10	0
DSUUU-DSUUU	2	2
DSUUD-DSUUD	4	2
DSUDD-DSUDD	6	2
DSUUU-DSUUD	3	2
DSUUU-DDDDD	6	1
DSUUD-DDDDD	7	1
DSUDD-DDDDD	8	1

- $E_{DLRS}^{TX_i(ic)}$: Received downlink reference signal energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $E_{SS}^{TX_i(ic)}$: Received SS energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $E_{PBCH}^{TX_i(ic)}$: Received PBCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $E_{PDCCH}^{TX_i(ic)}$: Received PDCCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $E_{PDSCH}^{TX_i(ic)}$: Received PDSCH energy per resource element from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $N_{Sym-PDCCH}^{TX_i(ic)}$: Number of PDCCH resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.
- $N_{Sym-PDSCH}^{TX_i(ic)}$: Number of PDSCH resource elements as calculated in "Downlink Transmission Power Calculation" on page 340.

- $n_{Sym}^{TX_i(ic)}$: Downlink noise for one subcarrier for the cell $TX_i(ic)$ as calculated in "Noise Calculation (DL)" on page 354.
- $\varepsilon_{DLRS}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over downlink reference signals from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ as calculated in "Interference Calculation (DL)" on page 355.
- $\varepsilon_{SS,\,PBCH}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over the SS and the PBCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ as calculated in "Interference Calculation (DL)" on page 355.
- $\varepsilon_{PDSCH}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over the PDSCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ as calculated in "Interference Calculation (DL)" on page 355.
- $\varepsilon_{PDCCH}^{TX_j(jc)}$: Interfering energy per resource element (dBm/Sym) received over the PDCCH from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ as calculated in "Interference Calculation (DL)" on page 355.
- $\varepsilon_{RSSI}^{TX_j(jc)}$: Interfering energy per frequency block (dBm/RB) received over 1 frequency block during an OFDM symbol carrying reference signals from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i as calculated in "Interference Calculation (DL)" on page 355.
- $NR_{DL}^{Inter-Tech}$: Inter-technology downlink noise rise.
- $CNR_{DLRS}^{TX_i(ic)}$: Downlink reference signal C/N from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 365.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the LTE equipment used by M_i's terminal.
- $B_{DL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{DL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{TX_i(ic)}$: Number of transmission (downlink) antenna ports defined for the cell $TX_i(ic)$.
- $N_{Ant-RX}^{M_i}$: Number of reception (downlink) antenna ports defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the LTE equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.

Calculations

The downlink reference signal C/(I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CINR_{DLRS}^{TX_i(ic)} = E_{DLRS}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{DLRS}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

The SS C/(I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CINR_{SS}^{TX_i(ic)} = E_{SS}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{SS,\,PBCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

The PBCH C/(I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CINR_{PBCH}^{TX_i(ic)} = E_{PBCH}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{SS,\ PBCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

The PDCCH C/(I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CINR_{PDCCH}^{TX_i(ic)} = E_{PDCCH}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDCCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

The PDSCH C/(I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CINR_{PDSCH}^{TX_i(ic)} = E_{PDSCH}^{TX_i(ic)} + G_{Useful\_Ant\_Div}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDSCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

$G_{Useful\_Ant\_Div}^{TX_i(ic)}$ is the diversity gain due to more than one transmission antenna port applied on desired signal: $G_{Useful\_Ant\_Div}^{TX_i(ic)} = 10 \times Log\left(N_{Ant-TX}^{TX_i(ic)}\right)$. If you do not wish to apply $G_{Useful\_Ant\_Div}^{TX_i(ic)}$, add the following lines in the Atoll.ini file:

```
[LTE]
MultiAntennaGainOnDesired = 0
```

MultiAntennaGainOnDesired is set to 1 by default.

The downlink reference signal received quality (RSRQ) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$RSRQ^{TX_i(ic)} = 10 \times Log\left(N_{FB}^{TX_i(ic)}\right) + E_{DLRS}^{TX_i(ic)} - RSSI^{TX_i(ic)}$$

Where $E_{DLRS}^{TX_i(ic)}$ is the cell's RSRP and $RSSI^{TX_i(ic)}$ is the received signal strength indicator, i.e., the received signals from the server ($TX_i(ic)$), and all the interfering cells ($TX_j(jc)$), calculated as follows:

For cells using more than 1 antenna port, the encircled 10 in the formulas below is replaced with 8.

$$RSSI^{TX_i(ic)} = 10 \times Log\left(\varepsilon_{RSSI}^{TX_i(ic)} + \sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{RSSI}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech} + 10 \times Log\left(N_{FB}^{TX_i(ic)}\right)$$

The downlink reference signal total noise (I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$(I+N)_{DLRS}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{DLRS}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech} + 10 \times Log\left(2 \times N_{FB}^{TX_i(ic)}\right)$$

The SS and PBCH total noise (I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$(I+N)_{SS,\ PBCH}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{SS,\ PBCH}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech} + 10 \times Log(N_{SCa-FB} \times N_{FB-SS,\ PBCH})$$

The PDSCH and PDCCH total noise (I+N) for cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

Method 1: Synchronised Transmission and Reception

For details, see "Interference Calculation (DL)" on page 313.

$$(I+N)_{PDCCH}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDCCH}^{TX_j(jc)}}{10}} \right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}} \right) + 10 \times Log\left(\frac{N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SF-DL}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)}} \right) + NR_{DL}^{Inter-Tech}$$

$$(I+N)_{PDSCH}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDSCH}^{TX_j(jc)}}{10}} \right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}} \right) + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)}}{N_{SF-DL}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)}} \right) + NR_{DL}^{Inter-Tech}$$

Method 2: Non-synchronised Transmission and Reception

For details, see "Interference Calculation (DL)" on page 313.

$$(I+N)_{PDCCH}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDCCH}^{TX_j(jc)}}{10}} \right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}} \right) + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)} + N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SD/Slot} \times N_{Slot/SF} \times N_{SF-DL}^{TX_i(ic)}} \right) + NR_{DL}^{Inter-Tech}$$

$$(I+N)_{PDSCH}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{\varepsilon_{PDSCH}^{TX_j(jc)}}{10}} \right) + 10^{\frac{n_{Sym}^{TX_i(ic)}}{10}} \right) + 10 \times Log\left(\frac{N_{Sym-PDSCH}^{TX_i(ic)} + N_{Sym-PDCCH}^{TX_i(ic)}}{N_{SD/Slot} \times N_{Slot/SF} \times N_{SF-DL}^{TX_i(ic)}} \right) + NR_{DL}^{Inter-Tech}$$

With N_{SCa-FB} calculated as follows:

$$N_{SCa-FB} = \frac{W_{FB}}{\Delta F}$$

Bearer Determination:

The bearers available for selection in the pixel, subscriber, or mobile M_i's LTE equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the PDSCH C/(I+N) at M_i: $T_B^{M_i} < CINR_{PDSCH}^{TX_i(ic)}$

  If the cell supports Transmit Diversity or AMS, the transmit diversity gain, G_{Div}^{DL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the LTE equipment assigned to the pixel, subscriber, or mobile M_i for $N_{Ant-TX}^{TX_i(ic)}$, $N_{Ant-RX}^{M_i}$, $Mobility(M_i)$, $BLER\left(B_{DL}^{M_i}\right)$.

  The additional downlink diversity gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{Div}^{DL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the LTE equipment for which the following is true:

  In case of Transmit Diversity:

  $$T_B^{M_i} - G_{Div}^{DL} - \Delta G_{Div}^{DL} < CINR_{PDSCH}^{TX_i(ic)}$$

  In case of AMS:

  $$T_B^{M_i} - G_{Div}^{DL} - \Delta G_{Div}^{DL} < CINR_{PDSCH}^{TX_i(ic)} \quad if \quad CNR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \quad or \quad CINR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$.

- Bearer Index

  From among the bearers available for selection, the selected bearer is the one with the highest index.

- Peak RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest downlink peak RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

- Effective RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest downlink effective RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

MIMO – Transmit Diversity Gain:

Once the bearer is known, the PDSCH C/(I+N) calculated above become:

In case of Transmit Diversity:

$$CINR_{PDSCH}^{TX_i(ic)} = CINR_{PDSCH}^{TX_i(ic)} + G_{Div}^{DL} + \Delta G_{Div}^{DL}$$

In case of AMS:

$$CINR_{PDSCH}^{TX_i(ic)} = CINR_{PDSCH}^{TX_i(ic)} + G_{Div}^{DL} + \Delta G_{Div}^{DL} \qquad if \quad CNR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \quad or \quad CINR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{Div}^{DL} is the transmit diversity gain corresponding to the selected bearer.

Output

- $CINR_{DLRS}^{TX_i(ic)}$: Downlink reference signal C/(I+N) from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CINR_{SS}^{TX_i(ic)}$: SS C/(I+N) from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CINR_{PBCH}^{TX_i(ic)}$: PBCH C/(I+N) from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CINR_{PDCCH}^{TX_i(ic)}$: PDCCH C/(I+N) from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $CINR_{PDSCH}^{TX_i(ic)}$: PDSCH C/(I+N) from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $RSRQ^{TX_i(ic)}$: Downlink reference signal received quality from cell $TX_i(ic)$ at pixel, subscriber, or mobile M_i.
- $RSSI^{TX_i(ic)}$: Received signal strength indicator, i.e., the received signals from the server ($TX_i(ic)$), and all the interfering cells ($TX_j(jc)$), at pixel, subscriber, or mobile M_i.
- $(I+N)_{DLRS}^{TX_i(ic)}$: Downlink reference signals total noise from the interfering cells $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $(I+N)_{SS,\ PBCH}^{TX_i(ic)}$: SS and PBCH total noise from the interfering cells $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $(I+N)_{PDCCH}^{TX_i(ic)}$: PDCCH total noise from the interfering cells $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $(I+N)_{PDSCH}^{TX_i(ic)}$: PDSCH total noise from the interfering cells $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $B_{DL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the downlink.

5.4.3.6 Signal Level Calculation (UL)

Input

- $CINR_{PUSCH-Max}^{TX_i(ic)}$: Maximum PUSCH C/(I+N) defined for the cell $TX_i(ic)$.

- $NR_{UL}^{TX_i(ic)}$: Uplink noise rise of the cell $TX_i(ic)$. This value can be user-defined or calculated as explained in "Interference Calculation (UL)" on page 375.
- $NR_{UL-ICIC}^{TX_i(ic)}$: ICIC uplink noise rise of the cell $TX_i(ic)$. This value can be user-defined or calculated as explained in "Interference Calculation (UL)" on page 375.
- $n_{PUSCH,\ PUCCH}^{TX_i(ic)}$: Uplink noise for the PUSCH and the PUCCH for the cell $TX_i(ic)$.
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $\alpha_{FPC}^{TX_i(ic)}$: Fractional uplink power control factor defined for the cell $TX_i(ic)$.
- $P_{Max}^{M_i}$: Maximum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- $P_{Eff}^{M_i}$: Effective transmission power of the terminal used by the pixel, subscriber, or mobile M_i after power control adjustment as calculated in "C/(I+N) and Bearer Calculation (UL)" on page 381.
- $G_{Ant}^{TX_i}$: Transmitter antenna gain for the antenna used by the transmitter TX_i.
- L^{TX_i} : Total transmitter losses for the transmitter TX_i ($L^{TX_i} = L_{Total-UL}$).
- L_{Path} : Path loss ($L_{Path} = L_{Model} + L_{Ant}^{TX_i}$).
- L_{Total} : Total loss calculated as explained in "Signal Level Calculation (DL)" on page 351.
- L_{Model} : Loss on the transmitter-receiver path (path loss) calculated using a propagation model.
- $L_{Ant}^{TX_i}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_i.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.
- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.
- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.
- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  For calculating the useful signal level from the best serving cell, $L_{Ant}^{M_i}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L_{Ant}^{M_i}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.
- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.
- D_{CP} : Cyclic prefix duration defined for the network in the Global Parameters.

Calculations

9955 first calculates the allowed maximum transmission power for the terminal used by the pixel, subscriber, or mobile M_i. This power is calculated by performing fractional power control.

Fractional Power Control:

Fractional power control imposes a limitation on the maximum transmission power of the terminal. A nominal PUSCH power is indicated by the cell to all the pixels, subscribers, or mobiles. This nominal PUSCH power is calculated as follows:

$$P_{O\_PUSCH}^{TX_i(ic)} = CINR_{PUSCH-Max}^{TX_i(ic)} + NR_{UL}^{TX_i(ic)} + n_{PUSCH,\ PUCCH}^{TX_i(ic)} - 10 \times Log\left(N_{FB}^{TX_i(ic)}\right)$$ for the non-ICIC zone.

$$P_{O\_PUSCH}^{TX_i(ic)} = CINR_{PUSCH-Max}^{TX_i(ic)} + NR_{UL-ICIC}^{TX_i(ic)} + n_{PUSCH, PUCCH}^{TX_i(ic)} - 10 \times Log\left(N_{FB}^{TX_i(ic)}\right)$$ for the ICIC zone.

Where $n_{PUSCH, PUCCH}^{TX_i(ic)} - 10 \times Log\left(N_{FB}^{TX_i(ic)}\right)$ corresponds to the uplink noise over 1 frequency block.

Next, the maximum allowed transmission power for the terminal used by the pixel, subscriber, or mobile M_i is calculated as follows:

$$P_{Allowed}^{M_i} = Min\left\{P_{Max}^{M_i}, 10 \times Log\left(N_{FB}^{TX_i(ic)}\right) + P_{O\_PUSCH}^{TX_i(ic)} + \alpha_{FPC}^{TX_i(ic)} \times L_{Total}\right\}$$

Once the maximum allowed power has been calculated, it is used as an upper limit for transmission power in all the remaining calculations.

The received PUSCH and PUCCH signal level (dBm) from a pixel, subscriber, or mobile M_i at its serving cell $TX_i(ic)$ is calculated as follows:

$$C_{PUSCH, PUCCH}^{M_i} = EIRP_{PUSCH, PUCCH}^{M_i} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G_{Ant}^{TX_i} - L^{TX_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} + f_{CP}$$

Where *EIRP* is the effective isotropic radiated power of the terminal calculated as follows:

$$EIRP_{PUSCH, PUCCH}^{M_i} = P^{M_i} + G^{M_i} - L^{M_i}$$

With $P^{M_i} = P_{Allowed}^{M_i}$ without power control adjustment at the start of the calculations, and is $P^{M_i} = P_{Eff}^{M_i}$ after power control adjustment.

f_{CP} is the cyclic prefix factor, i.e., the ratio of the useful symbol energy to the total symbol energy.

The total symbol duration of a modulation symbol comprises the useful symbol duration, carrying the actual data bits, and a cyclic prefix, added to the useful data bits as padding against multi-path to avoid inter-symbol interference. Hence, the total energy within a modulation symbol belongs in part to the useful data bits and in part to the cyclic prefix. Once a modulation symbol is received, only the energy of the useful data bits can be used for extracting the data. The energy belonging to the cyclic prefix is lost once it has served its purpose of combatting inter-symbol interference. Therefore, f_{CP} implies that the energy belonging to the cyclic prefix is excluded from the useful signal level.

$$f_{CP} = \begin{cases} 10 \times Log(7/7.5) & If\ \ D_{CP} = Normal \\ 10 \times Log(6/7.5) & If\ \ D_{CP} = Extended \\ 0 & If\ \ M_i\ is\ an\ interferer \end{cases}$$

The cyclic prefix energy and the useful data bits energy are both taken into account when calculating interfering signal levels.

Output

- $C_{PUSCH, PUCCH}^{M_i}$: Received PUSCH and PUCCH signal level from the pixel, subscriber, or mobile M_i at a cell *$TX_i(ic)$*.
- $P_{Allowed}^{M_i}$: Maximum allowed transmission power for the terminal used by the pixel, subscriber, or mobile M_i.

5.4.3.7 Noise Calculation (UL)

For determining the C/N and C/(I+N), **9955** calculates the uplink noise over the channel bandwidth used by the cell. The used bandwidth depends on the number of used subcarriers.

The uplink noise comprises thermal noise and the noise figure of the equipment. The thermal noise density depends on the temperature, i.e., it remains constant for a given temperature. However, the value of the thermal noise varies with the used bandwidth.

Input

- *K*: Boltzmann's constant.
- *T*: Temperature in Kelvin.
- W_{FB} : Width of a frequency block in the frequency domain (180 kHz).
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell *$TX_i(ic)$*.

- $nf^{TX_i(ic)}$: Noise figure of the cell $TX_i(ic)$.

Calculations

The power spectral density of thermal noise is calculated as follows:

$$n_0 = 10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$$

The thermal noise for the PUSCH and the PUCCH is calculated as:

$$n_{0-PUSCH, PUCCH}^{TX_i(ic)} = n_0 + 10 \times Log\left(N_{FB}^{TX_i(ic)} \times W_{FB} \times 1000\right)$$

The uplink noise is the sum of the thermal noise and the noise figure of the cell $TX_i(ic)$.

$$n_{PUSCH, PUCCH}^{TX_i(ic)} = n_{0-PUSCH, PUCCH}^{TX_i(ic)} + nf^{TX_i(ic)}$$

Output

- $n_{PUSCH, PUCCH}^{TX_i(ic)}$: Uplink noise for the PUSCH and the PUCCH for the cell $TX_i(ic)$.

5.4.3.8 Interference Calculation (UL)

The PUSCH and PUCCH interference is only calculated during Monte Carlo simulations. In coverage predictions, the uplink noise rise values already available in simulation results or in the Cells table are used.

The interference received by a cell $TX_i(ic)$ from an interfering mobile covered by a cell $TX_j(jc)$ can be defined as the PUSCH and PUCCH signal level received from the interfering mobile M_j depending on the overlap that exists between the channels used by the cells $TX_i(ic)$ and $TX_j(jc)$ and on the traffic load of the interfering mobile M_j.

The calculation of uplink interference can be divided into two parts:

- Calculation of the uplink interference from each individual interfering mobile as explained in "Interfering Signal Level Calculation (UL)" on page 375.
- Calculation of the uplink noise rise which represents the total uplink interference from all interfering mobiles as explained in "Noise Rise Calculation (UL)" on page 377.

5.4.3.8.1 Interfering Signal Level Calculation (UL)

Input

- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $N_{FB-CE}^{TX_i(ic)}$: Number of cell-edge frequency blocks (used in cell-edge areas in case of ICIC), determined from the list of frequency blocks corresponding to the cell's PSS ID (0, 1, or 2) defined in the ICIC configuration assigned to the cell $TX_i(ic)$. By default (if no ICIC configuration is assigned to the cell), $N_{FB-CE}^{TX_i(ic)} = \frac{N_{FB}^{TX_i(ic)}}{3}$.
- $N_{FB-CE}^{TX_j(jc)}$: Number of cell-edge frequency blocks (used in cell-edge areas in case of ICIC), determined from the list of frequency blocks corresponding to the cell's PSS ID (0, 1, or 2) defined in the ICIC configuration assigned to the cell $TX_j(jc)$. By default (if no ICIC configuration is assigned to the cell), $N_{FB-CE}^{TX_j(jc)} = \frac{N_{FB}^{TX_j(jc)}}{3}$.
- $C_{PUSCH, PUCCH}^{M_j}$: PUSCH and PUCCH signal level received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$ as calculated in "Signal Level Calculation (UL)" on page 372.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.
- $M_{Shadowing-C/I}$: Shadowing margin based on the C/I standard deviation.

  In Monte Carlo simulations, interfering signal levels already include $M_{Shadowing-Model}$, as explained in "Signal Level Calculation (UL)" on page 372.

In coverage predictions, the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$ is applied to the interfering signals (for more information, see "Shadow Fading Model" on page 85). As the interfering signal levels already include $M_{Shadowing-Model}$, $M_{Shadowing-C/I}$ is added to the received interfering signal levels in order to achieve the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$:

$$C^{M_j}_{PUSCH,\ PUCCH} = C^{M_j}_{PUSCH,\ PUCCH} + M_{Shadowing-C/I}$$

In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.

- $r_O^{TX_i(ic)-TX_j(jc)}$: Total channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 347.
- $TL^{M_j}_{UL}$: Uplink traffic load of the interfering mobile M_j.

  Traffic loads are calculated during Monte Carlo simulations as explained in "Scheduling and Radio Resource Allocation" on page 397.

Calculations

The uplink interference received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$ is calculated as follows:

$$I^{M_j}_{PUSCH,\ PUCCH} = C^{M_j}_{PUSCH,\ PUCCH} + f_O^{TX_i(ic)-TX_j(jc)} + f^{M_j}_{TL-UL} + f^{TX_i(ic)-TX_j(jc)}_{ICIC-UL}$$

Where $f^{M_j}_{TL-UL}$ is an interference reduction factor due to the uplink traffic load of the interfering mobile M_j, calculated as follows:

$$f^{M_j}_{TL-UL} = 10 \times Log\left(TL^{M_j}_{UL}\right)$$

Calculations for the interference reduction factors due to channel overlapping ($f_O^{TX_i(ic)-TX_j(jc)}$) and static uplink ICIC using fractional frequency reuse ($f^{TX_i(ic)-TX_j(jc)}_{ICIC-UL}$) are explained below:

Interference reduction due to the co- and adjacent channel overlap between the studied and the interfering cells:

Interference reduction due to the co- and adjacent channel overlap between the cells $TX_i(ic)$ and $TX_j(jc)$ is calculated as follows:

$$f_O^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$$

Interference reduction due to static uplink ICIC using fractional frequency reuse:

If the cell supports Static UL ICIC, it means that a part of the LTE frame may use a fraction of the channel bandwidth. The interference reduction factor due to static uplink ICIC using fractional frequency reuse is calculated as follows:

$$f^{TX_i(ic)-TX_j(jc)}_{ICIC-UL} = 10 \times Log\left(p^{TX_i(ic)-TX_j(jc)}_{Collision}\right)$$

Where $p^{TX_i(ic)-TX_j(jc)}_{Collision}$ is the collision probability between the subcarriers used by the fractions of the channels being used by the interfered and interfering cells. It is determined during Monte Carlo simulations as follows:

Case	Interfered cell $TX_i(ic)$	Interfering cell $TX_j(jc)$	$p^{TX_i(ic)-TX_j(jc)}_{Collision}$
a	ICIC	ICIC	$\frac{N^{Common}_{FB-CE}}{N^{TX_i(ic)}_{FB-CE}}$
b	ICIC	Non ICIC	1
c	Non ICIC	ICIC	$\frac{N^{Common}_{FB-CE}}{N^{TX_i(ic)}_{FB}}$

Case	Interfered cell $TX_i(ic)$	Interfering cell $TX_j(jc)$	$p_{Collision}^{TX_i(ic) - TX_j(jc)}$
d	Non ICIC	Non ICIC	1

Where, N_{FB-CE}^{Common} is the number of cell-edge frequency blocks common in $TX_i(ic)$ and $TX_j(jc)$, and $N_{FB-CE}^{TX_i(ic)}$ is the number of cell-edge frequency blocks in the cell $TX_i(ic)$.

Whether a pixel, subscriber, or mobile is covered by the ICIC part of the frame is determined as explained in "Best Server Determination" on page 384.

In Monte Carlo simulations, **9955** calculates two separate noise rise values; for the mobiles located in the ICIC zone of the interfered cell **9955** calculates the ICIC UL Noise Rise, and for the mobiles located in the non-ICIC zone of the interfered cell **9955** calculates the UL Noise Rise.

In coverage predictions, point analysis, and calculations on subscriber lists, according to the zone, ICIC or non-ICIC, that covers the pixel, receiver, or subscriber, **9955** uses either the ICIC UL Noise Rise or the UL Noise Rise to calculate the PUSCH and PUCCH C/(I+N). For more information on the calculation of the uplink noise rise, see "Noise Rise Calculation (UL)" on page 377.

Output

- $I_{PUSCH,\,PUCCH}^{M_j}$: PUSCH and PUCCH interference signal level received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$.

5.4.3.8.2 Noise Rise Calculation (UL)

The uplink noise rise is defined as the ratio of the total uplink interference received by any cell $TX_i(ic)$ from all interfering mobiles M_j present in the coverage areas of all other cells $TX_j(jc)$ to the uplink noise of the cell $TX_i(ic)$. In other words, it is the ratio (I+N)/N.

Input

- $I_{PUSCH,\,PUCCH}^{M_j}$: PUSCH and PUCCH interference signal levels received at a cell $TX_i(ic)$ from interfering mobiles M_j covered by other cells $TX_j(jc)$ as calculated in "Interfering Signal Level Calculation (UL)" on page 375.
- $n_{PUSCH,\,PUCCH}^{TX_i(ic)}$: Uplink noise for the PUSCH and the PUCCH for the cell $TX_i(ic)$ as calculated in "Noise Calculation (UL)" on page 374.
- $NR_{UL}^{Inter-Tech}$: Inter-technology uplink noise rise.

Calculations

For any mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$, **9955** calculates the UL Noise Rise as follows:

$$NR_{UL}^{TX_i(ic)} = 10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}} \left(10^{\frac{I_{PUSCH,\,PUCCH}^{M_j}\big|_{\forall\ non\text{-}ICIC\ M_i}}{10}} \right) + 10^{\frac{n_{PUSCH,\,PUCCH}^{TX_i(ic)}}{10}} \right) + NR_{UL}^{Inter-Tech} - n_{PUSCH,\,PUCCH}^{TX_i(ic)}$$

For any pixel, subscriber, or mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$, **9955** calculates the PUSCH and PUCCH total noise (I+N) as follows:

$$(I+N)_{PUSCH,\,PUCCH}^{TX_i(ic)} = NR_{UL}^{TX_i(ic)} + n_{PUSCH,\,PUCCH}^{TX_i(ic)}$$

For any mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$, **9955** calculates the ICIC UL Noise Rise as follows:

$$NR_{UL-ICIC}^{TX_i(ic)} = 10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}} \left(10^{\frac{I_{PUSCH,\,PUCCH}^{M_j}\big|_{\forall\ ICIC\ M_i}}{10}} \right) + 10^{\frac{n_{PUSCH,\,PUCCH}^{TX_i(ic)}}{10}} \right) + NR_{UL}^{Inter-Tech} - n_{PUSCH,\,PUCCH}^{TX_i(ic)}$$

For any pixel, subscriber, or mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$, **9955** calculates the the PUSCH and PUCCH total noise (I+N) as follows:

$$(I+N)_{PUSCH,\,PUCCH}^{TX_i(ic)} = NR_{UL-ICIC}^{TX_i(ic)} + n_{PUSCH,\,PUCCH}^{TX_i(ic)}$$

Output

- $NR_{UL}^{TX_i(ic)}$: Uplink noise rise for the cell $TX_i(ic)$.
- $NR_{UL-ICIC}^{TX_i(ic)}$: ICIC uplink noise rise for the cell $TX_i(ic)$.
- $(I+N)_{PUSCH,\,PUCCH}^{TX_i(ic)}$: PUSCH and PUCCH total noise for a cell $TX_i(ic)$ calculated for any pixel, subscriber, or mobile M_i.

5.4.3.9 C/N Calculation (UL)

Input

- $C_{PUSCH,\,PUCCH}^{M_i}$: Received PUSCH and PUCCH signal level from the pixel, subscriber, or mobile M_i at its serving cell $TX_i(ic)$ as calculated in "Signal Level Calculation (UL)" on page 372.
- $n_{PUSCH,\,PUCCH}^{TX_i(ic)}$: PUSCH and PUCCH noise for the cell $TX_i(ic)$ as calculated in "Noise Calculation (UL)" on page 374.
- $CNR_{DLRS}^{TX_i(ic)}$: Downlink reference signal C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 365.
- $CINR_{DLRS}^{TX_i(ic)}$: Downlink reference signal C/(I+N) from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $N_{FB-CE}^{TX_i(ic)}$: Number of cell-edge frequency blocks (used in cell-edge areas in case of ICIC), determined from the list of frequency blocks corresponding to the cell's PSS ID (0, 1, or 2) defined in the ICIC configuration assigned to the cell $TX_i(ic)$. By default (if no ICIC configuration is assigned to the cell), $N_{FB-CE}^{TX_i(ic)} = \frac{N_{FB}^{TX_i(ic)}}{3}$.
- $T_{B-Lowest}^{TX_i(ic)}$: Bearer selection threshold of the lowest bearer in the LTE equipment assigned to the cell $TX_i(ic)$.
- $P_{Allowed}^{M_i}$: Maximum allowed transmission power of the terminal used by the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (UL)" on page 372.
- $P_{Min}^{M_i}$: Minimum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- M_{PC} : Power control adjustment margin defined in the Global Parameters.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the LTE equipment used bythe cell $TX_i(ic)$.
- $B_{UL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{UL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{M_i}$: Number of transmission (uplink) antenna ports defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-RX}^{TX_i(ic)}$: Number of reception (uplink) antenna ports defined for the cell $TX_i(ic)$.
- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the LTE equipment assigned to the cell $TX_i(ic)$.

Calculations

The PUSCH and PUCCH C/N from a pixel, subscriber, or mobile M_i at its serving cell $TX_i(ic)$ is calculated as follows:

$$CNR^{M_i}_{PUSCH,\,PUCCH} = C^{M_i}_{PUSCH,\,PUCCH} - n^{TX_i(ic)}_{PUSCH,\,PUCCH}$$

Bearer Determination:

The bearers available for selection in the cell $TX_i(ic)$'s LTE equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the PUSCH and PUCCH C/N at M_i: $T_B^{M_i} < CNR^{M_i}_{PUSCH,\,PUCCH}$

  If the cell supports Receive Diversity or AMS, the Receive Diversity gain, G^{UL}_{Div}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the LTE equipment assigned to the cell $TX_i(ic)$ for $N^{M_i}_{Ant-TX}$, $N^{TX_i(ic)}_{Ant-RX}$, $Mobility(M_i)$, $BLER\left(B^{M_i}_{UL}\right)$.

  The additional uplink diversity gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG^{UL}_{Div} is also applied. Therefore, the bearers available for selection are all the bearers defined in the LTE equipment for which the following is true:

  In case of Receive Diversity:

  $$T_B^{M_i} - G^{UL}_{Div} - \Delta G^{UL}_{Div} < CNR^{M_i}_{PUSCH,\,PUCCH}$$

  In case of AMS:

  $$T_B^{M_i} - G^{UL}_{Div} - \Delta G^{UL}_{Div} < CNR^{M_i}_{PUSCH,\,PUCCH} \quad if \quad CNR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS} \quad or \quad CINR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$$

The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$.

- Bearer Index

  From among the bearers available for selection, the selected bearer is the one with the highest index.
- Peak RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest uplink peak RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.
- Effective RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest uplink effective RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

MIMO – Receive Diversity Gain:

Once the bearer is known, the PUSCH and PUCCH C/N calculated above become:

In case of Receive Diversity:

$$CNR^{M_i}_{PUSCH,\,PUCCH} = CNR^{M_i}_{PUSCH,\,PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div}$$

In case of AMS:

$$CNR^{M_i}_{PUSCH,\,PUCCH} = CNR^{M_i}_{PUSCH,\,PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div} \quad if \; CNR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS} \; or \; CINR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$$

Where G^{UL}_{Div} is the receive diversity gain corresponding to the selected bearer.

Uplink Bandwidth Allocation (No. of Used Frequency Blocks):

The uplink bandwidth allocation depends on the target defined for the scheduler used by the cell $TX_i(ic)$. The PUSCH and PUCCH C/N calculated above is given for the total number of frequency blocks associated with the channel bandwidth of the cell, i.e., $N_{FB}^{TX_i(ic)}$. Bandwidth allocation is performed for all the pixels, subscribers, or mobiles in the uplink, and may reduce the number of used frequency blocks in order to satisfy the selected target.

- Full Bandwidth

  Full channel width is used by each mobile in the uplink. As there is no reduction in the bandwidth used for transmission, there is no gain in the PUSCH and PUCCH C/N.

- Maintain Connection

  The bandwidth used for transmission by a mobile is reduced only if the PUSCH and PUCCH C/N is not enough to even access the lowest bearer. For example, as a mobile moves from good to bad radio conditions, the number of frequency blocks used by it for transmission in uplink are reduced one by one in order to improve the PUSCH and PUCCH C/N. The calculation of the gain introduced by the bandwidth reduction is explained below.

- Best Bearer

  The bandwidth used for transmission by a mobile is reduced in order to improve the PUSCH and PUCCH C/N enough to access the best bearer. For example, if using 5 frequency blocks, a mobile is able to access the best bearer, and using 6 it would only get access to the second best, it will be assigned 5 frequency blocks as the used uplink bandwidth. Although using 4 frequency blocks, its PUSCH and PUCCH C/N will be better than when using 5, the uplink bandwidth is not reduced to 4 because it does not provide any gain in terms of the bearer, i.e., the mobile already has the best bearer using 5 frequency blocks. The calculation of the gain introduced by the bandwidth reduction is explained below.

  The definition of the best bearer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$, i.e., bearer with the highest index, with the highest peak RLC throughput, or with the highest effective RLC throughput.

The uplink bandwidth allocation may result in the use of a number of frequency blocks which is less than the number of frequency blocks associated with the channel bandwidth of the cell. The gain related to this bandwidth reduction is applied to the PUSCH and PUCCH C/N:

$$CNR^{M_i}_{\underset{Final}{PUSCH,\ PUCCH}} = CNR^{M_i}_{\underset{All\ FB}{PUSCH,\ PUCCH}} + 10 \times Log\left(\frac{N_{FB}^{TX_i(ic)}}{N_{FB-UL}^{M_i}}\right)$$

Where $N_{FB-UL}^{M_i} < N_{FB}^{TX_i(ic)}$ for any pixel, subscriber, or mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$, and $N_{FB-UL}^{M_i} < Cieling\left(N_{FB-CE}^{TX_i(ic)}\right)$ for any pixel, subscriber, or mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$.

Uplink Power Control Adjustment:

Once the bandwidth allocation is performed, **9955** continues to work with the C/N given by the bandwidth allocation, i.e., $CNR^{M_i}_{PUSCH,\ PUCCH} = CNR^{M_i}_{\underset{Final}{PUSCH,\ PUCCH}}$.

The pixel, subscriber, or mobile M_i reduces its transmission power so that the PUSCH and PUCCH C/N from it at its cell is just enough to get the selected bearer.

If with $P^{M_i} = P^{M_i}_{Allowed}$ AND $CNR^{M_i}_{PUSCH,\ PUCCH} > T^{TX_i(ic)}_{B^{M_i}_{UL}} + M_{PC}$, where $T^{TX_i(ic)}_{B^{M_i}_{UL}}$ is the bearer selection threshold, from the LTE equipment assigned to the cell $TX_i(ic)$, for the bearer selected for the pixel, subscriber, or mobile M_i.

The transmission power of M_i is reduced to determine the effective transmission power from the pixel, subscriber, or mobile M_i as follows:

$$P^{M_i}_{Eff} = Max\left(P^{M_i}_{Allowed} - \left(CNR^{M_i}_{PUSCH,\ PUCCH} - \left(T^{TX_i(ic)}_{B^{M_i}_{UL}} + M_{PC}\right)\right), P^{M_i}_{Min}\right)$$

$CNR^{M_i}_{PUSCH,\ PUCCH}$ is calculated again using $P^{M_i}_{Eff}$.

Output

- $CNR_{PUSCH, PUCCH}^{M_i}$: PUSCH and PUCCH C/N from a pixel, subscriber, or mobile M_i at it serving cell $TX_i(ic)$.

5.4.3.10 C/(I+N) and Bearer Calculation (UL)

The carrier signal to interference and noise ratio is calculated in three steps. First, **9955** calculates the received signal level from each pixel, subscriber, or mobile at its serving cell using the effective power of the terminal used by the pixel, subscriber, or mobile as explained in "Signal Level Calculation (UL)" on page 372. Next, **9955** calculates the uplink carrier to noise ratio as explained in "C/N Calculation (UL)" on page 378. Finally, determines the uplink C/(I+N) by dividing the previously calculated uplink C/N by the uplink noise rise value of the cell as calculated in "Noise Rise Calculation (UL)" on page 377.

The uplink noise rise can be set by the user manually for each cell or calculated using Monte Carlo simulations.

The receiver terminal is always considered to be oriented towards its best server, except when the "Lock Status" is set to "Server+Orientation" for a subscriber in a subscriber list and its azimuth and tilt manually edited. In the case of NLOS between the receiver and the best server, **9955** does not try to find the direction of the strongest signal, the receiver is oriented towards the best server just as in the case of LOS.

Input

- $CNR_{PUSCH, PUCCH}^{M_i}$: PUSCH and PUCCH C/N from a pixel, subscriber, or mobile M_i at it serving cell $TX_i(ic)$ as calculated in "C/N Calculation (UL)" on page 378.
- $NR_{UL}^{TX_i(ic)}$: Uplink noise rise for the cell $TX_i(ic)$ as calculated in "Noise Rise Calculation (UL)" on page 377.
- $NR_{UL-ICIC}^{TX_i(ic)}$: ICIC uplink noise rise for the cell $TX_i(ic)$ as calculated in "Noise Rise Calculation (UL)" on page 377.
- $CNR_{DLRS}^{TX_i(ic)}$: Downlink reference signal C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 365.
- $CINR_{DLRS}^{TX_i(ic)}$: Downlink reference signal C/(I+N) from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 365.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(c)$.
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $N_{FB-CE}^{TX_i(ic)}$: Number of cell-edge frequency blocks (used in cell-edge areas in case of ICIC), determined from the list of frequency blocks corresponding to the cell's PSS ID (0, 1, or 2) defined in the ICIC configuration assigned to the cell $TX_i(ic)$. By default (if no ICIC configuration is assigned to the cell), $N_{FB-CE}^{TX_i(ic)} = \frac{N_{FB}^{TX_i(ic)}}{3}$.
- $T_{B-Lowest}^{TX_i(ic)}$: Bearer selection threshold of the lowest bearer in the LTE equipment assigned to the cell $TX_i(ic)$.
- $P_{Allowed}^{M_i}$: Maximum allowed transmission power of the terminal used by the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (UL)" on page 372.
- $P_{Min}^{M_i}$: Minimum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- M_{PC} : Power control adjustment margin defined in the Global Parameters.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the LTE equipment used bythe cell $TX_i(ic)$.
- $B_{UL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{UL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{M_i}$: Number of transmission (uplink) antenna ports defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-RX}^{TX_i(ic)}$: Number of reception (uplink) antenna ports defined for the cell $TX_i(ic)$.

- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the LTE equipment assigned to the cell $TX_i(ic)$.

Calculations

For any pixel, subscriber, or mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$, **9955** calculates the PUSCH and PUCCH C/(I+N) as follows:

$$CINR_{PUSCH,\,PUCCH}^{M_i} = CNR_{PUSCH,\,PUCCH}^{M_i} - NR_{UL}^{TX_i(ic)}$$

For any pixel, subscriber, or mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$, **9955** calculates the PUSCH and PUCCH C/(I+N) as follows:

$$CINR_{PUSCH,\,PUCCH}^{M_i} = CNR_{PUSCH,\,PUCCH}^{M_i} - NR_{UL-ICIC}^{TX_i(ic)}$$

Bearer Determination:

The bearers available for selection in the cell $TX_i(ic)$'s LTE equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the PUSCH and PUCCH C/(I+N) at M_i: $T_B^{M_i} < CINR_{PUSCH,\,PUCCH}^{M_i}$

  If the cell supports Receive Diversity or AMS, the Receive Diversity gain, G_{Div}^{UL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the LTE equipment assigned to the cell $TX_i(ic)$ for $N_{Ant-TX}^{M_i}$, $N_{Ant-RX}^{TX_i(ic)}$, $Mobility(M_i)$, $BLER\left(B_{UL}^{M_i}\right)$.

  The additional uplink diversity gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{Div}^{UL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the LTE equipment for which the following is true:

  In case of Receive Diversity:

  $$T_B^{M_i} - G_{Div}^{UL} - \Delta G_{Div}^{UL} < CINR_{PUSCH,\,PUCCH}^{M_i}$$

  In case of AMS:

  $$T_B^{M_i} - G_{Div}^{UL} - \Delta G_{Div}^{UL} < CINR_{PUSCH,\,PUCCH}^{M_i} \qquad if \quad CNR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \quad or \quad CINR_{DLRS}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$.

- Bearer Index

  From among the bearers available for selection, the selected bearer is the one with the highest index.
- Peak RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest uplink peak RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.
- Effective RLC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest uplink effective RLC channel throughput as calculated in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

MIMO – Receive Diversity Gain:

Once the bearer is known, the PUSCH and PUCCH C/(I+N) calculated above become:

In case of Receive Diversity:

$$CINR^{M_i}_{PUSCH,\,PUCCH} = CINR^{M_i}_{PUSCH,\,PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div}$$

In case of AMS:

$$CINR^{M_i}_{PUSCH,\,PUCCH} = CINR^{M_i}_{PUSCH,\,PUCCH} + G^{UL}_{Div} + \Delta G^{UL}_{Div} \quad \text{if } CNR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS} \text{ or } CINR^{TX_i(ic)}_{DLRS} < T^{TX_i(ic)}_{AMS}$$

Where G^{UL}_{Div} is the receive diversity gain corresponding to the selected bearer.

Uplink Bandwidth Allocation (No. of Used Frequency Blocks):

The uplink bandwidth allocation depends on the target defined for the scheduler used by the cell $TX_i(ic)$. The PUSCH and PUCCH C/(I+N) calculated above is given for the total number of frequency blocks associated with the channel bandwidth of the cell, i.e., $N^{TX_i(ic)}_{FB}$. Bandwidth allocation is performed for all the pixels, subscribers, or mobiles in the uplink, and may reduce the number of used frequency blocks in order to satisfy the selected target.

- Full Bandwidth

  Full channel width is used by each mobile in the uplink. As there is no reduction in the bandwidth used for transmission, there is no gain in the PUSCH and PUCCH C/(I+N).

- Maintain Connection

  The bandwidth used for transmission by a mobile is reduced only if the PUSCH and PUCCH C/(I+N) is not enough to even access the lowest bearer. For example, as a mobile moves from good to bad radio conditions, the number of frequency blocks used by it for transmission in uplink are reduced one by one in order to improve the PUSCH and PUCCH C/(I+N). The calculation of the gain introduced by the bandwidth reduction is explained below.

- Best Bearer

  The bandwidth used for transmission by a mobile is reduced in order to improve the PUSCH and PUCCH C/(I+N) enough to access the best bearer. For example, if using 5 frequency blocks, a mobile is able to access the best bearer, and using 6 it would only get access to the second best, it will be assigned 5 frequency blocks as the used uplink bandwidth. Although using 4 frequency blocks, its PUSCH and PUCCH C/(I+N) will be better than when using 5, the uplink bandwidth is not reduced to 4 because it does not provide any gain in terms of the bearer, i.e., the mobile already has the best bearer using 5 frequency blocks. The calculation of the gain introduced by the bandwidth reduction is explained below.

  The definition of the best bearer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$, i.e., bearer with the highest index, with the highest peak RLC throughput, or with the highest effective RLC throughput.

The uplink bandwidth allocation may result in the use of a number of frequency blocks which is less than the number of frequency blocks associated with the channel bandwidth of the cell. The gain related to this bandwidth reduction is applied to the PUSCH and PUCCH C/(I+N):

$$CINR^{M_i}_{\substack{PUSCH,\,PUCCH\\Final}} = CINR^{M_i}_{\substack{PUSCH,\,PUCCH\\All\ FB}} + 10 \times Log\left(\frac{N^{TX_i(ic)}_{FB}}{N^{M_i}_{FB-UL}}\right)$$

Where $N^{M_i}_{FB-UL} < N^{TX_i(ic)}_{FB}$ for any pixel, subscriber, or mobile M_i covered by the non-ICIC zone in the interfered cell $TX_i(ic)$, and $N^{M_i}_{FB-UL} < Cieling\left(N^{TX_i(ic)}_{FB-CE}\right)$ for any pixel, subscriber, or mobile M_i covered by the ICIC zone in the interfered cell $TX_i(ic)$.

Uplink Power Control Adjustment:

Once the bandwidth allocation is performed, **9955** continues to work with the C/(I+N) given by the bandwidth allocation, i.e., $CINR^{M_i}_{PUSCH,\,PUCCH} = CINR^{M_i}_{\substack{PUSCH,\,PUCCH\\Final}}$.

The pixel, subscriber, or mobile M_i reduces its transmission power so that the PUSCH and PUCCH C/(I+N) from it at its cell is just enough to get the selected bearer.

If with $P^{M_i} = P^{M_i}_{Allowed}$ AND $CINR^{M_i}_{PUSCH,\,PUCCH} > T^{TX_i(ic)}_{B^{M_i}_{UL}} + M_{PC}$, where $T^{TX_i(ic)}_{B^{M_i}_{UL}}$ is the bearer selection threshold, from the LTE equipment assigned to the cell $TX_i(ic)$, for the bearer selected for the pixel, subscriber, or mobile M_i.

The transmission power of M_i is reduced to determine the effective transmission power from the pixel, subscriber, or mobile M_i as follows:

$$P_{Eff}^{M_i} = Max\left(P_{Allowed}^{M_i} - \left(CINR_{PUSCH,\,PUCCH}^{M_i} - \left(T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}\right)\right), P_{Min}^{M_i}\right)$$

$CINR_{PUSCH,\,PUCCH}^{M_i}$ is calculated again using $P_{Eff}^{M_i}$.

Output

- $CINR_{PUSCH,\,PUCCH}^{M_i}$: PUSCH and PUCCH C/(I+N) from a pixel, subscriber, or mobile M_i at it serving cell *$TX_i(ic)$.*
- $N_{FB-UL}^{M_i}$: Number of frequency blocks used by the pixel, subscriber, or mobile M_i after uplink bandwidth allocation.
- $P_{Eff}^{M_i}$: Effective transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- $B_{UL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the uplink.

5.4.4 Best Server Determination

In LTE, best server refers to a cell ("serving transmitter"-"reference cell" pair) from which a pixel, subscriber, or mobile M_i gets the highest downlink reference signal level ($C_{DLRS}^{TX_i(ic)}$).

Input

- $C_{DLRS}^{TX_i(ic)}$: Downlink reference signal level received from any cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351 using the terminal and service parameters (L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$) of M_i.

Calculations

The best server of any pixel, subscriber, or mobile M_i, BS_{M_i}, is the cell from which the received downlink reference signal level is the highest among the downlink reference signal levels received from all the cells. The best server is determined as follows:

$$BS_{M_i} = TX_i(ic)\Big|_{C_{DLRS}^{TX_i(ic)} = \underset{All\ TX_i(ic)}{Best}\left\{C_{DLRS}^{TX_i(ic)}\right\}}$$

Here *ic* is the cell of the transmitter TX_i with the highest downlink reference signal power. However, if more than one cell of the same transmitter covers the pixel, subscriber, or mobile, the final reference cell *ic* might be different from the initial cell *ic* (the one with the highest power) depending on the serving cell selection method:

- **Random:** In coverage prediction calculations and in calculations on subsriber lists, the cell of the highest layer is selected as the serving (reference) cell. In Monte Carlo simulations, a random cell is selected as the serving (reference) cell.
- **Distributive:** In coverage prediction calculations and in calculations on subsriber lists, the cell of the highest layer is selected as the serving (reference) cell. In Monte Carlo simulations, mobiles are distributed among cell layers one by one, i.e., if more than one cell layer covers a set of mobiles, the first mobile is assigned to the highest cell layer, the 2nd mobile to the second highest cell layer, and so on.

  When using either the **Random** or the **Distributive** cell selection method, the reference cell once assigned to a mobile does not change during Monte Carlo simulations.

In case the cell supports static downlink ICIC using fractional frequency reuse, **9955** determines whether the pixel, subscriber, or mobile M_i is covered by the ICIC part of the frame or by the non-ICIC part of the frame. A pixel, subscriber, or mobile is covered by the ICIC part of the frame if it is considered to be at the cell edge, and it is covered by the non-ICIC part otherwise.

Whether a pixel, subscriber, or mobile M_i is at cell edge is determined by calculating the difference between the path loss from the second best server and the best server, and comparing it with the delta path loss threshold defined for the best server of the pixel, subscriber, or mobile M_i.

Therefore, a pixel, subscriber, or mobile M_i is considered to be a cell edge if $L_{Total}^{2ndBS_{M_i}} + 10 \times Log\left(r_O^{BS_{M_i} - 2ndBS_{M_i}}\right) - L_{Total}^{BS_{M_i}} \leq \Delta L_{Path}^{BS_{M_i}}$, and it is considered to be not at cell edge otherwise. Here, $L_{Total}^{BS_{M_i}}$ is the total loss from M_i's best server and $L_{Total}^{2ndBS_{M_i}}$ is the total loss from M_i's second best server calculated as explained in "Signal Level Calculation (DL)" on page 310. The second best server for a pixel, subscriber, or mobile M_i is calculated as follows:

$$2ndBS_{M_i} = TX_i(ic)\Big|_{C_{DLRS}^{TX_i(ic)} = \underset{All\ TX_i(ic)}{2ndBest}\left\{C_{DLRS}^{TX_i(ic)}\right\}}$$

$r_O^{BS_{M_i} - 2ndBS_{M_i}}$ is the total channel overlap ratio between the best server and the second best server as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 347. $\Delta L_{Path}^{BS_{M_i}}$ is the delta path loss threshold defined for the best server of the pixel, subscriber, or mobile M_i.

Output

- BS_{M_i} : Best serving cell of the pixel, subscriber, or mobile M_i.

5.4.5 Service Area Calculation

In LTE, a pixel, subscriber, or mobile M_i may be covered by a cell but still outside the effective service area of the cell. A pixel, subscriber, or mobile M_i is said to be within the service area of its best serving cell $TX_i(ic)$ if the downlink reference signal energy per resource element from the cell at the pixel, subscriber, or mobile is greater than or equal to the Min RSRP defined for the cell.

Input

- $E_{DLRS}^{TX_i(ic)}$: Downlink reference signal energy per resource element from the cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 351.
- $T_{RSRP}^{TX_i(ic)}$: Minimum RSRP defined for the cell $TX_i(ic)$.

Calculations

A pixel, subscriber, or mobile M_i is within the service area of its best serving cell $TX_i(ic)$ if:

$$E_{DLRS}^{TX_i(ic)} \geq T_{RSRP}^{TX_i(ic)}$$

Output

- *True*: If the calculation criterion is satisfied.
- *False*: Otherwise.

5.4.6 Throughput Calculation

Throughputs are calculated in two steps.

- Calculation of uplink and downlink total resources in a cell as explained in "Calculation of Total Cell Resources" on page 385.
- Calculation of uplink and downlink UE capacities as explained in "Calculation UE Capacities" on page 391.
- Calculation of throughputs as explained in "Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation" on page 392.

5.4.6.1 Calculation of Total Cell Resources

The total amount of resources in a cell is the number of modulation symbols that can be used for data transfer in each frame. The total cell resources can be calculated separately for the downlink and uplink as described in:

- "Calculation of Downlink Cell Resources" on page 386.
- "Calculation of Uplink Cell Resources" on page 389.

5.4.6.1.1 Calculation of Downlink Cell Resources

Input

- ΔF : Subcarrier width (15 kHz).
- W_{FB} : Width of a frequency block (180 kHz).
- $N_{FB-SS,PBCH}$: Number of frequency blocks that carry the SS and the PBCH (6).
- $N_{Slot/SF}$: Number of slots per subframe (2).
- D_{CP} : Cyclic prefix duration defined for the network in the Global Parameters.
- $N_{SD/Slot}$: Number of symbol durations per slot (7 is D_{CP} is Normal, 6 if D_{CP} is Extended).
- $N_{SD-PDCCH}$: Number of PDCCH symbol durations per subframe defined in the Global Parameters.
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell *TX$_i$(ic)*.
- $N_{SF-DL}^{TX_i(ic)}$: Number of downlink subframes in the frame for the cell *TX$_i$(ic)*. It is equal to 10 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.
- $N_{TDD-SSF}^{TX_i(ic)}$: Number of TDD special subframes (containing DwPTS, GP, and UpPTS) in the frame for the cell *TX$_i$(ic)*. It is equal to 0 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.

  $N_{SF-DL}^{TX_i(ic)}$ and $N_{TDD-SSF}^{TX_i(ic)}$ are determined as follows:

Configuration	$N_{SF-DL}^{TX_i(ic)}$	$N_{TDD-SSF}^{TX_i(ic)}$
FDD	10	0
DSUUU-DSUUU	2	2
DSUUD-DSUUD	4	2
DSUDD-DSUDD	6	2
DSUUU-DSUUD	3	2
DSUUU-DDDDD	6	1
DSUUD-DDDDD	7	1
DSUDD-DDDDD	8	1

- $N_{Ant-TX}^{TX_i(ic)}$: Number of transmission (downlink) antenna ports defined for the cell *TX$_i$(ic)*.

Calculations

In LTE, a resource block (RB) is defined as 1 frequency block by 1 slot. However, schedulers are able to perform resource allocation every subframe (2 slots). 1 frequency block by 1 subframe (2 slots) is called a scheduler resource block (SRB) in the calculations below.

The number of modulation symbols (resource elements) per scheduler resource block is calculated as follows:

$$N_{Sym/SRB} = N_{SCa-FB} \times N_{SD/Slot} \times N_{Slot/SF}$$

Where N_{SCa-FB} is the number of subcarriers per frequency block calculated as follows:

$$N_{SCa-FB} = \frac{W_{FB}}{\Delta F}$$

The number of modulation symbols (resource elements) corresponding to the DwPTS per scheduler resource block in the TDD special subframes is calculated as follows:

$$N_{Sym/SSF}^{DwPTS} = N_{SCa-FB} \times N_{SD/SSF}^{DwPTS}$$

Where $N_{SD/SSF}^{DwPTS}$ is the number of DwPTS symbol durations (OFDM symbols) per special subframe, determined from the TDD special subframe configuration according to the 3GPP specifications as follows:

<table>
<tr><th rowspan="2">Special Subframe Configuration</th><th colspan="3">Cyclic Prefix = Normal</th><th colspan="3">Cyclic Prefix = Extended</th></tr>
<tr><th>DwPTS $N_{SD/SSF}^{DwPTS}$</th><th>GP $N_{SD/SSF}^{GP}$</th><th>UpPTS $N_{SD/SSF}^{UpPTS}$</th><th>DwPTS $N_{SD/SSF}^{DwPTS}$</th><th>GP $N_{SD/SSF}^{GP}$</th><th>UpPTS $N_{SD/SSF}^{UpPTS}$</th></tr>
<tr><td>0</td><td>3</td><td>10</td><td rowspan="5">1</td><td>3</td><td>8</td><td rowspan="4">1</td></tr>
<tr><td>1</td><td>9</td><td>4</td><td>8</td><td>3</td></tr>
<tr><td>2</td><td>10</td><td>3</td><td>9</td><td>2</td></tr>
<tr><td>3</td><td>11</td><td>2</td><td>10</td><td>1</td></tr>
<tr><td>4</td><td>12</td><td>1</td><td>3</td><td>7</td><td rowspan="3">2</td></tr>
<tr><td>5</td><td>3</td><td>9</td><td rowspan="4">2</td><td>8</td><td>2</td></tr>
<tr><td>6</td><td>9</td><td>3</td><td>9</td><td>1</td></tr>
<tr><td>7</td><td>10</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>11</td><td>1</td><td></td><td></td><td></td></tr>
</table>

The total number of modulation symbols (resource elements) in downlink is calculated as follows:

$$N_{Sym-DL}^{TX_i(ic)} = N_{FB}^{TX_i(ic)} \times N_{Sym/SRB} \times N_{SF-DL}^{TX_i(ic)} + N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)} \times N_{Sym/SSF}^{DwPTS}$$

The total downlink cell resources, i.e., $R_{DL}^{TX_i(ic)}$, are calculated as follows:

$$R_{DL}^{TX_i(ic)} = N_{Sym-DL}^{TX_i(ic)} - O_{DLRS}^{TX_i(ic)} - O_{PSS} - O_{SSS} - O_{PBCH}^{TX_i(ic)} - O_{PDCCH}^{TX_i(ic)} - O_{UERS}^{TX_i(ic)}$$

Where $O_{DLRS}^{TX_i(ic)}$ is the overhead corresponding to the downlink reference signals, O_{PSS} is the overhead corresponding to the primary synchronisation signals, O_{SSS} is the overhead corresponding to the secondary synchronisation signals, $O_{PBCH}^{TX_i(ic)}$ is the overhead corresponding to the physical broadcast channel, and $O_{PDCCH}^{TX_i(ic)}$ is the overhead corresponding to the physical downlink control channel. $O_{UERS}^{TX_i(ic)}$ is the overhead corresponding to the UE-specific reference signals transmitted on the logical antenna port 5 when a user is served using smart antennas.

These overheads are calculated as follows:

Downlink reference signal overhead

The downlink reference signal overhead depends on the number of transmission antenna ports:

$$O_{DLRS}^{TX_i(ic)} = N_{FB}^{TX_i(ic)} \times N_{DLRS/SRB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)} + N_{FB}^{TX_i(ic)} \times N_{DLRS/DwPTS}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)}$$

Where $N_{DLRS/SRB}^{TX_i(ic)} = \begin{cases} 8 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 1\right) \\ 16 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 2\right) \\ 24 & \text{if } \left(N_{Ant-TX}^{TX_i(ic)} = 4 \text{ or } 8\right) \end{cases}$

And $N_{DLRS/DwPTS}^{TX_i(ic)}$ is determined from the table below:

<table>
<tr><th rowspan="2">Special Subframe Configuration</th><th colspan="3">Cyclic Prefix = Normal</th><th colspan="3">Cyclic Prefix = Extended</th></tr>
<tr><th>$N_{SD/SSF}^{DwPTS}$</th><th>$N_{Ant-TX}^{TX_i(ic)}$</th><th>$N_{DLRS/DwPTS}^{TX_i(ic)}$</th><th>$N_{SD/SSF}^{DwPTS}$</th><th>$N_{Ant-TX}^{TX_i(ic)}$</th><th>$N_{DLRS/DwPTS}^{TX_i(ic)}$</th></tr>
<tr><td rowspan="4">0</td><td rowspan="4">3</td><td>1</td><td>2</td><td rowspan="4">3</td><td>1</td><td>2</td></tr>
<tr><td>2</td><td>4</td><td>2</td><td>4</td></tr>
<tr><td>4</td><td>8</td><td>4</td><td>8</td></tr>
<tr><td>8</td><td>8</td><td>8</td><td>8</td></tr>
</table>

Special Subframe Configuration	Cyclic Prefix = Normal			Cyclic Prefix = Extended		
	$N_{SD/SSF}^{DwPTS}$	$N_{Ant-TX}^{TX_i(ic)}$	$N_{DLRS/DwPTS}^{TX_i(ic)}$	$N_{SD/SSF}^{DwPTS}$	$N_{Ant-TX}^{TX_i(ic)}$	$N_{DLRS/DwPTS}^{TX_i(ic)}$
1	9	1	6	8	1	6
		2	12		2	12
		4	20		4	20
		8	20		8	20
2	10	1	6	9	1	6
		2	12		2	12
		4	20		4	20
		8	20		8	20
3	11	1	6	10	1	8
		2	12		2	16
		4	20		4	24
		8	20		8	24
4	12	1	8	3	1	2
		2	16		2	4
		4	24		4	8
		8	24		8	8
5	3	1	2	8	1	6
		2	4		2	12
		4	8		4	20
		8	8		8	20
6	9	1	6	9	1	6
		2	12		2	12
		4	20		4	20
		8	20		8	20
7	10	1	6			
		2	12			
		4	20			
		8	20			
8	11	1	6			
		2	12			
		4	20			
		8	20			

PSS and SSS overhead

The primary and secondary synchonisation signals are transmitted on 1 symbol duration each in the 1st and the 6th downlink subframes, over the centre 6 frequency blocks. Therefore,

$$O_{PSS} = 2 \times N_{FB-SS,\,PBCH} \times N_{SCa-FB} = 144\ \ symbols$$

$$O_{SSS} = 2 \times N_{FB-SS,\,PBCH} \times N_{SCa-FB} = 144\ \ symbols$$

PBCH overhead

The physical broadcast channel is transmitted on four symbol durations in the 1st downlink subframe over the center 6 frequency blocks. The physical broadcast channel overlaps with the downlink reference signals, therefore, some downlink reference signal modulation symbols are subtracted:

$$O_{PBCH}^{TX_i(ic)} = \left(4 \times N_{SCa-FB} - \frac{N_{DLRS/SRB}^{TX_i(ic)}}{2}\right) \times N_{FB-SS,\,PBCH} \text{ for extended cyclic prefix}$$

$$O_{PBCH}^{TX_i(ic)} = \left(4 \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB-SS,\,PBCH}$$ for normal cyclic prefix

PDCCH overhead

The physical downlink control channel can be transmitted over up to 3 symbol durations in each subframe. The number of symbol durations for the PDCCH is defined in the global parameters. The PDCCH overlaps some downlink reference signal symbols. These downlink reference signal symbols are subtracted from the PDCCH overhead:

$$if \quad (N_{SD-PDCCH} = 0):$$

$$O_{PDCCH}^{TX_i(ic)} = 0$$

$$if \quad (N_{SD-PDCCH} = 1)\ AND \left(N_{Ant-TX}^{TX_i(ic)} = 4 \ \ or\ \ 8\right):$$

$$O_{PDCCH}^{TX_i(ic)} = \begin{array}{l} \left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)} \\ + \left(N_{SD-PDCCH} \times N_{SCa-FB} - N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)} \end{array}$$

Otherwise:

$$O_{PDCCH}^{TX_i(ic)} = \begin{array}{l} \left(N_{SD-PDCCH} \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)} \\ + \left(Min(2, N_{SD-PDCCH}) \times N_{SCa-FB} - 2 \times N_{Ant-TX}^{TX_i(ic)}\right) \times N_{FB}^{TX_i(ic)} \times N_{TDD-SSF}^{TX_i(ic)} \end{array}$$

UE-specific reference signal overhead

UE-specific reference signals (12 resource elements per scheduler resource block) are transmitted for users served using smart antennas on the logical antenna port 5.

With smart antennas: $O_{UERS}^{TX_i(ic)} = 12 \times N_{FB}^{TX_i(ic)} \times N_{SF-DL}^{TX_i(ic)}$

Without smart antennas: $O_{UERS}^{TX_i(ic)} = 0$

Output

- $R_{DL}^{TX_i(ic)}$: Amount of downlink resources in the cell $TX_i(ic)$.

5.4.6.1.2 Calculation of Uplink Cell Resources

Input

- ΔF : Subcarrier width (15 kHz).
- W_{FB} : Width of a frequency block (180 kHz).
- $N_{Slot/SF}$: Number of slots per subframe (2).
- D_{CP} : Cyclic prefix duration defined for the network in the Global Parameters.
- $N_{SD/Slot}$: Number of symbol durations per slot (7 is D_{CP} is Normal, 6 if D_{CP} is Extended).
- $N_{FB-PUCCH}$: Average number of PUCCH frequency blocks per frame defined in the Global Parameters.
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $N_{SF-UL}^{TX_i(ic)}$: Number of uplink subframes in the frame for the cell $TX_i(ic)$. It is equal to 10 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.
- $N_{TDD-SSF}^{TX_i(ic)}$: Number of TDD special subframes (containing DwPTS, GP, and UpPTS) in the frame for the cell $TX_i(ic)$. It is equal to 0 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.

$N_{SF-UL}^{TX_i(ic)}$ and $N_{TDD-SSF}^{TX_i(ic)}$ are determined as follows:

Configuration	$N_{SF-UL}^{TX_i(ic)}$	$N_{TDD-SSF}^{TX_i(ic)}$
FDD	10	0
DSUUU-DSUUU	6	2
DSUUD-DSUUD	4	2
DSUDD-DSUDD	2	2
DSUUU-DSUUD	5	2
DSUUU-DDDDD	3	1
DSUUD-DDDDD	2	1
DSUDD-DDDDD	1	1

UpPTS is used for SRS (sounding reference signals) if the UpPTS duration is 1 OFDM symbol, and for SRS and PRACH if the UpPTS duration is 2 OFDM symbols. Therefore, the uplink cell capacity can be determined without considering the UpPTS symbols.

Calculations

In LTE, a resource block (RB) is defined as 1 frequency block by 1 slot. However, schedulers are able to perform resource allocation every subframe (2 slots). 1 frequency block by 1 subframe (2 slots) is called a scheduler resource block (SRB) in the calculations below.

The number of modulation symbols (resource elements) per resource block is calculated as follows:

$$N_{Sym/SRB} = N_{SCa-FB} \times N_{SD/Slot} \times N_{Slot/SF}$$

Where N_{SCa-FB} is the number of subcarriers per frequency block calculated as follows:

$$N_{SCa-FB} = \frac{W_{FB}}{\Delta F}$$

The total number of modulation symbols (resource elements) in uplink is calculated as follows:

$$N_{Sym-UL}^{TX_i(ic)} = \left(N_{FB}^{TX_i(ic)} - N_{FB-PUCCH}\right) \times N_{Sym/SRB} \times N_{SF-UL}^{TX_i(ic)}$$

The total uplink cell resources, i.e., $R_{UL}^{TX_i(ic)}$, are calculated as follows:

$$R_{UL}^{TX_i(ic)} = N_{Sym-UL}^{TX_i(ic)} - O_{ULSRS}^{TX_i(ic)} - O_{ULDRS}^{TX_i(ic)}$$

Where $O_{ULSRS}^{TX_i(ic)}$ is the overhead corresponding to the uplink sounding reference signals, and $O_{ULDRS}^{TX_i(ic)}$ is the overhead corresponding to the uplink demodulation reference signals. These control channel overheads are calculated as follows:

Calculations of uplink control channel overheads

The uplink sounding reference signals are transmitted on 1 symbol duration in each uplink subframe. Therefore,

$$O_{ULSRS}^{TX_i(ic)} = \frac{N_{SCa-FB}}{N_{Sym/SRB}} \times N_{Sym-UL}^{TX_i(ic)}$$

The uplink demodulation reference signals are transmitted on two symbol durations in each uplink subframe. Therefore,

$$O_{ULDRS}^{TX_i(ic)} = 2 \times \frac{N_{SCa-FB}}{N_{Sym/SRB}} \times N_{Sym-UL}^{TX_i(ic)}$$

Output

- $R_{UL}^{TX_i(ic)}$: Amount of uplink resources in the cell $TX_i(ic)$.

5.4.6.2 Calculation UE Capacities

The UE category parameters define the maximum throughput that can be supported by a UE in downlink and uplink. The UE capacities are calculated for the downlink and uplink as described in:

- "Calculation of Downlink UE Capacity" on page 391.
- "Calculation of Uplink UE Capacity" on page 391.

5.4.6.2.1 Calculation of Downlink UE Capacity

Input

- D_{Frame} : Frame duration.
- $N_{TBB/TTI}^{Max-DL}$: Maximum number of transport block bits per TTI (subframe) in downlink defined for a UE category.
- $N_{SF-DL}^{TX_i(ic)}$: Number of downlink subframes in the frame for the cell $TX_i(ic)$. It is equal to 10 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.
- $N_{TDD-SSF}^{TX_i(ic)}$: Number of TDD special subframes (containing DwPTS, GP, and UpPTS) in the frame for the cell $TX_i(ic)$. It is equal to 0 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.

  $N_{SF-DL}^{TX_i(ic)}$ and $N_{TDD-SSF}^{TX_i(ic)}$ are determined as follows:

Configuration	$N_{SF-DL}^{TX_i(ic)}$	$N_{TDD-SSF}^{TX_i(ic)}$
FDD	10	0
DSUUU-DSUUU	2	2
DSUUD-DSUUD	4	2
DSUDD-DSUDD	6	2
DSUUU-DSUUD	3	2
DSUUU-DDDDD	6	1
DSUUD-DDDDD	7	1
DSUDD-DDDDD	8	1

Calculations

In LTE, the maximum throughput that can be supported by a user equipment is defined through its UE category parameter Transport Block Size. This is the maximum number of transport block bits that the UE can carry per subframe.

The downlink UE capacity in terms of the maximum throughput supported by a UE in downlink is calculated as follows:

$$TP_{UE-DL}^{Max} = N_{TBB/TTI}^{Max-DL} \times \frac{\left(N_{SF-DL}^{TX_i(ic)} + N_{TDD-SSF}^{TX_i(ic)}\right)}{D_{Frame}}$$

The maximum transport block sizes defined by the 3GPP for different UE categories correspond to the following maximum throughput capacities in FDD:

UE Category	1	2	3	4	5
$N_{TBB/TTI}^{Max-DL}$ **(bits/TTI)**	10296	51024	102048	150752	299552
TP_{UE-DL}^{Max} **(Mbps)**	10.296	51.024	102.048	150.752	299.552

Output

- TP_{UE-DL}^{Max} : Maximum downlink throughput capacity of a UE category.

5.4.6.2.2 Calculation of Uplink UE Capacity

Input

- D_{Frame} : Frame duration.

- $N_{TBB/TTI}^{Max-UL}$: Maximum number of transport block bits per TTI (subframe) in uplink defined for a UE category.
- $N_{SF-UL}^{TX_i(ic)}$: Number of uplink subframes in the frame for the cell $TX_i(ic)$. It is equal to 10 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.
- $N_{TDD-SSF}^{TX_i(ic)}$: Number of TDD special subframes (containing DwPTS, GP, and UpPTS) in the frame for the cell $TX_i(ic)$. It is equal to 0 for FDD frequency bands, and is determined from the cell's TDD frame configuration for TDD frequency bands.

$N_{SF-UL}^{TX_i(ic)}$ and $N_{TDD-SSF}^{TX_i(ic)}$ are determined as follows:

Configuration	$N_{SF-UL}^{TX_i(ic)}$	$N_{TDD-SSF}^{TX_i(ic)}$
FDD	10	0
DSUUU-DSUUU	6	2
DSUUD-DSUUD	4	2
DSUDD-DSUDD	2	2
DSUUU-DSUUD	5	2
DSUUU-DDDDD	3	1
DSUUD-DDDDD	2	1
DSUDD-DDDDD	1	1

Calculations

In LTE, the maximum throughput that can be supported by a user equipment is defined through its UE category parameter Transport Block Size. This is the maximum number of transport block bits that the UE can carry per subframe.

The uplink UE capacity in terms of the maximum throughput supported by a UE in uplink is calculated as follows:

$$TP_{UE-UL}^{Max} = N_{TBB/TTI}^{Max-UL} \times \frac{N_{SF-UL}^{TX_i(ic)}}{D_{Frame}}$$

The maximum transport block sizes defined by the 3GPP for different UE categories correspond to the following maximum throughput capacities in FDD:

UE Category	1	2	3	4	5
$N_{TBB/TTI}^{Max-UL}$ (bits/TTI)	5160	25456	51024	51024	75376
TP_{UE-UL}^{Max} (Mbps)	5.16	25.456	51.024	51.024	75.376

Output

- TP_{UE-UL}^{Max} : Maximum uplink throughput capacity of a UE category.

5.4.6.3 Channel Throughput, Cell Capacity, Allocated Bandwidth Throughput, and Average User Throughput Calculation

Channel throughputs are calculated for the entire channel resources allocated to the pixel, subscriber, or mobile M_i. Cell capacities are similar to channel throughputs but upper-bound by the maximum downlink and uplink traffic loads. Allocated bandwidth throughputs are calculated for the number of used frequency blocks in uplink allocated to the pixel, subscriber, or mobile M_i. Average user throughputs are calculated by dividing the downlink cell capacities or uplink allocated bandwidth throughputs by the average number of downlink or uplink users defined for the cell, respectively.

Input

- $TL_{DL-Max}^{TX_i(ic)}$: Maximum downlink traffic load for the cell $TX_i(ic)$.
- $TL_{UL-Max}^{TX_i(ic)}$: Maximum uplink traffic load for the cell $TX_i(ic)$.

- $R_{DL}^{TX_i(ic)}$: Amount of downlink resources in the cell $TX_i(ic)$ as calculated in "Calculation of Total Cell Resources" on page 385.
- $R_{UL}^{TX_i(ic)}$: Amount of uplink resources in the cell $TX_i(ic)$ as calculated in "Calculation of Total Cell Resources" on page 385.
- $\eta_{B_{DL}^{M_i}}$: Bearer efficiency (bits/symbol) of the bearer assigned to the pixel, subscriber, or mobile M_i in the downlink in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- $\eta_{B_{UL}^{M_i}}$: Bearer efficiency (bits/symbol) of the bearer assigned to the pixel, subscriber, or mobile M_i in the uplink in "C/(I+N) and Bearer Calculation (UL)" on page 381.
- D_{Frame} : Frame duration.
- $CNR_{DLRS}^{TX_i(ic)}$: Downlink reference signals C/N from the cell $TX_i(ic)$ as calculated in "C/N Calculation (DL)" on page 365.
- $CINR_{DLRS}^{TX_i(ic)}$: Downlink reference signals C/(I+N) from the cell $TX_i(ic)$ as calculated in "C/N Calculation (DL)" on page 365.
- $T_{AMS}^{TX_i(ic)}$: Adaptive MIMO switch threshold defined for the cell $TX_i(ic)$.
- $T_{MU-MIMO}^{TX_i(ic)}$: MU-MIMO threshold defined for the cell $TX_i(ic)$.
- $G_{MU-MIMO}^{TX_i(ic)}$: MU-MIMO gain defined for the cell $TX_i(ic)$.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the BLER vs. $CINR_{PDSCH}^{TX_i(ic)}$ graph available in the LTE equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the BLER vs. $CINR_{PUSCH,\,PUCCH}^{M_i}$ graph available in the LTE equipment assigned to the cell $TX_i(ic)$.
- $f_{TP-Scaling}^{M_i}$: Throughput scaling factor defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $TP_{Offset}^{M_i}$: Throughput offset defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{FB}^{TX_i(ic)}$: Number of frequency blocks, defined in the frequency bands table, for the channel bandwidth used by the cell $TX_i(ic)$.
- $N_{FB-UL}^{M_i}$: Number of frequency blocks used by the pixel, subscriber, or mobile M_i after uplink bandwidth allocation as calculated in "C/(I+N) and Bearer Calculation (UL)" on page 381.
- $N_{FB-CE}^{TX_i(ic)}$: Number of cell-edge frequency blocks (used in cell-edge areas in case of ICIC), determined from the list of frequency blocks corresponding to the cell's PSS ID (0, 1, or 2) defined in the ICIC configuration assigned to the cell $TX_i(ic)$. By default (if no ICIC configuration is assigned to the cell), $N_{FB-CE}^{TX_i(ic)} = \frac{N_{FB}^{TX_i(ic)}}{3}$.
- $N_{Users-DL}^{TX_i(ic)}$: Number of users connected to the cell $TX_i(ic)$ in downlink.
- $N_{Users-UL}^{TX_i(ic)}$: Number of users connected to the cell $TX_i(ic)$ in uplink.

Calculations

Downlink:

- **Peak RLC Channel Throughput:** $CTP_{P-DL}^{M_i} = \frac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}}{D_{Frame}}$

  In the above formula, the actual value of D_{Frame} is used to calculate the channel throughput for coverage predictions, while $D_{Frame} = 1\ sec$ for Monte Carlo simulations.

Static Downlink ICIC using Fractional Frequency Reuse:

If the pixel, subscriber, or mobile M_i is covered by the ICIC part of the frame (determined as explained in "Best Server Determination" on page 384), the channel throughput is calculated as:

$$CTP_{P-DL}^{M_i} = \frac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}}{D_{Frame}} \times \frac{N_{FB-CE}^{TX_i(ic)}}{N_{FB}^{TX_i(ic)}}$$

MIMO – SU-MIMO Gain:

If the cell supports SU-MIMO or AMS, SU-MIMO gain $G_{SU-MIMO}^{Max}$ is applied to the bearer efficiency. The gain is read from the properties of the LTE equipment assigned to the pixel, subscriber, or mobile M_i for:

- $N_{Ant-TX}^{TX_i(ic)}$: Number of transmission (downlink) antenna ports defined for the cell *$TX_i(ic)$.*
- $N_{Ant-RX}^{M_i}$: Number of reception (downlink) antenna ports defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- $B_{DL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the downlink as explained in "C/(I+N) and Bearer Calculation (DL)" on page 367.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the LTE equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i. BLER is determined for $CINR_{PDSCH}^{TX_i(ic)}$.

9955 also takes into account the SU-MIMO Gain Factor $f_{SU-MIMO}$ defined for the clutter class where the pixel, subscriber, or mobile M_i is located.

In case of SU-MIMO: $\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$

In case of AMS:

$$\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1)) \qquad if\ CNR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)} \quad or\ \ CINR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$$

If the Max SU-MIMO Gain for the exact value of the C/(I+N) is not availabe in the table, it is interpolated from the gain values available for the C/(I+N) just less than and just greater than the actual C/(I+N).

- **Effective RLC Channel Throughput:** $CTP_{E-DL}^{M_i} = CTP_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$
- **Application Channel Throughput:** $CTP_{A-DL}^{M_i} = CTP_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak RLC Cell Capacity:** $Cap_{P-DL}^{M_i} = CTP_{P-DL}^{M_i} \times TL_{DL-Max}^{TX_i(ic)}$
- **Effective RLC Cell Capacity:** $Cap_{E-DL}^{M_i} = Cap_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$
- **Application RLC Capacity:** $Cap_{A-DL}^{M_i} = Cap_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak RLC Throughput Averaged per User:** $AUTP_{P-DL}^{M_i} = \frac{Cap_{P-DL}^{M_i}}{N_{Users-DL}^{TX_i(ic)}}$
- **Effective RLC Throughput Averaged per User:** $AUTP_{E-DL}^{M_i} = \frac{Cap_{E-DL}^{M_i}}{N_{Users-DL}^{TX_i(ic)}}$
- **Application Throughput Averaged per User:** $AUTP_{A-DL}^{M_i} = AUTP_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$

Uplink:

- **Peak RLC Channel Throughput:** $CTP_{P-UL}^{M_i} = \frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}}$

  In the above formula, the actual value of D_{Frame} is used to calculate the channel throughput for coverage predictions, while $D_{Frame} = 1\,sec$ for Monte Carlo simulations.

  MIMO – SU-MIMO Gain:

  If the cell supports SU-MIMO or AMS, SU-MIMO gain $G_{SU-MIMO}^{Max}$ is applied to the bearer efficiency. The gain is read from the properties of the LTE equipment assigned to the cell $TX_i(ic)$ for:

  - $N_{Ant-TX}^{M_i}$: Number of transmission (uplink) antenna ports defined for the terminal used by the pixel, subscriber, or mobile M_i.
  - $N_{Ant-RX}^{TX_i(ic)}$: Number of reception (uplink) antenna ports defined for the cell $TX_i(ic)$.
  - $Mobility(M_i)$: Mobility used for the calculations.
  - $B_{UL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the uplink as explained in "C/(I+N) and Bearer Calculation (UL)" on page 381.
  - $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the LTE equipment assigned to the cell $TX_i(ic)$. BLER is determined for $CINR_{PUSCH,\,PUCCH}^{M_i}$.

  9955 also takes into account the SU-MIMO Gain Factor $f_{SU-MIMO}$ defined for the clutter class where the pixel, subscriber, or mobile M_i is located.

  In case of SU-MIMO: $\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$

  In case of AMS:

  $$\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1)) \quad if \quad CNR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)} \quad or \quad CINR_{DLRS}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$$

  If the Max SU-MIMO Gain for the exact value of the C/(I+N) is not availabe in the table, it is interpolated from the gain values available for the C/(I+N) just less than and just greater than the actual C/(I+N).

  MIMO – MU-MIMO Gain (for uplink throughput coverage predictions only):

  If the cell supports MU-MIMO and $CNR_{DLRS}^{TX_i(ic)} > T_{MU-MIMO}^{TX_i(ic)}$ and $N_{Ant-RX}^{TX_i(ic)} \geq 2$, the MU-MIMO gain $G_{MU-MIMO}^{TX_i(ic)}$ is applied to the channel throughput. The MU-MIMO gain is read from the properties of the cell $TX_i(ic)$.

  $$CTP_{P-UL}^{M_i} = \frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}} \times G_{MU-MIMO}^{TX_i(ic)}$$

- **Effective RLC Channel Throughput:** $CTP_{E-UL}^{M_i} = CTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Channel Throughput:** $CTP_{A-UL}^{M_i} = CTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak RLC Cell Capacity:** $Cap_{P-UL}^{M_i} = CTP_{P-UL}^{M_i} \times TL_{UL-Max}^{TX_i(ic)}$
- **Effective RLC Cell Capacity:** $Cap_{E-UL}^{M_i} = Cap_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Cell Capacity:** $Cap_{A-UL}^{M_i} = Cap_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$

- **Peak RLC Allocated Bandwidth Throughput:** $ABTP_{P-UL}^{M_i} = CTP_{P-UL}^{M_i} \times \frac{N_{FB-UL}^{M_i}{}_{TX_i(ic)}}{N_{FB}}$
- **Effective RLC Allocated Bandwidth Throughput:** $ABTP_{E-UL}^{M_i} = ABTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Allocated Bandwidth Throughput:** $ABTP_{A-UL}^{M_i} = ABTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak RLC Throughput Averaged per User:** $AUTP_{P-UL}^{M_i} = Min\left(\frac{Cap_{P-UL}^{M_i}{}_{TX_i(ic)}}{N_{Users-UL}}, ABTP_{P-UL}^{M_i}\right)$
- **Effective RLC Throughput Averaged per User:** $AUTP_{E-UL}^{M_i} = Min\left(\frac{Cap_{E-UL}^{M_i}{}_{TX_i(ic)}}{N_{Users-UL}}, ABTP_{E-UL}^{M_i}\right)$
- **Application Throughput Averaged per User:** $AUTP_{A-UL}^{M_i} = AUTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$

Output

- $CTP_{P-DL}^{M_i}$: Downlink peak RLC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{E-DL}^{M_i}$: Downlink effective RLC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{A-DL}^{M_i}$: Downlink application channel throughput at the pixel, subscriber, or mobile M_i.
- $Cap_{P-DL}^{M_i}$: Downlink peak RLC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{E-DL}^{M_i}$: Downlink effective RLC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{A-DL}^{M_i}$: Downlink application cell capacity at the pixel, subscriber, or mobile M_i.
- $AUTP_{P-DL}^{M_i}$: Downlink peak RLC throughput averaged per user at the pixel, subscriber, or mobile M_i.
- $AUTP_{E-DL}^{M_i}$: Downlink effective RLC throughput averaged per user at the pixel, subscriber, or mobile M_i.
- $AUTP_{A-DL}^{M_i}$: Downlink application throughput averaged per user at the pixel, subscriber, or mobile M_i.
- $CTP_{P-UL}^{M_i}$: Uplink peak RLC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{E-UL}^{M_i}$: Uplink effective RLC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{A-UL}^{M_i}$: Uplink application channel throughput at the pixel, subscriber, or mobile M_i.
- $Cap_{P-UL}^{M_i}$: Uplink peak RLC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{E-UL}^{M_i}$: Uplink effective RLC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{A-UL}^{M_i}$: Uplink application cell capacity at the pixel, subscriber, or mobile M_i.
- $ABTP_{P-UL}^{M_i}$: Uplink peak RLC allocated bandwidth throughput at the pixel, subscriber, or mobile M_i.
- $ABTP_{E-UL}^{M_i}$: Uplink effective RLC allocated bandwidth throughput at the pixel, subscriber, or mobile M_i.
- $ABTP_{A-UL}^{M_i}$: Uplink application allocated bandwidth throughput at the pixel, subscriber, or mobile M_i.
- $AUTP_{P-UL}^{M_i}$: Uplink peak RLC throughput averaged per user at the pixel, subscriber, or mobile M_i.
- $AUTP_{E-UL}^{M_i}$: Uplink effective RLC throughput averaged per user at the pixel, subscriber, or mobile M_i.
- $AUTP_{A-UL}^{M_i}$: Uplink application throughput averaged per user at the pixel, subscriber, or mobile M_i.

5.4.7 Scheduling and Radio Resource Management

9955 LTE module includes a number of scheduling methods which can be used for scheduling and radio resource allocation during Monte Carlo simulations. These resource allocation algorithms are explained in "Scheduling and Radio Resource Allocation" on page 397 and the calculation of user throughputs is explained in "User Throughput Calculation" on page 403.

5.4.7.1 Scheduling and Radio Resource Allocation

Input

- $TL_{DL-Max}^{TX_i(ic)}$: Maximum downlink traffic load for the cell $TX_i(ic)$.
- $TL_{UL-Max}^{TX_i(ic)}$: Maximum uplink traffic load for the cell $TX_i(ic)$.
- $N_{Users-Max}^{TX_i(ic)}$: Maximum number of users defined for the cell $TX_i(ic)$.
- p^{M_i}: Priority of the service accessed by a mobile M_i.
- $TPD_{Min-DL}^{M_i}$: Downlink minimum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Min-UL}^{M_i}$: Uplink minimum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Max-DL}^{M_i}$: Downlink maximum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Max-UL}^{M_i}$: Uplink maximum throughput demand for the service accessed by a mobile M_i.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the BLER vs. $CINR_{PDSCH}^{TX_i(ic)}$ graph available in the LTE equipment assigned to the terminal used by the mobile M_i.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the BLER vs. $CINR_{PUSCH,\,PUCCH}^{M_i}$ graph available in the LTE equipment assigned to the cell $TX_i(ic)$.
- $f_{TP-Scaling}^{M_i}$: Throughput scaling factor defined in the properties of the service used by the mobile M_i.
- $TP_{Offset}^{M_i}$: Throughput offset defined in the properties of the service used by the mobile M_i.
- $CTP_{P-DL}^{M_i}$: Downlink peak RLC channel throughput at the mobile M_i as calculated in "Throughput Calculation" on page 385.
- $CTP_{P-UL}^{M_i}$: Uplink peak RLC channel throughput at the mobile M_i as calculated in "Throughput Calculation" on page 385.
- $ABTP_{P-UL}^{M_i}$: Uplink peak RLC allocated bandwidth throughput at the mobile M_i as calculated in "Throughput Calculation" on page 385.
- TP_{UE-DL}^{Max}: Maximum downlink throughput capacity of the UE category of the mobile M_i as calculated in "Calculation of Downlink UE Capacity" on page 391.
- TP_{UE-UL}^{Max}: Maximum uplink throughput capacity of the UE category of the mobile M_i as calculated in "Calculation of Uplink UE Capacity" on page 391.

Calculations

The following calculations are described for any cell $TX_i(ic)$ containing the users M_i for which it is the best server.

Mobile Selection:

The scheduler selects $N_{Users}^{TX_i(ic)}$ mobiles for the scheduling and RRM process. If the Monte Carlo user distribution has generated a number of users which is less than $N_{Users-Max}^{TX_i(ic)}$, the scheduler keeps all the mobiles generated for the cell $TX_i(ic)$.

$$N_{Users}^{TX_i(ic)} = Min\left(N_{Users-Max}^{TX_i(ic)}, N_{Users-Generated}^{TX_i(ic)}\right)$$

For a cell, mobiles $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ are selected for RRM by the scheduler.

Calculation of Actual Minimum and Maximum Throughput Demands:

Depending on the selected target throughput of the scheduler assigned to the cell $TX_i(ic)$, the actual minimum and maximum throughput demands can be considered as the peak RLC, effective RLC, or application throughput. Therefore:

- **Target Throughput = Peak RLC Throughput**

Downlink: $TPD_{Min-DL}^{M_i^{Sel}}$, $TPD_{Max-DL}^{M_i^{Sel}}$

Uplink: $TPD_{Min-UL}^{M_i^{Sel}}$, $Min\left(TPD_{Max-UL}^{M_i^{Sel}}, ABTP_{P-UL}^{M_i}\right)$

- **Target Throughput = Effective RLC Throughput**

Downlink: $TPD_{Min-DL}^{M_i^{Sel}} = \dfrac{TPD_{Min-DL}^{M_i^{Sel}}}{\left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)}$, $TPD_{Max-DL}^{M_i^{Sel}} = \dfrac{TPD_{Max-DL}^{M_i^{Sel}}}{\left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)}$

Uplink: $TPD_{Min-UL}^{M_i^{Sel}} = \dfrac{TPD_{Min-UL}^{M_i^{Sel}}}{\left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)}$, $TPD_{Max-UL}^{M_i^{Sel}} = \dfrac{Min\left(TPD_{Max-UL}^{M_i^{Sel}}, ABTP_{P-UL}^{M_i}\right)}{\left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)}$

- **Target Throughput = Application Throughput**

Downlink: $TPD_{Min-DL}^{M_i^{Sel}} = \dfrac{TPD_{Min-DL}^{M_i^{Sel}} + TP_{Offset}^{M_i}}{\left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$, $TPD_{Max-DL}^{M_i^{Sel}} = \dfrac{TPD_{Max-DL}^{M_i^{Sel}} + TP_{Offset}^{M_i}}{\left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$

Uplink: $TPD_{Min-UL}^{M_i^{Sel}} = \dfrac{TPD_{Min-UL}^{M_i^{Sel}} + TP_{Offset}^{M_i}}{\left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$,

$$TPD_{Max-UL}^{M_i^{Sel}} = \frac{Min\left(TPD_{Max-UL}^{M_i^{Sel}}, ABTP_{P-UL}^{M_i}\right) + TP_{Offset}^{M_i}}{\left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$$

The *Min()* function selects the lower of the two values. This calculation is performed in order to limit the maximum uplink throughput demand to the maximum throughput that a user can get in uplink using the allocated bandwidth (number of frequency blocks) calculated for it in "C/(I+N) and Bearer Calculation (UL)" on page 381.

Resource Allocation for Minimum Throughput Demands:

1. **9955** sorts the $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ in order of decreasing service priority, $p^{M_i^{Sel}}$.
2. Starting with $M_i^{Sel} = 1$ up to $M_i^{Sel} = N_{Users}^{TX_i(ic)}$, **9955** allocates the downlink and uplink resources required to satisfy each user's minimum throughput demands in downlink and uplink as follows:

$$R_{Min-DL}^{M_i^{Sel}} = \frac{TPD_{Min-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } R_{Min-UL}^{M_i^{Sel}} = \frac{TPD_{Min-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

3. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} = TL_{DL-Max}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the minimum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} = TL_{UL-Max}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the minimum throughput demands of the mobiles.

4. Mobiles which are active DL+UL must be able to get their minimum throughput demands in both UL and DL in order to be considered connected DL+UL. If an active DL+UL mobile is only able to get its minimum throughput demand in one direction, it is rejected, and the resources that were allocated to it in the one direction in which it was able to get a throughput are allocated to other mobiles.
5. Mobiles with minimum throughput demands higher than their UE capacities, i.e., $R_{Min-DL}^{M_i^{Sel}} > \frac{TP_{UE-DL}^{Max}}{CTP_{P-DL}^{M_i^{Sel}}}$ or $R_{Min-UL}^{M_i^{Sel}} > \frac{TP_{UE-UL}^{Max}}{CTP_{P-UL}^{M_i^{Sel}}}$, are rejected due to No Service.
6. Mobiles which are active UL and whose minimum throughput demand in UL is higher than the uplink allocated bandwidth throughput ($TPD_{Min-UL}^{M_i^{Sel}} > ABTP_{P-UL}^{M_i^{Sel}}$) are rejected due to Resource Saturation.
7. If $\sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} < TL_{DL-Max}^{TX_i(ic)}$ or $\sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} < TL_{UL-Max}^{TX_i(ic)}$, and all the minimum throughput resources demanded by the mobiles have been allocated, **9955** goes to the next step for allocating resources to satisfy the maximum throughput demands.

The remaining cell resources available for the next step are:

Downlink: $R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}}$

Uplink: $R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}}$

Resource Allocation for Maximum Throughput Demands:

For each mobile, the remaining throughput demands are either the maximum UE capacities or the difference between the maximum and the minimum throughput demands, whichever is smaller:

Downlink: $TPD_{Rem-DL}^{M_i^{Sel}} = Min\left(TPD_{Max-DL}^{M_i^{Sel}} - TPD_{Min-DL}^{M_i^{Sel}}, TP_{UE-DL}^{Max}\right)$

Uplink: $TPD_{Rem-UL}^{M_i^{Sel}} = Min\left(TPD_{Max-UL}^{M_i^{Sel}} - TPD_{Min-UL}^{M_i^{Sel}}, TP_{UE-UL}^{Max}\right)$

For the remaining throughput demands of the mobiles, the following resource allocation methods are available:

1. **Proportional Fair:**

   The goal of this scheduling method is to distribute resources among users fairly in such a way that, on the average, each user gets the highest possible throughput that it can get under the radio conditions at its location.

Let the total number of users be $N \in M_i^{Sel}$.

a. Each user's channel throughput is increased by the multi-user diversity gain $G_{MUG-DL}^{TX_i(ic)}$ or $G_{MUG-UL}^{TX_i(ic)}$ read from the scheduler properties for the $Mobility(M_i)$ assigned to mobile M_i^{Sel} and the number of connected users, DL or UL, in the cell *TX$_i$(ic)* in the iteration *k-1*.

$$CTP_{P-DL}^{M_i^{Sel}} = CTP_{P-DL}^{M_i^{Sel}}\Big|_{Without\ MUG} \times G_{MUG-DL}^{TX_i(ic)} \text{ and } CTP_{P-UL}^{M_i^{Sel}} = CTP_{P-UL}^{M_i^{Sel}}\Big|_{Without\ MUG} \times G_{MUG-UL}^{TX_i(ic)}$$

$$G_{MUG-DL}^{TX_i(ic)} = 1 \text{ if } CINR_{PDSCH}^{M_i^{Sel}} \geq CINR_{MUG}^{Max} \text{ and } G_{MUG-UL}^{TX_i(ic)} = 1 \text{ if } CINR_{PUSCH,\ PUCCH}^{M_i^{Sel}} \geq CINR_{MUG}^{Max}.$$

If the multi-user diversity gain for the exact value of the number of connected users is not availabe in the graph, it is interpolated from the gain values available for the numbers of users just less than and just greater than the actual number of users.

b. **9955** divides the remaining resources in the cell into equal parts for each user:

$$\frac{R_{Rem-DL}^{TX_i(ic)}}{N} \text{ and } \frac{R_{Rem-UL}^{TX_i(ic)}}{N}$$

c. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

$$RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

d. The resources allocated to each user by the Proportional Fair scheduling method for satisfying its maximum throughput demands are:

$$R_{Max-DL}^{M_i^{Sel}} = Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right) \text{ and } R_{Max-UL}^{M_i^{Sel}} = Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$$

Each user gets either the resources it needs to achieve its maximum throughput demands or an equal share from the remaining resources of the cell, whichever is smaller.

e. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{Rem-DL}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the maximum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{Rem-UL}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the maximum throughput demands of the mobiles.

f. If the resources allocated to a user satisfy its maximum throughput demands, this user is removed from the list of remaining users.

g. **9955** recalculates the remaining resources as follows:

$$R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} \text{ and}$$

$$R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}}$$

h. **9955** repeats the all the above steps for the users whose maximum throughput demands have not been satisfied until either $R_{Rem-DL}^{TX_i(ic)} = 0$ and $R_{Rem-UL}^{TX_i(ic)} = 0$, or all the maximum throughput demands are satisfied.

2. **Round Robin:**

The goal of this scheduling method is to allocate equal resources to users fairly.

Let the total number of users be $N \in M_i^{Sel}$.

a. **9955** divides the remaining resources in the cell into equal parts for each user:

$$\frac{R_{Rem-DL}^{TX_i(ic)}}{N} \text{ and } \frac{R_{Rem-UL}^{TX_i(ic)}}{N}$$

b. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

$$RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

c. The resources allocated to each user by the Round Robin scheduling method for satisfying its maximum throughput demands are:

$$R_{Max-DL}^{M_i^{Sel}} = Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right) \text{ and } R_{Max-UL}^{M_i^{Sel}} = Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$$

Each user gets either the resources it needs to achieve its maximum throughput demands or an equal share from the remaining resources of the cell, whichever is smaller.

d. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{Rem-DL}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the maximum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{Rem-UL}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the maximum throughput demands of the mobiles.

e. If the resources allocated to a user satisfy its maximum throughput demands, this user is removed from the list of remaining users.

f. **9955** recalculates the remaining resources as follows:

$$R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} \text{ and}$$

$$R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}}$$

g. **9955** repeats the all the above steps for the users whose maximum throughput demands have not been satisfied until either $R_{Rem-DL}^{TX_i(ic)} = 0$ and $R_{Rem-UL}^{TX_i(ic)} = 0$, or all the maximum throughput demands are satisfied.

3. **Proportional Demand:**

The goal of this scheduling method is to allocate resources to users weighted according to their remaining throughput demands. Therefore, the user throughputs for users with high throughput demands will be higher than those with low throughput demands. In other words, this scheduler distributes channel throughput between users proportionally to their demands.

a. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

$$RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

b. **9955** calculates the amount of effective remaining resources of the cell to distribute among the users as follows:

$$R_{Eff-Rem-DL}^{TX_i(ic)} = Min\left(R_{Rem-DL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}\right) \text{ and } R_{Eff-Rem-UL}^{TX_i(ic)} = Min\left(R_{Rem-UL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}\right)$$

c. The resources allocated to each user by the Proportional Demand scheduling method for satisfying its maximum throughput demands are:

$$R_{Max-DL}^{M_i^{Sel}} = R_{Eff-Rem-DL}^{TX_i(ic)} \times \frac{RD_{Rem-DL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}} \text{ and } R_{Max-UL}^{M_i^{Sel}} = R_{Eff-Rem-UL}^{TX_i(ic)} \times \frac{RD_{Rem-UL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}}$$

4. **Max C/I:**

The goal of this scheduling method is to achieve the maximum aggregate throughput for the cells. This is done by allocating as much resources as needed to mobiles with high C/(I+N) conditions. As mobiles with high C/(I+N) can get higher bearers, and therefore require less amount of resources, more mobiles can therefore be allocated resources in the same frame, and the end-throughput for each cell will be the highest compared to other types of schedulers.

a. **9955** sorts the $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ in order of decreasing PDSCH, or PUSCH and PUCCH C/(I+N), depending on whether the allocation is being performed for the downlink or for the uplink.

b. Starting with the mobile with the highest rank, **9955** allocates the downlink and uplink resources required to satisfy each user's remaining throughput demands in downlink and uplink as follows:

$$R_{Max-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } R_{Max-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

c. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{Rem-DL}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the maximum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{Rem-UL}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the maximum throughput demands of the mobiles.

Spatial Multiplexing with Uplink Multi-User MIMO:

MU-MIMO lets the system/scheduler work with two parallel LTE frames (1 for each antenna). Therefore, a mobile connected to antenna 1 creates a corresponding resource availability on antenna 2. This resources made available on antenna 2 can then be assigned to another mobile without any effect on the overall load of the cell. When the second mobile is assigned to antenna 2, the resources allocated to it overlap with the resources made available by the first mobile on antenna 1. If the second mobile is allocated more resources than the first one made available, the second mobile will create resource availability on antenna 1. Each new mobile is either connected to antenna 1 or antenna 2. The part of the mobile's resources which are not coupled with resources allocated to another mobile on the other antenna is called the real resource consumption. The part of the mobile's resources which are coupled with the resources allocated to another mobile on the other antenna is called the virtual resource consumption.

MU-MIMO can be used if the cell supports MU-MIMO, $CNR_{DLRS}^{TX_i(ic)} > T_{MU-MIMO}^{TX_i(ic)}$, and $N_{Ant-RX}^{TX_i(ic)} \geq 2$.

Let *i* be the index of connected MU-MIMO mobiles: $i = 1 \text{ to } N$

Each mobile $M_i^{MU-MIMO}$ has a corresponding traffic load $TL_{UL}^{M_i^{MU-MIMO}}$. The scheduling starts with available real resources $RR_{UL}^{M_{i=0}^{MU-MIMO}} = 100\ \%$ and available virtual resources $\Delta V_{UL}^{M_{i=0}^{MU-MIMO}} = 0\ \%$. $i = 0$ means no MU-MIMO mobile has yet been scheduled.

The virtual resource consumption of a mobile $M_i^{MU-MIMO}$ is given by: $VC_{UL}^{M_i^{MU-MIMO}} = Min\left(TL_{UL}^{M_i^{MU-MIMO}}, \Delta V_{UL}^{M_{i-1}^{MU-MIMO}}\right)$

The real resource consumption of a mobile $M_i^{MU-MIMO}$ is given by: $RC_{UL}^{M_i^{MU-MIMO}} = TL_{UL}^{M_i^{MU-MIMO}} - VC_{UL}^{M_i^{MU-MIMO}}$

The virtual resources made available by the mobile $M_i^{MU-MIMO}$ are given by:

$$\Delta V_{UL}^{M_i^{MU-MIMO}} = \Delta V_{UL}^{M_{i-1}^{MU-MIMO}} - VC_{UL}^{M_i^{MU-MIMO}} + RC_{UL}^{M_i^{MU-MIMO}}$$

Saturation occurs when $\sum RC_{UL}^{M_i^{MU-MIMO}} = TL_{UL-Max}^{TX_i(ic)}$.

The following table gives an example:

Mobile	$TL_{UL}^{M_i^{MU-MIMO}}$ (%)	$VC_{UL}^{M_i^{MU-MIMO}}$ (%)	$RC_{UL}^{M_i^{MU-MIMO}}$ (%)	$\Delta V_{UL}^{M_i^{MU-MIMO}}$ (%)
M_1	10	0	10	10
M_2	5	5	0	5
M_3	20	5	15	15
M_4	40	15	25	25
…	…	…	…	…

Total Amount of Resources Assigned to Each Selected Mobile:

9955 calculates the amounts of downlink and uplink resources allocated to each individual mobile M_i^{Sel} (which can also be referred to as the traffic loads of the mobiles) as follows:

Downlink: $TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}} = R_{Min-DL}^{M_i^{Sel}} + R_{Max-DL}^{M_i^{Sel}}$

Uplink: $TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}} = R_{Min-UL}^{M_i^{Sel}} + R_{Max-UL}^{M_i^{Sel}}$

Output

- $TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}}$: Downlink traffic load or the amount of downlink resources allocated to the mobile M_i^{Sel}.
- $TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}}$: Uplink traffic load or the amount of uplink resources allocated to the mobile M_i^{Sel}.

5.4.7.2 User Throughput Calculation

User throughputs are calculated for the percentage of resources allocated to each mobile selected by the scheduling for RRM during the Monte Carlo simulations, M_i^{Sel}.

Input

- $R_{DL}^{M_i^{Sel}}$: Amount of downlink resources allocated to the mobile M_i^{Sel} as calculated in "Scheduling and Radio Resource Allocation" on page 397.
- $R_{UL}^{M_i^{Sel}}$: Amount of uplink resources allocated to the mobile M_i^{Sel} as calculated in "Scheduling and Radio Resource Allocation" on page 397.
- $CTP_{P-DL}^{M_i^{Sel}}$: Downlink peak RLC channel throughput at the mobile M_i^{Sel} as calculated in "Throughput Calculation" on page 385.
- $CTP_{P-UL}^{M_i^{Sel}}$: Uplink peak RLC channel throughput at the mobile M_i^{Sel} as calculated in "Throughput Calculation" on page 385.
- $BLER\left(B_{DL}^{M_i^{Sel}}\right)$: Downlink block error rate read from the BLER vs. $CINR_{PDSCH}^{TX_i(ic)}$ graph available in the LTE equipment assigned to the terminal used by the mobile M_i^{Sel}.
- $BLER\left(B_{UL}^{M_i^{Sel}}\right)$: Uplink block error rate read from the BLER vs. $CINR_{PUSCH,\,PUCCH}^{M_i}$ graph available in the LTE equipment assigned to the cell $TX_i(ic)$.
- $f_{TP-Scaling}^{M_i^{Sel}}$: Throughput scaling factor defined in the properties of the service used by the mobile M_i^{Sel}.
- $TP_{Offset}^{M_i^{Sel}}$: Throughput offset defined in the properties of the service used by the mobile M_i^{Sel}.

Calculations

Downlink:

- **Peak RLC User Throughput:** $UTP_{P-DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}} \times CTP_{P-DL}^{M_i^{Sel}}$
- **Effective RLC User Throughput:** $UTP_{E-DL}^{M_i^{Sel}} = UTP_{P-DL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)$
- **Application User Throughput:** $UTP_{A-DL}^{M_i^{Sel}} = UTP_{E-DL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$

Uplink:

- **Peak RLC User Throughput:** $UTP_{P-UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}} \times CTP_{P-UL}^{M_i^{Sel}}$
- **Effective RLC User Throughput:** $UTP_{E-UL}^{M_i^{Sel}} = UTP_{P-UL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)$
- **Application User Throughput:** $UTP_{A-UL}^{M_i^{Sel}} = UTP_{E-UL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$

Output

- $UTP_{P-DL}^{M_i^{Sel}}$: Downlink peak RLC user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{E-DL}^{M_i^{Sel}}$: Downlink effective RLC user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{A-DL}^{M_i^{Sel}}$: Downlink application user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{P-UL}^{M_i^{Sel}}$: Uplink peak RLC user throughput at the pixel, subscriber, or mobile M_i^{Sel}.

- $UTP_{E-UL}^{M_i^{Sel}}$: Uplink effective RLC user throughput at the pixel, subscriber, or mobile M_i^{Sel} .
- $UTP_{A-UL}^{M_i^{Sel}}$: Uplink application user throughput at the pixel, subscriber, or mobile M_i^{Sel} .

5.5 Automatic Planning Algorithms

The following sections describe the algorithms for:

- "Automatic Neighbour Planning" on page 405.
- "Automatic Inter-technology Neighbour Planning" on page 408.
- "Automatic Frequency Planning Using the AFP" on page 411.
- "Automatic Physical Cell ID Planning Using the AFP" on page 413.

5.5.1 Automatic Neighbour Planning

The intra-technology neighbour planning algorithm takes into account the cells of all the TBC transmitters. It means that the cells of all the TBC transmitters of your ATL document are potential neighbours.

The cells to be allocated will be called TBA cells. They must fulfil the following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This can be the Transmitters folder or a group of transmitters (subfolder).

Only TBA cells are assigned neighbours.

> If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

We assume a reference cell $TX_i(ic)$ and a candidate neighbour cell $TX_j(jc)$. When automatic allocation starts, **9955** checks the following conditions:

1. The distance between both cells must be less than the user-definable maximum inter-site distance. If the distance between the reference cell and the candidate neighbour is greater than this value, then the candidate neighbour is discarded.

   9955 calculates the effective distance between the reference cell and its candidate neighbour from the real distance between them and the azimuths of their antennas:

   $$Dist(CellA, CellB) = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

   Where x = 0.3% so that the maximum variation in *D* does not to exceed 1%. D is stated in m.

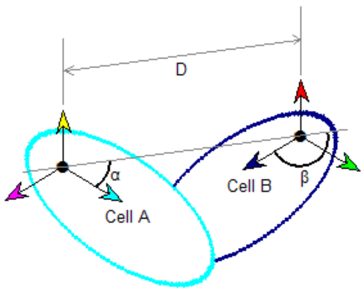


Figure 5.3: Inter-Transmitter Distance Calculation

   The formula above implies that two cells facing each other have a smaller effective distance than the actual distance. Candidate neighbours are ranked in the order of increasing effective distance from the reference cell.

2. The calculation options,

   - **Force Co-site Cells as Neighbours:** If selected, **9955** adds all the cells located on the same site as the reference cell to the candidate neighbour list. The weight of this constraint can be defined. It is used to calculate the rank of each neighbour, and its importance.

- **Force Adjacent Cells as Neighbours:** If selected, **9955** adds all the cells geographically adjacent to the reference cell to the candidate neighbour list. The weight of this constraint can be defined. It is used to calculate the rank of each neighbour, and its importance.

  Determination of Adjacent Cells: Geographically adjacent cells are determined on the basis of their best server coverage areas. A candidate neighbour cell $TX_j(ic)$ is considered adjacent to the reference cell $TX_i(ic)$ if there exists at least one pixel of $TX_j(jc)$'s best server coverage area where $TX_i(ic)$ is the second best server. The ranking of adjacent neighbour cells increases with the number of such pixels. Adjacent cells are sorted in the order of decreasing rank.

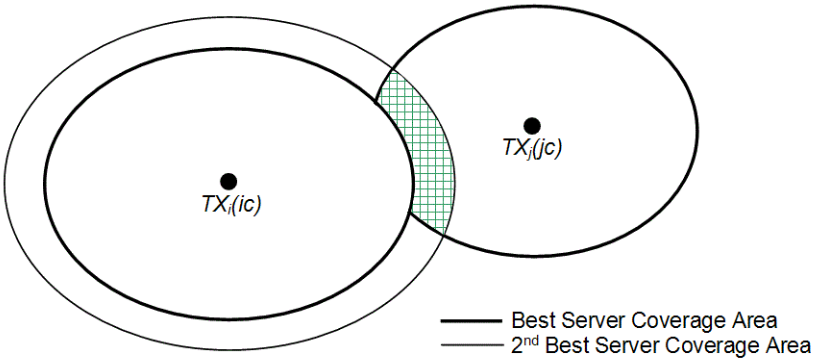


Figure 5.4: Determination of Adjacent Cells

- **Force Neighbour Symmetry:** If selected, **9955** adds the reference cell to the candidate neighbour list of the its candidate neighbour.

  A symmetric neighbour relation is allowed only if the neighbour list of the reference cell is not already full. If $TX_j(jc)$ is a neighbour of $TX_i(ic)$ but $TX_i(ic)$ is not a neighbour of $TX_j(jc)$, there can be two possibilities:

  i. The neighbour list of $TX_j(jc)$ is not full, **9955** will add $TX_i(ic)$ to the end of the list.

  ii. The neighbour list of $TX_j(jc)$ is full, **9955** will not be able to add $TX_i(ic)$ to the list, so it will also remove $TX_j(jc)$ from the neighbour list of $TX_i(ic)$.

- **Force Exceptional Pairs:** This option enables you to force/forbid some neighbour relations. Exceptional pairs are pairs of cells which will always or never be neighbours of each other.

  If you select "Force exceptional pairs" and "Force symmetry", **9955** considers the constraints between exceptional pairs in both directions so as to respect symmetry condition. On the other hand, if neighbourhood relationship is forced in one direction and forbidden in the other, symmetry cannot be respected. In this case, **9955** displays a warning in the Event viewer.

- **Delete Existing Neighbours:** If selected, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept in the list.

3. The coverage areas of $TX_i(ic)$ and $TX_j(jc)$ must have an overlap ($S_{TX_i(ic)} \cap S_{TX_j(jc)}$).

   - Here $S_{TX_i(ic)}$ is the surface area covered by the cell $TX_i(ic)$ that comprises all the pixels where:
     - The received reference signal energy per resource element is greater than or equal to the minimum RSRP: $E_{DLRS}^{TX_i(ic)} \geq T_{RSRP}^{TX_i(ic)}$
     - $S_{TX_i(ic)}$ is the surface area covered by $TX_i(ic)$ within $E_{DLRS}^{TX_i(ic)}$ and $E_{DLRS}^{TX_i(ic)} + M_{RSRP}$. M_{RSRP} is the RSRP margin with respect to the best downlink reference signal energy per resource element at which the handover ends.
   - $S_{TX_j(jc)}$ is the coverage area where the candidate cell $TX_j(jc)$ is the best server.

> For calculating the overlapping coverage areas, **9955** uses the service with the lowest body loss, the terminal that has the highest difference between gain and losses, and the shadowing margin calculated using the defined cell edge coverage probability, if the option is selected. The service and terminal are selected such that the selection gives the largest possible coverage areas for the cells.

When the above conditions are met, **9955** calculates the percentage of the coverage area overlap ($\frac{S_{TX_i(ic)} \cap S_{TX_j(jc)}}{S_{TX_i(ic)}} \times 100$), and compares this value with the % Min Covered Area. $TX_j(jc)$ is considered a neighbour of $TX_i(ic)$ if $\frac{S_{TX_i(ic)} \cap S_{TX_j(jc)}}{S_{TX_i(ic)}} \times 100 \geq \%\ Min\ Coverage\ Area$.

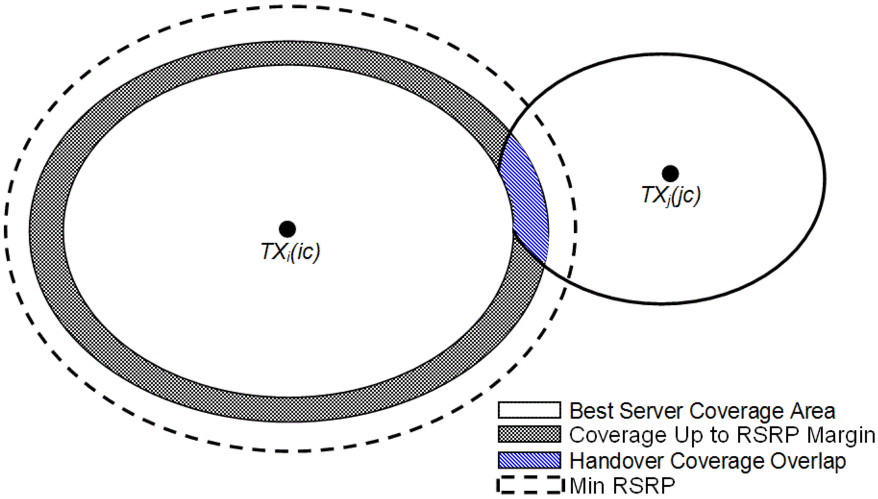


Figure 5.5: Overlapping Zones

Next, **9955** calculates the importance of the automatically allocated neighbours. **9955** sorts the neighbours by decreasing importance in order to keep the ones with high importance. If the maximum number of neighbours to be allocated to each cell is exceeded, **9955** keeps the ones with high importance.

The neighbour importance depends on the distance from the reference transmitter and on the neighbourhood cause (cf. table below); this value varies between 0 and 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	Only if the Delete Existing Neighbours option is not selected and in case of a new allocation	Existing importance
Exceptional pair	Only if the Force Exceptional Pairs option is selected	100 %
Co-site cell	Only if the Force Co-site Cells as Neighbours option is selected	Importance Function (IF)
Adjacent cell	Only if the Force Adjacent Cells as Neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	Only if the % Min Covered Area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	Only if the Force Neighbour Symmetry option is selected	Importance Function (IF)

The importance is evaluated using an Importance Function (IF), which takes into account the following factors:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance (D in m) weighted by the azimuths of antennas.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The adjacency factor (A): the percentage of adjacency,
- The overlapping factor (O): the percentage of overlapping.

The minimum and maximum importance assigned to each of the above factors can be defined.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	30%
Adjacency factor (A)	Min(A)	30%	Max(A)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The Importance Function is evaluated as follows:

Neighbourhood cause		Importance Function	Resulting IF using the default values from the table above
Co-site	Adjacent		
No	No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+20%{10%(Di)+90%(O)}
No	Yes	Min(A)+Delta(A){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	30%+30%{10%(Di)+30%(O) +60%(A)}
Yes	Yes	Min(C)+Delta(C){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	60%+40%{10%(Di)+30%(O) +60%(A)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours, adjacent neighbours, and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.
- By adding an option in the atoll.ini file, the neighbour allocation and importance calculation can be based on the distance criterion only. For more information, see the *Administrator Manual*.

In the results, **9955** lists only the cells for which it finds new neighbours. Cells whose channels have the same centre frequency are listed as intra-carrier neighbours. Otherwise, neighbour cells are listed as inter-carrier neighbours.

5.5.2 Automatic Inter-technology Neighbour Planning

The inter-technology neighbour planning algorithm takes into account all the TBC transmitters (if the other technology is GSM) or the cells of all the TBC transmitters (for any other technology than GSM). This means that all the TBC transmitters (GSM) or the cells of all the TBC transmitters (all other technologies) of the linked document are potential neighbours.

The cells to be allocated in the main document will be called TBA cells. They must fulfil the following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This can be the Transmitters folder or a group of transmitters (subfolder).

Only TBA cells are assigned neighbours.

If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

We assume a reference cell A and a candidate neighbour B. When automatic allocation starts, **9955** checks following conditions:

1. The distance between reference cell and the candidate neighbour must be less than the user-definable maximum inter-site distance. If the distance is greater than this value, the candidate neighbour is discarded.

   9955 calculates the effective distance between the reference cell and its candidate neighbour from the real distance between them and the azimuths of their antennas:

   $$Dist(CellA, CellB) = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

   Where x = 0.3% so that the maximum variation in *D* does not to exceed 1%. D is stated in m.

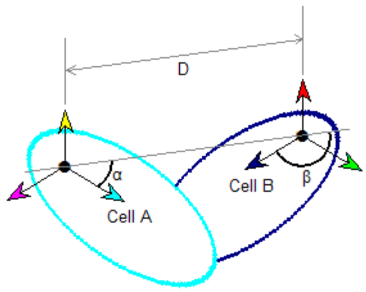
   

   Figure 5.6: Inter-Transmitter Distance Calculation

   The formula above implies that two cells facing each other have a smaller effective distance than the actual distance. Candidate neighbours are ranked in the order of increasing effective distance from the reference cell.

2. The calculation options:
   - **CDMA carriers:** This option is available when an LTE network is being co-planned with a UMTS, CDMA, or TD-SCDMA network. This option enables you to select the CDMA carrier(s) that you want **9955** to consider as potential neighbours of LTE cells. You may choose one or more carriers. **9955** will allocate only the cells using the selected carriers as neighbours.
   - **Force co-site cells as neighbours:** If selected, **9955** adds all the transmitters/cells located on the same site as the reference cell in its candidate neighbour list. The weight of this constraint can be defined. It is used to calculate the rank of each neighbour and its importance.
   - **Force exceptional pairs:** This option enables you to force/forbid some neighbour relations. Exceptional pairs are pairs of cells which will always or never be neighbours of each other.
   - **Delete existing neighbours:** If selected, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept in the list.

3. Neighbour relation criterion:
   - **Allocation based on distance:**

     The allocation algorithm is based on the effective distance between the reference cell and its candidate neighbour.

   - **Algorithm based on coverage overlapping:**

     The coverage areas of the reference cell A and the candidate neighbour B must overlap ($S_A \cap S_B$).

     Two cases may exist for S_A:

     - 1st case: S_A is the area where the cell A is the best serving cell, with a 0 dB margin.

       This means that the reference signal energy per resource element received from A is greater than the minimum required (Min RSRP), and is the highest one. .

     - 2nd case: The margin is other than 0 dB. S_A is the area where:

       The reference signal energy per resource element received from A exceeds the minimum required (Min RSRP) and is within a margin from the highest signal level.

     Two cases may exist for S_B:

     - 1st case: S_B is the area where the candidate neighbour is the best server. In this case, the margin must be set to 0dB.

       The signal level received from B exceeds the minimum required, and is the highest one.

     - 2nd case: The margin is other than 0dB. S_B is the area where:

The signal level received from B exceeds the minimum required and is within a margin from the best signal level.

9955 calculates the percentage of the coverage area overlap ($\frac{S_A \cap S_B}{S_A} \times 100$) and compares this value with the % Min Covered Area. B is considered a neighbour of A if $\frac{S_A \cap S_B}{S_A} \times 100 \geq \%\ Min\ Covered\ Area$.

Candidate neighbours are ranked in the order of decreasing coverage area overlap percentages.

Next, **9955** calculates the importance of the automatically allocated neighbours. **9955** sorts the neighbours by decreasing importance in order to keep the ones with high importance. If the maximum number of neighbours to be allocated to each cell is exceeded, **9955** keeps the ones with high importance.

The importance (%) of neighbours depends on the distance and on the reason of allocation:

- **For allocation based on distance:**

Neighbour cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter/cell	If the Force co-site cells as neighbours option is selected	100 %
Neighbour relation that fulfils distance conditions	If the maximum distance is not exceeded	$1 - \frac{d}{d_{max}}$

d is the effective distance between the reference cell and the neighbour and d_{max} is the maximum inter-site distance.

- **For allocation based on coverage overlapping:**

Neighbour cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter/cell	If the Force co-site cells as neighbours option is selected	IF
Neighbourhood relationship that fulfils coverage conditions	If the % minimum covered area is exceeded	IF

The importance is evaluated using an Importance Function (IF), which takes into account the following factors:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The overlapping factor (O): the percentage of overlapping.

The IF is user-definable using the Min importance and Max importance fields.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The IF evaluates importance as follows:

Co-site Neighbourhood cause	IF	Resulting IF using the default values from the table above
No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+50%{10%(Di)+90%(O)}
Yes	Min(C)+Delta(C){Max(Di)(Di)/(Max(Di)+Max(O))+ Max(O)(O)/(Max(Di)+Max(O))}	60%+40%{1/7%(Di)+6/7%(O)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.

In the results, **9955** displays only the cells for which it finds new neighbours.

5.5.3 Automatic Frequency Planning Using the AFP

The role of an Automatic Frequency Planning (AFP) tool is to assign frequencies (channels) to cells of a network such that the overall network performance is optimised. In other words, the interference within the network is reduced as much as possible. Co-channel interference is the main reason for overall network quality degradation in LTE. In order to improve network performance, the LTE AFP tries to minimise co- and adjacent channel interference as much as possible while respecting any constraints input to it. The main constraints are the resources available for allocation, i.e., the number of frequencies with which the AFP can work, and the relationships to take into account, i.e., interference matrices, neighbours, and distance between transmitters.

The AFP is based on a cost function which represents the interference level in the network. The aim of the AFP is to minimise the cost. The best, or optimum, frequency plan is the one which corresponds to the lowest cost.

The following describes the AFP's automatic planning method for carriers in LTE networks, which takes into account interference matrices, neighbour relations, and distance between transmitters.

The AFP takes into account the cells of all the TBC transmitters. The cells to be allocated will be called TBA cells. They must fulfil the following conditions:

- They are active,
- Their channel allocation status is not set to locked,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone.

If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

5.5.3.1 Constraint and Relationship Weights

The AFP is based on a cost function which takes into account the following separation constraint:

- Required channel separation Λ_{Req} for co-site cells: 2 channel bandwidths of the TBA cell.
- Required channel separation Λ_{Req} for neighbour cells: 1 channel bandwidth of the TBA cell.

The above separation constraint is studied between each TBA cell and its related cells. **9955** calculates the cost between each individual TBA and related cell, and then the overall cost for the TBA cell.

Related cells of a TBA cell are:

- Its neighbours, if the check box "Existing neighbours" is selected,

  Default weight $\omega_{Neighbour} = 0.5$

- Cells that are listed in the interference matrix of the TBA cell, Default weight $\omega_{IM} = 0.3$

- Cells within the cell's (or the default) minimum reuse distance, if the check box "Reuse distance" is selected,

  Default weight $\omega_{Distance} = 0.2$

> The sum of the weights assigned to the above relations is 1.

You can modify these weights in your LTE document. The absolute values of the constraint weights are calculated from the relative weights (%) defined in the **Constraint Weights** dialogue as follows:

$$\omega_{Neighbour} = \frac{\%\omega_{Neighbour}}{\%\omega_{Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{IM} = \frac{\%\omega_{IM}}{\%\omega_{Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{Distance} = \frac{\%\omega_{Distance}}{\%\omega_{Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

5.5.3.2 Cost Calculation

9955 calculates the separation constraint violation level between the TBA cell $TX_i(ic)$ and its related cell $TX_j(jc)$ as follows:

$$VL_{Sep}^{TX_i(ic)-TX_j(jc)} = \begin{cases} \left(\dfrac{\Lambda_{Req}^{TX_i(ic)-TX_j(jc)} - \Lambda^{TX_i(ic)-TX_j(jc)}}{\Lambda_{Req}^{TX_i(ic)-TX_j(jc)}}\right)^2 & if\ \ \Lambda^{TX_i(ic)-TX_j(jc)} < \Lambda_{Req}^{TX_i(ic)-TX_j(jc)} \\ 0 & Otherwise \end{cases}$$

Where $\Lambda_{Req}^{TX_i(ic)-TX_j(jc)}$ is the required separation, and $\Lambda^{TX_i(ic)-TX_j(jc)}$ is the actual separation between channels used by $TX_i(ic)$ and $TX_j(jc)$ calculated as follows:

$$\Lambda^{TX_i(ic)-TX_j(jc)} = \left|\frac{F_{Start}^{TX_j(jc)} - F_{Start}^{TX_i(ic)}}{W_{Channel}^{TX_i(ic)}}\right|$$

Where $F_{Start}^{TX_j(jc)}$ is the start frequency of the channel used by $TX_j(jc)$ calculated as follows:

$$F_{Start}^{TX_j(jc)} = F_{Start-Band}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times N_{Channel}^{TX_j(jc)}$$

$F_{Start}^{TX_i(ic)}$ is the start frequency of the channel used by $TX_i(ic)$ calculated as follows:

$$F_{Start}^{TX_i(ic)} = F_{Start-Band}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times N_{Channel}^{TX_i(ic)}$$

Where $F_{Start-Band}^{TX_i(ic)}$ and $F_{Start-Band}^{TX_j(jc)}$ are the start frequencies of the frequency bands assigned to the cells $TX_i(ic)$ and $TX_j(jc)$ respectively. $F_{Start-Band}$ can be the start frequency of a TDD frequency band ($F_{Start-TDD}$), or the downlink start frequency of an FDD frequency band ($F_{Start-FDD-DL}$). $N_{Channel}^{TX_i(ic)}$ and $N_{Channel}^{TX_j(jc)}$ are the channel numbers assigned to cells $TX_i(ic)$ and $TX_j(jc)$ respectively. For FDD networks, **9955** considers that the same channel number is assigned to a cell in the downlink and uplink, i.e., the channel number you assign to a cell is considered for uplink and downlink both. And, $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$ are the bandwidths of the channels assigned to cells $TX_i(ic)$ and $TX_j(jc)$ respectively.

The cost of the relation between the TBA cell and its related cell is calculated next:

$$\$^{TX_i(ic)-TX_j(jc)} = VL_{Sep}^{TX_i(ic)-TX_j(jc)} \times \left(\omega_{Neighbour} \times \iota_{Neighbour}^{TX_i(ic)-TX_j(jc)} + \omega_{Distance} \times \iota_{Distance}^{TX_i(ic)-TX_j(jc)}\right) + \omega_{IM} \times \iota_{IM}^{TX_i(ic)-TX_j(jc)}$$

Where $\iota_{Neighbour}^{TX_i(ic) - TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related neighbour cell. $\iota_{Neighbour}^{TX_i(ic) - TX_j(jc)}$ is calculated during automatic neighbour planning by **9955** as explained in "Automatic Neighbour Planning" on page 405. For manual neighbour planning, this value is equal to 1.

$\iota_{IM}^{TX_i(ic) - TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related interfering cell. $\iota_{IM}^{TX_i(ic) - TX_j(jc)}$ is calculated during interference matrix calculation as explained in "Interference Matrix Calculation" on page 417.

$\iota_{Distance}^{TX_i(ic) - TX_j(jc)}$ is the importance of the relationship between the TBA and its related cell with respect to the distance between them. $\iota_{Distance}^{TX_i(ic) - TX_j(jc)}$ is calculated as explained in "Distance Importance Calculation" on page 418.

9955 calculates the quality reduction factor for the TBA cell and its related cell from the cost calculated above as follows:

$$QRF^{TX_i(ic) - TX_j(jc)} = 1 - \$^{TX_i(ic) - TX_j(jc)}$$

The quality reduction factor is a measure of the cost of an individual relation.

The total cost of the current frequency plan for any TBA cell is given as follows, considering all the cells with which the TBA cell has relations:

$$\$_{Total}^{TX_i(ic)} = 1 - \prod_{TX_j(jc)} QRF^{TX_i(ic) - TX_j(jc)}$$

And, the total cost of the current frequency plan for the entire network is simply the sum of the total TBA cell costs calculated above, i.e.,

$$\$_{Total} = \sum_{TX_i(ic)} \$_{Total}^{TX_i(ic)}$$

5.5.3.3 AFP Algorithm

The AFP algorithm is an iterative algorithm which:

- Calculates the cost (as describe d above) of the initial frequency plan,
- Tries different frequency plans in order to reduce the cost,
- Memorises the different frequency plans in order to determine the best one, i.e., the frequency plan which provides the lowest total cost,
- Stops when it is unable to improve the cost of the network, and proposes the last known best frequency plan as the solution.

5.5.4 Automatic Physical Cell ID Planning Using the AFP

In LTE, 504 physical cell IDs are available, numbered from 0 to 503. There are as many pseudo-random sequences defined in the 3GPP specifications. Physical cell IDs are grouped into 168 unique cell ID groups (called SSS IDs in **9955**), with each group containing 3 unique identities (called PSS IDs in **9955**). An SSS ID is thus uniquely defined by a number in the range of 0 to 167, and a PSS ID is defined by a number in the range of 0 to 2.

Each cell's downlink reference signals transmit a pseudo-random sequence corresponding to the physical cell ID of the cell. The SSS and PSS are transmitted over the centre six frequency blocks independent of the channel bandwidths used by cells. Mobiles synchronise there transmission and reception frequency and time by listening first to the PSS. Once they know the PSS ID of the cell, they listen to the SSS of the cell in order to know the SSS ID. The combination of these two IDs gives the physical cell ID and the associated pseudo-random sequence that is transmitted over the downlink reference signals.

Once the physical cell ID and the associated pseudo-random sequence is known to the mobile, the cell is recognized by the mobile based on the received downlink reference signals. Downlink channel quality measurements are also made on the downlink reference signals.

As can be understood from the above description, if all the cells in the network transmit the same physical cell ID, it will be impossible for a mobile to identify different cells. Cell search and selection will be impossible. Therefore, it is important to intelligently allocate physical cell IDs to cells so as to allow easy recognition of cells by mobiles.

The following describes the AFP's automatic planning method for physical cell IDs in an LTE network, which takes into account interference matrices, neighbour relations (first-order neighbours, first-order neighbours of a common LTE cell, first-order neighbours of a common GSM or UMTS cell in 3GPP Multi-RAT documents, and optionally second-order neighbours), distance between transmitters, and the frequency plan of the network.

The AFP takes into account the cells of all the TBC transmitters. The cells to be allocated will be called TBA cells. They must fulfil the following conditions:

- They are active,
- Their status is not set to locked,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone.

If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

5.5.4.1 Constraint and Relationship Weights

The AFP is based on a cost-based function which takes into account the following constraints, in the order of priority:

1. Physical cell ID,

   Assigned weight $\omega_{ID} = 0.75$

2. PSS ID,

   Assigned weight $\omega_{PSS} = 0$

3. SSS ID,

   Assigned weight $\omega_{SSS} = 0.25$

4. UL DMRS sequence group,

   Assigned weight $\omega_{ULDMRS} = 0$

The sum of the weights assigned to the above constraints is 1.

You can modify these weights in your LTE document. The absolute values of the constraint weights are calculated from the relative weights (%) defined in the **Constraint Weights** dialogue as follows:

$$\omega_{ID} = \frac{\%\omega_{ID}}{\%\omega_{ID} + \%\omega_{PSS} + \%\omega_{SSS} + \%\omega_{ULDMRS}}$$

$$\omega_{PSS} = \frac{\%\omega_{PSS}}{\%\omega_{ID} + \%\omega_{PSS} + \%\omega_{SSS} + \%\omega_{ULDMRS}}$$

$$\omega_{SSS} = \frac{\%\omega_{SSS}}{\%\omega_{ID} + \%\omega_{PSS} + \%\omega_{SSS} + \%\omega_{ULDMRS}}$$

$$\omega_{ULDMRS} = \frac{\%\omega_{ULDMRS}}{\%\omega_{ID} + \%\omega_{PSS} + \%\omega_{SSS} + \%\omega_{ULDMRS}}$$

The above constraints are studied between each TBA cell and its related cells. **9955** calculates the cost between each individual TBA and related cell, and then the overall cost for the TBA cell.

Related cells of a TBA cell are:

- Its neighbours, if the check box "Existing neighbours" is selected,

  Assigned weight $\omega_{Neighbour} = 0.35$

  TBA cells which are first-order neighbours of a common cell are also related to each other through that cell. This relation is also taken into account,

  Assigned weight $\omega_{Inter-Neighbour} = 0.15$

  You can choose to not take into account the physical cell ID collision between neighbours of a common cell by adding an option in the Atoll.ini file (see the *Administrator Manual*). If the collision between neighbours of a common cell is not taken into account, the weight assigned to the direct first-order neighbour relation alone is $\omega_{Neighbour} = 0.5$ and that of the collision between neighbours of a common cell is of course $\omega_{Inter-Neighbour} = 0$.

By adding an option in the Atoll.ini file (see the *Administrator Manual*), second-order neighbours can also be taken into account. In this case, the assigned weights are: $\omega_{Neighbour} = 0.25$, $\omega_{2nd-Neighbour} = 0.10$, and $\omega_{Inter-Neighbour} = 0.15$.

$\omega_{Inter-Neighbour}$ applies to the relation between neighbours of a common cell, which can be an LTE cell or a GSM or UMTS cell in 3GPP Multi-RAT documents.

Figure 5.7 on page 415 depicts the different neighbour relations that may exist in LTE.

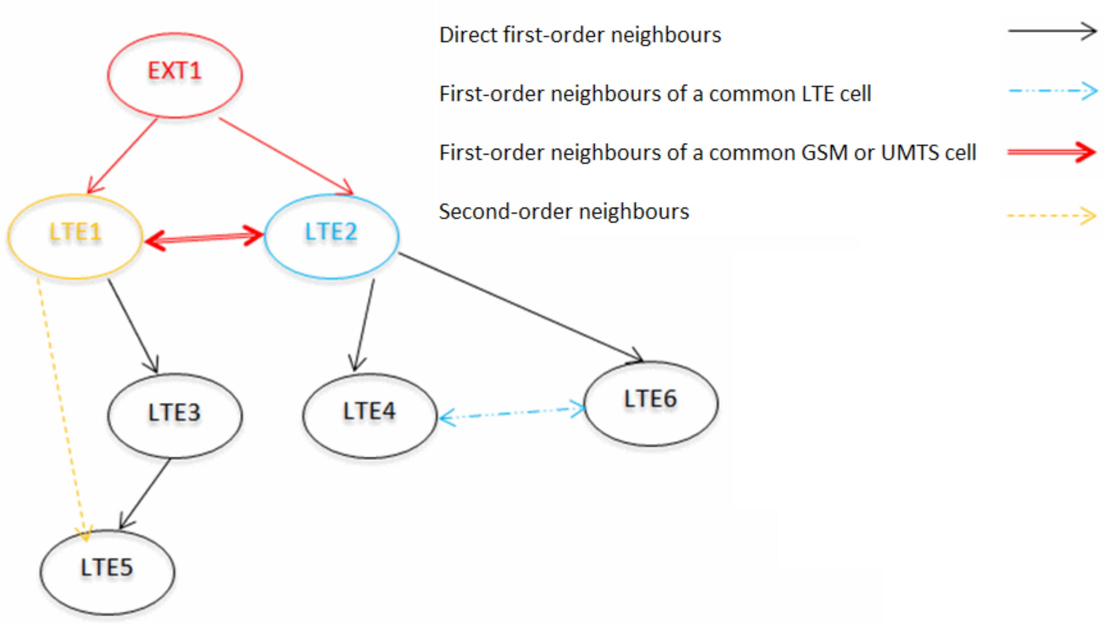


Figure 5.7: Neighbour Relations for Physical Cell ID Allocation

- Cells that are listed in the interference matrix of the TBA cell,
  Assigned weight $\omega_{IM} = 0.3$
- Cells within the cell’s (or the default) reuse distance, if the check box "Reuse distance" is selected,
  Assigned weight $\omega_{Distance} = 0.2$

The sum of the weights assigned to the above relations is 1.

You can modify these weights in your LTE document. The absolute values of the constraint weights are calculated from the relative weights (%) defined in the **Constraint Weights** dialogue as follows:

$$\omega_{Neighbour} = \frac{\%\omega_{Neighbour}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{Inter-Neighbour} = \frac{\%\omega_{Inter-Neighbour}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{2nd-Neighbour} = \frac{\%\omega_{2nd-Neighbour}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{IM} = \frac{\%\omega_{IM}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{Distance} = \frac{\%\omega_{Distance}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

5.5.4.2 Cost Calculation

9955 calculates the constraint violation levels between the TBA cell $TX_i(ic)$ and its related cell $TX_j(jc)$ as follows:

$$VL_1^{TX_i(ic) - TX_j(jc)} = r_O^{TX_i(ic) - TX_j(jc)} \times (\omega_{ID} \times p_{Coll}^{ID} + \omega_{SSS} \times p_{Penalty}^{SSS} + \omega_{ULDMRS} \times p_{Coll}^{ULDMRS})$$

$$VL_2^{TX_i(ic) - TX_j(jc)} = r_O^{TX_i(ic) - TX_j(jc)} \times (\omega_{PSS} \times p_{Coll}^{PSS})$$

Where ω_{ID}, ω_{PSS}, and ω_{SSS} are the weights assigned to the physical cell ID, PSS ID, and SSS ID constraints. $r_O^{TX_i(ic) - TX_j(jc)}$ is the total channel overlap ratio between the $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 347.

p_{Coll}^{ID} is the physical cell ID collision probability given by $p_{Coll}^{ID} = \begin{cases} 1 & \text{if } ID_{\varphi}^{TX_i(ic)} = ID_{\varphi}^{TX_j(jc)} \\ 0 & \text{if } ID_{\varphi}^{TX_i(ic)} \neq ID_{\varphi}^{TX_j(jc)} \end{cases}$.

p_{Coll}^{PSS} is the PSS ID collision probability given by $p_{Coll}^{PSS} = \begin{cases} 1 & \text{if } ID_{PSS}^{TX_i(ic)} = ID_{PSS}^{TX_j(jc)} \\ 0 & \text{if } ID_{PSS}^{TX_i(ic)} \neq ID_{PSS}^{TX_j(jc)} \end{cases}$.

$p_{Penalty}^{SSS}$ is the SSS ID penalty given by $p_{Penalty}^{SSS} = \begin{cases} 1 & \text{if } ID_{SSS}^{TX_i(ic)} \neq ID_{SSS}^{TX_j(jc)} \quad AND \quad Site^{TX_i(ic)} = Site^{TX_j(jc)} \\ 0 & Otherwise \end{cases}$ if the SSS ID planning strategy is set to "Same per site", and by $p_{Penalty}^{SSS} = 0$ if the SSS ID planning strategy is set to "Free". The SSS penalty models the SSS ID allocation constraint.

p_{Coll}^{ULDRMS} is the UL DMRS collision probability given by $p_{Coll}^{ULDMRS} = \begin{cases} 1 & \text{if } ID_{\varphi}^{TX_i(ic)} Mod30 = ID_{\varphi}^{TX_j(jc)} Mod30 \\ 0 & \text{if } ID_{\varphi}^{TX_i(ic)} Mod30 \neq ID_{\varphi}^{TX_j(jc)} Mod30 \end{cases}$.

Next, **9955** calculates the importance of the neighbour relations between the TBA cell and its related cell.

$$\iota_{\Sigma Neighbours}^{TX_i(ic) - TX_j(jc)} = \omega_{Neighbour} \times \iota_{Neighbour}^{TX_i(ic) - TX_j(jc)} + \omega_{Inter-Neighbour} \times \iota_{Inter-Neighbour} + \omega_{2nd-Neighbour} \times \iota_{2nd-Neighbour}$$

Where $\iota_{Neighbour}^{TX_i(ic) - TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related neighbour cell. $\iota_{Neighbour}^{TX_i(ic) - TX_j(jc)}$ is calculated during automatic neighbour planning by **9955** as explained in "Automatic Neighbour Planning" on page 405. For manual neighbour planning, this value is equal to 1.

$\iota_{Inter-Neighbour}$ is calculated from the neighbour relationship importance values calculated during automatic neighbour planning. If two cells are neighbours of a common cell and have the same physical cell ID assigned, the importance of the physical cell ID collision is the average of their neighbour importance values with the common neighbour cell. If more than one pair of neighbours of the TBA cell has the same physical cell ID assigned, then the importance is the highest value among all the averages:

$$\iota_{Inter-Neighbour} = \underset{\substack{\text{All Neighbour Pairs} \\ \text{with ID Collisions}}}{Max}\left(\frac{\iota_{Neighbour}^{TX_i(ic) - TX_{j1}(j1c)} + \iota_{Neighbour}^{TX_i(ic) - TX_{j2}(j2c)}}{2}\right)$$

Where $TX_{j1}(j1c)$ and $TX_{j2}(j2c)$ are two neighbours of the TBA cell $TX_i(ic)$ that have the same physical cell ID assigned. The above applies to intra-technology as well as inter-technology neighbours in 3GPP Multi-RAT documents.

$\iota_{2nd-Neighbour}$ is calculated from the neighbour relationship importance values calculated during automatic neighbour planning. If the TBA cell has the same physical cell ID assigned as one of its second-order neighbours, the importance of the physical cell ID collision is the multiple of the importance values of the first order neighbour relations between the TBA cell and its second order neighbour. If the TBA cell is related to its second order neighbour through more than one first order neighbour, the importance is the highest value among all the multiples:

$$\iota_{2nd-Neighbour} = \underset{\substack{\text{All Neighbour Pairs} \\ \text{with ID Collisions}}}{Max}\left(\iota_{Neighbour}^{TX_i(ic) - TX_j(jc)} \times \iota_{Neighbour}^{TX_j(jc) - TX_k(kc)}\right)$$

Where $TX_k(kc)$ is the second-order neighbour of $TX_i(ic)$ through $TX_j(jc)$.

Next, **9955** calculates the importance of the interference relations between the TBA cell and its related cell.

$$\iota_{Interference}^{TX_i(ic)-TX_j(jc)} = \omega_{IM} \times \iota_{IM}^{TX_i(ic)-TX_j(jc)} + \omega_{Distance} \times \iota_{Distance}^{TX_i(ic)-TX_j(jc)}$$

$\iota_{IM}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related interfering cell. $\iota_{IM}^{TX_i(ic)-TX_j(jc)}$ is calculated during interference matrix calculation as explained in "Interference Matrix Calculation" on page 417.

$\iota_{Distance}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA and its related cell with respect to the distance between them. $\iota_{Distance}^{TX_i(ic)-TX_j(jc)}$ is calculated as explained in "Distance Importance Calculation" on page 418.

From the constraint violation levels and the importance values of the relations between the TBA and its related cell, **9955** calculates the quality reduction factor for the pair as follows:

$$QRF^{TX_i(ic)-TX_j(jc)} = 1 - \left\{ \left(VL_1^{TX_i(ic)-TX_j(jc)} + VL_2^{TX_i(ic)-TX_j(jc)} \right) \times \iota_{Interference}^{TX_i(ic)-TX_j(jc)} + VL_1^{TX_i(ic)-TX_j(jc)} \times \iota_{\Sigma Neighbours}^{TX_i(ic)-TX_j(jc)} \right\}$$

The quality reduction factor is a measure of the cost of an individual relation.

The total cost of the current physical cell ID plan for any TBA cell is given as follows, considering all the cells with which the TBA cell has relations:

$$\$_{Total}^{TX_i(ic)} = 1 - \prod_{TX_j(jc)} QRF^{TX_i(ic)-TX_j(jc)}$$

And, the total cost of the current physical cell ID plan for the entire network is simply the sum of the total TBA cell costs calculated above, i.e.,

$$\$_{Total} = \sum_{TX_i(ic)} \$_{Total}^{TX_i(ic)}$$

5.5.4.3 AFP Algorithm

The AFP algorithm is an iterative algorithm which:

- Calculates the cost (as described above) of the current physical cell ID plan,
- Tries different physical cell IDs to cells in order to reduce the costs,
- Memorises the different plans in order to determine the best plan, i.e., which provides the lowest total cost,
- Stops when it is unable to improve the cost of the network, and proposes the last known best physical cell ID plan as the solution.

5.5.5 Appendices

5.5.5.1 Interference Matrix Calculation

The importance of an interference matrix entry ($\iota_{IM}^{TX_i(ic)-TX_j(jc)}$) is equal to the co- or adjacent chanenl interference probability calculated by taking the ratio of the interfered surface area to the total surface area of a cell.

The co-channel interference probability is calculated as follows:

$$\frac{S_{TX_i(ic)} \Big|_{C_{DLRS}^{TX_i(ic)} - 10 \times Log\left(10^{\frac{C_{Max}^{TX_j(jc)} + M_{Quality}}{10}} + 10^{\frac{n_{DLRS}^{TX_i(ic)}}{10}} \right) < \left(T_{RSRP}^{TX_i(ic)} + 174 - 10 \times Log(15000) \right)}}{S_{TX_i(ic)}}$$

The adjacent channel interference probability is calculated as follows:

$$\frac{S_{TX_i(ic)} \Big|_{C_{DLRS}^{TX_i(ic)} - 10 \times Log\left(10^{\frac{C_{Max}^{TX_j(jc)} + M_{Quality} + f_{ACS}^{TX_i(ic)}}{10}} + 10^{\frac{n_{DLRS}^{TX_i(ic)}}{10}} \right) < \left(T_{RSRP}^{TX_i(ic)} + 174 - 10 \times Log(15000) \right)}}{S_{TX_i(ic)}}$$

For frequencies farther than the adjacent channel, $\iota_{IM}^{TX_i(ic)-TX_j(jc)} = 0$.

Here $S_{TX_i(ic)}$ is the best server coverage area of the cell *TX_i(ic)*, that comprises all the pixels where $E_{DLRS}^{TX_i(ic)} \geq T_{RSRP}^{TX_i(ic)}$ as calculated in "Service Area Calculation" on page 385. $S_{TX_i(ic)}\Big|_{Condition}$ is the best server coverage area of the cell $TX_i(ic)$ where the given condition is true. $C_{DLRS}^{TX_i(ic)}$ is the received downlink reference signal level from the cell $TX_i(ic)$. $C_{Max}^{TX_j(jc)}$ is the received maximum signal level from the cell $TX_j(jc)$ calculated using the Max Power defined for this cell. $n_{DLRS}^{TX_i(ic)}$ is the downlink noise for the cell $TX_i(ic)$ as calculated in "Noise Calculation (DL)" on page 354. $M_{Quality}$ is the quality margin used for the interference matrices calculation. And, $f_{ACS}^{TX_i(ic)}$ is the adjacent channel suppression factor defined for the frequency band of the cell $TX_i(ic)$.

5.5.5.2 Distance Importance Calculation

The distance importance between two cells ($\iota_{Distance}^{TX_i(ic)-TX_j(jc)}$) is calculated as follows:

$$\iota_{Distance}^{TX_i(ic)-TX_j(jc)} = \begin{cases} 1 & \text{if } D^{TX_i(ic)-TX_j(jc)} < 1 \\ \dfrac{Log\left(\left(\dfrac{D_{Reuse}}{D^{TX_i(ic)-TX_j(jc)}}\right)^2\right)}{Log(D_{Reuse}^2)} & \text{Otherwise} \end{cases}$$

Where D_{Reuse} is the minimum reuse distance, either defined for each TBA cell individually or set for all the TBA cells in the AFP dialogue, and $D^{TX_i(ic)-TX_j(jc)}$ is the weighted distance between the TBA cell $TX_i(ic)$ and its related cell $TX_j(jc)$ calculated as follows:

$$D^{TX_i(ic)-TX_j(jc)} = d^{TX_i(ic)-TX_j(jc)} \times (1 + x \times (cos(\beta) - cos(\alpha) - 2))$$

$D^{TX_i(ic)-TX_j(jc)}$ is weighted according to the azimuths of the TBA cell and its related cell with respect to the straight line joining them. $d^{TX_i(ic)-TX_j(jc)}$ is the distance between the two cells considering any offsets with respect to the site locations. x is set to 15 % so that the maximum variation in $D^{TX_i(ic)-TX_j(jc)}$ due to the azimuths does not exceed 60 %. α and β are calculated from the azimuths of the two cells as shown in Figure 5.8 on page 418.

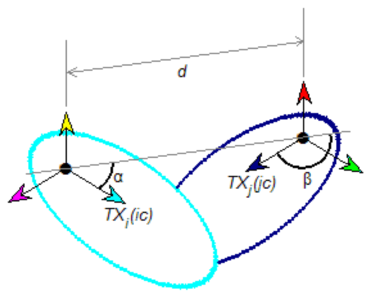


Figure 5.8: Weighted Distance Between Cells

The above formula implies that two cells facing each other will have a shorter effective distance between them than the real distance, and two cells pointing in opposite directions will have a greater effective distance.

The importance of the distance relation is explained in Figure 5.9 on page 419. This figure shows that cells that are located near (based on the effective distance which is weighted by the orientations of the cells) have high importance, which is interpreted as a high cost, and cells that are located far have low importance. Cells that are further than the reuse distance do not have any cost related to the distance relation.

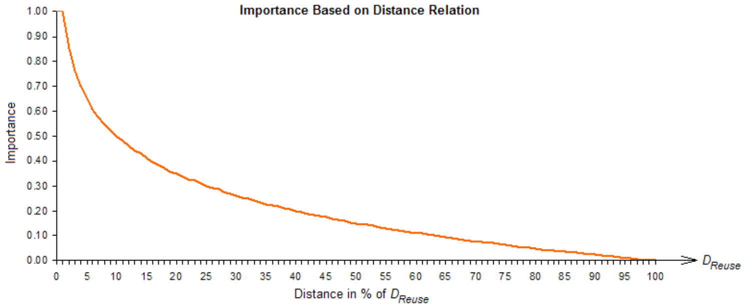


Figure 5.9: Importance Based on Distance Relation

Chapter 6

3GPP Multi-RAT Networks

This chapter describes 3GPP Multi-RAT calculations.

In this chapter, the following are explained:

- "Simulations in Multi-RAT Projects" on page 423

6 3GPP Multi-RAT Networks

This chapter describes the specific calculations performed in **9955** Multi-RAT documents. The calculations in common with the single-RAT documents can be found in the corresponding parts:

- "GSM GPRS EDGE Networks" on page 109 for the GSM GPRS EDGE part of the multi-RAT documents,
- "UMTS HSPA Networks" on page 179 for the UMTS HSPA part of the multi-RAT documents,
- "LTE Networks" on page 303 for the LTE part of the multi-RAT documents.

The first part refers to the traffic maps which can be used as traffic input for the Multi-RAT simulations. The second part refers to the specific algorithm implemented in multi-RAT simulations.

6.1 Simulations in Multi-RAT Projects

The tables in the following subsections list the input parameters, and formulas used in simulations.

6.1.1 Inputs

This table lists simulation and prediction inputs (calculation options, quality targets, active set management conditions, etc.).

Name	Value	Unit	Description
f_{act}^{UL}	Service parameter	kbps	Uplink activity factor for the service
f_{act}^{DL}	Service parameter	kbps	Downlink activity factor for the service
TL_{DL-GSM}	Subcell parameter	%	Downlink traffic load (GSM)

6.1.2 Simulation Process

Once you have modelled the network services and users and have created traffic maps, you can create simulations. The simulation process consists of five steps:

- Obtaining a realistic user distribution: **9955** generates a user distribution using a Monte-Carlo algorithm; this user distribution is based on the traffic database and traffic maps and is weighted by a Poisson distribution between simulations of the same group (See "Generating a Realistic User Distribution" on page 424).

  Each user is assigned a service, a mobility type, and an activity status by random trial, according to a probability law that uses the traffic database.

  The user activity status is an important output of the random trial and has direct consequences on the next step of the simulation and on the network interferences. A user may be either active or inactive. Both active and inactive users consume radio resources and create interference.

  Then, **9955** randomly assigns a shadowing error to each user using the probability distribution that describes the shadowing effect.

  Finally, another random trial determines user positions in their respective traffic zone (possibly according to the clutter weighting and the indoor ratio per clutter class).

- Technology selection: For each mobile generated at the beginning of the simulation, **9955** search for its serving cell in each possible technology. In case of multi-technology mobiles, a sort of active set of transmitters (having possibly different technologies) is then created. Finally, retained transmitters are sorted according to the priorities of technologies in the services as described in "Search and Selection of serving technologies" on page 431.

  When the technology to which each mobile is attached, the multi-technology simulation is made of as many single-technology "sub"-simulations run sequentially

- GSM network regulation mechanisms: for the GSM part of the traffic, **9955** manages the GSM resources as described in "Radio Resource Management in GSM" on page 432.
- UMTS network regulation mechanisms: for the UMTS part of the traffic, **9955** uses a power control algorithm for R99 users, and an algorithm mixing A-DPCH power control and fast link adaptation for HSDPA users and an additional loop modelling noise rise scheduling for HSUPA users. The power control simulation algorithm is described in "Power Control Simulation" on page 199.
- LTE network regulation mechanisms: for the LTE part of the traffic, **9955** manages the LTE resources as described in "Simulation Process" on page 336.

6.1.2.1 Generating a Realistic User Distribution

During the simulation, a first random trial is performed to determine the number of users and their activity status. Four activity status are modelled:

- Active UL: the user is active on UL and inactive on DL
- Active DL: the user is active on DL and inactive on UL
- Active UL+DL: the user is active on UL and on DL
- Inactive: the user is inactive on UL and on DL

The determination of the number of users and the activity status allocation depend on the type of traffic cartography used.

9955 determines the total number of users attempting connection in each simulation based on the Poisson distribution. This may lead to slight variations in the total numbers of users in different simulations. To have the same total number of users in each simulation of a group, add the following lines in the Atoll.ini file:
[Simulation]
RandomTotalUsers=0

In multi-RAT projects, services can be classified under two main types:

- Constant Bit Rate services
- Variable Bit Rate services

These services can be handled by one or several technologies and have to be consistent with the following table:

	GSM	UMTS	LTE
Constant Bit Rate	Circuit Packet (Constant Bit Rate)	Circuit R99 Packet HSPA (Constant Bit Rate)	Voice
Variable Bit Rate	Packet (Max Bit Rate)	Packet R99 Packet HSDPA (Best Effort) Packet HSPA (Best Effort)	Data

6.1.2.2 Simulations Based on User Profile Traffic Maps

User profile environment based traffic maps: Each pixel of the map is assigned an environment class which contains a list of user profiles with an associated mobility type and a given density, i.e., number of users of a user profile per km².

User profile traffic maps: Each polygon or line of the map is assigned a density of users with a given user profile and mobility type. If the map is composed of points, each point is assigned a number of users with given user profile and mobility type.

User profiles model the behaviour of the different user categories. Each user profile contains a list of services and parameters describing how these services are accessed by the user.

The number of users of each user profile is calculated from the surface area (S_{Env}) of each environment class map (or each polygon) and the user profile density (D_{UP}).

$$N_{Users} = S_{Env} \times D_{UP}$$

- In case of user profile traffic maps composed of lines, the number of users of each user profile is calculated from the line length (L) and the user profile density (D_{UP}) (users per km): $N_{Users} = L \times D_{UP}$
- The number of users is a direct input when a user profile traffic map is composed of points.

9955 calculates the probability for a user being active at a given instant in the uplink and in the downlink according to the service usage characteristics described in the user profiles, i.e., the number of service sessions, the average duration of each constant bit rate service session, or the volume of the data transfer in the uplink and the downlink in each variable bit rate service session.

6.1.2.2.1 Constant Bit Rate Service (i)

User profile parameters for constant bit rate services are:

- The used terminal (equipment used for the service (from the Terminals table)),
- The average number of calls per hour N_{call},
- The average duration of a call (seconds) d.

The number of users and their distribution per activity status is determined as follows:

- Calculation of the service usage duration per hour (p_0 : probability of a connection):

$$p_o = \frac{N_{call} \times d}{3600}$$

- Calculation of the number of users trying to access the service i (n_i):

$$n_i = N_{Users} \times p_0$$

Next, we can take into account activity periods during the connection in order to determine the activity status of each user.

- Calculation of activity probabilities:

Probability of being inactive on UL and DL: $p_{inactive} = (1 - f_{act}^{UL}) \times (1 - f_{act}^{DL})$

Probability of being active on UL only: $p_{UL} = f_{act}^{UL} \times (1 - f_{act}^{DL})$

Probability of being active on DL only: $p_{DL} = f_{act}^{DL} \times (1 - f_{act}^{UL})$

Probability of being active both on UL and DL: $p_{UL + DL} = f_{act}^{UL} \times f_{act}^{DL}$

Where, f_{act}^{UL} and f_{act}^{DL} are respectively the UL and DL activity factors defined for the constant bit rate service i.

- Calculation of number of users per activity status:

Number of inactive users on UL and DL: $n_i^{inactive} = n_i \times p_{inactive}$

Number of users active on UL and inactive on DL: $n_i(UL) = n_i \times p_{UL}$

Number of users active on DL and inactive on UL: $n_i(DL) = n_i \times p_{DL}$

Number of users active on UL and DL both: $n_i(UL + DL) = n_i \times p_{UL + DL}$

Therefore, a user when he is connected can have four different activity status: either active on both links, or inactive on both links, or active on UL only, or active on DL only.

6.1.2.2.2 Variable Bit Rate Service (j)

The way the number of users is calculated when using a variable bit rate service depends on the technologies which can manage this service. In the case a variable bit rate service can be handled by several technologies, **9955** calculates the number of users for each technology and finally averages:

- the number of inactive users for each technology to get the final number of inactive users,
- the number of active users in UL only for each technology to get the final number of active users in UL only,
- the number of active users in DL only for each technology to get the final number of active users in DL only,
- the number of active users in UL and DL for each technology to get the final number of active users in UL and DL.

For variable bit rate services, user profile parameters are:

- The user terminal equipment used for the service (from the Terminals table).
- The average number of data sessions per hour $N_{Session}$.
- The average data volume (in kBytes) transferred in the downlink V^{DL} and the uplink V^{UL} during a session.

For variable bit rate services which can be managed by GSM or LTE, the other parameters to consider are:

- The average requested throughputs in the downlink $TP_{Average}^{DL}$ and the uplink $TP_{Average}^{UL}$ for the service *d*.

  The number of users and their distribution per activity status is determined as follows:

  - Calculation of activity probabilities: $f^{UL} = \frac{N_{Session} \times V^{UL} \times 8}{TP_{Average}^{UL} \times 3600}$ and $f^{DL} = \frac{N_{Session} \times V^{DL} \times 8}{TP_{Average}^{DL} \times 3600}$

    Probability of being inactive: $p_{Inactive} = (1 - f^{UL}) \times (1 - f^{DL})$

    Probability of being active in the uplink: $p_{Active}^{UL} = f^{UL} \times (1 - f^{DL})$

    Probability of being active in the downlink: $p_{Active}^{DL} = f^{DL} \times (1 - f^{UL})$

Probability of being active in the uplink and downlink both: $p_{Active}^{UL+DL} = f^{UL} \times f^{DL}$

- Calculation of number of users:

  Number of inactive users: $n_{d-Inactive}\Big|_{GSM\ or\ LTE} = N_{Users} \times p_{Inactive}$

  Number of users active in the uplink: $n_{d-Active}^{UL}\Big|_{GSM\ or\ LTE} = N_{Users} \times p_{Active}^{UL}$

  Number of users active in the downlink: $n_{d-Active}^{DL}\Big|_{GSM\ or\ LTE} = N_{Users} \times p_{Active}^{DL}$

  Number of users active in the uplink and downlink both: $n_{d-Active}^{UL+DL}\Big|_{GSM\ or\ LTE} = N_{Users} \times p_{Active}^{UL+DL}$

- Calculation of the number of active users trying to access the service d (n_d):

  $$n_d\Big|_{GSM\ or\ LTE} = n_{d-Active}^{UL}\Big|_{GSM\ or\ LTE} + n_{d-Active}^{DL}\Big|_{GSM\ or\ LTE} + n_{d-Active}^{UL+DL}\Big|_{GSM\ or\ LTE}$$

Only DL users are considered in GSM.

For variable bit rate services which can be managed by UMTS, a packet session consists of several packet calls separated by a reading time. Each packet call is defined by its size and may be divided in packets of fixed size (1500 Bytes) separated by an inter arrival time.

In **9955**, a UMTS packet session is described by following parameters:

$N_{packet-call}^{UL}$: Average number of packet calls on the uplink during a session,

$N_{packet-call}^{DL}$: Average number of packet calls on the downlink during a session,

$\Delta T_{packet-call}^{UL}$: Average time (millisecond) between two packets calls on the uplink ,

$\Delta T_{packet-call}^{DL}$: Average time (millisecond) between two packets calls on the downlink ,

ΔT_{packet}^{UL} : Average time (millisecond) between two packets on the uplink ,

ΔT_{packet}^{DL} : Average time (millisecond) between two packets on the downlink ,

S_{packet}^{UL} : Packet size (Bytes) on uplink,

S_{packet}^{DL} : Packet size (Bytes) on downlink.

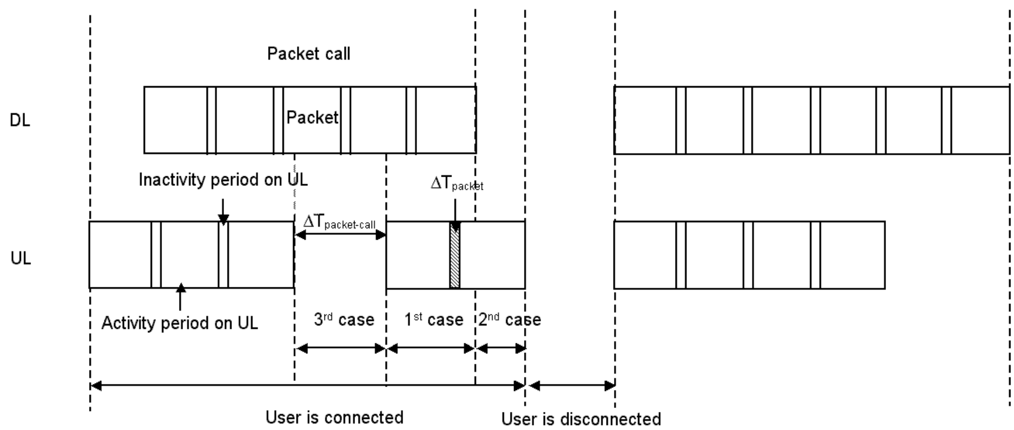


Figure 6.1: Description of a Packet Session

The number of users and their distribution per activity status is determined as follows:

- Calculation of the average packet call size (kBytes):

$$S^{UL}_{packet-call} = \frac{V_{UL}}{N^{UL}_{packet-call} \times f^{UL}_{eff}} \text{ and } S^{DL}_{packet-call} = \frac{V_{DL}}{N^{DL}_{packet-call} \times f^{DL}_{eff}}$$

Where f^{UL}_{eff} and f^{DL}_{eff} are the UL and DL efficiency factors defined for the packet switched service j.

> For packet (HSDPA) and packet (HSPA) services, f^{UL}_{eff} and f^{DL}_{eff} are set to 1.

- Calculation of the average number of packets per packet call:

$$N^{UL}_{packet} = int\left(\frac{S^{UL}_{packet-call}}{S^{UL}_{packet}/1024}\right) + 1 \text{ and } N^{DL}_{packet} = int\left(\frac{S^{DL}_{packet-call}}{S^{DL}_{packet}/1024}\right) + 1$$

> 1kBytes = 1024Bytes.

- Calculation of the average duration of inactivity within a packet call (s):

$$(D^{UL}_{Inactivity})_{packet-call} = \frac{(N^{UL}_{packet} - 1) \times \Delta T^{UL}_{packet}}{1000} \text{ and } (D^{DL}_{Inactivity})_{packet-call} = \frac{(N^{DL}_{packet} - 1) \times \Delta T^{DL}_{packet}}{1000}$$

- Calculation of the average duration of inactivity in a session (s):

$$(D^{UL}_{Inactivity})_{session} = N^{UL}_{packet-call} \times (D^{UL}_{Inactivity})_{packet-call}$$

and

$$(D^{DL}_{Inactivity})_{session} = N^{DL}_{packet-call} \times (D^{DL}_{Inactivity})_{packet-call}$$

- Calculation of the average duration of activity in a session (s):

$$(D^{UL}_{Activity})_{session} = N^{UL}_{packet-call} \times \frac{N^{UL}_{packet} \times S^{UL}_{packet} \times 8}{R^{UL}_{average} \times 1000} \text{ and } (D^{DL}_{Activity})_{session} = N^{DL}_{packet-call} \times \frac{N^{DL}_{packet} \times S^{DL}_{packet} \times 8}{R^{DL}_{average} \times 1000}$$

Where $R^{UL}_{average}$ and $R^{DL}_{average}$ are the uplink and downlink average requested throughputs defined for the service j.

Therefore, the average duration of a connection (in s) is:

$$D^{UL}_{Connection} = (D^{UL}_{Activity})_{session} + (D^{UL}_{Inactivity})_{session} \text{ and } D^{DL}_{Connection} = (D^{DL}_{Activity})_{session} + (D^{DL}_{Inactivity})_{session}$$

- Calculation of the service usage duration per hour (probability of a connection):

$$p^{UL}_{Connection} = \frac{N_{sess}}{3600} \times D^{UL}_{Connection} \text{ and } p^{DL}_{Connection} = \frac{N_{sess}}{3600} \times D^{DL}_{Connection}$$

- Calculation of the probability of being connected:

$$p_{Connected} = 1 - (1 - p^{UL}_{Connection}) \times (1 - p^{DL}_{Connection})$$

Therefore, the number of users who want to get the service j is:

$$n_j\big|_{UMTS} = N_{Users} \times p_{Connected}$$

As you can see on the picture above, we have to consider three possible cases when a user is connected:

- 1st case: At a given time, packets are downloaded and uploaded.

In this case, the probability of being connected is:

$$p^{UL+DL}_{Connected} = \frac{p^{UL}_{Connection} \times p^{DL}_{Connection}}{p_{Connected}}$$

- 2nd case: At a given time, packet are uploaded (no packet is downloaded).

Here, the probability of being connected is:

$$p_{Connected}^{UL} = \frac{p_{Connection}^{UL} \times (1 - p_{Connection}^{DL})}{p_{Connected}}$$

- 3rd case: At a given time, packet are downloaded (no packet is uploaded).

In this case, the probability of being connected is:

$$p_{Connected}^{DL} = \frac{p_{Connection}^{DL} \times (1 - p_{Connection}^{UL})}{p_{Connected}}$$

Now, we have to take into account activity periods during the connection in order to determine the activity status of each user.

- Calculation of the probability of being active:

$$f^{UL} = \frac{(D_{Activity}^{UL})_{session}}{((D_{Inactivity}^{UL})_{session} + (D_{Activity}^{UL})_{session})} \text{ and } f^{DL} = \frac{(D_{Activity}^{DL})_{session}}{((D_{Inactivity}^{DL})_{session} + (D_{Activity}^{DL})_{session})}$$

Therefore, we have:

- 1st case: At a given time, packets are downloaded and uploaded.

The user can be active on UL and inactive on DL; this probability is:

$$p_{UL}^{1} = f^{UL} \times (1 - f^{DL}) \times p_{Connected}^{UL+DL}$$

The user can be active on DL and inactive on UL; this probability is:

$$p_{DL}^{1} = f^{DL} \times (1 - f^{UL}) \times p_{Connected}^{UL+DL}$$

The user can be active on both links; this probability is:

$$p_{UL+DL}^{1} = f^{UL} \times f^{DL} \times p_{Connected}^{UL+DL}$$

The user can be inactive on both links; this probability is:

$$p_{inactive}^{1} = (1 - f^{UL}) \times (1 - f^{DL}) \times p_{Connected}^{UL+DL}$$

- 2nd case: At a given time, packet are uploaded (no packet is downloaded).

The user can be active on UL and inactive on DL; this probability is:

$$p_{UL}^{2} = f^{UL} \times p_{Connected}^{UL}$$

The user can be inactive on both links; this probability is:

$$p_{inactive}^{2} = (1 - f^{UL}) \times p_{Connected}^{UL}$$

- 3rd case: At a given time, packet are downloaded (no packet is uploaded).

The user can be active on DL and inactive on UL; this probability is:

$$p_{DL}^{3} = f^{DL} \times p_{Connected}^{DL}$$

The user can be inactive on both links; this probability is:

$$p_{inactive}^{3} = (1 - f^{DL}) \times p_{Connected}^{DL}$$

- Calculation of number of users per activity status

Number of inactive users on UL and DL: $n_j^{inactive}\big|_{UMTS} = n_j\big|_{UMTS} \times (p_{inactive}^{1} + p_{inactive}^{2} + p_{inactive}^{3})$

Number of users active on UL and inactive on DL: $n_j(UL)\big|_{UMTS} = n_j\big|_{UMTS} \times (p_{UL}^{1} + p_{UL}^{2})$

Number of users active on DL and inactive on UL: $n_j(DL)\big|_{UMTS} = n_j\big|_{UMTS} \times (p_{DL}^{1} + p_{DL}^{3})$

Number of users active on UL and DL: $n_j(UL+DL)\big|_{UMTS} = n_j\big|_{UMTS} \times p_{UL+DL}^{1}$

Therefore, a user when he is connected can have four different activity status: either active on both links, or inactive on both links, or active on UL only, or active on DL only.

Assuming several number of users are calculated for several technologies, the final numbers of users are obtains as follows:

Number of inactive users on UL and DL: $n_j^{inactive} = Average(n_j^{inactive}\big|_{GSM}, n_j^{inactive}\big|_{UMTS}, n_j^{inactive}\big|_{LTE})$

Number of users active on UL and inactive on DL: $n_j(UL) = Average(n_j(UL)\big|_{GSM}, n_j(UL)\big|_{UMTS}, n_j(UL)\big|_{LTE})$

Number of users active on DL and inactive on UL: $n_j(DL) = Average(n_j(DL)\big|_{GSM}, n_j(DL)\big|_{UMTS}, n_j(DL)\big|_{LTE})$

Number of users active on UL and DL: $n_j(UL+DL) = Average(n_j(UL+DL)\big|_{GSM}, n_j(UL+DL)\big|_{UMTS}, n_j(UL+DL)\big|_{LTE})$

The user distribution per service and the activity status distribution between the users are average distributions. The service and the activity status of each user are randomly drawn in each simulation. Therefore, if you calculate several simulations at once, the average number of users per service and average numbers of inactive, active on UL, active on DL and active on UL and DL users, respectively, will correspond to calculated distributions. But if you check each simulation, the user distribution between services as well as the activity status distribution between users can be different in each of them.

6.1.2.3 Simulations Based on Sector Traffic Maps

Sector traffic maps can be based on live traffic data from OMC (Operation and Maintenance Centre). Traffic is spread over the best server coverage area of each transmitter and each coverage area is assigned either the throughputs in the uplink and in the downlink or the number of users per activity status or the total number of users (including all activity statuses).

6.1.2.3.1 Throughputs in Uplink and Downlink

When selecting **Throughputs in Uplink and Downlink**, you can input the throughput demands in the uplink and downlink for each sector and for each listed service.

Only DL traffic is considered in GSM

9955 calculates the number of users active in uplink and in downlink in the Txi cell using the service (N_{UL} and N_{DL}) as follows:

$$N_{UL} = \frac{R_t^{UL}}{R_{average}^{UL}} \text{ and } N_{DL} = \frac{R_t^{DL}}{R_{average}^{DL}}$$

R_t^{UL} is the kbits per second transmitted in UL in the Txi cell to supply the service.

R_t^{DL} is the kbits per second transmitted in DL in the Txi cell to supply the service.

$R_{average}^{DL}$ is the downlink average requested throughput defined for the service,

$R_{average}^{UL}$ is the uplink average requested throughput defined for the service.

N_{UL} and N_{DL} values include:

- Users active in uplink and inactive in downlink ($n_i(UL)$),
- Users active in downlink and inactive in uplink ($n_i(DL)$),
- And users active in both links ($n_i(UL+DL)$).

9955 takes into account activity periods during the connection in order to determine the activity status of each user.

Activity probabilities are calculated as follows:

Probability of being inactive in UL and DL: $p_{inactive} = (1 - f_{act}^{UL}) \times (1 - f_{act}^{DL})$

Probability of being active in UL only: $p_{UL} = f_{act}^{UL} \times (1 - f_{act}^{DL})$

Probability of being active in DL only: $p_{DL} = f_{act}^{DL} \times (1 - f_{act}^{UL})$

Probability of being active both in UL and DL: $p_{UL+DL} = f_{act}^{UL} \times f_{act}^{DL}$

Where, f_{act}^{UL} and f_{act}^{DL} are respectively the UL and DL activity factors defined for the service i.

Then, **9955** calculates the number of users per activity status:

We have:

$$(p_{UL} + p_{UL+DL}) \times (n_j(UL) + n_j(DL) + n_j(UL+DL)) = N_{UL}$$

$$(p_{DL} + p_{UL+DL}) \times (n_j(UL) + n_j(DL) + n_j(UL+DL)) = N_{DL}$$

Therefore, we have:

Number of users active in UL and DL both: $n_i(UL+DL) = min\left(\frac{N_{UL} \times p_{UL+DL}}{p_{UL} + p_{UL+DL}}, \frac{N_{DL} \times p_{UL+DL}}{p_{DL} + p_{UL+DL}}\right)$

Number of users active in UL and inactive in DL: $n_i(UL) = N_{UL} - n_i(UL+DL)$

Number of users active in DL and inactive in UL: $n_i(DL) = N_{DL} - n_i(UL+DL)$

Number of inactive users in UL and DL: $n_i^{inactive} = \frac{(n_j(UL) + n_j(DL) + n_j(UL+DL))}{1 - p_{inactive}} \times p_{inactive}$

Therefore, a connected user can have four different activity status: either active in both links, or inactive in both links, or active in UL only, or active in DL only.

6.1.2.3.2 Total Number of Users (All Activity Statuses)

When selecting **Total Number of Users (All Activity Statuses)**, you can input the number of connected users for each sector and for each listed service (n_i).

9955 takes into account activity periods during the connection in order to determine the activity status of each user.

Activity probabilities are calculated as follows:

Probability of being inactive in UL and DL: $p_{inactive} = (1 - f_{act}^{UL}) \times (1 - f_{act}^{DL})$

Probability of being active in UL only: $p_{UL} = f_{act}^{UL} \times (1 - f_{act}^{DL})$

Probability of being active in DL only: $p_{DL} = f_{act}^{DL} \times (1 - f_{act}^{UL})$

Probability of being active both in UL and DL: $p_{UL+DL} = f_{act}^{UL} \times f_{act}^{DL}$

Where, f_{act}^{UL} and f_{act}^{DL} are respectively the UL and DL activity factors defined for the service i.

Then, **9955** calculates the number of users per activity status:

Number of inactive users in UL and DL: $n_i^{inactive} = n_i \times p_{inactive}$

Number of users active in UL and inactive in DL: $n_i(UL) = n_i \times p_{UL}$

Number of users active in DL and inactive in UL: $n_i(DL) = n_i \times p_{DL}$

Number of users active in UL and DL both: $n_i(UL+DL) = n_i \times p_{UL+DL}$

Therefore, a connected user can have four different activity status: either active in both links, or inactive in both links, or active in UL only, or active in DL only.

6.1.2.3.3 Number of Users per Activity Status

When selecting **Number of Users per Activity Status**, you can directly input the number of inactive users ($n_i^{inactive}$), the number of users active in the uplink ($n_i(UL)$), in the downlink ($n_i(DL)$) and in the uplink and downlink ($n_i(UL+DL)$), for each sector and for each service.

The activity status distribution between users is an average distribution. In fact, in each simulation, the activity status of each user is randomly drawn. Therefore, if you compute several simulations at once, average numbers of inactive, active on UL, active on DL and active on UL and DL users correspond to the calculated distribution. But if you check each simulation, the activity status distribution between users is different in each of them.

6.1.2.3.4 Distribution of terminals and mobilities

According to the throughput defined per sector, the number of users, their activities (see above) can be obtained on each area corresponding to a sector. Depending on the proportions of mobilities defined in each sector traffic map, each user easily obtains a certain mobility type. The way the terminal is assigned is more complex, since that terminal must be compatible with the service which has been assigned to the user, and the proportion of terminals defined in the traffic map has to be respected.

Let’s consider the following example where for a specific traffic map, the terminal proportions are defined as follows:

- Terminal A : 30%. Terminal A only supports GSM technology
- Terminal B : 50%. Terminal B supports GSM and UMTS technologies
- Terminal C : 20%. Terminal C supports GSM, UMTS and LTE technologies.

Assuming services have been assigned to each user. If some users have been assigned a service which may be served by any technology, the distribution of terminals will be :

- Terminal A : 30%.
- Terminal B : 50%.
- Terminal C : 20%.

If some users have been assigned a service which may be served by UMTS and LTE technologies only, the distribution is normalised and will be :

- Terminal B : 50/70 = 71.4 %.
- Terminal C : 20/70 = 28.6 %.

If some users have been assigned a service which may be served by LTE technology only, all of these users will have to be assigned Terminal C.

6.1.2.4 Search and Selection of serving technologies

The very first part of the simulation consists, for each distributed mobile, in analysing if this mobile can be served or not by cells of different technologies. Each mobile dropped at the beginning of the allocation has a specific mobility type and support or not several technologies as explained in "Distribution of terminals and mobilities" on page 431.

For each supported technology, the mobile verifies if it can be served by at least one transmitter or cell.

If the mobile supports GSM technology, **9955** realise an HCS server prediction where the mobile can only be served by a GSM transmitter if its mobility does not exceed the maximum speed supported on its HCS layer and the received signal level is stronger than its HCS layer threshold. The mobile can then be served by a GSM transmitter if these conditions are observed on at least one of its covering transmitters (on its HCS layer best server area). If no transmitter respect these conditions, the mobile will not be served by GSM technology.

If the mobile supports UMTS technology, **9955** evaluates Ec/Io values of nearby UMTS cells assuming Io is obtained from the common channel powers currently defined in cells (without considering dedicated traffic channel powers). Since Io is supposed to depend on the traffic, Io is arbitrarily computed by considering the sum of Pilot power, SCH power and other CCH power, for each cell. The mobile can then be served by an UMTS cell if its Ec/Io is the best Ec/Io on its location and it exceeds the minimum Ec/Io defined for its mobility. If no cell respect these conditions, the mobile will not be served by UMTS technology.

If the mobile supports LTE technology, **9955** extracts the best Reference Signal level of covering LTE cells, assuming its RSCP is better than the Min RSCP defined in its properties. The best LTE cell respecting this condition is then a serving candidate for this mobile. If no LTE cell has a sufficient RSCP to overlap it, the mobile will not be served by LTE technology.

Once the various potential serving technologies have been identified, **9955** selects the highest priority as defined in the General tab of the service the mobiles tries to connect. The technology to which the mobile is going to potentially be attached is fixed at this step and does not change any more for this user distribution. One simulation is then run by technology:

For the GSM part of the traffic: **9955** manages the GSM resources as described in "Radio Resource Management in GSM" on page 432

For the UMTS part of the traffic: **9955** uses a power control algorithm for R99 users, and an algorithm mixing A-DPCH power control and fast link adaptation for HSDPA users and an additional loop modelling noise rise scheduling for HSUPA users. The power control simulation algorithm is described in "Power Control Simulation" on page 199.

For the LTE part of the traffic: **9955** manages the LTE resources as described in "Scheduling and Radio Resource Management" on page 397.

6.1.2.5 Radio Resource Management in GSM

For each mobile, as explained in "Search and Selection of serving technologies" on page 431, a technology is selected. If the selected technology is GSM, a specific radio resource management is applied. In GSM, only DL activity and inactivity are considered.

6.1.2.5.1 MSA Definition

In order to understand the difference between each frequency hopping mode from the point of view of a mobile, it is interesting to consider the Mobile Station Allocation. MSA is characterised by the pair (Channel list, MAIO). In the following, we will use this notion to characterise the interference and resources set of a mobile.

For non-hopping (NH) mode, the channel list is 1 channel. For base-band hopping (BBH) or synthesized frequency hopping (SFH), the channel list corresponds to the mobile allocation list (MAL).

For BBH, channels of MAL belong to the same TRX type.

Examples:

In case of NH, we have:

TRX index	Channel list	MAIO	MSA
1	53	*	(53,*)
2	54	*	(54,*)

In case of BBH, assuming TRXs belong to the same TRX type, we have:

TRX index	Channel list	MAIO	MSA
1	53	*	([53,54,55],0)
2	54	*	([53,54,55],1)
3	55	*	([53,54,55],2)

In case of SFH, we have:

TRX index	Channel list	MAIO	MSA
1	53 54 55 56	2	([53,54,55,56],2)
2	53 54 55 56	3	([53,54,55,56],3)

Therefore, from the point of view of a mobile station, BBH and SFH work in the same way. An MSA will be attached to each mobile considered during the simulation and the level of interference will be evaluated on this MSA.

6.1.2.5.2 GSM Simulation Process

The GSM traffic which is distributed is the result of a GSM filtering on the Multi-RAT distribution, as explained in "Search and Selection of serving technologies" on page 431.

Figure 6.2 shows the GSM simulation algorithm. The specific simulation process in GSM consists of the following steps:

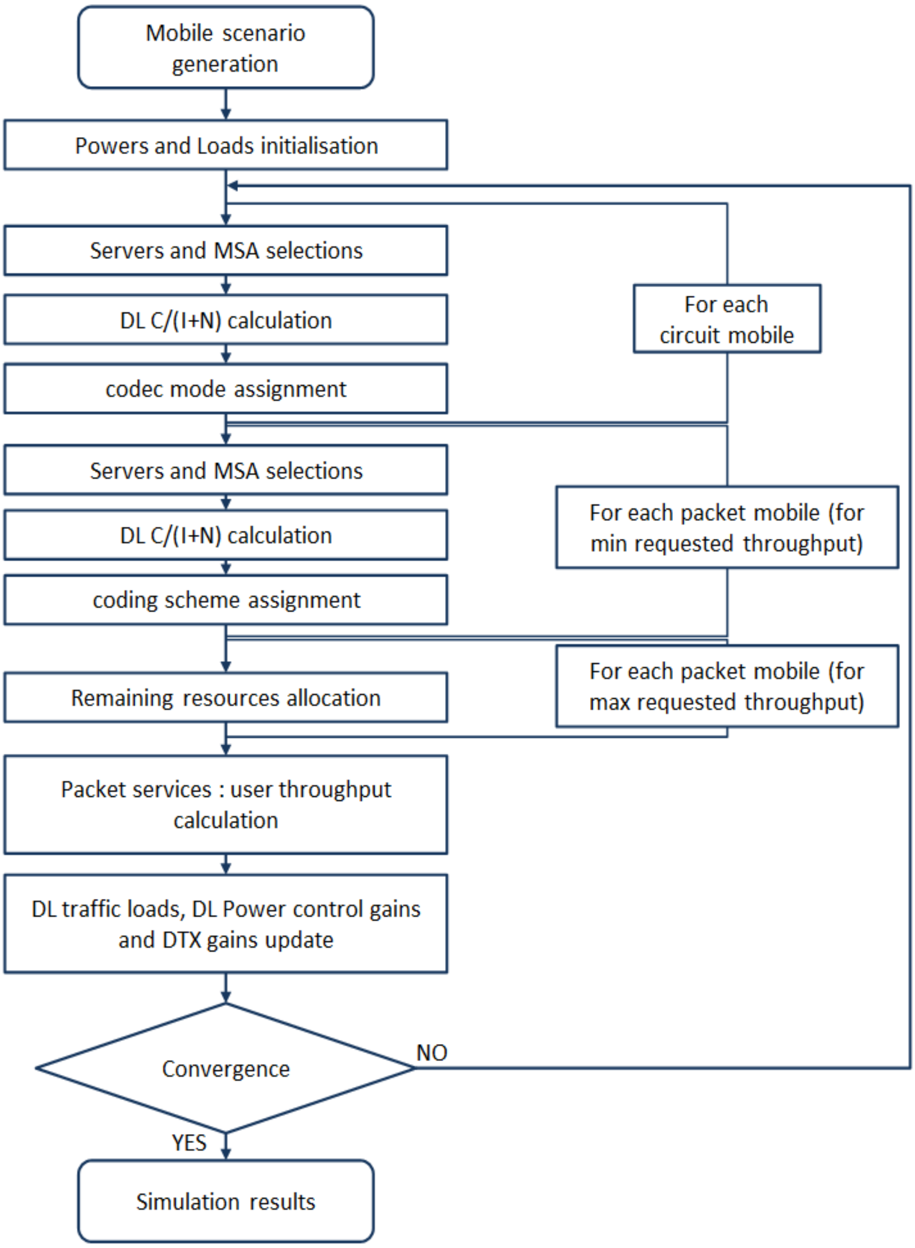


Figure 6.2: GSM simulation algorithm

For each simulation, the simulation process,

1. Sets initial values for the following parameters:
   a. Cell traffic loads for each MSA and transmitter are set to their average current value in the transmitters table (one traffic load value per subcell).
   b. Random drawing of shadowing losses following C and C/I standard deviations set per clutter class.

For each iteration k, the simulation process

2. For each circuit-switched mobile
   a. Determines the server and the MSA to which the circuit-switched mobile is attached.
   b. Determines the downlink C/(I+N) for each of these mobiles as explained in "Carrier-to-Interference Ratio Calculation" on page 114.
   c. Determines MSA codec modes at the mobile as explained in "Calculations Based on C/(I+N)" on page 131 part of "CQI Calculation With Ideal Link Adaptation" on page 131.
   d. Perform power control.

   See detailed information in "Servers Selection" on page 434 and "Codec Mode Assignment and DL Power Control" on page 435.

3. **For each packet-switched mobile**
   a. Determines the server and the MSA to which the packet-switched mobile is attached.
   b. Determines the downlink C/(I+N) for each of these mobiles as explained in "Carrier-to-Interference Ratio Calculation" on page 114.
   c. Determines MSA coding scheme at the mobile as explained in "Calculations Based on C/(I+N)" on page 122 part of "Coding Scheme Selection and Throughput Calculation With Ideal Link Adaptation" on page 122.
   d. Evaluates the number of necessary timeslots to reach the minimum throughput demand (defined in the requested service) of the users randomly ranked.
   e. Perform power control.

   See detailed information in "Servers Selection" on page 434 and "Coding Scheme Assignment, Throughput Evaluation and DL Power Control" on page 435.
4. Equally shares the remaining resources to packet-switched users which did not reach their maximum throughput demands. Resources and throughputs are finally assigned to each packet-switched user.

   See detailed information in "Codec Mode Assignment and DL Power Control" on page 435.
5. Updates the traffic loads, Half-Rate traffic ratios, DL power control gains and DTX gains of all the subcells according to the resources in use and the total resources.

   See detailed information in "Subcell Traffic Load Management" on page 436, "Half-Rate Traffic Ratio Management" on page 436, "DL Power Control Gain Management" on page 437and "DTX Gain Management" on page 437.
6. Performs the convergence test to see whether the differences between the current and the new loads are within the convergence thresholds.

   The convergence criteria are evaluated at the end of each iteration *k*, and can be written as follows:

$$\Delta TL_{DL-GSM}^{Subcell_i}\Big|_k = \underset{All\ Subcell_i}{Max}\left(TL_{DL-GSM}^{Subcell_i}\Big|_k - TL_{DL-GSM}^{Subcell_i}\Big|_{k-1}\right)$$

   If $\Delta TL_{DL-GSM}^{Subcell_i}\Big|_{Req}$ is the simulation convergence thresholds defined when creating the simulation, **9955** stops the simulation in the following cases.

   Convergence: Simulation has converged between iteration *k - 1* and *k* if: $\Delta TL_{DL-GSM}^{Subcell_i}\Big|_k \le \Delta TL_{DL-GSM}^{Subcell_i}\Big|_{Req}$.

   No convergence: Simulation has not converged even after the last iteration, i.e., *k* = Max Number of Iterations defined when creating the simulation, if: $\Delta TL_{DL-GSM}^{Subcell_i}\Big|_k > \Delta TL_{DL-GSM}^{Subcell_i}\Big|_{Req}$.
7. Repeats the above steps (from step 2.) for the iteration k+1 using the new calculated loads as the current loads until convergence.

6.1.2.5.3 Servers Selection

For a given network, the service areas of each transmitter are evaluated in the same way than an HCS server study with 0 dB margin. In other words, each pixel, is covered by the best server of each HCS layer, assuming the received signal strength is greater than the reception threshold defined on that layer.

In addition to the coverage condition above, for a given mobile distribution, a mobile might be served by a transmitter if its mobility (as assigned by **9955** at the beginning of the simulation) does not exceed the maximum speed permitted on that layer.

Finally the frequency band(s) in use in the transmitter have to be supported by the user terminal.

In none of these conditions are fulfilled, the mobile is rejected with the condition "No Coverage".

If these conditions are fulfilled, as a result, each mobile then has a list of potential servers, each server being on a different HCS layer. For each mobile list, **9955** sorts the potential servers according to their HCS layer priority in decreasing order.

On the very first iteration of the simulation, the mobile selects the highest priority transmitter. During the iterative process, if the mobile is regularly rejected from the highest priority transmitter, it will select the second highest priority transmitter and so on, until convergence.

In addition, if the mobile is rejected from a layer, even after convergence, the algorithm will try to attach this mobile to a lower priority layer until no solution can be found.

6.1.2.5.4 Codec Mode Assignment and DL Power Control

Two types of services can be assigned to users: circuit-switched and packet-switched ones. The network has been set up and dimensioned in order to first serve circuit services, and then to serve packet services with the remaining resources.

When serving a circuit-switched user, depending on the computed radio conditions at the server location, a codec mode is assigned to a user. Depending on this codec mode, the user will use either an entire timeslot (any AMR, EFR or FR codec mode) or half a timeslot (HR codec mode).

As explained in "MSA Definition" on page 432, the resource element assigned to a mobile station is an MSA. Depending on the assigned MSA, the level of quality at the mobile might be different, and consequently, its served codec mode so as the required number of timeslots.

Assuming a server is selected for each mobile, several MSAs are candidate. For each candidate MSA, a codec mode study is run, using the computed C/(I+N) and based on the user terminal and mobility (See "Calculations Based on C/(I+N)" on page 131 for more information). For each MSA, a codec mode is obtained. For each mobile, the list of candidate codec modes is saved.

At the beginning of a simulation iteration, no traffic is attached to MSAs. Their load starts from 0 and is increased as traffic increases and mobiles are attached to them. For a given user, within his MSA list, the MSA having currently the lowest load is selected and, as a consequence, the load of this MSA is now increased. The effect of this mechanism results in a load balancing of MSAs within a transmitter.

When MSAs are almost full, **9955** selects the MSAs the most optimised in term of timeslot occupancy. As an example, to optimise the resource allocation, a codec mode costing half a timeslot might be chosen instead of a codec mode costing an entire timeslot in the case the MSA with the lowest cost would have been chosen.

This mechanism is then reproduced for all the users requesting a circuit-switched service.

For each MSA *k*, the assigned codec mode *i* corresponds to a quality target : $(C/I)^{i}_{Target}$. Due to the radio conditions, and using the victim max power, a $(C/I)^{k}_{Max}$ is obtained.

If $(C/I)^{k}_{Max} < (C/I)^{i}_{Target}$, no codec mode can be served and the mobile is rejected with the condition "No Service".

If $(C/I)^{k}_{Max} > (C/I)^{i}_{Target}$, the corresponding codec mode is assigned to the mobile. If the MSA is on the BCCH, no power control is applied. For any other TRX type, **9955** evaluates the minimum required power P^{k}_{Min} in order to reduce the quality at the user's terminal to $(C/I)^{i}_{Target}$ for the assigned MSA *k*.

To summarise, at this step, each circuit-switched user is assigned a MSA, a codec mode, a corresponding number of timeslots (0.5 or 1) and a corresponding minimum required power to get the $(C/I)^{i}_{Target}$ of the served MSA.

Then, if the user has been dropped as inactive at the beginning of the simulation, his corresponding number of timeslots is consumed but no DL power is considered for this specific user. Inactive users only participate in the timeslot management but do not affect DL power.

Finally, if the user has been dropped as active at the beginning of the simulation, both timeslots and powers have to be considered to make him connected.

6.1.2.5.5 Coding Scheme Assignment, Throughput Evaluation and DL Power Control

After having served the circuit traffic over one iteration, the algorithm now tries to serve packet-switched traffic.

When serving a packet-switched user, depending on the computed radio conditions at the server location, a coding scheme is assigned to a user and a throughput per timeslot is obtained. Then some timeslots are assigned to each packet-switched service user in order to obtain a throughput between the min and the max DL throughput demand per user defined in the considered service properties.

As explained in "MSA Definition" on page 432, the resource element assigned to a mobile station is an MSA. Depending on the assigned MSA, the level of quality at the mobile might be different, and consequently, its served coding scheme so as the required number of timeslots to get a certain throughput demand. For packet-switched traffic, the timeslot Assignment is realised in two steps. In the first step, **9955** tries to allocate the minimum throughput demand of the service. In the second step, using remaining resources (timeslots), **9955** tries to allocate more throughput up to the maximum throughput demand of the service. If a user cannot get its minimum throughput demand for insufficient number of available timeslots, the user is rejected with the condition "Resource Saturation".

Assuming a server is selected for each mobile, several MSAs are candidate. For each candidate MSA, a coding scheme study is run, using the computed C/(I+N) and based on the user terminal and mobility (See "Calculations Based on C/(I+N)" on page 122 for more information). For each MSA, a coding scheme is obtained, from which we get a throughput per timeslot. As explained in "Packet Throughput and Quality Analysis: Max Application Throughput (kbps)" on page 127, the maximum of timeslots the user can benefit is the minimum between the number of DL timeslots defined in the selected terminal and service. Considering the minimum DL throughput demand for the service, one can estimate how many timeslots are needed to get that throughput on each MSA. Then, **9955** only keeps the MSAs for which this number of timeslots is lower than the number of timeslots supported (see above) and for which there is enough remaining timeslots. Then, for each mobile, the list of candidate coding schemes is saved.

For a given user, within his MSA list, the MSA having currently the lowest load is selected and, as a consequence, the load of this MSA is now increased. In the same way than for circuit traffic, the effect of this mechanism results in a load balancing of MSAs within a transmitter.

This mechanism is then reproduced for all the users requesting a packet-switched service. At this step, each packet-switched service has a coding scheme and, ideally, is supposed to be served his DL minimum throughput demand.

The second step of resources allocation for packet-switched traffic is to share the remaining resources between connected users in order they get their maximum throughput demand. As an example, let's imagine than a MSA is already occupied as follows:

- 2 TS for circuit-switched service users (3 users : 2 HR codec modes + 1 FR codec mode)
- 2.4 TS for packet-switched service users after the first step (2 users).

If this MSA is defined over a TCH subcell, its capacity is 8 TS. In other words, 4.4 TS have been used, and 3.6 TS remain. The two packet-switched users have obtained their minimum throughput demand. In order to reach their maximum throughput demand, the remaining TS are equally shared between the two connected users: 1.8 TS per user. If the first user can get his maximum throughput demand with only 1.5 TS, the remaining 0.3 TS will be able to be used by the user. As a consequence, this second user could benefit of 2.1 TS in order to get his maximum demand. If, finally, he only needs 1.3 TS to get this demand, 0.8 TS remain unused for that MSA.

This mechanism of equally share of remaining resources is then applied for all the connected packet-switched service users over all their MSAs.

For each MSA *k*, the assigned coding scheme *j* corresponds to a quality target : $(C/I)^j_{Target}$. Due to the radio conditions, and using the victim max power, a $(C/I)^k_{Max}$ is obtained.

If $(C/I)^k_{Max} < (C/I)^j_{Target}$, no coding scheme can be served and the mobile is rejected with the condition "No Service".

If $(C/I)^k_{Max} > (C/I)^j_{Target}$, the corresponding coding scheme is assigned to the mobile. If the MSA is on the BCCH, no power control is applied. For any other TRX type, **9955** evaluates the minimum required power P^k_{Min} in order to reduce the quality at the user's terminal to $(C/I)^j_{Target}$ for the assigned MSA *k*.

To summarise, at this step, each packet-switched user is assigned a MSA, a coding scheme, a corresponding number of timeslots (which might not be an integer value) and a corresponding minimum required power to get the $(C/I)^j_{Target}$ of the served MSA.

6.1.2.5.6 Subcell Traffic Load Management

When circuit-switched and packet-switched traffic have been served or rejected, **9955** performs an update on several parameters. The first parameter to be updated is the subcell traffic load. Considering that subcell load is a value which is common per traffic pool (e.g. BCCH and TCH subcells belong to the same traffic pool because they are in charge of the same traffic area), the number of timeslots necessary to connect the traffic have to be summed up over the several MSAs over a same traffic pool.

For the traffic pool TP_i, the subcell traffic load is computed as follows:

$$TL_{TP_i} = \frac{\sum_{MSA_{TP_i}} TS\ used}{\sum_{MSA_{TP_i}} TS\ available}$$ where the number of TS available for a BCCH subcell is 7 and 8 for any other subcell.

The traffic load value is then assigned to all the subcells of a same traffic pool.

6.1.2.5.7 Half-Rate Traffic Ratio Management

The second parameter at the end of an iteration is the Half-rate traffic ratio. This is the percentage of half-rate voice traffic in the subcell. This value is used to calculate the number of timeslots required to respond to the voice traffic demand and is evaluated per traffic pool. This value referring to voice traffic only, circuit-switched users only are taken into account in its evaluation.

$$HR\ RATIO_{TP_i} = \frac{\sum_{MSA_{TP_i}} HR\ users}{\sum_{MSA_{TP_i}} users}$$. $\sum_{MSA_{TP_i}} users$ represents HR and FR circuit-switched service users.

The Half-Rate traffic ratio is then assigned to all the subcells of a same traffic pool.

6.1.2.5.8 DL Power Control Gain Management

At the end of each iteration, the subcell DL power control gain is evaluated by taking into account all the connected users:

- active and inactive circuit-switched service users (assuming each inactive user does not cost any DL power but only some timeslots)
- all packet users

From the minimum required powers evaluated at the end of "Codec Mode Assignment and DL Power Control" on page 435 and "Coding Scheme Assignment, Throughput Evaluation and DL Power Control" on page 435 in order to get respectively the appropriate codec modes and coding schemes without any excess of unneeded power, an average minimum required power is obtained for each mobile connected to the subcell *S* as follows:

$$\frac{\sum_{i \in S} P_{Min}^{k_i} \times TS_i}{\sum_i TS_i} = P_{Moy}\big|_S$$ where *i* are the mobiles connected to the subcell S, over its MSAs

The ratio $\frac{P_{Max}|_S}{P_{Moy}|_S}$ (in dB), where $P_{Max}|_S$ is the max power of the considered subcell, represents the mean power control gain, due to active and inactive users, which can be assigned to the subcell.

It is essential to note that there is no power control on the BCCH and, consequently, the mean power control gain on the BCCH is 0.

6.1.2.5.9 DTX Gain Management

A certain gain representing inactive circuit-switched service users has also to be evaluated. In "DL Power Control Gain Management" on page 437, the mean DL power control gain concerns both active and inactive users. The DTX gain models the fact that inactive circuit-switched users, even if they are connected to the network, do not produce the same level of interference than active circuit-switched users.

From the minimum required powers evaluated at the end of "Codec Mode Assignment and DL Power Control" on page 435 in order to get the appropriate codec modes without any excess of unneeded power, an average minimum required power is obtained for each circuit-switched active mobile connected to the subcell *S* as follows:

$$\frac{\sum_{i_{active} \in S} P_{Min}^{k_{i_{active}}} \times TS_{i_{active}}}{\sum_{i_{active}} TS_{i_{active}}} = P_{Moy}\big|_{S_{active}}$$ where i_{active} are the circuit-switched active mobiles connected to the subcell S, over its MSAs

The ratio $\frac{P_{Moy}|_S}{P_{Moy}|_{S_{active}}}$ (in dB), where $P_{Moy}|_S$ is average requested power defined in "DL Power Control Gain Management" on page 437 above, represents the DTX gain, due to circuit-switched active users, which can be assigned to the subcell.

6.1.2.5.10 GSM Simulation Results

At the end of the simulations, an active user can be connected in DL if:

- he has a serving cell assigned,
- For a circuit-switched (resp. packet-switched) service, he has a codec mode (resp. coding scheme) corresponding to his activity status,
- he is not rejected due to resource saturation.

If a user is rejected during server determination, the cause of rejection is "No Coverage". If a user is rejected because quality is too low to obtain any codec mode or coding scheme, the cause of rejection is "No Service". If a user is rejected because he cannot be allocated a sufficient number of resources to obtain its codec mode or coding scheme, the cause of rejection is "Resource Saturation," i.e., all of the cell's resources were used up by other users.

Considering only the connected traffic at the end of the GSM part of the simulation process, the main results obtained are:

- Subcell traffic loads
- DL Power control gains
- DTX gains
- Half-rate traffic ratios

Subcell traffic loads and DL Power control gains can be used as input for GSM quality-based coverage predictions.

Chapter 7

CDMA2000 Networks

This chapter describes CDMA2000 calculations.

In this chapter, the following are explained:

- "General Prediction Studies" on page 441
- "Definitions and Formulas" on page 444
- "Active Set Management" on page 461
- "Simulations" on page 462
- "CDMA2000 Prediction Studies" on page 495
- "Automatic Neighbour Allocation" on page 525
- "PN Offset Allocation" on page 532
- "Automatic GSM-CDMA Neighbour Allocation" on page 539

7 CDMA2000 Networks

7.1 General Prediction Studies

7.1.1 Calculation Criteria

Three criteria can be studied in point analysis (*Profile* tab) and in common coverage studies. Study criteria are detailed in the table below:

Study criteria	Formulas
Signal level (P_{rec}) in dBm	Signal level received from a transmitter on a carrier (cell) $P_{rec}(ic) = EIRP(ic) - L_{path} - M_{Shadowing-model} - L_{Indoor} + G_{term} - L_{term}$
Path loss (L_{path}) in dBm	$L_{path} = L_{model} + L_{ant_{Tx}}$
Total losses (L_{total}) in dBm	$L_{total} = (L_{path} + L_{Tx} + L_{term} + L_{indoor} + M_{Shadowing-model}) - (G_{Tx} + G_{term})$

where,

EIRP is the effective isotropic radiated power of the transmitter,

ic is a carrier number,

L_{model} is the loss on the transmitter-receiver path (path loss) calculated by the propagation model,

$L_{ant_{Tx}}$ is the transmitter antenna attenuation (from antenna patterns),

$M_{Shadowing-model}$ is the shadowing margin. This parameter is taken into account when the option “Shadowing taken into account” is selected,

L_{Indoor} are the indoor losses, taken into account when the option “Indoor coverage” is selected,

L_{term} are the receiver losses,

G_{term} is the receiver antenna gain,

G_{Tx} is the transmitter antenna gain,

L_{Tx} is the transmitter loss ($L_{Tx} = L_{total-DL}$). For information on calculating transmitter loss, "UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents" on page 26.

- For CDMA2000 1xRTT systems, $EIRP(ic) = P_{pilot}(ic) + G_{Tx} - L_{Tx}$ (where, $P_{pilot}(ic)$ is the cell pilot power).
- For CDMA2000 1xEV-DO systems, $EIRP(ic) = P_{max}(ic) + G_{Tx} - L_{Tx}$ (where $P_{max}(ic)$ is the maximum cell power).
- It is also possible to analyse the best carrier. In this case, **9955** displays the best signal level received from a transmitter. Therefore, if the network consists of 1xRTT and 1xEV-DO carriers, **9955** takes the highest power of both cells for each transmitter (i.e. the highest value between the pilot power of the 1xRTT cell and the maximum power of the 1xEV-DO cell) to calculate the received signal level.
- **9955** considers that G_{term} and L_{term} equal zero.

7.1.2 Point Analysis

7.1.2.1 Profile Tab

9955 displays either the signal level received from the selected transmitter on a carrier ($P_{rec}(ic)$), or the highest signal level received from the selected transmitter on the best carrier.

- For a selected transmitter, it is also possible to study the path loss, L_{path}, or the total losses, L_{total}. Path loss and total losses are the same on any carrier.

7.1.2.2 Reception Tab

Analysis provided in the Reception tab is based on path loss matrices. So, you can study reception from TBC transmitters for which path loss matrices have been computed on their calculation areas.

For each transmitter, **9955** displays either the signal level received on a carrier, ($P_{rec}(ic)$), or the highest signal level received on the best carrier.

Reception bars are displayed in a decreasing signal level order. The maximum number of reception bars depends on the signal level received from the best server. Only reception bars of transmitters whose signal level is within a 30 dB margin from the best server can be displayed.

- For a selected transmitter, it is also possible to study the path loss, L_{path}, or the total losses, L_{total}. Path loss and total losses are the same on any carrier.
- You can use a value other than 30 dB for the margin from the best server signal level, for example a smaller value for improving the calculation speed. For more information on defining a different value for this margin, see the *Administrator Manual*.

7.1.3 Coverage Studies

For each TBC transmitter, Txi, **9955** determines the selected criterion on each bin inside the Txi calculation area. In fact, each bin within the Txi calculation area is considered as a potential (fixed or mobile) receiver.

Coverage study parameters to be set are:

- The study conditions in order to determine the service area of each TBC transmitter,
- The display settings to select how to colour service areas.

7.1.3.1 Service Area Determination

9955 uses parameters entered in the *Condition* tab of the coverage study property dialogue to predetermine areas where it will display coverage.

We can distinguish three cases:

7.1.3.1.1 All Servers

The service area of Txi corresponds to the bins where:

$$Minimum\ threshold \le P_{rec}^{Txi}(ic)(or\ L_{total}^{Txi}\ or\ L_{path}^{Txi}) < Maximum\ threshold$$

7.1.3.1.2 Best Signal Level and a Margin

The service area of Txi corresponds to the bins where:

$$Minimum\ threshold \le P_{rec}^{Txi}(ic)(or\ L_{total}^{Txi}\ or\ L_{path}^{Txi}) < Maximum\ threshold$$

And

$$P_{rec}^{Txi}(ic) \ge \underset{j \ne i}{Best}\,(P_{rec}^{Txj}(ic)) - M$$

M is the specified margin (dB).

Best function: considers the highest value.

- If the margin equals 0 dB, **9955** will consider bins where the signal level received from *Txi* is the highest.
- If the margin is set to 2 dB, **9955** will consider bins where the signal level received from *Txi* is either the highest or 2dB lower than the highest.
- If the margin is set to -2 dB, **9955** will consider bins where the signal level received from *Txi* is 2dB higher than the signal levels from transmitters, which are 2nd best servers.

7.1.3.1.3 Second Best Signal Level and a Margin

The service area of Txi corresponds to the bins where:

$$Minimum\ threshold \le P_{rec}^{Txi}(ic)(or\ L_{total}^{Txi}\ or\ L_{path}^{Txi}\ ) < Maximum\ threshold$$

And

$$P_{rec}^{Txi}(ic) \ge 2^{nd}\underset{j \ne i}{Best}\ (P_{rec}^{Txj}(ic)) - M$$

M is the specified margin (dB).

2nd Best function: considers the second highest value.

- If the margin equals 0 dB, **9955** will consider bins where the signal level received from *Txi* is the second highest.
- If the margin is set to 2 dB, **9955** will consider bins where the signal level received from *Txi* is either the second highest or 2dB lower than the second highest.
- If the margin is set to -2 dB, **9955** will consider bins where the signal level received from *Txi* is 2dB higher than the signal levels from transmitters, which are 3rd best servers.

7.1.3.2 Coverage Display

7.1.3.2.1 Plot Resolution

Prediction plot resolution is independent of the matrix resolutions and can be defined on a per study basis. Prediction plots are generated from multi-resolution path loss matrices using bilinear interpolation method (similar to the one used to evaluate site altitude).

7.1.3.2.2 Display Types

It is possible to display the transmitter service area with colours depending on any transmitter attribute or other criteria such as:

Signal Level (in dBm, dBµV, dBµV/m)

9955 calculates signal level received from the transmitter on each bin of each transmitter service area. A bin of a service area is coloured if the signal level is greater than or equal to the defined minimum thresholds (bin colour depends on signal level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as transmitter service areas. Each layer shows the different signal levels available in the transmitter service area.

Best Signal Level (in dBm, dBµV, dBµV/m)

9955 calculates signal levels received from transmitters on each bin of each transmitter service area. Where other service areas overlap the studied one, **9955** chooses the highest value. A bin of a service area is coloured if the signal level is greater than or equal to the defined thresholds (the bin colour depends on the signal level). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the signal level from the best server exceeds a defined minimum threshold.

Path Loss (dB)

9955 calculates path loss from the transmitter on each bin of each transmitter service area. A bin of a service area is coloured if path loss is greater than or equal to the defined minimum thresholds (bin colour depends on path loss). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as service areas. Each layer shows the different path loss levels in the transmitter service area.

Total Losses (dB)

9955 calculates total losses from the transmitter on each bin of each transmitter service area. A bin of a service area is coloured if total losses is greater than or equal to the defined minimum thresholds (bin colour depends on total losses). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as service areas. Each layer shows the different total losses levels in the transmitter service area.

Best Server Path Loss (dB)

9955 calculates signal levels received from transmitters on each bin of each transmitter service area. Where other service areas overlap the studied one, **9955** determines the best transmitter and evaluates path loss from the best transmitter. A bin of a service area is coloured if the path loss is greater than or equal to the defined thresholds (bin colour depends on path loss). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the path loss from the best server exceeds a defined minimum threshold.

Best Server Total Losses (dB)

9955 calculates signal levels received from transmitters on each bin of each transmitter service area. Where service areas overlap the studied one, **9955** determines the best transmitter and evaluates total losses from the best transmitter. A bin of a service area is coloured if the total losses is greater than or equal to the defined thresholds (bin colour depends on total losses). Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the total losses from the best server exceed a defined minimum threshold.

Number of Servers

9955 evaluates how many service areas cover a bin in order to determine the number of servers. The bin colour depends on the number of servers. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the number of servers is greater than or equal to a defined minimum threshold.

Cell Edge Coverage Probability (%)

On each bin of each transmitter service area, the coverage corresponds to the pixels where the signal level from this transmitter fulfils signal conditions defined in Conditions tab with different Cell edge coverage probabilities. There is one coverage area per transmitter in the explorer.

Best Cell Edge Coverage Probability (%)

On each bin of each transmitter service area, the coverage corresponds to the pixels where the best signal level received fulfils signal conditions defined in Conditions tab. There is one coverage area per cell edge coverage probability in the explorer.

7.2 Definitions and Formulas

7.2.1 Parameters Used for CDMA2000 1xRTT Modelling

7.2.1.1 Inputs

This table lists simulation and prediction inputs (calculation options, quality targets, active set management conditions, etc.)

Name	Value	Unit	Description
F_{ortho}	Clutter parameter	None	Orthogonality factor
F_{MUD}^{Tx}	Site equipment parameter	None	MUD factor
ic	Frequency band parameter	None	Carrier number
Q_{pilot}^{req}	$Q_{pilot}^{req}(txi, ic) + \Delta Q_{pilot}^{req}$	None	Active set upper threshold (used to determine the best server in the active set)
Q_{pilot}^{min}	$Q_{pilot}^{min}(txi, ic) + \Delta Q_{pilot}^{min}$	None	Active set lower threshold (used to determine other members of the active set)

Name	Value	Unit	Description
$Q_{pilot}^{req}(txi, ic)$	*Min. Ec/I0* - Cell parameter	None	Minimum Ec/I0 required from the cell to be the best server in the active set
$Q_{pilot}^{min}(txi, ic)$	*T_Drop* - Cell parameter	None	Minimum Ec/I0 required from the cell not to be rejected from the active set
ΔQ_{pilot}^{req}	*Delta Min. Ec/I0* - Mobility parameter	None	Variation of the minimum Ec/I0 required from the cell to be the best server in the active set
ΔQ_{pilot}^{min}	*Delta T_Drop* - Mobility parameter	None	Variation of the minimum Ec/I0 required from the cell not to be rejected from the active set
$(Q_{req}^{DL})_{FCH}$	$\left(\frac{E_b}{N_t}\right)_{req}^{FCH-DL}$ (Service, Terminal, Mobility) parameter	None	Eb/Nt target for FCH channel on downlink
$(Q_{req}^{DL})_{SCH}$	$\left(\frac{E_b}{N_t}\right)_{req}^{SCH-DL}$ (Service, Terminal, Mobility, SCH rate multiple) parameter	None	Eb/Nt target for SCH channel on downlink
$(Q_{req}^{UL})_{FCH}$	$\left(\frac{E_b}{N_t}\right)_{req}^{FCH-UL}$ (Service, Terminal, Mobility) parameter	None	Eb/Nt target for FCH channel on uplink
$(Q_{req}^{UL})_{SCH}$	$\left(\frac{E_b}{N_t}\right)_{req}^{SCH-UL}$ (Service, Terminal, Mobility, SCH rate multiple) parameter	None	Eb/Nt target for SCH channel on uplink
$N_{max}^{CE-UL}(N_l)$	Site parameter	None	Number of channel elements available for a site on uplink
$N_{max}^{CE-DL}(N_l)$	Site parameter	None	Number of channel elements available for a site on downlink
$N^{CE-UL}(N_l)$	Simulation result	None	Number of channel elements of a site consumed by users on uplink
$N^{CE-DL}(N_l)$	Simulation result	None	Number of channel elements of a site consumed by users on downlink
$N^{Overhead-CE-UL}$	Site equipment parameter	None	Number of channel elements used by the cell for common channels on uplink
$N^{Overhead-CE-DL}$	Site equipment parameter	None	Number of channel elements used by the cell for common channels on downlink
$N^{FCH-CE-UL}$	(Terminal, site equipment) parameter	None	Number of channel elements used for FCH on uplink
$N^{FCH-CE-DL}$	(Terminal, site equipment) parameter	None	Number of channel elements used for FCH on downlink
$N_{max}^{Codes}(txi, ic)$	Simulation constraint	None	Maximum number of Walsh codes available per cell (128)
$N^{Codes}(txi, ic)$	Simulation result	None	Number of Walsh codes used by the cell
NF_{term}	Terminal parameter	None	Terminal Noise Figure
NF_{Tx}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	Transmitter Noise Figure
K	$1.38\ 10^{-23}$	J/K	Boltzman constant
T	293	K	Ambient temperature
W	1.23 MHz	Hz	Spreading Bandwidth
$NR_{inter-technology}^{Tx,DL}$	Cell parameter	None	Inter-technology downlink noise rise

Name	Value	Unit	Description
$NR^{Tx, UL}_{inter-technology}$	Cell parameter	None	Inter-technology uplink noise rise
$RF(ic, ic_{adj})$	Network parameter If not defined, it is assumed that there is no inter-carrier interference	None	Interference reduction factor between two adjacent carriers ic and ic_{adj}
$ICP^{Tx, m}_{ic_i, ic}$	Network parameter If not defined, it is assumed that there is no inter-technology downlink interferences due to external transmitters	None	Inter-technology Channel Protection between the signal transmitted by Tx and received by m assuming the frequency gap between ic_i (external network) and ic
X^{UL}_{max}	Simulation constraint (global parameter or cell parameter)	%	Maximum uplink load factor
$\%Power^{DL}_{max}$	Simulation constraint (global parameter or cell parameter)	%	Maximum percentage of used power
N^{Tx}_{0}	$NF_{Tx} \times K \times T \times W \times NR^{Tx, UL}_{inter-technology}$	W	Thermal noise at transmitter
N^{Term}_{0}	$NF_{Term} \times K \times T \times W \times NR^{Tx, DL}_{inter-technology}$	W	Thermal noise at terminal
R_c	W	bps	Chip rate
$f^{UL}_{rake\ efficiency}$	Equipment parameter	None	Uplink rake receiver efficiency factor
$f^{DL}_{rake\ efficiency}$	Terminal parameter	None	Downlink rake receiver efficiency factor
$Frate^{DL}_{SCH}$	Simulation result	None	SCH rate factor (drawn following the SCH probabilities of the service)
R^{DL}_{FCH}	Terminal parameter	bps	Downlink FCH nominal rate
R^{DL}_{SCH}	$R^{DL}_{FCH} \times Frate^{DL}_{SCH}$	bps	Downlink SCH bit rate
$Frate^{UL}_{SCH}$	Simulation result	None	SCH rate factor (drawn following the SCH probabilities of the service)
R^{UL}_{FCH}	Terminal parameter	bps	Uplink FCH nominal rate
R^{UL}_{SCH}	$R^{UL}_{FCH} \times Frate^{UL}_{SCH}$	bps	Uplink SCH bit rate
G^{FCH-DL}_{p}	$\frac{W}{R^{DL}_{FCH}}$	None	Downlink service processing gain on FCH
G^{SCH-DL}_{p}	$\frac{W}{R^{DL}_{SCH}}$	None	Downlink service processing gain on SCH
G^{FCH-UL}_{p}	$\frac{W}{R^{UL}_{FCH}}$	None	Uplink service processing gain on FCH
G^{SCH-UL}_{p}	$\frac{W}{R^{UL}_{SCH}}$	None	Uplink service processing gain on SCH
AF^{DL}_{FCH}	Service parameter	None	Downlink activity factor on FCH
AF^{UL}_{FCH}	Service parameter	None	Uplink activity factor on FCH
$P_{Sync}(txi, ic)$	Cell parameter	W	Cell synchronisation channel power
$P_{paging}(txi, ic)$	Cell parameter	W	Cell other common channels (except CPICH and SCH) power
$P_{pilot}(txi, ic)$	Cell parameter	W	Cell pilot power
$P_{max}(txi, ic)$	Cell parameter	W	Maximum cell power

Name	Value	Unit	Description
$M_{pooling}(txi, ic)$	Cell parameter	dB	Maximum amount of power reserved for pooling
P_{FCH}^{min}	Service parameter	W	Minimum power allowed for FCH
P_{FCH}^{max}	Service parameter	W	Maximum power allowed for FCH
P_{SCH}^{min}	Service parameter	W	Minimum power allowed for SCH
P_{SCH}^{max}	Service parameter	W	Maximum power allowed for SCH
$P_{FCH}(txi, ic, tch)$	Simulation result including the term $AF_{FCH}^{DL}(Serv)$	W	Cell FCH power for a traffic channel on carrier ic
$P_{FCH}(txi, ic)$	$\sum\limits_{tch(FCH(ic))} P_{FCH}(txi, ic, tch)$	W	Total FCH power on carrier ic
$P_{SCH}(txi, ic, tch)$	Simulation result	W	Transmitter SCH power for a traffic channel on carrier ic
$P_{SCH}(txi, ic)$	$\sum\limits_{tch(SCH(ic))} P_{SCH}(ic, tch)$	W	Total SCH power on carrier ic
$P_{tx}(txi, ic)$	$P_{pilot}(txi, ic) + P_{Sync}(txi, ic) + P_{paging}(txi, ic) + P_{SCH}(txi, ic) + P_{FCH}(txi, ic)$	W	Transmitter total transmitted power on carrier ic
P_{term}^{min}	Terminal parameter	W	Minimum terminal power allowed
P_{term}^{max}	Terminal parameter	W	Maximum terminal power allowed
$P_{term}^{FCH}(ic)$	Simulation result including the term $AF_{FCH}^{UL}(Serv)$	W	Terminal FCH power transmitted in carrier ic
$P_{term}^{SCH}(ic)$	Simulation result	W	Terminal SCH power transmitted on carrier ic
ρ_{BTS}	BTS parameter	%	Percentage of BTS signal correctly transmitted
ρ_{term}	Terminal parameter	%	Percentage of terminal signal correctly transmitted
α	Clutter parameter	%	Percentage of pilot finger - percentage of signal received by the terminal pilot finger
G_{Tx}	Antenna parameter	None	Transmitter antenna gain
G_{Term}	Terminal parameter	None	Terminal gain
L_{Tx}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	Transmitter loss[a]
L_{body}	Service parameter	None	Body loss
L_{Term}	Terminal parameter	None	Terminal loss
L_{indoor}	Clutter (and, optionally, frequency band) parameter		Indoor loss
L_{path}	Propagation model result	None	Path loss
f	Terminal parameter	None	Number of fingers
p	Terminal parameter	%	Pilot power percentage
$M_{Shadowing-model}$	Result calculated from cell edge coverage probability and model standard deviation	None	Model Shadowing margin Only used in prediction studies
$M_{Shadowing-Ec/Io}$	Result calculated from cell edge coverage probability and Ec/I0 standard deviation	None	Ec/I0 Shadowing margin Only used in prediction studies

Name	Value	Unit	Description
$G^{DL}_{macro-diversity}$	$G^{DL}_{macro-diversity} = M^{npaths}_{Shadowing-Ec/Io} - M_{Shadowing-Ec/Io}$ n=2 or 3	None	DL gain due to availability of several pilot signals at the mobile [b].
$M_{Shadowing-(Eb/Nt)_{DL}}$	Result calculated from cell edge coverage probability and DL Eb/Nt standard deviation	None	DL Eb/Nt Shadowing margin Only used in prediction studies
$M_{Shadowing-(Eb/Nt)_{UL}}$	Result calculated from cell edge coverage probability and UL Eb/Nt standard deviation	None	UL Eb/Nt Shadowing margin Only used in prediction studies
$G^{UL}_{macro-diversity}$	$G^{UL}_{macro-diversity} = M^{npaths}_{Shadowing-(Eb/Nt)_{UL}} - M_{Shadowing-(Eb/Nt)_{UL}}$ n=2 or 3 Global parameter (default value)	None	UL quality gain due to signal diversity in soft handoff[c].
$E_{Shadowing}$	Simulation result	None	Random shadowing error drawn during Monte-Carlo simulation Only used in simulations
L_T	In prediction studies[d] For Ec/I0 calculation $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}}$ For DL Eb/Nt calculation $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{DL}}}{G_{Tx} \times G_{term}}$ For UL Eb/Nt calculation $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$ In simulations $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}}$	None	Transmitter-terminal total loss
$P_c(txi, ic)$	$\frac{P_{pilot}(txi, ic)}{L_T}$	W	Chip power received at terminal
$P_b^{FCH-DL}(txi, ic, tch)$	$\frac{P_{FCH}(txi, ic, tch)}{L_T}$	W	Bit received power at terminal for FCH on carrier ic
$P_b^{SCH-DL}(txi, ic, tch)$	$\frac{P_{SCH}(txi, ic, tch)}{L_T}$	W	Bit received power at terminal for SCH on carrier ic
$P_b^{DL}(txi, ic, tch)$	$P_b^{FCH-DL}(txi, ic, tch) + P_b^{SCH-DL}(txi, ic, tch)$	W	Bit received power at terminal for FCH+SCH on carrier ic
$P^{DL}_{tot}(txi, ic)$	$\frac{P_{tx}(txi, ic)}{L_T}$	W	Total received power at terminal from a transmitter on carrier ic
$P^{DL}_{traf}(txi, ic)$	$\sum_{tch(ic)} \frac{P_{FCH}(txi, ic) + P_{SCH}(txi, ic)}{L_T}$	W	Total power received at terminal from traffic channels of a transmitter on carrier ic
$P_b^{FCH-UL}(ic)$	$\frac{P^{FCH}_{term}}{L_T}$	W	Bit received power at transmitter for FCH on carrier *ic*
$P_b^{SCH-UL}(ic)$	$\frac{P^{SCH}_{term}}{L_T}$	W	Bit received power at transmitter for SCH on carrier *ic*
$P_b^{UL}(ic)$	$P_b^{FCH-UL}(ic) + P_b^{SCH-UL}(ic)$	W	Bit received power at transmitter for SCH+FCH on carrier *ic*
$P^{UL}_{tot}(ic)$	$P_b^{UL}(ic) + P_c^{UL}(ic) = \frac{P_b^{UL}(ic)}{(1-p)}$	W	Total power transmitted by the terminal on carrier ic
$P_c^{UL}(ic)$	$p \times P^{UL}_{tot}(ic)$	W	Chip received power at transmitter

Alcatel·Lucent

a. $L_{Tx} = L_{total-UL}$ *on uplink and* $L_{Tx} = L_{total-DL}$ *on downlink.* For information on calculating transmitter losses on uplink and downlink, see "UMTS, CDMA2000, TD-SCDMA, WiMAX, and LTE Documents" *on page 26*.

b. $M^{npaths}_{Shadowing-Ec/Io}$ *corresponds to the shadowing margin evaluated from the shadowing error probability density function (n paths) in case of downlink Ec/I0 modelling.*

c. $M^{npaths}_{Shadowing-(Eb/Nt)_{UL}}$ *corresponds to the shadowing margin evaluated from the shadowing error probability density function (n paths) in case of uplink soft handoff modelling.*

d. *In uplink prediction studies, only carrier power level is downgraded by the shadowing margin (*$M_{Shadowing-(Eb/Nt)_{UL}}$*). In downlink prediction studies, carrier power level and intra-cell interference are downgraded by the shadowing model (*$M_{Shadowing-(Eb/Nt)_{DL}}$ *or* $M_{Shadowing-Ec/Io}$*) while extra-cell interference level is not. Therefore,* $M_{Shadowing-(Eb/Nt)_{DL}}$ *or* $M_{Shadowing-Ec/Io}$ *is set to 1 in downlink extra-cell interference calculation.*

7.2.1.2 Ec/I0 Calculation

This table details the pilot quality (Q_{pilot} or Ec/Io) calculations.

Name	Value	Unit	Description
$I^{DL}_{intra}(txi, ic)$	$P^{DL}_{tot}(txi, ic)$	W	Downlink intra-cell interference at terminal on carrier *ic*
$I^{DL}_{extra}(ic)$	$\sum_{txj, j \neq i} P^{DL}_{tot}(txj, ic)$	W	Downlink extra-cell interference at terminal on carrier *ic*
$I^{DL}_{inter-carrier}(ic)$	$\frac{\sum_{txj, \forall j} P^{DL}_{tot}(txj, ic_{adj})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference at terminal on carrier *ic*
$I^{DL}_{inter-technology}(ic)$	$\sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic}}$	W	Downlink inter-technology interference at terminal on carrier *ic* [a]
$I^{DL}_{0}(ic)$	$I^{DL}_{intra}(txi, ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic) + N^{Term}_0$	W	Total received noise at terminal on carrier *ic* [b]
$Q_{pilot}(txi, ic) \Leftrightarrow \left(\frac{E_c}{I_0}\right)$	$\frac{\rho_{BTS} \times \alpha \times P_c(txi, ic)}{I^{DL}_0(ic)}$	None	Quality level at terminal on pilot for carrier *ic*

a. *In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.*

b. *In an active set,* N^{Term}_0 *is calculated for all its members with* Inter-technology downlink noise rise of the best server.

7.2.1.3 DL Eb/Nt Calculation

This table details calculations of downlink traffic channel quality (Q^{DL}_{tch} (*tch* could be FCH or SCH) or $\left(\frac{Eb}{Nt}\right)_{DL}$).

Name	Value	Unit	Description
$I^{DL}_{intra}(txi, ic)$	$(1 - \rho_{BTS} \times F_{ortho}) \times P^{DL}_{tot}(txi, ic)$	W	Downlink intra-cell interference at terminal on carrier *ic*
$I^{DL}_{extra}(ic)$	$\sum_{txj, j \neq i} P^{DL}_{tot}(txj, ic)$	W	Downlink extra-cell interference at terminal on carrier *ic*
$I^{DL}_{inter-carrier}(ic)$	$\frac{\sum_{txj, \forall j} P^{DL}_{tot}(txj, ic_{adj})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference at terminal on carrier *ic*

Name	Value	Unit	Description
$I^{DL}_{inter-technology}(ic)$	$\sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx,m}_{ic_i,ic}}$	W	Downlink inter-technology interference at terminal on carrier *ic* [a]
$N^{DL}_{tot}(ic)$	$I^{DL}_{intra}(ic) + I^{DL}_{extra}(ic) + I^{DL}_{inter-carrier}(ic) + I^{DL}_{inter-technology}(ic) + N^{Term}_0$	W	Total received noise at terminal on carrier *ic*
$Q^{DL}_{FCH}(txi, ic) \Leftrightarrow \left(\frac{E_b}{N_t}\right)^{DL}_{FCH}$	Without useful signal: $\frac{\rho_{BTS} \times P^{FCH-DL}_b(txi, ic, tch)}{N^{DL}_{tot}(ic) - (1 - F_{ortho}) \times \rho_{BTS} \times P^{DL}_b(txi, ic)} \times G^{FCH-DL}_p$ Total noise: $\frac{\rho_{BTS} \times P^{FCH-DL}_b(txi, ic, tch)}{N^{DL}_{tot}(ic)} \times G^{FCH-DL}_p$	None	Quality level at terminal on a traffic channel from one transmitter for a FCH channel on carrier ic [b]
$Q^{DL}_{FCH}(ic)$	$f^{DL}_{rake\ efficiency} \times \sum_{tx_k \in ActiveSet(FCH)} Q^{DL}_{FCH}(tx_k, ic)$	None	Quality level at terminal for FCH using carrier *ic* due to combination of all transmitters of the active set (Macro-diversity conditions).
$Q^{DL}_{SCH}(txi, ic) \Leftrightarrow \left(\frac{E_b}{N_t}\right)^{DL}_{SCH}$	Without useful signal: $\frac{\rho_{BTS} \times P^{SCH-DL}_b(txi, ic, tch)}{N^{DL}_{tot}(ic) - (1 - F_{ortho}) \times \rho_{BTS} \times P^{DL}_b(txi, ic)} \times G^{SCH-DL}_p$ Total noise: $\frac{\rho_{BTS} \times P^{SCH-DL}_b(txi, ic, tch)}{N^{DL}_{tot}(ic)} \times G^{SCH-DL}_p$	None	Quality level at terminal on a traffic channel from one transmitter for a SCH channel on carrier ic [c]
$Q^{DL}_{SCH}(ic)$	$f^{DL}_{rake\ efficiency} \times \sum_{tx_k \in ActiveSet(SCH)} Q^{DL}_{SCH}(tx_k, ic)$	None	Quality level at terminal for SCH using carrier *ic* due to combination of all transmitters of the active set (Macro-diversity conditions).
$(G^{DL}_{SHO})_{FCH}$	$\frac{Q^{DL}_{FCH}(ic)}{Q^{DL}_{FCH}(BestServer, ic)}$	None	Downlink soft handover gain for FCH channel on carrier ic
$(G^{DL}_{SHO})_{SCH}$	$\frac{Q^{DL}_{SCH}(ic)}{Q^{DL}_{SCH}(BestServer, ic)}$	None	Downlink soft handover gain for SCH channel on carrier ic
$P^{req}_{FCH}(txi, ic)$	$\frac{(Q^{DL}_{req})_{FCH}}{Q^{DL}_{FCH}(ic)} \times P_{FCH}(txi, ic)$	W	Required transmitter FCH traffic channel power to achieve Eb/Nt target at terminal on carrier ic
$P^{req}_{SCH}(txi, ic)$	$\frac{(Q^{DL}_{req})_{SCH}}{Q^{DL}_{SCH}(ic)} \times P_{SCH}(txi, ic)$	W	Required transmitter SCH traffic channel power to achieve Eb/Nt target at terminal on carrier ic
$P^{req}_{tch}(txi, ic)$	$P^{req}_{FCH}(txi, ic) + P^{req}_{SCH}(txi, ic)$	W	Required transmitter traffic channel power on carrier ic

a. *In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.*
b. *Calculation option may be selected in the Global parameters tab. The chosen option will be taken into account only in simulations. In point analysis and coverage studies, **9955** uses the option "Total noise" to evaluate DL and UL Eb/Nt.*
c. *Calculation option may be selected in the Global parameters tab. The chosen option will be taken into account only in simulations. In point analysis and coverage studies, **9955** uses the option "Total noise" to evaluate DL and UL Eb/Nt.*

7.2.1.4 UL Eb/Nt Calculation

This table details calculations of uplink traffic channel quality (Q^{UL}_{tch} (*tch* could be FCH or SCH) or $\left(\frac{Eb}{Nt}\right)_{UL}$).

Name	Value	Unit	Description
$I_{tot}^{UL_{intra}}(txi, ic)$	$\sum_{\substack{term \\ txi}} (P_b^{UL}(ic) + P_c^{UL}(ic))$	W	Total power received at transmitter from intra-cell terminals using carrier *ic*
$I_{tot}^{UL_{extra}}(txi, ic)$	$\sum_{\substack{term \\ txj, j \neq i}} (P_b^{UL}(ic) + P_c^{UL}(ic))$	W	Total power received at transmitter from extra-cell terminals using carrier *ic*
$I_{inter-carrier}^{UL}(txi, ic)$	$\dfrac{\sum_{\substack{term \\ txi, \forall i}} (P_b^{UL}(ic_{adj}) + P_c^{UL}(ic_{adj}))}{RF(ic, ic_{adj})}$	W	Uplink inter-carrier interference at terminal on carrier *ic*
$I_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL_{extra}}(txi, ic) + (1 - F_{MUD}^{Tx} \times \rho_{term}) \times I_{tot}^{UL_{intra}}(txi, ic) + I_{inter-carrier}^{UL}(txi, ic)$	W	Total received interference at transmitter on carrier *ic*
$N_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL}(txi, ic) + N_0^{tx}$	W	Total noise at transmitter on carrier *ic* (Uplink interference) [a]
$Q_{FCH}^{UL}(txi, ic) \Leftrightarrow \left(\frac{E_b}{N_t}\right)_{UL}$	Without useful signal: $\dfrac{\rho_{term} \times P_b^{FCH-UL}(ic)}{N_{tot}^{UL}(txi, ic) - (1 - F_{MUD}^{Tx}) \times \rho_{term} \times P_b^{UL}(ic)} \times G_p^{FCH-UL}$ Total noise: $\dfrac{\rho_{term} \times P_b^{FCH-UL}(ic)}{N_{tot}^{UL}(txi, ic)} \times G_p^{FCH-UL}$	None	Quality level at transmitter on a traffic channel for the FCH channel on carrier *ic* [b]
$Q_{SCH}^{UL}(txi, ic) \Leftrightarrow \left(\frac{E_b}{N_t}\right)_{UL}$	Without useful signal: $\dfrac{\rho_{term} \times P_b^{SCH-UL}(ic)}{N_{tot}^{UL}(txi, ic) - (1 - F_{MUD}^{Tx}) \times \rho_{term} \times P_b^{UL}(ic)} \times G_p^{SCH-UL}$ Total noise: $\dfrac{\rho_{term} \times P_b^{SCH-UL}(ic)}{N_{tot}^{UL}(txi, ic)} \times G_p^{SCH-UL}$	None	Quality level at transmitter on a traffic channel for the SCH channel on carrier *ic* [c]
$Q_{tch}^{UL}(ic)$	No HO: $Q_{tch}^{UL}(txi, ic)$ Softer HO: $f_{rake\ efficiency}^{UL} \times \sum_{\substack{tx_k \in ActiveSet \\ (samesite)}} Q_{tch}^{UL}(tx_k, ic)$ Soft, Softer/Soft HO (No MRC): $\underset{tx_k \in ActiveSet}{Max} (Q_{tch}^{UL}(tx_k, ic)) \times G_{macro-diversity}^{UL}$ Softer/Soft HO (MRC): $\underset{\substack{tx_k, tx_l \in ActiveSet \\ tx_k \in samesite \\ tx_l \in othersite}}{Max} \left(f_{rake\ efficiency}^{UL} \times \sum_{tx_k} Q_{tch}^{UL}(tx_k, ic), Q_{tch}^{UL}(tx_l, ic) \right)$ $\times G_{macro-diversity}^{UL}$	None	Quality level at site using carrier *ic* due to combination of all transmitters of the active set located at the same site and taking into account increase of the quality due to macro-diversity (macro-diversity gain). *tch* could be FCH or SCH In simulations, $G_{macro-diversity}^{UL} = 1$.
$(G_{SHO}^{UL})_{FCH}$	$\dfrac{Q_{FCH}^{UL}(ic)}{Q_{FCH}^{UL}(BestServer, ic)}$	None	Uplink soft handover gain for FCH channel on carrier ic

Name	Value	Unit	Description
$(G_{SHO}^{UL})_{SCH}$	$\frac{Q_{SCH}^{UL}(ic)}{Q_{SCH}^{UL}(BestServer, ic)}$	None	Uplink soft handover gain for SCH channel on carrier ic
$P_{term}^{FCH-req}(ic)$	$\frac{(Q_{req}^{UL})_{FCH}}{Q_{FCH}^{UL}(ic)} \times P_{term}^{FCH}(ic)$	W	Required terminal power to achieve Eb/Nt target at transmitter for FCH on carrier ic
$P_{term}^{SCH-req}(ic)$	$\frac{(Q_{req}^{UL})_{SCH}}{Q_{SCH}^{UL}(ic)} \times P_{term}^{SCH}(ic)$	W	Required terminal power to achieve Eb/Nt target at transmitter for SCH on carrier ic
$P_{term}^{req}(ic)$	$P_{term}^{FCH-req}(ic) + P_{term}^{SCH-req}(ic)$	W	Required terminal power on carrier ic

a. *In an active set, N_0^{tx} is calculated for all its members with Inter-technology uplink noise rise of the best server.*

b. *Calculation option may be selected in the Global parameters tab. The chosen option will be taken into account only in simulations. In point analysis and coverage studies, **9955** uses the option "Total noise" to evaluate DL and UL Eb/Nt.*

c. *Calculation option may be selected in the Global parameters tab. The chosen option will be taken into account only in simulations. In point analysis and coverage studies, **9955** uses the option "Total noise" to evaluate DL and UL Eb/Nt.*

7.2.1.5 Simulation Results

This table contains some simulation results provided in the Cells and Mobiles tabs of the simulation property dialogue.

Name	Value	Unit	Description
$I_{intra}^{DL}(txi, ic)$	$P_{tot}^{DL}(txi, ic) - F_{ortho} \times \rho_{BTS} \times P_{tot}^{DL}(txi, ic)$ $-(1 - F_{ortho} \times \rho_{BTS}) \times P_b^{DL}(txi, ic)$	None	Downlink intra-cell interference at terminal on carrier *ic*
$I_{extra}^{DL}(ic)$	$\sum_{txj, j \neq i} P_{tot}^{DL}(txj, ic)$	W	Downlink extra-cell interference at terminal on carrier *ic*
$I_{inter-carrier}^{DL}(ic)$	$\frac{\sum_{txj, \forall j} P_{tot}^{DL}(txj, ic_{adj})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference at terminal on carrier *ic*
$I_{inter-technology}^{DL}(ic)$	$\sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic}^{Tx, m}}$	W	Downlink inter-technology interference at terminal on carrier *ic* [a]
$I_{tot}^{DL}(ic)$	$I_{intra}^{DL}(ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic)$	W	Total effective interference at terminal on carrier *ic* (after unscrambling)
$N_{tot}^{DL}(ic)$	$I_{tot}^{DL}(ic) + N_0^{Term}$	W	Total received noise at terminal on carrier *ic*
$I_{tot}^{UL_{intra}}(txi, ic)$	$\sum_{term \atop txi} (P_b^{UL}(ic) + P_c^{UL}(ic))$	W	Total power received at transmitter from intra-cell terminals using carrier *ic*
$I_{tot}^{UL_{extra}}(txi, ic)$	$\sum_{term \atop txj, j \neq i} (P_b^{UL}(ic) + P_c^{UL}(ic))$	W	Total power received at transmitter from extra-cell terminals using carrier *ic*
$I_{inter-carrier}^{UL}(txi, ic)$	$\frac{\sum_{term \atop txj, \forall j} (P_b^{UL}(ic_{adj}) + P_c^{UL}(ic_{adj}))}{RF(ic, ic_{adj})}$	W	Uplink inter-carrier interference at terminal on carrier *ic*
$I_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL_{extra}}(txi, ic) + (1 - F_{MUD}^{Tx} \times \rho_{term}) \times I_{tot}^{UL_{intra}}(txi, ic) + I_{inter-carrier}^{UL}(txi, ic)$	W	Total received interference at transmitter on carrier *ic*

Name	Value	Unit	Description
$N_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL}(txi, ic) + N_0^{tx}$	W	Total noise at transmitter on carrier ic (Uplink interference)
$X^{UL}(txi, ic)$	$\frac{I_{tot}^{UL}(txi, ic)}{N_{tot}^{UL}(txi, ic)}$	None	Cell uplink load factor on carrier ic
$F^{UL}(txi, ic)$	$\frac{I_{tot}^{UL}(txi, ic)}{I_{tot}^{UL_{intra}}(txi, ic) \times (1 - F_{MUD}^{Tx} \times \rho_{term})}$	None	Cell uplink reuse factor on carrier ic
$E^{UL}(txi, ic)$	$\frac{1}{F^{UL}(txi, ic)}$	None	Cell uplink reuse efficiency factor on carrier ic
$\%Power^{DL}(txi, ic)$	$\left(\frac{P_{tx}(txi, ic)}{P_{max}(txi, ic)}\right) \times 100$	None	Percentage of max transmitter power used.
$X^{DL}(txi, ic)$	Simulation result available per cell $\sum_{tch} \frac{\frac{(I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic)) \times L_T}{P_{tx}(txi, ic)} + 1 - F_{ortho} \times \rho_{BTS}}{\frac{1}{CI_{req}^{DL}} + (1 - F_{ortho} \times \rho_{BTS})}$ with $CI_{req}^{DL} = \frac{Q_{req}^{SCH-DL}}{G_p^{SCH-DL}} + \frac{Q_{req}^{FCH-DL}}{G_p^{FCH-DL}}$ Simulation result available per mobile: $\frac{I_{tot}^{DL}(ic)}{N_{tot}^{DL}(ic)}$	None	Downlink load factor on carrier ic
$F^{DL}(txi, ic)$	$\frac{I_{tot}^{DL}(ic)}{I_{intra}^{DL}(txi, ic)}$	None	Downlink reuse factor on a carrier ic
$NR^{DL}(txi, ic)$	$-10log(1 - X^{DL}(txi, ic))$	dB	Noise rise on downlink
$NR^{UL}(txi, ic)$	$-10log(1 - X^{UL}(txi, ic))$	dB	Noise rise on uplink

a. *In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.*

7.2.2 Parameters Used for CDMA2000 1xEV-DO Modelling

7.2.2.1 Inputs

This table lists simulation and prediction inputs (calculation options, quality targets, active set management conditions, etc.)

Name	Value	Unit	Description
F_{ortho}	Clutter parameter	None	Orthogonality factor
F_{MUD}^{Tx}	Site equipment parameter	None	MUD factor
ic	Frequency band parameter	None	Carrier number
Q_{pilot}^{req}	$Q_{pilot}^{req}(txi, ic) + \Delta Q_{pilot}^{req}$	None	Active set upper threshold (used to determine the best server in the active set)
Q_{pilot}^{min}	$Q_{pilot}^{min}(txi, ic) + \Delta Q_{pilot}^{min}$	None	Active set lower threshold (used to determine other members of the active set)
$Q_{pilot}^{req}(txi, ic)$	*Min. Ec/I0* - Cell parameter	None	Minimum Ec/I0 required from the cell to be the best server in the active set

Name	Value	Unit	Description
$Q_{pilot}^{min}(txi, ic)$	*T_Drop* - Cell parameter	None	Minimum Ec/I0 required from the cell not to be rejected from the active set
ΔQ_{pilot}^{req}	*Delta Min. Ec/I0* - Mobility parameter	None	Variation of the minimum Ec/I0 required from the cell to be the best server in the active set
ΔQ_{pilot}^{min}	*Delta T_Drop* - Mobility parameter	None	Variation of the minimum Ec/I0 required from the cell not to be rejected from the active set
$\left(\frac{E_c}{N_t}\right)_{min-Rev0}^{UL}$	Mobility parameter for 1xEV-DO Rev. 0 users	None	Minimum pilot quality required in the uplink to operate EV-DO Rev. 0
$\left(\frac{E_c}{N_t}\right)_{min-RevB}^{UL}$	Transmitter parameter	None	Minimum pilot quality required in the uplink to operate multi-carrier EV-DO
$\left(\frac{E_c}{N_t}\right)_{min}^{UL}$	Parameter read in the 1xEV-DO Radio Bearer Selection (Uplink) table for 1xEV-DO Rev. A and Rev. B users	None	Minimum pilot quality level required to obtain a radio bearer in the uplink
n_{SF}	1xEV-DO Radio Bearer Selection (Uplink) table	None	Number of subframes associated with the 1xEV-DO radio bearer in the uplink
$R_{RLC-peak}^{UL}$	1xEV-DO Radio Bearer Selection (Uplink) table	None	Uplink RLC peak rate provided by the 1xEV-DO radio bearer
$\left(\frac{E_c}{N_t}\right)_{min}^{DL}$	Parameter read in the 1xEV-DO Radio Bearer Selection (Downlink) table for 1xEV-DO Rev. A and Rev. B users	None	Minimum pilot quality level required to obtain a radio bearer in the downlink
n_{TS}	1xEV-DO Radio Bearer Selection (Downlink) table	None	Number of timeslots associated with the 1xEV-DO radio bearer in the downlink
$R_{RLC-peak}^{DL}$	Downlink 1xEV-DO Radio Bearer Table	None	Downlink RLC peak rate provided by the 1xEV-DO radio bearer
$N_{max}^{EVDO-CE}(N_l)$	Site parameter	None	Number of EVDO channel elements available for a site on uplink and downlink
$N^{EVDO-CE}(N_l)$	Simulation result	None	Total number of EVDO channel elements of a site consumed by users on uplink and downlink
$N^{TCH-CE-UL}$	(Terminal, site equipment) parameter	None	Number of channel elements used for TCH on uplink
$N_{max}^{MacIndexes}(txi, ic)$	Simulation constraint	None	Maximum number of MAC indexes available per cell (59 for Rev0 and 114 for RevA)
$N^{MacIndexes}(txi, ic)$	Simulation result	None	Number of MAC indexes used by the cell
$n_{max}^{EVDO}(txi, ic)$	Simulation constraint (cell parameter)	None	Maximum number of EVDO users that can be connected to the cell
$n^{EVDO}(txi, ic)$	Simulation result	None	Number of EVDO users connected to the cell
NF_{term}	Terminal parameter	None	Terminal Noise Figure
NF_{Tx}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	Transmitter Noise Figure
K	$1.38\ 10^{-23}$	J/K	Boltzman constant
T	293	K	Ambient temperature
W	1.23 MHz	Hz	Spreading Bandwidth
$NR_{inter-technology}^{Tx, DL}$	Cell parameter	None	Inter-technology downlink noise rise

Name	Value	Unit	Description
$NR^{Tx,\,UL}_{inter-technology}$	Cell parameter	None	Inter-technology uplink noise rise
$RF(ic, ic_{adj})$	Network parameter If not defined, it is assumed that there is no inter-carrier interference	None	Interference reduction factor between two adjacent carriers ic and ic_{adj}
$ICP^{Tx,\,m}_{ic_i,\,ic}$	Network parameter If not defined, it is assumed that there is no inter-technology downlink interferences due to external transmitters	None	Inter-technology Channel Protection between the signal transmitted by Tx and received by m assuming the frequency gap between ic_i (external network) and ic
X^{UL}_{max}	Simulation constraint (global parameter or cell parameter)	%	Maximum uplink load factor
N^{Tx}_0	$NF_{Tx} \times K \times T \times W \times NR^{Tx,\,UL}_{inter-technology}$	W	Thermal noise at transmitter
N^{Term}_0	$NF_{Term} \times K \times T \times W \times NR^{Tx,\,DL}_{inter-technology}$	W	Thermal noise at terminal
R_c	W	bps	Chip rate
$f^{UL}_{rake\ efficiency}$	Equipment parameter	None	Uplink rake receiver efficiency factor
R^{UL}	Simulation result	bps	Uplink data rate
$R^{UL}_{TCP-ACK}$	Simulation result	bps	Uplink data rate due to TCP aknowledgements
R_{BCMCS}	Cell parameter	bps	Downlink data rate for Broadcast/ Multicast services
R^{DL}_{max}	Simulation result	bps	Downlink maximum data rate supplied to the terminal
R^{DL}_{avg}	Simulation result	bps	Downlink average cell data rate
$R^{UL}_{Guaranteed}$	Service parameter	kbps	Minimum required bit rate that the service should have in order to be available in the uplink
$R^{DL}_{Guaranteed}$	Service parameter	kbps	Minimum required bit rate that the service should have in order to be available in the downlink
$R^{DL}_{application}$	$SF_{rate} \times R^{DL}_{max} - \Delta R$	bps	Downlink user application throughput
SF_{Rate}	Service parameter	%	Scaling factor
ΔR	Service parameter	kbps	Offset
$C_{DL-Bearer}$	$\dfrac{R^{DL}_{Guaranteed}}{R^{DL}_{RLC-peak}(Index_{DL-Bearer})}$	%	Downlink radio bearer consumption for a (1xEV-DO Rev. A - Guaranteed Bit Rate) service user
$C_{UL-Bearer}$	$\dfrac{R^{UL}_{Guaranteed}}{R^{UL}_{RLC-peak}(Index_{UL-Bearer})}$	%	Uplink radio bearer consumption for a (1xEV-DO Rev. A - Guaranteed Bit Rate) service user
G^{UL}_p	$\dfrac{W}{R^{UL}}$	None	Uplink service processing gain on FCH
$G_{idle-power}$	Cell parameter	None	Idle power gain
G_{MU}	Cell parameter	None	Multi user gain
$P_{max}(txi, ic)$	Cell parameter	W	Max cell power

Name	Value	Unit	Description
$P_{tx}(txi, ic, b_{pilot})$	$P_{max}(txi, ic)$	W	Pilot burst transmitted by the transmitter on carrier *ic*.
$P_{tx}(txi, ic, b_{traffic})$	$P_{max}(txi, ic)$ if users to support $P_{max}(txi, ic) \times G_{idle-power}$ if no user to support	W	Traffic burst transmitted by the transmitter on carrier *ic*.
ER_{DRC}	Cell parameter	%	Error rate on the DRC channel
TS_{BCMCS}	Cell parameter	%	Pourcentage of EVDO timeslots dedicated to Broadcast/Multicast services
$TS_{EVDO-CCH}$	Cell parameter	%	Pourcentage of EVDO timeslots dedicated to control channels
$P_{term}(ic)$	Simulation result	W	Terminal power transmitted on carrier ic
P_{term}^{min}	Terminal parameter	W	Minimum terminal power allowed
P_{term}^{max}	Terminal parameter	W	Maximum terminal power allowed
ρ_{BTS}	BTS parameter	%	Percentage of BTS signal correctly transmitted
ρ_{term}	Terminal parameter	%	Percentage of terminal signal correctly transmitted
α	Clutter parameter	%	Percentage of pilot finger - percentage of signal received by the terminal pilot finger
G_{Tx}	Antenna parameter	None	Transmitter antenna gain
G_{Term}	Terminal parameter	None	Terminal gain
L_{Tx}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	Transmitter loss[a]
L_{body}	Service parameter	None	Body loss
L_{Term}	Terminal parameter	None	Terminal loss
L_{indoor}	Clutter (and, optionally, frequency band) parameter		Indoor loss
L_{path}	Propagation model result	None	Path loss
G_{ACK}	Terminal parameter	None	Acknowledgement Channel gain
G_{RRI}	Terminal parameter (for 1xEV-DO Rev A terminals only)	None	Reverse Rate Indicator Channel gain
G_{DRC}	Terminal parameter	None	Data Rate Control Channel gain
$G_{Auxiliary-pilot}$	Terminal parameter (for 1xEV-DO Rev A terminals only)	None	Auxiliary Pilot Channel gain
G_{TCH}	Terminal parameter	None	Traffic data Channel gain
$n_{max}^{carriers}$	Terminal parameter	None	Maximum number of carriers in multi-carrier mode
$M_{Shadowing-model}$	Result calculated from cell edge coverage probability and model standard deviation	None	Model Shadowing margin Only used in prediction studies
$M_{Shadowing-Ec/Io}$	Result calculated from cell edge coverage probability and Ec/I0 standard deviation	None	Ec/I0 Shadowing margin Only used in prediction studies
$G_{macro-diversity}^{DL}$	$G_{macro-diversity}^{DL} = M_{Shadowing-Ec/Io}^{npaths} - M_{Shadowing-Ec/Io}$ n=2 or 3	None	DL gain due to availability of several pilot signals at the mobile [b].
$M_{Shadowing-(Eb/Nt)_{UL}}$	Result calculated from cell edge coverage probability and UL Eb/Nt standard deviation	None	UL Eb/Nt Shadowing margin Only used in prediction studies

Name	Value	Unit	Description
$G^{UL}_{macro-diversity}$	$G^{UL}_{macro-diversity} = M^{npaths}_{Shadowing-(Eb/Nt)_{UL}} - M_{Shadowing-(Eb/Nt)_{UL}}$ n=2 or 3 Global parameter (default value)	None	UL quality gain due to signal diversity in soft handoff[c].
$E_{Shadowing}$	Simulation result	None	Random shadowing error drawn during Monte-Carlo simulation Only used in simulations
L_T	In prediction studies[d] For Ec/I0 and Ec/Nt calculations $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}}$ For UL Eb/Nt calculation $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$ In simulations $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times E_{Shadowing}}{G_{Tx} \times G_{term}}$	None	Transmitter-terminal total loss
$P^{DL}_{tot}(txi, ic, b_{pilot})$	$\frac{P_{tx}(txi, ic, b_{pilot})}{L_T}$	W	Pilot burst received at terminal from a transmitter on carrier *ic*
$P^{DL}_{tot}(txi, ic, b_{traffic})$	$\frac{P_{tx}(txi, ic, b_{traffic})}{L_T}$	W	Traffic burst received at terminal from a transmitter on carrier *ic*
$P^{UL}_b(ic)$	$\frac{P_{term}}{L_T}$	W	Bit received power at transmitter on carrier *ic*
$NR^{UL}_{threshold}(txi, ic)$	Cell parameter	dB	Cell uplink noise rise threshold
$\Delta NR^{UL}_{threshold}(txi, ic)$	Cell parameter	dB	Cell uplink noise rise upgrading/ downgrading delta

a. $L_{Tx} = L_{total-UL}$ *on uplink and* $L_{Tx} = L_{total-DL}$ *on downlink.*

b. $M^{npaths}_{Shadowing-Ec/Io}$ *corresponds to the shadowing margin evaluated from the shadowing error probability density function (n paths) in case of downlink Ec/I0 modelling.*

c. $M^{npaths}_{Shadowing-(Eb/Nt)_{UL}}$ *corresponds to the shadowing margin evaluated from the shadowing error probability density function (n paths) in case of uplink soft handoff modelling.*

d. *In uplink prediction studies, only carrier power level is downgraded by the shadowing margin (*$M_{Shadowing-(Eb/Nt)_{UL}}$*). In downlink prediction studies, carrier power level and intra-cell interference are downgraded by the shadowing model (*$M_{Shadowing-Ec/Io}$*) while extra-cell interference level is not. Therefore,* $M_{Shadowing-Ec/Io}$ *is set to 1 in downlink extra-cell interference calculation.*

7.2.2.2 Ec/I0 and Ec/Nt Calculations

This table details $\frac{E_c}{I_0}(txi, ic, b_{pilot})$, $\frac{E_c}{N_t}(txi, ic, b_{pilot})$ and $\frac{E_c}{N_t}(txi, ic, b_{traffic})$ calculations.

Name	Value	Unit	Description
$I^{DL}_{intra}\begin{pmatrix} txi, ic \\ b_{pilot} \text{ or } b_{traffic} \end{pmatrix}$	*0*	W	Downlink intra-cell interference at terminal on carrier *ic* (only one mobile is served at a time)
$I^{DL}_{extra}(ic, b_{pilot})$	$\sum_{txj, j \neq i} P^{DL}_{tot}(txj, ic, b_{pilot})$	W	Downlink extra-cell interference based on pilot at terminal on carrier *ic*

Name	Value	Unit	Description
$I_{extra}^{DL}(ic, b_{traffic})$	$\sum_{txj, j \neq i} P_{tot}^{DL}(txj, ic, b_{traffic})$	W	Downlink extra-cell interference based on traffic at terminal on carrier *ic*
$I_{inter-carrier}^{DL}(ic, b_{pilot})$	$\frac{\sum_{txj, \forall j} P_{tot}^{DL}(txj, ic_{adj}, b_{pilot})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference based on pilot at terminal on carrier *ic*
$I_{inter-carrier}^{DL}(ic, b_{traffic})$	$\frac{\sum_{txj, \forall j} P_{tot}^{DL}(txj, ic_{adj}, b_{traffic})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference based on traffic at terminal on carrier *ic*
$I_{inter-technology}^{DL}(ic)$	$\sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic}^{Tx, m}}$	W	Downlink inter-technology interference at terminal on carrier *ic* [a]
$I_0^{DL}(ic, b_{pilot})$	$P_{tot}^{DL}(txi, ic, b_{pilot}) + I_{extra}^{DL}(ic, b_{pilot}) + I_{inter-carrier}^{DL}(ic, b_{pilot}) + I_{inter-technology}^{DL}(ic) + N_0^{term}$	W	Total noise based on pilot received at terminal on carrier *ic*
$I_0^{DL}(ic, b_{traffic})$	$P_{tot}^{DL}(txi, ic, b_{traffic}) + I_{extra}^{DL}(ic, b_{traffic}) + I_{inter-carrier}^{DL}(ic, b_{traffic}) + I_{inter-technology}^{DL}(ic) + N_0^{term}$	W	Total noise based on traffic received at terminal on carrier *ic*
$N_{tot}^{DL}(ic, b_{pilot})$	$I_{extra}^{DL}(ic, b_{pilot}) + N_0^{term}$	W	Total noise based on pilot received at terminal on carrier *ic*
$N_{tot}^{DL}(ic, b_{traffic})$	$I_{extra}^{DL}(ic, b_{traffic}) + N_0^{term}$	W	Total noise based on traffic received at terminal on carrier *ic*
$Q_{pilot}(txi, ic) \Leftrightarrow \frac{E_c}{I_0}(txi, ic, b_{pilot})$	$\frac{\rho_{BTS} \times \alpha \times P_{tot}^{DL}(txi, ic, b_{pilot})}{I_0^{DL}(ic, b_{pilot})}$	None	Pilot quality level at terminal on carrier *ic*
$\frac{E_c}{N_t}(txi, ic, b_{pilot})$	$\frac{\rho_{BTS} \times \alpha \times P_{tot}^{DL}(txi, ic, b_{pilot})}{N_{tot}^{DL}(ic, b_{pilot}) + (1-\rho_{BTS}) \times P_{tot}^{DL}(txi, ic, b_{pilot})}$	None	Pilot quality level at terminal on carrier *ic*
$\frac{E_c}{N_t}(txi, ic, b_{traffic})$	$\frac{\rho_{BTS} \times \alpha \times P_{tot}^{DL}(txi, ic, b_{traffic})}{N_{tot}^{DL}(ic, b_{traffic}) + (1-\rho_{BTS}) \times P_{tot}^{DL}(txi, ic, b_{traffic})}$	None	Traffic quality level at terminal on carrier *ic*

a. *In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.*

7.2.2.3 UL Eb/Nt Calculation

This table details calculations of uplink quality (Q^{UL} or $\left(\frac{Eb}{Nt}\right)_{UL}$).

Name	Value	Unit	Description
$I_{tot}^{UL_{intra}}(txi, ic)$	$\sum_{\substack{term \\ txi}} P_b^{UL}(ic)$	W	Total power received at transmitter from intra-cell terminals using carrier *ic*
$I_{tot}^{UL_{extra}}(txi, ic)$	$\sum_{\substack{term \\ txj, j \neq i}} P_b^{UL}(ic)$	W	Total power received at transmitter from extra-cell terminals using carrier *ic*

Alcatel·Lucent

Name	Value	Unit	Description
$I^{UL}_{inter-carrier}(txi, ic)$	$\dfrac{\sum\limits_{\substack{term \\ txi, \forall j}} P^{UL}_b(ic_{adj})}{RF(ic, ic_{adj})}$	W	Uplink inter-carrier interference at terminal on carrier *ic*
$I^{UL}_{tot}(txi, ic)$	$I^{UL_{extra}}_{tot}(txi, ic) + (1 - F^{Tx}_{MUD} \times \rho_{term}) \times I^{UL_{intra}}_{tot}(txi, ic) + I^{UL}_{inter-carrier}(txi, ic)$	W	Total received interference at transmitter on carrier *ic*
$N^{UL}_{tot}(txi, ic)$	$I^{UL}_{tot}(ic) + N^{tx}_0$	W	Total noise at transmitter on carrier *ic* (Uplink interference)
$Q^{UL}(txi, ic) \Leftrightarrow \left(\dfrac{E_b}{N_t}\right)_{UL}$	Without useful signal: $\dfrac{\rho_{term} \times P^{UL}_b(ic)}{N^{UL}_{tot}(txi, ic) - (1 - F^{Tx}_{MUD}) \times \rho_{term} \times P^{UL}_b(ic)} \times G^{UL}_p$ Total noise: $\dfrac{\rho_{term} \times P^{UL}_b(ic)}{N^{UL}_{tot}(txi, ic)} \times G^{UL}_p$	None	Quality level at transmitter on carrier *ic*[a]
$Q^{UL}_{total}(ic)$	No HO: $Q^{UL}(txi, ic)$ Softer HO: $f^{UL}_{rake\ efficiency} \times \sum\limits_{\substack{tx_k \in ActiveSet \\ (samesite)}} Q^{UL}_{tch}(tx_k, ic)$ Soft, Softer/Soft HO (No MRC): $\underset{tx_k \in ActiveSet}{Max}\ (Q^{UL}_{tch}(tx_k, ic)) \times G^{UL}_{macro-diversity}$ Softer/Soft HO (MRC): $\underset{\substack{tx_k, tx_l \in ActiveSet \\ tx_k \in samesite \\ tx_l \in othersite}}{Max} \left(f^{UL}_{rake\ efficiency} \times \sum\limits_{tx_k} Q^{UL}_{tch}(tx_k, ic), Q^{UL}_{tch}(tx_l, ic) \right)$ $\times G^{UL}_{macro-diversity}$	None	Quality level at site using carrier *ic* due to combination of all transmitters of the active set located at the same site and taking into account increase of the quality due to macro-diversity (macro-diversity gain). In simulations, $G^{UL}_{macro-diversity} = 1$.
G^{UL}_{SHO}	$\dfrac{Q^{UL}_{total}(ic)}{Q^{UL}(BestServer, ic)}$	None	Uplink soft handover gain on carrier ic
Q^{UL}_{req}	For 1xEV-DO Rev 0 terminal $\left(\dfrac{E_c}{N_t}\right)^{UL}_{min} \times G^{UL}_p \times (1 + G_{ACK} + G_{DRC} + G_{TCH})$ For 1xEV-DO Rev A terminal[b] When the acknoledgement signal is considered $\left(\dfrac{E_c}{N_t}\right)^{UL}_{min} \times G^{UL}_p \times (1 + G_{ACK} + G_{RRI} + G_{DRC} + G_{TCH} + G_{Auxiliary-Pilot})$ When the acknoledgement signal is not considered $\left(\dfrac{E_c}{N_t}\right)^{UL}_{min} \times G^{UL}_p \times (1 + G_{RRI} + G_{DRC} + G_{TCH} + G_{Auxiliary-Pilot})$	None	Eb/Nt target on uplink
$P^{req}_{term}(ic)$	$\dfrac{Q^{UL}_{req}}{Q^{UL}_{total}(ic)} \times P_{term}$	W	Required terminal power to achieve Eb/Nt target at transmitter on carrier ic

a. *Calculation option may be selected in the Global parameters tab. The chosen option will be taken into account only in simulations. In point analysis and coverage studies, **9955** uses the option "Total noise" to evaluate DL and UL Eb/Nt.*
b. *In simulations, the uplink Eb/Nt target is calculated without considering the aknowledgement signal.*

7.2.2.4 Simulation Results

This table contains some simulation results provided in the Cells and Mobiles tabs of the simulation property dialogue.

Name	Value	Unit	Description
$I_{intra}^{DL}(txi, ic, b_{traffic})$	$(1 - F_{ortho} \times \rho_{BTS}) \times P_{tot}^{DL}(txi, ic, b_{traffic}) = 0$	W	Downlink intra-cell interference at terminal on carrier *ic* (only one mobile is served at a time)
$I_{extra}^{DL}(ic, b_{traffic})$	$\sum_{txj, j \neq i} P_{tot}^{DL}(txj, ic, b_{traffic})$	W	Downlink extra-cell interference based on traffic at terminal on carrier *ic*
$I_{inter-carrier}^{DL}(ic, b_{traffic})$	$\frac{\sum_{txj, \forall j} P_{tot}^{DL}(txj, ic_{adj}, b_{traffic})}{RF(ic, ic_{adj})}$	W	Downlink inter-carrier interference based on traffic at terminal on carrier *ic*
$I_{inter-technology}^{DL}(ic)$	$\sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{n_i, ic}^{Tx, m}}$	W	Downlink inter-technology interference at terminal on carrier *ic* [a]
$I_{tot}^{DL}(ic, b_{traffic})$	$I_{intra}^{DL}(ic, b_{traffic}) + I_{extra}^{DL}(ic, b_{traffic}) + I_{inter-carrier}^{DL}(ic, b_{traffic}) + I_{inter-technology}^{DL}(ic)$	W	Total effective interference based on traffic at terminal on carrier *ic* (after unscrambling)
$N_{tot}^{DL}(ic, b_{traffic})$	$I_{tot}^{DL}(ic, b_{traffic}) + N_0^{term}$	W	Total noise based on traffic received at terminal on carrier *ic*
$I_{tot}^{UL_{intra}}(txi, ic)$	$\sum_{\substack{term \\ txi}} P_b^{UL}(ic)$	W	Total power received at transmitter from intra-cell terminals using carrier *ic*
$I_{tot}^{UL_{extra}}(txi, ic)$	$\sum_{\substack{term \\ txj, j \neq i}} P_b^{UL}(ic)$	W	Total power received at transmitter from extra-cell terminals using carrier *ic*
$I_{inter-carrier}^{UL}(txi, ic)$	$\frac{\sum_{\substack{term \\ txj, \forall j}} P_b^{UL}(ic_{adj})}{RF(ic, ic_{adj})}$	W	Uplink inter-carrier interference at terminal on carrier *ic*
$I_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL_{extra}}(txi, ic) + (1 - F_{MUD}^{Tx} \times \rho_{term}) \times I_{tot}^{UL_{intra}}(txi, ic) + I_{inter-carrier}^{UL}(txi, ic)$	W	Total received interference at transmitter on carrier *ic*
$N_{tot}^{UL}(txi, ic)$	$I_{tot}^{UL}(txi, ic) + N_0^{tx}$	W	Total noise at transmitter on carrier *ic* (Uplink interference)
$N_{mobiles}(txi, ic)$	Simulation result	None	Number of mobiles connected to transmitter *txi* on carrier *ic*
$N_{GBR-mobiles}(txi, ic)$	Simulation result	None	Number of (1xEV-DO Rev. A - Guaranteed bit rate) service users connected to transmitter *txi* on carrier *ic*
$N_{VBR-mobiles}(txi, ic)$	Simulation result	None	Number of (1xEV-DO - Variable bit rate) service users connected to transmitter *txi* on carrier *ic*
$X^{DL}(txi, ic)$	$\frac{I_{tot}^{DL}(ic, b_{traffic})}{N_{tot}^{DL}(ic, b_{traffic})}$	None	Cell downlink load factor on carrier *ic*

Name	Value	Unit	Description
$X^{UL}(txi, ic)$	$\frac{I_{tot}^{UL}(txi, ic)}{N_{tot}^{UL}(txi, ic)}$	None	Cell uplink load factor on carrier *ic*
$F^{UL}(txi, ic)$	$\frac{I_{tot}^{UL}(txi, ic)}{I_{tot}^{UL_{intra}}(txi, ic) \times (1 - F_{MUD}^{Tx} \times \rho_{term})}$	None	Cell uplink reuse factor on carrier *ic*
$E^{UL}(txi, ic)$	$\frac{1}{F^{UL}(txi, ic)}$	None	Cell uplink reuse efficiency factor on carrier *ic*
$NR^{DL}(txi, ic)$	$-10\log(1 - X^{DL}(txi, ic))$	dB	Noise rise on downlink
$NR^{UL}(txi, ic)$	$-10\log(1 - X^{UL}(txi, ic))$	dB	Noise rise on uplink

a. *In the case of an interfering GSM external network in frequency hopping, the ICP value is weighted according to the fractional load.*

7.3 Active Set Management

The mobile active set is the list of the transmitters to which the mobile is connected. The active set may consist of one or more transmitters; depending on whether the service supports soft handoff and on the terminal active set size. The terminal frequency bands are taken into account and transmitters in the mobile active set must use a frequency band with which the terminal is compatible.

It is, however, the quality of the pilot (Ec⁄I0) that finally determines whether or not a transmitter can belong to the active set.

Cells entering the mobile's active set must fulfill the following conditions:

- The best server (first cell entering active set)

  In order for a given transmitter to enter the mobile active set as best server, the quality of this transmitter's pilot must be the highest one and it must exceed an upper threshold equal to the sum of the minimum Ec/I0 defined in the properties of the best serving cell and the Delta minimum Ec/I0 defined in the properties of the mobility type. The upper threshold is set for the carrier as defined in the cell properties and can also take into account the user mobility type if the Delta minimum Ec/I0 defined in the mobility type is different from 0. The carrier used by the transmitters in the active set corresponds to the best carrier of the best server. For information on the best carrier selection, see the *Technical Reference Guide*.

- In order for a transmitter to enter the active set (other cells of active set):
  - They must use the same carrier as the best server cell,
  - The pilot quality from other candidate cells must exceed a lower threshold. The lower threshold depends both on the type of carrier and the mobility type. It is equal to the sum of T_Drop defined in the properties of the best server and the Delta T_Drop defined in the properties of the mobility type.
  - If you have selected to restrict the active set to neighbours, the cell must be a neighbour of the best server (the "restricted to neighbours" option is selected in the equipment properties).

For multi-carrier EVDO Rev.B users, the active set may consist of several sub-active sets, each one being associated with one carrier. The number of sub-active sets depends on the maximum number of carriers supported by the terminal. As detailed above, the quality of the pilot (Ec⁄I0) determines whether or not a transmitter can belong to a sub-active set. The sub-active set associated with the best carrier is the same as the active set of a single-carrier user. For the other carriers, the uplink Ec⁄Nt received by the best server on the best carrier and on the studied carrier determines whether or not a carrier can have a sub-active set, and the transmitters in the sub-active sets depend on the mode supported by the terminal (locked mode or unlocked mode):

- The Ec/Nt received by the best serving transmitter on the best carrier must exceed the minimum uplink Ec/Nt defined in the properties of the transmitter.
- The Ec/Nt received by the best serving transmitter on the studied carrier must exceed the minimum uplink Ec/Nt defined in the properties of the transmitter.
- When the locked mode is used, the serving transmitters must be the same in all sub-active sets. With the unlocked mode, the serving transmitters may be different from one sub-active set to another.

7.4 Simulations

The simulation process is divided into two steps:

1. **Obtaining a realistic user distribution**

   9955 generates a user distribution using a Monte-Carlo algorithm, which requires traffic maps and data as input. The resulting user distribution complies with the traffic database and maps provided to the algorithm.

   Each user is assigned a service, a mobility type, and an activity status by random trial, according to a probability law that uses the traffic database.

   The user activity status is an important output of the random trial and has direct consequences on the next step of the simulation and on the network interferences. A user may be either active or inactive. Both active and inactive users consume radio resources and create interference.

   Additionally, each 1xEV-DO Rev. 0 user is assigned a transition flag ("True" or "False") for each possible data rate transition (from 9.6 to 19.2 kbps, 19.2 to 38.4 kbps, 38.4 to 76.8 kbps, and 76.8 to 153.6 kbps for data rate upgrading and from 153.6 to 76.8 kbps, 76.8 to 38.4 kbps, 38.4 to 19.2 kbps, and 19.2 to 9.6 kbps for data rate downgrading). These transition flags are based on the data rate downgrading and upgrading probabilities. If a transition flag is "True," the user data rate can be downgraded or upgraded if necessary.

   Then, **9955** randomly assigns a shadowing error to each user using the probability distribution that describes the shadowing effect.

   Finally, another random trial determines user positions in their respective traffic zone and whether they are indoors or outdoors (according to the clutter weighting and the indoor ratio per clutter class defined for the traffic maps).

2. **Modelling the network regulation mechanism**

   This algorithm depends on the network. **9955** uses a power control algorithm in case of CDMA2000 1xRTT networks and a different algorithm, which mixes data rate control on downlink and power control on uplink, for CDMA2000 1xEV-DO networks.

7.4.1 Generating a Realistic User Distribution

7.4.1.1 Number of Users, User Activity Status and User Data Rate

During the simulation, a first random trial is performed to determine the number of users and their activity status. The determination of the number of users and the activity status allocation depend on the type of traffic cartography used.

> **9955** determines the total number of users attempting connection in each simulation based on the Poisson distribution. This may lead to slight variations in the total numbers of users in different simulations. To have the same total number of users in each simulation of a group, add the following lines in the Atoll.ini file:
> [Simulation]
> RandomTotalUsers=0

7.4.1.1.1 Simulations Based on User Profile Traffic Maps

User profile environment based traffic maps: Each pixel of the map is assigned an environment class which contains a list of user profiles with an associated mobility type and a given density (number of subscribers with the same profile per km²).

User profile traffic maps: Each polygon and line of the map is assigned a density of subscribers with given user profile and mobility type. If the map is composed of points, each point is assigned a number of subscribers with given user profile and mobility type.

The user profile models the behaviour of the different subscriber categories. Each user profile contains a list of services and their associated parameters describing how these services are accessed by the subscriber.

From environment (or polygon) surface (S) and user profile density (D), a number of subscribers (X) per user profile is inferred.

$$X = S \times D$$

> - In case of user profile traffic maps composed of lines, the number of subscribers (X) per user profile is calculated from the line length (L) and the user profile density (D) (nb of subscribers per km) as follows: $X = L \times D$
> - The number of subscribers (X) is an input when a user profile traffic map is composed of points.

For each behaviour described in a user profile, according to the service, frequency use and exchange volume, **9955** calculates the probability for the user being connected in uplink and in downlink at an instant t.

- Calculation of the service usage duration per hour (p_0 : probability of a connection):

$$p_0 = \frac{N_{call} \times d}{3600}$$

where N_{call} is the number of calls per hour and d is the average call duration (in second).

Then, **9955** calculates the total number of users trying to access a certain service.

- Calculation of the number of users trying to access the service j (n_j):

$$n_j = X \times p_0$$

The next step determines the activity status of each user.

- Calculation of number of users per activity status:

This steps depends on the type of service (Voice, 1xRTT data, 1xEV-DO data…).

- **CDMA2000 1xRTT Services**

Activity status of voice and data service users is determined as follows.

Users are always active on FCH in both directions, uplink and downlink. Therefore, we have:

Probability of being active on UL: $p_{UL} = 0$

Probability of being active on DL: $p_{DL} = 0$

Probability of being active both on UL and DL: $p_{UL+DL} = 1$

Probability of being inactive: $p_{inactive} = 0$

Thus, for voice and data services, we have:

Number of inactive users: $n_j(inactive) = n_j \times p_{inactive} = 0$

Number of users active on UL: $n_j(UL) = n_j \times p_{UL} = 0$

Number of users active on DL: $n_j(DL) = n_j \times p_{DL} = 0$

Number of users active on UL and DL both: $n_j(UL+DL) = n_j \times p_{UL+DL} = n_j$

$$n_j = n_j(UL) + n_j(DL) + n_j(UL+DL) + n_j(inactive) = n_j(UL+DL)$$

- **Voice Users**

Voice users are active on uplink and downlink. However, the FCH can have inactivity periods on both links. This is modelled by the FCH activity factor, AF_{FCH}^{UL} and AF_{FCH}^{DL}. Therefore, all voice service users try to access the service with the following FCH rates, $R_{FCH}^{UL} \times AF_{FCH}^{UL}$ on uplink and $R_{FCH}^{DL} \times AF_{FCH}^{DL}$ on downlink.

R_{FCH}^{UL} and R_{FCH}^{DL} are respectively the uplink and downlink FCH nominal rates.

- **Data Users**

Data service users are active on uplink and downlink. FCH is always allocated but can have inactivity periods on both links; this is modelled by the FCH activity factor, AF_{FCH}^{UL} and AF_{FCH}^{DL}. SCH may be allocated with four possible rates (2x, 4x, 8x and 16xFCH nominal rate).

Therefore, data service users can access the service with different rates. Possible rates are detailed in the table below:

	SCH rate factor r_k	Allocated rates	
		On UL	On DL
Only FCH is used	-	$R_{FCH}^{UL} \times AF_{FCH}^{UL}$	$R_{FCH}^{DL} \times AF_{FCH}^{DL}$

	SCH rate factor r_k	Allocated rates	
		On UL	On DL
Both FCH and SCH are used	2x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 2)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 2)$
	4x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 4)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 4)$
	8x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 8)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 8)$
	16x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 16)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 16)$

R_{FCH}^{UL} and R_{FCH}^{DL} are respectively the uplink and downlink FCH nominal rates.

Then, **9955** determines the distribution of users between the different possible rates.

In case of a data service, j, several data rate probabilities, P_k^{UL} and P_k^{DL}, can be assigned to different rate factors, r_k, for SCH channel.

For non-data services, these probabilities are 0.

For data service users, a random trial compliant with data rate probabilities is performed for each link in order to determine the rate for each user.

On uplink, we have:

For each SCH rate factor, r_k, the number of users $n_j^{r_k}$ with the data rate $R_{FCH}^{UL} \times (AF_{FCH}^{UL} + r_k)$ is calculated as follows,

$$n_j^{r_k} = P_{r_k}^{UL} \times n_j$$

Therefore, the number of users n_j^{FCH} with the data rate, $R_{FCH}^{UL} \times AF_{FCH}^{UL}$, is:

$$n_j^{FCH} = n_j - \sum_{r_k} n_j^{r_k}$$

On downlink, we have:

For each SCH rate factor, r_k, the number of users, $n_j^{r_k}$ with the data rate, $R_{FCH}^{DL} \times (AF_{FCH}^{DL} + r_k)$, is calculated as follows,

$$n_j^{r_k} = P_{r_k}^{DL} \times n_j$$

Therefore, the number of users n_j^{FCH} with the data rate, $R_{FCH}^{DL} \times AF_{FCH}^{DL}$, is:

$$n_j^{FCH} = n_j - \sum_{r_k} n_j^{r_k}$$

- **CDMA2000 1xEV-DO Services**

As power control is performed in the uplink only, 1xEV-DO data service users will be considered either active in the uplink or inactive. 1xEV-DO data Rev. 0 service users can access the service with uplink rates of 9.6, 19.2, 38.4, 76.8 and 153.6 kbps. 1xEV-DO data Rev. A and Rev. B service users can access the service with uplink rates of 4.8, 9.6, 19.2, 38.4, 76.8, 115.2, 153.6, 230.4, 307.2, 460.8, 614.4, 921.6, 1,228.8 and 1,848.2 kbps.

For each service, j, several data rate probabilities, P_k^{UL}, can be assigned to different rates R_k^{UL}. The number of users active on uplink ($n_j(UL)$) and the number of inactive users ($n_j(inactive)$) are calculated as follows:

Probability of being active on UL: $p_{UL} = \sum_{R_k^{UL}} P_k^{UL}(R_k^{UL})$

Probability of being inactive: $p_{inactive} = 1 - \sum_{R_k^{UL}} P_k^{UL}(R_k^{UL})$

Probability of being active on DL: $p_{DL} = 0$

Probability of being active on UL and DL both: $p_{UL+DL} = 0$

Therefore, we have:

Number of users active on UL: $n_j(UL) = n_j \times p_{UL}$

Number of inactive users: $n_j(inactive) = n_j \times p_{inactive}$

Number of users active on DL: $n_j(DL) = n_j \times p_{DL} = 0$

Number of users active on UL and DL both: $n_j(UL+DL) = n_j \times p_{UL+DL} = 0$

$$n_j = n_j(UL) + n_j(DL) + n_j(UL+DL) + n_j(inactive) = n_j(UL) + n_j(inactive)$$

Then, **9955** determines the distribution of users between the different possible rates, R_k^{UL}. The number of users with the data rate R_k^{UL}, $n_j(R_k^{UL})$, is calculated as follows:

$$n_j(R_k^{UL}) = P_k^{UL} \times n_j$$

Inactive users have a requested data rate equal to 0.

- The user distribution per service is an average distribution and the service of each user is randomly drawn in each simulation. Therefore, if you compute several simulations at once, the average number of users per service will correspond to the calculated distribution. But if you check each simulation, the user distribution between services is different in each of them.
- It is the same for the SCH rate distribution between 1xRTT data service users and the traffic data rate distribution between 1xEV-DO data service users.
- In calculations detailed above, we assume that the sum of data rate probabilities is less than or equal to 1. If the sum of data rate probabilities exceeds 1, **9955** considers normalised data rate probabilities values, $P_{r_k} / \left(\sum_{r_k} P_{r_k} \right)$, instead of specified data rate probabilities P_{r_k}.

7.4.1.1.2 Simulations Based on Sector Traffic Maps

Sector traffic maps can be based on live traffic data from OMC (Operation and Maintenance Centre). Traffic is spread over the best server coverage area of each transmitter and each coverage area is assigned either the throughputs in the uplink and in the downlink, or the number of users per activity status or the total number of users (including all activity statuses).

CDMA2000 1xRTT Services

- **Voice Service (j)**

For each transmitter, Tx_i, **9955** proceeds as follows:

- When selecting **Throughputs in Uplink and Downlink**, you can input the throughput demands in UL (R_t^{UL}) and DL (R_t^{DL}) for each sector.

  9955 calculates the number of users active in UL and DL using the voice service in the Txi cell as follows:

  $$N_{UL} = \frac{R_t^{UL}}{R_j^{UL}} \text{ and } N_{DL} = \frac{R_t^{DL}}{R_j^{DL}}$$

  Where,

  R_t^{UL} is the number of kbits per second transmitted in UL in the Txi cell to provide the service j to the users (user-defined value in the traffic map properties)

R_t^{DL} is the number of kbits per second transmitted in DL in the Txi cell to provide the service j to the users (user-defined value in the traffic map properties).

R_j^{UL} and R_j^{DL} correspond to the UL and DL rates of a user. FCH is always allocated to active users but can have inactivity periods on both links. Therefore, we have $R_j^{UL} = R_{FCH}^{UL} \times AF_{FCH}^{UL}$ (where R_{FCH}^{UL} is the service FCH nominal rate on UL and AF_{FCH}^{UL} corresponds to the FCH activity factor on UL) and $R_j^{DL} = R_{FCH}^{DL} \times AF_{FCH}^{DL}$ (where R_{FCH}^{DL} is the service FCH nominal rate on DL and AF_{FCH}^{DL} corresponds to the FCH activity factor on DL).

Users are always active on FCH for both links. Therefore, we have following activity probabilities.

Probability of being active in UL: $p_{UL} = 0$

Probability of being active in DL: $p_{DL} = 0$

Probability of being active in UL and DL both: $p_{UL+DL} = 1$

Probability of being inactive: $p_{inactive} = 0$

Then, **9955** calculates the number of users per activity status:

Number of users active in UL and DL both: $n_j(UL+DL) = max(N_{UL}, N_{DL})$

Number of users active in UL and inactive in DL: $n_j(UL) = 0$

Number of users active in DL and inactive in UL: $n_j(DL) = 0$

Number of inactive users in UL and DL: $n_j^{inactive} = 0$

Therefore, all connected voice users (n_j) are active in both links.

- When selecting **Total Number of Users (All Activity Statuses)**, you can input the number of connected users for each sector (n_j).

  Users are always active on FCH for both links. Therefore, we have following activity probabilities.

  Probability of being active in UL: $p_{UL} = 0$

  Probability of being active in DL: $p_{DL} = 0$

  Probability of being active in UL and DL both: $p_{UL+DL} = 1$

  Probability of being inactive: $p_{inactive} = 0$

  Then, **9955** calculates the number of users per activity status:

  Number of inactive users in UL and DL: $n_j^{inactive} = n_j \times p_{inactive} = 0$

  Number of users active in UL and inactive in DL: $n_j(UL) = n_j \times p_{UL} = 0$

  Number of users active in DL and inactive in UL: $n_j(DL) = n_j \times p_{DL} = 0$

  Number of users active in UL and DL both: $n_j(UL+DL) = n_j \times p_{UL+DL} = n_j$

  Therefore, all connected users (n_j) are active in both links.

- When selecting **Number of Users per Activity Status**, you can directly input the number of users active in the uplink and downlink ($n_j(UL+DL)$), for each sector.

Voice service users try to access the service with the FCH rates, $R_{FCH}^{UL} \times AF_{FCH}^{UL}$ on uplink and $R_{FCH}^{DL} \times AF_{FCH}^{DL}$ on downlink.

All user characteristics determined, a second random trial is performed to obtain their geographical positions.

- **Data Service Users (j)**

FCH is always allocated to active users but can have inactivity periods on both links. This is modelled by the FCH activity factors, AF_{FCH}^{UL} and AF_{FCH}^{DL}. SCH may be allocated with four possible rates (2x, 4x, 8x, 16xFCH nominal rate). Several data rate probabilities, P_k^{UL} and P_k^{DL}, can be assigned to different rates factor, r_k, for SCH channel.

For non-data services, these probabilities are 0.

For each transmitter, Tx_i, **9955** proceeds as follows:

- When selecting **Throughputs in Uplink and Downlink**, you can input the throughput demands in UL (R_t^{UL}) and DL (R_t^{DL}) for each sector.

  9955 calculates the number of users active in UL and DL using the service in the Txi cell as follows:

  $N_{UL} = \frac{R_t^{UL}}{R_j^{UL}}$ and $N_{DL} = \frac{R_t^{DL}}{R_j^{DL}}$

  Where,

  R_t^{UL} is the number of kbits per second transmitted in UL in the Txi cell to provide the service j to the users (user-defined value in the traffic map properties)

  R_t^{DL} is the number of kbits per second transmitted in DL in the Txi cell to provide the service j to the users (user-defined value in the traffic map properties).

  R_j^{UL} and R_j^{DL} correspond to uplink and downlink rates of a user.

  $$R_j^{UL} = \sum_{r_k}(r_k + AF_{FCH}^{UL}) \times R_{FCH}^{UL} \times P_{r_k}^{UL} + \left(1 - \sum_{r_k} P_{r_k}^{UL}\right) \times R_{FCH}^{UL} \times AF_{FCH}^{UL}$$

  $$R_j^{DL} = \sum_{r_k}(r_k + AF_{FCH}^{DL}) \times R_{FCH}^{DL} \times P_{r_k}^{DL} + \left(1 - \sum_{r_k} P_{r_k}^{DL}\right) \times R_{FCH}^{DL} \times AF_{FCH}^{DL}$$

  R_{FCH}^{UL} and R_{FCH}^{DL} are the uplink and downlink FCH nominal rates respectively.

  - In calculations detailed above, we assume that the sum of data rate probabilities is less than or equal to 1. If the sum of data rate probabilities exceeds 1, **9955** considers normalised data rate probabilities values, $P_{r_k} / \left(\sum_{r_k} P_{r_k}\right)$, instead of specified data rate probabilities P_{r_k}.

  Users are always active on FCH for both links. Therefore, we have following activity probabilities.

  Probability of being active in UL: $p_{UL} = 0$

  Probability of being active in DL: $p_{DL} = 0$

  Probability of being active in UL and DL both: $p_{UL+DL} = 1$

  Probability of being inactive: $p_{inactive} = 0$

  Then, **9955** calculates the number of users per activity status and the total number of users:

  Number of users active in UL and DL both: $n_j(UL + DL) = max(N_{UL}, N_{DL})$

  Number of users active in UL and inactive in DL: $n_j(UL) = 0$

Number of users active in DL and inactive in UL: $n_j(DL) = 0$

Number of inactive users in UL and DL: $n_j^{inactive} = 0$

Therefore, all connected users (n_j) are active in both links.

- When selecting **Total Number of Users (All Activity Statuses)**, you can input the number of connected users for each sector (n_j).

  Users are always active on FCH for both links. Therefore, we have following activity probabilities.

  Probability of being active in UL: $p_{UL} = 0$

  Probability of being active in DL: $p_{DL} = 0$

  Probability of being active in UL and DL both: $p_{UL+DL} = 1$

  Probability of being inactive: $p_{inactive} = 0$

  Then, **9955** calculates the number of users per activity status:

  Number of inactive users in UL and DL: $n_j^{inactive} = n_j \times p_{inactive} = 0$

  Number of users active in UL and inactive in DL: $n_j(UL) = n_j \times p_{UL} = 0$

  Number of users active in DL and inactive in UL: $n_j(DL) = n_j \times p_{DL} = 0$

  Number of users active in UL and DL both: $n_j(UL + DL) = n_j \times p_{UL+DL} = n_j$

  Therefore, all connected users (n_j) are active in both links.

- When selecting **Number of Users per Activity Status**, you can directly input the number of users active in the uplink and downlink ($n_j(UL + DL)$), for each sector.

As explained above, data service users can access the service with different rates. Possible rates are detailed in the table below:

	SCH rate factor r_k	Allocated rates	
		On UL	**On DL**
Only FCH is used	-	$R_{FCH}^{UL} \times AF_{FCH}^{UL}$	$R_{FCH}^{DL} \times AF_{FCH}^{DL}$
Both FCH and SCH are used	2x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 2)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 2)$
	4x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 4)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 4)$
	8x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 8)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 8)$
	16x	$R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 16)$	$R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 16)$

9955 determines the distribution of users with the different possible rates. A random trial compliant with data rate probabilities is performed for each link in order to determine the data rate of each user.

On uplink, we have,

For each SCH rate factor, r_k, the number of users $n_j^{r_k}$ with the data rate $R_{FCH}^{UL} \times (AF_{FCH}^{UL} + r_k)$ is calculated as follows,

$$n_j^{r_k} = P_{r_k}^{UL} \times n_j$$

Therefore, the number of users n_j^{FCH} with the data rate, $R_{FCH}^{UL} \times AF_{FCH}^{UL}$, is,

$$n_j^{FCH} = n_j - \sum_{r_k} n_j^{r_k}$$

On downlink, we have,

For each SCH rate factor, r_k, the number of users, $n_j^{r_k}$ with the data rate, $R_{FCH}^{DL} \times (AF_{FCH}^{DL} + r_k)$, is calculated as follows,

$$n_j^k = P_k^{DL} \times n_j$$

Therefore, the number of users n_j^{FCH} with the data rate, $R_{FCH}^{DL} \times AF_{FCH}^{DL}$, is,

$$n_j^{FCH} = n_j - \sum_{r_k} n_j^{r_k}$$

CDMA2000 1xEV-DO Services

As power control is performed in the uplink only, 1xEV-DO data service users will be considered either active in the uplink or inactive. 1xEV-DO data Rev. 0 service users can access the service with uplink rates of 9.6, 19.2, 38.4, 76.8 and 153.6 kbps. 1xEV-DO data Rev. A and Rev. B service users can access the service with uplink rates of 4.8, 9.6, 19.2, 38.4, 76.8, 115.2, 153.6, 230.4, 307.2, 460.8, 614.4, 921.6, 1,228.8 and 1,848.2 kbps.

For each service, j, several data rate probabilities, P_k^{UL}, can be assigned to different uplink rates R_k^{UL}. The number of users active in uplink ($n_j(UL)$) and the number of inactive users ($n_j(inactive)$) are calculated into several steps. First of all, **9955** determines the number of users active in UL using the service j in the Txi cell.

For each transmitter, Tx$_i$, and each service j:

- When selecting **Throughputs in Uplink and Downlink**, you can input the throughput demands in UL (R_t^{UL}) for each sector.

  9955 calculates the number of users active in UL using the service j in the Txi cell as follows:

  $$N_{UL} = \frac{R_t^{UL}}{R_j^{UL}}$$

  Where R_t^{UL} is the number of kbits per second transmitted on UL in the Txi cell to provide the service j (user-defined value in the traffic map properties).

  R_j^{UL} corresponds to the uplink data rate for a user.

  $$R_j^{UL} = \sum_k P_k^{UL} \times R_k^{UL}$$

> In the above calculations, we assume that the sum of data rate probabilities is less than or equal to 1. If the sum of data rate probabilities exceeds 1, **9955** considers normalised data rate probabilities values, $P_{r_k} / \left(\sum_{r_k} P_{r_k} \right)$, instead of specified data rate probabilities P_{r_k}.

  We have the following activity probabilities:

  Probability of being active in UL: $p_{UL} = \sum_{R_k^{UL}} P_k^{UL}(R_k^{UL})$

  Probability of being inactive: $p_{inactive} = 1 - \sum_{R_k^{UL}} P_k^{UL}(R_k^{UL})$

  Probability of being active in DL: $p_{DL} = 0$

  Probability of being active in UL and DL both: $p_{UL+DL} = 0$

  Therefore, we have:

Number of users active in UL: $n_j(UL) = N_{UL} \times p_{UL}$

Number of inactive users: $n_j(inactive) = N_{UL} \times p_{inactive}$

Number of users active in DL: $n_j(DL) = 0$

Number of users active in UL and DL both: $n_j(UL + DL) = 0$

Total number of connected users: $n_j = n_j(UL) + n_j(inactive)$

- When selecting **Total Number of Users (All Activity Statuses)**, you can input the number of connected users for each sector (n_j).

  We have the following activity probabilities:

  Probability of being active in UL: $p_{UL} = \sum_{R_k^{UL}} P_k^{UL}(R_k^{UL})$

  Probability of being inactive: $p_{inactive} = 1 - \sum_{R_k^{UL}} P_k^{UL}(R_k^{UL})$

  Probability of being active in DL: $p_{DL} = 0$

  Probability of being active in UL and DL both: $p_{UL+DL} = 0$

  Therefore, we have:

  Number of users active in UL: $n_j(UL) = n_j \times p_{UL}$

  Number of inactive users: $n_j(inactive) = n_j \times p_{inactive}$

  Number of users active in DL: $n_j(DL) = 0$

  Number of users active in UL and DL both: $n_j(UL + DL) = 0$

- When selecting **Number of Users per Activity Status**, you can directly input the number of inactive users ($n_j(inactive)$) and the number of users active in the uplink ($n_j(UL)$), for each sector.

  The total number of connected users (n_j) is calculated as follows

  $n_j = n_j(UL) + n_j(inactive)$

Then, **9955** determines the distribution of users with the different possible rates. The number of users with the data rate R_k^{UL}, $n_j(R_k^{UL})$, is calculated as follows:

$$n_j(R_k^{UL}) = P_k^{UL} \times n_j$$

Inactive users have a requested data rate equal to 0.

> The user distribution per service is an average distribution and the service of each user is randomly drawn In each simulation. Therefore, if you compute several simulations at once, the average number of users per service will correspond to the calculated distribution. But if you check each simulation, the user distribution between services is different in each of them.
>
> It is the same for the SCH rate distribution between 1xRTT data service users and the traffic data rate distribution between 1xEV-DO data service users.

7.4.1.2 Transition Flags for 1xEV-DO Rev.0 User Data Rates

For 1xEV-DO Rev. 0 services supporting data rate downgrading, you can define the probability of the service being upgraded ($P_{Upg-k}^{UL}(R_k^{UL})$) or downgraded ($P_{Downg-k}^{UL}(R_k^{UL})$) on the uplink (reverse link) for each data rate (R_k^{UL}). The probabilities are taken into account in order to determine if a user with a certain data rate can be upgraded or downgraded. User data rate downgrading and upgrading occur during congestion control when the cell is over- or underloaded.

The following table shows the data rate changes that are possible when a data rate is upgraded or downgraded. The probabilities are defined with a number from 1 to 255 for each data rate.

Possible Data Rate Changes During Upgrading	
From	To
9.6 kbps	19.2 kbps
19.2 kbps	38.4 kbps
38.4 kbps	76.8 kbps
76.8 kbps	153.6 kbps

Possible Data Rate Changes During Downgrading	
From	To
153.6 kbps	76.8 kbps
76.8 kbps	38.4 kbps
38.4 kbps	19.2 kbps
19.2 kbps	9.6 kbps

During the generation of the user distribution, each 1xEV-DO Rev. 0 user is assigned a random number between 1 and 255 for each possible data rate transition. When this number is lower or equal to the value of the probability, the transition flag for this data rate transition is set to "True" meaning that this data rate transition can be performed if necessary.

The number of 1xEV-DO Rev. 0 users with a certain data rate that can be downgraded ($n_j(R_k^{UL})_{Downg}$) and upgraded ($n_j(R_k^{UL})_{Upg}$) are calculated as follows:

$$n_j(R_k^{UL})_{Upg} = \frac{P_{Upg-k}^{UL}(R_k^{UL}) \times n_j(R_k^{UL})}{255}$$

And

$$n_j(R_k^{UL})_{Downg} = \frac{P_{Downg-k}^{UL}(R_k^{UL}) \times n_j(R_k^{UL})}{255}$$

The number of users with a certain data rate that can be downgraded or upgraded is an average. Therefore, if you compute several simulations at once, the average number of users with a certain data rate that can be downgraded or upgraded will correspond to the calculated value. But if you check each simulation, this number is different in each of them.

7.4.1.3 User Geographical Position

Once all the user characteristics determined, another random trial is performed to obtain their geographical positions and whether they are indoors or outdoors according to the percentage of indoor users per clutter class defined for the traffic maps.

7.4.2 Network Regulation Mechanism

7.4.2.1 CDMA2000 1xRTT Power Control Simulation Algorithm

CDMA2000 1xRTT network automatically regulates itself using traffic driven uplink and downlink power control on the fundamental and supplemental channels (FCH and SCH respectively) in order to minimize interference and maximize capacity. **9955** simulates this network regulation mechanism with an iterative algorithm and calculates, for each user distribution, network parameters such as base station power, mobile terminal power, active set and handoff status for each terminal.

The power control simulation is based on an iterative algorithm, where in each iteration, all the mobiles selected during the user distribution generation (1^{st} step) try to connect to network active transmitters with a calculation area. The process is repeated from iteration to iteration until convergence is achieved. The algorithm steps are detailed below.

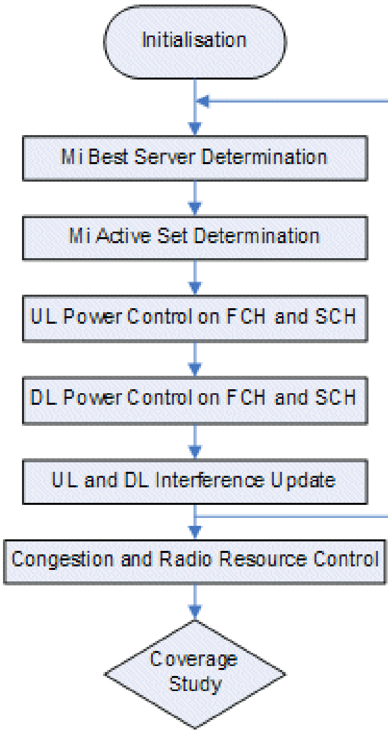


Figure 7.1: CDMA2000 1xRTT Power Control Algorithm

7.4.2.1.1 Algorithm Initialization

Total power on carrier *ic*, $P_{Tx}(ic)$, of base station S_j is initialised to $P_{pilot}(ic) + P_{sync}(ic) + P_{paging}(ic)$.

Uplink received powers on carrier *ic*, $I_{tot}^{UL_{intra}}(ic)$, $I_{tot}^{UL_{extra}}(ic)$ and $I_{inter-carrier}^{UL}(ic)$, at base station S_j are initialised to 0 W (no connected mobile).

$$\Leftrightarrow X_k^{UL}(S_j, ic) = \frac{I_{tot}^{UL}(S_j, ic)}{N_{tot}^{UL}(S_j, ic)} = 0$$

7.4.2.1.2 Presentation of the Algorithm

The algorithm is detailed for any iteration *k*. X_k is the value of the variable *X* at the iteration *k*. In the algorithm, all Q_{req}^{UL} and Q_{req}^{DL} thresholds depend on user mobility type and are defined in Service and Mobility parameters tables. All variables are described in Definitions and formulas part.

The algorithm applies to single frequency band networks and to dual-band networks. Dual-band terminals can have the following configurations:

- Configuration 1: The terminal can work on *f1* and *f2* without any priority (select "All" as main frequency band in the terminal property dialogue).
- Configuration 2: The terminal can work on *f1* and *f2* but *f1* has a higher priority (select "*f1*" as main frequency band and "*f2*" as secondary frequency band in the terminal property dialogue).

For each mobile M_i

Determination of M_i's Best Serving Cell

For each transmitter *Sj* containing M_i in its calculation area and working on the main frequency band supported by the M_i's terminal (i.e. either *f1* for a single frequency band network, or *f1* or *f2* for a dual-band terminal with the configuration 1, or *f1* for a dual-band terminal with the configuration 2).

Calculation of $Q_{pilot_k}(Sj, ic, M_i) = \dfrac{\alpha \times \rho_{BTS} \times P_c(Sj, M_i, ic)}{P_{tot}^{DL}(Sj, ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{Term}}$

Determination of the candidate cells, (S_{BS}, ic).

For each carrier *ic*, selection of the transmitter with the highest $Q_{pilot_k}(Sj, M_i, ic)$, $(S_{BS}, ic)(M_i)$.

Analysis of candidate cells, *(S_{BS},ic)*.

For each pair *(S_{BS},ic)*, calculation of the uplink load factor:

$$X_k^{UL}(S_{BS}, ic) = \frac{I_{tot}^{UL}(S_{BS}, ic)}{N_{tot}^{UL}(S_{BS}, ic)} + \Delta X^{UL}$$

Rejection of bad candidate cells if the pilot is not received or if the uplink load factor is exceeded during the admission load control (if simulation respects a loading factor constraint and M_b was not connected in previous iteration)

If $Q_{pilot_k}(S_{BS}, M_i, ic) < Q_{req}^{pilot}$ then *(S_{BS},ic)* is rejected by M_i

If $X_k^{UL}(S_{BS}, ic) > X_{max}^{UL}$, then *($S_{BS}$,ic)* is rejected by M_i

Else

Keep *(S_{BS},ic)* as good candidate cell

For dual band terminals with the configuration 1 or terminals working on one frequency band only, if no good candidate cell has been selected, M_i has failed to be connected to the network and is rejected.

For dual band terminals with the configuration 2, if no good candidate cell has been selected, try to connect M_i to transmitters *txi* containing M_i in their calculation area and working on the secondary frequency band supported by the M_i's terminal (i.e. f2). If no good candidate cell has been selected, M_i has failed to be connected to the network and is rejected.

Determination of the best carrier, *ic_{BS}*.

If a given carrier is specified for the service requested by M_i

$ic_{BS}(M_i)$ is the carrier specified for the service

Else the carrier selection mode defined for the site equipment is considered.

If carrier selection mode is “Min. UL Load Factor”

$ic_{BS}(M_i)$ is the cell with the lowest $X_k^{UL}(S_{BS}, ic)$

Else if carrier selection mode is “Min. DL Total Power”

$ic_{BS}(M_i)$ is the cell with the lowest $P_{tx}(S_{BS}, ic)_k$

Else if carrier selection mode is “Random”

$ic_{BS}(M_i)$ is randomly selected

Else if carrier selection mode is "Sequential"

$ic_{BS}(M_i)$ is the first carrier where $X_k^{UL}(S_{BS}, ic)X_{max}^{UL}$

Endif

Determination of the best serving cell, *(S_{BS},ic_{BS})*.

$(S_{BS},ic_{BS})_k(M_i)$ is the best serving cell ($BestCell_k(M_i)$) and its pilot quality is $Q_{pilot_k}^{max}(M_i)$.

In the following lines, we will consider ic as the carrier used by the best serving cell.

Determination of the Active Set

For each station S_j containing M_i in its calculation area, using *ic*, and if neighbours are used, neighbour of $BestCell_k(M_i)$

Calculation of $Q_{pilot_k}(M_i, S_j, ic) = \dfrac{\alpha \times \rho_{BTS} \times P_c(M_i, S_j)}{I_0^{DL}(ic)}$

Rejection of station S_j if the pilot is not received

If $Q_{pilot_k}(M_i, S_j, ic) < Q_{min}^{pilot}$ then S_j is rejected by M_i

Else S_j is included in the M_i active set

Rejection of S_j if the M_i active set is full

Station with the lowest Q_{pilot_k} in the active set is rejected

EndFor

Uplink Power Control

Calculation of the required power for M_i, $P_{term}^{req}(M_i, ic)_k$

For each cell (S_j, ic) present in the M_i active set

Calculation of quality level on M_i traffic channel at (S_j,ic), with the minimum power allowed on traffic channel for the M_i service

$$P_b^{FCH-UL}(M_i, S_j, ic) = \frac{P_{term}^{FCH-req}(M_i, ic)_{k-1}}{L_T(M_i, S_j)} \text{ and } P_b^{SCH-UL}(M_i, S_j, ic) = \frac{P_{term}^{SCH-req}(M_i, ic)_{k-1}}{L_T(M_i, S_j)}$$

$$Q_{FCH}^{UL}(M_i, S_j, ic)_k = \frac{\rho_{term} \times P_b^{FCH-UL}(M_i, S_j, ic)}{N_{tot}^{UL}(ic) - (1 - F_{MUD}) \times \rho_{term} \times (P_b^{FCH-UL}(M_i, S_j, ic) + P_b^{SCH-UL}(M_i, S_j, ic))} \times G_p^{FCH-UL}(Service)$$

$$Q_{SCH}^{UL}(M_i, S_j, ic)_k = \frac{\rho_{term} \times P_b^{SCH-UL}(M_i, S_j, ic)}{N_{tot}^{UL}(ic) - (1 - F_{MUD}) \times \rho_{term} \times (P_b^{FCH-UL}(M_i, S_j, ic) + P_b^{SCH-UL}(M_i, S_j, ic))} \times G_p^{SCH-UL}(Service)$$

If the user selects the option “Total noise”

$$Q_{FCH}^{UL}(M_i, S_j, ic)_k = \frac{\rho_{term} \times P_b^{FCH-UL}(M_i, S_j, ic)}{N_{tot}^{UL}(ic)} \times G_p^{FCH-UL}(Service)$$

$$Q_{SCH}^{UL}(M_i, S_j, ic)_k = \frac{\rho_{term} \times P_b^{SCH-UL}(M_i, S_j, ic)}{N_{tot}^{UL}(ic)} \times G_p^{SCH-UL}(Service)$$

End For

If (M_i is not in handoff)

$$Q_{FCH_k}^{UL}(M_i) = Q_{FCH}^{UL}(M_i, S_j, ic)_k \text{ and } Q_{SCH_k}^{UL}(M_i) = Q_{SCH}^{UL}(M_i, S_j, ic)_k$$

Else if (M_i is in softer handoff)

$$Q_{FCH_k}^{UL}(M_i) = f_{rake\ efficiency}^{UL} \times \sum_{S_j \in ActiveSet} Q_{FCH}^{UL}(M_i, S_j, ic)_k$$

$$Q_{SCH_k}^{UL}(M_i) = f_{rake\ efficiency}^{UL} \times \sum_{S_j \in ActiveSet} Q_{SCH}^{UL}(M_i, S_j, ic)_k$$

Else if (M_i is in soft or softer/soft without MRC)

$$Q_{FCH_k}^{UL}(M_i) = (G_{macro-diversity}^{UL})_{2\ links} \times \underset{S_j \in ActiveSet}{Max}(Q_{FCH}^{UL}(M_i, S_j, ic)_k)$$

$$Q_{SCH_k}^{UL}(M_i) = (G_{macro-diversity}^{UL})_{2\ links} \times \underset{S_j \in ActiveSet}{Max}(Q_{SCH}^{UL}(M_i, S_j, ic)_k)$$

Else if (M_i is in soft/soft)

$$Q_{FCH_k}^{UL}(M_i) = (G_{macro-diversity}^{UL})_{3\ links} \times \underset{S_j \in ActiveSet}{Max}(Q_{FCH}^{UL}(M_i, S_j, ic)_k)$$

$$Q_{SCH_k}^{UL}(M_i) = (G_{macro-diversity}^{UL})_{3\ links} \times \underset{S_j \in ActiveSet}{Max}(Q_{SCH}^{UL}(M_i, S_j, ic)_k)$$

Else if (M_i is in softer/soft with MRC)

$$Q^{UL}_{FCH_k}(M_i) = Max\left(f^{UL}_{rake\ efficiency} \times \sum_{\substack{i_{AS} \in ActiveSet \\ (same\ site)}} Q^{UL}_{FCH}(ic), Q^{UL}_{\substack{FCH \\ other\ site}}(ic)\right) \times (G^{UL}_{macro-diversity})_{2\ links}$$

$$Q^{UL}_{SCH_k}(M_i) = Max\left(f^{UL}_{rake\ efficiency} \times \sum_{\substack{i_{AS} \in ActiveSet \\ (same\ site)}} Q^{UL}_{SCH}(ic), Q^{UL}_{\substack{SCH \\ other\ site}}(ic)\right) \times (G^{UL}_{macro-diversity})_{2\ links}$$

EndIf

$$P^{FCH-req}_{term}(M_i, ic)_k = \frac{(Q^{UL}_{req}(Service(M_i), Term(M_i), Mobility(M_i)))_{FCH}}{Q^{UL}_{FCH_k}(M_i)} \times P^{FCH-req}_{term}(M_i, ic)_{k-1}$$

$$P^{SCH-req}_{term}(M_i, ic)_k = \frac{(Q^{UL}_{req}(Service(M_i), Term(M_i), Mobility(M_i), SCH\_rate\_multiple))_{SCH}}{Q^{UL}_{SCH_k}(M_i)} \times P^{SCH-req}_{term}(M_i, ic)_{k-1}$$

$$P^{req}_{term}(M_i, ic)_k = P^{FCH-req}_{term}(M_i, ic)_k + P^{SCH-req}_{term}(M_i, ic)_k$$

If $P^{req}_{term}(M_i, ic)_k < P^{min}_{term}(M_i)$ then

$$P^{FCH-req}_{term}(M_i, ic)_k = \frac{P^{min}_{term}(M_i, S_j)}{P^{req}_{term}(M_i)_k} \times P^{FCH-req}_{term}(M_i, ic)_k$$

$$P^{SCH-req}_{term}(M_i, ic)_k = \frac{P^{min}_{term}(M_i, S_j)}{P^{req}_{term}(M_i)_k} \times P^{SCH-req}_{term}(M_i, ic)_k$$

EndIf

If $P^{FCH-req}_{term}(M_i, ic)_k > P^{max}_{term}(M_i)$ then M_i cannot select any station and its active set is cleared

If $P^{req}_{term}(M_i, ic)_k > P^{max}_{term}(M_i)$ and M_i uses SCH then:

Downgrading the service SCH rate:

While $P^{req}_{term}(M_i, ic)_k > P^{max}_{term}(M_i)$ and $R^{UL}_{SCH}(Service(M_i)) > R^{UL}_{FCH}(Service(M_i)) \times 2$

$$R^{UL}_{SCH}(Service(M_i)) > \frac{R^{UL}_{SCH}(Service(M_i))}{2}$$

$$P^{SCH-req}_{term}(M_i, ic)_k = \frac{P^{SCH-req}_{term}(M_i, ic)_k}{2} \times \frac{(Q^{UL}_{req}(Service(M_i), Term(M_i), Mobility(M_i), R^{UL}_{SCH}(Service(M_i))))_{SCH}}{(Q^{UL}_{req}(Service(M_i), Term(M_i), Mobility(M_i), R^{UL}_{SCH}(Service(M_i) \times 2)))_{SCH}}$$

$$P^{req}_{term}(M_i, ic)_k = P^{FCH-req}_{term}(M_i, ic)_k + P^{SCH-req}_{term}(M_i, ic)_k$$

EndWhile

If $P^{req}_{term}(M_i, ic)_k > P^{max}_{term}(M_i)$ then M_i will not use SCH

Endif

Endif

If the required number of channel elements exceeds the available quantity in the site of S_j (Best server of M_i) and M_i uses SCH then:

Downgrading the service SCH rate:

While $N^{CE-UL}(M_i) > N^{CE-UL}_{max}(S_j)$ and $R^{UL}_{SCH}(Service(M_i)) > R^{UL}_{FCH}(Service(M_i)) \times 2$

$$R_{SCH}^{UL}(Service(M_i)) > \frac{R_{SCH}^{UL}(Service(M_i))}{2}$$

$$N_{SCH}^{CE-UL}(M_i)_k = \frac{N_{SCH}^{CE-UL}(M_i)_k}{2}$$

$$P_{term}^{SCH-req}(M_i, ic)_k = \frac{P_{term}^{SCH-req}(M_i, ic)_k}{2} \times \frac{Q_{req}^{SCH-UL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{UL}(Service(M_i)))}{Q_{req}^{SCH-UL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{UL}(Service(M_i) \times 2))}$$

$$P_{term}^{req}(M_i, ic)_k = P_{term}^{FCH-req}(M_i, ic)_k + P_{term}^{SCH-req}(M_i, ic)_k$$

$$N^{CE-UL}(M_i)_k = N_{SCH}^{CE-UL}(M_i)_k + N_{FCH}^{CE-UL}(M_i)_k$$

EndWhile

Endif

Downlink Power Control

If M_i uses an SCH on the downlink

For each cell *(S_j,ic)* in M_i FCH active set

Calculation of quality level on *(S_j,ic)* FCH at M_i, with the minimum power allowed on FCH for the M_i service

$$P_b^{FCH-DL}(M_i, S_j, ic) = \frac{P_{FCH}^{min}(Service(M_i))}{L_T(M_i, S_j)}$$

$$Q_{FCH}^{DL}(M_i, S_j, ic)_k = \frac{\rho_{BTS} \times P_b^{FCH-DL}(M_i, S_j)}{N_{tot}^{DL}(ic) - (1 - F_{ortho}) \times \rho_{BTS} \times P_b^{DL}(M_i, S_j, ic)} \times G_p^{FCH-DL}(Service(M_i))$$

If the user selects the option “Total noise”

$$Q_{FCH}^{DL}(M_i, S_j, ic)_k = \frac{\rho_{BTS} \times P_b^{FCH-DL}(M_i, S_j)}{N_{tot}^{DL}(ic)}$$

If cell *(S_j,ic)* in M_i SCH active set

Calculation of quality level on *(S_j,ic)* SCH at M_i, with the minimum power allowed on SCH for the M_i service

$$P_b^{SCH-DL}(M_i, S_j, ic) = \frac{P_{SCH}^{min}(Service(M_i))}{L_T(M_i, S_j)}$$

$$Q_{SCH}^{DL}(M_i, S_j, ic)_k = \frac{\rho_{BTS} \times P_b^{SCH-DL}(M_i, S_j)}{N_{tot}^{DL}(ic) - (1 - F_{ortho}) \times \rho_{BTS} \times P_b^{DL}(M_i, S_j, ic)} \times G_p^{SCH-DL}(Service(M_i))$$

If the user selects the option “Total noise”

$$Q_{SCH}^{DL}(M_i, S_j, ic)_k = \frac{\rho_{BTS} \times P_b^{SCH-DL}(M_i, S_j)}{N_{tot}^{DL}(ic)}$$

EndIf

End For

Recombination of the first *f* active set links (*f* is the number of fingers of the M_i terminal): only quality levels from the first *f* cells *(S_f,ic)* of active set are recombined.

$$Q_{FCH_k}^{DL}(M_i) = f_{rake\ efficiency}^{DL} \times \sum_{S_f \in ActiveSet(FCH)} Q_{FCH}^{DL}(M_i, S_j, ic)_k$$

$$Q_{SCH_k}^{DL}(M_i) = f_{rake\ efficiency}^{DL} \times \sum_{S_f \in ActiveSet(SCH)} Q_{SCH}^{DL}(M_i, S_j, ic)_k$$

Do

For each cell (S_j,ic) in M_i FCH active set

Calculation of the required power for DL traffic channel between (S_j,ic) and M_i:

$$P_{FCH}^{req}(M_i, S_j, ic)_k = \frac{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{FCH}^{DL}(Service(M_i))))_{FCH}}{Q_{FCH_k}^{DL}(M_i)} \times P_{FCH}^{min}(Service(M_i))$$

If $P_{FCH}^{req}(M_i, S_j, ic)_k > P_{FCH}^{max}(Service(M_i))$ then (S_j, ic) is excluded from M_i active set

Recalculation of a decreased Q_{req}^{DL}

If cell (S_j,ic) in M_i SCH active set

Calculation of the required power for DL traffic channel between (S_j,ic) and M_i:

$$P_{SCH}^{req}(M_i, S_j, ic)_k = \frac{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{DL}(Service(M_i))))_{SCH}}{Q_{SCH_k}^{DL}(M_i)} \times P_{SCH}^{min}(Service(M_i))$$

Downgrading the service SCH rate (only for (S_j,ic) best server cell of M_i):

While $P_{SCH}^{req}(M_i, S_j, ic)_k > P_{SCH}^{max}(Service(M_i), R_{SCH}^{DL}(Service(M_i)))$

Or $P_{tx}(S_j, ic)_k + P_{tch}^{req}(M_i, S_j, ic)_k > P_{max}(S_j, ic)$ and $R_{SCH}^{DL}(Service(M_i)) > R_{FCH}^{DL}(Service(M_i)) \times 2$

$$R_{SCH}^{DL}(Service(M_i)) = \frac{R_{SCH}^{DL}(Service(M_i))}{2}$$

$$P_{SCH}^{req}(M_i, S_j, ic)_k = \frac{P_{SCH}^{req}(M_i, S_j, ic)_k}{2} \times \frac{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{DL}(Service(M_i))))_{SCH}}{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{DL}(Service(M_i) \times 2)))_{SCH}}$$

$$P_{tch}^{req}(M_i, S_j, ic)_k = P_{SCH}^{req}(M_i, S_j, ic)_k + P_{FCH}^{req}(M_i, S_j, ic)_k$$

EndWhile

If $P_{SCH}^{req}(M_i, S_j, ic)_k > P_{SCH}^{max}(Service(M_i))$ or $P_{tx}(S_j, ic)_k + P_{tch}^{req}(M_i, S_j, ic)_k > P_{max}(S_j, ic)$ then M_i will not use SCH

Endif

While $N^{CE-DL}(M_i) > N_{max}^{CE-DL}(S_j)$ and $R_{SCH}^{DL}(Service(M_i)) > R_{FCH}^{DL}(Service(M_i)) \times 2$

$$R_{SCH}^{DL}(Service(M_i)) = \frac{R_{SCH}^{DL}(Service(M_i))}{2}$$

$$N_{SCH}^{CE-DL}(M_i)_k = \frac{N_{SCH}^{CE-DL}(M_i)_k}{2}$$

$$P_{SCH}^{req}(M_i, S_j, ic)_k = \frac{P_{SCH}^{req}(M_i, S_j, ic)_k}{2} \times \frac{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{DL}(Service(M_i))))_{SCH}}{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{DL}(Service(M_i) \times 2)))_{SCH}}$$

$$P_{tch}^{req}(M_i, S_j, ic)_k = P_{SCH}^{req}(M_i, S_j, ic)_k + P_{FCH}^{req}(M_i, S_j, ic)_k$$

$$N^{CE-DL}(M_i)_k = N_{SCH}^{CE-DL}(M_i)_k + N_{FCH}^{CE-DL}(M_i)_k$$

EndWhile

If $N^{CE-DL}(M_i) > N_{max}^{CE-DL}(S_j)$ then M_i will not use SCH

Endif

While $N^{Codes}(M_i) > N_{max}^{Codes}(S_j, ic)$ and $R_{SCH}^{DL}(Service(M_i)) > R_{FCH}^{DL}(Service(M_i)) \times 2$

$$R_{SCH}^{DL}(Service(M_i)) = \frac{R_{SCH}^{DL}(Service(M_i))}{2}$$

$$N_{SCH}^{Codes}(M_i)_k = \frac{N_{SCH}^{Codes}(M_i)_k}{2}$$

$$P_{SCH}^{req}(M_i, S_j, ic)_k = \frac{P_{SCH}^{req}(M_i, S_j, ic)_k}{2} \times \frac{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{DL}(Service(M_i))))_{SCH}}{(Q_{req}^{DL}(Service(M_i), Term(M_i), Mobility(M_i), R_{SCH}^{DL}(Service(M_i) \times 2)))_{SCH}}$$

$$P_{tch}^{req}(M_i, S_j, ic)_k = P_{SCH}^{req}(M_i, S_j, ic)_k + P_{FCH}^{req}(M_i, S_j, ic)_k$$

$$N^{Codes}(M_i)_k = N_{FCH}^{Codes}(M_i)_k + N_{SCH}^{Codes}(M_i)_k$$

EndWhile

If $N^{Codes}(M_i) > N_{max}^{Codes}(S_j)$ then M_i will not use SCH

Endif

Endif

EndFor

Recombination of the first *f* active set links (*f* is the number of fingers of the M_i terminal): only quality levels from the first *f* cells *(S_f,ic)* of active set are recombined.

$$Q_{FCH_k}^{DL}(M_i) = f_{rake\ efficiency}^{DL} \times \sum_{S_f \in ActiveSet(FCH)} Q_{FCH}^{DL}(M_i, S_f, ic)_k$$

$$Q_{SCH_k}^{DL}(M_i) = f_{rake\ efficiency}^{DL} \times \sum_{S_f \in ActiveSet(SCH)} Q_{SCH}^{DL}(M_i, S_f, ic)_k$$

While $Q_k^{DL}(M_i) < Q_{req}^{DL}(Service(M_i), Mobility(M_i))$ and M_i *FCH* active set is not empty

And $Q_k^{DL}(M_i) < Q_{req}^{DL}(Service(M_i), Mobility(M_i))$ (if SCH active set is not empty)

Endif

Uplink and Downlink Interference Updates

Update of interference on active mobiles only (old contributions of mobiles and stations are replaced by the new ones)

For each cell *(S_j,ic)*

Update of $N_{tot}^{UL}(S_j, ic)$

EndFor

For each mobile M_i

Update of $N_{tot}^{DL}(ic)$

EndFor

Control of Radio Resource Limits (Walsh Codes, Cell Power and Site Channel Elements)

For each cell *(S_j,ic)* on a site N_l

While $\frac{P_{tx}(S_j, ic)_k}{P_{max}} > \%Power_{max}^{DL}$

Rejection of mobile with highest $P_{tch}^{req}(S_j, M_b, ic)_k$ for the lowest service priority

EndWhile

EndFor

For each site N_l

The list of rejected mobiles for the site N_l is $L_{rejected}(N_l)$

If the equipment installed on N_l supports power pooling between transmitters

Activation of power pooling between transmitters for each cell (S_j, ic) containing rejected users

Control of the available power for the other cells (S_i, ic) of the site where power pooling between transmitters is not activated

If $\sum_{\substack{(S_i, ic) \\ S_i \in N_l}} (\%Power^{DL}_{max} \times P_{max} - P_{tx}(S_i, ic)_k) > 0$

Then, the power unused by the cells (S_i, ic) of the site can be allocated to cells (S_j, ic)

Sort of all the rejected mobiles by priority in a descending order and by simulation rank in a descending order

For the first mobile M_b of the list ($M_b \in L_{rejected}(N_l)$)

If $P_{tx}(S_j, ic)_k + P^{req}_{tch}(S_j, M_b, ic)_k < \%Power^{DL}_{max} \times P_{max} + M_{Pooling}(S_j, ic)$

M_b is reconnected

EndIf

EndFor

EndIf

EndFor

For each cell (S_j, ic)

While $N^{Codes}(S_j, ic)_k > N^{Codes}_{max}(S_j, ic)$

Rejection of last admitted mobile

EndFor

For each site (Node B) Nl

While $N^{CE-DL}(N_l)_k > N^{CE-DL}_{max}(N_l)$

Rejection of mobile with highest $P^{req}_{tch}(M_i, S_j)_k$ for the lowest service priority

While $N^{CE-UL}(N_l)_k > N^{CE-UL}_{max}(N_l)$

Rejection of mobile with highest $P^{req}_{term}(M_i, ic)_k$ for the lowest service priority

EndFor

Uplink Load Factor Control

For each cell (S_j, ic) with $X^{UL}(S_j, ic) > X^{UL}_{max}$

Rejection of a mobile with the lowest service priority

EndFor

While at least one cell with $X^{UL}(S_j, ic) > X^{UL}_{max}$ exists

7.4.2.1.3 Convergence Criterion

The convergence criteria are evaluated at each iteration, and can be written as follow:

$$\Delta_{DL} = max\left(int\left(\max_{Stations}\left|\frac{P_{tx}(ic)_k - P_{tx}(ic)_{k-1}}{P_{tx}(ic)_k}\right| \times 100\right), int\left(\max_{Stations}\left|\frac{N^{DL}_{user}(ic)_k - N^{DL}_{user}(ic)_{k-1}}{N^{DL}_{user}(ic)_k}\right| \times 100\right)\right)$$

$$\Delta_{UL} = max\left(int\left(\max_{Stations}\left|\frac{I^{UL}_{tot}(ic)_k - I^{UL}_{tot}(ic)_{k-1}}{I^{UL}_{tot}(ic)_k}\right| \times 100\right), int\left(\max_{Stations}\left|\frac{N^{UL}_{user}(ic)_k - N^{UL}_{user}(ic)_{k-1}}{N^{UL}_{user}(ic)_k}\right| \times 100\right)\right)$$

9955 stops the algorithm if:

1st case: Between two successive iterations, Δ_{UL} and Δ_{DL} are lower ($\leq$) than their respective thresholds (defined when creating a simulation).

The simulation has reached convergence.

Example: Let us assume that the maximum number of iterations is 100, UL and DL convergence thresholds are set to 5. If $\Delta_{UL} \le 5$ and $\Delta_{DL} \le 5$ between the 4th and the 5th iteration, **9955** stops the algorithm after the 5th iteration. Convergence has been achieved.

2nd case: After 30 iterations, Δ_{UL} or/and Δ_{DL} are still higher than their respective thresholds and from the 30th iteration, Δ_{UL} or/and Δ_{DL} do not decrease during the next 15 successive iterations.

The simulation has not reached convergence (specific divergence symbol).

Examples: Let us assume that the maximum number of iterations is 100, UL and DL convergence thresholds are set to 5.

1. After the 30th iteration, Δ_{UL} and/or Δ_{DL} equal 100 and do not decrease during the next 15 successive iterations: **9955** stops the algorithm at the 46th iteration. Convergence has not been achieved.

2. After the 30th iteration, Δ_{UL} and/or Δ_{DL} equal 80, they start decreasing slowly until the 40th iteration (without going under the thresholds) and then do not change during the next 15 successive iterations: **9955** stops the algorithm at the 56th iteration without achieving convergence.

3rd case: After the last iteration.

If Δ_{UL} and/or Δ_{DL} are still strictly higher than their respective thresholds, the simulation has not converged (specific divergence symbol).

If Δ_{UL} and Δ_{DL} are lower than their respective thresholds, the simulation has converged.

7.4.2.2 CDMA2000 1xEV-DO Power/Data Rate Control Simulation Algorithm

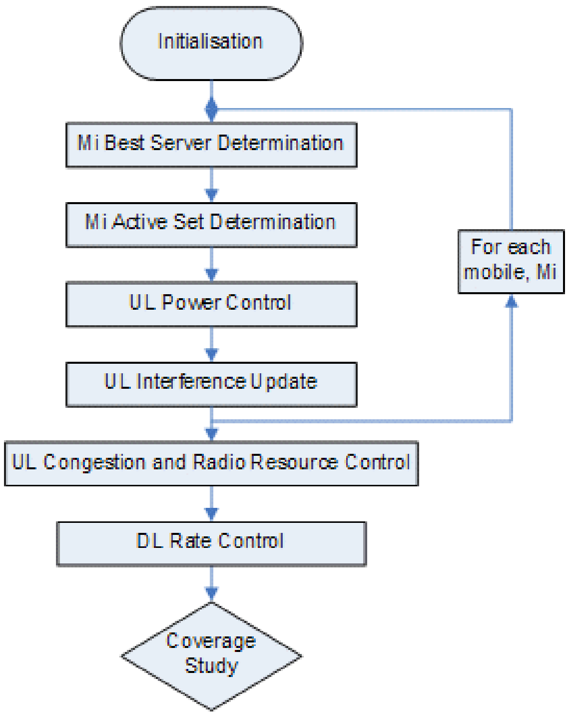


Figure 7.2: CDMA2000 1xEVDO Power Control Algorithm

In a CDMA2000 1xEV-DO system, power control is performed in the uplink only. In the downlink, the transmitter transmits at the full power (P_{max}) when a connection is established. Instead of power control, there is a data rate control based on the C/I ratio calculated at the mobile. For each distribution of users, **9955** simulates the power control mechanism for the UL and the data rate control for the DL.

The simulation uses an iterative algorithm, where in each iteration, all the 1xEV-DO data service users selected during the user distribution generation (1st step) try to connect to network active transmitters with a calculation area. **9955** considers the guaranteed bit rate service users first, in the order established during the generation of the user distribution, and then, it processes the variable bit rate service users, in the order established during the generation of the user distribution.

The process is repeated from iteration to iteration until convergence is achieved. The algorithm steps are detailed below.

7.4.2.2.1 Algorithm Initialization

Uplink received powers on carrier *ic*, $I_{tot}^{UL_{intra}}(ic)$, $I_{tot}^{UL_{extra}}(ic)$ and $I_{inter-carrier}^{UL}(ic)$, at base station S_j are initialised to 0 W (no connected mobile).

$$\Leftrightarrow X_k^{UL}(S_j, ic) = \frac{I_{tot}^{UL}(S_j, ic)}{N_{tot}^{UL}(S_j, ic)} = 0$$

7.4.2.2.2 Presentation of the Algorithm

The algorithm is detailed for any iteration *k*. X_k is the value of the variable *X* at the iteration *k*.

In the algorithm, $\left(\frac{E_c}{N_t}\right)_{min-Rev0}^{UL}$ is the minimum pilot quality level required in the uplink to operate 1xEV-DO Rev. 0. This threshold depends on the user mobility type and is defined in the Mobility parameters table.

$\left(\frac{E_c}{N_t}\right)_{min-RevB}^{UL}$ is the minimum pilot quality level required in the uplink to operate EV-DO multi-carrier. This threshold is defined in the Transmitter properties dialogue.

For 1xEV-DO Rev. A and Rev. B users, the value of $\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ depends on the user requested data rate. This data rate can be obtained by using a certain uplink 1xEV-DO radio bearer ($Index_{UL-Bearer}$) in a certain number of subframes (n_{SF}). $\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ is the value defined in the 1xEV-DO Radio Bearer Selection (Uplink) table for the combination (radio bearer Index, mobility and number of subframe) providing the user requested data rate. Two values are available for this parameter, one when the service uplink mode is "Low Latency" and another one for high capacity services.

All variables are described in Definitions and formulas part (see "Definitions and Formulas" on page 444).

The algorithm applies to single frequency band networks and to dual-band networks. Dual-band terminals can have the following configurations:

- <u>Configuration 1</u>: The terminal can work on *f1* and *f2* without any priority (select "All" as main frequency band in the terminal property dialogue).
- <u>Configuration 2:</u> The terminal can work on *f1* and *f2* but *f1* has a higher priority (select "*f1*" as main frequency band and "*f2*" as secondary frequency band in the terminal property dialogue).

For each mobile M_i

Determination of M_i's Best Serving Cell

For each transmitter *Sj* containing M_i in its calculation area and working on the main frequency band supported by the M_i's terminal (i.e. either *f1* for a single frequency band network, or *f1* or *f2* for a dual-band terminal with the configuration 1, or *f1* for a dual-band terminal with the configuration 2).

Calculation of $Q_{pilot_k}(Sj, ic, M_i) = \dfrac{\alpha \times \rho_{BTS} \times P_c(Sj, M_i, ic, b_{pilot})}{P_{tot}^{DL}(Sj, ic, b_{pilot}) + I_{extra}^{DL}(ic, b_{pilot}) + I_{inter-carrier}^{DL}(ic, b_{pilot}) + N_0^{Term}}$

Determination of the candidate cells, *(S_{BS},ic)*.

For each carrier *ic*, selection of the transmitter with the highest $Q_{pilot_k}(Sj, M_i, ic)$, $(S_{BS}, ic)(M_i)$.

Analysis of candidate cells, *(S_{BS},ic)*.

For each pair *(S_{BS},ic)*, calculation of the uplink load factor:

$$X_k^{UL}(S_{BS}, ic) = \frac{I_{tot}^{UL}(S_{BS}, ic)}{N_{tot}^{UL}(S_{BS}, ic)} + \Delta X^{UL}$$

Rejection of bad candidate cells if the pilot is not received or if the uplink load factor is exceeded during the admission load control (if simulation respects a loading factor constraint and M_b was not connected in previous iteration)

If $Q_{pilot_k}(S_{BS}, M_i, ic) < Q_{req}^{pilot}$ then *(S_{BS},ic)* is rejected by M_i

If $X_k^{UL}(S_{BS}, ic) > X_{max}^{UL}$, then *($S_{BS}$,ic)* is rejected by M_i

Else

Keep *(S_{BS},ic)* as good candidate cell

For dual band terminals with the configuration 1 or terminals working on one frequency band only, if no good candidate cell has been selected, M_i has failed to be connected to the network and is rejected.

For dual band terminals with the configuration 2, if no good candidate cell has been selected, try to connect M_i to transmitters *txi* containing M_i in their calculation area and working on the secondary frequency band supported by the M_i's terminal (i.e. f2). If no good candidate cell has been selected, M_i has failed to be connected to the network and is rejected.

Determination of the best carrier, ic_{BS}.

If a given carrier is specified for the service requested by M_i

$ic_{BS}(M_i)$ is the carrier specified for the service

Else the carrier selection mode defined for the site equipment is considered.

If carrier selection mode is "Min. UL Load Factor"

$ic_{BS}(M_i)$ is the cell with the lowest $X_k^{UL}(S_{BS}, ic)$

Else if carrier selection mode is "Min. DL Total Power"

$ic_{BS}(M_i)$ is the cell with the lowest $P_{tx}(S_{BS}, ic)_k$

Else if carrier selection mode is "Random"

$ic_{BS}(M_i)$ is randomly selected

Else if carrier selection mode is "Sequential"

$ic_{BS}(M_i)$ is the first carrier where $X_k^{UL}(S_{BS}, ic) \le X_{max}^{UL}$

Endif

Determination of the best serving cell, (S_{BS},ic_{BS}).

$(S_{BS},ic_{BS})_k(M_i)$ is the best serving cell ($BestCell_k(M_i)$) and its pilot quality is $Q_{pilot_k}^{max}(M_i)$.

In the following lines, we will consider ic as the carrier used by the best serving cell.

Determination of the Active Set

For each station S_j containing M_i in its calculation area, using *ic*, and if neighbours are used, neighbour of $S_{BS}(M_i)$

Calculation of $Q_{pilot_k}(M_i, S_j, ic) = \dfrac{\rho_{BTS} \times \alpha \times P_{tot}^{DL}(M_i, S_j, ic, b_{pilot})}{I_0^{DL}(ic, b_{pilot})}$

Rejection of station S_j if the pilot is not received

If $Q_{pilot_k}(M_i, S_j, ic) < Q_{pilot}^{min}$ then S_j is rejected by M_i

Else S_j is included in the M_i active set

Rejection of S_j if the M_i active set is full

Station with the lowest Q_{pilot_k} in the active set is rejected

EndFor

Determination of the Sub-active Sets of a EVDO Multi-carrier User

For multi-carrier EV-DO Rev.B service users with a 1xEV-DO Rev. B capable terminal, calculation of the quality level received by the best serving cell *(S_{BS},ic)*

$$\left(\frac{E_c}{N_t}\right)^{UL}(S_{BS}, ic) = \frac{\rho_{term} \times P_{term}^{max}(M_i)}{L_T \times N_{tot}^{UL}(S_{BS}, ic)}$$

If $\left(\frac{E_c}{N_t}\right)^{UL}(S_{BS}, ic) < \left(\frac{E_c}{N_t}\right)^{UL}_{min}(S_{BS})$ then EV-DO multi-carrier is not activated.

For each transmitter *Sj* containing M_i in its calculation area and using other EV-DO carriers, ic_n (either ic_n belongs to *f1* for a single frequency band network, or it belongs to *f1* or *f2* for a dual-band terminal)

Calculation of $Q_{pilot_k}(Sj, ic_n, M_i)$

Ranking of carriers, ic_n,according to $Q_{pilot_k}(Sj, ic_n, M_i)$, from the highest to the lowest value.

For each received carrier, ic_n, in the defined order:

While $n_{max}^{carriers}(M_i)$ is not exceeded

Determination of the best transmitter of the sub-active set, based on the received pilot quality, $Q_{pilot_k}(Sj, ic_n, M_i)$.

Determination of the other transmitters of the sub-active set, based on the received pilot quality, $Q_{pilot_k}(Sj, ic_n, M_i)$.

Calculation of the quality level received by the best serving cell *(S_{BS},ic_n)*

$$\left(\frac{E_c}{N_t}\right)^{UL}(S_{BS}, ic_n) = \frac{\rho_{term} \times P_{term}^{max}(M_i)}{L_T \times N_{tot}^{UL}(S_{BS}, ic_n)}$$

If $\left(\frac{E_c}{N_t}\right)^{UL}(S_{BS}, ic_n) < \left(\frac{E_c}{N_t}\right)^{UL}_{min}(S_{BS})$, then no sub-active set is associated with ic_n

If the user terminal supports the ’Locked’ mode, analysis of the sub-active set

If a transmitter of the studied sub-active set does not belong to the sub-active set associated with the best carrier, then it is removed.

If the studied sub-active set does not contain the same transmitters as the sub-active set associated with the best carrier, then the studied sub-active set is removed.

EndIf

Endwhile

EndFor

Uplink Power Control

Calculation of the required power for M_i, $P_{term}^{req}(M_i, ic)_k$

For each cell (S_j,*ic)* present in the M_i active set or sub-active set

Calculation of quality level on M_i traffic channel at (S_j,*ic)*, with the minimum power allowed on traffic channel for the M_i service

$$P_b^{UL}(M_i, S_j, ic) = \frac{P_{term}^{req}(M_i, ic)_{k-1}}{L_T(M_i, S_j)}$$

$$Q^{UL}(M_i, S_j, ic)_k = \frac{\rho_{term} \times P_b^{UL}(M_i, S_j, ic)}{N_{tot}^{UL}(ic) - (1 - F_{MUD}^{Tx}) \times \rho_{term} \times P_b^{UL}(M_i, S_j, ic)} \times G_p^{UL}(Service)$$

If the user selects the option “Total noise”

$$Q^{UL}(M_i, S_j, ic)_k = \frac{\rho_{term} \times P_b^{UL}(M_i, S_j, ic)}{N_{tot}^{UL}(ic)} \times G_p^{UL}(Service)$$

End For

If (M_i is not in handoff)

$$Q_{total_k}^{UL}(M_i) = Q^{UL}(M_i, S_j, ic)$$

Else if (M_i is in softer handoff)

$$Q_{total_k}^{UL}(M_i) = f_{rake\ efficiency}^{UL} \times \sum_{S_j \in ActiveSet} Q^{UL}(M_i, S_j, ic)_k$$

Else if (M_i is in soft or softer/soft without MRC)

$$Q^{UL}_{total_k}(M_i) = \underset{i_{AS} \in ActiveSet}{Max}\ (Q^{UL}(M_i, S_j, ic)_k) \times (G^{UL}_{macro-diversity})_{2\ links}$$

Else if (M_i is in soft/soft)

$$Q^{UL}_{total_k}(M_i) = \underset{i_{AS} \in ActiveSet}{Max}\ (Q^{UL}(M_i, S_j, ic)_k) \times (G^{UL}_{macro-diversity})_{3\ links}$$

Else if (M_i is in softer/soft with MRC)

$$Q^{UL}_{total_k}(M_i) = Max\left(f^{UL}_{rake\ efficiency} \times \sum_{\substack{i_{AS} \in ActiveSet \\ (same\ site)}} Q^{UL}(M_i, S_j, ic)_k, \underset{othersite}{Q^{UL}(M_i, S_j, ic)_k} \right) \times (G^{UL}_{macro-diversity})_{2\ links}$$

EndIf

$$P^{req}_{term}(M_i, ic)_k = \frac{Q^{UL}_{req}(Service(M_i), Term(M_i), Mobility(M_i))}{Q^{UL}_{total_k}(M_i)} \times P^{req}_{term}(M_i, ic)_{k-1}$$

If the service of M_i uses Transmission Control Protocol (TCP)

For the best server cell (S_k, ic) of M_i

Calculation of the M_i downlink application throughput

Calculation of $N^{DL}_{tot}(ic, b_{traffic})$

$$N^{DL}_{tot}(ic, b_{traffic}) = \sum_{j, j \neq k} P^{DL}_{tot}(S_j, ic, b_{traffic}) + \frac{\sum_{txj, \forall j} P^{DL}_{tot}(txj, ic_{adj}, b_{traffic})}{RF(ic, ic_{adj})} + N^{term}_0$$

Calculation of the maximum data rate supplied to M_i, $R^{DL}_{max}(M_i, S_k)$

Calculation of pilot quality level at M_i

$$\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot}) = \frac{P^{DL}_{tot}(M_i, S_k, ic, b_{pilot})}{N^{DL}_{tot}(ic, b_{pilot})}$$

If M_i is a 1xEV-DO Rev. 0 service user, determination of the maximum data rate from the graph (Max rate=f(C/I)) specified for the mobility type of M_i

$$R^{DL}_{max}(M_i, S_k) = f\left(\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot})\right)$$

If M_i is a 1xEV-DO Rev. A service user, selection of the downlink 1xEV-DO radio bearer ($Index_{DL-Bearer}$): $Index_{DL-Bearer}$ where $\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot}) \geq \left(\frac{E_c}{N_t}(Index_{DL-Bearer})\right)^{DL}_{min}$

If M_i is a 1xEV-DO Rev. B service user, selection of the downlink 1xEV-DO radio bearer ($Index_{DL-Bearer}$): $Index_{DL-Bearer}$ where $\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot}) \geq \left(\frac{E_c}{N_t}(Index_{DL-Bearer})\right)^{DL}_{min}$ and the modulation scheme is supported by the terminal.

Determination of the maximum data rate: $R^{DL}_{max}(M_i, S_k) = \frac{R^{DL}_{RLC-Peak}(Index_{DL-Bearer})}{n_{TS}(Index_{DL-Bearer})}$

$$R^{DL}_{application}(M_i, S_k) = R^{DL}_{max}(M_i, S_k) \times SF_{rate}(Service(Mi)) - \Delta R(Service(Mi))$$

Determination of the uplink data rate due to TCP acknowledgements, $R^{UL}_{TCP-ACK}(M_i, S_k)$ from the graph (UL Thr due to TCP=f(DL Thr) specified for the service of M_i

$$R^{UL}_{TCP-ACK}(M_i, S_k) = f(R^{DL}_{application}(M_i, S_k))$$

Determination of the nearest lower and higher supported rates (R^{UL}_{low} and R^{UL}_{high}) for $R^{UL}_{TCP-ACK}(M_i, S_k)$

For R^{UL}_{low} and R^{UL}_{high}, calculation of $CI^{UL}_{req}(R^{UL}_{low})$ and $CI^{UL}_{req}(R^{UL}_{high})$

$CI^{UL}_{req} = \left(\frac{E_c}{N_t}\right)^{UL}_{min} \times (1 + G_{DRC} + G_{TCH})$ for DO Rev.0 terminals

And

$CI^{UL}_{req} = \left(\frac{E_c}{N_t}\right)^{UL}_{min} \times (1 + G_{DRC} + G_{TCH} + G_{RRI} + G_{Auxiliary-pilot})$ for DO Rev.A and DO Rev.B terminals

EndFor

Linear interpolation of $CI^{UL}_{req}(R^{UL}_{TCP-ACK})$ between $CI^{UL}_{req}(R^{UL}_{low})$ and $CI^{UL}_{req}(R^{UL}_{high})$

$$CI^{UL}_{req} = CI^{UL}_{req}(R^{UL}) + CI^{UL}_{req}(R^{UL}_{TCP-ACK})$$

$$Q^{UL}_{req} = CI^{UL}_{req} \times \frac{W}{(R^{UL} + R^{UL}_{TCP-ACK})}$$

EndIf

$$P^{req}_{term}(M_i, ic)_k = Max(P^{req}_{term}(M_i, ic)_k, P^{min}_{term}(M_i, S_j))$$

For DO Rev.0 and DO Rev.A users

If $P^{req}_{term}(M_i, ic)_k > P^{max}_{term}(M_i)$ then:

Downgrading the traffic data channel data rate

While $P^{req}_{term}(M_i, ic)_k \geq P^{max}_{term}(M_i)$

And

$R^{UL}(Service(M_i)) \geq 9.6kbps$ for 1xEV-DO Rev. 0 users,

$R^{UL}(Service(M_i)) \geq 4.8kbps$ for (1xEV-DO Rev. A - Variable bit rate) service users,

$R^{UL}(Service(M_i)) \geq 4.8kbps$ for single-carrier 1xEV-DO Rev. B service users,

$R^{UL}(Service(M_i)) \geq R^{UL}_{Guaranteed}(Service(M_i))$ for (1xEV-DO Rev. A - Guaranteed bit rate) service users,

$P^{req}_{term}(M_i, ic)_k = \frac{P^{req}_{term}(M_i, ic)_k}{R^{UL}(Service(M_i))} \times R^{UL}_{low}(Service(M_i))$ ($R^{UL}_{low}(Service(M_i))$ is the nearest lower supported data rate)

For 1xEV-DO Rev. 0, (1xEV-DO Rev. A - Variable bit rate) and single-carrier 1xEV-DO Rev. B service users, $R^{UL}(Service(M_i)) = R^{UL}_{low}(Service(M_i))$

For (1xEV-DO Rev. A - Guaranteed bit rate) service users, $R^{UL}(Service(M_i)) = R^{UL}_{Guaranteed}(Service(M_i))$

EndWhile

If $P^{req}_{term}(M_i, ic)_k > P^{max}_{term}(M_i)$ then M_i is rejected

For 1xEV-DO Rev. 0, (1xEV-DO Rev. A - Variable bit rate) and single-carrier 1xEV-DO Rev. B service users, $P_{term}(M_i, ic) = P^{req}_{term}(M_i, ic)_k$

For (1xEV-DO Rev. A - Guaranteed bit rate) service users, $P_{term}(M_i, ic) = P^{req}_{term}(M_i, ic)_k \times C_{UL-Bearer}$

Endif

Endif

For multi-carrier 1xEV-DO Rev. B service users, load balancing between carriers is performed. The available terminal power is equally shared between each carrier:

If $P_{term}^{req}(M_i, ic)_k > \frac{P_{term}^{max}(M_i)}{n^{carriers}(M_i)}$, then:

Downgrading the traffic data channel data rate

While $P_{term}^{req}(M_i, ic)_k > \frac{P_{term}^{max}(M_i)}{n^{carriers}(M_i)}$ and $R^{UL}(Service((M_i), ic)) > 153, 6kbps$

$P_{term}^{req}(M_i, ic)_k = \frac{P_{term}^{req}(M_i, ic)_k}{R^{UL}(Service((M_i), ic))} \times R_{low}^{UL}(Service(M_i))$ ($R_{low}^{UL}(Service(M_i))$ is the nearest lower supported data rate)

$R^{UL}(Service((M_i), ic)) = R_{low}^{UL}(Service(M_i))$

EndWhile

If $P_{term}^{req}(M_i, ic)_k > \frac{P_{term}^{max}(M_i)}{n^{carriers}(M_i)}$, then M_i is not connected to cells of the sub-active set.

Endif

If no sub-active set can be used, then M_i is rejected.

Endif

Calculation of $R^{UL}(Service(M_i))$ for each combination of carriers

$R^{UL}(Service(M_i)) = \sum_{ic=1}^{n} R^{UL}(Service((M_i), ic))$ where n corresponds to the number of carriers in the combination.

Selection of the configuration providing the highest total throughput, $Max(R^{UL}(Service(M_i)))$.

If $Max(R^{UL}(Service(M_i))) > R_{high}^{UL}(Service(M_i))$ ($R_{high}^{UL}(Service(M_i))$ is the nearest supported data rate higher than the requested data rate)

Downgrading the traffic data channel rate

While $Max((R^{UL}(Service(M_i))) > R_{high}^{UL}(Service(M_i)))$ and $R^{UL}(Service((M_i), ic)) > 153, 6kbps$

EndWhile

EndIf

Endfor

Uplink Interference Updates

Update of interference on active mobiles only (old contributions of mobiles and stations are replaced by the new ones)

For each cell *(S_j,ic)*

Update of $N_{tot}^{UL}(S_j, ic)$

EndFor

Control of Radio Resource Limits (Number of EVDO users, MAC Indices and Site Channel Elements)

For each cell *(S_j,ic)*

While $n^{EVDO}(S_j, ic) > n_{max}^{EVDO}(S_j, ic)$

Rejection of the last admitted mobile

EndFor

For each cell *(S_j,ic)*

While $N^{MacIndexes}(S_j, ic) > N_{max}^{MacIndexes}(S_j, ic)$

Rejection of the last admitted mobile

EndFor

For each site (Node B) Nl

While $N^{EVDO-CE}(N_l)_k > N^{EVDO-CE}_{max}(N_l)$

Rejection of the last admitted mobile

EndFor

Uplink Load Factor Control

For each cell *(S_j,ic)* with $NR^{UL}(S_j, ic) > NR^{UL}_{threshold}(S_j, ic) + \Delta NR^{UL}_{threshold}(S_j, ic)$

While $NR^{UL}(S_j, ic) > NR^{UL}_{threshold}(S_j, ic) + \Delta NR^{UL}_{threshold}(S_j, ic)$ and there is at least one mobile that can be downgraded

Downgrading the traffic data channel rate for all 1xEV-DO Rev. 0 mobiles for which the data rate transition flag is set to "True".

Update of $N^{UL}_{tot}(S_j, ic)$

Endwhile

For each cell (S_j,ic) with $NR^{UL}(S_j, ic) < NR^{UL}_{threshold}(S_j, ic) - \Delta NR^{UL}_{threshold}(S_j, ic)$

While $NR^{UL}(S_j, ic) < NR^{UL}_{threshold}(S_j, ic) - \Delta NR^{UL}_{threshold}(S_j, ic)$ and there is at least one mobile that can be upgraded

Upgrading the traffic data channel rate for all 1xEV-DO Rev. 0 mobiles for which the data rate transition flag is set to "True". (only 1xEV-DO Rev. 0 mobiles which have not been downgraded can be upgraded. In addition, the upgraded data rate cannot exceed the initial user data rate drawn by the Monte-Carlo algorithm. This means that only mobiles downgraded during the uplink power control step can be upgraded).

Update of $N^{UL}_{tot}(S_j, ic)$

Endwhile

For each cell (S_j,ic) with $X^{UL}(S_j, ic) > X^{UL}_{max}$

Rejection of a mobile with the lowest service priority

EndFor

While at least one cell with $X^{UL}(S_j, ic) > X^{UL}_{max}$ exists

Downlink Data Rate Control

For each mobile M_i connected to a cell (S_k,ic)

Calculation of $N^{DL}_{tot}(ic, b_{traffic})$

For each cell (S_j,ic) $(k \neq j)$

Determination of the number of mobiles connected to the cell (S_j,ic), $N_{mobiles}(S_j, ic)$

If $N_{mobiles}(S_j, ic) = 0$ then, $P_{tx}(S_j, ic, b_{traffic}) = G_{idle-power} \times P_{max}(S_j, ic)$

Else $P_{tx}(S_j, ic, b_{traffic}) = P_{max}(S_j, ic)$

EndFor

$$N^{DL}_{tot}(ic, b_{traffic}) = \sum_{j, j \neq k} P^{DL}_{tot}(S_j, ic, b_{traffic}) + N^{term}_{0}$$

EndFor

Calculation of the maximum data rate supplied to M_i, R^{DL}_{max}

For the M_i's best server cell (S_k,ic) (in the active set or each sub-active set)

Calculation of pilot quality level at M_i

$$\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot}) = \frac{P_{tot}^{DL}(M_i, S_k, ic, b_{pilot})}{N_{tot}^{DL}(ic, b_{pilot})}$$

If M_i is a 1xEV-DO Rev. 0 service user, determination of the maximum data rate from the graph (Max rate=f(C/I)) specified for the mobility type of M_i

$$R_{max}^{DL}(M_i, S_k) = f\left(\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot})\right)$$

If M_i is a 1xEV-DO Rev. A service user, selection of the downlink 1xEV-DO radio bearer ($Index_{DL-Bearer}$) for which $\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot}) \geq \left(\frac{E_c}{N_t}(Index_{DL-Bearer})\right)_{min}^{DL}$

If M_i is a 1xEV-DO Rev. B service user, selection of the downlink 1xEV-DO radio bearer ($Index_{DL-Bearer}$) for which $\frac{E_c}{N_t}(M_i, S_k, ic, b_{pilot}) \geq \left(\frac{E_c}{N_t}(Index_{DL-Bearer})\right)_{min}^{DL}$ and the modulation is supported by M_i's terminal.

If M_i is a (1xEV-DO Rev. A - Guaranteed bit rate) service user and $R_{RLC-peak}^{DL}(Index_{DL-Bearer}) < R_{Guaranteed}^{DL}(Service(M_i))$, M_i is rejected.

Determination of the maximum data rate: $R_{max}^{DL}(M_i, S_k, ic) = \frac{R_{RLC-Peak}^{DL}(Index_{DL-Bearer})}{n_{TS}}$

For 1xEV-DO Rev. 0, (1xEV-DO Rev. A - Variable bit rate) and single-carrier 1xEV-DO Rev. B service users, $R_{max}^{DL}(M_i) = R_{max}^{DL}(M_i, S_k, ic)$

For (1xEV-DO Rev. A - Guaranteed bit rate) service users, $R_{max}^{DL}(M_i) = R_{Guaranteed}^{DL}(Service(M_i))$

For multi-carrier 1xEV-DO Rev. B service users, $R_{max}^{DL}(M_i) = \sum_{(S_k, ic)} R_{max}^{DL}(M_i, S_k, ic)$

For (1xEV-DO Rev. A - Guaranteed bit rate) service users, calculation of $C_{DL-Bearer}$

EndFor

Calculation of the average cell data rate, R_{av}^{DL}

For each cell *(S_j,ic)*

If $N_{mobiles}(S_j, ic) = 1$, then $R_{av}^{DL}(S_j, ic) = R_{max}^{DL}(M_i, S_j, ic)$

Else if $N_{mobiles}(S_j, ic) > 1$, determination of the multi-user gain G_{MU}

G_{MU} is determined from the graph (MUG table=f(nb users)) specified for *(S_j,ic)*. If the transmitter supports the multi-carrier EV-DO mode, G_{MU} is determined from the graph (MUG table=f(nb users)) specified for *Sj*.

$$R_{av}^{DL}(S_j, ic) = \begin{array}{c} G_{MU}(N_{mobiles}(S_j, ic)) \times \\ \left[\begin{array}{l} \left(\frac{\sum_{M_i \in N_{VBR-mobiles}(S_j, ic)} R_{max}^{DL}(M_i, S_j, ic)}{N_{VBR-mobiles}(S_j, ic)}\right) \times \left(1 - \sum_{M_k \in N_{GBR-mobiles}(S_j, ic)} C_{DL-Bearer}(M_k, S_j, ic)\right) \\ + \left(\frac{\sum_{M_k \in N_{GBR-mobiles}(S_j, ic)} R_{Guaranteed}^{DL}(M_k)}{N_{GBR-mobiles}(S_j, ic)}\right) \times \sum_{M_k \in N_{GBR-mobiles}(S_j, ic)} C_{DL-Bearer}(M_k, S_j, ic) \end{array} \right] \times \\ \left(1 - (ER_{DRC}(S_j, ic))^{N_{mobiles}}\right) \times (1 - TS_{BCMCS}(S_j, ic) - TS_{EVDO-CCH}(S_j, ic)) + R_{BCMCS}(S_j, ic) \times TS_{BCMCS}(S_j, ic) \end{array}$$

EndIf

EndFor

7.4.2.2.3 Convergence Criterion

The algorithm convergence is studied on uplink only. The uplink convergence criterion is evaluated at each iteration, and can be written as follow:

$$\Delta_{UL} = max\left(int\left(\max_{Stations}\left|\frac{I_{tot}^{UL}(ic)_k - I_{tot}^{UL}(ic)_{k-1}}{I_{tot}^{UL}(ic)_k}\right| \times 100\right), int\left(\max_{Stations}\left|\frac{N_{user}^{UL}(ic)_k - N_{user}^{UL}(ic)_{k-1}}{N_{user}^{UL}(ic)_k}\right| \times 100\right)\right)$$

9955 stops the algorithm if:

1st case: Between two successive iterations, Δ_{UL} is lower ($\leq$) than the threshold (defined when creating a simulation).

The simulation has reached convergence.

Example: Let us assume that the maximum number of iterations is 100, UL convergence threshold is set to 5. If $\Delta_{UL} \leq 5$ between the 4th and the 5th iteration, **9955** stops the algorithm after the 5th iteration. Convergence has been achieved.

2nd case: After 30 iterations, Δ_{UL} is still higher than the threshold and from the 30th iteration, Δ_{UL} does not decrease during the next 15 successive iterations.

The simulation has not reached convergence (specific divergence symbol).

Examples: Let us assume that the maximum number of iterations is 100, UL convergence threshold is set to 5.

1. After the 30th iteration, Δ_{UL} equals 100 and do not decrease during the next 15 successive iterations: **9955** stops the algorithm at the 46th iteration. Convergence has not been achieved.

2. After the 30th iteration, Δ_{UL} equals 80, it starts decreasing slowly until the 40th iteration (without going under the threshold) and then does not change during the next 15 successive iterations: **9955** stops the algorithm at the 56th iteration without achieving convergence.

3rd case: After the last iteration.

If Δ_{UL} is still strictly higher than the threshold, the simulation has not converged (specific divergence symbol).

If Δ_{UL} is lower than the threshold, the simulation has converged.

7.4.3 Appendices

7.4.3.1 Admission Control

During admission control, **9955** calculates the uplink load factor of a considered cell assuming the mobile concerned is connected with it. Here, activity status assigned to users is not taken into account. So even if the mobile is not active on UL, it can be rejected due to cell load saturation. To calculate the cell UL load factor, either **9955** takes into account the mobile power determined during power control if mobile was connected in previous iteration, or it estimates a load rise due to the mobile and adds it to the current load. The load rise (ΔX^{UL}) is calculated as follows:

$$\Delta X^{UL} = \frac{1}{1 + \frac{W}{Q_{req}^{UL} \times R^{UL}}}$$

In case of CDMA2000 1xRTT networks, we have:

$$Q_{req}^{UL} = (Q_{req}^{UL})_{FCH} + (Q_{req}^{UL})_{SCH} \text{ and } R^{UL} = R_{FCH}^{UL} + R_{SCH}^{UL}$$

7.4.3.2 Resources Management

7.4.3.2.1 Walsh Code Management

Walsh codes are managed in the downlink during the simulation in case of CDMA2000 1xRTT networks. **9955** performs Walsh code allocation during the radio resource control step.

Walsh codes form a binary tree with codes of a longer length generated from codes of a shorter length. Length-k Walsh codes are generated from length-k/2 Walsh codes. Therefore, if a channel needs 1 length-k/2 Walsh code, it is equivalent to using 2 length-k Walsh codes, or 4 length-2k Walsh codes and so on.

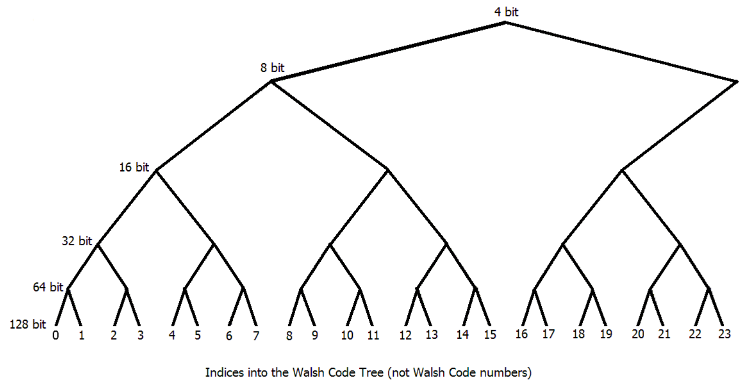


Figure 7.3: Walsh Code Tree Indices (Not Walsh Code Numbers)

128 128-bit-length Walsh codes per cell are available in CDMA2000 documents.

During the resource control, **9955** determines the number of 128-bit-length Walsh codes that will be consumed by each cell. Therefore, it allocates :

- A code with the longest length (i.e. a 128 bit-length code) per common channel for each cell. The number of common channels per cell corresponds to the value defined for the DL overhead resources for common channels per cell parameter available in the site equipment properties.
- Two 128 bit-length codes per cell-receiver link for FCH in RC1, RC2, RC3 or RC5 and only one for FCH in RC4.
- The number of 128 bit-length codes to be allocated per cell-receiver link for SCH (in case SCH is supported by the user radio configuration), $N_{128\ bits}^{Walsh\ codes}$, is determined as follows:

$N_{128\ bits}^{Walsh\ codes} = Frate_{SCH}^{DL} \times 2$ for RC1, RC2, RC3 and RC5,

And

$N_{128\ bits}^{Walsh\ codes} = Frate_{SCH}^{DL}$ for RC4.

Where

$Frate_{SCH}^{DL}$ is the SCH rate factor.

The Walsh code allocation follows the “Buddy” algorithm, which guarantees that:

- If a k-length Walsh code is used, all of its children with lengths 2k, 4k, ..., cannot be used as they are not orthogonal.
- If a k-length Walsh code is used, all of its ancestors with lengths k/2, k/4, ..., cannot be used as they are not orthogonal.

> - The Walsh code allocation follows the mobile connection order (mobile order in the Mobiles tab).
> - The Walsh code and channel element management is dealt with differently in case of “softer” handoff. **9955** allocates Walsh codes for each transmitter-receiver link while it assigns channel elements globally to a site.

7.4.3.2.2 Channel Element Management

Channel elements are controlled in the simulation.

CDMA2000 1xRTT networks

9955 checks the availability of this resource on uplink and downlink.

On uplink, **9955** consumes $N^{CE-UL}(j)$ channel elements for each cell *j* on a site N_l. This figure includes:

- $N^{Overhead-CE-UL}$ channel elements for control channels (Pilot channel),
- $N^{FCH-CE-UL} \times (1 + Frate_{SCH}^{UL})$ per cell-receiver link, for TCH (TCH correspond to Traffic channels i.e. FCH and SCH).

Therefore, the number of channel elements required on uplink at the site level, $N^{CE-UL}(N_l)$, is:

$$N^{CE-UL}(N_l) = \sum_{j \in N_l} N^{CE-UL}(j)$$

In the downlink, **9955** consumes $N^{CE-DL}(j)$ channel elements for each cell *j* on a site N_I. This figure includes:

- $N^{Overhead-CE-DL}$ channel elements for control channels (Pilot channel, Synchronisation channel, Paging channel),
- $N^{FCH-CE-DL} \times (1 + Frate^{DL}_{SCH})$ per cell-receiver link, for TCH (TCH correspond to Traffic channels i.e. FCH and SCH).

Therefore, the number of channel elements required on downlink at the site level, $N^{CE-DL}(N_I)$, is:

$$N^{CE-DL}(N_I) = \sum_{j \in N_I} N^{CE-DL}(j)$$

> In case of “softer” handover (the mobile has several links with co-site cells), **9955** allocates channel elements for the best serving cell-mobile link only.

CDMA2000 1xEV-DO networks

In the uplink, **9955** consumes $N^{CE-UL}(j)$ channel elements for each cell *j* on a site N_I. This figure includes:

- 2 channel elements for control channels (Pilot channel, Data Rate Control channel, etc). This value is fixed and hard-coded.
- $N^{TCH-CE-UL}$ per cell-receiver link, for (EV-DO - Variable bit rate) service users.
- $N^{TCH-CE-UL} \times C_{UL-Bearer}$ per cell-receiver link, for (EV-DO - Guaranteed bit rate) service users.

Therefore, the number of channel elements required on uplink at the site level, $N^{CE-UL}(N_I)$, is:

$$N^{CE-UL}(N_I) = \sum_{j \in N_I} N^{CE-UL}(j)$$

In the downlink, only one user can be served by a cell at a time, so this resource is not limited.

7.4.3.3 Downlink Load Factor Calculation

9955 calculates the downlink load factor for each cell (available in the Cells tab of any given simulation results) and each connected mobile (available in the Mobiles tab of any given simulation results).

7.4.3.3.1 Downlink Load Factor per Cell

The downlink load factor is calculated for each CDMA2000 1xRTT cell.

Approach for downlink load factor evaluation is highly inspired by the downlink load factor defined in the book “WCDMA for UMTS by Harry Holma and Antti Toskala”.

Let $CI_{req} = \frac{Q^{DL-FCH}_{req}}{G^{DL-FCH}_{p}} + \frac{Q^{DL-SCH}_{req}}{G^{DL-SCH}_{p}}$ be the required quality.

So, we have $CI_{req} = CI^{FCH}_{req} + CI^{SCH}_{req}$

In case of soft handoff, required quality is limited to the effective contribution of the transmitter.

$$P^{DL}_{tx}(ic) = P_{pilot}(ic) + P_{sync}(ic) + P_{paging}(ic) + P_{SCH}(ic) + P_{FCH}(ic) = P^{ortho}_{CCH}(ic) + \sum_{tch} P_{tch}(ic)$$

where

$$P^{ortho}_{CCH}(ic) = P_{pilot}(ic) + P_{sync}(ic) + P_{paging}(ic)$$

$$\sum_{tch} P_{tch}(ic) = P_{SCH}(ic) + P_{FCH}(ic)$$

At mobile level, we have a required power, P_{tch}:

$$P_{tch}(ic) = CI_{req} \times (I_{extra}(ic) + I_{intra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic) + N^{term}_{0}) \times L_T$$

$$P_{tch}(ic) = CI_{req} \times \begin{pmatrix} I_{extra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic) \\ + (1 - F_{ortho} \times \rho_{BTS}) \times \left(\frac{P_{tx}^{DL}(ic) - P_{tch}(ic)}{L_T}\right) + N_0^{term} \end{pmatrix} \times L_T$$

$$P_{tch}(ic) = \frac{(I_{extra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic)) \times L_T + (1 - F_{ortho} \times \rho_{BTS}) \times P_{tx}^{DL}(ic) + N_0^{term} \times L_T}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})}$$

where

$I_{intra}^{DL}(ic)$ is the total power received at receiver from the cell to which it is connected.

$I_{extra}^{DL}(ic)$ is the total power received at receiver from other cells.

$I_{inter-carrier}(ic)$ is the inter-carrier interference received at receiver.

$I_{inter-technology}(ic)$ is the inter-technology interference received at receiver.

$$P_{tx}^{DL}(ic) = P_{CCH}^{ortho}(ic) + \sum_{tch} \left(\frac{\begin{pmatrix} (I_{extra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic)) \times L_T \\ + (1 - F_{ortho} \times \rho_{BTS}) \times P_{tx}^{DL}(ic) + N_0^{term} \times L_T \end{pmatrix}}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})} \right)$$

We have:

$$P_{tx}^{DL}(ic) = P_{CCH}^{ortho}(ic) + \sum_{tch} \left(\frac{\begin{pmatrix} \frac{(I_{extra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic)) \times L_T}{P_{tx}^{DL}(ic)} \\ + (1 - F_{ortho} \times \rho_{BTS}) \times P_{tx}^{DL}(ic) + N_0^{term} \times L_T \end{pmatrix}}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})} \right)$$

$$P_{tx}^{DL}(ic) - \left(\frac{\sum_{tch} \left(\frac{(I_{extra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic)) \times L_T}{P_{tx}^{DL}(ic)} + 1 - F_{ortho} \times \rho_{BTS} \right)}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})} \right) \cdot P_{tx}^{DL}(ic)$$

$$= \left(P_{CCH}^{ortho}(ic) + \sum_{tch} \frac{N_0^{term} \times L_T}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})} \right)$$

$$P_{tx}^{DL}(ic) = \frac{\left(P_{CCH}^{ortho}(ic) + \sum_{tch} \frac{N_0^{term} \times L_T}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})} \right)}{\left(1 - \sum_{tch} \frac{\frac{(I_{extra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic)) \times L_T}{P_{tx}^{DL}(ic)} + 1 - F_{ortho} \times \rho_{BTS}}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})} \right)}$$

Therefore, the downlink load factor can be expressed as:

$$X^{DL} = \sum_{tch}\left(\frac{\frac{(I_{extra}(ic) + I_{inter-carrier}(ic) + I_{inter-technology}(ic)) \times L_T}{P_{tx}^{DL}(ic)} + 1 - F_{ortho} \times \rho_{BTS}}{\frac{1}{CI_{req}} + (1 - F_{ortho} \times \rho_{BTS})}\right)$$

The downlink load factor represents the signal degradation in relative to the reference interference (thermal noise).

7.4.3.3.2 Downlink Load Factor per Mobile

9955 evaluates the downlink load factor for any connected mobile (CDMA2000 1xRTT 1xEV-DO user) as follows,

$$X^{DL} = \frac{I_{tot}^{DL}(ic)}{N_{tot}^{DL}(ic)}$$

7.4.3.4 Best Server Determination in Monte Carlo Simulations - Old Method

Before **9955** V6.8, best server determination used to be performed by selecting the best carrier within transmitters according to the selected method (site equipment) and then the best transmitter using the best carrier. To switch back to this method, add the following lines in the Atoll.ini file:

```
[CDMA]
MultiBandSimu = 0
```

The method is described below:

For each station *Sj* containing M_i in its calculation area and using the main frequency band supported by the M_i's terminal (i.e. either *f1* for a single frequency band network, or *f1* or *f2* for a dual-band terminal without any priority on frequency bands, or *f1* for a dual-band terminal with *f1* as main frequency band).

Determination of $BestCarrier_k(S_j, M_i)$.

If a given carrier is specified for the service requested by *Mi* and if it is used by S_j

$BestCarrier_k(S_j, M_i)$ is the carrier specified for the service.

Else the carrier selection mode defined for S_j is considered.

If carrier selection mode is “Min. UL Load Factor”

For each carrier *ic* used by S_j, we calculate current loading factor:

$$X_k^{UL}(S_j, ic) = \frac{I_{tot}^{UL}(S_j, ic)}{N_{tot}^{UL}(S_j, ic)} + \Delta X^{UL}$$

EndFor

$BestCarrier_k(S_j, M_i)$ is the carrier with the lowest $X_k^{UL}(S_j, ic)$

Else if carrier selection mode is “Min. DL Total Power”

$BestCarrier_k(S_j, M_i)$ is the carrier with the lowest $P_{tx}(S_j, ic)_k$

Else if carrier selection mode is “Random”

$BestCarrier_k(S_j, M_i)$ is randomly selected

Else if carrier selection mode is "Sequential"

$BestCarrier_k(S_j, M_i)$ is the first carrier so that $X_k^{UL}(S_j, ic) \le X_{max}^{UL}$

Calculation of $Q_{pilot_k}(M_i, S_j, BestCarrier) = \frac{\alpha \times \rho_{BTS} \times P_c(M_i, S_j, BestCarrier)}{I_0^{DL}(BestCarrier_k(S_j, M_i))}$

Rejection of station S_j if the pilot is not received

If $Q_{pilot_k}(M_i, S_j, BestCarrier) < Q_{req}^{pilot}$ then S_j is rejected by M_i

If $Q_{pilot_k}(M_i, S_j, BestCarrier) > Q_{pilot_k}^{max}(M_i)$

Admission control (If simulation respects a load factor constraint and M_i was not connected in previous iteration).

If $X_k^{UL}(S_j, BestCarrier_k(S_j, M_i)) > X_{max}^{UL}$, then S_j is rejected by M_i

Else

$$Q_{pilot_k}^{max}(M_i) = Q_{pilot_k}(M_i, S_j, BestCarrier)$$

$$S_{BS}(M_i) = S_j$$

Endif

EndFor

If no S_{BS} has been selected and M_i's terminal can work on one frequency band only, M_i has failed to be connected to the network and is rejected.

If no S_{BS} has been selected and M_i's terminal can work on another frequency band.

Determination of $BestCarrier_k(Sj, M_i)$ for each station *txj* containing M_i in its calculation area and using another frequency band supported by the M_i's terminal (i.e. *f1* or *f2* for a dual-band terminal without any priority on frequency bands, or *f2* for a dual-band terminal with *f2* as secondary frequency band)

If a given carrier is specified for the service requested by *Mi* and if it is used by S_j

$BestCarrier_k(S_j, M_i)$ is the carrier specified for the service.

Else the carrier selection mode defined for S_j is considered.

If carrier selection mode is “Min. UL Load Factor”

For each carrier *ic* used by S_j, we calculate current loading factor:

$$X_k^{UL}(S_j, ic) = \frac{I_{tot}^{UL}(S_j, ic)}{N_{tot}^{UL}(S_j, ic)} + \Delta X^{UL}$$

EndFor

$BestCarrier_k(S_j, M_i)$ is the carrier with the lowest $X_k^{UL}(S_j, ic)$

Else if carrier selection mode is “Min. DL Total Power”

$BestCarrier_k(S_j, M_i)$ is the carrier with the lowest $P_{tx}(S_j, ic)_k$

Else if carrier selection mode is “Random”

$BestCarrier_k(S_j, M_i)$ is randomly selected

Else if carrier selection mode is "Sequential"

$BestCarrier_k(S_j, M_i)$ is the first carrier so that $X_k^{UL}(S_j, ic) \le X_{max}^{UL}$

Calculation of $Q_{pilot_k}(M_i, S_j, BestCarrier) = \dfrac{\alpha \times \rho_{BTS} \times P_c(M_i, S_j, BestCarrier)}{I_0^{DL}(BestCarrier_k(S_j, M_i))}$

Rejection of station S_j if the pilot is not received

If $Q_{pilot_k}(M_i, S_j, BestCarrier) < Q_{req}^{pilot}$ then S_j is rejected by M_i

If $Q_{pilot_k}(M_i, S_j, BestCarrier) > Q_{pilot_k}^{max}(M_i)$

Admission control (If simulation respects a load factor constraint and M_i was not connected in previous iteration).

If $X_k^{UL}(S_j, BestCarrier_k(S_j, M_i)) > X_{max}^{UL}$, then S_j is rejected by M_i

Else

$$Q_{pilot_k}^{max}(M_i) = Q_{pilot_k}(M_i, S_j, BestCarrier)$$

$$S_{BS}(M_i) = S_j$$

Endif

EndFor

If no S_{BS} has been selected, M_i has failed to be connected to the network and is rejected.

7.5 CDMA2000 Prediction Studies

7.5.1 Point Analysis: The AS Analysis Tab

Let us assume a receiver with a terminal, a mobility type and a service with certain UL and DL rates. This receiver does not create any interference. You can make the prediction for a specific carrier or for the best 1xRTT or 1xEV-DO carrier. The type of carrier and the carriers you can select depend on the service and on the frequency band(s) supported by the terminal. The analysis is based on the uplink load percentage and the downlink total power of cells. These parameters can be either outputs of a given simulation, average values calculated from a group of simulations, or user-defined cell inputs.

7.5.1.1 Bar Graph and Pilot Sub-Menu

We can consider the following cases:

1st case: Analysis based on a specific carrier

The carrier that can be used by transmitters is fixed. In this case, for each transmitter *i* containing the receiver in its calculation area and using the selected carrier, **9955** calculates the pilot quality at the receiver on this carrier. Then, it determines the best serving transmitter using the selected carrier *ic*.

2nd case: Analysis based on the best carrier

9955 determines the best carrier for each transmitter i which contains the receiver in its calculation area and uses a frequency band supported by the receiver's terminal. The best carrier selection depends on the option selected for the site equipment (UL minimum noise, DL minimum power, random, sequential). Then, **9955** calculates the pilot quality at the receiver from these transmitters on their best carriers (*ic)* and defines the best server (on its best carrier).

9955 provides the same outputs in the bar graph and pilot sub-menu whichever the studied network, CDMA2000 1xRTT or 1xEV-DO.

- Ec/I0 (or $Q_{pilot}(ic)$) evaluation

We assume that *ic* is the best carrier of a transmitter *i* containing the receiver in its calculation radius.

For CDMA2000 1xRTT users we have,

$$Q_{pilot}(i, ic) = \frac{\rho_{BTS} \times \alpha \times P_c(i, ic)}{I_0^{DL}(ic)}$$

with $I_0^{DL}(ic) = P_{tot}^{DL}(i, ic) + I_{extra}^{DL}(ic) + I_{inter-carrier}^{DL}(ic) + I_{inter-technology}^{DL}(ic) + N_0^{term}$

For CDMA2000 1xEV-DO users, we have,

$$Q_{pilot}(i, ic) = \frac{\rho_{BTS} \times \alpha \times P_{tot}^{DL}(i, ic, b_{pilot})}{I_0^{DL}(ic, b_{pilot})}$$

With $I_0^{DL}(ic, b_{pilot}) = P_{tot}^{DL}(i, ic, b_{pilot}) + I_{extra}^{DL}(ic, b_{pilot}) + I_{inter-carrier}^{DL}(ic, b_{pilot}) + I_{inter-technology}^{DL}(ic) + N_0^{term}$

The calculation of $Q_{pilot}(i, ic)$ can be divided into 6 steps explained in the table below.

	CDMA2000 1xRTT users	CDMA2000 1xEV-DO users
1st step	$P_c(i, ic)$ **calculation for each cell *(i,ic)*** $P_c(i, ic)$ is the pilot power from a transmitter *i* on the carrier *ic* at the receiver. $P_c(i, ic) = \frac{P_{pilot}(i, ic)}{L_{T_l}}$	$P^{DL}_{tot}(i, ic, b_{pilot})$ **calculation for each cell *(i,ic)*** $P^{DL}_{tot}(i, ic, b_{pilot})$ is the pilot burst from the transmitter *i* on the carrier *ic* at the receiver. $P^{DL}_{tot}(i, ic, b_{pilot}) = \frac{P_{tx}(i, ic, b_{pilot})}{L_{T_l}}$ and $P_{tx}(i, ic, b_{pilot}) = P_{max}(i, ic)$
	L_{T_l} is the total loss between the transmitter *i* and the receiver: $\frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-Ec/Io}}{G_{Tx} \times G_{term}}$	
2nd step	$I^{DL}_{extra}(ic)$, $I^{DL}_{inter-carrier}(ic)$ and $I^{DL}_{inter-technology}(ic)$ **calculation** We have, $I^{DL}_{extra}(ic) = \sum_{j, j \neq i} P^{DL}_{tot}(j, ic)$ For each transmitter of the network, $P^{DL}_{tot}(j, ic)$ is the total power received at the receiver from the transmitter *j* on the best carrier *ic* of the transmitter *i*. $P^{DL}_{tot}(j, ic) = \frac{P_{tx}(j, ic)}{L_T}$ $P_{tx}(j, ic)$ is the total power transmitted by the transmitter *j* on the best carrier of the transmitter *i*. Finally, we have, $I^{DL}_{inter-carrier}(ic) = \frac{\sum_{j, \forall j} P^{DL}_{tot}(j, ic_{adj})}{RF(ic, ic_{adj})}$ and $I^{DL}_{inter-technology}(ic) = \sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic}}$	$I^{DL}_{extra}(ic, b_{pilot})$ and $I^{DL}_{inter-carrier}(ic, b_{pilot})$ **calculation** We have, $I^{DL}_{extra}(ic, b_{pilot}) = \sum_{j, j \neq i} P^{DL}_{tot}(j, ic, b_{pilot})$ $I^{DL}_{inter-carrier}(ic, b_{pilot}) = \frac{\sum_{j, \forall j} P^{DL}_{tot}(j, ic_{adj}, b_{pilot})}{RF(ic, ic_{adj})}$ and $I^{DL}_{inter-technology}(ic) = \sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic}}$
3rd step	N_0^{term} **calculation** $NF_{Term} \times K \times T \times W \times NR^{Tx, DL}_{inter-technology}$	
4th step	$I_0^{DL}(ic)$ **and** $Q_{pilot}(i, ic)$ **evaluation based on formulas defined above**	
5th step	$G^{DL}_{macro-diversity}$ **calculation** The macro-diversity gain, $G^{DL}_{macro-diversity}$, models the decrease in shadowing margin due to the fact there are several pilot signals at the mobile. $G^{DL}_{macro-diversity} = M^{npaths}_{Shadowing-Ec/Io} - M_{Shadowing-Ec/Io}$ $M^{npaths}_{Shadowing-Ec/Io}$ is the shadowing margin for the mobile receiving n pilot signals (not necessarily from transmitters belonging to the mobile active set). **Note:** This parameter is determined from the fixed cell edge coverage probability and the model standard deviation. When the model standard deviation is set to 0, the macro-diversity gain equals 0.	

	CDMA2000 1xRTT users	CDMA2000 1xEV-DO users
6th step	**Determination of active set** **9955** takes the transmitter *i* with the highest $Q_{pilot}(i, ic)$ and calculates the best pilot quality received with a fixed cell edge coverage probability $Q_{pilot}^{Resulting}(ic)$. $Q_{pilot}^{Resulting}(ic) = G_{macro-diversity}^{DL} \times max(Q_{pilot}(i, ic))$ $Q_{pilot}^{Resulting} \geq Q_{pilot}^{req}$ means that the pilot quality at the receiver exceeds $Q_{pilot}^{Resulting}(ic)$ x% of times (x is the fixed cell edge coverage probability). The cell with the highest $Q_{pilot}(i, ic)$ enters the active set as best server ($Q_{pilot}(BS, ic)$) and the best carrier (ic_{BS}) of the best server *BS* will be the one used by other transmitters of active set (when active set size is greater than 1). Pilot is available. If $Q_{pilot}^{Resulting}(ic) < Q_{pilot}^{req}$, no cell *(i,ic)* can enter the active set. Pilot is unavailable. Then, pilot qualities at the receiver from transmitters *i* (other than the best server) on the best carrier of the best server, ic_{BS}, are recalculated to determine the entire receiver active set (when active set is greater than 1). Same formulas and calculation method are used to update	
	$I_0^{DL}(ic_{BS})$ and determine $Q_{pilot}(i, ic_{BS})$. Other cells *(i,*ic_{BS}*)* in active set must fulfill the following criteria: $Q_{pilot}(i, ic_{BS}) \geq Q_{min}^{pilot}$ $(i, ic_{BS}) \in neighbour\ list(BS, ic_{BS})$ (optional)	

For multi-carrier 1xEV-DO Rev.B service users, these results are detailed for each sub-active set. For each carrier, **9955** displays the thermal noise, I0 (Best server), the pilot quality from the best server and from the other servers of the sub-active set, and the downlink macro-diversity gain. They are calculated as described above.

- Number of cells in active set

This is a user-defined input in the terminal properties. It corresponds to the active set size.

- Number of fingers

The number of fingers, *f*, of the rake receiver. This parameter is defined in the terminal properties. It is relevant in CDMA2000 1xRTT only[11]. This is the maximum number of active set links that the terminal (rake) can combine.

- Thermal noise

This parameter is calculated as described above (3rd step).

- I0 (Best server)

I0 (Best server) is the total noise received at the receiver on ic_{BS}.

- Downlink macro-diversity gain

This parameter is calculated as described above (5th step).

7.5.1.2 Downlink Sub-Menu

Outputs calculated by **9955** depend on the studied network (CDMA2000 1xRTT or CDMA2000 1xEV-DO).

7.5.1.2.1 CDMA2000 1xRTT

Let m_{FCH} and m_{SCH} respectively denote the number of cells in the receiver active set for the fundamental channel (FCH) and the supplemental channel (SCH) and *f* be the number of rake fingers defined for the terminal. We assume that *f* is less than or equal to m_{FCH} and m_{SCH}.

Among the m_{FCH} cells of the receiver active set, only the first *f* cells will be considered in order to determine the FCH availability on downlink. In the same way, only the first *f* cells among the m_{SCH} cells of the receiver active set will be considered in order to determine the SCH availability on downlink. Each of these cells is noted *(k,*ic_{BS}*)*.

9955 calculates the traffic channel quality on FCH from each cell *(k,*ic_{BS}*)*. No power control is performed as in simulations. Here, **9955** determines the downlink traffic channel quality on FCH at the receiver for the maximum traffic channel power per transmitter allowed on FCH. Then, after combination, the total downlink traffic channel quality on FCH is evaluated and compared with the specified target quality.

11. *CDMA2000 1xEV-DO systems do not support soft handover on downlink.*

9955 calculates the traffic channel quality on SCH from each cell *(k,ic$_{BS}$)*. No power control is performed as in simulations. Here, **9955** determines the downlink traffic channel quality on SCH at the receiver for the maximum traffic channel power per transmitter allowed on SCH. This value depends on the downlink data rate specified in the analysis. Then, after combination, the total downlink traffic channel quality on SCH is evaluated and compared with the specified target quality.

- Eb/Nt target on FCH and Eb/Nt target on SCH

Eb/Nt target on FCH ($(Q_{req}^{DL})_{FCH}$) is the downlink traffic data quality target on the fundamental channel (FCH). This value is user-defined for a given service and terminal.

Eb/Nt target on SCH ($(Q_{req}^{DL})_{SCH}$) is the downlink traffic data quality target on the supplemental channel (SCH). This value is specified for a given service, terminal and SCH rate.

- Required transmitter powers on FCH and SCH

The calculation of the required transmitter powers on FCH and SCH (P_{FCH}^{req} and P_{SCH}^{req}) may be divided into three steps.

<u>1st step</u>: Eb/Nt max for the first *f* (number of fingers) cells of active set

Let us assume the following notations: Eb/Nt max on FCH and SCH respectively correspond to $(Q_{max}^{DL})_{FCH}$ and $(Q_{max}^{DL})_{SCH}$.

Therefore, for each cell *(k,ic$_{BS}$)*, we have:

$$(Q_{max}^{DL}(k, ic_{BS}))_{FCH} = \frac{\rho_{BTS} \times P_{b-max}^{DL-FCH}(k, ic_{BS})}{N_{tot}^{DL}(ic_{BS})} \times G_p^{DL-FCH}$$

And

$$(Q_{max}^{DL}(k, ic_{BS}))_{SCH} = \frac{\rho_{BTS} \times P_{b-max}^{DL-SCH}(k, ic_{BS})}{N_{tot}^{DL}(ic_{BS})} \times G_p^{DL-SCH}$$

With $P_b^{DL-FCH}(k, ic_{BS}) = \frac{P_{FCH}^{max}}{L_{T_k}}$, $P_{b-max}^{DL-SCH}(k, ic_{BS}) = \frac{P_{SCH}^{max}}{L_{T_k}}$

And $N_{tot}^{DL}(ic_{BS}) = I_{intra}^{DL}(ic_{BS}) + I_{extra}^{DL}(ic_{BS}) + I_{inter-carrier}^{DL}(ic_{BS}) + I_{inter-technology}^{DL}(ic_{BS}) + N_0^{term}$

Where

P_{FCH}^{max} is the maximum power allowed on FCH. This parameter is user-defined in the Services table for a certain terminal.

P_{SCH}^{max} is the maximum power allowed on SCH for the specified downlink data rate. This parameter is user-defined in the Services table for a certain terminal and SCH rate.

L_{T_k} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{DL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{DL}(ic_{BS})$ is the total noise at the receiver on the best carrier of the best server.

With

$$I_{intra}^{DL}(ic_{BS}) = (1 - \rho_{BTS} \times F_{ortho}) \times P_{tot}^{DL}(k, ic_{BS})$$

And

$$I_{extra}^{DL}(ic_{BS}) = \sum_{j, j \neq k} P_{tot}^{DL}(j, ic_{BS})$$

For each transmitter in the network, $P_{tot}^{DL}(ic_{BS})$ is the total power received at the receiver from this transmitter on ic_{BS}.

$I_{inter-carrier}^{DL}(ic_{BS})$ is the inter-carrier interference at the receiver on the best carrier of the best server.

$$I^{DL}_{inter-carrier}(ic_{BS}) = \frac{\sum_{txj, \forall j} P^{DL}_{tot}(j, ic_{adj})}{RF(ic_{BS}, ic_{adj})}$$

ic_{adj} is a carrier adjacent to ic_{BS}.

$RF(ic_{BS}, ic_{adj})$ is the interference reduction factor, defined between ic and ic_{adj} and set to a value different from 0.

$I^{DL}_{inter-technology}(ic_{BS})$ is the inter-technology interference at the receiver on the best carrier of the best server.

$$I^{DL}_{inter-technology}(ic_{BS}) = \sum_{n_i} \frac{P^{Tx}_{Transmitted}(ic_i)}{L^{Tx}_{total} \times ICP^{Tx, m}_{ic_i, ic_{BS}}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP^{Tx, m}_{ic_i, ic_{BS}}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by m assuming the frequency gap between ic_i (external network) and ic_{BS}.

2^nd^ step: Calculation of the total traffic channel quality on FCH and SCH

$(Q^{DL}_{MAX})_{FCH}$ is the traffic channel quality on FCH at the receiver on ic_{BS} after combining the signal from each cell *(k,ic_{BS})*.

On downlink, if there is no handoff, we have:

$$(Q^{DL}_{MAX}(ic_{BS}))_{FCH} = (Q^{DL}_{max}(k, ic_{BS}))_{FCH}$$

For any other handoff status, we have:

$$(Q^{DL}_{MAX}(ic_{BS}))_{FCH} = f^{DL}_{rake\ efficiency} \times \sum_k (Q^{DL}_{max}(k, ic_{BS}))_{FCH}$$

Where

$f^{DL}_{rake\ efficiency}$ is the downlink rake efficiency factor defined in Terminal properties.

$(Q^{DL}_{MAX})_{SCH}$ is the traffic channel quality on SCH at the receiver on ic_{BS} after combining the signal from each cell *(k,ic_{BS})*.

On downlink, if there is no handoff, we have:

$$(Q^{DL}_{MAX}(ic_{BS}))_{SCH} = (Q^{DL}_{max}(k, ic_{BS}))_{SCH}$$

For any other handoff status, we have:

$$(Q^{DL}_{MAX}(ic_{BS}))_{SCH} = f^{DL}_{rake\ efficiency} \times \sum_k (Q^{DL}_{max}(k, ic_{BS}))_{SCH}$$

3^rd^ step: P^{req}_{FCH} and P^{req}_{SCH} calculation

$$P^{req}_{FCH} = \frac{(Q^{DL}_{req})_{FCH}}{(Q^{DL}_{MAX}(ic_{BS}))_{FCH}} \times P^{max}_{FCH}$$

$$P^{req}_{SCH} = \frac{(Q^{DL}_{req})_{SCH}}{(Q^{DL}_{MAX}(ic_{BS}))_{SCH}} \times P^{max}_{SCH}$$

- Eb/Nt max on FCH for the first f (number of fingers) cells of active set

Let us assume the following notation: Eb/Nt max on FCH corresponds to $(Q^{DL}_{max})_{FCH}$.

Therefore, for each cell *(k,ic_{BS})*, we have:

$$(Q^{DL}_{max}(k, ic_{BS}))_{FCH} = \frac{\rho_{BTS} \times P^{DL-FCH}_{b-max}(k, ic_{BS})}{N^{DL}_{tot}(ic_{BS})} \times G^{DL-FCH}_p$$

With $P_{b-max}^{DL-FCH}(k, ic_{BS}) = \frac{P_{FCH}^{max}}{L_{T_k}}$ and $N_{tot}^{DL}(ic_{BS}) = I_{intra}^{DL}(ic_{BS}) + I_{extra}^{DL}(ic_{BS}) + I_{inter-carrier}^{DL}(ic_{BS}) + N_0^{term}$

Where

P_{FCH}^{max} is the maximum power allowed on FCH. This parameter is user-defined in the Services table for a certain terminal.

L_{T_k} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{DL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{DL}(ic_{BS})$ is the total noise at the receiver on the best carrier of the best server.

With

$$I_{intra}^{DL}(ic_{BS}) = (1-\rho_{BTS} \times F_{ortho}) \times P_{tot}^{DL}(k, ic_{BS}) - (1-\rho_{BTS}) \times max\left(\frac{P_{FCH}^{max} - P_{FCH}^{req}}{L_{T_k}}, 0\right)$$

And

$$I_{extra}^{DL}(ic_{BS}) = \sum_{j, j \neq k} P_{tot}^{DL}(j, ic_{BS})$$

For each transmitter in the network, $P_{tot}^{DL}(ic_{BS})$ is the total power received at the receiver from the transmitter on ic_{BS}.

$I_{inter-carrier}^{DL}(ic_{BS})$ is the inter-carrier interference at the receiver on the best carrier of the best server.

$$I_{inter-carrier}^{DL}(ic_{BS}) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(j, ic_{adj})}{RF(ic_{BS}, ic_{adj})}$$

ic_{adj} is a carrier adjacent to ic_{BS}.

$RF(ic_{BS}, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I_{inter-technology}^{DL}(ic_{BS})$ is the inter-technology interference at the receiver on the best carrier of the best server.

$$I_{inter-technology}^{DL}(ic_{BS}) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic_{BS}}^{Tx, m}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP_{ic_i, ic_{BS}}^{Tx, m}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic_{BS}.

- Eb/Nt max on SCH for the first *f* (number of fingers) cells of active set

Let us assume the following notation: Eb/Nt max on SCH corresponds to $(Q_{max}^{DL})_{SCH}$.

Therefore, for each cell *(k,ic$_{BS}$)*, we have:

$$(Q_{max}^{DL}(k, ic_{BS}))_{SCH} = \frac{\rho_{BTS} \times P_{b-max}^{DL-SCH}(k, ic_{BS})}{N_{tot}^{DL}(ic_{BS})} \times G_p^{DL-SCH}$$

With $P_{b-max}^{DL-SCH}(k, ic_{BS}) = \frac{P_{SCH}^{max}}{L_{T_k}}$

and $N_{tot}^{DL}(ic_{BS}) = I_{intra}^{DL}(ic_{BS}) + I_{extra}^{DL}(ic_{BS}) + I_{inter-carrier}^{DL}(ic_{BS}) + I_{inter-technology}^{DL}(ic_{BS}) + N_0^{term}$

Where

P_{SCH}^{max} is the maximum power allowed on SCH for the specified downlink data rate. This parameter is user-defined in the Services table for a certain terminal and SCH rate.

L_{T_k} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{DL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{DL}(ic_{BS})$ is the total noise at the receiver on the best carrier of the best server.

With

$$I_{intra}^{DL}(ic_{BS}) = (1-\rho_{BTS} \times F_{ortho}) \times P_{tot}^{DL}(k, ic_{BS}) - (1-\rho_{BTS}) \times max\left(\frac{P_{SCH}^{max} - P_{SCH}^{req}}{L_{T_k}}, 0\right)$$

And

$$I_{extra}^{DL}(ic_{BS}) = \sum_{j, j \neq k} P_{tot}^{DL}(j, ic_{BS})$$

For each transmitter in the network, $P_{tot}^{DL}(ic_{BS})$ is the total power received at the receiver from the transmitter on ic_{BS}.

$I_{inter-carrier}^{DL}(ic_{BS})$ is the inter-carrier interference at the receiver on the best carrier of the best server.

$$I_{inter-carrier}^{DL}(ic_{BS}) = \frac{\sum_{txj, \forall j} P_{tot}^{DL}(j, ic_{adj})}{RF(ic_{BS}, ic_{adj})}$$

ic_{adj} is a carrier adjacent to ic_{BS}.

$RF(ic_{BS}, ic_{adj})$ is the interference reduction factor, defined between *ic* and ic_{adj} and set to a value different from 0.

$I_{inter-technology}^{DL}(ic_{BS})$ is the inter-technology interference at the receiver on the best carrier of the best server.

$$I_{inter-technology}^{DL}(ic_{BS}) = \sum_{n_i} \frac{P_{Transmitted}^{Tx}(ic_i)}{L_{total}^{Tx} \times ICP_{ic_i, ic_{BS}}^{Tx, m}}$$

ic_i is the i^{th} interfering carrier of an external transmitter

$ICP_{ic_i, ic_{BS}}^{Tx, m}$ is the inter-technology Channel Protection between the signal transmitted by Tx and received by *m* assuming the frequency gap between ic_i (external network) and ic_{BS} .

- Eb/Nt max on FCH and Eb/Nt max on SCH

$(Q_{MAX}^{DL})_{FCH}$ is the traffic channel quality on FCH at the receiver on ic_{BS} after combining the signal from each cell *(k,*ic_{BS}*)*.

On downlink, if there is no handoff, we have:

$$(Q_{MAX}^{DL}(ic_{BS}))_{FCH} = (Q_{max}^{DL}(k, ic_{BS}))_{FCH}$$

For any other handoff status, we have:

$$(Q_{MAX}^{DL}(ic_{BS}))_{FCH} = f_{rake\ efficiency}^{DL} \times \sum_k (Q_{max}^{DL}(k, ic_{BS}))_{FCH}$$

Where

$f_{rake\ efficiency}^{DL}$ is the downlink rake efficiency factor defined in Terminal properties.

$(Q_{MAX}^{DL})_{SCH}$ is the traffic channel quality on SCH at the receiver on ic_{BS} after combining the signal from each cell *(k,*ic_{BS}*)*.

On downlink, if there is no handoff, we have:

$$(Q_{MAX}^{DL}(ic_{BS}))_{SCH} = (Q_{max}^{DL}(k, ic_{BS}))_{SCH}$$

For any other handoff status, we have:

$$(Q_{MAX}^{DL}(ic_{BS}))_{SCH} = f_{rake\ efficiency}^{DL} \times \sum_k (Q_{max}^{DL}(k, ic_{BS}))_{SCH}$$

Therefore, the service on the downlink traffic channel is available if $(Q_{MAX}^{DL}(ic_{BS}))_{FCH} \geq (Q_{req}^{DL})_{FCH}$ and $(Q_{MAX}^{DL}(ic_{BS}))_{SCH} \geq (Q_{req}^{DL})_{SCH}$.

- Effective Eb/Nt on FCH and Eb/Nt on SCH

$(Q_{eff}^{DL})_{FCH}$ and $(Q_{eff}^{DL})_{SCH}$ are respectively effective traffic channel qualities at the receiver on ic_{BS} supplied on FCH and SCH.

$$(Q_{eff}^{DL})_{FCH} = min((Q_{MAX}^{DL})_{FCH}, (Q_{req}^{DL})_{FCH})$$

And

$$(Q_{eff}^{DL})_{SCH} = min((Q_{MAX}^{DL})_{SCH}, (Q_{req}^{DL})_{SCH})$$

- Downlink soft handover gain on FCH and downlink soft handover gain on SCH

$(G_{SHO}^{DL})_{FCH}$ and $(G_{SHO}^{DL})_{SCH}$ respectively correspond to DL soft handover gains on FCH and SCH.

$$(G_{SHO}^{DL})_{FCH} = \frac{(Q_{MAX}^{DL}(ic_{BS}))_{FCH}}{\max_k ((Q_{max}^{DL}(k, ic_{BS}))_{FCH})}$$

And

$$(G_{SHO}^{DL})_{SCH} = \frac{(Q_{MAX}^{DL}(ic_{BS}))_{SCH}}{\max_k ((Q_{max}^{DL}(k, ic_{BS}))_{SCH})}$$

$\max_k (Q_{max}^{DL}(k, ic_{BS}))$ corresponds to the highest $Q_{max}^{DL}(k, ic_{BS})$ value.

7.5.1.2.2 CDMA2000 1xEV-DO

9955 calculates the effective pilot quality level at the receiver and compares this value with the required quality level.

1xEV-DO Rev.0 and 1xEV-DO Rev. A Service Users

For 1xEV-DO Rev.0 and 1xEV-DO Rev. A users, **9955** displays the following results:

- Required rate

The required rate, R_{req}^{DL}, is the downlink data rate selected for the analysis.

- Required C/I

For 1xEV-DO Rev. 0 users, the required C/I ($\left(\frac{C}{I}\right)_{req}$) is determined from the graph “Max Rate=f(C/I)” defined for the mobility type selected in the analysis. It corresponds to the value read in the graph “Max Rate=f(C/I) (Rev0)” for the specified required rate, R_{req}^{DL}.

For 1xEV-DO Rev. A users, the required data rate (R_{req}^{DL}) is obtained by using a certain downlink transmission format (i.e. a 1xEV-DO radio bearer ($Index_{DL-Bearer}$) with a certain number of timeslots (n_{TS})). It is calculated as follows:

$$R_{req}^{DL} = \frac{R_{RLC-peak}^{DL}(Index_{DL-Bearer})}{n_{TS}}$$

$\left(\frac{C}{I}\right)_{req}$ is the value defined in the 1xEV-DO Radio Bearer Selection (Downlink) table for this downlink transmission format (radio bearer Index, mobility and number of timeslots). It corresponds to the C/I required to obtain the defined required rate, R_{req}^{DL}.

- Effective C/I

Let $\frac{E_c}{N_t}(ic_{BS}, b_{pilot})$ be the effective C/I at the receiver on ic_{BS}.

For the best cell *(BS,ic$_{BS}$)* of the receiver active set, we have:

$$\frac{E_c}{N_t}(ic_{BS}, b_{pilo,t}) = \left(\frac{1}{\frac{1}{Q_{resulting}^{pilot}} - 1}\right)$$

Where

$$Q_{resulting}^{pilot}(ic_{BS}) = G_{macro-diversity}^{DL} \times Q_{pilot_{BS}}(ic_{BS})$$

- Effective data rate

For 1xEV-DO Rev. 0 users, the effective data rate, R^{DL}, is determined from the graph “Max Rate=f(C/I) (Rev0)” defined for the mobility type selected in the analysis. R^{DL} is the value read in the graph “Max Rate=f(C/I) (Rev0)” for the calculated effective C/I, $\frac{E_c}{N_t}(ic_{BS}, b_{pilot})$.

For 1xEV-DO Rev. A users, the effective data rate (R^{DL}) provided on downlink depends on the downlink transmission format, i.e the radio bearer index ($Index_{DL-Bearer}$) with the number of timeslots (n_{TS}). For the defined mobility type, **9955** selects the downlink transmission format where $\frac{E_c}{N_t}(ic_{BS}, b_{pilot}) \geq \left(\frac{C}{I}\right)_{req}$. Then, it determines the downlink effective data rate as follows:

$$R^{DL} = \frac{R_{RLC-peak}^{DL}(Index_{DL-Bearer})}{n_{TS}}$$

The traffic data channel in downlink is available if $R^{DL} \geq R_{req}^{DL}$.

- Bearer Consumption

For (1xEV-DO Rev. A - Guaranteed bit rate) service users, **9955** calculates the 1xEV-DO bearer consumption.

$$C_{DL-Bearer} = \frac{R_{Guaranteed}^{DL}}{R_{RLC-peak}^{DL}(Index_{DL-Bearer})}$$

Where $R_{Guaranteed}^{DL}$ corresponds to the minimum bit rate required by the service in the downlink.

1xEV-DO Rev. B Service Users

For single-carrier and multi-carrier 1xEV-DO Rev. B users, **9955** displays the following results:

- Required rate

The required rate, R_{req}^{DL}, is the downlink data rate selected for the analysis.

- Effective data rate

The effective data rate corresponds to the sum of the effective data rates obtained on each carrier.

$$R^{DL} = \sum_{ic} R^{DL}(ic)$$

The traffic data channel on downlink is available if $R^{DL} \geq R_{req}^{DL}$.

- For each sub-active set, **9955** indicates the effective C/I and the effective data rate:

Let $\frac{E_c}{N_t}(ic, b_{pilot})$ be the effective C/I at the receiver on *ic*, the carrier associated with the sub-active set.

For the best cell *(BS,ic)* of the receiver sub-active set, we have:

$$\frac{E_c}{N_t}(ic, b_{pilot}) = \frac{\alpha \times Q^{pilot}_{resulting}(ic)}{\alpha - Q^{pilot}_{resulting}(ic)}$$

Where

$$Q^{pilot}_{resulting}(ic) = G^{DL}_{macro-diversity} \times Q_{pilot_{BS}}(ic)$$

The effective data rate ($R^{DL}(ic)$) provided on downlink depends on the downlink transmission format, i.e the radio bearer index ($Index_{DL-Bearer}$) with the number of timeslots (n_{TS}). For the defined mobility type, **9955** selects the downlink transmission format where $\frac{E_c}{N_t}(ic, b_{pilot}) \geq \left(\frac{C}{I}\right)_{req}$ and whose modulation scheme is supported by the terminal.

$\left(\frac{C}{I}\right)_{req}$ is the value defined in the 1xEV-DO Radio Bearer Selection (Downlink) table for this downlink transmission format (radio bearer Index, mobility and number of timeslots). It corresponds to the C/I required to obtain the defined required rate, R^{DL}_{req}.

The downlink effective data rate is determined as follows:

$$R^{DL}(ic) = \frac{R^{DL}_{RLC-peak}(Index_{DL-Bearer})}{n_{TS}}$$

7.5.1.3 Uplink Sub-Menu

Outputs calculated by **9955** depend on the studied network (CDMA2000 1xRTT or CDMA2000 1xEV-DO).

7.5.1.3.1 CDMA2000 1xRTT

For each cell *(i,ic$_{BS}$)* in the receiver active set, **9955** calculates the uplink traffic channel quality on FCH and SCH from the receiver. No power control is performed as in simulations. Here, **9955** determines the uplink traffic channel quality on FCH at the cell for the maximum terminal power allowed on FCH. In the same way, it evaluates the uplink traffic channel quality on SCH at the cell for the maximum terminal power allowed on SCH. Then, total uplink traffic channel qualities on FCH and SCH are evaluated with respect to the receiver handover status. From these values, **9955** deduces required terminal powers on FCH and SCH, calculates the total terminal power required and compares this value with the maximum terminal power allowed.

- Max terminal power on FCH and SCH

The Max terminal power parameter (P^{max}_{term}) is user-defined for each terminal. It corresponds to the maximum terminal power allowed. On uplink, the terminal power is shared between pilot, FCH and SCH channels. So, we may write:

$$P^{max}_{term} = (P^{max}_{term})_{pilot} + (P^{max}_{term})_{FCH} + (P^{max}_{term})_{SCH}$$

We have:

$$(P^{max}_{term})_{pilot} = p \times P^{max}_{term}$$

Where *p* is the percentage of the terminal power dedicated to pilot. This parameter is user-defined in the terminal properties.

And

$$\frac{(P^{max}_{term})_{FCH}}{(P^{max}_{term})_{SCH}} = \frac{(Q^{UL}_{req})_{FCH}}{(Q^{UL}_{req})_{SCH}} \times \frac{R^{UL}_{FCH} \times AF^{UL}_{FCH}}{R^{UL}_{SCH}}$$

Therefore,

$$(P^{max}_{term})_{FCH} = \frac{(1-p) \times P^{max}_{term}}{1 + \frac{(Q^{UL}_{req})_{SCH} \times R^{UL}_{SCH}}{(Q^{UL}_{req})_{FCH} \times R^{UL}_{FCH} \times AF^{UL}_{FCH}}}$$

And

$$(P_{term}^{max})_{SCH} = \frac{(1-p) \times P_{term}^{max}}{1 + \frac{(Q_{req}^{UL})_{FCH} \times R_{FCH}^{UL} \times AF_{FCH}^{UL}}{(Q_{req}^{UL})_{SCH} \times R_{SCH}^{UL}}}$$

- Required terminal power on FCH and SCH

The required terminal powers on FCH and SCH, respectively $(P_{term}^{req})_{FCH}$ and $(P_{term}^{req})_{SCH}$, are calculated as follows:

1st step: Evaluation of uplink traffic channel qualities on FCH and SCH, $(Q_{max_i}^{UL}(ic_{BS}))_{FCH}$ and $(Q_{max_i}^{UL}(ic_{BS}))_{SCH}$, for each cell of active set.

For each cell *(i,ic$_{BS}$)*, we have:

$$(Q_{max}^{UL}(i, ic_{BS}))_{FCH} = \frac{\rho_{term} \times P_{b-max}^{UL-FCH}(i, ic_{BS})}{N_{tot}^{UL}(i, ic_{BS})} \times G_p^{UL-FCH}$$

And

$$(Q_{max}^{UL}(i, ic_{BS}))_{SCH} = \frac{\rho_{term} \times P_{b-max}^{UL-SCH}(i, ic_{BS})}{N_{tot}^{UL}(i, ic_{BS})} \times G_p^{UL-SCH}$$

With $P_{b-max}^{UL-FCH}(i, ic_{BS}) = \frac{(P_{term}^{max})_{FCH}}{L_{T_i}}$ and $P_{b-max}^{UL-SCH}(i, ic_{BS}) = \frac{(P_{term}^{max})_{SCH}}{L_{T_i}}$

L_{T_i} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{UL}(i, ic_{BS})$ is the total noise at the transmitter on the best carrier of the best server. This value is deduced from the cell uplink load factor $X^{UL}(i, ic_{BS})$.

$$N_{tot}^{UL}(i, ic_{BS}) = \frac{N_0^{tx}}{1 - X^{UL}(i, ic_{BS})}$$

N_0^{tx} is the transmitter thermal noise.

2nd step: Calculation of FCH and SCH total traffic channel qualities at the transmitter on ic_{BS}, $(Q_{MAX}^{UL})_{FCH}$ and $(Q_{max}^{UL})_{SCH}$, based on the receiver handover status.

If there is no handoff, we have:

$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (Q_{max}^{UL}(i, ic_{BS}))_{FCH}$ and $(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (Q_{max}^{UL}(i, ic_{BS}))_{SCH}$

For soft handover, we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{FCH})$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{SCH})$$

$(G_{macro-diversity}^{UL})_{2\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option “Shadowing taken into account” is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

$\max_i(Q_{max}^{UL}(i, ic_{BS}))$ corresponds to the highest $Q_{max}^{UL}(i, ic_{BS})$ value.

For soft-soft handover, we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{3\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{FCH})$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{3\ links} \times \max_i ((Q_{max}^{UL}(i, ic_{BS}))_{SCH})$$

$(G_{macro-diversity}^{UL})_{3\ links}$ is the uplink macro-diversity gain.This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option “Shadowing taken into account” is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

For softer and softer-softer handovers, we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = f_{rake\ efficiency}^{UL} \times \sum_i (Q_{max}^{UL}(i, ic_{BS}))_{FCH}$$

And $(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = f_{rake\ efficiency}^{UL} \times \sum_i (Q_{max}^{UL}(i, ic_{BS}))_{SCH}$

For softer-soft handover, there are two possibilities. If the MRC option is selected (option available in Global parameters), we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max\left(f_{rake\ efficiency}^{UL} \times \sum_{i \text{ on the same site}} (Q_{max}^{UL}(i, ic_{BS}))_{FCH}, (Q_{\substack{max \\ i \text{ on the other site}}}^{UL}(i, ic_{BS}))_{FCH}\right)$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max\left(f_{rake\ efficiency}^{UL} \times \sum_{i \text{ on the same site}} (Q_{max}^{UL}(i, ic_{BS}))_{SCH}, (Q_{\substack{max \\ i \text{ on the other site}}}^{UL}(i, ic_{BS}))_{SCH}\right)$$

otherwise,

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i ((Q_{max}^{UL}(i, ic_{BS}))_{FCH})$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i ((Q_{max}^{UL}(i, ic_{BS}))_{SCH})$$

3rd step: Calculation of $(P_{term}^{req})_{FCH}$ and $(P_{term}^{req})_{SCH}$

$$(P_{term}^{req})_{FCH} = \frac{(Q_{req}^{UL})_{FCH}}{(Q_{MAX}^{UL}(ic_{BS}))_{FCH}} \times (P_{term}^{max})_{FCH} \text{ and } (P_{term}^{req})_{SCH} = \frac{(Q_{req}^{UL})_{SCH}}{(Q_{MAX}^{UL}(ic_{BS}))_{SCH}} \times (P_{term}^{max})_{SCH}$$

Where

$(Q_{req}^{UL})_{FCH}$ is the user-defined uplink data traffic quality target on FCH for a given service and a terminal. This parameter is available in the Services table.

$(Q_{req}^{UL})_{SCH}$ is the user-defined uplink data traffic quality target on SCH for a given service, terminal and SCH rate. This parameter is available in the Services table.

Then, from the required terminal power on FCH and SCH, **9955** determines the total terminal power required (P_{term}^{req}).

$$P_{term}^{req} = (P_{term}^{req})_{FCH} + (P_{term}^{req})_{SCH} + (P_{term}^{req})_{pilot}$$

As $(P_{term}^{req})_{pilot} = p \times P_{term}^{req}$, we have:

$$P_{term}^{req} = \frac{(P_{term}^{req})_{FCH} + (P_{term}^{req})_{SCH}}{1-p}$$

Therefore, the service on the uplink data traffic channel is available if $P_{term}^{req} \le P_{term}^{max}$.

- Eb/Nt max on FCH for each cell in active set

For each cell *(i,ic$_{BS}$)*, we have:

$$(Q_{max}^{UL}(i, ic_{BS}))_{FCH} = \frac{\rho_{term} \times P_{b-max}^{UL-FCH}(i, ic_{BS})}{N_{tot}^{UL}(i, ic_{BS})} \times G_p^{UL-FCH}$$

With $P_{b-max}^{UL-FCH}(i, ic_{BS}) = \frac{(P_{term}^{max})_{FCH}}{L_{T_i}}$

L_{T_i} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{UL}(i, ic_{BS})$ is the total noise at the transmitter on the best carrier of the best server. This value is deduced from the cell uplink load factor $X^{UL}(i, ic_{BS})$.

$$N_{tot}^{UL}(i, ic_{BS}) = \frac{N_0^{tx}}{1 - X^{UL}(i, ic_{BS})} + (1 - \rho_{term}) \times max\left(\frac{P_{FCH}^{max} - P_{FCH}^{req}}{L_{T_i}}, 0\right)$$

N_0^{tx} is the transmitter thermal noise.

- Eb/Nt max on SCH for each cell in active set

For each cell *(i,ic$_{BS}$)*, we have:

$$(Q_{max}^{UL}(i, ic_{BS}))_{SCH} = \frac{\rho_{term} \times P_{b-max}^{UL-SCH}(i, ic_{BS})}{N_{tot}^{UL}(i, ic_{BS})} \times G_p^{UL-SCH}$$

With $P_{b-max}^{UL-SCH}(i, ic_{BS}) = \frac{(P_{term}^{max})_{SCH}}{L_{T_i}}$

L_{T_i} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{UL}(i, ic_{BS})$ is the total noise at the transmitter on the best carrier of the best server. This value is deduced from the cell uplink load factor $X^{UL}(i, ic_{BS})$.

$$N_{tot}^{UL}(i, ic_{BS}) = \frac{N_0^{tx}}{1 - X^{UL}(i, ic_{BS})} + (1 - \rho_{term}) \times max\left(\frac{P_{SCH}^{max} - P_{SCH}^{req}}{L_{T_i}}, 0\right)$$

N_0^{tx} is the transmitter thermal noise.

- Eb/Nt max on FCH and SCH

$(Q_{MAX}^{UL}(ic_{BS}))_{FCH}$ and $(Q_{MAX}^{UL}(ic_{BS}))_{SCH}$ are respectively the traffic channel qualities on FCH and SCH at the transmitter on ic_{BS} after signal combination of all the transmitters of the active set.

If there is no handoff, we have:

$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (Q_{max}^{UL}(i, ic_{BS}))_{FCH}$ and $(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (Q_{max}^{UL}(i, ic_{BS}))_{SCH}$

For soft handover, we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{FCH})$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{SCH})$$

$(G_{macro-diversity}^{UL})_{2\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

$\max_i(Q_{max}^{UL}(i, ic_{BS}))$ corresponds to the highest $Q_{max}^{UL}(i, ic_{BS})$ value.

For soft-soft handover, we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{3\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{FCH})$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{3\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{SCH})$$

$(G_{macro-diversity}^{UL})_{3\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

For softer and softer-softer handovers, we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = f_{rake\ efficiency}^{UL} \times \sum_i (Q_{max}^{UL}(i, ic_{BS}))_{FCH}$$

And $(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = f_{rake\ efficiency}^{UL} \times \sum_i (Q_{max}^{UL}(i, ic_{BS}))_{SCH}$

For softer-soft handover, there are two possibilities. If the MRC option is selected (option available in Global parameters), we have:

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max\left(f_{rake\ efficiency}^{UL} \times \sum_{i\ \text{on the same site}} (Q_{max}^{UL}(i, ic_{BS}))_{FCH}, (Q_{\substack{max \\ i\ \text{on the other site}}}^{UL}(i, ic_{BS}))_{FCH}\right)$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max\left(f_{rake\ efficiency}^{UL} \times \sum_{i\ \text{on the same site}} (Q_{max}^{UL}(i, ic_{BS}))_{SCH}, (Q_{\substack{max \\ i\ \text{on the other site}}}^{UL}(i, ic_{BS}))_{SCH}\right)$$

otherwise,

$$(Q_{MAX}^{UL}(ic_{BS}))_{FCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{FCH})$$

And

$$(Q_{MAX}^{UL}(ic_{BS}))_{SCH} = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i((Q_{max}^{UL}(i, ic_{BS}))_{SCH})$$

- Effective Eb/Nt on FCH and SCH

$(Q_{eff}^{UL})_{FCH}$ is the uplink effective traffic channel quality on FCH at the receiver on ic_{BS}.

$(Q_{eff}^{UL})_{SCH}$ is the uplink effective traffic channel quality on SCH at the receiver on ic_{BS}.

$(Q_{eff}^{UL})_{FCH} = min((Q_{MAX}^{UL})_{FCH}, (Q_{req}^{UL})_{FCH})$ and $(Q_{eff}^{UL})_{SCH} = min((Q_{MAX}^{UL})_{SCH}, (Q_{req}^{UL})_{SCH})$

- Uplink soft handover gain FCH and SCH

$(G_{SHO}^{UL})_{FCH}$ corresponds to the UL soft handover gain on FCH.

$(G_{SHO}^{UL})_{SCH}$ corresponds to the UL soft handover gain on SCH.

$$(G_{SHO}^{UL})_{FCH} = \frac{(Q_{MAX}^{UL}(ic_{BS}))_{FCH}}{\max_l((Q_{max}^{UL}(i, ic_{BS}))_{FCH})} \text{ and } (G_{SHO}^{UL})_{SCH} = \frac{(Q_{MAX}^{UL}(ic_{BS}))_{SCH}}{\max_l((Q_{max}^{UL}(i, ic_{BS}))_{SCH})}$$

$\max_l(Q_{max}^{UL}(i, ic_{BS}))$ corresponds to the highest $Q_{max}^{UL}(i, ic_{BS})$ value.

7.5.1.3.2 CDMA2000 1xEV-DO

1xEV-DO Rev.0 and 1xEV-DO Rev. A Service Users

For each cell *(l,ic$_{BS}$)* in the receiver active set, **9955** calculates the uplink quality level from the receiver. No power control is performed as in simulations. Here, **9955** determines the uplink quality level at the cell for the maximum terminal power allowed. Then, the total uplink quality level is evaluated with respect to the receiver handover status. From this value, **9955** calculates the required terminal power and compares it with the maximum terminal power allowed.

- Max terminal power

The Max terminal power parameter (P_{term}^{max}) is user-defined for each terminal. It corresponds to the maximum terminal power allowed.

- Required terminal power with ACK

The required terminal power (P_{term}^{req}) calculation may be divided into four steps:

1st step: Evaluation of the uplink quality, $Q_{max}^{UL}(i, ic_{BS})$, for each cell of active set

For each cell *(i,ic$_{BS}$)*, we have:

$$Q_{max}^{UL}(i, ic_{BS}) = \frac{\rho_{term} \times P_{b-max}^{UL}(i, ic_{BS})}{N_{tot}^{UL}(i, ic_{BS})} \times G_p^{UL}$$

With $P_{b-max}^{UL}(i, ic_{BS}) = \frac{P_{term}^{max}}{L_{T_i}}$

L_{T_i} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{UL}(i, ic_{BS})$ is the total noise at the transmitter on the best carrier of the best server. This value is deduced from the cell uplink load factor $X^{UL}(i, ic_{BS})$.

$$N_{tot}^{UL}(i, ic_{BS}) = \frac{N_0^{tx}}{1 - X^{UL}(i, ic_{BS})} + (1 - \rho_{term}) \times max\left(\frac{P_{term}^{max} - P_{term}^{req}}{L_{T_i}}, 0\right)$$

N_0^{tx} is the transmitter thermal noise.

2nd step: Calculation of the total quality at the transmitter on ic_{BS} (Q_{MAX}^{UL}) based on the receiver handover status.

If there is no handoff, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = Q_{max}^{UL}(i, ic_{BS})$$

For soft handover, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i (Q_{max}^{UL}(i, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{2\ links}$ is the uplink macro-diversity gain.This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option “Shadowing taken into account” is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

$\max_i (Q_{max}^{UL}(i, ic_{BS}))$ corresponds to the highest $Q_{max}^{UL}(i, ic_{BS})$ value.

For soft-soft handover, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{3\ links} \times \max_i (Q_{max}^{UL}(i, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{3\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option “Shadowing taken into account” is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

For softer and softer-softer handovers, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = f_{rake\ efficiency}^{UL} \times \sum_i Q_{max}^{UL}(i, ic_{BS})$$

For softer-soft handover, there are two possibilities. If the MRC option is selected (option available in Global parameters), we have:

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times max\left(f_{rake\ efficiency}^{UL} \times \sum_{i\ on\ the\ same\ site} Q_{max}^{UL}(i, ic_{BS}), Q_{max_{i\ on\ the\ other\ site}}^{UL}(i, ic_{BS})\right)$$

otherwise,

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i (Q_{max}^{UL}(i, ic_{BS}))$$

3rd step: Evaluation of the required quality level on uplink, Q_{req}^{UL}

In case of a 1xEV-DO Rev. 0 capable terminal, we have:

$$Q_{req}^{UL} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{ACK} + G_{DRC} + G_{TCH})$$

Where

$\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ is the minimum pilot quality level on uplink. This parameter is available in the Mobility types table.

G_{ACK}, G_{DRC} and G_{TCH} are respectively acknowledgement, data rate control and traffic data gains relative to the pilot. They are defined in the terminal properties (1xEV-DO Rev. 0 tab).

In case of a 1xEV-DO Rev. A capable terminal, we have:

$$Q_{req}^{UL} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{ACK} + G_{DRC} + G_{TCH} + G_{RRI} + G_{Auxiliary-pilot})$$

Where

$\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ is the minimum pilot quality level required on uplink to obtain the defined data rate, R_{req}^{UL}. The required data rate, R_{req}^{UL} (i.e. the uplink data rate selected for the analysis) is obtained by using a certain uplink transmission format (i.e. 1xEV-DO radio bearer ($Index_{UL-Bearer}$) with a certain number of subframes (n_{SF})) and calculated as follows:

$$R_{req}^{UL} = \frac{R_{RLC-peak}^{UL}(Index_{UL-Bearer})}{n_{SF}}$$

$\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ is the value defined in the 1xEV-DO Radio Bearer Selection (Uplink) table for this uplink transmission format (radio bearer Index, mobility and number of subframe). Two values are available for this parameter, one when the service uplink mode is "Low Latency" and another one for high capacity services.

G_{ACK}, G_{DRC}, G_{TCH}, G_{RRI} and $G_{Auxiliary-pilot}$ are respectively acknowledgement, data rate control, traffic data channel, reverse rate indicator and auxiliary pilot channel gains relative to the pilot. They are defined in the terminal properties (1xEV-DO Rev. A tab). Two values of G_{TCH} are available, one when the service uplink mode is "Low Latency" and another one for high capacity services.

4th step: Calculation of P_{term}^{req}

$$P_{term}^{req} = \frac{Q_{req}^{UL}}{Q_{MAX}^{UL}(ic_{BS})} \times P_{term}^{max}$$

Therefore, the service on the uplink traffic data channel is available if $P_{term}^{req} \le P_{term}^{max}$.

- Required terminal power without ACK

9955 also calculates the required terminal power without taking into account the ACK channel contribution. Calculations are quite similar to those detailed in the previous paragraph, only the evaluation of the required quality on uplink is different.

In this case, we have:

$$(Q_{req}^{UL})_{withoutACK} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{DRC} + G_{TCH}) \text{ for 1xEV-DO Rev. 0 capable terminals}$$

And

$$(Q_{req}^{UL})_{withoutACK} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{DRC} + G_{TCH} + G_{RRI} + G_{Auxiliary-pilot})$$ for 1xEV-DO Rev. A capable terminals

And then,

$$(P_{term}^{req})_{withoutACK} = \frac{(Q_{req}^{UL})_{withoutACK}}{Q_{MAX}^{UL}(ic_{BS})} \times P_{term}^{max}$$

- UL SHO gain

1st step: Evaluation of the uplink quality, $Q_{max}^{UL}(i, ic_{BS})$, for each cell of active set.

For each cell *(i,ic$_{BS}$)*, we have:

$$Q_{max}^{UL}(i, ic_{BS}) = \frac{\rho_{term} \times P_{b-max}^{UL}(i, ic_{BS})}{N_{tot}^{UL}(i, ic_{BS})} \times G_p^{UL}$$

With $P_{b-max}^{UL}(i, ic_{BS}) = \frac{P_{term}^{max}}{L_{T_i}}$

L_{T_i} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{UL}(i, ic_{BS})$ is the total noise at the transmitter on the best carrier of the best server. This value is deduced from the cell uplink load factor $X^{UL}(i, ic_{BS})$.

$$N_{tot}^{UL}(i, ic_{BS}) = \frac{N_0^{tx}}{1 - X^{UL}(i, ic_{BS})} + (1 - \rho_{term}) \times max\left(\frac{P_{term}^{max} - P_{term}^{req}}{L_{T_i}}, 0\right)$$

N_0^{tx} is the transmitter thermal noise.

2nd step: Calculation of the total quality at the transmitter on ic_{BS} (Q_{MAX}^{UL}) based on the receiver handover status.

$Q_{MAX}^{UL}(ic_{BS})$ is the traffic channel quality at the transmitter on ic_{BS} after signal combination of all the transmitters of the active set.

If there is no handoff, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = Q_{max}^{UL}(i, ic_{BS})$$

For soft handover, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i (Q_{max}^{UL}(i, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{2\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

$\max_i (Q_{max}^{UL}(i, ic_{BS}))$ corresponds to the highest $Q_{max}^{UL}(i, ic_{BS})$ value.

For soft-soft handover, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{3\ links} \times \max_i (Q_{max}^{UL}(i, ic_{BS}))$$

$(G_{macro-diversity}^{UL})_{3\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

For softer and softer-softer handovers, we have:

$$Q_{MAX}^{UL}(ic_{BS}) = f_{rake\ efficiency}^{UL} \times \sum_i Q_{max}^{UL}(i, ic_{BS})$$

For softer-soft handover, there are two possibilities. If the MRC option is selected (option available in Global parameters), we have:

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity})_{2\ links} \times max\left(f_{rake\ efficiency}^{UL} \times \sum_{i\ on\ the\ same\ site} Q_{max}^{UL}(i, ic_{BS}), Q_{max_{i\ on\ the\ other\ site}}^{UL}(i, ic_{BS})\right)$$

otherwise,

$$Q_{MAX}^{UL}(ic_{BS}) = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i (Q_{max}^{UL}(i, ic_{BS}))$$

3rd step: Calculation of the UL SHO gain

G_{SHO}^{UL} corresponds to the uplink soft handover gain.

$$G_{SHO}^{UL} = \frac{Q_{MAX}^{UL}(ic_{BS})}{\max_i (Q_{max}^{UL}(i, ic_{BS}))}$$

- Bearer Consumption

For (1xEV-DO Rev. A - Guaranteed bit rate) service users, **9955** calculates the 1xEV-DO bearer consumption.

$$C_{UL-Bearer} = \frac{R_{Guaranteed}^{UL}}{R_{RLC-peak}^{UL}(Index_{UL-Bearer})}$$

Where $R_{Guaranteed}^{UL}$ corresponds to the minimum bit rate required by the service in the uplink.

1xEV-DO Rev. B Service Users

For multi-carrier 1xEV-DO Rev. B users, **9955** models load balancing between carriers. **9955** equally shares the available terminal power between each carrier and determines the uplink 1xEV-DO radio bearer obtained on each carrier. Then, it selects the best configuration among all combinations of carriers, i.e., the combination which provides the highest effective rate.

The following results are displayed:

- For each carrier used in the selected configuration, **9955** indicates the UL SHO Gain, the effective data rate and the required power.

The calculations can be divided into four steps:

1st step: Evaluation of the uplink quality, $Q_{max}^{UL}(i, ic)$, for each cell of the sub-active set

For each cell *(i,ic)*, we have:

$$Q_{max}^{UL}(i, ic) = \frac{\rho_{term} \times P_{b-max}^{UL}(i, ic)}{N_{tot}^{UL}(i, ic)} \times G_p^{UL}$$

With $P_{b-max}^{UL}(i, ic) = \dfrac{P_{term}^{max}/n^{carriers}}{L_{T_i}}$

$n^{carriers}$ is the number of carriers in the user active set.

L_{T_i} is the total loss between the transmitter *i* and the receiver.

$$L_T = \frac{L_{path} \times L_{Tx} \times L_{term} \times L_{body} \times L_{indoor} \times M_{Shadowing-(Eb/Nt)_{UL}}}{G_{Tx} \times G_{term}}$$

$N_{tot}^{UL}(i, ic)$ is the total noise at the transmitter on the carrier *ic*. This value is deduced from the cell uplink load factor $X^{UL}(i, ic)$.

$$N_{tot}^{UL}(i, ic) = \frac{N_0^{tx}}{1 - X^{UL}(i, ic)} + (1 - \rho_{term}) \times max\left(\frac{P_{term}^{max}/n^{carriers} - P_{term}^{req}}{L_{T_i}}, 0\right)$$

N_0^{tx} is the transmitter thermal noise.

2nd step: Calculation of the total quality at the transmitter on *ic* (Q_{MAX}^{UL}) based on the receiver handover status.

If there is no handoff, we have:

$$Q_{MAX}^{UL}(ic) = Q_{max}^{UL}(i, ic)$$

For soft handover, we have:

$$Q_{MAX}^{UL}(ic) = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i (Q_{max}^{UL}(i, ic))$$

$(G_{macro-diversity}^{UL})_{2\ links}$ is the uplink macro-diversity gain.This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

$\max_i (Q_{max}^{UL}(i, ic))$ corresponds to the highest $Q_{max}^{UL}(i, ic)$ value.

For soft-soft handover, we have:

$$Q_{MAX}^{UL}(ic) = (G_{macro-diversity}^{UL})_{3\ links} \times \max_i (Q_{max}^{UL}(i, ic))$$

$(G_{macro-diversity}^{UL})_{3\ links}$ is the uplink macro-diversity gain. This parameter is determined from the fixed cell edge coverage probability and the uplink Eb/Nt standard deviation. When the option "Shadowing taken into account" is not selected (Prediction properties), **9955** considers the uplink macro-diversity gain defined by the user in Global parameters.

For softer and softer-softer handovers, we have:

$$Q_{MAX}^{UL}(ic) = f_{rake\ efficiency}^{UL} \times \sum_i Q_{max}^{UL}(i, ic)$$

For softer-soft handover, there are two possibilities. If the MRC option is selected (option available in Global parameters), we have:

$$Q_{MAX}^{UL}(ic) = (G_{macro-diversity}^{UL})_{2\ links} \times \max\left(f_{rake\ efficiency}^{UL} \times \sum_{i\ on\ the\ same\ site} Q_{max}^{UL}(i, ic), Q_{max_{i\ on\ the\ other\ site}}^{UL}(i, ic)\right)$$

otherwise,

$$Q_{MAX}^{UL}(ic) = (G_{macro-diversity}^{UL})_{2\ links} \times \max_i (Q_{max}^{UL}(i, ic))$$

3rd step: Calculation of the UL SHO gain (G_{SHO}^{UL})

$$G_{SHO}^{UL} = \frac{Q_{MAX}^{UL}(ic)}{\max_i (Q_{max}^{UL}(i, ic))}$$

4th step: Selection of the uplink 1xEV-DO radio bearer

9955 evaluates of the required quality level in the uplink (Q_{req}^{UL}) and the required terminal power ($P_{term}^{req}(ic)$) for each 1xEV-DO radio bearer.

$$Q_{req}^{UL} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{ACK} + G_{DRC} + G_{TCH} + G_{RRI} + G_{Auxiliary-pilot})$$

Where

$\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ is the minimum pilot quality level required in the uplink to obtain the 1xEV-DO radio bearer. The values are defined in the 1xEV-DO Radio Bearer Selection (Uplink) table for each uplink transmission format (radio bearer Index, mobility and number of subframe). Two values are available, one when the service uplink mode is "Low Latency" and another one for high capacity services.

G_{ACK}, G_{DRC}, G_{TCH}, G_{RRI} and $G_{Auxiliary-pilot}$ are respectively acknowledgement, data rate control, traffic data channel, reverse rate indicator and auxiliary pilot channel gains relative to the pilot. They are defined in the terminal properties (1xEV-

DO Rev. A tab). Two values of G_{TCH} are available, one when the service uplink mode is "Low Latency" and another one for high capacity services.

And

$$P_{term}^{req}(ic) = \frac{Q_{req}^{UL}}{Q_{MAX}^{UL}(ic)} \times \frac{P_{term}^{max}}{n^{carriers}}$$

Then, **9955** selects the best 1xEV-DO radio bearer. This is the 1xEV-DO radio bearer ($Index_{UL-Bearer}$) with the highest effective rate ($R^{UL}(ic) = \frac{R_{RLC-peak}^{UL}(Index_{UL-Bearer})}{n_{SF}(Index_{UL-Bearer})}$) where:

- $P_{term}^{req}(ic) \le \frac{P_{term}^{max}}{n^{carriers}}$,
- And the required modulation scheme is supported by the terminal.

n_{SF} is the number of subframes associated with the 1xEV-DO radio bearer ($Index_{UL-Bearer}$).

- Max terminal power

The Max terminal power parameter (P_{term}^{max}) is user-defined for each terminal. It corresponds to the maximum terminal power allowed.

- Required Rate

The required rate, R_{req}^{UL}, is the uplink data rate selected for the analysis.

- Effective Rate

9955 calculates the total rate for all combinations of carriers.

$$R_{total}^{UL} = \sum_{ic=1}^{m} R^{UL}(ic)$$ where m corresponds to the number of carriers in the combination.

The effective rate (R^{UL}) corresponds to the best configuration among all combinations of carriers, i.e., the combination which provides the highest total rate, $Max(R_{total}^{UL})$.

The traffic data channel is available in uplink if $R^{UL} \ge R_{req}^{UL}$.

- Required terminal power

$$P_{term}^{req} = \sum_{ic=1}^{m} P_{term}^{req}(ic)$$

7.5.2 Coverage Studies

Let us assume each pixel of the map corresponds to a probe receiver with a terminal, a mobility type and a service. This receiver does not create any interference. You can make the coverage prediction for a specific carrier or for the best 1xRTT or 1xEV-DO carrier. The type of carrier and the carriers you can select depend on the service and on the frequency band(s) supported by the terminal. Coverage studies are based on the uplink load percentage and the downlink total power of cells. These parameters can either be either simulation results, or average values calculated from a group of simulations, or user-defined cell inputs.

7.5.2.1 Pilot Quality Analysis

For further details on calculation formulas, see "Definitions and Formulas" on page 444. For further details on calculations, see "Bar Graph and Pilot Sub-Menu" on page 495

1st Case: Analysis based on the best carrier

9955 proceeds as in point analysis. It determines the best carrier of each transmitter *i* containing the receiver in its calculation area. The best carrier selection depends on the option chosen in Equipment (UL minimum noise, DL minimum power, random, sequential) and is based on the UL load percentage and the downlink total power of cells (simulation results or cell properties). **9955** calculates the pilot quality at the receiver from these transmitters on their best carrier and determines the best serving transmitter *BS* on its best carrier ic_{BS} ($Q_{pilot_{BS}}(ic_{BS})$). Then, it deduces the best pilot quality received with a fixed cell edge coverage probability, $Q_{pilot}^{Resulting}(ic_{BS})$.

9955 displays the best pilot quality received with a fixed cell edge coverage probability.

2nd Case: Analysis based on a specific carrier

The carrier that can be used by transmitters is fixed. In this case, for each transmitter *i* containing the receiver in its calculation area that may use the specified carrier (carrier specified in Cell Properties), **9955** calculates pilot quality at the receiver on this carrier ic_{given}. Then, it determines the best serving transmitter *BS* using the carrier ic_{given} ($Q_{pilot_{BS}}(ic_{given})$) and deduces the best pilot quality received with a fixed cell edge coverage probability, $Q_{pilot}^{Resulting}(ic_{given})$.

9955 displays the best pilot quality received with a fixed cell edge coverage probability.

- Single colour

9955 displays a coverage if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$. Coverage consists of a single layer with a unique colour. $ic = ic_{BS}$ or ic_{given}

- Colour per transmitter

9955 displays a coverage if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}). Coverage consists of several layers with associated colours. There is a layer per transmitter with no intersection between layers. Layer colour is the colour assigned to the best serving transmitter *BS*.

- Colour per mobility

In this case, the receiver is not completely defined and no mobility assigned. Coverage consists of several layers with a layer per user-defined mobility type defined in the Mobility Types sub-folder. For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

- Colour per probability

This display option is available only if analysis is based on all simulations in a group (i.e. if you select a group of simulations and the “All” option in the Condition tab of prediction properties).

Coverage consists of several layers with a layer per user-defined probability level defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}) in the required number of simulations. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per cell edge coverage probability

Coverage consists of several layers with a layer per user-defined cell edge coverage probability, *p*, defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic, p) \geq Q_{pilot}^{req}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

- Colour per quality level (Ec/I0)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq (Q_{pilot})_{threshold}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

- Colour per quality margin (Ec/I0 margin)

Coverage consists of several layers with a layer per user-defined quality margin defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) - Q_{pilot}^{req} \geq (Q_{pilot})_{margin}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

Colour per pilot signal level (Ec)

Coverage consists of several layers with a layer per user-defined pilot signal level defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{pilot}^{Resulting}(ic) \geq (Q_{pilot})_{threshold}$ ($ic = ic_{BS}$ or ic_{given}). Each layer is assigned a colour and displayed with intersections between layers.

7.5.2.2 Downlink Service Area Analysis

The downlink service area analysis depends on the studied network (CDMA2000 1xRTT or CDMA2000 1xEV-DO). Several display options are available when calculating this study, some of which are dedicated to CDMA2000 1xRTT networks while others are relevant when analysing CDMA2000 1xEV-DO systems only.

7.5.2.2.1 CDMA2000 1xRTT

As in point analysis, **9955** calculates downlink quality on FCH at the receiver for each cell *(k,ic)* (with $ic=ic_{BS}$ *or* ic_{given}) (these cells are the first *f* cells in the receiver's active set and *f* is the number of fingers defined for the terminal). No power control is performed as in simulations. Here, **9955** determines the downlink quality on FCH at the receiver for a maximum traffic channel power per transmitter allowed on the fundamental channel (FCH). Then, the total downlink quality on FCH $((Q^{DL}_{MAX}(ic))_{FCH})$ is evaluated after recombination.

> Best server and active set determination is performed as in point prediction.

9955 displays total traffic channel quality at the receiver on the carrier *ic* (ic_{BS} or ic_{given}).

For further details on formulas, see "Definitions and Formulas" on page 444. For further details on calculation, see "Downlink Sub-Menu" on page 497.

You may choose following display options:

- Single colour

9955 displays a coverage with a unique colour if $(Q^{DL}_{MAX}(ic))_{FCH} \geq (Q^{DL}_{req})_{FCH}$. $(Q^{DL}_{req})_{FCH}$ is the downlink traffic data quality target on the fundamental channel (FCH). This parameter is user-defined for a given service and a terminal in the Services sub-folder.

- Colour per transmitter

9955 displays a coverage if $(Q^{DL}_{MAX}(ic))_{FCH} \geq (Q^{DL}_{req})_{FCH}$. Coverage consists of several layers with associated colours. There is a layer per transmitter with no intersection between layers. Layer colour is the colour assigned to best serving transmitter.

- Colour per mobility

In this case, receiver is not completely defined and no mobility is assigned. Coverage consists of several layers with a layer per user-defined mobility defined in Mobility sub-folder. For each layer, area is covered if $(Q^{DL}_{MAX}(ic))_{FCH} \geq (Q^{DL}_{req})_{FCH}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per service

In this case, receiver is not completely defined and no service is assigned. Coverage consists of several layers with a layer per user-defined service defined in Services sub-folder. For each layer, area is covered if $(Q^{DL}_{MAX}(ic))_{FCH} \geq (Q^{DL}_{req})_{FCH}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per probability

This display option is available only if analysis is based on all simulations in a group (i.e. if you select a group of simulations and the "All" option in the Condition tab of prediction properties).

Coverage consists of several layers with a layer per user-defined probability level defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q^{DL}_{MAX}(ic))_{FCH} \geq (Q^{DL}_{req})_{FCH}$ in the required number of simulations. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per cell edge coverage probability

Coverage consists of several layers with a layer per user-defined cell edge coverage probability, *p*, defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q^{DL}_{MAX}(ic, p))_{FCH} \geq (Q^{DL}_{req})_{FCH}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per maximum quality level (max Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q^{DL}_{MAX}(ic))_{FCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per effective quality level (Effective Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{eff}^{DL}(ic))_{FCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per quality margin (Eb/Nt margin)

Coverage consists of several layers with a layer per user-defined quality margin defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{MAX}^{DL}(ic))_{FCH} - (Q_{req}^{DL})_{FCH} \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per required power

9955 calculates the downlink power required on FCH, $P_{FCH}^{req}(ic)$, as follows:

$$P_{FCH}^{req}(ic) = \frac{(Q_{req}^{DL})_{FCH}}{Q_{MAX}^{DL}(ic)} \times P_{FCH}^{max}$$

Where P_{FCH}^{max} is a user-defined input for a given service and terminal. It corresponds to the maximum traffic data power allowed on FCH for a transmitter.

Coverage consists of several layers with a layer per user-defined required power threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{FCH}^{req}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per required power margin

Coverage consists of several layers with a layer per user-defined power margin defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{FCH}^{max} - P_{FCH}^{req}(ic) \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per data rate

This display option is relevant for CDMA2000 1xRTT data services only. For each possible data rate, R^{DL} ($R_{FCH}^{DL} \times AF_{FCH}^{DL}$, $R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 2)$, $R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 4)$, $R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 8)$, $R_{FCH}^{DL} \times (AF_{FCH}^{DL} + 16)$), **9955** calculates traffic channel quality at the receiver for each cell *(k,ic)* (with *$ic=ic_{BS}$ or ic_{given}*). Downlink traffic channel quality at the receiver is evaluated from a maximum traffic channel power per transmitter allowed for the corresponding data rate. Then, the total downlink traffic channel quality ($Q_{MAX}^{DL}(ic, R^{DL})$) is calculated after recombination.

Coverage consists of several layers with a layer per possible data rate, R^{DL}. For each layer, area is covered if $Q_{MAX}^{DL}(ic, R^{DL}) \geq Q_{req}^{DL}(R^{DL})$. Each layer is assigned a colour and displayed with intersections between layers.

$Q_{req}^{DL}(R^{DL})$ is the downlink traffic data quality target for the data rate, R^{DL}. This parameter is user-defined for a given service, terminal and data rate in the Services sub-folder.

7.5.2.2.2 CDMA2000 1xEV-DO

As in point analysis, **9955** calculates the effective pilot quality level at the receiver from the best server cell, $\frac{E_c}{N_t}(ic, b_{pilot})$.

Best server and active set determination is performed as in point prediction (AS analysis). Then, from this value, it determines the effective downlink data rate received, R^{DL}.

For further details on formulas, see "Definitions and Formulas" on page 444. For further details on calculations, see "Downlink Sub-Menu" on page 497.

1xEV-DO Rev. 0 Users

For 1xEV-DO Rev. 0 users (users with EV-DO Rev. 0-capable terminals and EV-DO Rev. 0 services), the effective data rate (R^{DL}) provided on downlink is determined from the graph “Max Rate=f(C/I) (Rev0)” defined for the mobility type selected in the Condition tab (Prediction properties). R^{DL} is the value read in the graph “Max Rate=f(C/I) (Rev0)” for the calculated effective pilot quality level, $\frac{E_c}{N_t}(ic_{BS}, b_{pilot})$.

1xEV-DO Rev. A Users

For 1xEV-DO Rev. A users (users with EV-DO Rev. A-capable terminals and EV-DO Rev. A services), the effective data rate (R^{DL}) provided on downlink depends on the downlink transmission format, i.e the radio bearer index ($Index_{DL-Bearer}$) with the number of timeslots (n_{TS}). **9955** selects the downlink transmission format where $\frac{E_c}{N_t}(ic_{BS}, b_{pilot}) \geq \left(\frac{C}{I}\right)_{req}$. Then, it determines the downlink effective data rate as follows:

$$R^{DL} = \frac{R^{DL}_{RLC-peak}(Index_{DL-Bearer})}{n_{TS}}.$$

The effective data rate corresponds to the guaranted data rate after a certain number of retransmissions (i.e. the number of timeslots, n_{TS}).

When HARQ (Hybrid Automatic Repeat Request) is used, the required average number of retransmissions is smaller and the data rate is an average data rate (R^{DL}_{av}) calculated as follows:

$$R^{DL}_{av} = \frac{R^{DL}_{RLC-peak}(Index_{DL-Bearer})}{(n^{DL}_{Rtx}(Index_{DL-Bearer}, n_{TS}))_{av}}$$

The average number of retransmissions ($(n^{DL}_{Rtx})_{av}$) is determined from early termination probabilities defined for the selected downlink transmission format. The Early Termination Probability graph shows the probability of early termination (p) as a function of the number of retransmissions (n^{DL}_{Rtx}). **9955** calculates the average number of retransmissions ($(n^{DL}_{Rtx})_{av}$) as follows:

$$(n^{DL}_{Rtx})_{av} = \frac{\sum_{n^{DL}_{Rtx}=1}^{(n^{DL}_{Rtx})_{max}} (p(n^{DL}_{Rtx}) - p(n^{DL}_{Rtx} - 1)) \times n^{DL}_{Rtx}}{p((n^{DL}_{Rtx})_{max})}$$

1xEV-DO Rev. B Users

Single-carrier EV-DO Rev. B service users are managed as 1xEV-DO Rev. A service users.

For multi-carrier EV-DO Rev. B service users, the effective data rate (R^{DL}) provided in the downlink corresponds to the sum of the effective data rates obtained on each carrier.

The effective data rate ($R^{DL}(ic)$) obtained on a carrier depends on the downlink transmission format, i.e the radio bearer index ($Index_{DL-Bearer}$) with the number of timeslots (n_{TS}). **9955** selects the downlink transmission format where $\frac{E_c}{N_t}(ic, b_{pilot}) \geq \left(\frac{C}{I}\right)_{req}$ and whose modulation scheme is supported by the terminal.

The downlink effective data rate corresponds to the guaranted data rate after a certain number of retransmissions (i.e. the number of timeslots, n_{TS}). It is determined as follows:

$$R^{DL}(ic) = \frac{R^{DL}_{RLC-peak}(Index_{DL-Bearer})}{n_{TS}}$$

When HARQ (Hybrid Automatic Repeat Request) is used, the required average number of retransmissions is smaller and the data rate on a carrier is an average data rate ($R^{DL}_{av}(ic)$) calculated as follows:

$$R^{DL}_{av}(ic) = \frac{R^{DL}_{RLC-peak}(Index_{DL-Bearer})}{(n^{DL}_{Rtx}(Index_{DL-Bearer}, n_{TS}))_{av}}$$

The average number of retransmissions ($(n^{DL}_{Rtx})_{av}$) is determined from early termination probabilities defined for the selected downlink transmission format. The Early Termination Probability graph shows the probability of early termination (p) as a function of the number of retransmissions (n^{DL}_{Rtx}). **9955** calculates the average number of retransmissions ($(n^{DL}_{Rtx})_{av}$) as follows:

$$(n_{Rtx}^{DL})_{av} = \frac{\sum_{n_{Rtx}^{DL}=1}^{(n_{Rtx}^{DL})_{max}} (p(n_{Rtx}^{DL}) - p(n_{Rtx}^{DL} - 1)) \times n_{Rtx}^{DL}}{p((n_{Rtx}^{DL})_{max})}$$

The average data rate (R_{av}^{DL}) provided on downlink corresponds to the sum of the average data rates obtained on each carrier.

Display Options

You may choose the following display options:

- Colour per C/I

Coverage consists of several layers with a layer per quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $\frac{E_c}{N_t}(ic, b_{pilot}) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per rate

Coverage consists of several layers with a layer per possible data rate (R^{DL}). For each layer, area is covered if the data rate, R^{DL}, can be obtained. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per average rate

This display option is available for 1xEV-DO Rev. A and 1xEV-DO Rev. B users only. It enables you to view the obtained downlink data rate when HARQ is used. Coverage consists of several layers with a layer per possible average data rate (R_{av}^{DL}). For each layer, area is covered if the average data rate, R_{av}^{DL}, can be obtained. Each layer is assigned a colour and displayed with intersections between layers.

7.5.2.3 Uplink Service Area Analysis

The results displayed when calculating the uplink service area analysis depend on the studied network (CDMA2000 1xRTT or CDMA2000 1xEV-DO).

7.5.2.3.1 CDMA2000 1xRTT

As in point analysis, **9955** calculates uplink quality on FCH from receiver for each cell *(l,ic)* (with $ic = ic_{BS}$ *or* ic_{given}) in receiver active set. No power control simulation is performed. **9955** determines uplink quality on FCH at the transmitter for the maximum terminal power. Then, the total uplink traffic channel quality ($(Q_{MAX}^{UL}(ic))_{FCH}$) is evaluated with respect to the receiver handover status.

> Best server and active set determination is performed as in point prediction (AS analysis).

9955 displays uplink quality on FCH at transmitters in active set on the carrier *ic* (ic_{BS} or ic_{given}) received from the receiver.

For further details on formulas, see "Definitions and Formulas" on page 444. For further details on calculations, see "Uplink Sub-Menu" on page 504.

- Single colour

9955 displays a coverage if $(Q_{MAX}^{UL}(ic))_{FCH} \geq (Q_{req}^{UL})_{FCH}$. Coverage colour is unique. $(Q_{req}^{UL})_{FCH}$ is the uplink data traffic quality target on the fundamental channel (FCH). This parameter is user-defined for a given service and a terminal in the Services sub-folder.

- Colour per transmitter

9955 displays a coverage if $(Q_{MAX}^{UL}(ic))_{FCH} \geq (Q_{req}^{UL})_{FCH}$. Coverage consists of several layers with associated colours. There is a layer per transmitter with no intersection between layers. Layer colour is the colour assigned to best server transmitter.

- Colour per mobility

In this case, receiver is not completely defined and no mobility is assigned. Coverage consists of several layers with a layer per user-defined mobility defined in Mobility sub-folder. For each layer, area is covered if $(Q_{MAX}^{UL}(ic))_{FCH} \geq (Q_{req}^{UL})_{FCH}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per service

In this case, receiver is not completely defined and no service is assigned. Coverage consists of several layers with a layer per user-defined service defined in Services sub-folder. For each layer, area is covered if $(Q_{MAX}^{UL}(ic))_{FCH} \geq (Q_{req}^{UL})_{FCH}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per probability

This display option is available only if analysis is based on all simulations in a group (i.e. if you select a group of simulations and the “All” option in the Condition tab of prediction properties). Coverage consists of several layers with a layer per user-defined probability level defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{MAX}^{UL}(ic))_{FCH} \geq (Q_{req}^{UL})_{FCH}$ in the required number of simulations. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per cell edge coverage probability

Coverage consists of several layers with a layer per user-defined cell edge coverage probability, *p*, defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{MAX}^{UL}(ic, p))_{FCH} \geq (Q_{req}^{UL})_{FCH}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per maximum quality level (Max Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{MAX}^{UL}(ic))_{FCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per effective quality level (Effective Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{effective}^{UL}(ic))_{FCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per quality margin (Eb/Nt margin)

Coverage consists of several layers with a layer per user-defined quality margin defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{MAX}^{UL}(ic))_{FCH} - (Q_{req}^{UL})_{FCH} \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per required power

The required terminal power, $P_{term}^{FCH-req}$, is calculated as described in the Point analysis – AS analysis tab – Uplink sub-menu part. Coverage consists of several layers with a layer per user-defined power threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{term}^{FCH-req}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per required power margin

Coverage consists of several layers with a layer per user-defined power margin defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{term}^{max} - P_{term}^{FCH-req}(ic) \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per rate

This display option is relevant for CDMA2000 1xRTT data services only. For each possible data rate, R^{UL} ($R_{FCH}^{UL} \times AF_{FCH}^{UL}$, $R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 2)$, $R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 4)$, $R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 8)$, $R_{FCH}^{UL} \times (AF_{FCH}^{UL} + 16)$), **9955** calculates the total uplink traffic channel quality ($Q_{MAX}^{UL}(ic, R^{UL})$). Coverage consists of several layers with a layer per possible data rate, R^{UL}. For each layer, area is covered if $Q_{MAX}^{UL}(ic, R^{UL}) \geq Q_{req}^{UL}(R^{UL})$. Each layer is assigned a colour and displayed with intersections between layers. $Q_{req}^{UL}(R^{UL})$ is the uplink traffic data quality target for the data rate, R^{UL}. This parameter is user-defined for the service, a given terminal and data rate in the service properties.

7.5.2.3.2 CDMA2000 1xEV-DO

As in point analysis, **9955** calculates the uplink quality from receiver for each cell *(l,ic)* (with $ic = ic_{BS}$ or ic_{given}) in receiver active set. No power control simulation is performed. For 1xEV-DO Rev. 0 users, **9955** determines the uplink quality at the transmitter for the maximum terminal power allowed and an uplink data channel rate of 9.6 kbps. For 1xEV-DO Rev. A and 1xEV-DO Rev. B users, **9955** determines the uplink quality at the transmitter for the maximum terminal power allowed and an uplink data channel rate of 4.8 kbps. Then, the total uplink quality ($Q_{MAX}^{UL}(ic)$) is evaluated with respect to the receiver handover status.

Best server and active set determination is performed as in point prediction (AS analysis).

9955 displays the uplink quality at transmitters in active set on the carrier *ic* (ic_{BS} or ic_{given}) received from the receiver. For multi-carrier EV-DO users, Atoll considers the best sub-active set.

For further details on formulas, see "Definitions and Formulas" on page 444. For further details on calculations, see "Uplink Sub-Menu" on page 504.

- Single colour

9955 displays a coverage if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$. Coverage colour is unique. For 1xEV-DO Rev. 0 users, Q_{req}^{UL} is the quality required on uplink for a 9.6 kbps data channel rate. For 1xEV-DO Rev. A and 1xEV-DO Rev. B users, Q_{req}^{UL} is the quality required on uplink for a 4.8 kbps data channel rate. This parameter is calculated from the minimum uplink pilot quality and gains on the different uplink channels.

We have:

$$Q_{req}^{UL} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{ACK} + G_{DRC} + G_{TCH})$$ for 1xEV-DO Rev. 0 terminals,

And

$$Q_{req}^{UL} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{ACK} + G_{RRI} + G_{DRC} + G_{TCH} + G_{Auxiliary-Pilot})$$ for 1xEV-DO Rev. A and 1xEV-DO Rev. B terminals.

- Colour per transmitter

9955 displays a coverage if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$. Coverage consists of several layers with associated colours. There is a layer per transmitter with no intersection between layers. Layer colour is the colour assigned to best server transmitter.

- Colour per mobility

In this case, receiver is not completely defined and no mobility is assigned. Coverage consists of several layers with a layer per user-defined mobility defined in Mobility sub-folder. For each layer, area is covered if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per service

In this case, receiver is not completely defined and no service is assigned. Coverage consists of several layers with a layer per user-defined service defined in Services sub-folder. For each layer, area is covered if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per probability

This display option is available only if analysis is based on all simulations in a group (i.e. if you select a group of simulations and the “All” option in the Condition tab of prediction properties). Coverage consists of several layers with a layer per user-defined probability level defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{MAX}^{UL}(ic) \geq Q_{req}^{UL}$ in the required number of simulations. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per cell edge coverage probability

Coverage consists of several layers with a layer per user-defined cell edge coverage probability, *p*, defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{MAX}^{UL}(ic, p) \geq Q_{req}^{UL}$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per maximum quality level (Max Eb/Nt)

Here, **9955** calculates the total uplink traffic channel quality ($(Q_{MAX}^{UL}(ic))_{TCH}$).

$$(Q_{MAX}^{UL}(ic))_{TCH} = \frac{(Q_{req}^{UL})_{TCH}}{P_{term}^{req}} \times P_{term}^{max}$$

With

$$(Q_{req}^{UL})_{TCH} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times G_{TCH}$$

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{MAX}^{UL}(ic))_{TCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per effective quality level (Effective Eb/Nt)

Coverage consists of several layers with a layer per user-defined quality threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $(Q_{effective}^{UL}(ic))_{TCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

$$(Q_{effective}^{UL}(ic))_{TCH} = min((Q_{MAX}^{UL}(ic))_{TCH}, (Q_{req}^{UL})_{TCH})$$

- Colour per quality margin (Eb/Nt margin)

Coverage consists of several layers with a layer per user-defined quality margin defined in the Display tab (Prediction properties). For each layer, area is covered if $Q_{MAX}^{UL}(ic) - Q_{req}^{UL} \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per required power

1xEV-DO Rev. 0, 1xEV-DO Rev.A and single-carrier 1xEV-DO Rev. B service users

Coverage consists of several layers with a layer per user-defined power threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{term}^{TCH-req}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

The required terminal power on traffic data channel, $P_{term}^{TCH-req}$, is calculated as described in the Point analysis – AS analysis tab – Uplink sub-menu part.

$$P_{term}^{TCH-req} = \frac{P_{term}^{req}}{1 + G_{ACK} + G_{DRC} + G_{TCH}} \times G_{TCH} \text{ for 1xEV-DO Rev. 0 terminals,}$$

And

$$P_{term}^{TCH-req} = \frac{P_{term}^{req}}{1 + G_{ACK} + G_{RRI} + G_{DRC} + G_{TCH} + G_{Auxiliary-Pilot}} \times G_{TCH} \text{ for 1xEV-DO Rev. A terminals.}$$

Multi-carrier 1xEV-DO Rev. B service users

For multi-carrier EV-DO users, the coverage consists of several layers with a layer per user-defined power threshold defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{term}^{TCH-req} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

For the selected configuration (i.e., the combination of carriers which provides the highest total data rate), $P_{term}^{TCH-req}$ corresponds to the sum of the terminal powers required on each carrier of the configuration.

- Colour per required power margin

Coverage consists of several layers with a layer per user-defined power margin defined in the Display tab (Prediction properties). For each layer, area is covered if $P_{term}^{max} - P_{term}^{req}(ic) \geq Margin$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per rate

1xEV-DO Rev. 0 service users

For each possible data rate, R^{UL}, **9955** calculates the total uplink quality ($Q_{MAX}^{UL}(ic, R^{UL})$). Coverage consists of several layers with a layer per possible data rate. For each layer, area is covered if $Q_{MAX}^{UL}(ic, R^{UL}) \geq Q_{req}^{UL}(R^{UL})$. Each layer is assigned a colour and displayed with intersections between layers.

$Q_{req}^{UL}(R^{UL})$ is the uplink quality required to obtain the data rate, R^{UL}.

The possible data rates on uplink, R^{UL}, are: 9.6, 19.2, 38.4, 76.8 and 153.6 kbps

$$Q_{req}^{UL} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{ACK} + G_{DRC} + G_{TCH})$$

Where

$\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ is the minimum pilot quality level on uplink. This parameter is available in the Mobility types table.

G_{ACK}, G_{DRC} and G_{TCH} are respectively acknowledgement, data rate control and traffic data gains relative to the pilot. They are defined in the terminal properties (1xEV-DO Rev. 0 tab).

1xEV-DO Rev. A and single-carrier 1xEV-DO Rev. B service users

For each possible data rate, R^{UL}, **9955** calculates the total uplink quality ($Q_{MAX}^{UL}(ic, R^{UL})$). Coverage consists of several layers with a layer per possible data rate. For each layer, area is covered if $Q_{MAX}^{UL}(ic, R^{UL}) \geq Q_{req}^{UL}(R^{UL})$. Each layer is assigned a colour and displayed with intersections between layers.

$Q_{req}^{UL}(R^{UL})$ is the uplink quality required to obtain the data rate, R^{UL}.

The data rate, R^{UL} is obtained when a certain uplink transmission format (i.e. 1xEV-DO radio bearer ($Index_{UL-Bearer}$) with a certain number of subframes (n_{SF})) is used. It is calculated as follows:

$$R_{req}^{UL} = \frac{R_{RLC-peak}^{UL}(Index_{UL-Bearer})}{n_{SF}}$$

$$Q_{req}^{UL} = \left(\frac{E_c}{N_t}\right)_{min}^{UL} \times G_p^{UL} \times (1 + G_{ACK} + G_{DRC} + G_{TCH} + G_{RRI} + G_{Auxiliary-pilot})$$

Where

$\left(\frac{E_c}{N_t}\right)_{min}^{UL}$ is the minimum pilot quality level required on uplink to obtain the data rate, R^{UL}. The value is defined in the 1xEV-DO Radio Bearer Selection (Uplink) table for the uplink transmission format (radio bearer Index, mobility and number of subframe). Two values are available for this parameter, one when the service uplink mode is "Low Latency" and another one for high capacity services.

G_{ACK}, G_{DRC}, G_{TCH}, G_{RRI} and $G_{Auxiliary-pilot}$ are respectively acknowledgement, data rate control, traffic data channel, reverse rate indicator and auxiliary pilot channel gains relative to the pilot. They are defined in the terminal properties (1xEV-DO Rev. A tab). Two values of G_{TCH} are available, one when the service uplink mode is "Low Latency" and another one for high capacity services.

Multi-carrier 1xEV-DO Rev. B service users

For multi-carrier 1xEV-DO Rev. B users, **9955** models load balancing between carriers. **9955** equally shares the available terminal power between each carrier and determines the uplink 1xEV-DO radio bearer obtained on each carrier. Then, it selects the best configuration among all combinations of carriers, i.e., the combination which provides the highest data rate.

Coverage consists of several layers with a layer per possible data rate. For each layer, area is covered if $R^{UL} \geq R_{req}^{UL}$. Each layer is assigned a colour and displayed with intersections between layers.

R_{req}^{UL} is the uplink data rate associated with the layer.

R^{UL} corresponds to the data rate of the best configuration, i.e., the combination which provides the highest total rate.

- Colour per average rate

This display option is available for 1xEV-DO Rev. A and 1xEV-DO Rev. B users only. When HARQ (Hybrid Automatic Repeat Request) is used, the required average number of retransmissions is smaller and the data rate is an average data rate (R_{av}^{UL}) calculated as follows:

$$R_{av}^{UL} = \frac{R_{RLC-peak}^{UL}(Index_{UL-Bearer})}{(n_{Rtx}^{UL}(Index_{UL-Bearer}, n_{SF}))_{av}}$$

The average number of retransmissions ($(n_{Rtx}^{UL})_{av}$) is determined from early termination probabilities defined for the selected uplink transmission format (i.e. the radio bearer index ($Index_{UL-Bearer}$) with the number of subframes (n_{SF})). The Early Termination Probability graph shows the probability of early termination (p) as a function of the number of retransmissions (n_{Rtx}^{UL}). **9955** calculates the average number of retransmissions ($(n_{Rtx}^{UL})_{av}$) as follows:

$$(n_{Rtx}^{UL})_{av} = \frac{\sum_{n_{Rtx}^{UL}=1}^{(n_{Rtx}^{UL})_{max}} (p(n_{Rtx}^{UL}) - p(n_{Rtx}^{UL} - 1)) \times n_{Rtx}^{UL}}{p((n_{Rtx}^{UL})_{max})}$$

1xEV-DO Rev. A and single-carrier 1xEV-DO Rev. B service users

For each possible average data rate, R_{av}^{UL}, **9955** calculates the total uplink quality ($Q_{MAX}^{UL}(ic, R_{av}^{UL})$). Coverage consists of several layers with a layer per possible average data rate. For each layer, area is covered if $Q_{MAX}^{UL}(ic, R_{av}^{UL}) \geq Q_{req}^{UL}(R_{av}^{UL})$. Each layer is assigned a colour and displayed with intersections between layers.

$Q_{req}^{UL}(R_{av}^{UL})$ is the uplink quality required to obtain the average data rate, R_{av}^{UL}.

Multi-carrier 1xEV-DO Rev. B service users

For multi-carrier 1xEV-DO Rev. B users, the coverage consists of several layers with a layer per possible data rate. For each layer, area is covered if $R_{av}^{UL} \geq R_{req}^{UL}$. Each layer is assigned a colour and displayed with intersections between layers.

R_{req}^{UL} is the uplink data rate associated with the layer.

For the selected configuration (i.e., the combination of carriers which provides the highest total data rate), R_{av}^{UL} corresponds to the sum of the average data rates obtained on each carrier of the configuration.

7.5.2.4 Downlink Total Noise Analysis

9955 determines downlink total noise generated by cells.

For CDMA2000 1xRTT systems, we have:

$$N_{tot}^{DL}(ic) = \sum_{txj, \forall j} P_{tot}^{DL}(ic) + \frac{\sum_{txj, \forall j} P_{tot}^{DL}(ic_{adj})}{RF(ic, ic_{adj})} + N_0^{term}$$

For CDMA2000 1xEV-DO systems, we have:

$$N_{tot}^{DL}(ic) = \sum_{txj, \forall j} P_{tot}^{DL}(ic, b_{pilot}) + \frac{\sum_{txj, \forall j} P_{tot}^{DL}(ic_{adj}, b_{pilot})}{RF(ic, ic_{adj})} + N_0^{term}$$

Downlink noise rise, $NR_{DL}(ic)$, is calculated from the downlink total noise, N_{tot}^{DL}, as: $NR_{DL}(ic) = -10\log\left(\frac{N_0^{term}}{N_{tot}^{DL}}\right)$

7.5.2.4.1 Analysis on the Best Carrier

If the best carrier is selected, **9955** determines DL total noise for the best carrier. Then, allows the user to choose different displays.

- Colour per minimum noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $\min_{ic} NR^{DL}_{tot}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per maximum noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $\max_{ic} NR^{DL}_{tot}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per average noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $\underset{ic}{average}\ NR^{DL}_{tot}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per minimum noise rise

9955 displays bins where $\min_{ic} NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

- Colour per maximum noise rise

9955 displays bins where $\max_{ic} NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

- Colour per average noise rise

9955 displays bins where $\underset{ic}{average}\ NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

7.5.2.4.2 Analysis on a Specific Carrier

When only one carrier is analysed, **9955** determines DL total noise or DL noise rise on this carrier. In this case, the displayed coverage is the same for any selected display per noise level (average, minimum or maximum) or any display per noise rise (average, minimum or maximum).

- Colour per noise level

Coverage consists of several layers with a layer per user-defined noise level defined in the Display tab (Prediction properties). For each layer, area is covered if $N^{DL}_{tot}(ic) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- Colour per noise rise

9955 displays bins where $NR_{DL}(ic) \geq Threshold$. Coverage consists of several areas with an area per user-defined noise rise threshold defined in the Display tab. Each area is assigned a colour with intersections between areas.

7.6 Automatic Neighbour Allocation

9955 permits the automatic allocation of intra-technology neighbours in the current network. Two allocation algorithms are available, one dedicated to intra-carrier neighbours and the other for inter-carrier neighbours.

The intra-technology neighbour allocation algorithms take into account all the cells of TBC transmitters. It means that all the cells of TBC transmitters of your .atl document are potential neighbours.

The cells to be allocated will be called TBA cells. They must fulfill the following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters or a single transmitter.

Only TBA cells may be assigned neighbours.

If no focus zone exists in the .atl document, **9955** takes into account the computation zone.

In this section, the following are explained:

- "Neighbour Allocation for all Transmitters" on page 526.
- "Neighbour Allocation for a Group of Transmitters or One Transmitter" on page 529.
- "Importance Calculation" on page 529.

7.6.1 Neighbour Allocation for all Transmitters

We assume that we have a reference cell A and a candidate neighbour, cell B. When automatic allocation starts, **9955** checks following conditions:

- The distance between both cells must be less than the user-definable maximum inter-site distance. If the distance between the reference cell and the candidate neighbour is greater than this value, then the candidate neighbour is discarded.

  9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 532.

- The calculation options,

Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

Force co-site cells as neighbours: This option enables you to force cells located on the reference cell site in the candidate neighbour list. This constraints can be weighted among the others and ranks the neighbours through the importance field (see after).

Force adjacent cells as neighbours (only for intra-carrier neighbours): This option enables you to force cells geographically adjacent to the reference cell in the candidate neighbour list.This constraints can be weighted among the others and ranks the neighbours through the importance field (see after).

Force neighbour symmetry: This option enables user to force the reciprocity of a neighbourhood link. Therefore, if the reference cell is a candidate neighbour of another cell, this one will be considered as candidate neighbour of the reference cell.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a cell to be candidate neighbour of the reference cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept.

Adjacence criterion: Let CellB be a candidate neighbour cell of CellA. CellB is considered adjacent to CellA if there exists at least one pixel in the CellA Best Server coverage area where CellB is Best Server (if several cells have the same best server value) or CellB is the second best server that enters the Active Set (respecting the T_Drop of the allocation).

When this option is checked, adjacent cells are sorted and listed from the most adjacent to the least, depending on the above criterion. Adjacence is relative to the number of pixels satisfying the criterion.

- There must be an overlapping zone ($S_A \cap S_B$) with a given cell edge coverage probability:
- Intra-carrier neighbours: intra-carrier handover is a soft handover.

The reference cell A and the candidate cell B are located inside a continuous layer of cells with carrier c1 (c1 is the selected carrier on which you run the allocation).

S_A is the area where the cell A is the best serving cell. It means that the cell A is the first one in the active set.

- The pilot signal received from the cell A is greater than the minimum pilot signal level.
- The pilot quality from A exceeds Min. Ec/I0.
- The pilot quality from A is the best.

S_B is the area where the cell B can enter the active set.

- The pilot signal received from the cell B is greater than the minimum pilot signal level.
- The pilot quality from B is greater than T_Drop.

- Inter-carrier neighbours: inter-frequency handover is a hard handover. It is needed in a multi-carrier (1xRTT and 1xEV-DO carriers) CDMA network:
  - To balance loading between carriers and layers (1^{st} case),
  - To make a coverage reason handover from micro cell frequency to macro cells (2^{nd} case).

1^{st} case: the reference cell A is located inside a continuous layer of cells with carrier c1 (c1 is the selected carrier on which you run the allocation) and the candidate cell B belongs to a layer of cells with carrier c2.

S_A is the area where:

- The pilot signal received from the cell A is greater than the minimum pilot signal level.
- The pilot signal from A is not the highest one. It is strictly lower than the best pilot signal received and higher than the best pilot signal minus the margin.

S_B is the area where:

- The pilot signal received from the cell B is greater than the minimum pilot signal level.
- The pilot signal from B is the highest one.

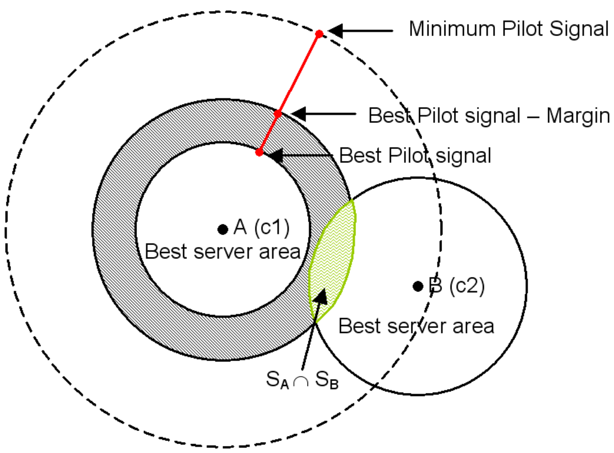


Figure 7.4: Overlapping Zones - 1st Case

2^{nd} case: the reference cell A is located on the border of a layer with carrier c1 (c1 is the selected carrier on which you run the allocation) and the candidate cell B belongs to a layer of cells with carrier c2.

S_A is the area where:

- The pilot signal received from the cell A is greater than the minimum pilot signal level.
- The pilot signal from A is the highest one
- The pilot signal from A is lower than the minimum pilot signal level plus the margin.

S_B is the area where:

- The pilot signal received from the cell B is greater than the minimum pilot signal level.
- The pilot signal from B is the highest one.

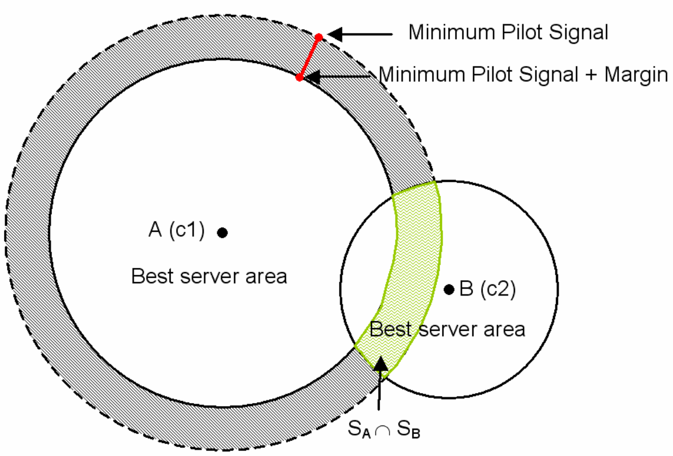


Figure 7.5: Overlapping Zones - 2nd Case

> Two ways enable you to determine the I_0 value:
>
> - **Global Value**: A percentage of the cell maximum power is considered. If the % of maximum power is too low, i.e. if $\% \times P_{max} < P_{pilot}$, **9955** takes into account the pilot power of the cell. Then, I_0 represents the sum of values calculated for each cell.
> - **Defined per Cell**: **9955** takes into account the total downlink power defined per cell. I_0 represents the sum of total transmitted powers.

9955 calculates the percentage of covered area ($\frac{S_A \cap S_B}{S_A} \times 100$) and compares this value to the % minimum covered area. If this percentage is not exceeded, the candidate neighbour B is discarded.

The coverage condition can be weighted among the others and ranks the neighbours through the importance field (see after).

- The importance of neighbours.

For information on the importance calculation, see "Importance Calculation" on page 529.

Importance values are used by the allocation algorithm to rank the neighbours. **9955** lists all neighbours and sorts them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each transmitter is exceeded. If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference cell is 8. Among these 15 candidate neighbours, only 8 (having the highest importance values) will be allocated to the reference cell. Note that specific maximum numbers of neighbours (maximum number of intra-carrier neighbours, maximum number of inter-carrier neighbours) can be defined at the cell level (property dialogue or cell table). If defined there, this value is taken into account instead of the default one available in the **Neighbour Allocation** dialogue.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site, adjacent, coverage or symmetric. For neighbours accepted for co-site, adjacency and coverage reasons, **9955** displays the percentage of area meeting the coverage conditions and the corresponding surface area (km^2), the percentage of area meeting the adjacency conditions and the corresponding surface area (km^2). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

- No simulation or prediction study is needed to perform an automatic neighbour allocation. When starting an automatic neighbour allocation, **9955** automatically calculates the path loss matrices if not found.
- Even if no specific terminal, mobility or service is selected in the automatic allocation, it is interesting to know that the algorithm works such as finding the maximum number of neighbours by selection the multi-service traffic data as follows:
- Service: selection of the one with the lowest body loss.
- Mobility: no impact on the allocation, no specific selection.
- Terminal: selection of the one with the greatest (Gain - Loss) value, and, if equal, the one with the lowest noise figure.
- The neighbour lists may be optionally used in the power control simulations to determine the mobile's active set.
- A forbidden neighbour must not be listed as neighbour except if the neighbourhood relationship already exists and the Delete existing neighbours option is unchecked when you start the new allocation. In this case, **9955** displays a warning in the Event viewer indicating that the constraint on the forbidden neighbour will be ignored by algorithm because the neighbour already exists.
- The force neighbour symmetry option enables the users to consider the reciprocity of a neighbourhood link. This reciprocity is allowed only if the neighbour list is not already full. Thus, if the cell B is a neighbour of the cell A while the cell A is not a neighbour of the cell B, two cases are possible:
- 1st case: There is space in the cell B neighbour list: the cell A will be added to the list. It will be the last one.
- 2nd case: The cell B neighbour list is full: **9955** will not include cell A in the list and will cancel the link by deleting cell B from the cell A neighbour list.
- When the options “Force exceptional pairs” and “Force symmetry” are selected, **9955** considers the constraints between exceptional pairs in both directions so as to respect symmetry condition. On the other hand, if neighbourhood relationship is forced in one direction and forbidden in the other one, symmetry cannot be respected. In this case, **9955** displays a warning in the Event viewer.
- In the Results, **9955** displays only the cells for which it finds new neighbours. Therefore, if a TBA cell has already reached its maximum number of neighbours before starting the new allocation, it will not appear in the Results table.
-

7.6.2 Neighbour Allocation for a Group of Transmitters or One Transmitter

In this case, **9955** allocates neighbours to:

- TBA cells,
- Neighbours of TBA cells marked as exceptional pair, adjacent and symmetric,
- Neighbours of TBA cells that satisfy coverage conditions.

Automatic neighbour allocation parameters are described in "Neighbour Allocation for all Transmitters" on page 526.

7.6.3 Importance Calculation

Importance values are used by the allocation algorithm to rank the neighbours according to the allocation reason, and to quantify the neighbour importance.

7.6.3.1 Importance of Intra-carrier Neighbours

The neighbour importance depends on the distance from the reference transmitter and on the neighbourhood cause (cf. table below); this value varies between 0 and 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	Only if the Delete existing neighbours option is not selected and in case of a new allocation	Existing importance
Exceptional pair	Only if the Force exceptional pairs option is selected	100 %
Co-site cell	Only if the Force co-site cells as neighbours option is selected	Importance Function (IF)

Neighbourhood cause	When	Importance value
Adjacent cell	Only if the Force adjacent cells as neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	Only if the % minimum covered area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	Only if the Force neighbour symmetry option is selected	Importance Function (IF)

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers the following factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 532.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The adjacency factor (A): the percentage of adjacency,
- The overlapping factor (O): the percentage of overlapping.

The minimum and maximum importance assigned to each of the above factors can be defined.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	30%
Adjacency factor (A)	Min(A)	30%	Max(A)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The Importance Function is evaluated as follows:

Neighbourhood cause		Importance Function	Resulting IF using the default values from the table above
Co-site	Adjacent		
No	No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+20%{10%(Di)+90%(O)}
No	Yes	Min(A)+Delta(A){Max(Di)(Di)+Max(O)(O)+(100%-Max(Di)-Max(O))(A)}	30%+30%{10%(Di)+30%(O)+60%(A)}
Yes	Yes	Min(C)+Delta(C){Max(Di)(Di)+Max(O)(O)+(100%-Max(Di)-Max(O))(A)}	60%+40%{10%(Di)+30%(O)+60%(A)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours, adjacent neighbours, and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.

7.6.3.2 Importance of Inter-carrier Neighbours

As indicated in the table below, the neighbour importance depends on the distance and on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site cell	If the Force co-site cells as neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	If the % minimum covered area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	If the Force neighbour symmetry option is selected	Importance Function (IF)

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers the following factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 532.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The overlapping factor (O): the percentage of overlapping.

The IF is user-definable using the Min importance and Max importance fields.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The IF evaluates importance as follows:

Co-site Neighbourhood cause	IF	Resulting IF using the default values from the table above
No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+50%{10%(Di)+90%(O)}
Yes	Min(C)+Delta(C){Max(Di)(Di)/(Max(Di)+Max(O))+ Max(O)(O)/(Max(Di)+Max(O))}	60%+40%{1/7%(Di)+6/7%(O)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.

7.6.4 Appendices

7.6.4.1 Calculation of the Inter-Transmitter Distance

9955 takes into account the real distance (D in m) and azimuths of antennas in order to calculate the effective inter-transmitter distance (d in m).

$$d = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

where x = 0.3% so that the maximum D variation does not exceed 1%.

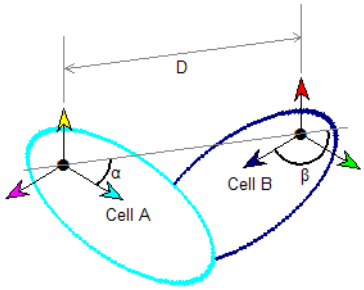


Figure 7.6: Inter-Transmitter Distance Computation

The formula above implies that two cells facing each other will have a smaller effective distance than the real physical distance. It is this effective distance that will be taken into account rather than the real distance.

7.7 PN Offset Allocation

PN offset is used to identify a cell. It is a time offset used by a cell to shift a Pseudo Noise sequence. Mobile processes the strongest received PN sequence and reads its phase that identifies the cell.

By default, there are 512 PN Offsets. PN Offsets are numbered (0...511).

The cells to which **9955** allocates PN Offsets are referred to as the *TBA cells* (cells to be allocated). TBA cells fulfil following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters or a single transmitter.

If no focus zone exists in the .atl document, **9955** takes into account the computation zone.

7.7.1 Automatic Allocation Description

7.7.1.1 Options and Constraints

The PN Offset allocation algorithm can take into account following constraints and options:

- PILOT_INC parameter,

  9955 uses this parameter to determine the pool of possible PN offsets (512 divided by PILOT_INC value). The first PN offset is PILOT_INC and other ones are multiples of this value.

  For example: When PILOT_INC is set to 4, the pool of possible PN offsets consists of PN offsets from 4 to 508 with a separation interval of 4 (i.e. [4,8,12,16,...508]).

- Neighbourhood between cells,

You may consider:

- First order neighbours: The neighbours of TBA cells listed in the Intra-technology neighbours table,
- Second order neighbours: The neighbours of neighbours,

- Third order neighbours: The neighbour's neighbour's neighbours.

> - In the context of the PN Offset allocation, the term "neighbours" refers to intra-carrier neighbours.
> - **9955** can take into account inter-technology neighbour relations as constraints to allocate different PN Offsets to the CDMA neighbours of a GSM transmitter. In order to consider inter-technology neighbour relations in the PN Offset allocation, you must make the Transmitters folder of the GSM .atl document accessible in the CDMA .atl document. For information on making links between GSM and CDMA .atl documents, see the *User Manual*.
> - **9955** considers symmetry relationship between a cell, its first order neighbours, its second order neighbours and its third order neighbours.

- Cells fulfilling a criterion on Ec/I0 (option "Additional Ec/I0 conditions"),

For a reference cell "A", **9955** considers all the cells "B" that can enter the active set on the area where the reference cell is the best server (area where $(Ec/I0)_A$ exceeds Min. Ec/I0 and is the highest one and $(Ec/I0)_B$ exceeds T_Drop).

> **9955** considers either a percentage of the cell maximum powers or the total downlink power used by the cells in order to evaluate I0. In this case, I0 equals the sum of total transmitted powers. When this parameter is not specified in the cell properties, **9955** uses 50% of the maximum power.

- Co-PN Reuse distance,

Reuse distance is a constraint on the allocation of PN offsets. A PN offset cannot be reused at a site that is not at least as far away as the reuse distance from the site allocated with the particular PN offset.

> PN offset reuse distance can be defined at cell level. If this value is not defined, then **9955** will use the default reuse distance defined in the **PN offset Automatic Allocation** dialogue.

- PN-cluster size. Within the context of PN offset allocation, the term "PN-cluster" refers to a sub-group of PN offsets.
- Exceptional pairs,
- Domains of PN Offsets,

> When no domain is assigned to cells, **9955** considers the PILOT_INC parameter only to determine available PN offsets (e.g., If PILOT_INC is set to 4, all PN offsets from 4 to 508 with a separation interval of 4 can be allocated).

- The carrier on which the allocation is run: It can be a given carrier or all of them. In this case, either **9955** independently plans PN Offsets for the different carriers, or it allocates the same PN Offset to each carrier of a transmitter if the option "Allocate carriers identically" is selected.
- The possibility to use a maximum of PN offsets (option "Use a Maximum of PN Offsets"): **9955** will try to spread the PN offset spectrum the most.
- The "Delete All Codes" option: When selecting this option, **9955** deletes all the current PN Offsets and carries out a new PN Offset allocation. If not selected, the existing PN Offsets are kept.

In addition, it depends on the selected allocation strategy. Allocation strategies can be:

- PN offset per cell: The purpose of this strategy is to reduce the spectrum of allocated PN offsets the maximum possible. **9955** will allocate the first possible PN offsets in the domain.
- Adjacent PN-Clusters per site: This strategy consists of allocating one cluster of adjacent PN offsets to each site, then, one PN offset of the cluster to each cell of each transmitter according to its azimuth. When all the clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the clusters at another site.
- Distributed PN-clusters per site: This strategy consists of allocating one cluster of PN offsets to each site in the network, then, one PN offset of the cluster to each cell of each transmitter according to its azimuth. With this strategy, the cluster is made of PN offsets separated as much as possible. When all the clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the clusters at another site.

In the Results table, **9955** only displays PN offsets allocated to TBA cells.

7.7.1.2 Allocation Process

For each TBA cell, **9955** lists all cells which have constraints with the cell. They are referred to as *near cells*. The near cells of a TBA cell may be:

- Its neighbour cells: the neighbours listed in the Intra-technology neighbours table (options “Existing neighbours” and "First Order"),
- The neighbours of its neighbours (options “Existing neighbours” and “Second Order”),
- The third order neighbours (options “Existing neighbours” and “Third Order”),
- The cells that fulfil Ec/I0 condition (option “Additional Ec/I0 conditions”),
- The cells with distance from the TBA cell less than the reuse distance,
- The cells that make exceptional pairs with the TBA cell.

One additional constraint is considered when:

- The cell and its near cells are neighbours of a same GSM transmitter (only if the Transmitters folder of the GSM .atl document is accessible in the CDMA .atl document),

These constraints have a certain weight taken into account to determine the TBA cell priority during the allocation process and the cost of the PN Offset plan. During the allocation, **9955** tries to assign different PN Offsets to the TBA cell and its near cells. If it respects all the constraints, the cost of the PN Offset plan is 0. When a cell has too many constraints and there are not anymore PN Offsets available, **9955** breaks the constraint with the lowest cost so as to generate the PN Offset plan with the lowest cost. For information on the cost generated by each constraint, see "Cell Priority" on page 535.

7.7.1.2.1 Single Carrier Network

The allocation process depends on the selected strategy. Algorithm works as follows:

Strategy: PN offset per cell

9955 processes TBA cells according to their priority. It allocates PN Offsets starting with the highest priority cell and its near cells, and continuing with the lowest priority cells not allocated yet and their near cells. For information on calculating cell priority, see "Cell Priority" on page 535.

Strategy: Adjacent PN-Clusters per site

All sites which have constraints with the studied site are referred to as *near sites.*

9955 assigns a PN-cluster of adjacent PN offsets to each site, starting with the highest priority site and its near sites, and continuing with the lowest priority sites not allocated yet and their near sites. When all the clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the clusters at another site. When the Co-PN Reuse Distance option is selected, the algorithm reuses the clusters as soon as the Co-PN reuse distance is exceeded. Otherwise, when the option is not selected, the algorithm tries to assign reused clusters as spaced out as possible.

Then, **9955** allocates a PN offset from the cluster to each cell of each transmitter located on the sites according to the transmitter azimuth. It starts with the highest priority cell and its near cells and goes on with the lowest priority cells not allocated yet and their near cells.

For information on calculating site priority, see "Site Priority" on page 537. For information on calculating cell priority, see "Cell Priority" on page 535.

Strategy: Distributed PN-Clusters per site

All sites which have constraints with the studied site are referred to as *near sites.*

9955 assigns one cluster to each site, starting with the highest priority site and its near sites, and continuing with the lowest priority sites not allocated yet and their near sites. When all the clusters have been allocated and there are still sites remaining to be allocated, **9955** reuses the clusters at another site. When the Co-PN Reuse Distance option is selected, the algorithm reuses the clusters as soon as the Co-PN reuse distance is exceeded. Otherwise, when the option is not selected, the algorithm tries to assign reused clusters as spaced out as possible.

Then, **9955** assigns a PN offset from the cluster to each cell of each transmitter located on the sites according to the transmitter azimuth. It starts with the highest priority cell and its near cells and goes on with the lowest priority cells not allocated yet and their near cells.

For information on calculating site priority, see "Site Priority" on page 537. For information on calculating cell priority, see "Cell Priority" on page 535.

7.7.1.2.2 Multi-Carrier Network

In case you have a multi-carrier network and you run the PN Offset allocation on all the carriers, the allocation process depends on wether the option "Allocate Carriers Identically" is selected or not.

When the option is not selected, algorithm works for each strategy, as explained above. On the other hand, when the option is selected, allocation order changes. It is no longer based on the cell priority but depends on the transmitter priority. All transmitters which have constraints with the studied transmitter will be referred to as *near transmitters*.

In case of a "Per cell" strategy (PN offset per cell), **9955** starts PN offset allocation with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same PN offset is assigned to each cell of the transmitter.

In case of a "Per site" strategy (Adjacent and Distributed PN-clusters per site strategies), **9955** assigns a cluster to each site and then, allocates a PN offset to each transmitter. It starts with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same PN offset is assigned to each cell of the transmitter.

For information on calculating cell priority, see "Cell Priority" on page 535. For information on calculating transmitter priority, see "Transmitter Priority" on page 537.

When cells, transmitters or sites have the same priority, processing is based on an alphanumeric order.

7.7.1.2.3 Difference between Adjacent and Distributed PN-Clusters

The following example explains the difference between "Adjacent PN-clusters" and "Distributed PN-clusters". The PILOT_INC has been set to 4 and the PN-cluster size to 3. There are:

- 128 PN offsets that can be allocated: they are all PN offsets from 4 to 508 with a separation interval of 4.
- Each PN-cluster consists of three PN offsets. So, there are 42 PN-clusters available.

If you select "Adjacent PN-cluster per site" as allocation strategy, **9955** will consider PN-clusters consisted of adjacent PN offsets (e.g. {4,8,12}, {16,20,24}, ...,{496,500,504}).

If you select "Distributed PN-cluster per site" as allocation strategy, **9955** will consider PN-clusters consisted of PN offsets separated as much as possible (e.g. {4,172,340}, {8,176,344}, ...,{168,336,504}).

7.7.1.3 Priority Determination

7.7.1.3.1 Cell Priority

PN Offset allocation algorithm in **9955** allots priorities to cells before performing the actual allocation. Priorities assigned to cells depend upon how much constrained each cell is and the cost defined for each constraint. A cell without any constraint has a default cost, C, equal to 0. The higher the cost on a cell, the higher the priority it has for the PN Offset allocation process.

There are five criteria employed to determine the cell priority:

- PN Offset Domain Criterion

The cost due to the domain constraint, $C_i(Dom)$, depends on the number of PN Offsets available for the allocation. The domain constraint is mandatory and cannot be broken.

When no domain is assigned to cells, 512 PN Offsets are available and we have:

$$C_i(Dom) = 0$$

When domains of PN Offsets are assigned to cells, each unavailable PN Offset generates a cost. The higher the number of codes available in the domain, the less will be the cost due to this criterion. The cost is given as:

$$C_i(Dom) = 512 - \text{Number of PN Offsets in the domain}$$

- Distance Criterion

The constraint level of any cell *i* depends on the number of cells (*j*) present within a radius of "reuse distance" from its centre. The total cost due to the distance constraint is given as:

$$C_i(Dist) = \sum_j C_j(Dist(i))$$

Each cell *j* within the reuse distance generates a cost given as:

$$C_j(Dist(i)) = w(d_{ij}) \times c_{distance}$$

Where

$w(d_{ij})$ is a weight depending on the distance between *i* and *j*. This weight is inversely proportional to the inter-cell distance. For a reuse distance of 2000m, the weight for an inter-cell distance of 1500m is 0.25, the weight for co-site cells is 1 and the weight for two cells spaced out 2100m apart is 0.

$c_{distance}$ is the cost of the distance constraint. This value can be defined in the **Constraint Cost** dialogue.

- Exceptional Pair Criterion

The constraint level of any cell *i* depends on the number of exceptional pairs (*j*) for that cell. The total cost due to exceptional pair constraint is given as:

$$C_i(EP) = \sum_j c_{EP}(i-j)$$

Where

c_{EP} is the cost of the exceptional pair constraint. This value can be defined in the **Constraint Cost** dialogue.

- Neighbourhood Criterion

The constraint level of any cell *i* depends on the number of its neighbour cells *j*, the number of second order neighbours *k* and the number of third order neighbours *l*.

Let's consider the following neighbour schema:

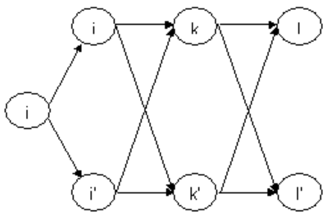


Figure 7.7: Neighbourhood Constraints

The total cost due to the neighbour constraint is given as:

$$C_i(N) = \left(\sum_j C_j(N1(i)) + \sum_{j'} C_{j-j'}(N1(i))\right) + \left(\sum_k C_k(N2(i)) + \sum_{k'} C_{k-k'}(N2(i))\right) + \left(\sum_l C_l(N3(i)) + \sum_{l'} C_{l-l'}(N3(i))\right)$$

Each first order neighbour cell *j* generates a cost given as:

$$C_j(N1(i)) = I_j \times c_{N1}$$

Where

I_j is the importance of the neighbour cell *j*.

c_{N1} is the cost of the first order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two first order neighbours must not have the same PN Offset, **9955** considers the cost created by two first order neighbours to be each other.

$$C_{j-j'}(N1(i)) = \frac{C_j(N1(i)) + C_{j'}(N1(i))}{2}$$

Each second order neighbour cell *k* generates a cost given as:

$$C_k(N2(i)) = Max((C_j(N1(i)) \times C_k(N1(j))),(C_{j'}(N1(i)) \times C_k(N1(j')))) \times c_{N2}$$

Where

c_{N2} is the cost of the second order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two second order neighbours must not have the same PN Offset, **9955** considers the cost created by two second order neighbours to be each other.

$$C_{k-k'}(N2(i)) = \frac{C_k(N2(i)) + C_{k'}(N2(i))}{2}$$

Each third order neighbour cell *l* generates a cost given as:

$$C_l(N3(i)) = Max\begin{pmatrix} C_j(N1(i)) \times C_k(N1(j)) \times C_l(N1(k)), C_{j'}(N1(i)) \times C_k(N1(j')) \times C_l N1(k), \\ (C_j(N1(i)) \times C_{k'}(N1(j))) \times C_l N1(k'), C_{j'}(N1(i)) \times C_{k'}(N1(j')) \times C_l N1(k') \end{pmatrix} \times c_{N3}$$

Where

c_{N3} is the cost of the third order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two third order neighbours must not have the same PN Offset, **9955** considers the cost created by two third order neighbours to be each other.

$$C_{l-l'}(N3(i)) = \frac{C_l(N3(i)) + C_{l'}(N3(i))}{2}$$

9955 considers the highest cost of both links when a neighbour relation is symmetric and the importance value is different.

In this case, we have:

$$C_j(N1(i)) = Max(I_{i-j}, I_{j-i}) \times c_{N1}$$

And

$$C_k(N2(i)) = Max(C_j(N1(i)) \times C_k(N1(j)), C_j(N1(k)) \times C_i(N1(j))) \times c_{N2}$$

- GSM Neighbour Criterion

This criterion is considered when the co-planning mode is activated (i.e. the Transmitters folder of the GSM .atl document is made accessible in the CDMA .atl document) and inter-technology neighbours have been allocated. If the cell *i* is neighbour of a GSM transmitter, the cell constraint level depends on how many cells *j* are neighbours of the same GSM transmitter. The total cost due to GSM neighbour constraint is given as:

$$C_i(N_{2G}) = \sum_j c_{N_{2G}}(j - Tx_{2G})$$

Where

$c_{N_{2G}}$ is the cost of the GSM neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Therefore, the total cost due to constraints on any cell *i* is defined as:

$$C_i = C_i(Dom) + C_i(U)$$

With

$$C_i(U) = C_i(Dist) + C_i(EP) + C_i(N) + C_i(N_{2G})$$

7.7.1.3.2 Transmitter Priority

In case you have a multi-carrier network and you run PN Offset allocation on "all" the carriers with the option "allocate carriers identically", algorithm in **9955** allots priorities to transmitters. Priorities assigned to transmitters depend on how much constrained each transmitter is and the cost defined for each constraint. The higher the cost on a transmitter, the higher the priority it has for the PN Offset allocation process.

Let us consider a transmitter Tx with two cells using carriers 0 and 1. The cost due to constraints on the transmitter is given as:

$$C_{Tx} = C_{Tx}(Dom) + C_{Tx}(U)$$

With $C_{Tx}(U) = \underset{i \in Tx}{Max}(C_i(U))$ and $C_{Tx}(Dom) = 512 - Number\ of\ PN\ offsets\ in\ the\ domain$

Here, the domain available for the transmitter is the intersection of domains assigned to cells of the transmitter. The domain constraint is mandatory and cannot be broken.

7.7.1.3.3 Site Priority

In case of "Per Site" allocation strategies (Adjacent PN-clusters per site and Distributed PN-clusters per site), algorithm in **9955** allots priorities to sites. Priorities assigned to sites depend on how much constrained each site is. The higher the constraint on a site, the higher the priority it has for the PN Offset allocation process.

Let us consider a site S with three transmitters; each of them has two cells using carriers 0 and 1. The site constraint is given as:

$$C_S = C_S(U) + C_S(Dom)$$

With, $C_S(U) = \sum_{Tx} C_{Tx}(U)$, and $C_S(Dom) = 512 - \text{Number of PN offsets in the domain}$

Here, the domain considered for the site is the intersection of domains available for transmitters of the site.

7.7.2 Allocation Examples

In order to understand the differences between the different allocation strategies and the behaviour of the algorithm when using a maximum of PN offsets or not, let us consider the following sample scenario:

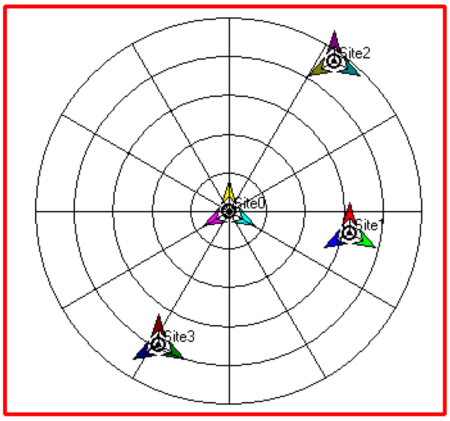


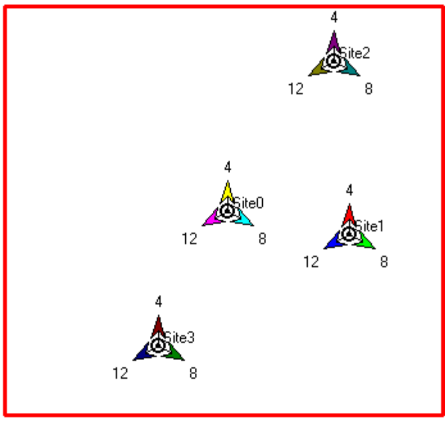
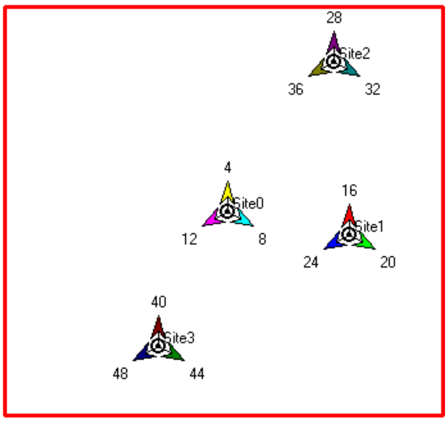
Figure 7.8: PN Offset Allocation

Let Site0, Site1, Site2 and Site3 be four sites with 3 cells using carrier 0 whom PN Offsets have to be allocated. The PILOT_INC parameter has been set to 4 and the PN Cluster Size is 3. Therefore, all PN offsets from 4 to 508 with a separation interval of 4 can be allocated. The reuse distance is supposed to be lower than the inter-site distance. Only co-site neighbours exist and all of them have the same importance.

The following section lists the results of each combination of options with explanation where necessary.

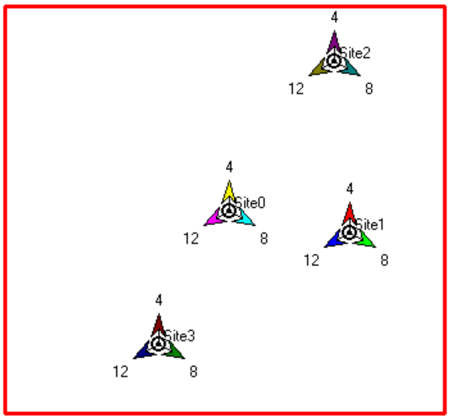
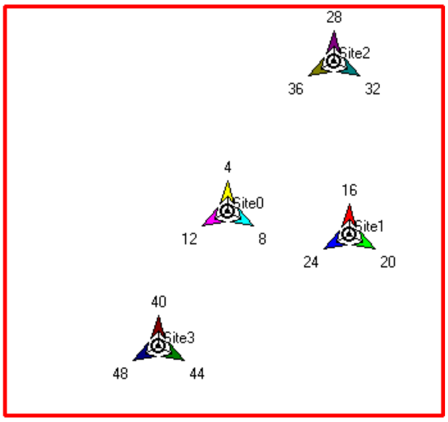
7.7.2.1 Strategy: PN Offset per Cell

Since the restrictions of neighbourhood only apply to co-sites with the same importance and inter-site distances are greater than reuse distances, every cell has the same priority. Then, the PN offset allocation to cells is performed in an alphanumeric order.

Without 'Use a Maximum of PN Offsets'	With 'Use a Maximum of PN Offsets'
	
9955 allocates the first three PN offsets in the domain (4, 8 and 12) to the Site0's cells. Under given constraints of neighbourhood and reuse distance, same PN offsets can be allocated to each site's cells.	**9955** allocates the first three PN offsets in the domain (4, 8 and 12) to the Site0's cells. As it is allowed to use a maximum of PN offsets, **9955** allocates different PN offsets to each site's cells so that there is least repetition.

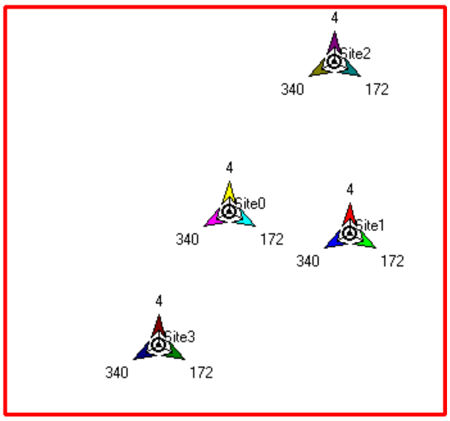
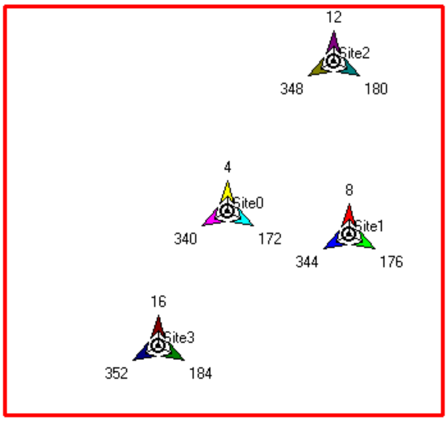
7.7.2.2 Strategy: Adjacent PN-Clusters Per Site

Since the restrictions of neighbourhood only apply to co-sites with the same importance and inter-site distances are greater than reuse distances, every cell has the same priority. Then, the PN offset allocation to cells is performed in an alphanumeric order.

<table>
<tr><th>Without ‘Use a Maximum of PN Offsets’</th><th>With ‘Use a Maximum of PN Offsets’</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>9955 allocates a PN cluster of adjacent PN offsets to Site0 and then, one PN offset of the PN cluster to each cell. Under given constraints of neighbourhood and reuse distance, the same PN cluster can be allocated to each site and same PN offsets to each site’s cells.</td><td>As it is possible to use a maximum of PN offsets, 9955 allocates different PN clusters of adjacent PN offsets to sites so that there is least repetition of PN offsets.</td></tr>
</table>

7.7.2.3 Strategy: ‘Distributed PN-Clusters Per Site

Since the restrictions of neighbourhood only apply to co-sites with the same importance and inter-site distances are greater than reuse distances, every cell has the same priority. Then, the PN offset allocation to cells is performed in an alphanumeric order.

<table>
<tr><th>Without ‘Use a Maximum of PN Offsets’</th><th>With ‘Use a Maximum of PN Offsets’</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>9955 allocates a PN cluster of distributed PN offsets to Site0 and then, one PN offset of the PN cluster to each cell. Under given constraints of neighbourhood and reuse distance, the same PN cluster can be allocated to each site and same PN offsets to each site’s cells.</td><td>As it is possible to use a maximum of PN offsets, 9955 allocates different PN clusters of distributed PN offsets to sites so that there is least repetition of PN offsets.</td></tr>
</table>

7.8 Automatic GSM-CDMA Neighbour Allocation

7.8.1 Overview

You can automatically calculate and allocate neighbours between GSM/TDMA and CDMA2000 networks. In **9955**, it is called inter-technology neighbour allocation.

Inter-technology handover is used in two cases:

- When the CDMA coverage is not continuous. In this case, the CDMA coverage is extended by CDMA-GSM handover into the GSM network,
- And in order to balance traffic and service distribution between both networks.

Note that the automatic inter-technology neighbour allocation algorithm takes into account both cases.

In order to be able to use the inter-technology neighbour allocation algorithm, you must have:

- An .atl document containing the GSM/TDMA network, GSM.atl, and another one containing the CDMA2000 network, CDMA.atl,
- An existing link on the Transmitters folder of GSM.atl into CDMA.atl.

The external neighbour allocation algorithm takes into account all the GSM TBC transmitters. It means that all the TBC transmitters of GSM.atl are potential neighbours. The cells to be allocated will be called TBA cells which, being cells of CDMA.atl, fulfill following conditions:

- They are active,
- They satisfy the filter criteria applied to Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder for which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters subfolder.

Only CDMA TBA cells may be assigned neighbours.

7.8.2 Automatic Allocation Description

The allocation algorithm takes into account criteria listed below:

- The inter-transmitter distance,
- The maximum number of neighbours fixed,
- Allocation options,
- The selected allocation strategy,

Two allocation strategies are available: the first one is based on distance and the second one on coverage overlapping.

We assume we have a CDMA reference cell, A, and a GSM candidate neighbour, transmitter B.

7.8.2.1 Algorithm Based on Distance

When the automatic allocation starts, **9955** checks the following conditions:

- The distance between the CDMA reference cell and the GSM neighbour must be less than the user-definable maximum inter-site distance. If the distance between the CDMA reference cell and the GSM neighbour is greater than this value, then the candidate neighbour is discarded.

  9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 532.

- The calculation options,

Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

Force co-site cells as neighbours: It enables you to automatically include GSM transmitters located on the same site as the reference CDMA cell in the candidate neighbour list. This option is automatically selected.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a GSM transmitter to be candidate neighbour of the reference CDMA cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, existing neighbours are kept.

- The importance of neighbours.

Importance values are used by the allocation algorithm to rank the neighbours. **9955** lists all neighbours and sorts them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each cell is exceeded. If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference cell is 8. Among these 15 candidate neighbours, only 8 (having the highest importance values) will be allocated to the reference cell. Note that the maximum number of inter-technology neighbours can be defined at the cell level (property dialogue or cell table). If defined there, this value is taken into account instead of the default one available in the **Neighbour Allocation** dialogue.

As indicated in the table below, the neighbour importance depends on the distance and on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter	If the Force co-site cells as neighbours option is selected	100 %
Neighbourhood relationship that fulfils distance conditions	If the maximum distance is not exceeded	$1 - \frac{d}{d_{max}}$

Where d is the effective distance between the CDMA reference cell and the GSM neighbour and d_{max} is the maximum inter-site distance.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site, or distance. For neighbours accepted for distance reasons, **9955** displays the distance from the reference cell (m). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

7.8.2.2 Algorithm Based on Coverage Overlapping

When automatic allocation starts, **9955** checks following conditions:

- The distance between the CDMA reference cell and the GSM neighbour must be less than the user-definable maximum inter-site distance. If the distance between the CDMA reference cell and the GSM neighbour is greater than this value, then the candidate neighbour is discarded.

  9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 532.

- The calculation options,

Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

Force co-site cells as neighbours: It enables you to automatically include GSM transmitters located on the same site as the reference CDMA cell in the candidate neighbour list. This option is automatically selected.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a GSM transmitter to be candidate neighbour of the reference CDMA cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, existing neighbours are kept.

- There must be an overlapping zone ($S_A \cap S_B$) with a given cell edge coverage probability where:

Four different cases may be considered for S_A:

- 1st case: S_A is the area where the cell A is the best serving cell of the CDMA network.
  - The pilot signal received from A is greater than the minimum pilot signal level,
  - The pilot quality from A exceeds a user-definable minimum value (minimum Ec/I_0) and is the highest one.

    In this case, the Ec/I_0 margin must be equal to 0dB and the max Ec/I0 option disabled.

- 2nd case: S_A represents the area where the pilot quality from the cell A strats decreasing but the cell A is still the best serving cell of the CDMA network.

  The Ec/I_0 margin must be equal to 0dB, the max Ec/I0 option selected and a maximum Ec/I0 user-defined.

  - The pilot signal received from A is greater than the minimum pilot signal level,
  - The pilot quality from A exceeds the minimum Ec/I_0 but is lower than the maximum Ec/I0.
  - The pilot quality from A is the highest one.

- 3rd case: S_A represents the area where the cell A is not the best serving cell but can enter the active set.

  Here, the Ec/I_0 margin has to be different from 0dB and the max Ec/I0 option disabled.

  - The pilot signal received from A is greater than the minimum pilot signal level,
  - The pilot quality from A is within a margin from the best Ec/I0, where the best Ec/I0 exceeds the minimum Ec/I0.

- 4th case: S_A represents the area where:
  - The pilot signal received from A is greater than the minimum pilot signal level,

- The pilot quality from A is within a margin from the best Ec/I0 (where the best Ec/I0 exceeds the minimum Ec/I0) and lower than the maximum Ec/I0.

  In this case, the margin must be different from 0dB, the max Ec/I0 option selected and a maximum Ec/I0 user-defined.

Two different cases may be considered for S_B:

- 1st case: S_B is the area where the cell B is the best serving cell of the GSM network.

  In this case, the margin must be set to 0dB.

  - The signal level received from B on the BCCH TRX type exceeds the user-defined minimum threshold and is the highest one.
- 2nd case: The margin is different from 0dB and S_B is the area where:
  - The signal level received from B on the BCCH TRX type exceeds the user-defined minimum threshold and is within a margin from the best BCCH signal level.

9955 calculates the percentage of covered area ($\frac{S_A \cap S_B}{S_A} \times 100$) and compares this value to the % minimum covered area. If this percentage is not exceeded, the candidate neighbour B is discarded.

Candidate neighbours fulfilling coverage conditions are sorted in descending order with respect to percentage of covered area.

> When the automatic allocation is based on coverage overlapping, we recommend you to perform two successive automatic allocations:
>
> - A first allocation in order to find handovers due to non-continuous CDMA coverage. In this case, you have to select the max Ec/I_0 option and define a high enough value.
> - A second allocation in order to complete the previous list with handovers motivated for reasons of traffic and service distribution. Here, the max Ec/I_0 option must be disabled.

- The importance of neighbours.

Importance values are used by the allocation algorithm to rank the neighbours according to the distance and the allocation reason. **9955** lists all neighbours and sorts them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each cell is exceeded. If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference cell is 8. Among these 15 candidate neighbours, only 8 (having the highest importance values) will be allocated to the reference cell. Note that the maximum number of inter-technology neighbours can be defined at the cell level (property dialogue or cell table). If defined there, this value is taken into account instead of the default one available in the **Neighbour Allocation** dialogue.

As indicated in the table below, the neighbour importance depends on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood reason	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter	If the Force co-site cells as neighbours option is selected	IF
Neighbourhood relationship that fulfils coverage conditions	If the % minimum covered area is exceeded	IF

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers the following factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Calculation of the Inter-Transmitter Distance" on page 532.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.
- The co-site factor (C): a Boolean,

- The overlapping factor (O): the percentage of overlapping.

The IF is user-definable using the Min importance and Max importance fields.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The IF evaluates importance as follows:

Co-site Neighbourhood cause	IF	Resulting IF using the default values from the table above
No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+50%{10%(Di)+90%(O)}
Yes	Min(C)+Delta(C){Max(Di)(Di)/(Max(Di)+Max(O))+ Max(O)(O)/(Max(Di)+Max(O))}	60%+40%{1/7%(Di)+6/7%(O)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site or coverage. For neighbours accepted for co-site and coverage reasons, **9955** displays the percentage of area meeting the coverage conditions and the corresponding surface area (km^2). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

- No prediction study is needed to perform an automatic neighbour allocation. When starting an automatic neighbour allocation, **9955** automatically calculates the path loss matrices if not found.
- A forbidden neighbour must not be listed as neighbour except if the neighbourhood relationship already exists and the Delete existing neighbours option is unchecked when you start the new allocation. In this case, **9955** displays a warning in the Event viewer indicating that the constraint on the forbidden neighbour will be ignored by algorithm because the neighbour already exists.
- In the Results, **9955** displays only the cells for which it finds new neighbours. Therefore, if a TBA cell has already reached its maximum number of neighbours before starting the new allocation, it will not appear in the Results table.

7.8.2.3 Delete Existing Neighbours Option

As explained above, **9955** keeps the existing inter-technology neighbours when the Delete existing neighbours option is not checked. We assume that we have an existing allocation of inter-technology neighbours.

A new TBA cell *i* is created in CDMA.atl. Therefore, if you start a new allocation without selecting the Delete existing neighbours option, **9955** determines the neighbour list of the cell *i*,

If you change some allocation criteria (e.g. increase the maximum number of neighbours or create a new GSM TBC transmitter) and start a new allocation without selecting the Delete existing neighbours option, it examines the neighbour list of TBA cells and checks allocation criteria if there is space in their neighbour lists. A new GSM TBC transmitter can enter the TBA cell neighbour list if allocation criteria are satisfied. It will be the first one in the neighbour list.

Chapter 8

TD-SCDMA Networks

This chapter describes TD-SCDMA calculations.

In this chapter, the following are explained:

- "Definitions and Formulas" on page 547
- "Signal Level Based Calculations" on page 554
- "Monte Carlo Simulations" on page 559
- "TD-SCDMA Prediction Studies" on page 578
- "Smart Antenna Modelling" on page 590
- "N-Frequency Mode and Carrier Allocation" on page 602
- "Neighbour Allocation" on page 603
- "Scrambling Code Allocation" on page 608
- "Automatic GSM/TD-SCDMA Neighbour Allocation" on page 618

8 TD-SCDMA Networks

This chapter describes in detail the algorithms, calculation parameters, and processes of the coverage predictions and the simulations available in TD-SCDMA documents. The first part of this chapter lists all the input and output parameters in the TD-SCDMA documents, their significance, location in the **9955** GUI, and their usage. Detailed explanation of the basic coverage predictions, which do not require simulation results, is provided in the second part. The third part describes the traffic scenario generation and Montel Carlo simulation algorithms including smart antenna modelling and dynamic channel allocation. The next sections are dedicated to TD-SCDMA coverage predictions which can be based on results obtained from simulations. The last three sections describe in detail the allocation of frequencies, i.e., master and slave carriers, the allocation of neigbours, and the allocation of scrambling codes.

8.1 Definitions and Formulas

The tables in the following subsections list the input and output parameters and formulas used in simulations and other computations.

8.1.1 Inputs

This table lists the inputs to computations, coverage predictions, and simulations.

Name	Value	Unit	Description
R_{Ch}	Global parameter	Mcps	Chip rate (or Spreading rate) (1.28)
F_{Min}^{Spread}	Global parameter	None	Minimum spreading factor (1)
F_{Max}^{Spread}	Global parameter	None	Maximum spreading factor (16)
$G_{P-CCPCH}^{Proc}$	Global parameter	None	P-CCPCH processing gain (13.8 dB)
N_{TS}^{SF}	Global parameter	None	Number of timeslots per subframe (7)
D^{SF}	Global parameter	ms	Subframe duration (5)
D^{Frame}	Global parameter	ms	Frame duration (10)
$N_{Ch/TS}^{GP}$	Global parameter	None	Number of guard period chips per timeslot (16)
$N_{Ch/TS}^{Data}$	Global parameter	None	Number of data chips per timeslot (704)
$N_{Ch/TS}^{Midamble}$	Global parameter	None	Number of midamble chips per timeslot (144)
$N_{Ch/PTS}^{GP}$	Global parameter	None	Number of guard period chips per pilot timeslot (96)
$N_{Ch/DwPTS}^{GP}$	Global parameter	None	Number of guard period chips per DwPTS timeslot (32)
$N_{Ch/DwPTS}^{SYNC\_DL}$	Global parameter	None	Number of SYNC_DL chips per DwPTS timeslot (64)
$N_{Ch/DwPTS}^{Total}$	Global parameter $N_{Ch/DwPTS}^{Total} = N_{Ch/DwPTS}^{GP} + N_{Ch/DwPTS}^{SYNC\_DL}$	None	Total number of chips per DwPTS timeslot (96)
$N_{Ch/UpPTS}^{GP}$	Global parameter	None	Number of guard period chips per UpPTS timeslot (32)
$N_{Ch/UpPTS}^{SYNC\_UL}$	Global parameter	None	Number of SYNC_UL chips per UpPTS timeslot (128)
$N_{Ch/UpPTS}^{Total}$	Global parameter $N_{Ch/UpPTS}^{Total} = N_{Ch/UpPTS}^{GP} + N_{Ch/UpPTS}^{SYNC\_UL}$	None	Total number of chips per UpPTS timeslot (160)

Name	Value	Unit	Description
W	Calculated global parameter $W = \frac{N_{Ch/TS}^{Data}}{D^{SF}}$	bps	Chip rate (140800 bps)
F_{Avg}	Frequency band parameter	MHz	Average frequency range of the frequency band (2010)
BW	Frequency band parameter	MHz	Channel bandwidth of the carriers of a frequency band (1.6)
F_{IRF}	Cell parameter	None	Interference reduction factor
F_{JD}^{TX}	Site equipment parameter	None	Joint Detection (JD) factor
F_{MCJD}^{TX}	Site equipment parameter	None	Multi-Cell Joint Detection factor
NF^{TX}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	BTS Noise Figure
L^{TX}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	None	Transmitter loss $L_{Tx} = L_{Total-UL}$ on uplink $L_{Tx} = L_{Total-DL}$ on downlink
ρ^{TX}	BTS parameter	None	Percentage of BTS signal correctly transmitted
P_{TCH}^{Max}	Cell parameter	W	Maximum cell traffic timeslot power
$P_{P-CCPCH}$	Cell parameter	W	P-CCPCH power on TS0
P_{DwPCH}	Cell parameter	W	DwPCH power on DwPTS
$P_{OCCH-TS0}$	Cell parameter	W	Other common channel power on TS0
$TComp_{P-CCPCH}$	Cell parameter	None	P-CCPCH RSCP comparative threshold for baton handover
ΔP_{Max}	Cell parameter	None	Maximum difference between two transmitted powers
RU_{UL}^{Req}	Cell parameter	None	Required resource units in uplink
RU_{DL}^{Req}	Cell parameter	None	Required resource units in downlink
$P_{HS-PDSCH}^{Available}$	Cell parameter	W	HS-PDSCH power available per downlink timeslot
P_{HR}	Cell parameter	None	Power headroom
$P_{HS-SCCH}$	Cell parameter	W	HS-SCCH power per downlink timeslot
$N_{HS-SCCH}$	Cell parameter	None	Number of HS-SCCH channels
$N_{HS-SICH}$	Cell parameter	None	Number of HS-SICH channels
N_{HSDPA}^{Max}	Cell parameter	None	Maximum number of HSDPA users
$N_{HS\text{-}PDSCH\ Codes}^{Min}$	Cell parameter	None	Minimum number of HS-PDSCH codes
$N_{HS\text{-}PDSCH\ Codes}^{Max}$	Cell parameter	None	Maximum number of HS-PDSCH codes
$N_{Intra-Neigh}^{Max}$	Cell parameter	None	Maximum number of intra-technology neighbours
$N_{Intra-Neigh}^{Max}$	Cell parameter	None	Maximum number of inter-technology neighbours

Name	Value	Unit	Description
P_{OCCH}	Timeslot parameter	W	Other common channel power
P_{TCH}^{DL}	Timeslot parameter	W	Downlink traffic power
$\%P_{DL}^{Max}$	Timeslot parameter (Simulation constraint)	None	Maximum percentage of downlink used power
X_{UL}	Timeslot parameter (Simulation result)	None	Uplink load factor
X_{UL}^{Max}	Timeslot parameter (Simulation constraint)	None	Maximum uplink load factor
$P_{HS-PDSCH}^{Available}$	Timeslot parameter	W	HS-PDSCH power available
$N_{HS\text{-}PDSCH\ Codes}^{Min}$	Timeslot parameter	None	Minimum number of HS-PDSCH codes
$N_{HS\text{-}PDSCH\ Codes}^{Max}$	Timeslot parameter	None	Maximum number of HS-PDSCH codes
$RU_{Overhead}$	Timeslot parameter		Overhead resource units
L^{Body}	Service parameter	None	Body loss
f_{DL}^{Act}	Service parameter	None	Downlink activity factor for circuit-switched services and the A-DPCH activity factor for HSDPA services
f_{UL}^{Act}	Service parameter	None	Uplink activity factor for circuit-switched services and the A-DPCH activity factor for HSDPA services
f_{DL}^{Eff}	Service parameter	None	Downlink efficiency factor for circuit-switched services
f_{UL}^{Eff}	Service parameter	None	Uplink efficiency factor for circuit-switched services
$F_{Scaling}$	Service parameter	None	Application througput scaling factor
O_{TP}	Service parameter	kbps	Application throughput offset
$N_{PacketCall}^{UL}$	Service parameter (packet session modelling)	None	Average number of packet calls on the uplink during a session
$N_{PacketCall}^{DL}$	Service parameter (packet session modelling)	None	Average number of packet calls on the downlink during a session
$\Delta T_{PacketCall}^{UL}$	Service parameter (packet session modelling)	ms	Average time between two packet calls on the uplink
$\Delta T_{PacketCall}^{DL}$	Service parameter (packet session modelling)	ms	Average time between two packet calls on the downlink
$S_{Min-PacketCall}^{UL}$	Service parameter (packet session modelling)	KBytes	Minimum packet call size on the uplink
$S_{Min-PacketCall}^{DL}$	Service parameter (packet session modelling)	KBytes	Minimum packet call size on the downlink
$S_{Max-PacketCall}^{UL}$	Service parameter (packet session modelling)	KBytes	Maximum packet call size on the uplink
$S_{Max-PacketCall}^{DL}$	Service parameter (packet session modelling)	KBytes	Maximum packet call size on the downlink
ΔT_{Packet}^{UL}	Service parameter (packet session modelling)	ms	Average time between two packets on the uplink
ΔT_{Packet}^{DL}	Service parameter (packet session modelling)	ms	Average time between two packets on the downlink
S_{Packet}^{UL}	Service parameter (packet session modelling)	Bytes	Packet size on uplink
S_{Packet}^{DL}	Service parameter (packet session modelling)	Bytes	Packet size on downlink

Name	Value	Unit	Description
R_{DL}^{Nom}	R99 bearer parameter	kbps	Downlink nominal bit rate
R_{UL}^{Nom}	R99 bearer parameter	kbps	Uplink nominal bit rate
G_{DL}^{Proc}	R99 bearer parameter (Can be calculated as $\frac{W}{R_{DL}^{Nom}}$)	None	Downlink processing gain
G_{UL}^{Proc}	R99 bearer parameter (Can be calculated as $\frac{W}{R_{UL}^{Nom}}$)	None	Uplink processing gain
P_{TCH-DL}^{Min}	R99 bearer parameter	W	Allowed minimum downlink traffic channel power
P_{TCH-DL}^{Max}	R99 bearer parameter	W	Allowed maximum downlink traffic channel power
N_{DL}^{TS}	R99 bearer parameter	None	Number of downlink timelots
N_{UL}^{TS}	R99 bearer parameter	None	Number of uplink timelots
Q_{TCH-UL}^{Req}	R99 bearer parameter per mobility ($\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{Req}$ or $\left(\frac{C}{I}\right)_{TCH-UL}^{Req}$)	None	Eb/Nt or C/I target on uplink
Q_{TCH-DL}^{Req}	R99 bearer parameter per mobility ($\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{Req}$ or $\left(\frac{C}{I}\right)_{TCH-DL}^{Req}$)	None	Eb/Nt or C/I target on downlink
$RSCP_{TCH-UL}^{Req}$	R99 bearer parameter per mobility	W	Target RSCP on uplink TCH
$RSCP_{TCH-DL}^{Req}$	R99 bearer parameter per mobility	W	Target RSCP on downlink TCH
G_{DL}^{Div}	R99 bearer parameter per mobility	None	Downlink diversity gain
G_{UL}^{Div}	R99 bearer parameter per mobility	None	Uplink diversity gain
P_{Max}^{Term}	Terminal parameter	W	Maximum terminal power
P_{Min}^{Term}	Terminal parameter	W	Minimum terminal power
P_{UpPCH}	Terminal parameter	W	UpPCH power
NF^{Term}	Terminal parameter	None	Terminal Noise Figure
F_{JD}^{Term}	Terminal parameter	None	Joint Detection (JD) factor
ρ^{Term}	Terminal parameter	None	Percentage of terminal signal correctly transmitted
G^{Term}	Terminal parameter	None	Terminal gain
L^{Term}	Terminal parameter	None	Terminal loss
$TAdd_{P-CCPCH}$	Mobility parameter	W	Required RSCP T_Add for P-CCPCH
$TDrop_{P-CCPCH}$	Mobility parameter	W	Required RSCP T_Drop for P-CCPCH
$RSCP_{DwPCH}^{Req}$	Mobility parameter	W	Required RSCP threshold for DwPCH
$RSCP_{UpPCH}^{Req}$	Mobility parameter	W	Required RSCP threshold for UpPCH
$Q_{P-CCPCH}^{Req}$	Mobility parameter ($\left(\frac{E_b}{N_t}\right)_{P-CCPCH}^{Req}$ or $\left(\frac{C}{I}\right)_{P-CCPCH}^{Req}$)	None	Required quality threshold for P-CCPCH
$Q_{HS-SCCH}^{Req}$	Mobility parameter ($\left(\frac{E_c}{N_t}\right)_{HS-SCCH}^{Req}$)	None	Required quality threshold for HS-SCCH

Name	Value	Unit	Description
$Q_{HS-SICH}^{Req}$	Mobility parameter ($\left(\frac{E_c}{N_t}\right)_{HS-SICH}^{P-CCPCH}$)	None	Required quality threshold for P-CCPCH
Q_{DwPCH}^{Req}	Mobility parameter ($\left(\frac{C}{I}\right)_{DwPCH}^{Req}$)	None	Required quality threshold for DwPCH
σ^{Model}	Clutter class parameter	None	Model standard deviation
$\sigma_{P-CCPCH}^{Eb/Nt}$ or $\sigma_{P-CCPCH}^{C/I}$	Clutter class parameter	None	P-CCPCH Eb/Nt or C/I standard deviation
$\sigma_{DL}^{Eb/Nt}$ or $\sigma_{DL}^{C/I}$	Clutter class parameter	None	Downlink Eb/Nt or C/I standard deviation
$\sigma_{UL}^{Eb/Nt}$ or $\sigma_{UL}^{C/I}$	Clutter class parameter	None	Uplink Eb/Nt or C/I standard deviation
L_{Indoor}	Clutter (and, optionally, frequency band) parameter	None	Indoor loss
F_{DL}^{Ortho}	Clutter class parameter	None	Downlink orthogonality factor
F_{UL}^{Ortho}	Clutter class parameter	None	Uplink orthogonality factor
θ_{Spread}	Clutter class parameter	°	Spreading angle
K	1.38 x 10^{-23}	J/K	Boltzman constant
T	293	K	Ambient temperature
N_0^{TX}	$NF_{TX} \times K \times T \times BW$	W	Thermal noise at transmitter
N_0^{Term}	$NF_{Term} \times K \times T \times BW$	W	Thermal noise at terminal
G^{TX}	Antenna parameter	None	Transmitter antenna gain
L_{Path}	Propagation model result	None	Path loss
$M_{Shadowing}^{Model}$	Result calculated from cell edge coverage probability and model standard deviation	None	Model shadowing margin used in coverage predictions
$M_{Shadowing}^{P-CCPCH}$	Result calculated from cell edge coverage probability and P-CCPCH Eb/Nt standard deviation	None	P-CCPCH Eb/Nt shadowing margin used in coverage predictions
$M_{Shadowing}^{(Eb/Nt)_{DL}}$	Result calculated from cell edge coverage probability and DL Eb/Nt standard deviation	None	DL Eb/Nt shadowing margin used in coverage predictions
$M_{Shadowing}^{(Eb/Nt)_{UL}}$	Result calculated from cell edge coverage probability and UL Eb/Nt standard deviation	None	UL Eb/Nt shadowing margin used in coverage predictions
L_T	For RSCP calculation $L_T^{Model} = \frac{L_{Path} \times L^{TX} \times L^{Term} \times L^{Body} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX} \times G^{Term}}$ For P-CCPCH Eb/Nt calculation $L_T^{(Eb/Nt)_P} = \frac{L_{Path} \times L^{TX} \times L^{Term} \times L^{Body} \times L_{Indoor} \times M_{Shadowing}^{P-CCPCH}}{G^{TX} \times G^{Term}}$ For DL Eb/Nt calculation $L_T^{(Eb/Nt)_{DL}} = \frac{L_{Path} \times L^{TX} \times L^{Term} \times L^{Body} \times L_{Indoor} \times M_{Shadowing}^{(Eb/Nt)_{DL}}}{G^{TX} \times G^{Term}}$ For UL Eb/Nt calculation $L_T^{(Eb/Nt)_{UL}} = \frac{L_{Path} \times L^{TX} \times L^{Term} \times L^{Body} \times L_{Indoor} \times M_{Shadowing}^{(Eb/Nt)_{UL}}}{G^{TX} \times G^{Term}}$	None	Transmitter-terminal total loss in coverage predictions In UL, only carrier power is attenuated by $M_{Shadowing}^{(Eb/Nt)_{UL}}$. In DL, carrier power and intra-cell interference are attenuated by $M_{Shadowing}^{(Eb/Nt)_{DL}}$ or $M_{Shadowing}^{P-CCPCH}$ while extra-cell interference is not. Therefore, $M_{Shadowing}^{(Eb/Nt)_{DL}}$ or $M_{Shadowing}^{P-CCPCH}$ are set to 1 in DL extra-cell interference calculation.

8.1.2 P-CCPCH Eb/Nt and C/I Calculation

Name	Value	Unit	Description
$\left(\frac{E_b}{N_t}\right)_{P-CCPCH}^{TX_i(ic)}$	$\frac{\rho^{TX_i} \times RSCP_{P-CCPCH}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}} \times G_{P-CCPCH}^{Proc}$	None	P-CCPCH Eb/Nt for the cell $TX_i(ic)$
$\left(\frac{C}{I}\right)_{P-CCPCH}^{TX_i(ic)}$	$\frac{\rho^{TX_i} \times RSCP_{P-CCPCH}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}}$	None	P-CCPCH C/I for the cell $TX_i(ic)$
$N_{Tot-DL}^{TX_i(ic)}$	$I_{Intra-DL}^{TX_i(ic)} + I_{Extra-DL}^{TX_i(ic)} + I_{IC-DL}(ic, jc) + N_0^{Term}$	W	Downlink total noise for the cell $TX_i(ic)$
$I_{Intra-DL}^{TX_i(ic)}$	$RSCP_{P-CCPCH}^{TX_i(ic)} \times \beta \times \gamma^{TX_i} + RSCP_{OCCH-TS0}^{TX_i(ic)} \times \gamma^{TX_i}$ With $\gamma^{TX_i} = \rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times (1 - F_{JD}^{Term})$ and $\beta = \begin{cases} 0 & \textit{Without Useful Signal} \\ 1 & \textit{Total Noise} \end{cases}$	W	Downlink intra-cell interference for the cell $TX_i(ic)$
$I_{Extra-DL}^{TX_i(ic)}$	$\sum_{j \neq i} \left(RSCP_{P-CCPCH}^{TX_j(ic)} + RSCP_{OCCH-TS0}^{TX_j(ic)}\right)$	W	Downlink extra-cell interference for the cell $TX_i(ic)$
$I_{IC-DL}(ic, jc)$	$\frac{\sum_{TX_j} \left(RSCP_{P-CCPCH}^{TX_j(jc)} + RSCP_{OCCH-TS0}^{TX_j(jc)}\right)}{F_{IRF}(ic, jc)}$	W	Inter-carrier interference

8.1.3 DwPCH C/I Calculation

Name	Value	Unit	Description
$\left(\frac{C}{I}\right)_{DwPCH}^{TX_i(ic)}$	$\frac{\rho^{TX_i} \times RSCP_{DwPCH}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}}$	None	DwPCH C/I for the cell $TX_i(ic)$
$N_{Tot-DL}^{TX_i(ic)}$	$I_{Intra-DL}^{TX_i(ic)} + I_{Extra-DL}^{TX_i(ic)} + I_{IC-DL}(ic, jc) + N_0^{Term}$	W	Downlink total noise for the cell $TX_i(ic)$
$I_{Intra-DL}^{TX_i(ic)}$	$RSCP_{DwPCH}^{TX_i(ic)} \times \beta \times \gamma^{TX_i}$ With $\gamma^{TX_i} = \rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times (1 - F_{JD}^{Term})$ and $\beta = \begin{cases} 0 & \textit{Without Useful Signal} \\ 1 & \textit{Total Noise} \end{cases}$	W	Intra-cell interference for the cell $TX_i(ic)$
$I_{Extra-DL}^{TX_i(ic)}$	$\sum_{j \neq i} \left(RSCP_{DwPCH}^{TX_j(ic)}\right)$	W	Extra-cell interference for the cell $TX_i(ic)$
$I_{IC-DL}(ic, jc)$	$\frac{\sum_{TX_j} \left(RSCP_{DwPCH}^{TX_j(jc)}\right)}{F_{IRF}(ic, jc)}$	W	Inter-carrier interference

8.1.4 DL TCH Eb/Nt and C/I Calculation

Name	Value	Unit	Description
$\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)}$	$\frac{\rho^{TX_i} \times RSCP_{TCH-DL}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}} \times G_{DL}^{Proc} \times G_{DL}^{Div}$	None	Downlink TCH Eb/Nt for the cell $TX_i(ic)$
$\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)}$	$\frac{\rho^{TX_i} \times RSCP_{TCH-DL}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}} \times G_{DL}^{Div}$	None	Downlink TCH C/I for the cell $TX_i(ic)$
$N_{Tot-DL}^{TX_i(ic)}$	$I_{Intra-DL}^{TX_i(ic)} + I_{Extra-DL}^{TX_i(ic)} + I_{IC-DL}(ic, jc) + N_0^{Term}$	W	Downlink total noise for the cell $TX_i(ic)$
$I_{Intra-DL}^{TX_i(ic)}$	$\left\{\rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times (1 - F_{JD}^{Term}) + \left(1 - \rho^{TX_i}\right)\right\} \times \left(RSCP_{TCH-DL}^{TX_i(ic)} + RSCP_{OCCH}^{TX_i(ic)}\right)$	W	Downlink intra-cell interference for the cell $TX_i(ic)$
$I_{Extra-DL}^{TX_i(ic)}$	$\sum_{j \neq i}\left(RSCP_{TCH-DL}^{TX_j(ic)} + RSCP_{OCCH}^{TX_j(ic)}\right)$	W	Downlink extra-cell interference for the cell $TX_i(ic)$
$I_{IC-DL}(ic, jc)$	$\frac{\sum_{TX_j}\left(RSCP_{TCH-DL}^{TX_j(jc)} + RSCP_{OCCH}^{TX_j(jc)}\right)}{F_{IRF}(ic, jc)}$	W	Inter-carrier interference

8.1.5 UL TCH Eb/Nt and C/I Calculation

Name	Value	Unit	Description
$\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)}$	$\frac{\rho^{Term} \times RSCP_{TCH-UL}^{TX_i(ic)}}{N_{Tot-UL}^{TX_i(ic)}} \times G_{UL}^{Proc} \times G_{UL}^{Div}$	None	Uplink TCH Eb/Nt for the cell $TX_i(ic)$
$\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)}$	$\frac{\rho^{Term} \times RSCP_{TCH-UL}^{TX_i(ic)}}{N_{Tot-UL}^{TX_i(ic)}} \times G_{UL}^{Div}$	None	Uplink TCH C/I for the cell $TX_i(ic)$
P_{Req}^{Term}	$P_{Max}^{Term} \times \frac{Q_{TCH-UL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)}}$ or $P_{Max}^{Term} \times \frac{Q_{TCH-UL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)}}$	W	Uplink required power for the terminal

8.1.6 Interference Calculation

Name	Value	Unit	Description
$I_{C2C}(TX_i, TX_j)$	$\sum_{TX_j}\left(RSCP_{TCH-DL}^{TX_j(ic)} + RSCP_{OCCH}^{TX_j(ic)}\right) + \frac{\sum_{TX_j}\left(RSCP_{TCH-DL}^{TX_j(jc)} + RSCP_{OCCH}^{TX_j(jc)}\right)}{F_{IRF}(ic, jc)}$	W	Cell to cell interference
$I_{TS1-UL}^{TX_i(ic)}$	$N_0^{TX_i} \times \frac{X_{TS1-UL}^{TX_i(ic)}}{\left(1 - X_{TS1-UL}^{TX_i(ic)}\right)}$	W	UpPCH interference

8.1.7 HSDPA Dynamic Power Calculations

Name	Value	Unit	Description
$P_{HS-SCCH}^{TX_i(ic)}$	$\dfrac{\left(\frac{E_c}{N_t}\right)_{HS-SCCH}^{TX_i(ic)} \times \left(N_{Tot-DL}^{TX_i(ic)} - \beta \times \gamma^{TX_i} \times RSCP_{HS-SCCH}^{TX_i(ic)}\right)}{\rho^{TX_i}} \times L_T^{Model}$	W	HS-SCCH power
$P_{HS-PDSCH}^{TX_i(ic)}$	$P_{Max-DL-Eff}^{TX_i(ic)} - P_{R99-DL}^{TX_i(ic)} - P_{HR}^{TX_i(ic)} - P_{HS-SCCH}^{TX_i(ic)}$	W	HS-PDSCH power
$P_{HS-SICH}^{M_i}$	$\dfrac{\left(\frac{E_c}{N_t}\right)_{HS-SICH}^{TX_i(ic)} \times \left(N_{Tot-UL}^{TX_i(ic)} - \beta \times \gamma^{M_i} \times RSCP_{HS-SICH}^{M_i}\right)}{\rho^{M_i}} \times L_T^{Model}$	W	HS-SICH power

8.2 Signal Level Based Calculations

Two types of signal level based calculations are available in **9955**:

1. Point Analysis: Real-time calculations for profile and reception analysis using the mouse to move a probe mobile on the map.
2. RSCP Based Coverage Predictions: Calculation of RSCP related parameters on each pixel and colouring according to the selected display.

8.2.1 Point Analysis

For the selected transmitted TX_i and carrier (*ic*), you can study three parameters in point analysis *Profile* tab:

Study criteria	Formulas
Signal level ($RSCP$) in dBm	Signal level received from a transmitter on a carrier (cell) $RSCP^{TX_i(ic)} = EIRP^{TX_i(ic)} - L_{Path} - M_{Shadowing}^{Model} - L_{Indoor}$
Path loss (L_{Path}) in dB	$L_{Path} = L_{Model} + L_{Ant}^{TX_i}$
Total losses (L_T) in dB	$L_T = L_{Path} + L^{TX_i} + L_{Indoor} + M_{Shadowing}^{Model} - G^{TX_i}$

Where,

$RSCP$ is the received signal code power for the P-CCPCH.

$EIRP$ is the effective isotropic radiated power of the transmitter. $EIRP^{TX_i(ic)} = P_{P-CCPCH}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$.

ic is a carrier number

L_{Model} is the loss on the transmitter-receiver path (path loss) calculated by the propagation model

$L_{Ant}^{TX_i}$ is the transmitter antenna attenuation (from antenna patterns)

$M_{Shadowing}^{Model}$ is the shadowing margin. This parameter is taken into account when the option “Shadowing taken into account” is selected

L_{Indoor} are the indoor losses, taken into account when the option "Indoor coverage" is selected

G^{TX_i} is the transmitter antenna gain

L^{TX_i} is the transmitter loss ($L^{TX_i} = L_{Total-DL}$)

It is possible to analyse the best carrier. In this case, 9955 takes the highest P-CCPCH power of cells to calculate the signal level received from a transmitter.

8.2.1.1 Profile Tab

9955 displays either the signal level received from the selected transmitter on a carrier ($RSCP_{P-CCPCH}^{TX_i(ic)}$), or the highest signal level received from the selected transmitter on the best carrier.

For a selected transmitter, it is also possible to study the path loss, L_{Path}, or the total losses, L_T. Path loss and total losses are the same on any carrier.

8.2.1.2 Reception Tab

Analysis provided in the Reception tab is based on path loss matrices. You can study reception from TBC transmitters for which path loss matrices have been calculated on their calculation areas.

For each transmitter, **9955** displays either the signal level received on a carrier, ($RSCP_{P-CCPCH}^{TX_i(ic)}$), or the highest signal level received on the best carrier.

Received signal level bar graphs are displayed in a decreasing signal level order. The number of bars in the graph depends on the signal level received from the best server. Only bars for transmitters whose signal level is within a 30 dB margin from the best server signal are displayed.

You can use a value other than 30 dB for the margin from the best server signal level, for example a smaller value for improving the calculation speed. For more information on defining a different value for this margin, see the *Administrator Manual*.

8.2.2 RSCP Based Coverage Predictions

For each TBC transmitter, TX_i, **9955** determines the value of the selected parameter on each studied pixel inside the TX_i calculation area. Each pixel within the TX_i calculation area is considered a probe receiver.

Coverage study parameters to be set are:

- The study conditions to determine the service area of each TBC transmitter
- The display settings to for colouring the covered pixels

9955 uses the parameters entered in the *Condition* tab of the coverage study properties dialogue to determine pixels covered by the each transmitter. Coverage prediction display resolution is independent of the path loss matrix and geographic data resolutions, and can be different for each coverage prediction. Coverage predictions are calculated using bilinear interpolation of multi-resolution path loss matrices (similar to the evaluation of site altitudes).

8.2.2.1 Calculation Criteria

The RSCP from a transmitter TX_i and a selected carrier (ic) is given by:

$$RSCP^{TX_i(ic)} = EIRP^{TX_i(ic)} - L_{Path} - M_{Shadowing}^{Model} - L_{Body} - L_{Indoor} + G^{Term} - L^{Term}$$

Where,

$RSCP$ is the received signal code power. RSCP can be calculated for P-CCPCH, DwPCH, or the downlink TCH.

$EIRP$ is the effective isotropic radiated power of the transmitter. $EIRP_{P-CCPCH}^{TX_i(ic)} = P_{P-CCPCH}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$, $EIRP_{DwPCH}^{TX_i(ic)} = P_{DwPCH}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$, or $EIRP_{DL-TCH}^{TX_i(ic)} = P_{DL-TCH}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$.

ic is a carrier number

$$L_{Path} = L_{Model} + L_{Ant}^{TX_i}$$

L_{Model} is the loss on the transmitter-receiver path (path loss) calculated by the propagation model

$L_{Ant}^{TX_i}$ is the transmitter antenna attenuation (from antenna patterns)

$M_{Shadowing}^{Model}$ is the shadowing margin. This parameter is taken into account when the option “Shadowing taken into account” is selected

L_{Indoor} are the indoor losses, taken into account when the option "Indoor coverage" is selected

L^{Term} is the terminal loss

L_{Body} is the body loss defined in the service

G^{Term} is the receiver total gain

G^{TX_i} is the transmitter antenna gain

L^{TX_i} is the transmitter loss ($L^{TX_i} = L_{Total-DL}$)

8.2.2.2 P-CCPCH RSCP Coverage Prediction

8.2.2.2.1 Coverage Condition

This coverage prediction calculates and displays the Received Signal Code Power (RSCP) for the P-CCPCH. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for TS0. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

You can select the display colours according to the RSCP, or on any best server parameter.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ are covered and coloured according to the selected display parameter.

8.2.2.2.2 Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **Best Signal Level (dBm)**

  9955 calculates the best $RSCP_{P-CCPCH}^{TX_i(ic)}$ received from each transmitter $TX_i(ic)$ on each pixel. Where other service areas overlap the studied one, **9955** chooses the highest RSCP. A pixel of a service area is coloured if $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$. The pixel colour depends on the RSCP level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the RSCP from the best server exceeds a defined minimum threshold.

- **RSCP Margin (dB)**

  Coverage consists of several layers with a layer per user-defined RSCP margin defined in the Display tab (Prediction properties). For each layer, area is covered if $RSCP_{P-CCPCH}^{TX_i(ic)} - TAdd_{P-CCPCH}(Mobility) \geq M_{P-CCPCH}^{RSCP}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  On each pixel of each transmitter service area, the coverage corresponds to the pixels where the $RSCP_{P-CCPCH}^{TX_i(ic)}$ from the transmitter exceeds $TAdd_{P-CCPCH}$ defined in the mobility selected in the Conditions tab, with different cell edge coverage probabilities. There is one coverage area per transmitter in the explorer.

8.2.2.3 Best Server P-CCPCH Coverage Prediction

This coverage prediction calculates and displays the best server RSCP for the P-CCPCH. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for TS0. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and where $RSCP_{P-CCPCH}^{TX_i(ic)} = \underset{j = All}{Best}\left(RSCP_{P-CCPCH}^{TX_j(jc)}\right)$ will be covered and coloured according to the transmitter colour.

8.2.2.4 P-CCPCH Pollution Analysis Coverage Prediction

This coverage prediction calculates and displays the number of P-CCPCH polluters. **9955** calculates the Received Signal Code Power (RSCP) for the P-CCPCH for each pixel in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and determines the polluting transmitters according to:

$$RSCP_{P-CCPCH}^{TX_i(ic)} \geq \underset{j \neq i}{Best}\left(RSCP_{P-CCPCH}^{TX_j(jc)}\right) - M$$

Where M is the specified pollution margin.

The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for TS0. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

9955 determines the number of transmitters covering each pixel and colours the pixel according to the number of polluting transmitters. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the number of servers is greater than or equal to a defined minimum threshold.

8.2.2.5 DwPCH RSCP Coverage Prediction

8.2.2.5.1 Coverage Condition

This coverage prediction calculates and displays the Received Signal Code Power (RSCP) for the DwPCH. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for DwPTS. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{DwPCH}^{TX_i(ic)} \geq RSCP_{DwPCH}^{Req}(Mobility)$ are covered and coloured according to the selected display parameter.

8.2.2.5.2 Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **DwPCH RSCP (dBm)**

9955 calculates the best $RSCP_{DwPCH}^{TX_i(ic)}$ received from each transmitter $TX_i(ic)$ on each pixel.. Where other service areas overlap the studied one, **9955** chooses the highest RSCP. A pixel of a service area is coloured if $RSCP_{DwPCH}^{TX_i(ic)} \geq RSCP_{DwPCH}^{Req}(Mobility)$. The pixel colour depends on the RSCP level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the RSCP from the best server exceeds a defined minimum threshold.

- **RSCP Margin (dB)**

  Coverage consists of several layers with a layer per user-defined RSCP margin defined in the Display tab (Prediction properties). For each layer, area is covered if $RSCP_{DwPCH}^{TX_i(ic)} - RSCP_{DwPCH}^{Req}(Mobility) \geq M_{DwPCH}^{RSCP}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell edge coverage probability (%)**

  On each pixel of each transmitter service area, the coverage corresponds to the pixels where the $RSCP_{DwPCH}^{TX_i(ic)}$ from the transmitter $TX_i(ic)$ exceeds $RSCP_{DwPCH}^{TX_i(ic)}$ defined in the mobility selected in the Conditions tab, with different cell edge coverage probabilities. There is one coverage area per transmitter in the explorer.

8.2.2.6 UpPCH RSCP Coverage Prediction

8.2.2.6.1 Coverage Condition

This coverage prediction calculates and displays the Received Signal Code Power (RSCP) for the UpPCH in the uplink. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for UpPTS. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

9955 uses the UpPCH power of the selected terminal to calculate the RSCP from each pixel of each transmitter's best server coverage area.

The pixels where $RSCP_{UpPCH}^{Term} \geq RSCP_{UpPCH}^{Req}(Mobility)$ are covered and coloured according to the selected display parameter.

8.2.2.6.2 Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **UpPCH RSCP (dBm)**

  9955 calculates the best $RSCP_{UpPCH}^{Term}$ received from each pixel of each transmitter service area at the transmitter. Where other service areas overlap the studied one, **9955** chooses the highest RSCP. A pixel of a service area is coloured if $RSCP_{UpPCH}^{Term} \geq RSCP_{UpPCH}^{Req}(Mobility)$. The pixel colour depends on the RSCP level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the RSCP at the best server exceeds a defined minimum threshold.

- **RSCP Margin (dB)**

  Coverage consists of several layers with a layer per user-defined RSCP margin defined in the Display tab (Prediction properties). For each layer, area is covered if $RSCP_{UpPCH}^{Term} - RSCP_{UpPCH}^{Req}(Mobility) \geq M_{UpPCH}^{RSCP}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  On each pixel of each transmitter service area, the coverage corresponds to the pixels from which the $RSCP_{UpPCH}^{Term}$ at the transmitter exceeds $RSCP_{UpPCH}^{Term}$ defined in the mobility selected in the Conditions tab, with different cell edge coverage probabilities. There is one coverage area per transmitter in the explorer.

8.2.2.7 Baton Handover Coverage Prediction

8.2.2.7.1 Coverage Condition

This coverage prediction determines the pixels which receive RSCP from cells other than the best server high enough to perform baton handovers. Received Signal Code Power (RSCP) is calculated for the P-CCPCH. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for TS0. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels are covered and coloured according to the selected display parameters, where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and $RSCP_{P-CCPCH}^{TX_j(jc)} \geq TDrop_{P-CCPCH}(Mobility) - TComp_{P-CCPCH}^{TX_j(jc)}$.

8.2.2.7.2 Coverage Display

It is possible to display the potential handover areas or the number of transmitters covering each pixel.

- **Handover Areas**

  9955 displays the pixels where there are transmitters other than the best server that satisfy the above criteria. Coverage consists of a single layer with a defined colour whose visibility in the workspace can be managed.

- **Number of Potential Servers**

  9955 determines the number of transmitters covering each pixel and colours the pixel according to the number of transmitters. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as defined thresholds. Each layer corresponds to an area where the number of servers is greater than or equal to a defined minimum threshold.

8.2.2.8 Scrambling Code Interference Analysis

This coverage prediction calculates and displays the pixels covered by two cells using the same scrambling code. **9955** calculates the Received Signal Code Power (RSCP) for the P-CCPCH for each pixel in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and determines the interfering transmitters according to:

$$RSCP_{P-CCPCH}^{TX_i(ic)} \geq \underset{j \neq i}{Best}\left(RSCP_{P-CCPCH}^{TX_j(jc)}\right) - M$$

Where M is the specified pollution margin.

The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for TS0. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

9955 determines whether the cells of two transmitters covering a pixel have the same scrambling code. If the pixel is interfered, **9955** colours it according to the colour assigned to the scrambling code in the display parameters. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as scrambling codes. Each layer corresponds to the area where the corresponding scrambling code has interference. A layer corresponding to areas where more than one scrambling code interferes is also available.

8.3 Monte Carlo Simulations

The simulation process is divided into two steps.

- Generating a realistic user distribution as explained in "Generating a Realistic User Distribution" on page 560.

9955 generates user distributions as part of the Monte Carlo algorithm based on traffic data. The resulting user distribution complies with the traffic database and maps selected when creating simulations.

- Dynamic channel allocation and power control as explained under "Power Control Simulation" on page 565.

8.3.1 Generating a Realistic User Distribution

During each simulation, **9955** performs two random trials. The first random trial generates the number of users and their activity status as explained in the following sections depending on the type of traffic input.

- "Simulations Based on User Profile Traffic Maps" on page 560.
- "Simulations Based on Sector Traffic Maps" on page 563.

> 9955 determines the total number of users attempting connection in each simulation based on the Poisson distribution. This may lead to slight variations in the total numbers of users in different simulations. To have the same total number of users in each simulation of a group, add the following lines in the Atoll.ini file:
> [Simulation]
> RandomTotalUsers=0

Each user is randomly assigned a service, a terminal, and a mobility type. The activity status is determined based on the calculations of activity probabilities using the traffic inputs.

The user activity status influences the next step of the simulation, i.e., the interference in the network. Both active and inactive users use radio resources and generate interference.

Once all the user characteristics have been determined, a second random trial is performed to obtain their geographical locations weighted according to the clutter classes, and whether they are indoor or outdoor according to the percentage of indoor users per clutter class defined for the traffic maps.

9955 also calculates the shadowing margin for each user based on the standard deviations defined for the clutter class of each user.

In TD-SCDMA networks users accessing packet-switched services can transmit either on uplink or on downlink, but never on both simultaneously. Users accessing circuit-switched services transmit on both uplink and downlink simultaneously. Circuit-switched service users, mobiles connected in uplink and downlink both, are modelled in **9955** by two mobiles generated at the same location with one connected on the uplink and the other on the downlink. If one of these two mobiles is rejected for some reason, the other is also rejected due to the same reason.

8.3.1.1 Simulations Based on User Profile Traffic Maps

User profile environment based traffic maps: Each pixel of the map is assigned an environment class which contains a list of user profiles with an associated mobility type and a given density, i.e., number of users of a user profile per km².

User profile traffic maps: Each polygon or line of the map is assigned a density of users with a given user profile and mobility type. If the map is composed of points, each point is assigned a number of users with given user profile and mobility type.

The user profile models the behaviour of the different user categories. Each user profile contains a list of services and their associated parameters describing how these services are accessed by the user.

The number of users of each user profile is calculated from the surface area (S_{Env}) of each environment class map (or each polygon) and the user profile density (D_{UP}).

$$N_{Users} = S_{Env} \times D_{UP}$$

> - In case of user profile traffic maps composed of lines, the number of users per user profile is calculated from the line length (L) and the user profile density (D_{UP}) (users per km): $N_{Users} = L \times D_{UP}$
> - The number of users is an input when a user profile traffic map is composed of points.

At any given instant, **9955** calculates the probability for a user being active in the uplink and in the downlink according to the service usage characteristics described in the user profiles, i.e., the number of voice calls or data sessions, the average duration of each voice call, or the volumes of the data exchanged in the uplink and the downlink in each data session.

8.3.1.1.1 Circuit Switched Service (*i*)

User profile parameters for circuit switched services are:

- The user terminal equipment used for the service (from the Terminals table),

- The average number of calls per hour N_{Call},
- The average duration of a call (seconds) D_{Call}.

The number of users and their distribution per activity status is determined as follows:

- Calculation of the service usage duration per hour (p_0 : probability of a connection):

$$p_o = \frac{N_{call} \times d}{3600}$$

- Calculation of the number of users trying to access the service i (n_i):

$$n_i = N_{Users} \times p_0$$

The activity status of each user depends on the activity periods during the connection, i.e., the uplink and downlink activity factors defined for the circuit switched service *i*, f_{Act}^{UL} and f_{Act}^{DL}.

- Calculation of activity probabilities:

  Probability of being inactive: $p_{Inactive} = (1 - f_{Act}^{UL}) \times (1 - f_{Act}^{DL})$

  Probability of being active on UL: $p_{Active}^{UL} = f_{Act}^{UL} \times (1 - f_{Act}^{DL})$

  Probability of being active on DL: $p_{Active}^{DL} = f_{Act}^{DL} \times (1 - f_{Act}^{UL})$

  Probability of being active both on UL and DL: $p_{Active}^{UL+DL} = f_{Act}^{UL} \times f_{Act}^{DL}$

- Calculation of number of users per activity status:

  Number of inactive users: $n_{i-Inactive} = n_i \times p_{Inactive}$

  Number of users active in the uplink: $n_{i-Active}^{UL} = n_i \times p_{Active}^{UL}$

  Number of users active in the downlink: $n_{i-Active}^{DL} = n_i \times p_{Active}^{DL}$

  Number of users active in the uplink and downlink both: $n_{i-Active}^{UL+DL} = n_i \times p_{Active}^{UL+DL}$

Therefore, a connected user can be either active on both links, inactive on both links, active on UL only, or active on DL only.

8.3.1.1.2 Packet Switched Service (*j*)

User profile parameters for packet switched services are:

- The user terminal equipment used for the service (from the Terminals table),
- The average number of packet sessions per hour N_{Sess},
- The volume (in kBytes) which is transferred on the downlink V^{DL} and the uplink V^{UL} during a session.

A packet session consists of several packet calls separated by a reading time. Each packet call is defined by its size and may be divided in packets of fixed size (1500 Bytes) separated by an inter-packet arrival time.

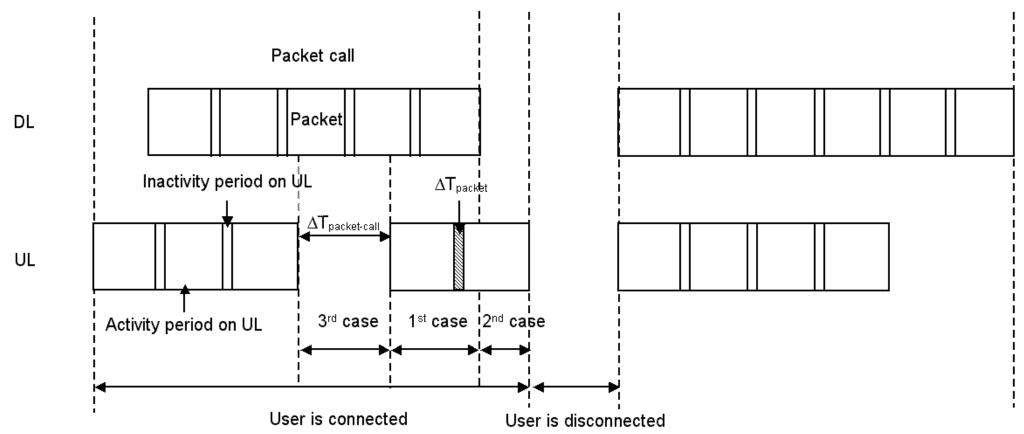


Figure 8.1: Description of a Packet Session

Calculation of the average packet call size (kBytes):

$$S^{UL}_{PacketCall} = \frac{V^{UL}}{N^{UL}_{PacketCall} \times f^{UL}_{Eff}} \text{ and } S^{DL}_{PacketCall} = \frac{V^{DL}}{N^{DL}_{PacketCall} \times f^{DL}_{Eff}}$$

In case of HSDPA services, f^{UL}_{Eff} and f^{DL}_{Eff} are the uplink and downlink A-DPCH activity factors, respectively.

Calculation of the average number of packets per packet call:

$$N^{UL}_{Packet} = Int\left(\frac{S^{UL}_{PacketCall}}{S^{UL}_{Packet}/1024}\right) + 1 \text{ and } N^{DL}_{Packet} = Int\left(\frac{S^{DL}_{PacketCall}}{S^{DL}_{Packet}/1024}\right) + 1$$

> 1 kBytes = 1024 Bytes.

Calculation of the average duration of inactivity within a packet call (*c*):

$$(D^{UL}_{Inactivity})_{PacketCall} = \frac{(N^{UL}_{Packet} - 1) \times \Delta T^{UL}_{Packet}}{1000} \text{ and } (D^{DL}_{Inactivity})_{PacketCall} = \frac{(N^{DL}_{Packet} - 1) \times \Delta T^{DL}_{Packet}}{1000}$$

Calculation of the average duration of inactivity in a session (*s*):

$$(D^{UL}_{Inactivity})_{Session} = N^{UL}_{PacketCall} \times (D^{UL}_{Inactivity})_{PacketCall} \text{ and}$$

$$(D^{DL}_{Inactivity})_{Session} = N^{DL}_{PacketCall} \times (D^{DL}_{Inactivity})_{PacketCall}$$

Calculation of the average duration of activity in a session (*s*):

$$(D^{UL}_{Activity})_{Session} = N^{UL}_{PacketCall} \times \frac{N^{UL}_{Packet} \times S^{UL}_{Packet} \times 8}{R^{UL}_{Nom} \times 1000} \text{ and}$$

$$(D^{DL}_{Activity})_{Session} = N^{DL}_{PacketCall} \times \frac{N^{DL}_{Packet} \times S^{DL}_{Packet} \times 8}{R^{DL}_{Nom} \times 1000}$$

Therefore, the average duration of a connection in the session *s* is:

$$D^{UL}_{Connection} = (D^{UL}_{Activity})_{Session} + (D^{UL}_{Inactivity})_{Session} \text{ and } D^{DL}_{Connection} = (D^{DL}_{Activity})_{Session} + (D^{DL}_{Inactivity})_{Session}$$

Calculation of the service usage duration per hour (probability of a connection):

$$p^{UL}_{Connection} = \frac{N_{Sess}}{3600} \times D^{UL}_{Connection} \text{ and } p^{DL}_{Connection} = \frac{N_{Sess}}{3600} \times D^{DL}_{Connection}$$

Calculation of the probability of being connected:

$$p_{Connected} = 1 - (1 - p^{UL}_{Connection}) \times (1 - p^{DL}_{Connection})$$

Therefore, the number of users trying to access the service *j* is:

$$n_j = N_{Users} \times p_{Connected}$$

As Figure 8.1 on page 561 shows, there can be three possible cases when a user is connected:

a. 1st case: At a given time, packets are downloaded and uploaded.

The probability of being connected is: $p^{UL+DL}_{Connected} = \frac{p^{UL}_{Connection} \times p^{DL}_{Connection}}{p_{Connected}}$

b. 2nd case: At a given time, packet are uploaded only.

The probability of being connected is: $p^{UL}_{Connected} = \frac{p^{UL}_{Connection} \times (1 - p^{DL}_{Connection})}{p_{Connected}}$

c. 3rd case: At a given time, packet are downloaded only.

The probability of being connected is: $p^{DL}_{Connected} = \frac{p^{DL}_{Connection} \times (1 - p^{UL}_{Connection})}{p_{Connected}}$

Calculation of the probability of being active:

To determine the activity status of each user, the activity periods during the connection are taken into account.

$$f^{UL} = \frac{(D^{UL}_{Activity})_{Session}}{(D^{UL}_{Inactivity})_{Session} + (D^{UL}_{Activity})_{Session}} \text{ and } f^{DL} = \frac{(D^{DL}_{Activity})_{Session}}{(D^{DL}_{Inactivity})_{Session} + (D^{DL}_{Activity})_{Session}}$$

Therefore, we have:

a. 1st case: At a given time, packets are downloaded and uploaded.

The probability of the user being active on UL and inactive on DL: $p1^{UL}_{Active} = f^{UL} \times (1 - f^{DL}) \times p^{UL+DL}_{Connected}$

The probability of the user being active on DL and inactive on UL: $p1^{DL}_{Active} = f^{DL} \times (1 - f^{UL}) \times p^{UL+DL}_{Connected}$

The probability of the user being active on both UL and DL: $p1^{UL+DL}_{Active} = f^{UL} \times f^{DL} \times p^{UL+DL}_{Connected}$

The probability of the user being inactive on both UL and DL: $p1_{Inactive} = (1 - f^{UL}) \times (1 - f^{DL}) \times p^{UL+DL}_{Connected}$

b. 2nd case: At a given time, packet are uploaded only.

The probability of the user being active on UL and inactive on DL: $p2^{UL}_{Active} = f^{UL} \times p^{UL}_{Connected}$

The probability of the user being inactive on both UL and DL: $p2_{Inactive} = (1 - f^{UL}) \times p^{UL}_{Connected}$

c. 3rd case: At a given time, packet are downloaded only.

The probability of the user being active on DL and inactive on UL: $p1^{DL}_{Active} = f^{DL} \times p^{DL}_{Connected}$

The probability of the user being inactive on both UL and DL: $p3_{Inactive} = (1 - f^{DL}) \times p^{DL}_{Connected}$

Calculation of number of users per activity status:

Number of inactive users on UL and DL: $n_{j-Inactive} = n_j \times (p1_{Inactive} + p2_{Inactive} + p3_{Inactive})$

Number of users active on UL and inactive on DL: $n^{UL}_{j-Active} = n_j \times (p1^{UL}_{Active} + p2^{UL}_{Active})$

Number of users active on DL and inactive on UL: $n^{DL}_{j-Active} = n_j \times (p1^{DL}_{Active} + p3^{DL}_{Active})$

Number of users active on UL and DL: $n^{UL+DL}_{j-Active} = n_j \times (p1^{UL+DL}_{Active})$

Therefore, a connected user can be active on both links, inactive on both links, active on UL only, or active on DL only.

> The user distribution per service, and the activity status distribution between the users are average distributions. The service and the activity status of each user are random in each simulation. Therefore, if you compute several simulations at once, the average number of users per service and average numbers of inactive, active on UL, active on DL, and active on UL and DL users, will correspond to calculated distributions. But, if you compare each simulation, you will observe that the user distribution between services as well as the activity status distribution between users is different in each simulation.

8.3.1.2 Simulations Based on Sector Traffic Maps

Sector traffic maps are also referred to as live traffic maps. Live traffic data from the OMC is spread over the best server coverage areas of the transmitters included in the traffic map. Throughput demands per service, the numbers of active users per service, or Erlangs per service are assigned to the coverage areas of each transmitter.

8.3.1.2.1 Throughputs in Uplink and Downlink

When selecting **Throughputs in Uplink and Downlink**, you can input the throughput demands in the uplink and downlink for each sector and for each listed service.

9955 calculates the number of users active in uplink and in downlink in the Txi cell using the service (N_{UL} and N_{DL}) as follows:

$N^{UL} = \frac{R_S^{UL}}{R_{Nom}^{UL}}$ and $N^{DL} = \frac{R_S^{DL}}{R_{Nom}^{DL}}$ for R99 circuit and packet switched services

$N^{DL} = \frac{R_S^{DL}}{R_{Avg}^{DL}}$ for HSDPA service

R_S^{UL} and R_S^{DL} are the uplink and downlink rates for service *S* in the TX_i cell from the traffic map.

N_{UL} and N_{DL} values include:

- Users active in uplink and inactive in downlink ($n_{i-Active}^{UL}$),
- Users active in downlink and inactive in uplink ($n_{i-Active}^{DL}$),
- And users active in both links ($n_{i-Active}^{UL+DL}$).

9955 takes into account activity periods during the connection in order to determine the activity status of each user.

Activity probabilities are calculated as follows:

Probability of being inactive in UL and DL: $p_{Inactive} = (1-f_{Act}^{UL}) \times (1-f_{Act}^{DL})$

Probability of being active in UL only: $p_{Active}^{UL} = f_{Act}^{UL} \times (1-f_{Act}^{DL})$

Probability of being active in DL only: $p_{Active}^{DL} = f_{Act}^{DL} \times (1-f_{Act}^{UL})$

Probability of being active both in UL and DL: $p_{Active}^{UL+DL} = f_{Act}^{UL} \times f_{Act}^{DL}$

Where, f_{Act}^{UL} and f_{Act}^{DL} are respectively the UL and DL activity factors defined for the service i.

Then, **9955** calculates the number of users per activity status:

We have:

$$(p_{Active}^{UL} + p_{Active}^{UL+DL}) \times (n_{i-Active}^{UL} + n_{i-Active}^{DL} + n_{i-Active}^{UL+DL}) = N_{UL}$$

$$(p_{Active}^{DL} + p_{Active}^{UL+DL}) \times (n_{i-Active}^{UL} + n_{i-Active}^{DL} + n_{i-Active}^{UL+DL}) = N_{DL}$$

Therefore, we have:

Number of users active in UL and DL both: $n_{i-Active}^{UL+DL} = min\left(\frac{N_{UL} \times p_{Active}^{UL+DL}}{p_{Active}^{UL} + p_{Active}^{UL+DL}}, \frac{N_{DL} \times p_{Active}^{UL+DL}}{p_{Active}^{DL} + p_{Active}^{UL+DL}}\right)$

Number of users active in UL and inactive in DL: $n_{i-Active}^{UL} = N_{UL} - n_{i-Active}^{UL+DL}$

Number of users active in DL and inactive in UL: $n_{i-Active}^{DL} = N_{DL} - n_{i-Active}^{UL+DL}$

Number of inactive users in UL and DL: $n_{i-Inactive} = \frac{(n_{i-Active}^{UL} + n_{i-Active}^{DL} + n_{i-Active}^{UL+DL})}{1 - p_{inactive}} \times p_{inactive}$

Therefore, a connected user can have four different activity status: either active in both links, or inactive in both links, or active in UL only, or active in DL only.

8.3.1.2.2 Total Number of Users (All Activity Statuses)

When selecting **Total Number of Users (All Activity Statuses)**, you can input the number of connected users for each sector and for each listed service (n_i).

9955 takes into account activity periods during the connection in order to determine the activity status of each user.

Activity probabilities are calculated as follows:

Probability of being inactive in UL and DL: $p_{Inactive} = (1-f_{Act}^{UL}) \times (1-f_{Act}^{DL})$

Probability of being active in UL only: $p_{Active}^{UL} = f_{Act}^{UL} \times (1-f_{Act}^{DL})$

Probability of being active in DL only: $p_{Active}^{DL} = f_{Act}^{DL} \times (1 - f_{Act}^{UL})$

Probability of being active both in UL and DL: $p_{Active}^{UL+DL} = f_{Act}^{UL} \times f_{Act}^{DL}$

Where, f_{Act}^{UL} and f_{Act}^{DL} are respectively the UL and DL activity factors defined for the service i.

Then, **9955** calculates the number of users per activity status:

Number of inactive users in UL and DL: $n_{i-Inactive} = n_i \times p_{Inactive}$

Number of users active in UL and inactive in DL: $n_{i-Active}^{UL} = n_i \times p_{Active}^{UL}$

Number of users active in DL and inactive in UL: $n_{i-Active}^{DL} = n_i \times p_{Active}^{DL}$

Number of users active in UL and DL both: $n_{i-Active}^{UL+DL} = n_i \times p_{Active}^{UL+DL}$

Therefore, a connected user can have four different activity status: either active in both links, or inactive in both links, or active in UL only, or active in DL only.

8.3.1.2.3 Number of Users per Activity Status

When selecting **Number of Users per Activity Status**, you can directly input the number of inactive users ($n_{i-Inactive}$), the number of users active in the uplink ($n_{i-Active}^{UL}$), in the downlink ($n_{i-Active}^{DL}$) and in the uplink and downlink ($n_{i-Active}^{UL+DL}$), for each sector and for each service.

> The activity status of users is based on an average distribution. The activity status of each user is random in each simulation. Therefore, if you compute several simulations at once, the average numbers of inactive, active on UL, active on DL, and active on UL and DL users, will correspond to calculated distributions. But, if you compare each simulation, you will observe that the activity status distribution between users is different in each simulation.

8.3.2 Power Control Simulation

Based on CDMA air interface, a TD-SCDMA network automatically regulates itself by using uplink and downlink power control in order to minimise interference and maximise capacity. For each user distribution, **9955** simulates these network regulation mechanisms using an iterative algorithm and calculates network parameters such as traffic power per cell and per timeslot, mobile terminal power, and handoff status for each terminal.

In each iteration, all the mobiles (R99 and HSDPA service users) selected during generation of the user distribution attempt to connect to the network one by one. The process is repeated from iteration to iteration and ends when the network is balanced, i.e., when the convergence criteria on uplink and downlink are satisfied.

The simulation algorithm also models the impact of smart antennas in the power control loop. The influence of smart antennas is taken into account in signal quality calculations. Smart antennas improve the signal quality of each served mobile, decrease the required powers and the loads of all the surrounding cells. Interference on the downlink and the uplink is calculated on a per user. Power control is simulated over a sub-frame, i.e., 7 timeslots.

For HSDPA users, uplink and downlink power control is performed on the associated A-DCH bearer before fast link adaptation on downlink. The steps of this algorithm are detailed below.

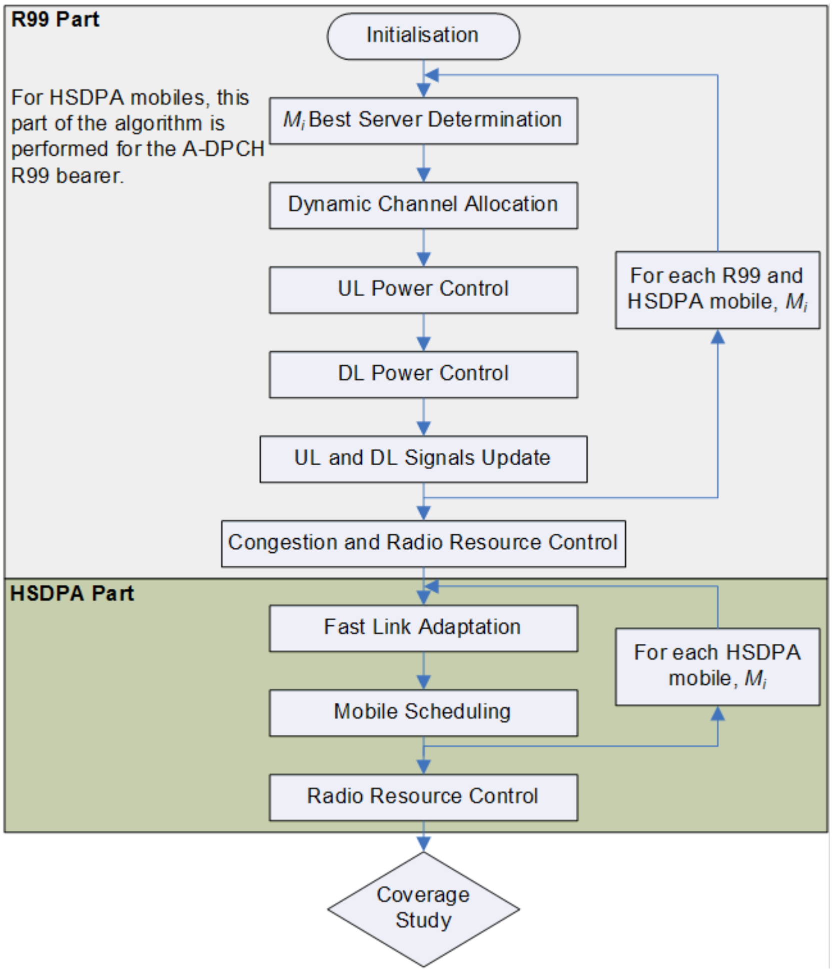


Figure 8.2: TD-SCDMA Power Control Algorithm

8.3.2.1 Algorithm Initialisation

At the start of each simulation, the system loads for each carrier and timeslot are reset to initial values:

- Downlink traffic powers of cells P_{TCH-DL} are initialised to 0 Watts
- Uplink interference powers received on all the carriers and timeslots $I_{Intra-UL}$ and $I_{Extra-UL}$ are initialised to 0 Watts (i.e., no connected mobiles)
- Uplink required power for mobiles is set to P_{Min}^{Term}

8.3.2.2 R99 Part of the Algorithm

The algorithm is described for an iteration *k*. Here, X_k is the value of the variable *X* at the iteration *k*. In the algorithm, all Q_{UL}^{Req} and Q_{DL}^{Req} thresholds depend on the user mobility, and are defined in the Service and Mobility parameter tables. All the variables used in the description below are listed in "Definitions and Formulas" on page 547.

The following calculations are made for all R99 and HSDPA mobiles (M_i) using R99 bearers.

8.3.2.2.1 Determination of M_i's Best Server ($S_{BS}(M_i)$)

This step is performed for TS0 for each station TX_i containing M_i in its calculation area.

The best server for M_i is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the P-CCPCH RSCP is calculated for:

- the preferred carrier of the service used by M_i, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The RSCP from a transmitter TX_i and a selected carrier *ic* is given by:

$$RSCP_{P-CCPCH}^{TX_i(ic)} = P_{P-CCPCH}^{TX_i(ic)} + G^{TX_i} - L^{TX_i} - L_{Path} - M_{Shadowing}^{Model} - L_{Body}^{M_i} - L_{Indoor} + G^{M_i} - L^{M_i} \text{ in dBm}$$

Where,

$$L_{Path} = L_{Model} + L_{Ant}^{TX_i}$$

L_{Model} is the loss on the transmitter-receiver path (path loss) calculated by the propagation model

$L_{Ant}^{TX_i}$ is the transmitter antenna attenuation (from antenna patterns)

$M_{Shadowing}^{Model}$ is the shadowing margin. This parameter is taken into account when the option “Shadowing taken into account” is selected

L_{Indoor} are the indoor losses, taken into account when the option "Indoor coverage" is selected

L^{M_i} is the los of the terminal used by M_i

$L_{Body}^{M_i}$ is the body loss defined in the service used by M_i

G^{M_i} is the receiver gain of the terminal user by M_i

G^{TX_i} is the transmitter antenna gain

L^{TX_i} is the transmitter loss ($L^{TX_i} = L_{Total-DL}$)

A cell $TX_i(ic)$ is considered the best server of a mobile M_i if it satisfies the following conditions:

$$RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility) \text{ and } RSCP_{P-CCPCH}^{TX_i(ic)} = \underset{j = All}{Best}\left(RSCP_{P-CCPCH}^{TX_j(jc)}\right).$$

The best server is determined once for the whole simulation during the first iteration, i.e., $k = 0$, because the best server does not change during the simulation and smart antennas do not influence this step.

M_i is considered unable to connect to the network if no best server has been selected. In this case, M_i is rejected for the reason P-CCPCH RSCP < Min P-CCPCH RSCP. If M_i has no best server, it is not taken into account in the next steps.

8.3.2.2.2 Dynamic Channel Allocation

The dynamic channel allocation is performed once for the whole simulation during the first iteration, i.e., $k = 0$. The DCA controls the mobile admission. Once a mobile has been admitted for a simulation, it remains admitted for the all the iterations unless there are other reasons to reject it (following steps).

The aim of Dynamic Channel Allocation (DCA) is to reduce interference in order to maximise the usage of the radio resources. In other words, the DCA tries to find the "best carrier" and the "best timeslots", which when allocated to the mobiles will optimise the load balance between carriers.

If a preferred carrier is defined for the service requested by M_i and if it is available at TX_i. $BestCarrier(TX_i, M_i) =$ the carrier preferred for the service. In the case of N-frequency compatible transmitters, M_i can be allocated timeslots over more than one slave carrier.

M_i is considered unable to connect to the network if no carrier or not enough timeslots have been selected. In this case, the mobile M_i will be rejected for the reason "RU Saturation". If the carrier and timeslot(s) selected by the DCA do not satisfy the control of radio resource limits for DL power or UL load, then the mobile will be rejected for the reason "DL Load Saturation" or "Admission Rejection" respectively.

There are four strategies for the DCA available in **9955**. These strategies are described below one by one.

1. **Load**

   Carrier Selection by Load: The DCA determines the least loaded carrier with enough timeslots to accomodate the service being used by each mobile M_i. The best carrier for a mobile is the one that is least loaded:

   $$BestCarrier(TX_i, M_i) = Carrier\Big|_{Min(X^{DCA})}$$

   Where, $X^{DCA} = X_{DL}^{DCA} = N_{Tot-DL}^{TX_i(ic,\, TS(M_i))}$ if the mobile is connected in the downlink.

And, $X^{DCA} = X_{UL}^{DCA} = \dfrac{N_{Tot-UL}^{TX_i(ic,\,TS(M_i))}}{N_{Tot-UL}^{TX_i(ic,\,TS(M_i))} + N_0^{TX_i}} \times \Delta X^{DCA}$ if the mobile is connected in the uplink.

ΔX^{DCA} is the load increment given by:

$$\Delta X^{DCA} = \frac{\rho^{M_i} \times (1 - f_{UL}^{Ortho}) \times \left(1 - f_{JD}^{TX_i}\right)}{1 + \dfrac{1}{Q_{UL}^{Req}}}$$

Where $Q_{UL}^{Req} = \left(\frac{C}{I}\right)_{UL}^{Req} = \dfrac{\left(\frac{E_b}{N_t}\right)_{UL}^{Req}}{G_{UL}^{Proc}}$ is the uplink required signal quality. The uplink processing gain G_{UL}^{Proc} calculated from the service parameters, if no smart antenna is used by the transmitter in the uplink.

If a smart antenna is used by the transmitter in the uplink, the smart antenna gain is taken into account in calculating Q_{UL}^{Req}.

- $N_{Tot-UL}^{TX_i(ic,\,TS(M_i))}$ is described in "Uplink Power Control" on page 569.
- $N_{Tot-DL}^{TX_i(ic,\,TS(M_i))}$ is described in "Downlink Power Control" on page 570.
- The carrier is the same in the uplink and in the downlink for mobiles accessing circuit-switched services.

Timeslot selection by Load: From the selected carrier, **9955** selects the timeslots which are the least loaded and have enough resource units for the service being accessed by M_i.

2. **Available RUs**

   Carrier selection by Available RUs: The DCA determines the carrier which has the highest number of available resource units with enough timeslots to accomodate the service being used by each mobile M_i. The best carrier for a mobile is the one that has the highest number of resource units:

   $$BestCarrier(TX_i, M_i) = Carrier|_{Max(RUs)}$$

   Timeslot selection by Available RUs: From the selected carrier, **9955** selects the timeslots which have the highest numbers of available resource units.

3. **Direction of Arrival**

   Carrier selection by Direction of Arrival: The DCA determines the direction of arrival of the signal from the served user M_i and checks whether there is an interfering mobile in the same direction as M_i. **9955** searches for interfering mobiles within the angle defined by the Angular Step. For example, if you enter an angular step of 15 degrees, **9955** searches for interfering mobiles within 15 degrees to the right and to the left of the served user, and allocates a different carrier than the ones used by any interfering mobiles found. The best carrier for a mobile is the one which is not interfered by another mobile in the direction of the mobile M_i.

   $$BestCarrier(TX_i, M_i) = Carrier|_{DoA(Mi) \neq DoA(Mj)}$$

   In other words, the direction of arrival for the served user M_i should not be the direction of arrival of an interfering mobile.

   Timeslot selection by Direction of Arrival: From the selected carrier, **9955** selects the timeslots which are not being used by any other mobile M_j located in the same direction as the served user M_i.

4. **Sequential**

   Sequential carrier selection: The DCA allocates carriers to served users M_i in a sequential order.

   Sequential timeslot selection: From the selected carrier, **9955** allocates timeslots to served users M_i in a sequential order.

At the end of the DCA, each admitted mobile has an associated carrier and timeslots. In case of N-frequency mode compatible transmitters, an admitted mobile can have associated timeslots over more than one slave carrier.

8.3.2.2.3 Uplink Power Control

For each mobile M_i, the uplink power control step calculates the uplink power required to satisfy the required quality level on the traffic channel, which is defined for the service being accessed by M_i.

If the mobile M_i is connected (active or inactive) in the uplink and has a best server $TX_i(ic)$ assigned to it, **9955** calculates the signal quality on the uplink timeslots allocated to M_i by the DCA:

$$\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic,\,TS(M_i))} = \frac{\rho^{M_i} \times RSCP_{TCH-UL}^{TX_i(ic,\,TS(M_i))}}{N_{Tot-UL}^{TX_i(ic,\,TS(M_i))}} \times G_{UL}^{Proc} \times G_{UL}^{Div} \text{ or } \left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic,\,TS(M_i))} = \frac{\rho^{M_i} \times RSCP_{TCH-UL}^{TX_i(ic,\,TS(M_i))}}{N_{Tot-UL}^{TX_i(ic,\,TS(M_i))}} \times G_{UL}^{Div}$$

Calculation of Uplink Total Noise (N_{Tot-UL}):

The uplink total noise is calculated for the uplink connection between each mobile M_i and its best server $TX_i(ic)$.

$$N_{Tot-UL}^{TX_i(ic,\,TS(M_i))} = I_{Tot-UL}^{TX_i(ic,\,TS(M_i))} + N_0^{TX_i}$$

Where

$$\begin{aligned} I_{Tot-UL}^{TX_i(ic,\,TS(M_i))} = {} & RSCP_{TCH-UL}^{M_i}(TX_i(ic,\,TS(M_i))) \times \beta \times \gamma^{M_i} + \\ & \sum_{\substack{M_j \in TX_i(ic,\,TS(M_i)) \\ M_j \neq M_i}} RSCP_{TCH-UL}^{M_j}(TX_i(ic,\,TS(M_i))) \times \gamma^{M_i} + \\ & \sum_{\substack{M_j \in TX_i(ic,\,TS(M_i)) \\ M_j \neq M_i}} \left(1-\rho^{M_j}\right) \times RSCP_{TCH-UL}^{M_j}(TX_i(ic,\,TS(M_i))) + \\ & \sum_{M_j \notin TX_i(ic,\,TS(M_i))} RSCP_{TCH-UL}^{M_j}(TX_i(ic,\,TS(M_i))) \times \left(1-F_{MCJD}^{TX_i}\right) \end{aligned}$$

$$\gamma^{M_i} = \rho^{M_i} \times (1-F_{UL}^{Ortho}) \times \left(1-F_{JD}^{TX_i}\right) \text{ and } \beta = \begin{cases} 0 & \textit{Without Useful Signal} \\ 1 & \textit{Total Noise} \end{cases}$$

The above formula gives the value of I_{Tot-UL} for the uplink connection between M_i and $TX_i(ic)$, taking into account the interference received from other mobiles, M_j, which are located in the M_i best server coverage area, as well as located in the coverage areas of other cells. The mobile M_i is the focus, i.e., the mobile that is listened to by the transmitter $TX_i(ic)$.

The four terms comprising I_{Tot-UL} are:

- The useful signal for which the received mobile is the focus (M_i).
- The intra-cell interference for which the best-server is the same for the received mobile M_j and the focus M_i, $TX_i(ic)$.
- The intra-cell interference due to distortion in the terminal transmission.
- The extra-cell interference for which the best-server for the received mobile M_j is not $TX_i(ic)$.

The uplink received signal code power is: $RSCP_{TCH-UL}^{M_i}(TX_i(ic,\,TS(M_i))) = \dfrac{P_{Req}^{M_i}(TX_i(ic,\,TS(M_i)))\big|_{k-1}}{L_T^{Model}}$

$L_T^{Model} = \dfrac{L_{Path} \times L^{TX_i} \times L^{M_i} \times L_{Body}^{M_i} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{M_i}}$ and $P_{Req}^{M_i}(TX_i(ic,\,TS(M_i)))$ is the uplink required mobile power calculated for the timeslot allocated to M_i. If M_i is an HSDPA user, $P_{Req}^{M_i}(TX_i(ic,\,TS(M_i))) = 0.1 \times P_{Req}^{M_i}(TX_i(ic,\,TS(M_i)))$

In L_T^{Model}, $G^{TX_i} = G_{UL}^{SA}$ and $L^{TX_i} = L_{UL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{Req}^{M_i}(TX_i(ic, TS(M_i)))$, if a smart antenna is available in the uplink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

> Interference is updated only for active mobiles on the uplink for circuit- and packet-switched services. However, if these mobiles are rejected, they are considered in the number of rejected mobiles.

Calculation of Uplink Required Power ($P_{Req}^{M_i}$):

Then **9955** determines the required uplink power by:

$$P_{Req}^{M_i}(TX_i(ic, TS(M_i)))\Big|_k = P_{Req}^{M_i}(TX_i(ic, TS(M_i)))\Big|_{k-1} \times \frac{\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic, TS(M_i))}}$$

or $$P_{Req}^{M_i}(TX_i(ic, TS(M_i)))\Big|_k = P_{Req}^{M_i}(TX_i(ic, TS(M_i)))\Big|_{k-1} \times \frac{\left(\frac{C}{I}\right)_{TCH-UL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic, TS(M_i))}}$$

And if $P_{Req}^{M_i}(TX_i(ic, TS(M_i))) < P_{Min}^{M_i}$ then $P_{Req}^{M_i}(TX_i(ic, TS(M_i))) = P_{Min}^{M_i}$

If $P_{Req}^{M_i}(TX_i(ic, TS(M_i))) > P_{Max}^{M_i}$ then the mobile M_i is rejected for the reason "Pmob > PmobMax", and $P_{Req}^{M_i}(TX_i(ic, TS(M_i)))$ is set to 0.

$P_{Min}^{M_i}$ and $P_{Max}^{M_i}$ are set in the properties of the terminal used by the mobile M_i.

Where $RSCP_{TCH-UL}^{TX_i(ic, TS(M_i))} = \dfrac{P_{Req}^{M_i}(TX_i(ic, TS(M_i)))\Big|_{k-1}}{L_T^{Model}}$

$L_T^{Model} = \dfrac{L_{Path} \times L^{TX_i} \times L^{M_i} \times L_{Body}^{M_i} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{M_i}}$ and $P_{Req}^{M_i}(TX_i(ic, TS(M_i)))\Big|_{k-1}$ is the uplink required mobile power for iteration k - 1 transmitted on the timeslot allocated to M_i.

In L_T^{Model}, $G^{TX_i} = G_{UL}^{SA}$ and $L^{TX_i} = L_{UL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{Req}^{M_i}(TX_i(ic, TS(M_i)))$, if a smart antenna is available in the uplink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

> The uplink required powers for mobiles inactive in the uplink accessing circuit- or packet-switched services are calculated for information only. However, if these mobiles are rejected, they are considered in the number of rejected mobiles.

8.3.2.2.4 Downlink Power Control

For each mobile M_i, the downlink power control step calculates the downlink power for the best server $TX_i(ic)$ required to satisfy the required quality level on the traffic channel, which is defined for the service being accessed by M_i.

If the mobile M_i is connected (active or inactive) in the downlink and has a best server $TX_i(ic)$ assigned to it, **9955** calculates the signal quality on the uplink timeslots allocated to M_i by the DCA:

$$\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic,\,TS(M_i))} = \frac{\rho^{TX_i} \times RSCP_{TCH-DL}^{TX_i(ic,\,TS(M_i))}}{N_{Tot-DL}^{TX_i(ic,\,TS(M_i))}} \times G_{DL}^{Proc} \times G_{DL}^{Div} \text{ or } \left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic,\,TS(M_i))} = \frac{\rho^{TX_i} \times RSCP_{TCH-DL}^{TX_i(ic,\,TS(M_i))}}{N_{Tot-DL}^{TX_i(ic,\,TS(M_i))}} \times G_{DL}^{Div}$$

Calculation of Downlink Total Noise (N_{Tot-DL}):

The downlink total noise is calculated for the downlink connection between each mobile M_i and its best server $TX_i(ic)$.

$$N_{Tot-DL}^{TX_i(ic,\,TS(M_i))} = I_{Tot-DL}^{TX_i(ic,\,TS(M_i))} + I_{IC-DL}(ic, jc) + I_{MM}(M_i, M_j) + N_0^{M_i}$$

Where

$$\begin{aligned} I_{Tot-DL}^{TX_i(ic,\,TS(M_i))} = {} & RSCP_{Tot-DL}^{TX_i(ic,\,TS(M_i))}(M_i) \times \beta \times \gamma^{TX_i} + \\ & \sum_{\substack{M_j \in TX_i(ic,\,TS(M_i)) \\ M_j \neq M_i}} RSCP_{Tot-DL}^{TX_i(ic,\,TS(M_i))}(M_j) \times \gamma^{TX_i} + \\ & \sum_{\substack{M_j \in TX_i(ic,\,TS(M_i)) \\ M_j \neq M_i}} \left(1 - \rho^{TX_i}\right) \times RSCP_{Tot-DL}^{TX_i(ic,\,TS(M_i))}(M_j) + \\ & \sum_{M_j \notin TX_i(ic,\,TS(M_i))} RSCP_{Tot-DL}^{TX_j(ic,\,TS(M_i))}(M_j) \end{aligned}$$

The four terms comprising I_{Tot-DL} are:

- The useful signal for which the received mobile is the focus (M_i).
- The intra-cell interference for which the best-server is the same for the received mobile M_j and the focus M_i, $TX_i(ic)$.
- The intra-cell interference due to distortion in the transmitter.
- The extra-cell interference for which the best-server for the received mobile M_j is not $TX_i(ic)$.

$$I_{IC-DL}(ic, jc) = \frac{\sum_{All\ TX_j} RSCP_{Tot-DL}^{TX_j(jc,\,TS(M_i))}(M_i)}{F_{IRF}(ic, jc)}$$

$$\gamma^{TX_i} = \rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times \left(1 - F_{JD}^{M_i}\right) \text{ and } \beta = \begin{cases} 0 & \textit{Without Useful Signal} \\ 1 & \textit{Total Noise} \end{cases}$$

$I_{IC-DL}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$RSCP_{Tot-DL}^{TX_i(ic,\,TS(M_i))} = RSCP_{TCH-DL}^{TX_i(ic,\,TS(M_i))} + RSCP_{OCCH}^{TX_i(ic,\,TS(M_i))}$$

With $RSCP_{TCH-DL}^{TX_i(ic,\,TS(M_i))} = \dfrac{P_{TCH-DL}^{TX_i(ic,\,TS(M_i))}\Big|_{k-1}}{L_T^{Model}}$ and $RSCP_{OCCH}^{TX_i(ic,\,TS(M_i))} = \dfrac{P_{OCCH}^{TX_i(ic,\,TS(M_i))}}{L_T^{Model}}$

$L_T^{Model} = \dfrac{L_{Path} \times L^{TX_i} \times L^{M_i} \times L_{Body}^{M_i} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{M_i}}$ and $P_{TCH-DL}^{TX_i(ic,\,TS(M_i))}\Big|_{k-1}$ is the downlink traffic power transmitted on the timeslot allocated to M_i during the iteration *k* - 1. If M_i is an HSDPA user, $P_{TCH-DL}^{TX_i(ic,\,TS(M_i))} = 0.1 \times P_{TCH-DL}^{TX_i(ic,\,TS(M_i))}$

In L_T^{Model}, $G^{TX_i} = G_{DL}^{SA}$ and $L^{TX_i} = L_{DL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{TCH-DL}^{TX_i(ic,\,TS(M_i))}$ only and not for $P_{OCCH}^{TX_i(ic,\,TS(M_i))}$, if a smart antenna is available in the downlink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

$I_{MM}(M_i, M_j) = \dfrac{\sum_{M_j} RSCP_{TCH-UL}^{M_j}(M_i)}{F_{IRF}(ic, jc)}$ is the interference from each mobile M_j transmitting in the uplink on the same timeslots as those on which the mobile M_i is receiving in the downlink. M_j can interfere M_i directly if and only if:

- The distance between M_i and M_j (d^{Mi-Mj}) is less than the Max Distance between interfering mobiles defined by the user when starting the simulation, and
- The downlink timeslot of M_i (TS_{Mi}) is the same as the uplink timeslot of M_j, (TS_{Mj}).

The interference received from the mobile M_j at the mobile M_i is calculated using either the free-space propagation model or the Xia model.

$$RSCP_{TCH-UL}^{M_j}(M_i) = \frac{P_{TCH-UL}^{M_j}}{L_{MM}}$$

$L_{MM} = \begin{cases} 32.4 + 20 \times Log(F_{Avg}) + 20 \times Log(d) & \text{If } d^{M_i-M_j} \leq 3\,m \\ 49 + 30 \times Log(F_{Avg}) + 40 \times Log(d) & \text{If } d^{M_i-M_j} > 3\,m \end{cases}$ with F_{Avg} being the average frequency in MHz of the frequency band used by the best server of the mobile M_i, and d is the distance between the mobiles M_i and M_j in km.

Calculation of Downlink Required Power ($P_{Req}^{TX_i(ic,\,TS(M_i))}$):

Then **9955** determines the required downlink power by:

$$P_{Req}^{TX_i(ic,\,TS(M_i))}\Big|_k = P_{Req}^{TX_i(ic,\,TS(M_i))}\Big|_{k-1} \times \frac{\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic,\,TS(M_i))}}$$

or $P_{Req}^{TX_i(ic,\,TS(M_i))}\Big|_k = P_{Req}^{TX_i(ic,\,TS(M_i))}\Big|_{k-1} \times \dfrac{\left(\frac{C}{I}\right)_{TCH-DL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic,\,TS(M_i))}}$

And if $P_{Req}^{TX_i(ic,\,TS(M_i))} < P_{TCH-DL}^{Min}(Service)$ then $P_{Req}^{TX_i(ic,\,TS(M_i))} = P_{TCH-DL}^{Min}(Service)$

If $P_{Req}^{TX_i(ic,\,TS(M_i))} > P_{TCH-DL}^{Max}(Service)$ then the mobile M_i is rejected for the reason "Ptch > PtchMax", and $P_{Req}^{TX_i(ic,\,TS(M_i))}$ is set to 0.

$P_{TCH-DL}^{Min}(Service)$ and $P_{TCH-DL}^{Max}(Service)$ are set in the properties of the R99 bearer associated with the service used by the mobile M_i.

Otherwise, the downlink traffic power is incremented $P_{TCH-DL}^{TX_i(ic,\,TS(M_i))} = P_{TCH-DL}^{TX_i(ic,\,TS(M_i))} + P_{Req}^{TX_i(ic,\,TS(M_i))}$

For each mobile, **9955** also calculates the downlink traffic power for the different values of the Angular Step θ_{Step}.

$$RSCP_{TCH-DL}^{TX_i(ic,\,TS(M_i))}\Big|_{\theta_{Step}} = RSCP_{TCH-DL}^{TX_i(ic,\,TS(M_i))} \times \frac{G_{DL}^{SA}}{L_{DL}^{SA}(\theta_{Step})}$$

Where $RSCP_{TCH-DL}^{TX_i(ic,\,TS(M_i))} = \dfrac{P_{Req}^{TX_i(ic,\,TS(M_i))}\Big|_{k-1}}{L_T^{Model}}$

$L_T^{Model} = \frac{L_{Path} \times L^{TX_i} \times L^{M_i} \times L_{Body}^{M_i} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{M_i}}$ and $P_{Req}^{TX_i(ic, TS(M_i))}\Big|_{k-1}$ is the downlink traffic power for iteration k - 1 transmitted on the timeslot allocated to M_i.

In L_T^{Model}, $G^{TX_i} = G_{DL}^{SA}$ and $L^{TX_i} = L_{DL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{Req}^{TX_i(ic, TS(M_i))}$, if a smart antenna is available in the downlink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

> The downlink power for mobiles inactive in the downlink accessing circuit- or packet-switched services are calculated for information only.

8.3.2.2.5 Uplink Signals Update

This step uses the uplink terminal powers calculated for each timeslot allocated to the mobiles. The Dynamic Channel Allocation allocates timeslots and carriers to all the connected and active mobiles. The Dynamic Channel Allocation is performed once only, during the first iteration, and the timeslot and carrier allocation remains the same for all the following iterations of a simulation.

This step updates the received signals for all the mobiles M_i interfered in the uplink by the uplink connection between interfering mobiles M_j and their best servers $TX_j(ic)$, only if $TX_j(ic)$ contain M_i in their coverage areas. $TX_i(ic)$ is the interfered receiver and M_i is the focus, i.e., the mobile that is listened to by the transmitter $TX_i(ic)$.

For each mobile M_i interfered by M_j in the uplink by the connection between M_j and $TX_j(ic)$, **9955** updates $RSCP_{TCH-UL}^{TX_i(ic, TS(M_i))}$.

8.3.2.2.6 Downlink Signals Update

For the first iteration, i.e., k = 0, the downlink traffic powers for all the downlink timeslots are set to 0 Watts. Therefore, for the first iteration, this step is performed for any downlink timeslot for each mobile M_i that is connected and active.

However, for the following iterations, the downlink signals update step uses the actual downlink traffic powers calculated for each timeslot and the actual timeslots allocated to the mobiles. The Dynamic Channel Allocation allocates timeslots and carriers to all the connected and active mobiles. The Dynamic Channel Allocation is performed once only during the first iteration and the timeslot and carrier allocation remains the same for all the following iterations of a simulation.

Therefore, this step is performed for any downlink timeslot for each mobile M_i that is connected and active for the first iteration, and this step is performed for all the downlink timeslots allocated to the mobile M_i on which it is connected and active, for the following iterations since the DCA has been performed.

This step updates the received signals for all the mobiles in the $TX_i(ic)$ coverage area which are interfered in the downlink by the connection between $TX_i(ic)$ and M_i.

For each mobile interfered by M_i, **9955** updates $RSCP_{TCH-DL}^{TX_i(ic, TS(M_i))}$

Where $TX_i(ic)$ is the transmitter considered and M_i is the focus, i.e., the mobile that is the target for $TX_i(ic)$.

8.3.2.2.7 Control of Radio Resource Limits (Downlink Traffic Power and Uplink Load)

This step checks whether the downlink traffic powers of the downlink timeslots and the uplink loads of the uplink timeslots of all the cells satisfy the conditions defined globally or per cell and timeslot.

Downlink Power Control:

9955 verifies that the total R99 power transmitted by any cell on any timeslot does not exceed the effective maximum cell power per timeslot. The effective maximum cell traffic power per timeslot is calculated as:

$$P_{Max-DL-Eff}^{TX_i(ic, TS(M_i))} = P_{Max-DL}^{TX_i(ic, TS(M_i))} \times \%P_{Max-DL}$$

Where $P_{Max-DL}^{TX_i(ic, TS(M_i))}$ is the maximum cell power per timeslot defined per cell, and $\%P_{Max-DL}$ is the maximum allowed downlink load either taken from the properties of each cell or from the simulation properties if a global value is defined.

For each transmitter TX_i, carrier ic, and downlink timeslot TS_{M_i},

$$P_{R99-DL}^{TX_i(ic,\,TS(M_i))} = P_{TCH-DL}^{TX_i(ic,\,TS(M_i))} + P_{OCCH}^{TX_i(ic,\,TS(M_i))}$$

If $P_{R99-DL}^{TX_i(ic,\,TS(M_i))} > P_{Max-DL-Eff}^{TX_i(ic,\,TS(M_i))}$ the mobile with the lowest service priority is rejected for the reason "DL Load Saturation".

Uplink Load Control:

9955 verifies that the uplink load of any cell on any timeslot does not exceed the maximum uplink cell load allowed per timeslot.

The maximum allowed uplink cell load, $X_{Max-UL}^{TX_i(ic,\,TS(M_i))}$, is either taken from the properties of each cell or from the simulation properties if a global value is defined.

For each transmitter TX_i, carrier ic, and uplink timeslot TS_{M_i},

If $X_{UL}^{TX_i(ic,\,TS(M_i))} > X_{Max-UL}^{TX_i(ic,\,TS(M_i))}$ the mobile with the lowest service priority is rejected for the reason "UL Load Saturation".

The uplink load is given by:

$$X_{UL}^{TX_i(ic,\,TS(M_i))} = \frac{N_{Tot-UL}^{TX_i(ic,\,TS(M_i))}}{N_{Tot-UL}^{TX_i(ic,\,TS(M_i))} + N_0^{TX_i}}$$ if no smart antenna is used by the transmitter in the uplink.

If a smart antenna is used by the transmitter in the uplink, the smart antenna gain is taken into account in the calculation of uplink load.

8.3.2.3 HSDPA Part of the Algorithm

The following calculations are made for all HSDPA mobiles (M_i).

8.3.2.3.1 HSDPA Power Allocation

The total transmitted power of the cell ($P_{Tot-DL}^{TX_i(ic)}$) is the sum of the R99 transmitted power and the HSDPA powers.

$$P_{Tot-DL}^{TX_i(ic)} = P_{R99-DL}^{TX_i(ic)} + P_{HR}^{TX_i(ic)} + P_{HS-SCCH}^{TX_i(ic)} + P_{HS-PDSCH}^{TX_i(ic)}$$

The HSDPA powers, i.e., the HS-SCCH and HS-PDSCH powers are calculated as follows:

- **HS-SCCH Power:**

  HS-SCCH channels are transmitted on DL traffic timeslots. The maximum number of supported HS-SCCH channels is defined per cell. Power can be allocated to HS-SCCH statically or dynamically:

  - **Static Allocation**

    The static HS-SCCH power is defined in the properties of the HSDPA cell.

  - **Dynamic Allocation**

    HS-SCCH power is calculated for $\left(\frac{E_c}{N_t}\right)_{HS-SCCH}^{TX_i(ic)} = Q_{HS-SCCH}^{Req}(Mobility)$ so that $P_{HS-SCCH}^{TX_i(ic)} < P_{Available-HS-SCCH}^{TX_i(ic)}$.

    Where $P_{Available-HS-SCCH}^{TX_i(ic)} = P_{Max-DL-Eff}^{TX_i(ic)} - P_{R99-DL}^{TX_i(ic)} - P_{HR}^{TX_i(ic)}$ is the power available for HS-SCCH in the cell $TX_i(ic)$, and $P_{R99-DL}^{TX_i(ic)} = P_{TCH-DL}^{TX_i(ic)} + P_{OCCH}^{TX_i(ic)}$.

    The effective maximum cell traffic power per timeslot is calculated as: $P_{Max-DL-Eff}^{TX_i(ic)} = P_{Max-DL}^{TX_i(ic)} \times \%P_{Max-DL}$.

    $P_{Max-DL}^{TX_i(ic)}$ is the maximum power defined per cell, and $\%P_{Max-DL}$ is the maximum allowed downlink load either taken from the properties of each cell or from the simulation properties if a global value is defined.

$$P_{HS-SCCH}^{TX_i(ic)} = \frac{\left(\frac{E_c}{N_t}\right)_{HS-SCCH}^{TX_i(ic)} \times \left(N_{Tot-DL}^{TX_i(ic)} - \beta \times \gamma^{TX_i} \times RSCP_{HS-SCCH}^{TX_i(ic)}\right)}{\rho^{TX_i}} \times L_T^{Model}$$

Where $N_{Tot-DL}^{TX_i(ic)}$ is the downlink total noise calculated in "Downlink Power Control" on page 570,

$\gamma^{TX_i} = \rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times \left(1 - F_{JD}^{M_i}\right)$ and $\beta = \begin{cases} 0 & \textit{Without Useful Signal} \\ 1 & \textit{Total Noise} \end{cases}$

$L_T^{Model} = \dfrac{L_{Path} \times L^{TX_i} \times L^{M_i} \times L_{Body}^{M_i} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{M_i}}$ and $P_{HS-SCCH}^{TX_i(ic)}$ is the HS-SCCH power calculated for the timeslots allocated to M_i.

In L_T^{Model}, $G^{TX_i} = G_{DL}^{SA}$ and $L^{TX_i} = L_{DL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{HS-SCCH}^{TX_i(ic)}$, if a smart antenna is available in the downlink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

- **HS-PDSCH Power:**

  HS-PDSCH channels are transmitted on DL traffic timeslots. Power can be allocated to HS-PDSCH statically or dynamically:

  - **Static Allocation**

    The static HS-PDSCH power is defined in the properties of the HSDPA cell.

  - **Dynamic Allocation**

    HS-PDSCH power is calculated as follows:

    $P_{HS-PDSCH}^{TX_i(ic)} = P_{Max-DL-Eff}^{TX_i(ic)} - P_{R99-DL}^{TX_i(ic)} - P_{HR}^{TX_i(ic)} - P_{HS-SCCH}^{TX_i(ic)}$

    Where $P_{R99-DL}^{TX_i(ic)} = P_{TCH-DL}^{TX_i(ic)} + P_{OCCH}^{TX_i(ic)}$. The effective maximum cell traffic power per timeslot is calculated as: $P_{Max-DL-Eff}^{TX_i(ic)} = P_{Max-DL}^{TX_i(ic)} \times \%P_{Max-DL}$. $P_{Max-DL}^{TX_i(ic)}$ is the maximum power defined per cell, and $\%P_{Max-DL}$ is the maximum allowed downlink load either taken from the properties of each cell or from the simulation properties if a global value is defined.

The HS-SICH power is calculated as follows:

- **HS-SICH Power:**

  HS-SICH channels can be transmitted on any UL traffic timeslot. The maximum number of supported HS-SICH channels is defined per cell. Power can be allocated to HS-SICH statically or dynamically:

  - **Static Allocation**

    The static HS-SICH power is defined in the properties of the terminal used by the HSDPA mobile M_i.

  - **Dynamic Allocation**

    HS-SICH power is calculated for $\left(\dfrac{E_c}{N_t}\right)_{HS-SICH}^{TX_i(ic)} = Q_{HS-SICH}^{Req}(Mobility)$ so that $P_{HS-SICH}^{M_i} < P_{Max-HS-SICH}^{TX_i(ic)}$ and $P_{HS-SICH}^{M_i} < P_{Max-HS-SICH}^{M_i}$.

    $$P_{HS-SICH}^{M_i} = \frac{\left(\dfrac{E_c}{N_t}\right)_{HS-SICH}^{TX_i(ic)} \times \left(N_{Tot-UL}^{TX_i(ic)} - \beta \times \gamma^{M_i} \times RSCP_{HS-SICH}^{M_i}\right)}{\rho^{M_i}} \times L_T^{Model}$$

    Where $N_{Tot-UL}^{TX_i(ic)}$ is the uplink total noise calculated in "Uplink Power Control" on page 569,

    $\gamma^{M_i} = \rho^{M_i} \times (1 - F_{UL}^{Ortho}) \times \left(1 - F_{JD}^{TX_i}\right)$ and $\beta = \begin{cases} 0 & \textit{Without Useful Signal} \\ 1 & \textit{Total Noise} \end{cases}$

    $L_T^{Model} = \dfrac{L_{Path} \times L^{TX_i} \times L^{M_i} \times L_{Body}^{M_i} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{M_i}}$ and $P_{HS-SICH}^{M_i}$ is the HS-SICH power calculated for the timeslots allocated to M_i.

In L_T^{Model}, $G^{TX_i} = G_{UL}^{SA}$ and $L^{TX_i} = L_{UL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{HS-SICH}^{M_i}$, if a smart antenna is available in the uplink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

The total transmitted power of the cell ($P_{Tot-DL}^{TX_i(ic)}$) is the sum of the R99 transmitted power and the HSDPA powers.

$$P_{Tot-DL}^{TX_i(ic)} = P_{R99-DL}^{TX_i(ic)} + P_{HR}^{TX_i(ic)} + P_{HS-SCCH}^{TX_i(ic)} + P_{HS-PDSCH}^{TX_i(ic)}$$

8.3.2.3.2 Connection Status and Number of HSDPA Users

HSDPA users cannot receive HS-SCCH and HS-PDSCH powers simultaneously. HS-PDSCH arrives 3 timeslots after the HS-SCCH. HS-SICH is 9 timeslots afte the HS-PDSCH. **9955** assumes that an active HSDPA user has the same probability of receiving HS-SCCH and HS-PDSCH, and transmitting HS-SICH because their occurence is equally likely. Therefore, each HSDPA user is assigned a sub-connection status randomly. The sub-connection status can be:

- HS-SCCH: HSDPA mobile that is receiving HS-SCCH power
- HS-PDSCH: HSDPA mobile that is receiving traffic power
- HS-SICH: HSDPA mobile that is transmitting HS-SICH power

The number of active HSDPA users belonging to each sub-connection status is 1/3rd of the total number of active HSDPA users.

$n_{HS-SCCH}$ is the maximum number of HS-SCCH channels and $n_{HS-SICH}$ is the maximum number of HS-SICH channels that the cell can manage. Each HSDPA user consumes one HS-SCCH and HS-SICH channels. Therefore, at a given instance, the number of connected HSDPA users cannot exceed the number of HS-SCCH and HS-SICH channels per cell. The maximum number of HSDPA users (n_{Max}) corresponds to the maximum number of HSDPA users that the cell can support.

8.3.2.3.3 HSDPA Admission Control

HS-SCCH

HS-SCCH admission control is performed for active HSDPA users connected to A-DCH bearers on the downlink and having an HS-SCCH sub-connection status. Each cell is able to manage a maximum number of HS-SCCH channels, $n_{HS-SCCH}$. During the R99 part, the DCA provides a DL timeslot with one SF16 resource unit that has the downlink Ec/Nt higher than the required quality. If no cell with such a resource unit is available, the user is rejected.

HS-SICH

HS-SICH admission control is performed for active HSDPA users connected to A-DCH bearers on the uplink and having an HS-SICH sub-connection status. Each cell is able to manage a maximum number of HS-SICH channels, $n_{HS-SICH}$. During the R99 part, the DCA provides an UL timeslot with one SF16 resource unit that has the uplink Ec/Nt higher than the required quality. If no cell with such a resource unit is available, the user is rejected.

HS-PDSCH

Scheduling is performed for active HSDPA users connected to A-DCH bearers on the downlink and having an HS-PDSCH sub-connection status. The scheduling is performed as follows:

1. Each HS-PDSCH user is considered as the only served user. The scheduler allocates the best available HSDPA bearer to each user. The best available HSDPA bearer is selected depending on the user's Ec/Nt. If no bearer can be allocated due to low Ec/Nt, the user is rejected for the reason "HSDPA Scheduler Saturation".

   The required HS-PDSCH Ec/Nt value is read from receiver equipment properties. For each bearer, **9955** checks that the Ec/Nt reaches the quality target. HS-PDSCH Ec/Nt is calculated by taking into account all intra and extra cells interferences.

2. The scheduler sorts the HS-PDSCH users to whom bearers have been assigned in the order of decreasing RLC peak rates. If two users have the same bearer, the user with the higher Ec/Nt has the higher rank.
3. The scheduler considers the group of HS-PDSCH users to whom bearers, HS-SCCH, and HS-SICH have been assigned. The number of HS-PDSCH users cannot exceed the maximum number of HSDPA users (n_{Max}) supported by the cell. If there are enough HSDPA power and resource units available in order to obtain a HSDPA bearer, the users will be connected. Otherwise, they will be delayed and their connection status will be "HSDPA Delayed".
4. Other HS-PDSCH users will be rejected for the reason "HSDPA Scheduler Saturation".

For N-frequency mode compatible transmitters, the resource units available in the master and slave carriers can be shared, i.e., a mobile can be connected to timeslots belonging more than one carrier.

8.3.2.3.4 HSDPA Dynamic Channel Allocation

For each mobile connected to the A-DPCH bearer:

1. **9955** selects the HSDPA bearers that match to the mobile terminal and UE category parameters.
2. For each bearer supported by a mobile:
   a. The scheduler searches for the best collection of "n" ordered timeslots that can provide enough resource units to support the service, and whose Ec/Nt is better than the minimum required and enough to reach the bearer’s resource unit requirements. The best is determined by applying the R99 Dynamic Channel Allocation algorithm.
   b. The scheduler calculates the HS-PDSCH Ec/Nt for each timeslot of the best collection. The Ec/Nt value associated with the mobile-bearer pair is the worst one of all selected timeslots.
   c. If the scheduler is unable to find a satisfactory timeslot collection, the bearer is removed from the list of supported bearers.
3. The mobile is connected to the supported bearer having the highest RLC peak rate. If two bearers have the same RLC peak rate, the best one is the one with the highest Ec/Nt.

8.3.2.3.5 Ressource Unit Saturation

For each time slot, a minimum and maximum number of resource units for HSDPA users are defined in the cell properties. **9955** dynamically allocates the required number of codes respecting these limitations. The minimum number of HSDPA codes is excluded from the set of codes available for R99 users. The scheduler checks if enough codes are available for the selected HSDPA bearer (taking into account the maximum number of HSDPA codes). If not, the scheduler allocates a lower HSDPA bearer which needs fewer codes. If there are no more resource units available for the lowest HSDPA bearer, the user will be delayed or rejected.

8.3.2.4 Convergence Criteria

The convergence criteria are evaluated for each iteration and can be written as follows:

$$\Delta_{DL} = Int\left(\underset{All\ TX_i}{Max} \left(P_{Err}^{TX_i(ic,\ TS(M_i))} \right) \times 100 \right)$$

$$\Delta_{UL} = Int\left(\underset{All\ TX_i}{Max} \left| \frac{N_{Tot-UL}^{TX_i(ic,\ TS(M_i))}\Big|_k - N_{Tot-UL}^{TX_i(ic,\ TS(M_i))}\Big|_{k-1}}{N_{Tot-UL}^{TX_i(ic,\ TS(M_i))}\Big|_k} \right| \times 100 \right)$$

Where, $P_{Err}^{TX_i(ic,\ TS(M_i))}$ is given by:

$$P_{Err}^{TX_i(ic,\ TS(M_i))} = \underset{0° \le \theta_{Step} < 360°}{Max} \left| \frac{P_{Rec}^{TX_i(ic,\ TS(M_i))}\Big|_{\theta_{Step},\ k} - P_{Rec}^{TX_i(ic,\ TS(M_i))}\Big|_{\theta_{Step},\ k-1}}{P_{Rec}^{TX_i(ic,\ TS(M_i))}\Big|_{\theta_{Step},\ k}} \right|$$ with smart antennas.

$$P_{Err}^{TX_i(ic,\ TS(M_i))} = \left| \frac{P_{Rec}^{TX_i(ic,\ TS(M_i))}\Big|_k - P_{Rec}^{TX_i(ic,\ TS(M_i))}\Big|_{k-1}}{P_{Rec}^{TX_i(ic,\ TS(M_i))}\Big|_k} \right|$$ without smart antennas.

9955 stops the simulations in the following cases:

- **Convergence:** Between two successive iterations, Δ_{DL} and Δ_{UL} are less than or equal to their respective thresholds (defined when creating a simulation).

  Example: Let us assume that the maximum number of iterations is 100, and the UL and DL convergence thresholds are set to 5 %. If $\Delta_{DL} \le 5$ and $\Delta_{UL} \le 5$ between the 4th and the 5th iteration, **9955** stops the algorithm after the 5th iteration. The simulation has converged.

- **Divergence:** After 30 iterations, Δ_{DL} and/or Δ_{UL} are still higher than their respective thresholds and from the 30th iteration, Δ_{DL} and/or Δ_{UL} do not decrease during the next 15 successive iterations.

Examples: Let us assume that the maximum number of iterations is 100, and the UL and DL convergence thresholds are set to 5 %.

a. After the 30th iteration, Δ_{DL} and/or Δ_{DL} equal 100 and do not decrease during the next 15 successive iterations. **9955** stops the algorithm at the 46th iteration. The simulation has not converged.

b. After the 30th iteration, Δ_{DL} and/or Δ_{UL} equal 80, they start decreasing slowly until the 40th iteration (without going under the thresholds) and then, do not change during 15 successive iterations. **9955** stops the algorithm at the 56th iteration without converging.

- **Last Iteration:** If Δ_{DL} and/or Δ_{UL} are still much higher than their respective thresholds after the last iteration, the simulation has not converged. If Δ_{DL} and Δ_{UL} are lower than their respective thresholds, the simulation has reached convergence.

8.4 TD-SCDMA Prediction Studies

For each TBC transmitter, TX_i, **9955** determines the value of the selected parameter on each studied pixel inside the TX_i calculation area. Each pixel within the TX_i calculation area is considered a probe receiver.

Coverage study parameters to be set are:

- The study conditions to determine the service area of each TBC transmitter
- The display settings to for colouring the covered pixels

9955 uses the parameters entered in the *Condition* tab of the coverage study properties dialogue to determine pixels covered by the each transmitter. Coverage prediction display resolution is independent of the path loss matrix and geographic data resolutions, and can be different for each coverage prediction. Coverage predictions are calculated using bilinear interpolation of multi-resolution path loss matrices (similar to the evaluation of site altitudes).

8.4.1 P-CCPCH Reception Analysis (Eb/Nt) or (C/I)

These coverage predictions calculate and display the Eb/Nt or C/I on the P-CCPCH, $\left(\frac{E_b}{N_t}\right)_{P-CCPCH}$ or $\left(\frac{C}{I}\right)_{P-CCPCH}$. The coverage predictions are calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for TS0. The best servers for the coverage predictions are determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage predictions are calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform these coverage predictions for the best carrier, **9955** calculates the Eb/Nt or C/I considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and $\left(\frac{E_b}{N_t}\right)_{P-CCPCH}^{TX_i(ic)} \geq Q_{P-CCPCH}^{Req}$ or $\left(\frac{C}{I}\right)_{P-CCPCH}^{TX_i(ic)} \geq Q_{P-CCPCH}^{Req}$ are covered and coloured according to the selected display option.

Where $\left(\frac{E_b}{N_t}\right)_{P-CCPCH}^{TX_i(ic)} = \frac{\rho^{TX_i} \times RSCP_{P-CCPCH}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}} \times G_{P-CCPCH}^{Proc}$ and $\left(\frac{C}{I}\right)_{P-CCPCH}^{TX_i(ic)} = \frac{\rho^{TX_i} \times RSCP_{P-CCPCH}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}}$

$$RSCP_{P-CCPCH}^{TX_i(ic)} = \frac{P_{P-CCPCH}^{TX_i(ic)}}{L_T}$$

The downlink total noise is calculated as follows:

$$N_{Tot-DL}^{TX_i(ic)} = I_{Intra-DL}^{TX_i(ic)} + I_{Extra-DL}^{TX_i(ic)} + I_{IC-DL}(ic, jc) + N_0^{Term}$$

Where

$$I_{Intra-DL}^{TX_i(ic)} = RSCP_{P-CCPCH}^{TX_i(ic)} \times \beta \times \gamma^{TX_i} + RSCP_{OCCH-TS0}^{TX_i(ic)} \times \gamma^{TX_i}$$

With $\gamma^{TX_i} = \rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times (1 - F_{JD}^{Term})$ and $\beta = \begin{cases} 0 & \text{Without Useful Signal} \\ 1 & \text{Total Noise} \end{cases}$

$$I_{Extra-DL}^{TX_i(ic)} = \sum_{j \neq i} \left(RSCP_{P-CCPCH}^{TX_j(ic)} + RSCP_{OCCH-TS0}^{TX_j(ic)} \right)$$

$$I_{IC-DL}(ic, jc) = \frac{\sum_{TX_j} \left(RSCP_{P-CCPCH}^{TX_j(jc)} + RSCP_{OCCH-TS0}^{TX_j(jc)} \right)}{F_{IRF}(ic, jc)}$$

$I_{IC-DL}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$RSCP_{OCCH-TS0}^{TX_i(ic)} = \frac{P_{OCCH-TS0}^{TX_i(ic)}}{L_T}$$

$$L_T = \frac{L_{Path} \times L^{TX_i} \times L^{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{Eb/Nt}}{G^{TX_i} \times G^{Term}}$$

ρ^{TX_i} and N_0^{Term} are defined in "Definitions and Formulas" on page 547.

Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **Eb/Nt or C/I (dB)**

  9955 calculates the Eb/Nt or C/I on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the Eb/Nt or C/I level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{E_b}{N_t}\right)_{P-CCPCH}^{TX_i(ic)} \geq Threshold$ or $\left(\frac{C}{I}\right)_{P-CCPCH}^{TX_i(ic)} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **Eb/Nt Margin or C/I Margin (dB)**

  9955 calculates the Eb/Nt or C/I margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the Eb/Nt or C/I margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{E_b}{N_t}\right)_{P-CCPCH}^{TX_i(ic)} - Q_{P-CCPCH}^{Req} \geq M_{P-CCPCH}^{Eb/Nt}$ or $\left(\frac{C}{I}\right)_{P-CCPCH}^{TX_i(ic)} - Q_{P-CCPCH}^{Req} \geq M_{P-CCPCH}^{C/I}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  9955 calculates the cell edge coverage probability on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the cell edge coverage probability value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left.\left(\frac{E_b}{N_t}\right)_{P-CCPCH}^{TX_i(ic)}\right|_{CECP} \geq Q_{P-CCPCH}^{Req}$ or $\left.\left(\frac{C}{I}\right)_{P-CCPCH}^{TX_i(ic)}\right|_{CECP} \geq Q_{P-CCPCH}^{Req}$. Each layer is assigned a colour and displayed with intersections between layers.

8.4.2 DwPCH Reception Analysis (C/I)

This coverage prediction calculates and displays the C/I on the DwPCH, $\left(\frac{C}{I}\right)_{DwPCH}$. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for DwPTS. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the C/I considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and $\left(\frac{C}{I}\right)_{DwPCH}^{TX_i(ic)} \geq Q_{DwPCH}^{Req}$ are covered and coloured according to the selected display option.

Where $\left(\frac{C}{I}\right)_{DwPCH}^{TX_i(ic)} = \frac{\rho^{TX_i} \times RSCP_{DwPCH}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}}$

$$RSCP_{DwPCH}^{TX_i(ic)} = \frac{P_{DwPCH}^{TX_i(ic)}}{L_T}$$

The downlink total noise is calculated as follows:

$$N_{Tot-DL}^{TX_i(ic)} = I_{Intra-DL}^{TX_i(ic)} + I_{Extra-DL}^{TX_i(ic)} + I_{IC-DL}(ic, jc) + N_0^{Term}$$

Where

$$I_{Intra-DL}^{TX_i(ic)} = RSCP_{DwPCH}^{TX_i(ic)} \times \beta \times \gamma^{TX_i}$$

With $\gamma^{TX_i} = \rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times (1 - F_{JD}^{Term})$ and $\beta = \begin{cases} 0 & \text{Without Useful Signal} \\ 1 & \text{Total Noise} \end{cases}$

$$I_{Extra-DL}^{TX_i(ic)} = \sum_{j \neq i} \left(RSCP_{DwPCH}^{TX_j(ic)}\right)$$

$$I_{IC-DL}(ic, jc) = \frac{\sum_{TX_j} \left(RSCP_{DwPCH}^{TX_j(jc)}\right)}{F_{IRF}(ic, jc)}$$

$I_{IC-DL}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$L_T = \frac{L_{Path} \times L^{TX_i} \times L^{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{Eb/Nt}}{G^{TX_i} \times G^{Term}}$$

ρ^{TX_i} and N_0^{Term} are defined in "Definitions and Formulas" on page 547.

Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **C/I (dB)**

  9955 calculates the C/I on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the C/I level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{C}{I}\right)_{DwPCH}^{TX_i(ic)} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **C/I Margin (dB)**

  9955 calculates the C/I margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the C/I margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{C}{I}\right)^{TX_i(ic)}_{DwPCH} - Q^{Req}_{DwPCH} \geq M^{C/I}_{DwPCH}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  9955 calculates the cell edge coverage probability on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the cell edge coverage probability value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left.\left(\frac{C}{I}\right)^{TX_i(ic)}_{DwPCH}\right|_{CECP} \geq Q^{Req}_{DwPCH}$. Each layer is assigned a colour and displayed with intersections between layers.

8.4.3 Downlink TCH RSCP Coverage

This coverage prediction calculates and displays the RSCP for the downlink traffic channel, $RSCP_{TCH-DL}$. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for a downlink timeslot. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP^{TX_i(ic)}_{P-CCPCH} \geq TAdd_{P-CCPCH}(Mobility)$ and $RSCP^{TX_i(ic)}_{TCH-DL} \geq RSCP^{Req}_{TCH-DL}(Service, Mobility)$ are covered and coloured according to the selected display option.

Where $RSCP^{TX_i(ic)}_{TCH-DL}$ is given by:

$$RSCP^{TX_i(ic)}_{TCH-DL} = \frac{P^{Max}_{TCH-DL}(Service)}{L^{Model}_T}$$

$L^{Model}_T = \dfrac{L_{Path} \times L^{TX_i} \times L^{Term} \times L_{Body} \times L_{Indoor} \times M^{Model}_{Shadowing}}{G^{TX_i} \times G^{Term}}$ and $P^{Max}_{TCH-DL}(Service)$ is the maximum downlink traffic power defined for the selected service.

In L^{Model}_T, $G^{TX_i} = G^{SA}_{DL}$ and $L^{TX_i} = L^{SA}_{DL}$ are calculated according to the smart antenna modelling method used, for $P^{Max}_{TCH-DL}(Service)$, if a smart antenna is available in the downlink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **DL TCH RSCP (dBm)**

  9955 calculates the DL TCH RSCP on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the RSCP level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $RSCP^{TX_i(ic)}_{TCH-DL} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **RSCP Margin (dB)**

  9955 calculates the RSCP margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the RSCP margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $RSCP_{TCH-DL}^{TX_i(ic)} - RSCP_{TCH-DL}^{Req}(Service, Mobility) \geq M_{TCH-DL}^{RSCP}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  9955 calculates the cell edge coverage probability on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the cell edge coverage probability value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $RSCP_{TCH-DL}^{TX_i(ic)}\Big|_{CECP} \geq RSCP_{TCH-DL}^{Req}(Service, Mobility)$. Each layer is assigned a colour and displayed with intersections between layers.

8.4.4 Uplink TCH RSCP Coverage

This coverage prediction calculates and displays the RSCP for the uplink traffic channel, $RSCP_{TCH-UL}$. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for an uplink timeslot. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and $RSCP_{TCH-UL}^{TX_i(ic)} \geq RSCP_{TCH-UL}^{Req}(Service, Mobility)$ are covered and coloured according to the selected display option.

Where $RSCP_{TCH-UL}^{TX_i(ic)}$ is given by:

$$RSCP_{TCH-UL}^{TX_i(ic)} = \frac{P_{Max}^{Term}}{L_T^{Model}}$$

$$L_T^{Model} = \frac{L_{Path} \times L^{TX_i} \times L^{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{Term}}$$

and P_{Max}^{Term} is the maximum uplink traffic power defined for the selected terminal.

In L_T^{Model}, $G^{TX_i} = G_{UL}^{SA}$ and $L^{TX_i} = L_{UL}^{SA}$ are calculated according to the smart antenna modelling method used, for P_{Max}^{Term}, if a smart antenna is available in the uplink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **UL TCH RSCP (dBm)**

  9955 calculates the UL TCH RSCP on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the RSCP level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $RSCP_{TCH-UL}^{TX_i(ic)} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **RSCP Margin (dB)**

  9955 calculates the RSCP margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the RSCP margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $RSCP_{TCH-UL}^{TX_i(ic)} - RSCP_{TCH-UL}^{Req}(Service, Mobility) \geq M_{TCH-UL}^{RSCP}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  9955 calculates the cell edge coverage probability on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the cell edge coverage probability value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $RSCP_{TCH-UL}^{TX_i(ic)}\Big|_{CECP} \geq RSCP_{TCH-UL}^{Req}(Service, Mobility)$. Each layer is assigned a colour and displayed with intersections between layers.

8.4.5 Downlink Total Noise

This coverage prediction calculates and displays the total noise on the downlink, N_{Tot-DL}. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for a downlink timeslot. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the downlink noise for all the carriers but keeps the worst case value, i.e., the most interfered carrier. You can choose to display the minimum, the maximum, or the average total noise values from among the values calculated for all the carriers. Pixels are covered and coloured according to the total downlink noise thresholds defined in the display options.

Total downlink noise is given by: $N_{Tot-DL} = \sum_{\text{All TX, c, and TS}} (RSCP_{TCH-DL} + RSCP_{OCCH}) + N_0^{Term}$

With $RSCP_{TCH-DL} = \frac{P_{TCH-DL}}{L_T^{Model}}$ and $RSCP_{OCCH} = \frac{P_{OCCH}}{L_T^{Model}}$

$L_T^{Model} = \frac{L_{Path} \times L^{TX_i} \times L^{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{Model}}{G^{TX_i} \times G^{Term}}$ and P_{TCH-DL} and P_{TCH-DL} are respectively the downlink traffic power and the other common control channel power for the selected timeslot.

In L_T^{Model}, $G^{TX_i} = G_{DL}^{SA}$ and $L^{TX_i} = L_{DL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{TCH-DL}^{Max}(Service)$, if a smart antenna is available in the downlink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

8.4.6 Downlink Service Area Analysis (Eb/Nt) or (C/I)

These coverage predictions calculate and display the Eb/Nt or C/I on the downlink traffic channel, $\left(\frac{E_b}{N_t}\right)_{TCH-DL}$ or $\left(\frac{C}{I}\right)_{TCH-DL}$.

The coverage predictions are calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for a downlink timeslot. The best servers for the coverage predictions are determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage predictions are calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform these coverage predictions for the best carrier, **9955** calculates the Eb/Nt or C/I considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$, $RSCP_{TCH-DL}^{TX_i(ic)} \geq RSCP_{TCH-DL}^{Req}(Service, Mobility)$, and $\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)} \geq Q_{TCH-DL}^{Req}$ or $\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)} \geq Q_{TCH-DL}^{Req}$ are covered and coloured according to the selected display option.

Where $\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)} = \frac{\rho^{TX_i} \times RSCP_{TCH-DL}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}} \times G_{DL}^{Proc} \times G_{DL}^{Div}$ and $\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)} = \frac{\rho^{TX_i} \times RSCP_{TCH-DL}^{TX_i(ic)}}{N_{Tot-DL}^{TX_i(ic)}} \times G_{DL}^{Div}$

With $RSCP_{TCH-DL}^{TX_i(ic)} = \frac{P_{TCH-DL}^{Max}(Service)}{L_T^{(Eb/Nt)_{DL}}}$

$L_T^{(Eb/Nt)_{DL}} = \frac{L_{Path} \times L^{TX_i} \times L^{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{(Eb/Nt)_{DL}}}{G^{TX_i} \times G^{Term}}$ and $P_{TCH-DL}^{Max}(Service)$ is the maximum downlink traffic power defined for the selected service.

In $L_T^{(Eb/Nt)_{DL}}$, $G^{TX_i} = G_{DL}^{SA}$ and $L^{TX_i} = L_{DL}^{SA}$ are calculated according to the smart antenna modelling method used, for $P_{TCH-DL}^{Max}(Service)$, if a smart antenna is available in the downlink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

$$N_{Tot-DL}^{TX_i(ic)} = I_{Intra-DL}^{TX_i(ic)} + I_{Extra-DL}^{TX_i(ic)} + I_{IC-DL}(ic, jc) + N_0^{Term}$$

Where

$$I_{Intra-DL}^{TX_i(ic)} = \left\{\rho^{TX_i} \times (1 - F_{DL}^{Ortho}) \times (1 - F_{JD}^{Term}) + \left(1 - \rho^{TX_i}\right)\right\} \times \left(RSCP_{TCH-DL}^{TX_i(ic)} + RSCP_{OCCH}^{TX_i(ic)}\right)$$

With $RSCP_{OCCH}^{TX_i(ic)} = \frac{P_{OCCH}^{TX_i(ic)}}{L_T^{(Eb/Nt)_{DL}}}$

$$I_{Extra-DL}^{TX_i(ic)} = \sum_{j \neq i}\left(RSCP_{TCH-DL}^{TX_j(ic)} + RSCP_{OCCH}^{TX_j(ic)}\right)$$

$$I_{IC-DL}(ic, jc) = \frac{\sum_{TX_j}\left(RSCP_{TCH-DL}^{TX_j(jc)} + RSCP_{OCCH}^{TX_j(jc)}\right)}{F_{IRF}(ic, jc)}$$

$I_{IC-DL}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **Max Eb/Nt or Max C/I (dB)**

  9955 calculates the Eb/Nt or C/I on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the Eb/Nt or C/I level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)} \geq Threshold$ or $\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **Effective Eb/Nt or Effective C/I (dB)**

  9955 calculates the effective Eb/Nt or C/I on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the effective Eb/Nt or C/I level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $Min\left(\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)}, Q_{TCH-DL}^{Req}\right) \geq Threshold$ or $Min\left(\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)}, Q_{TCH-DL}^{Req}\right) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **Eb/Nt Margin or C/I Margin (dB)**

9955 calculates the Eb/Nt or C/I margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the Eb/Nt or C/I margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)} - Q_{TCH-DL}^{Req} \geq M_{TCH-DL}^{Eb/Nt}$ or $\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)} - Q_{TCH-DL}^{Req} \geq M_{TCH-DL}^{C/I}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Required Power (dBm)**

  9955 calculates the downlink required power on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the required power level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $P_{TCH-DL}^{Req} \geq Threshold$, where $P_{TCH-DL}^{Req} = \frac{Q_{TCH-DL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)}} \times P_{TCH-DL}^{Max}(Service)$ or $P_{TCH-DL}^{Req} = \frac{Q_{TCH-DL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)}} \times P_{TCH-DL}^{Max}(Service)$. Each layer is assigned a colour and displayed with intersections between layers.

- **Required Power Margin (dB)**

  9955 calculates the downlink required power margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the required power margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $P_{TCH-DL}^{Req} - P_{TCH-DL}^{Max}(Service) \geq Margin$, where $P_{TCH-DL}^{Req} = \frac{Q_{TCH-DL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)}} \times P_{TCH-DL}^{Max}(Service)$ or $P_{TCH-DL}^{Req} = \frac{Q_{TCH-DL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)}} \times P_{TCH-DL}^{Max}(Service)$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  9955 calculates the cell edge coverage probability on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the cell edge coverage probability value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left.\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)}\right|_{CECP} \geq Q_{TCH-DL}^{Req}$ or $\left.\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)}\right|_{CECP} \geq Q_{TCH-DL}^{Req}$. Each layer is assigned a colour and displayed with intersections between layers.

8.4.7 Uplink Service Area Analysis (Eb/Nt) or (C/I)

These coverage predictions calculate and display the Eb/Nt or C/I on the uplink traffic channel, $\left(\frac{E_b}{N_t}\right)_{TCH-UL}$ or $\left(\frac{C}{I}\right)_{TCH-UL}$.

The coverage predictions are calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for an uplink timeslot. The best servers for the coverage predictions are determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage predictions are calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform these coverage predictions for the best carrier, **9955** calculates the Eb/Nt or C/I considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$, $RSCP_{TCH-UL}^{TX_i(ic)} \geq RSCP_{TCH-UL}^{Req}(Service, Mobility)$, and $\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)} \geq Q_{TCH-UL}^{Req}$ or $\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)} \geq Q_{TCH-UL}^{Req}$ are covered and coloured according to the selected display option.

Where $\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)} = \frac{\rho^{Term} \times RSCP_{TCH-UL}^{TX_i(ic)}}{N_{Tot-UL}^{TX_i(ic)}} \times G_{UL}^{Proc} \times G_{UL}^{Div}$ and $\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)} = \frac{\rho^{Term} \times RSCP_{TCH-UL}^{TX_i(ic)}}{N_{Tot-UL}^{TX_i(ic)}} \times G_{UL}^{Div}$

With $RSCP_{TCH-UL}^{TX_i(ic)} = \frac{P_{Max}^{Term}}{L_T^{(Eb/Nt)_{UL}}}$ and $P_{Req}^{Term} = P_{Max}^{Term} \times \frac{Q_{TCH-UL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)}}$ or $P_{Req}^{Term} = P_{Max}^{Term} \times \frac{Q_{TCH-UL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)}}$

$L_T^{(Eb/Nt)_{UL}} = \frac{L_{Path} \times L^{TX_i} \times L^{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{(Eb/Nt)_{UL}}}{G^{TX_i} \times G^{Term}}$ and P_{Max}^{Term} is the maximum power defined for the selected terminal.

In $L_T^{(Eb/Nt)_{UL}}$, $G^{TX_i} = G_{UL}^{SA}$ and $L^{TX_i} = L_{UL}^{SA}$ are calculated according to the smart antenna modelling method used, for P_{Max}^{Term}, if a smart antenna is available in the uplink. Otherwise, G^{TX_i} and L^{TX_i} are read from the main antenna model.

Coverage Display

It is possible to colour the transmitter service areas using a unique colour per transmitter, or colour the pixels in the coverage areas by any transmitter attribute or other criteria such as:

- **Max Eb/Nt or Max C/I (dB)**

  9955 calculates the Eb/Nt or C/I on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the Eb/Nt or C/I level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)} \geq Threshold$ or $\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **Effective Eb/Nt or Effective C/I (dB)**

  9955 calculates the effective Eb/Nt or C/I on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the effective Eb/Nt or C/I level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $Min\left(\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)}, Q_{TCH-UL}^{Req}\right) \geq Threshold$ or $Min\left(\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)}, Q_{TCH-UL}^{Req}\right) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

- **Eb/Nt Margin or C/I Margin (dB)**

  9955 calculates the Eb/Nt or C/I margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the Eb/Nt or C/I margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)} - Q_{TCH-UL}^{Req} \geq M_{TCH-UL}^{Eb/Nt}$ or $\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)} - Q_{TCH-UL}^{Req} \geq M_{TCH-UL}^{C/I}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Required Power (dBm)**

  9955 calculates the uplink required power on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the required power level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties).

For each layer, a pixel is covered if $P_{Req}^{Term} \geq Threshold$, where $P_{Req}^{Term} = \frac{Q_{TCH-UL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)}} \times P_{Max}^{Term}$ or $P_{Req}^{Term} = \frac{Q_{TCH-UL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)}} \times P_{Max}^{Term}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Required Power Margin (dB)**

  9955 calculates the uplink required power margin on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the required power margin value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $P_{Req}^{Term} - P_{Max}^{Term} \geq Margin$, where $P_{Req}^{Term} = \frac{Q_{TCH-UL}^{Req}}{\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)}} \times P_{Max}^{Term}$ or $P_{Req}^{Term} = \frac{Q_{TCH-UL}^{Req}}{\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)}} \times P_{Max}^{Term}$. Each layer is assigned a colour and displayed with intersections between layers.

- **Cell Edge Coverage Probability (%)**

  9955 calculates the cell edge coverage probability on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the cell edge coverage probability value. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $\left.\left(\frac{E_b}{N_t}\right)_{TCH-UL}^{TX_i(ic)}\right|_{CECP} \geq Q_{TCH-UL}^{Req}$ or $\left.\left(\frac{C}{I}\right)_{TCH-UL}^{TX_i(ic)}\right|_{CECP} \geq Q_{TCH-UL}^{Req}$. Each layer is assigned a colour and displayed with intersections between layers.

8.4.8 Effective Service Area Analysis (Eb/Nt) or (C/I)

These coverage predictions consist of pixels covered by the both the uplink and the downlink service areas. These coverage predictions calculate the Eb/Nt or C/I on the downlink and uplink traffic channels, $\left(\frac{E_b}{N_t}\right)_{TCH-DL}$ or $\left(\frac{C}{I}\right)_{TCH-DL}$ and $\left(\frac{E_b}{N_t}\right)_{TCH-UL}$ or $\left(\frac{C}{I}\right)_{TCH-UL}$, and display the pixels where both downlink and uplink Eb/Nt or C/I are above the required quality thresholds.

The coverage predictions are calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for all the 6 timeslots. The best servers for the coverage predictions are determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage predictions are calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform these coverage predictions for the best carrier, **9955** calculates the Eb/Nt or C/I considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area are covered and coloured according to the selected display option if all the following conditions are satisfied:

- $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$
- $RSCP_{TCH-DL}^{TX_i(ic)} \geq RSCP_{TCH-DL}^{Req}(Service, Mobility)$
- $RSCP_{TCH-UL}^{TX_i(ic)} \geq RSCP_{TCH-UL}^{Req}(Service, Mobility)$
- $\left(\frac{E_b}{N_t}\right)_{TCH-DL}^{TX_i(ic)} \geq Q_{TCH-DL}^{Req}$ or $\left(\frac{C}{I}\right)_{TCH-DL}^{TX_i(ic)} \geq Q_{TCH-DL}^{Req}$ for any of the 6 timeslots

- $\left(\frac{E_b}{N_t}\right)^{TX_i(ic)}_{TCH-UL} \geq Q^{Req}_{TCH-UL}$ or $\left(\frac{C}{I}\right)^{TX_i(ic)}_{TCH-UL} \geq Q^{Req}_{TCH-UL}$ for any of the 6 timeslots

8.4.9 Cell to Cell Interference

This coverage prediction calculates and displays the interference received by cells receiving in uplink from other cells which are transmitting in downlink. The timeslot configuration of each cell defines the direction of the link at any given instance. During each subframe, the direction of the link changes twice (downlink to uplink, and then uplink to downlink). These transitions are referred to as switching points.

The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and a timeslot. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the RSCP considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The mobility, service, and terminal are used to calculate the best server coverage of the interfered cell.

Assuming that a transmitter TX_j is interfering a studied transmitter TX_i on a timeslot, on the same carrier *ic* or on another carrier *jc*, the cell to cell interference is given by:

$$I_{C2C}(TX_i, TX_j) = \sum_{TX_j}\left(RSCP^{TX_j(ic)}_{TCH-DL} + RSCP^{TX_j(ic)}_{OCCH}\right) + \frac{\sum_{TX_j}\left(RSCP^{TX_j(jc)}_{TCH-DL} + RSCP^{TX_j(jc)}_{OCCH}\right)}{F_{IRF}(ic, jc)}$$

Where $RSCP^{TX_j(ic)}_{TCH-DL} = \frac{P^{TX_j(ic)}_{TCH-DL}(\theta)}{L_T}$ and $RSCP^{TX_j(jc)}_{TCH-DL} = \frac{P^{TX_j(jc)}_{TCH-DL}(\theta)}{L_T}$ using a smart antenna, and $RSCP^{TX_j(ic)}_{TCH-DL} = \frac{P^{TX_j(ic)}_{TCH-DL}}{L_T} \times \frac{G^{TX_j}_{Ant}}{L^{TX_j}_{Ant}}$ and $RSCP^{TX_j(jc)}_{TCH-DL} = \frac{P^{TX_j(jc)}_{TCH-DL}}{L_T} \times \frac{G^{TX_j}_{Ant}}{L^{TX_j}_{Ant}}$ otherwise.

$RSCP^{TX_j(ic)}_{OCCH} = \frac{P^{TX_j(ic)}_{OCCH}}{L_T} \times \frac{G^{TX_j}_{Ant}}{L^{TX_j}_{Ant}}$ and $RSCP^{TX_j(jc)}_{OCCH} = \frac{P^{TX_j(jc)}_{OCCH}}{L_T} \times \frac{G^{TX_j}_{Ant}}{L^{TX_j}_{Ant}}$ otherwise.

$$L_T = L^{ITU526-5}_{Path} \times L^{TX_j}_{TX} \times L^{TX_i}_{RX}$$

$L^{ITU526-5}_{Path}$ is the path loss calculated using the ITU526-5 propagation model without antenna loss.

θ is the angle for the smart antenna pattern.

$L^{TX_j}_{Ant}$ is the main antenna attenuation.

$G^{TX_j}_{Ant}$ is the main antenna gain.

9955 calculates the cell to cell interference on each pixel of the $TX_i(ic)$ best server coverage area. The pixel colour depends on the cell to cell interference level. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). For each layer, a pixel is covered if $I_{C2C}(TX_i, TX_j) \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

8.4.10 UpPCH Interference

UpPCH is usually carried by the UpPTS timeslot. However, if the interference on UpPTS is high, from unsynchronised DwPTS or TS0 timeslots of other cells, it is possible to shift the UpPCH to TS1. This is called UpPCH shifting. If some cells in a network use UpPCH shifting, you can use this coverage prediction to study the interference on the shifted UpPCH of these cells from other cells. The interference from other cells is in this case generated by the traffic on the TS1 of interfering cells.

This coverage prediction calculates and displays the uplink interference on the TS1, I_{TS1-UL}. The coverage prediction is calculated for a given set of a terminal type, a mobility type, a service, a carrier, and for TS1. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage prediction is calculated for the selected carrier. If the selected carrier does not exist on a transmitter, there will not be any pixels covered by this transmitter. If you perform this coverage prediction for the best carrier, **9955** calculates the interference for all the carriers but keeps the worst case value, i.e., the most interfered carrier. You can choose to display the minimum, the maximum, or the average total noise. The coverage prediction is calculated using the main antenna.

Pixels in the $TX_i(ic)$ coverage area where $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$ and $I_{TS1-UL}^{TX_i(ic)} \geq Threshold$ are covered and coloured according to the selected display option.

The uplink interference on TS1 is calculated from the uplink load calculated in the simulations or manually defiend for the TS1.

The uplink interference on TS1 is given by: $I_{TS1-UL}^{TX_i(ic)} = N_0^{TX_i} \times \frac{X_{TS1-UL}^{TX_i(ic)}}{\left(1 - X_{TS1-UL}^{TX_i(ic)}\right)}$

8.4.11 HSDPA Predictions

This coverage prediction calculates and displays the RLC peak rate or the MAC rate per pixel covered by HSDPA cells. The coverage prediction is calculated for a given set of an HSDPA terminal type, a mobility type, an HSDPA service, a carrier, and for all downlink timeslots. The best server for the coverage prediction is determined according to the P-CCPCH RSCP from the carrier with the highest P-CCPCH power, or from the master carrier in case of N-frequency mode compatible transmitters. Afterwards, the coverage predictions are calculated for the selected carrier. If the selected carrier does not exist on a transmitter or if it does not support HSDPA, there will not be any pixels covered by this transmitter. If you perform these coverage predictions for the best carrier, **9955** calculates the RLC or MAC rate considering:

- the preferred carrier of the selected service, or
- the carrier with the highest P-CCPCH power, if no preferred carrier is defined for the service, or
- the master carrier in case of N-frequency mode compatible transmitters.

The pixels in the $TX_i(ic)$ coverage area are covered and coloured if:

- $RSCP_{P-CCPCH}^{TX_i(ic)} \geq TAdd_{P-CCPCH}(Mobility)$,
- $\left(\frac{E_c}{N_t}\right)_{HS-PDSCH}^{TX_i(ic)} \geq Q_{HS-PDSCH}^{Req}$, and
- $\left(\frac{E_c}{N_t}\right)_{HS-PDSCH}^{TX_i(ic)}$ is enough to select a bearer for the pixels.

For more information on HSDPA bearer selection, see "HSDPA Part of the Algorithm" on page 574.

Coverage Display

It is possible to colour the pixels in the coverage areas by criteria such as:

- **Min HS-PDSCH RSCP:** On each pixel, **9955** calculates $RSCP_{HS-SCCH}^{TX_i(ic)}$ for all timeslots and selects the lowest value.
- **Average HS-PDSCH RSCP:** On each pixel, **9955** calculates $RSCP_{HS-SCCH}^{TX_i(ic)}$ for all timeslots and calculates the average of these values.
- **Max HS-PDSCH RSCP:** On each pixel, **9955** calculates $RSCP_{HS-SCCH}^{TX_i(ic)}$ for all timeslots and selects the highest value.
- **Min HS-PDSCH Ec/Nt:** On each pixel, **9955** calculates $\left(\frac{E_c}{N_t}\right)_{HS-PDSCH}^{TX_i(ic)}$ for all timeslots and selects the lowest value.

- **Average HS-PDSCH Ec/Nt:** On each pixel, **9955** calculates $\left(\frac{E_c}{N_t}\right)^{TX_i(ic)}_{HS-PDSCH}$ for all timeslots and calculates the average of these values.
- **Max HS-PDSCH Ec/Nt:** On each pixel, **9955** calculates $\left(\frac{E_c}{N_t}\right)^{TX_i(ic)}_{HS-PDSCH}$ for all timeslots and selects the highest value.
- **RLC Peak Rate:** After selecting the bearer, **9955** reads the corresponding RLC peak rate. This is the highest rate that the bearer can provide on each pixel. The pixel colour depends on the RLC peak rate. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). Each layer is assigned a colour and displayed with intersections between layers.
- **MAC Rate: 9955** displays the MAC rate (R^{MAC}_{DL}) provided on each pixel. The MAC rate is calculated as follows:

  $$R^{MAC}_{DL} = S_{Block} \times 500$$

  Where, S_{Block} is the transport block size (in kbits) of the selected HSDPA bearer; it is defined for each HSDPA bearer in the related table. The value 500 corresponds to the number of blocks per second (there are 4 blocks per TTI and 2000 TTI in one second, i.e $\frac{2000}{4}$ blocks per second).

  The pixel colour depends on the MAC rate. Coverage consists of several independent layers whose visibility in the workspace can be managed. There are as many layers as thresholds defined in the Display tab (Prediction properties). Each layer is assigned a colour and displayed with intersections between layers.

- **Max DL A-DPCH Eb/Nt: 9955** displays the A-DPCH Eb/Nt at the receiver ($\left(\frac{E_b}{N_t}\right)^{TX_i(ic,\,TS)}_{TCH-DL-Max}$) for the best server and the selected timeslot. No power control is performed as in simulations. Here, **9955** determines downlink traffic channel quality at the receiver for a maximum traffic channel power allowed for the best server.
- **Max UL A-DPCH Eb/Nt: 9955** displays the A-DPCH Eb/Nt at the best server ($\left(\frac{E_b}{N_t}\right)^{TX_i(ic,\,TS)}_{TCH-UL-Max}$) and the selected timeslot. No power control is performed as in simulations. Here, **9955** determines uplink traffic channel quality for the maximum terminal power allowed.
- **HS-SCCH Power:** On each pixel, **9955** calculates $P^{TX_i(ic)}_{HS-SCCH}$ for the selected timeslot.
- **HS-SCCH RSCP:** On each pixel, **9955** calculates $RSCP^{TX_i(ic)}_{HS-SCCH}$ for the selected timeslot.
- **HS-SCCH Ec/Nt:** On each pixel, **9955** calculates $\left(\frac{E_c}{N_t}\right)^{TX_i(ic)}_{HS-SCCH}$ for the selected timeslot.
- **HS-SICH Power:** On each pixel, **9955** calculates $P^{M_i}_{HS-SICH}$ for the selected timeslot.
- **HS-SICH RSCP:** On each pixel, **9955** calculates $RSCP^{M_i}_{HS-SICH}$ for the selected timeslot.
- **HS-SICH Ec/Nt:** On each pixel, **9955** calculates $\left(\frac{E_c}{N_t}\right)^{M_i}_{HS-SICH}$ for the selected timeslot.
- **HS-PDSCH RSCP:** On each pixel, **9955** calculates $RSCP^{TX_i(ic)}_{HS-PDSCH}$ for the selected timeslot.
- **HS-PDSCH Ec/Nt:** On each pixel, **9955** calculates $\left(\frac{E_c}{N_t}\right)^{TX_i(ic)}_{HS-PDSCH}$ for the selected timeslot.

8.5 Smart Antenna Modelling

9955 calculates the smart antenna gains and losses in the direction of a user during the simulations, and in the direction of each pixel in coverage predictions. During simulations, **9955** determines the gains and losses using the smart antenna models. In coverage predictions, **9955** determines the gains and losses from the angular distributions calculated during the simulations for each timeslot and stored in the Cell Parameters per Timeslot table.

If a smart antenna model is only downlink or only uplink, the other direction uses the main antenna gain and losses for calculations. Therefore,

- If a smart antenna is available on the downlink and uplink:

$G_{UL}^{TX} = G_{UL}^{SA}$, $L_{UL}^{TX} = L_{UL}^{SA}$ and $G_{DL}^{TX} = G_{DL}^{SA}$, $L_{DL}^{TX} = L_{DL}^{SA}$

- If a smart antenna is available on the downlink only:

$G_{DL}^{TX} = G_{DL}^{SA}$, $L_{DL}^{TX} = L_{DL}^{SA}$ and $G_{UL}^{TX} = G_{Ant}^{TX}$, $L_{UL}^{TX} = L^{TX} = L_{Total-UL}$

- If a smart antenna is available on the uplink only:

$G_{UL}^{TX} = G_{UL}^{SA}$, $L_{UL}^{TX} = L_{UL}^{SA}$ and $G_{DL}^{TX} = G_{Ant}^{TX}$, $L_{DL}^{TX} = L^{TX} = L_{Total-DL}$

- If no smart antenna equipment is defined:

$G_{DL}^{TX} = G_{UL}^{TX} = G_{Ant}^{TX}$, $L_{UL}^{TX} = L^{TX} = L_{Total-UL}$, and $L_{DL}^{TX} = L^{TX} = L_{Total-DL}$

8.5.1 Modelling in Simulations

8.5.1.1 Grid of Beams Modelling

A grid-of-beams smart antenna, called GOB, consists of more than one directional antenna pattern (beam) in different directions. Each beam of a GOB has a different azimuth so that the GOB as a whole covers an entire sector. During the simulations, **9955** determines the most suitable beam from the GOB for each user served by the smart antenna. The most suitable beam (best beam) is the one which provides the highest gain towards the served user:

$$Beam_{Best} = Beam\Big|_{Max\left(G_{Beam} - L_{Beam}^{H} - L_{Beam}^{V}\right)}$$

Where G_{Beam}, L_{Beam}^{H}, and L_{Beam}^{V} are the gains, horizontal, and vertical attenuations of the beams of the GOB. In words, the best beam is the one among all the beams of a GOB that has the highest difference between gain, and horizontal and vertical attenuations. The gains and losses of the GOB (G_{DL}^{SA}, G_{UL}^{SA}, L_{DL}^{SA}, and L_{UL}^{SA}) are determined from the selected best beam.

The following example shows how **9955** calculates the GOB gains and losses.

Example:

Let us assume a GOB with 5 beams that have the same vertical patterns, and whose horizontal patterns are pointed towards different directions as shown in the figure below:

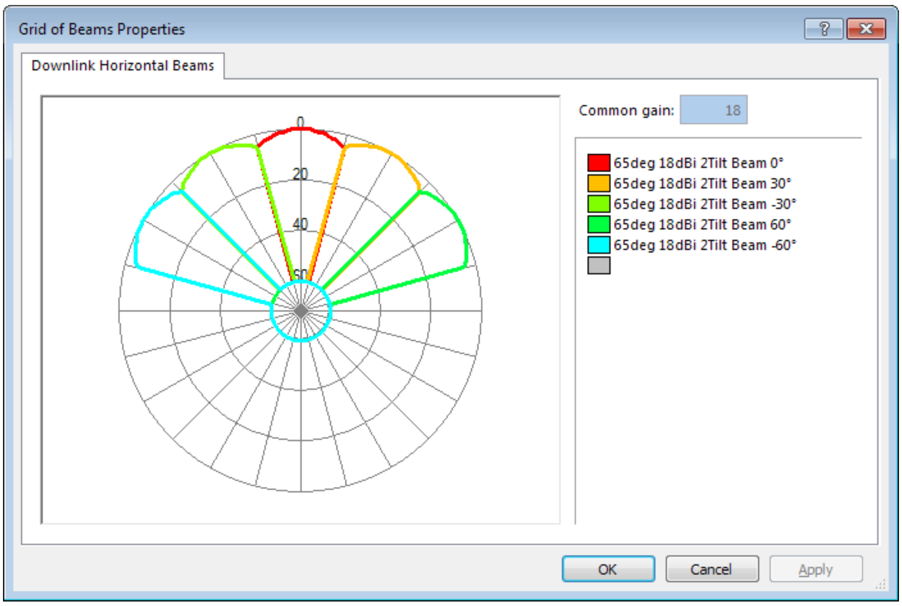


Figure 8.3: Grid Of Beams Modelling

Let us assume that all the beams and the main antenna have the same 18 dBi gain, and the vertical attenuation at the user location is 15 dB, which is also the same for all the beams because we assume that the vertical patterns are the same.

If the user is located at $\alpha = 70°$ azimuth, as shown in the figure below, **9955** determines the best beam, which has the highest gain towards α, as follows:

Beam	Gain (dBi)	Horizontal Attenuation (dB)	Vertical Attenuation (dB)	$G_{Beam} - L^{H}_{Beam} - L^{V}_{Beam}$	Total Gain (dB)
0°	18	60	15	18 - 60 - 15	-57
30°	18	60	15	18 - 60 - 15	-57
60°	18	2.21	15	18 - 2.21- 15	0.79
-30°	18	60	15	18 - 60 - 15	-57
-60°	18	60	15	18 - 60 - 15	-57

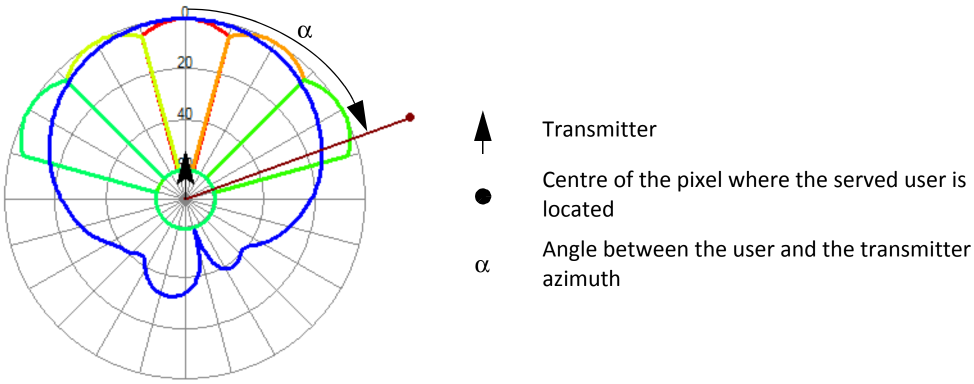


Figure 8.4: GOB Modelling - Determination of the Best Beam

In our example, the total gain of the beam at 60° is the highest. Therefore this beam is selected as the best beam.

If this beam has been selected in the downlink,

$$G^{SA}_{DL} = 18\ dB \text{ and } L^{SA}_{DL} = L^{H}_{Beam} + L^{V}_{Beam} = 17.21\ dB$$

If this beam has been selected in the uplink,

$$G^{SA}_{UL} = 18\ dB \text{ and } L^{SA}_{UL} = L^{H}_{Beam} + L^{V}_{Beam} = 17.21\ dB$$

8.5.1.2 Adaptive Beam Modelling

An adaptive beam smart antenna is capable of steering a given antenna pattern towards the direction of the served signal. In **9955**, this is modelled using a single antenna pattern, called a beam because of its highly directional shape. During the simulations, this adaptive beam is oriented in the direction of each served user in order to model the effect of the smart antenna.

The adaptive beam gains (G^{SA}_{DL} and G^{SA}_{UL}) are the antenna gains defined for the beam, and the adaptive beam losses (L^{SA}_{DL} and L^{SA}_{UL}) are the horizontal and vertical pattern attenuations $L^{H}_{Beam} + L^{V}_{Beam}$ towards the user direction.

The following example shows how **9955** calculates the adaptive beam gains and losses.

Example:

Let us assume an adaptive beam smart antenna selected for a transmitter along with a main antenna. Let us assume that the adaptive beam and the main antenna have the same 18 dBi gain, and the vertical attenuation at the user location is 15 dB.

If the user is located at $\alpha = 60°$ azimuth, as shown in the figure below:

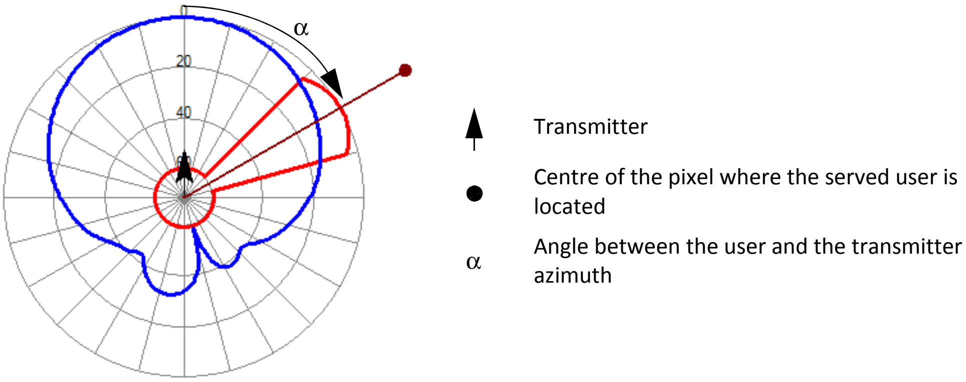


Figure 8.5: Adaptive Beam Modelling - Determination of the Best Beam

If the adaptive beam smart antenna is selected in the downlink, the gain and losses of the adaptive beam at α are:

$G_{DL}^{SA} = 18\ dB$ and $L_{DL}^{SA} = L_{Beam}^{H} + L_{Beam}^{V} = 15\ dB$

If the adaptive beam smart antenna is selected in the uplink, the gain and losses of the adaptive beam at α are:

$G_{UL}^{SA} = 18\ dB$ and $L_{UL}^{SA} = L_{Beam}^{H} + L_{Beam}^{V} = 15\ dB$

In fact, as the ideal beam steering algorithm steers the beam towards the served user, $L_{Beam}^{H} = 0$. These values are used in interference calculation to determine the downlink interfering signal due to transmission towards the served user, as well as for calculating the uplink interfering signals received at transmitter when decoding signal received from the served user.

8.5.1.3 Statistical Modelling

A statistical modelling approach is also available in **9955** which can be used to model the effect of smart antennas through C/I gains. You can create smart antenna equipment in **9955** based on the statistical approach by providing C/I gains and their cumulative probabilities for different spreading angles, θ_{Spread}.

You can assign a spreading angle to each clutter class in your document. **9955** reads the clutter class in which the served user is located to determine the spreading angle. Different clutter types have different spreading effects on the propagation of radio waves. Urban and dense urban clutter types introduce more multipath and spread the signal at a wider angle than an open or rural clutte type.

Once you have assigned the spreading angles to clutter classes, you can enter the C/I gains and their cumulative probabilities for each spreading angle, in the smart antenna equipment based on the statistical model. For each smart antenna equipment based on statistical modelling, you can set a probability threshold, $TProb^{SA}$.

To find the smart antenna gain, **9955** determines the clutter class of the served user, it reads the spreading angle from the clutter class properties, it reads the probability threshold from the smart antenna properties, and reads the smart antenna C/I gain defined for the $Probability = 1 - TProb^{SA}$ corresponding to the spreading angle.

The following example shows how **9955** calculates the statistical C/I gains and losses.

Example:

Let us assume that the served user is located at a an urban clutter class with $\theta_{Spread} = 10°$. The smart antenna equipment has $TProb^{SA} = 80\ \%$. **9955** will read the smart antenna C/I gain G^{SA} for $Prob = 20\ \%$. If a gain for the exact probability value of *20%* is not defined, **9955** linearly interpolates the gain value from the two surrounding values.

If $G^{SA}\Big|_{Prob\ =\ 19\%} = 4.6298\ dB$ and $G^{SA}\Big|_{Prob\ =\ 20.4\%} = 4.7196\ dB$, then $G^{SA}\Big|_{Prob\ =\ 20\%} = 4.6941\ dB$

The smart antenna gains are the same for uplink and downlink. Their are no losses for this type of smart antenna equipment. Negative values of C/I gains are considered as losses.

8.5.1.4 Beamforming Smart Antenna Models

See "Beamforming Smart Antenna Models" on page 41.

8.5.1.5 3rd Party Smart Antenna Modelling

3rd party smart antenna models can be used in **9955** to determine the gains and losses during the simulations for a given user distribution generated. The smart antenna gains and losses are used during the simulations and the results are stored in the Cell Parameters per Timeslot table, which can be used in coverage predictions.

8.5.2 Construction of the Geographic Distributions

During simulations, **9955** uses the smart antenna model selected for each transmitter to calculate the smart antenna gains and losses. These values are calculated and stored for each user generated for the simulations. Therefore, these values are calculated and are available for the given locations of the users, i.e., points, only. **9955** uses the Angular Step value that you set when creating and running simulations to construct the geographic distributions of these results.

Once **9955** has calculated the downlink traffic power and the uplink load using the smart antenna gains and losses determined as explained in the previous section, at the location of a given user, it calculates the same for points located at the angle equal to that of the Angular Step of the simulations.

At the end of the simulations, **9955** has a number of points, Angular Step apart, available with the values of these results. The geographic distribution of these results, i.e., downlink traffic power and uplink loads, is constructed by connecting the resulting value points.

The following example explains how the geographic distribution of downlink traffic power is created. The geographic distribution of uplink loads is constructed in the same manner.

Example:

Let us assume a smart antenna equipment using adaptive beam modelling. The angular step defined for the simulations is $\theta_{Step} = 30°$. Therefore, the results are calculated for each point located at regular steps of $30°$, i.e., 12 points. The downlink traffic power at the served user (*W*) with the adaptive beam pointing in the user's direction is P_W . The downlink traffic powers, using the same adaptive beam pointed towards the served user, at the 12 other points are also determined.

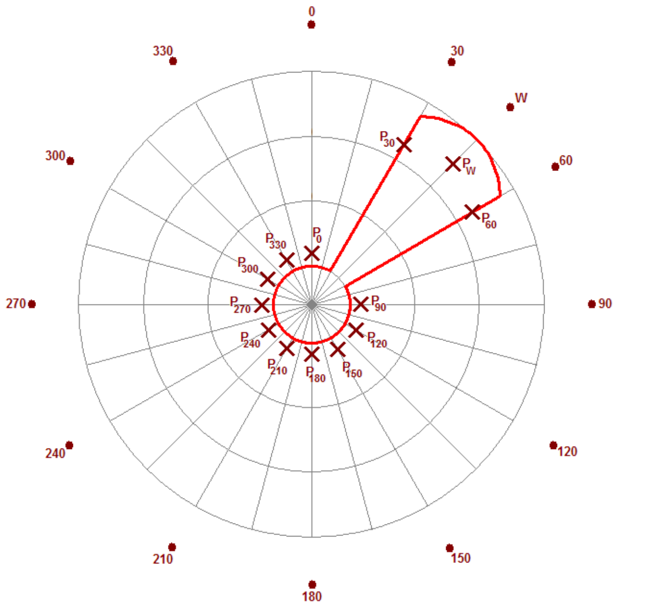


Figure 8.6: Construction of the Geographic Distribution of Downlink Traffic Power

The resulting geographic distribution is formed by linearly joining the obtained results.

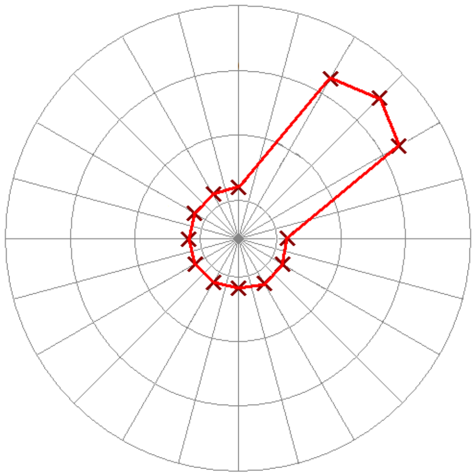


Figure 8.7: Geographic Distribution of Downlink Traffic Power

The accuracy of the geographic distribution depends upon the value of the angular step. A radiation pattern created at a $1°$ step will be much more accurate than one created at $45°$, for example. But, the latter will be computed 45 times faster than the first. The value of the Angular Step should be the best possible compromise between calculation speed and accuracy.

8.5.3 Modelling in Coverage Predictions

The results of Monte Carlo simulations, including the smart antenna results, can be stored in the Cells and in the Cell Parameters per Timeslot tables, and can be used to carry out coverage predictions. The main results of Monte Carlo simulations used in coverage predictions are:

- If a smart antenna is used in both uplink and downlink:

  Geographic distribution of UL load $X^{UL-\angle\alpha}$ and DL traffic power $P_{Traffic}^{DL-\angle\alpha}$

- If a smart antenna is used in downlink only:

  Geographic distribution of DL traffic power $P_{Traffic}^{DL-\angle\alpha}$

- Without smart antenna:

  UL load X^{UL} and DL traffic power $P_{Traffic}^{DL}$

The uplink load and the downlink traffic power at a given pixel are determined by calculating the angle α of that pixel with respect to the transmitter azimuth, and reading the uplink load and downlink traffic power from the geographic distribution results. If an exact value for the angle is not available, the load and power are determined using linear interpolation for the given angle between two available values.

For example, the figure below shows the distribution of downlink traffic power and uplink traffic load results from a simulation. For a pixel located at $\alpha = 315°$, the downlink traffic power $P_{Traffic}^{DL-\angle315°}$ and the uplink load $X^{UL-\angle315°}$ are read from these results. In this example, $P_{Traffic}^{DL-\angle315°} \approx 30\ dBm$, and $X^{UL-\angle315°} = 2.75\ \%$.

For each pixel, **9955** determines the downlink traffic powers and the uplink loads from all the transmitters.

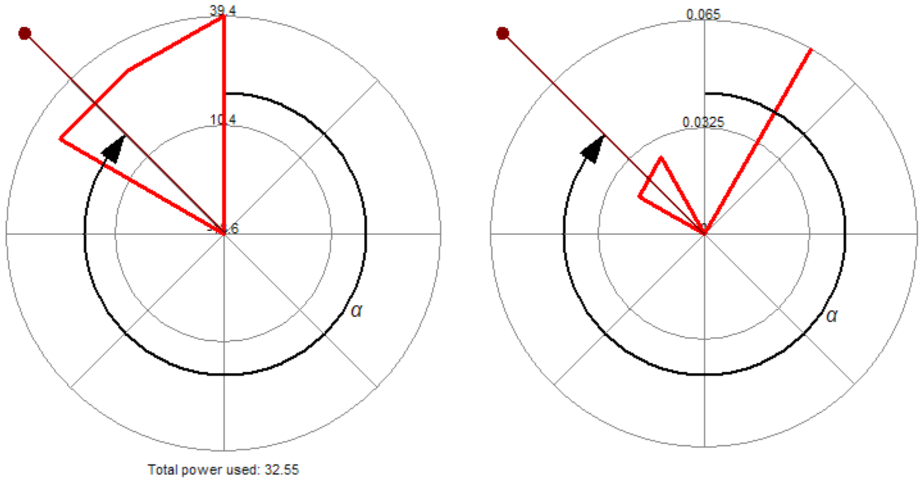


Figure 8.8: Geographic Distribution of downlink traffic power and uplink load

8.5.4 HSDPA Quality and Throughput Analysis

Fast link adaptation (or Adaptive Modulation and Coding) is used in HSDPA. The power on the HS-DSCH channel is transmitted at a constant power while the modulation, the coding, and the number of codes are changed to adapt to the radio conditions variations. Based on the reported channel quality indicator (CQI), the Node-B may change the modulation (QPSK and optionally 16QAM), the coding, and the number of codes every 2 ms during a communication.

Fast link adaptation is modelled in a dedicated HSDPA coverage prediction. Let us assume each bin on the map corresponds to a probe receiver with HSDPA capable terminal, mobility, and HSDPA service. The probe receiver on each bin is allocated the cell's HSDPA. This receiver may be using a specific carrier or all of them. The probe receiver does not create any interference.

9955 calculates on each bin either the best pilot quality (P-CCPCH Ec/Nt) or the best HS-PDSCH quality (HS-PDSCH Ec/Nt); this depends on the option selected in Global parameters (HSDPA part): CQI based on P-CCPCH quality or CQI based on HS-PDSCH quality (CQI means channel quality indicator). Then, it determines the HS-PDSCH CQI, deduces the best HSDPA bearer that can be used and selects the suitable bearer so as to comply with cell and terminal user equipment capabilities. Once the bearer selected, **9955** finds the highest downlink rate that can be carried at each bin and may deduce the application throughput. Coverage area is limited by the RSCP P-CCPCH threshold.

The coverage prediction can be calculated for an HSDPA compatible terminal, an HSDPA service, a mobility, a carrier, and a downlink timeslot. Smart antenna results are taken into account in the computation of this study.

8.5.4.1 Fast Link Adaptation Modelling

As explained above, the way of calculating the dedicated HSDPA study depends on if CQI is based on the P-CCPCH quality or on the HS-PDSCH quality.

8.5.4.1.1 CQI Based on P-CCPCH Quality

When the option "CQI based on CPICH quality" is selected, **9955** proceeds as follows.

P-CCPCH Quality Calculation

Let us assume the following notation: $\left(\frac{Ec}{Nt}(ic)\right)_{P-CCPCH}$ corresponds to the P-CCPCH quality.

Two options, available in Global Parameters, may be used to calculate Nt: option Without useful signal or option Total noise.

Therefore, we have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{P-CCPCH} = \frac{\rho_{BTS}\times\alpha\times RSCP^{TXi}_{P-CCPCH}(ic)}{N^{DL}_{Tot}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{P-CCPCH} = \frac{\rho_{BTS}\times\alpha\times RSCP^{TXi}_{P-CCPCH}(ic)}{N^{DL}_{Tot}(ic)-(1-\alpha)\times\rho_{BTS}\times RSCP^{TXi}_{P-CCPCH}(ic)}$$ for the without useful signal option.

With

$$N_{Tot}^{DL}(ic) = I_{Intra}^{DL}(ic) + I_{Extra}^{DL}(ic) + I_{Inter-Carrier}^{DL}(ic, jc) + N_0^{Term}$$

$I_{Inter-Carrier}^{DL}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$RSCP_{P-CCPCH}^{TXi}(ic) = \frac{P_{P-CCPCH}(ic)}{L_T}$$

$$L_T = \frac{L_{Path} \times L_{TX} \times L_{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{C/I}}{G_{TX} \times G_{Term}}$$

ρ_{BTS}, α and N_0^{Term} are defined in "Definitions and Formulas" on page 547.

P-CCPCH CQI Determination

Let us assume the following notation: $CQI_{P-CCPCH}$ corresponds to the P-CCPCH CQI. $CQI_{P-CCPCH}$ is deduced from the table $CQI_{P-CCPCH} = f\left(\left(\frac{Ec}{Nt}(ic)\right)_{P-CCPCH}\right)$. This table is defined for the terminal reception equipment and the specified mobility.

HS-PDSCH Quality Calculation

9955 proceeds as follows:

1st step: **9955** calculates the HS-PDSCH power ($P_{HS-PDSCH}$).

$P_{HSDPA}(ic)$ is the power available for HSDPA on the carrier *ic*. This parameter is a user-defined cell input.

$$P_{HSDPA}(ic) = P_{HS-PDSCH}(ic) + n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

Therefore, we have:

$$P_{HS-PDSCH}(ic) = P_{HSDPA}(ic) - n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

$n_{HS-SCCH}$ is the number of HS-SCCH channels and $P_{HS-SCCH}(ic)$ is the HS-SCCH power on carrier *ic*. It is either fixed by the user. $P_{HS-SCCH}(ic)$ is controlled so as to reach the required HS-SCCH Ec/Nt ($\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH}^{Req}$). It is specified in mobility properties.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times RSCP_{HS-SCCH}^{TXi}(ic)}{N_{Tot}^{DL}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times RSCP_{HS-SCCH}^{TXi}(ic)}{N_{Tot}^{DL}(ic) - (1 - F_{Ortho}^{DL}) \times (1 - F_{JD}^{Term}) \times \rho_{BTS} \times RSCP_{HS-SCCH}^{TXi}(ic)}$$ for the without useful signal option.

With

$$N_{Tot}^{DL}(ic) = I_{Intra}^{DL}(ic) + I_{Extra}^{DL}(ic) + I_{Inter-Carrier}^{DL}(ic, jc) + N_0^{Term}$$

$I_{Inter-Carrier}^{DL}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$RSCP_{HS-SCCH}^{TXi}(ic) = \frac{P_{HS-SCCH}(ic)}{L_T}$$

and

$$L_T = \frac{L_{Path} \times L_{TX} \times L_{Term} \times L_{Body} \times L_{Indoor} \times M_{Shadowing}^{C/I}}{G_{TX} \times G_{Term}}$$

ρ_{BTS}, F_{Ortho}, F_{JD}^{Term} and N_0^{Term} are defined in "Definitions and Formulas" on page 547.

Therefore,

$$RSCP^{TXi}_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{Req}_{HS-SCCH} \times N^{DL}_{Tot}(ic)}{\rho_{BTS}}\right) \times L_T$$ for the total noise option,

And

$$RSCP^{TXi}_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{Req}_{HS-SCCH} \times N^{DL}_{Tot}(ic)}{\rho_{BTS} \times \left(1 + (1 - F^{DL}_{Ortho}) \times (1 - F^{Term}_{JD}) \times \left(\frac{Ec}{Nt}(ic)\right)^{Req}_{HS-SCCH}\right)}\right) \times L_T$$ for the without useful signal option.

2nd step: Then, **9955** calculates the HS-PDSCH quality

Let us assume the following notation: $\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH}$ corresponds to the HS-PDSCH quality.

Therefore, we have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times RSCP^{TXi}_{HS-PDSCH}(ic)}{N^{DL}_{Tot}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times RSCP^{TXi}_{HS-PDSCH}(ic)}{N^{DL}_{Tot}(ic) - (1 - F^{DL}_{Ortho}) \times (1 - F^{Term}_{JD}) \times \rho_{BTS} \times \frac{RSCP^{TXi}_{HS-PDSCH}(ic)}{n}}$$ for the without useful signal option.

Here, **9955** works on the assumption that five HS-PDSCH channels are used (n=5).

With

$$N^{DL}_{Tot}(ic) = I^{DL}_{Intra}(ic) + I^{DL}_{Extra}(ic) + I^{DL}_{Inter-Carrier}(ic, jc) + N^{Term}_0$$

$I^{DL}_{Inter-Carrier}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$RSCP^{TXi}_{HS-PDSCH}(ic) = \frac{P_{HS-PDSCH}(ic)}{L_T}$$

And

$$L_T = \frac{L_{Path} \times L_{TX} \times L_{Term} \times L_{Body} \times L_{Indoor} \times M^{C/I}_{Shadowing}}{G_{TX} \times G_{Term}}$$

ρ_{BTS}, F_{Ortho}, F^{Term}_{JD} and N^{Term}_0 are defined in "Definitions and Formulas" on page 547.

HS-PDSCH CQI Determination

The best bearer that can be used depends on the HS-PDSCH CQI. Let us assume the following notation: $CQI_{HS-PDSCH}$ corresponds to the HS-PDSCH CQI. **9955** deduces $CQI_{HS-PDSCH}$ as follows:

$$CQI_{HS-PDSCH} = CQI_{P-CCPCH} - P_{P-CCPCH} + P_{HS-PDSCH}$$

Bearer Selection

Knowing the HS-PDSCH CQI, **9955** finds the best bearer that can be used in the table Best Bearer=f(HS-PDSCH CQI). This table is defined for the terminal reception equipment and the specified mobility.

Then, **9955** checks if best bearer characteristics are compliant with cell and user equipment category capabilities. **9955** selects the bearer which is the best bearer compliant with the cell and UE category capabilities.

Bearer characteristics are provided in the HSDPA Bearer table. Assuming the best bearer = 23. Characteristics of this bearer are:

- Transport block size: 9719 Bytes

- Number of HS-PDSCH channels used: 7
- 16QAM modulation used: Yes
- Peak Rate: 4.48 Mb/s

Document2: HSDPA Radio Bearers

Radio Bearer Index	Transport Block Size (bits)	Number of HS-PDSCH Channels Used per TS	RLC Peak Rate (bps)	Number of Timeslots Used	UE Category	Modulation
1	342	10	64 000	2	Category	QPSK
2	342	10	64 000	2	Category	QPSK
3	342	10	64 000	2	Category	QPSK
4	342	10	64 000	2	Category	QPSK
5	342	10	64 000	2	Category	QPSK
6	342	10	64 000	2	Category	QPSK
7	338	10	64 000	2	Category	QPSK
8	338	10	64 000	2	Category	QPSK
9	338	10	64 000	2	Category	QPSK
10	370	10	64 000	2	Category	QPSK
11	370	10	64 000	2	Category	QPSK
12	370	10	64 000	2	Category	QPSK
13	355	10	64 000	2	Category	QPSK
14	355	10	64 000	2	Category	QPSK
15	355	10	64 000	2	Category	QPSK
16	698	10	128 000	2	Category	QPSK
17	698	10	128 000	2	Category	QPSK
18	698	10	128 000	2	Category	QPSK
19	697	10	128 000	2	Category	QPSK
20	697	10	128 000	2	Category	QPSK
21	697	10	128 000	2	Category	QPSK
22	674	10	128 000	2	Category	QPSK
23	674	10	128 000	2	Category	QPSK
24	674	10	128 000	2	Category	QPSK

Figure 8.9: Radio Bearers Table

Assuming user equipment category = 3. Its capabilities are:

- Maximum transport block size: 7298 Bytes
- Maximum number of HS-PDSCH channels used: 5
- 16QAM modulation used: Yes
- Minimum number of TTI between two TTI used: 2

Document1: HSDPA UE Categories

Index	Category Name	Max Number of HS-PDSCH Channels Used by HSDPA TS	Max Transport Block Size (bits)	Highest modulation	Max Number of HS-PDSCH TS per TTI
1	Category 1	16	2 788	QPSK	2
2	Category 2	16	2 788	QPSK	2
3	Category 3	16	2 788	QPSK	2
4	Category 4	16	5 600	16QAM	2
5	Category 5	16	5 600	16QAM	2
6	Category 6	16	5 600	16QAM	2
7	Category 7	16	8 416	16QAM	3
8	Category 8	16	8 416	16QAM	3
9	Category 9	15	8 416	16QAM	3
10	Category 10	16	11 226	16QAM	4
11	Category 11	16	11 226	16QAM	4
12	Category 12	16	11 226	16QAM	4
13	Category 13	16	14 043	16QAM	5
14	Category 14	16	14 043	16QAM	5
15	Category 15	16	14 043	16QAM	5

Figure 8.10: UE Categories Table

HSDPA cell capabilities are:

- Maximum number of HS-PDSCH channels: 15.

The bearer 23 cannot be selected because:

- The number of HS-PDSCH channels (7) exceeds the maximum number of HS-PDSCH channels the terminal can use (5),
- And the transport block size (9719 Bytes) exceeds the maximum transport block size (7298 Bytes) the terminal can carried.

In the Bearer table, **9955** searches a suitable bearer and selects the bearer index 22.

- The number of HS-PDSCH channels (5) does not exceed the maximum number of HS-PDSCH channels the terminal can use (5) and the maximum number of HS-PDSCH channels available at the cell level (15),

- The transport block size (7168 Bytes) does not exceed the maximum transport block size (7298 Bytes) the terminal can carried.
- 16QAM modulation is supported by the terminal.

HS-PDSCH Quality Update

Once the bearer selected, **9955** knows the number of HS-PDSCH channels. Therefore, when the method “Without useful signal” is used, **9955** can recalculate the HS-PDSCH quality with the real number of HS-PDSCH channels (A default value of 5 was taken into account in the first HS-PDSCH quality calculation).

8.5.4.1.2 CQI Based on HS-PDSCH Quality

When the option “CQI based on HS-PDSCH quality” is selected, **9955** proceeds as follows.

HS-PDSCH Quality Calculation

9955 proceeds as follows:

1st step: **9955** calculates the HS-PDSCH power ($P_{HS-PDSCH}$).

$P_{HSDPA}(ic)$ is the power available for HSDPA on the carrier *ic*. This parameter is a user-defined cell input.

$$P_{HSDPA}(ic) = P_{HS-PDSCH}(ic) + n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

Therefore, we have:

$$P_{HS-PDSCH}(ic) = P_{HSDPA}(ic) - n_{HS-SCCH} \times P_{HS-SCCH}(ic)$$

$n_{HS-SCCH}$ is the number of HS-SCCH channels and $P_{HS-SCCH}(ic)$ is the HS-SCCH power on carrier *ic* fixed by the user. The HS-SCCH power is controlled so as to reach the required HS-SCCH Ec/Nt ($\left(\frac{Ec}{Nt}(ic)\right)^{Req}_{HS-SCCH}$) specified in mobility properties.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times RSCP^{TXi}_{HS-SCCH}(ic)}{N^{DL}_{Tot}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-SCCH} = \frac{\rho_{BTS} \times RSCP^{TXi}_{HS-SCCH}(ic)}{N^{DL}_{Tot}(ic) - (1 - F^{DL}_{Ortho}) \times (1 - F^{Term}_{JD}) \times \rho_{BTS} \times RSCP^{TXi}_{HS-SCCH}(ic)}$$ for the without useful signal option.

With

$$N^{DL}_{Tot}(ic) = I^{DL}_{Intra}(ic) + I^{DL}_{Extra}(ic) + I^{DL}_{Inter-Carrier}(ic, jc) + N^{Term}_{0}$$

$I^{DL}_{Inter-Carrier}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$RSCP^{TXi}_{HS-SCCH}(ic) = \frac{P_{HS-SCCH}(ic)}{L_{T_i}}$$

And

$$L_T = \frac{L_{Path} \times L_{TX} \times L_{Term} \times L_{Body} \times L_{Indoor} \times M^{C/I}_{Shadowing}}{G_{TX} \times G_{Term}}$$

ρ_{BTS}, F_{Ortho}, F^{Term}_{JD} and N^{Term}_{0} are defined in "Definitions and Formulas" on page 547.

Therefore,

$$P_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{Req}_{HS-SCCH} \times N^{DL}_{Tot}(ic)}{\rho_{BTS}}\right) \times L_T$$ for the total noise option,

And

$$P_{HS-SCCH}(ic) = \left(\frac{\left(\frac{Ec}{Nt}(ic)\right)^{Req}_{HS-SCCH} \times N^{DL}_{Tot}(ic)}{\rho_{BTS} \times \left(1 + (1 - F^{DL}_{Ortho}) \times (1 - F^{Term}_{JD}) \times \left(\frac{Ec}{Nt}(ic)\right)^{Req}_{HS-SCCH}\right)}\right) \times L_T$$ for the without useful signal option.

2nd step: Then, **9955** evaluates the HS-PDSCH quality

Let us assume the following notation: $\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH}$ corresponds to the HS-PDSCH quality.

Two options, available in Global parameters, may be used to calculate Nt: option Without useful signal or option Total noise.

We have:

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times RSCP^{TXi}_{HS-PDSCH}(ic)}{N^{DL}_{Tot}(ic)}$$ for the total noise option,

And

$$\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} = \frac{\rho_{BTS} \times RSCP^{TXi}_{HS-PDSCH}(ic)}{N^{DL}_{Tot}(ic) - (1 - F^{DL}_{Ortho}) \times (1 - F^{Term}_{JD}) \times \rho_{BTS} \times \frac{RSCP^{TXi}_{HS-PDSCH}(ic)}{n}}$$ for the without useful signal option.

Here, **9955** works on the assumption that five HS-PDSCH channels are used (n=5). Then, it deduces the HS-PDSCH CQI and the bearer to be used. Once the bearer selected, **9955** exactly knows the number of HS-PDSCH channels and recalculates the HS-PDSCH quality with the real number of HS-PDSCH channels.

With

$$N^{DL}_{Tot}(ic) = I^{DL}_{Intra}(ic) + I^{DL}_{Extra}(ic) + I^{DL}_{Inter-Carrier}(ic, jc) + N^{Term}_0$$

$I^{DL}_{Inter-Carrier}(ic, jc)$ is the inter-carrier interference from a carrier *jc* to another carrier *ic* on the downlink, which is reduced by the interference reduction factor $F_{IRF}(ic, jc)$ defined for the pair (*ic*, *jc*).

$$RSCP^{TXi}_{HS-PDSCH}(ic) = \frac{P_{HS-PDSCH}(ic)}{L_T}$$

And

$$L_T = \frac{L_{Path} \times L_{TX} \times L_{Term} \times L_{Body} \times L_{Indoor} \times M^{C/I}_{Shadowing}}{G_{TX} \times G_{Term}}$$

ρ_{BTS}, F_{Ortho}, F^{Term}_{JD} and N^{Term}_0 are defined in "Definitions and Formulas" on page 547.

HS-PDSCH CQI Determination

Let us assume the following notation: $CQI_{HS-PDSCH}$ corresponds to the HS-PDSCH CQI. $CQI_{HS-PDSCH}$ is deduced from the table $CQI_{HS-PDSCH} = f\left(\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH}\right)$. This table is defined for the terminal reception equipment and the specified mobility.

Bearer Selection

The bearer is selected as described in "Bearer Selection" on page 598.

8.5.4.2 Coverage Prediction Display Options

Three display options are available in the study property dialogue.

8.5.4.2.1 Colour per CQI

9955 displays either the P-CCPCH CQI when the selected option in Global Parameters (HSDPA part) is CQI based on P-CCPCH quality, or the HS-PDSCH CQI when considering the CQI based on HS-PDSCH quality option.

Coverage consists of several layers with a layer per CQI threshold ($CQI_{Threshold}$). For each layer, area is covered if $CQI \geq CQI_{Threshold}$. Each layer is assigned a colour and displayed with intersections between layers.

8.5.4.2.2 Colour per Peak Throughput

After selecting the bearer, **9955** reads the corresponding RLC peak rate. This is the highest rate that the bearer can provide on each bin.

Coverage consists of several layers with a layer per possible peak rate (R_{Peak}^{DL}). For each layer, area is covered if the peak rate can be provided. Each layer is assigned a colour and displayed with intersections between layers.

8.5.4.2.3 Colour per HS-PDSCH Ec/Nt

9955 displays on each bin the HS-PDSCH quality. Coverage consists of several layers with a layer per threshold. For each layer, area is covered if $\left(\frac{Ec}{Nt}(ic)\right)_{HS-PDSCH} \geq Threshold$. Each layer is assigned a colour and displayed with intersections between layers.

8.6 N-Frequency Mode and Carrier Allocation

Transmitters that support N-frequency mode are multi carrier transmitters with a master and one or more slave carrier. You can assign master and slave carriers to transmitters manually, or use the automatic frequency allocation in **9955** to assign carrier types automatically.

8.6.1 Automatic Carrier Allocation

For each transmitter, **9955** determines a list of "near" transmitters. For any transmitter TX_i, its "near" transmitters are geographically located close to the transmitter, and are sorted according to their distance from it. The calculation of distance between TX_i and any other transmitter TX_j is performed using the equation below:

$$D^{TX_i - TX_j} = d^{TX_i - TX_j} \times (1 + x \times (\cos(\beta) - \cos(\alpha) - 2))$$

Where $D^{TX_i - TX_j}$ is the weighted distance between TX_i and TX_j, $d^{TX_i - TX_j}$ is the real distance between between TX_i and TX_j considering any offsets with respect to the site locations, x is set to 15 % so that the maximum variation in $D^{TX_i - TX_j}$ due to the azimuths does not exceed 60 %. α and β are calculated from the azimuths of the two cells as shown in Figure 8.11 on page 602.

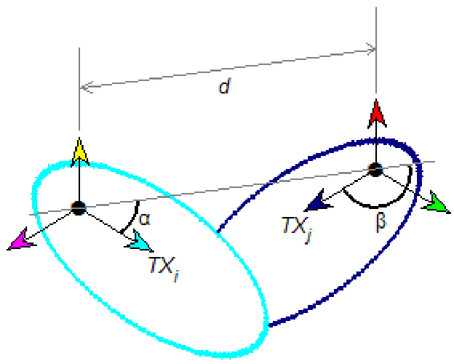
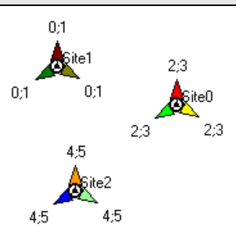
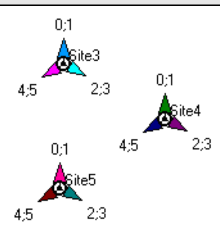


Figure 8.11: Weighted Distance Between Transmitters

The above formula implies that two transmitters facing each other will have a shorter weighted distance between them than the real distance, and two transmitters pointing in opposite directions will have a greater weighted distance.

Allocation of All Carriers

Co-N-Frequency Allocation	Diff-N-Frequency Allocation
	

Co-N-Frequency Allocation	Diff-N-Frequency Allocation
9955 assigns the same carriers to cells of each co-site transmitter.	**9955** assigns different carriers to cells of each co-site transmitter.

Allocation of Master Carriers

9955 assigns one master carrier to each transmitter TX_i, such that the master carrier of TX_i is different from the master carrier of TX_j, where TX_j belongs to the list of "near" transmitters. The master carrier is one of the cells defined in the transmitter. All the other cells of the transmitter are assigned the carrier-type "slave".

For transmitters that support the N-frequency mode and have master carriers properly assigned, **9955** performs the neighbour and scrambling code allocation for the master carrier only.

8.7 Neighbour Allocation

9955 permits the automatic allocation of intra-technology neighbours in a TD-SCDMA document. The intra-technology neighbour allocation algorithms take into account all the cells of TBC transmitters. It means that all the cells of TBC transmitters of your .atl document are potential neighbours.

The cells to be allocated will be called TBA cells. They must fulfill the following conditions:

- They are active
- Their transmitters support the N-frequency mode, and the cells are master carriers of their transmitters (neighbours are not allocated to standalone carriers)
- They satisfy the filter criteria applied to the Transmitters folder
- They are located inside the focus zone
- They belong to the folder on which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters or a single transmitter.

Only TBA cells may be assigned neighbours.

> If no focus zone exists in the .atl document, 9955 takes into account the computation zone.

In this section, the following are explained:

- "Neighbour Allocation for All Transmitters" on page 603.
- "Neighbour Allocation for a Group of Transmitters or One Transmitter" on page 606.
- "Importance Calculation" on page 606.

8.7.1 Neighbour Allocation for All Transmitters

We assume that we have a reference cell A and a candidate neighbour, cell B. When automatic allocation starts, **9955** checks following conditions:

1. The distance between both cells must be less than the user-defined maximum inter-site distance. If the distance between the reference cell and the candidate neighbour is greater than this value, the candidate neighbour is discarded.

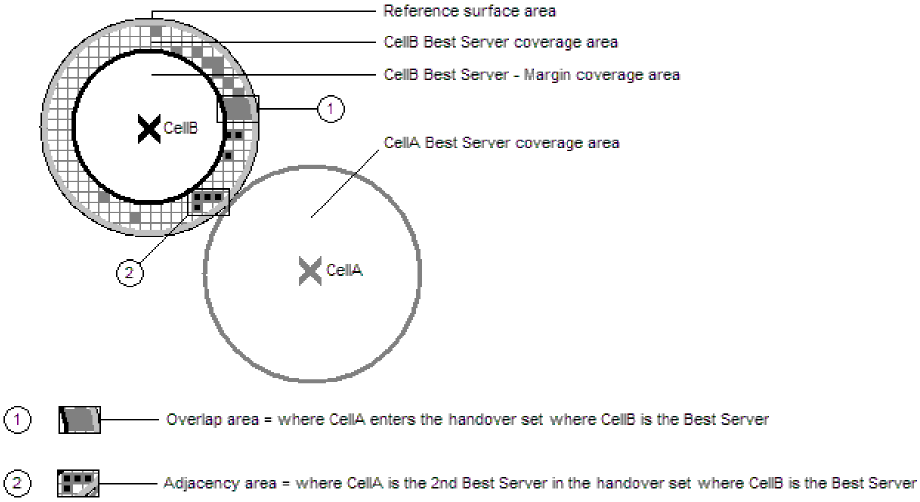
   9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Appendix: Calculation of the Inter-Transmitter Distance" on page 608.

2. The calculation options:

   Force co-site cells as neighbours: This option enables you to force cells located on the same site as reference cell in the candidate neighbour list. This constraint can be weighted among the others and ranks the neighbours through the importance field.

   Force adjacent cells as neighbours: This option enables you to force cells geographically adjacent to the reference cell in the candidate neighbour list. This constraint can be weighted among the others and ranks the neighbours through the importance field.

- **Adjacency criterion:** Geographically adjacent cells are determined on the basis of their best server coverages in TD-SCDMA projects. Let CellA be a candidate neighbour cell of CellB. CellA is considered adjacent to CellB if there exists at least one pixel in the CellB best server coverage area (and P-CCPCH RSCP of CellB > P-CCPCH RSCP T_Add) where CellA is best server (of several cells have the same best server value) or CellA is the second best server that enters the handover set (i.e., P-CCPCH RSCP of CellA > P-CCPCH RSCP T_Drop and P-CCPCH RSCP of CellA > P-CCPCH RSCP of CellB - T_Comp.)



- When this option is selected, adjacent cells are sorted and listed from the most adjacent to the least, depending on the above criterion. Adjacency is relative to the number of pixels satisfying the criterion.

Force neighbour symmetry: This option enables you to force the reciprocity of a neighbourhood link. Therefore, if the reference cell is a candidate neighbour of another cell, the later will be considered as candidate neighbour of the reference cell.

Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a cell to be candidate neighbour of the reference cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept.

3. There must be an overlapping zone ($S_A \cap S_B$) with a given cell edge coverage probability.

N-frequency handover is a baton handover. Assuming that the reference cell A and the candidate cell B are located inside a continuous layer of cells:

S_A is the area where the cell A is the best serving cell.

- The P-CCPCH RSCP from the cell A is greater than the P-CCPCH RSCP T_Add.
- The P-CCPCH RSCP from the cell A is greater than the P-CCPCH RSCP from all other cells.

S_B is the area where the cell B can enter the handover set.

- The P-CCPCH RSCP from the cell B is greater than the P-CCPCH RSCP T_Drop.
- The P-CCPCH RSCP from the cell B is greater than the P-CCPCH RSCP from the cell A minus the P-CCPCH RSCP T_Comp.

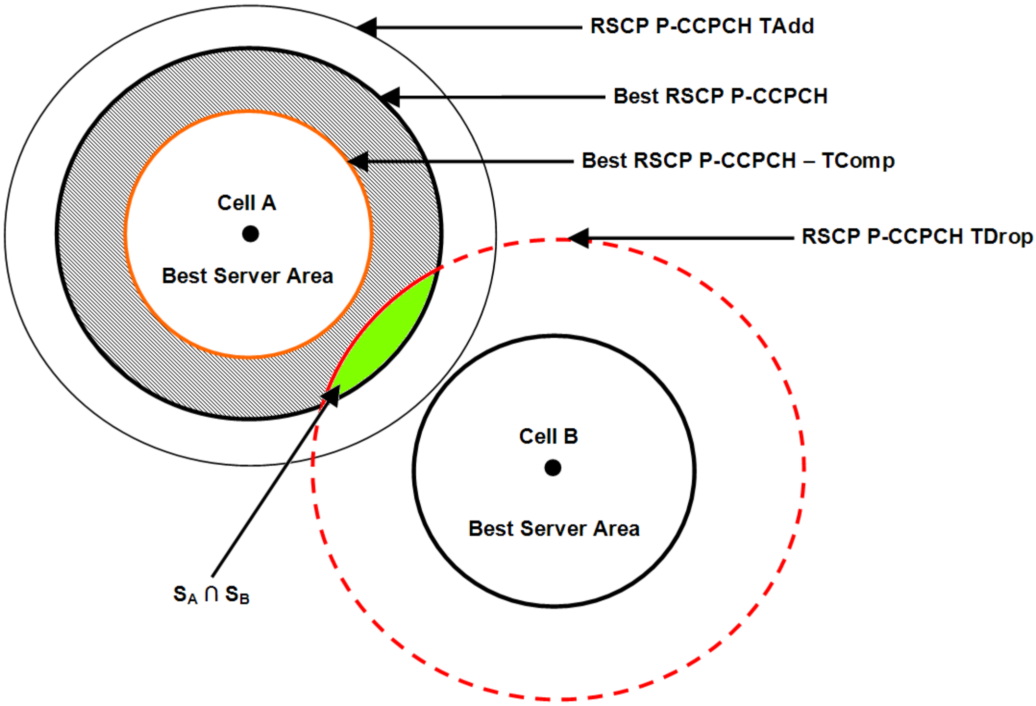
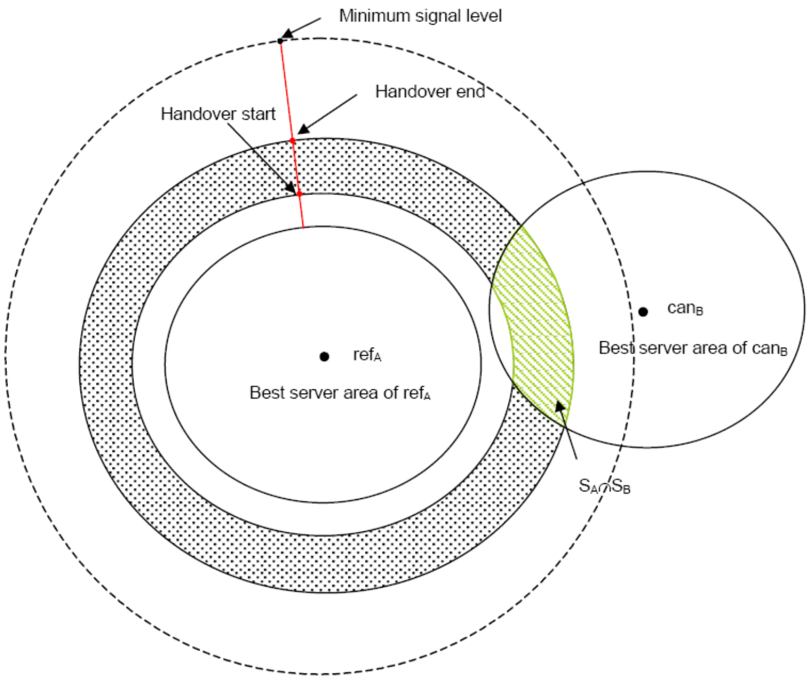


Figure 8.12: N-frequency Neighbour Allocation

9955 calculates the percentage of covered area ($\frac{S_A \cap S_B}{S_A} \times 100$), which it compares with the % minimum covered area. If this percentage is not exceeded, the candidate neighbour B is discarded.

The coverage condition can be weighted among the others and ranks the neighbours through the importance field.



: Overlapping Coverages

4. The importance of neighbours.

For information on the importance calculation, see "Importance Calculation" on page 606.

Importance values are used by the allocation algorithm to rank the neighbours according to the allocation reason. **9955** lists all neighbours and sorts them by importance value so as to eliminate some of them from the neighbour list if the maximum number of neighbours to be allocated to each transmitter is exceeded.

If we consider the case for which there are 15 candidate neighbours and the maximum number of neighbours to be allocated to the reference cell is 8. Among these 15 candidate neighbours, only 8 (having the highest importance values) will be allocated to the reference cell. Note that maximum numbers of neighbours can be defined at the cell level (properties dialogue or Cells table). If defined there, this value is taken into account instead of the default one available in the dialogue.

In the Results part, **9955** provides the list of neighbours, the number of neighbours, and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason, i.e., a neighbour may be marked as exceptional pair, co-site, adjacent, coverage, or symmetric. For neighbours accepted for co-site, adjacency, and coverage reasons, **9955** displays the percentage of area that satisfies the coverage conditions and the corresponding surface area (km²), the percentage of area that satisfies the adjacency conditions and the corresponding surface area (km²). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

- You do not require simulations or coverage predictions for an automatic neighbour allocation. For automatic neighbour allocation, 9955 automatically calculates the missing path loss matrices.
- Although no specific terminal, mobility, or service is selected for automatic neighbour allocation, the algorithm tries to find the maximum number of neighbours by selecting:
  - The service with the lowest body loss
  - The terminal with the highest difference between Gain and Losses. If this is the same for all terminals, **9955** uses the terminal with the lowest noise figure.
  - Mobility does not impact the allocation
- A forbidden neighbour must not be listed as neighbour except if the neighbourhood relationship already exists and the Delete existing neighbours option is not selected. In this case, 9955 displays a warning message in the Event Viewer indicating that the constraint on the forbidden neighbour will be ignored by the algorithm because the neighbour already exists.
- Symmetric neighbour relations are only added to the neighbour lists if the neighbour lists are not already full. Thus, if the cell B is a neighbour of the cell A, but cell A is not a neighbour of the cell B, there can be two possibilities:
  1. There is space in the cell B neighbour list: cell A will be added to the list. It will be the last one.
  2. The cell B neighbour list is full: **9955** will not include cell A in the list and will remove the symmetric relation by deleting cell B from the cell A neighbour list.
- If you select Force exceptional pairs and Force symmetry options, 9955 considers the constraints between exceptional pairs in both directions so as to respect the symmetric relation. On the other hand, if a neighbour relation is forced in one direction and forbidden in the other, symmetry cannot be respected. In this case, 9955 displays a warning message in the Event Viewer.
- In the results, 9955 displays only the cells for which it finds new neighbours. Therefore, if a TBA cell has already reached its maximum number of neighbours before starting the new allocation, it will not appear in the Results table.

8.7.2 Neighbour Allocation for a Group of Transmitters or One Transmitter

In this case, **9955** allocates neighbours to:

- TBA cells
- Neighbours of TBA cells marked as exceptional pair, adjacent, or symmetric
- Neighbours of TBA cells that satisfy coverage conditions

Automatic neighbour allocation parameters are described in "Neighbour Allocation for All Transmitters" on page 603.

8.7.3 Importance Calculation

Importance values are used by the allocation algorithm to rank the neighbours according to the allocation reason and the distance, and to quantify the neighbour importance. The neighbour importance depends on the distance from the reference transmitter and on the neighbourhood cause (cf. table below); this value varies between 0 and 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	Only if the Delete existing neighbours option is not selected and in case of a new allocation	Existing importance
Exceptional pair	Only if the Force exceptional pairs option is selected	100 %

Neighbourhood cause	When	Importance value
Co-site cell	Only if the Force co-site cells as neighbours option is selected	Importance Function (IF)
Adjacent cell	Only if the Force adjacent cells as neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	Only if the % minimum covered area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	Only if the Force neighbour symmetry option is selected	Importance Function (IF)

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers the following factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Appendix: Calculation of the Inter-Transmitter Distance" on page 608.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The adjacency factor (A): the percentage of adjacency,
- The overlapping factor (O): the percentage of overlapping.

The minimum and maximum importance assigned to each of the above factors can be defined.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	30%
Adjacency factor (A)	Min(A)	30%	Max(A)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The Importance Function is evaluated as follows:

Neighbourhood cause		Importance Function	Resulting IF using the default values from the table above
Co-site	Adjacent		
No	No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+20%{10%(Di)+90%(O)}
No	Yes	Min(A)+Delta(A){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	30%+30%{10%(Di)+30%(O) +60%(A)}
Yes	Yes	Min(C)+Delta(C){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	60%+40%{10%(Di)+30%(O) +60%(A)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours, adjacent neighbours, and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.
- By adding an option in the atoll.ini file, the neighbour allocation and importance calculation can be based on the distance criterion only. For more information, see the *Administrator Manual*.

8.7.4 Appendix: Calculation of the Inter-Transmitter Distance

9955 takes into account the real distance (D in m) and azimuths of antennas in order to calculate the effective inter-transmitter distance (d in m).

$$d = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

where x = 0.3% so that the maximum D variation does not exceed 1%.

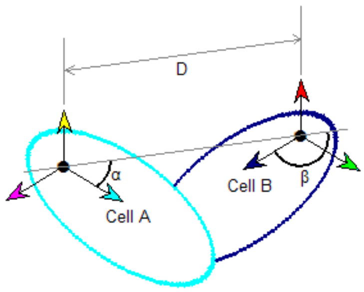


Figure 8.13: Inter-Transmitter Distance Computation

The formula above implies that two cells facing each other will have a smaller effective distance than the real physical distance. It is this effective distance that will be taken into account rather than the real distance.

8.8 Scrambling Code Allocation

Downlink scrambling codes enable mobile to distinguish one cell from another. In TD-SCDMA, there are 128 scrambling codes (or P-CCPCH midamble codes) distributed in 32 clusters of 4 codes each. A different DL synchronisation code, or SYNC_DL code, is assigned to each cluster. Scrambling codes are numbered from 0 to 127, and SYNC_DL codes from 0 to 31.

Depending on the options you select for automatic allocation of scrambling and SYNC_DL codes, **9955** takes into account either all the cells of TBC transmitters, or only cells of active and filtered transmitters located inside the computation zone.

9955 calculates a scrambling code and a SYNC_DL code to all these cells. But, it allocates scrambling codes and SYNC_DL codes only to TBA cells (cells to be allocated). TBA cells are the cells that fulfill the following conditions:

- They are active
- They satisfy the filter criteria applied to the Transmitters folder
- They are located inside the focus zone
- They belong to the folder on which allocation has been executed. This folder can be either the Transmitters folder or a group of transmitters or a single transmitter.

Furthermore, if there are transmitters that support the N-frequency mode among the TBC transmitters of your network, the scrambling code allocation also considers the master and slave carrier allocations.

If no focus zone exists in the .atl document, 9955 takes into account the computation zone.

8.8.1 Automatic Allocation Description

8.8.1.1 Allocation Constraints and Options

The scrambling code and SYNC_DL code allocation algorithm can take into account following constraints:

1. Neighbour relations between cells

   You may consider:

   - First order neighbours: The neighbours of TBA cells listed in the Intra-technology neighbours table,
   - Second order neighbours: The neighbours of neighbours,
   - Third order neighbours: The neighbour's neighbour's neighbours.

   - 9955 can take into account inter-technology neighbour relations as constraints to allocate different scrambling codes to the TD-SCDMA neighbours of a GSM transmitter. In order to consider inter-technology neighbour relations in the scrambling code allocation, you must make the Transmitters folder of the GSM.atl document accessible in the TD-SCDMA.atl document. For information on making links between GSM and TD-SCDMA .atl documents, see the *User Manual*.
   - 9955 considers symmetry relationship between a cell, its first order neighbours, its second order neighbours and its third order neighbours.

2. The scrambling code reuse distance

   Reuse Distance: It is a constraint on the allocation of scrambling codes. The same scarmbling code or SYNC_DL code cannot be allocated to two sites that are not farther apart than the reuse distance. Scrambling code reuse distance can be defined for each cell in the cell properties. If this value is not defined, **9955** uses the default reuse distance defined in the **Automatic Scrambling Code** and **SYNC_DL code Allocation** dialogue. The reuse distance constraint is used for clustered and distributed per cell allocation strategies.

3. The carrier for which you want to perform the automatic allocation

   Carrier: You can select "All" or a specific carrier. If you select "All", **9955** allocates the same scrambling code to each carrier of a transmitter.

4. The number of scrambling codes per SYNC_DL code

   Each SYNC_DL code corresponds to a group of scrambling codes as defined in 3GPP specifications. 3GPP specifications define 32 SYNC_DL codes with 4 corresponding scrambling codes each (SYNC_DL codes are numbered from 0 to 31). However, it is possible to define a different value (e.g. if you set the number of scrambling codes per SYNC_DL codes to 2, scrambling codes will be distributed among 64 SYNC_DL codes).

   When the allocation is based on a Distributed strategy (Distributed per Cell or Distributed per Site), this parameter can also be used to define the interval between the scrambling codes assigned to cells on a same site. The defined interval is applied by adding the following lines in the Atoll.ini file:

```
[PSC]
ConstantStep=1
```

   For more information about setting options in the atoll.ini file, see the *Administrator Manual*.

5. **9955** can use a maximum of codes

   Use a Maximum of Codes: If you choose to use a maximum of codes, **9955** will try to spread the allocated spectrum of scrambling codes as much as possible.

6. Existing allocation

   Delete All Codes: If you select this option, **9955** will delete any existing scrambling code allocation and perform a fresh allocation. Otherwise, **9955** keeps the existing allocation.

8.8.1.2 Allocation Strategies

You can choose from the following four allocation strategies:

- Clustered: The purpose of this strategy is to choose for a group of mutually constrained cells, scrambling codes among a minimum number of clusters. In this case, **9955** will preferentially allocate all the codes within the same cluster.
- Distributed per Cell: This strategy consists in using as many clusters as possible. **9955** will preferentially allocate codes from different clusters.
- One SYNC_DL code per site: This strategy allocates one cluster, i.e., one SYNC_DL code, per site, then one scrambling code from the cluster to each cell of the site. When all the clusters have been allocated but there are still sites remaining, **9955** reuses the clusters as far as possible at another site.

> Same carriers must be assigned different scrambling codes. Different carriers of the same site can be assigned the same scrambling code. Therefore, cells of a transmitter (i.e. different carriers) are assigned the same scrambling code, if the scrambling code domains associated with the carriers have a common cluster or enough codes in one cluster.

- Distributed per site: This strategy allocates a group of adjacent clusters, i.e., consecutive SYNC_DL codes, to each site, then one cluster, or SYNC_DL code, to each transmitter on the site according to its azimuth, and finally one scrambling code from each cluster to each cell of each transmitter. The number of adjacent clusters, or consecutive SYNC_DL codes, depends on the number of transmitters per site. When all the sites have been allocated adjacent clusters, and there are still sites remaining to be allocated, **9955** reuses the adjacent clusters as far as possible at another site.

In the Results table, **9955** only displays scrambling codes and SYNC_DL codes allocated to TBA cells.

8.8.1.3 Allocation Process

For each TBA cell, **9955** lists all cells which have constraints with the cell. They are referred to as *near cells*. The near cells of a TBA cell may be:

- Its neighbour cells: the neighbours listed in the Intra-technology neighbours table (options “Existing neighbours” and "First Order"),
- The neighbours of its neighbours (options “Existing neighbours” and “Second Order”),
- The third order neighbours (options “Existing neighbours” and “Third Order”),
- The cells with distance from the TBA cell less than the reuse distance,
- The cells that make exceptional pairs with the TBA cell.

Additional constraints are considered when:

- The cell and its near cells are neighbours of a same GSM transmitter (only if the Transmitters folder of the GSM.atl document is accessible in the TD-SCDMA.atl document),
- The neighbour cells cannot share the same cluster (for the "Distributed per site" allocation strategy only).

These constraints have a certain weight taken into account to determine the TBA cell priority during the allocation process and the cost of the scrambling code plan. During the allocation, **9955** tries to assign different scrambling codes to the TBA cell and its near cells. If it respects all the constraints, the cost of the scrambling code plan is 0. When a cell has too many constraints and there are not anymore scrambling codes available, **9955** breaks the constraint with the lowest cost so as to generate the scrambling code plan with the lowest cost. For information on the cost generated by each constraint, see "Cell Priority" on page 612.

8.8.1.3.1 Single Carrier Network

The allocation process depends on the selected strategy. Algorithm works as follows:

Strategies: Clustered and Distributed per Cell

9955 processes TBA cells according to their priority. It allocates scrambling codes starting with the highest priority cell and its near cells, and continuing with the lowest priority cells not allocated yet and their near cells. For information on calculating cell priority, see "Cell Priority" on page 612.

Strategy: One SYNC_DL Code per Site

All sites which have constraints with the studied site are referred to as *near sites.*

9955 assigns a cluster, i.e., a SYNC_DL code, to each site, starting with the highest priority site and its near sites, and continuing with the lowest priority sites not allocated yet and their near sites. When all the clusters have been allocated but there are still sites remaining, **9955** reuses the clusters at the other sites. When the Reuse Distance option is selected, the algorithm reuses the clusters as soon as the reuse distance is exceeded. Otherwise, when the option is not selected, the algorithm tries to assign reused clusters as spaced out as possible.

Then, **9955** allocates a scrambling code from the cluster to each cell located on the sites (codes belong to the assigned clusters). It starts with the highest priority cell and its near cells and goes on with the lowest priority cells not allocated yet and their near cells.

For information on calculating site priority, see "Site Priority" on page 615. For information on calculating cell priority, see "Cell Priority" on page 612.

Strategy: Distributed per Site

All sites which have constraints with the studied site are referred to as *near sites.*

9955 assigns a group of adjacent clusters, i.e., SYNC_DL codes, to each site, starting with the highest priority site and its near sites, and continuing with the lowest priority sites not allocated yet and their near sites. When all the sites have been allocated adjacent clusters, and there are still sites remaining to be allocated, **9955** reuses the adjacent clusters at other sites. When the Reuse Distance option is selected, the algorithm reuses the clusters as soon as the reuse distance is exceeded. Otherwise, when the option is not selected, the algorithm tries to assign reused clusters as spaced out as possible.

Then, **9955** assigns each cluster of the group to each transmitter of the site according to the transmitter azimuth and selected neighbourhood constraints (options "Neighbours in Other Clusters" and "Secondary Neighbours in Other Clusters"). Then, **9955** allocates a scrambling code to each cell located on the transmitters (codes belong to the assigned clusters). It starts with the highest priority cell and its near cells and goes on with the lowest priority cells not allocated yet and their near cells.

For information on calculating site priority, see "Site Priority" on page 615. or information on calculating cell priority, see "Cell Priority" on page 612.

Determination of Groups of Adjacent Clusters

In order to determine the groups of adjacent clusters to be used, **9955**:

- Defines theoretical groups of adjacent clusters, independent of the defined domain, considering the 128 scrambling codes available and 4 codes per cluster.
- Starts the distribution of clusters to groups from the cluster 0
- Takes into account the maximum number of transmitters per site in order to determine the number of clusters in each group
- Determines the total number of groups

If the number of scrambling codes per cluster is set to 4 and the maximum number of transmitters per site in the network is 3, the theoretical groups of adjacent clusters will be:

Group 1	Group 2	Group 3	Group 4	...	Group 11
Cluster 0	Cluster 3	Cluster 6	Cluster 9	...	Cluster 30
Cluster 1	Cluster 4	Cluster 7	Cluster 10		Cluster 31
Cluster 2	Cluster 5	Cluster 8	Cluster 11		

If no domain is assigned to cells, **9955** can use all these groups for the allocation. On the other hand, if a domain is used, **9955** compares adjacent clusters actually available in the assigned domain with the theoretical groups and only keeps adjacent clusters common with the theoretical groups.

If we have a domain comprising 12 clusters: clusters 1 to 8 and clusters 12 to 15. In this case, **9955** will use the following groups of adjacent clusters:

- Group 2 with cluster 3, 4 and 5
- Group 3 with cluster 6, 7 and 8
- Group 6 with cluster 12, 13 and 14

The clusters 1, 2 and 15 will not be used.

If a domain does not contain any adjacent clusters, **9955** displays a warning message in the Event Viewer.

8.8.1.3.2 Multi-Carrier Network

In case you have a multi-carrier network and you run the scrambling code allocation on all the carriers, the allocation order changes. It is no longer based on the cell priority but depends on the transmitter priority. All transmitters which have constraints with the studied transmitter will be referred to as *near transmitters*.

In case of a "Per cell" strategy (Clustered and Distributed per cell), **9955** starts scrambling code allocation with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same scrambling code is assigned to each cell of the transmitter.

In case of the "One SYNC_DL code per site" strategy, **9955** assigns a cluster, i.e., a SYNC_DL code, to each site and then, allocates a scrambling code to each transmitter. It starts with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same scrambling code is assigned to each cell of the transmitter.

In case of the "Distributed per site" strategy, **9955** assigns a group of adjacent clusters, i.e., SYNC_DL codes, to each site, then a cluster to each transmitter and finally, allocates a scrambling code to each transmitter. It starts with the highest priority transmitter and its near transmitters and continues with the lowest priority transmitters not allocated yet and their near transmitters. The same scrambling code is assigned to each cell of the transmitter.

For information on calculating transmitter priority, see "Transmitter Priority" on page 614.

When cells, transmitters or sites have the same priority, processing is based on an alphanumeric order.

8.8.1.4 Priority Determination

8.8.1.4.1 Cell Priority

Scrambling code allocation algorithm in **9955** allots priorities to cells before performing the actual allocation. Priorities assigned to cells depend upon how much constrained each cell is and the cost defined for each constraint. A cell without any constraint has a default cost, C, equal to 0. The higher the cost on a cell, the higher the priority it has for the scrambling code allocation process.

There are seven criteria employed to determine the cell priority. The total cost due to constraints on any cell *i* is defined as:

$$C_i = C_i(Dom) + C_i(U)$$

With

$$C_i(U) = C_i(Dist) + C_i(EP) + C_i(N) + C_i(N_{2G}) + C_i(Cluster) + C_i(CN)$$

All the cost components are described below:

- Scrambling Code Domain Criterion

The cost due to the domain constraint, $C_i(Dom)$, depends on the number of scrambling codes available for the allocation. The domain constraint is mandatory and cannot be broken.

When no domain is assigned to cells, 128 scrambling codes are available and we have:

$$C_i(Dom) = 0$$

When domains of scrambling codes are assigned to cells, each unavailable scrambling code generates a cost. The higher the number of codes available in the domain, the less will be the cost due to this criterion. The cost is given as:

$$C_i(Dom) = 128 - \textit{Number of scrambling codes in the domain}$$

- Distance Criterion

The constraint level of any cell *i* depends on the number of cells (*j*) present within a radius of "reuse distance" from its centre. The total cost due to the distance constraint is given as:

$$C_i(Dist) = \sum_j C_j(Dist(i))$$

Each cell *j* within the reuse distance generates a cost given as:

$$C_j(Dist(i)) = w(d_{ij}) \times c_{distance}$$

Where

$w(d_{ij})$ is a weight depending on the distance between *i* and *j*. This weight is inversely proportional to the inter-cell distance. For a reuse distance of 2000m, the weight for an inter-cell distance of 1500m is 0.25, the weight for co-site cells is 1 and the weight for two cells spaced out 2100m apart is 0.

$c_{distance}$ is the cost of the distance constraint. This value can be defined in the **Constraint Cost** dialogue.

- Exceptional Pair Criterion

The constraint level of any cell *i* depends on the number of exceptional pairs (*j*) for that cell. The total cost due to exceptional pair constraint is given as:

$$C_i(EP) = \sum_j c_{EP}(i-j)$$

Where

c_{EP} is the cost of the exceptional pair constraint. This value can be defined in the **Constraint Cost** dialogue.

- Neighbourhood Criterion

The constraint level of any cell *i* depends on the number of its neighbour cells *j*, the number of second order neighbours *k* and the number of third order neighbours *l*.

Let's consider the following neighbour schema:

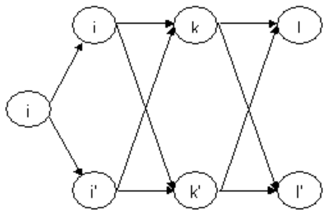


Figure 8.14: Neighbourhood Constraints

The total cost due to the neighbour constraint is given as:

$$C_i(N) = \left(\sum_j C_j(N1(i)) + \sum_{j'} C_{j-j'}(N1(i))\right) + \left(\sum_k C_k(N2(i)) + \sum_{k'} C_{k-k'}(N2(i))\right) + \left(\sum_l C_l(N3(i)) + \sum_{l'} C_{l-l'}(N3(i))\right)$$

Each first order neighbour cell *j* generates a cost given as:

$$C_j(N1(i)) = I_j \times c_{N1}$$

Where

I_j is the importance of the neighbour cell *j*.

c_{N1} is the cost of the first order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two first order neighbours must not have the same scrambling code, **9955** considers the cost created by two first order neighbours to be each other.

$$C_{j-j'}(N1(i)) = \frac{C_j(N1(i)) + C_{j'}(N1(i))}{2}$$

Each second order neighbour cell *k* generates a cost given as:

$$C_k(N2(i)) = Max((C_j(N1(i)) \times C_k(N1(j))),(C_{j'}(N1(i)) \times C_k(N1(j')))) \times c_{N2}$$

Where

c_{N2} is the cost of the second order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two second order neighbours must not have the same scrambling code, **9955** considers the cost created by two second order neighbours to be each other.

$$C_{k-k'}(N2(i)) = \frac{C_k(N2(i)) + C_{k'}(N2(i))}{2}$$

Each third order neighbour cell *l* generates a cost given as:

$$C_l(N3(i)) = Max\begin{pmatrix} C_j(N1(i)) \times C_k(N1(j)) \times C_l(N1(k)), C_{j'}(N1(i)) \times C_k(N1(j')) \times C_l N1(k), \\ (C_j(N1(i)) \times C_{k'}(N1(j))) \times C_l N1(k'), C_{j'}(N1(i)) \times C_{k'}(N1(j')) \times C_l N1(k') \end{pmatrix} \times c_{N3}$$

Where

c_{N3} is the cost of the third order neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

Because two third order neighbours must not have the same scrambling code, **9955** considers the cost created by two third order neighbours to be each other.

$$C_{l-l'}(N3(i)) = \frac{C_l(N3(i)) + C_{l'}(N3(i))}{2}$$

9955 considers the highest cost of both links when a neighbour relation is symmetric and the importance value is different.

In this case, we have:

$$C_j(N1(i)) = Max(I_{i-j}, I_{j-i}) \times c_{N1}$$

And

$$C_k(N2(i)) = Max(C_j(N1(i)) \times C_k(N1(j)), C_j(N1(k)) \times C_i(N1(j))) \times c_{N2}$$

- Close Neighbour Criterion

The constraint level of any cell *i* depends on the number of its close neighbour cells *j*. The close neighbour cost ($C_i(CN)$) depends on two components: the importance of the neighbour relation (I_{i-j}) and the distance (d_{i-j}) relative to maximum close neighbour distance (d_{CN}^{Max}).

$$C_i(CN) = \sum_j \left(\frac{I_{i-j} + \left(1 - \frac{d_{i-j}}{d_{CN}^{Max}}\right)}{2} \times c_{CN} \right)$$

Where

c_{CN} is the cost of the close neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

- GSM Neighbour Criterion

This criterion is considered when the co-planning mode is activated (i.e. the Transmitters folder of the GSM .atl document is made accessible in the TD-SCDMA.atl document) and inter-technology neighbours have been allocated. If the cell *i* is neighbour of a GSM transmitter, the cell constraint level depends on how many cells *j* are neighbours of the same GSM transmitter. The total cost due to GSM neighbour constraint is given as:

$$C_i(N_{2G}) = \sum_j c_{N_{2G}}(j - Tx_{2G})$$

Where

$c_{N_{2G}}$ is the cost of the GSM neighbour constraint. This value can be defined in the **Constraint Cost** dialogue.

- Cluster Criterion

When the "Distributed per Site" allocation strategy is used, you can consider additional constraints on allocated clusters (one cell, its first order neighbours and its second order neighbours must be assigned scrambling codes from different clusters). In this case, the constraint level of any cell *i* depends on the number of first and second order neighbours, *j* and *k*. The total cost due to the cluster constraint is given as:

$$C_i(Cluster) = \sum_j C_j(N1(i)) \times c_{Cluster} + \sum_k C_k(N2(i)) \times c_{Cluster}$$

Where

$c_{Cluster}$ is the cost of the cluster constraint. This value can be defined in the **Constraint Cost** dialogue.

8.8.1.4.2 Transmitter Priority

In case you have a multi-carrier network and you run scrambling code allocation on "all" the carriers, **9955** allots priorities to transmitters. Priorities assigned to transmitters depend on how much constrained each transmitter is and the cost defined for each constraint. The higher the cost on a transmitter, the higher the priority it has for the scrambling code allocation process.

Let us consider a transmitter Tx with two cells using carriers 0 and 1. The cost due to constraints on the transmitter is given as:

$$C_{Tx} = C_{Tx}(Dom) + C_{Tx}(U)$$

With $C_{Tx}(U) = \underset{i \in Tx}{Max}(C_i(U))$ and $C_{Tx}(Dom) = 128 - \textit{Number of scrambling codes in the domain}$

Here, the domain available for the transmitter is the intersection of domains assigned to cells of the transmitter. The domain constraint is mandatory and cannot be broken.

8.8.1.4.3 Site Priority

In case of "Per Site" allocation strategies (One SYNC_DL code per Site and Distributed per Site), **9955** allots priorities to sites. Priorities assigned to sites depend on how much constrained each site is and the cost defined for each constraint. The higher the cost on a site, the higher the priority it has for the scrambling code allocation process.

Let us consider a site S with three transmitters; each of them has two cells using carriers 0 and 1. The cost due to constraints on the site is given as:

$$C_S = C_S(U) + C_S(Dom)$$

With $C_S(U) = \underset{Tx \in S}{Max}(C_{Tx}(U))$ and $C_S(Dom) = 128 - \textit{Number of scrambling codes in the domain}$

Here, the domain considered for the site is the intersection of domains available for transmitters of the site. The domain constraint is mandatory and cannot be broken.

8.8.2 Scrambling Code Allocation Example

8.8.2.1 Single Carrier Network

In order to understand the differences between the different allocation strategies and the behaviour of algorithm when using a maximum of codes or not, let us consider the following sample scenario:

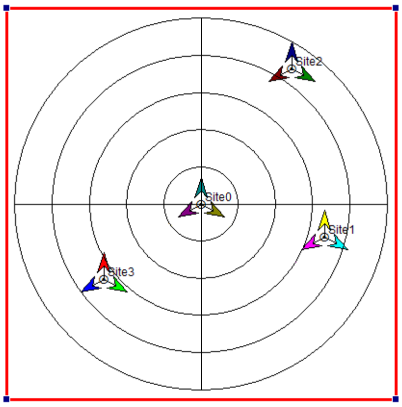


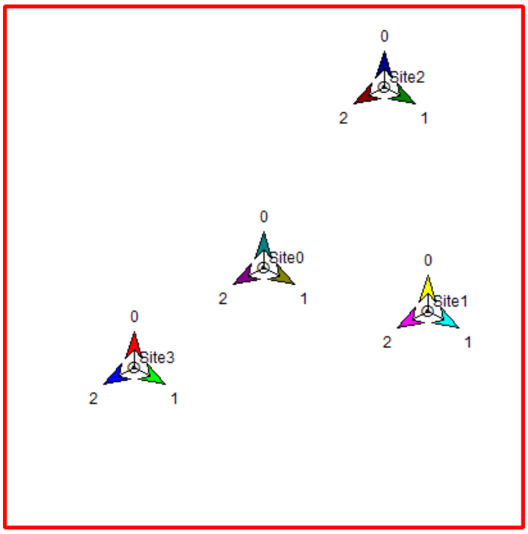
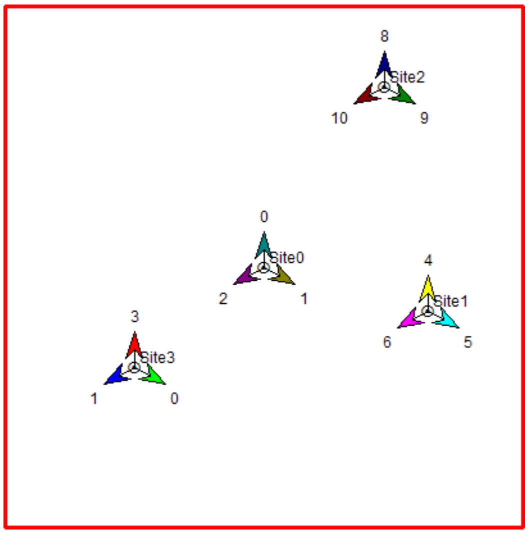
Figure 8.15: Scrambling Code Allocation Example

Let Site0, Site1, Site2, and Site3 be four sites, with 3 transmitters each using carrier 0, to whom scrambling codes have to be allocated out of 6 clusters of 4 scrambling codes. This implies that the domain of scrambling codes for the four sites is from 0 to 23 (cluster 0 to cluster 5). The reuse distance is supposed to be less than the inter-site distance. Only co-site neighbours exist.

The following section shows the results of each combination of options with explanations where necessary.

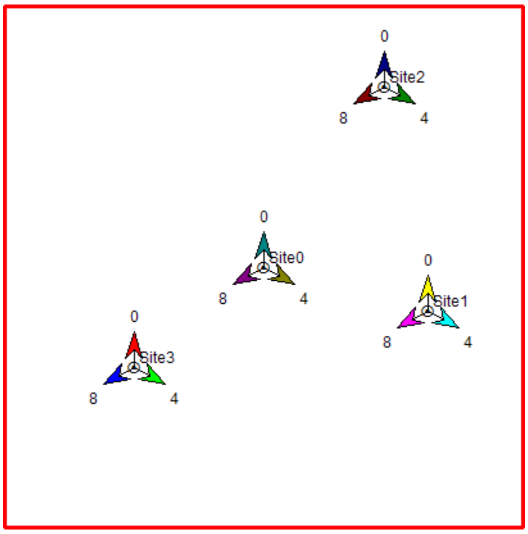
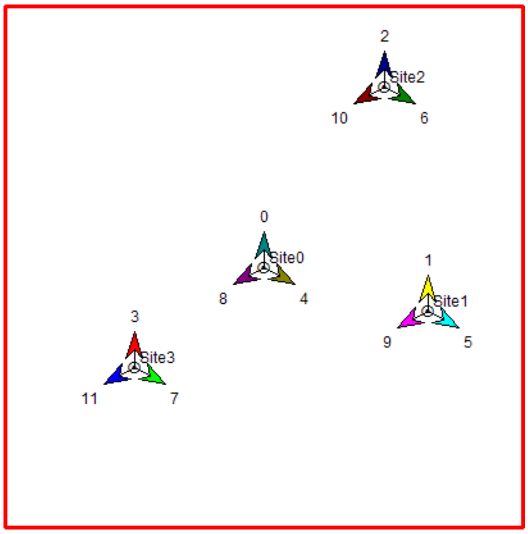
8.8.2.1.1 Strategy: Clustered

Since the restrictions of neighbourhood only apply to co-sites and, in our case, the distances between sites are greater than the reuse distance, every cell has the same priority. Allocation is performed in an alphanumeric order.

<table>
<tr><th>Without "Use a Maximum of Code"</th><th>With "Use a Maximum of Code"</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>9955 starts allocating the codes from the start of cluster 0 at each site.</td><td>As it is possible to use a maximum of codes, 9955 starts allocation at the start of a different cluster at each site. When a cluster is reused, and there are non allocated codes left in the cluster, 9955 first allocates those codes before reusing the already used ones.</td></tr>
</table>

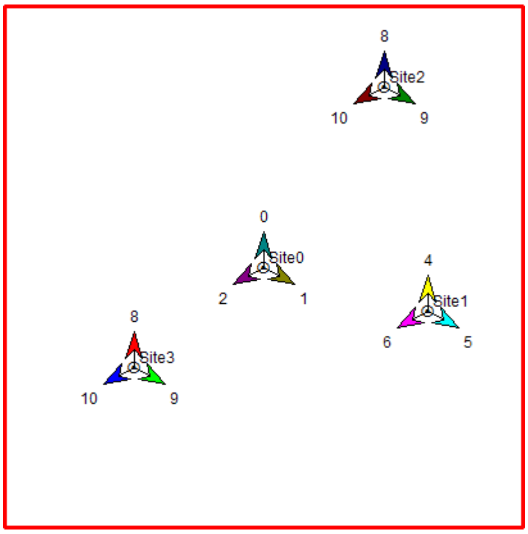
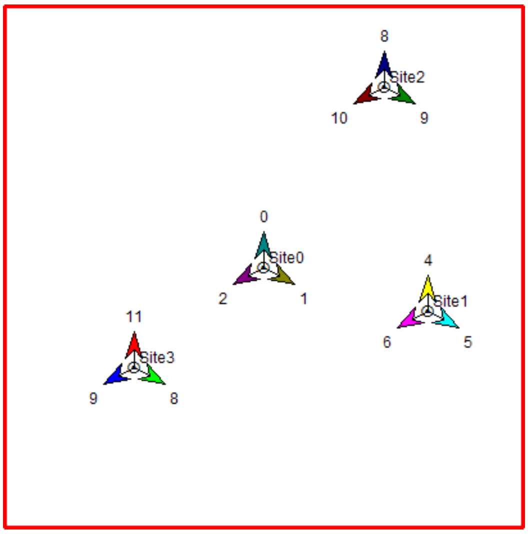
8.8.2.1.2 Strategy: Distributed per Cell

Since the restrictions of neighbourhood only apply to co-sites and, in our case, the distances between sites are greater than the reuse distance, every cell has the same priority. Allocation is performed in an alphanumeric order.

<table>
<tr><th>Without "Use a Maximum of Code"</th><th>With "Use a Maximum of Code"</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>9955 allocates codes from different clusters to each cell of the same site. Under given constraints of neighbourhood and reuse distance, same codes can be allocated to each site’s cells.</td><td>9955 allocates codes from different clusters to each site’s cells. As it is possible to use a maximum of codes, 9955 allocates the codes so that there is least repetition of codes.</td></tr>
</table>

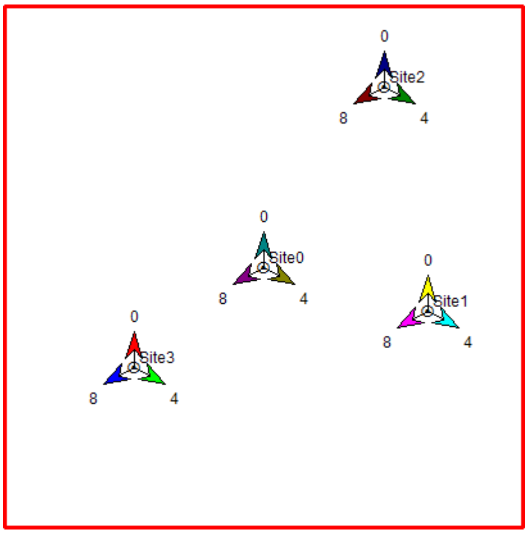
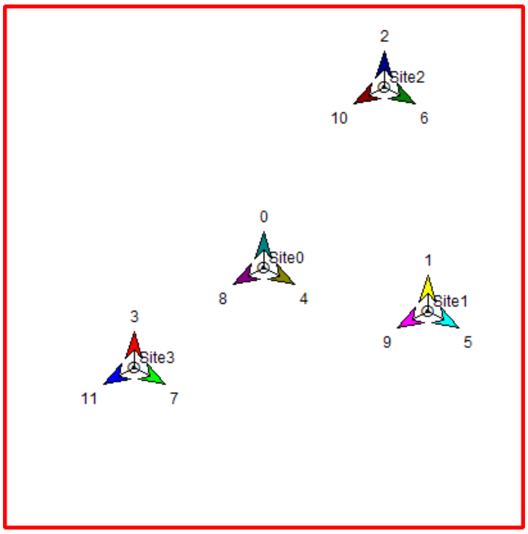
8.8.2.1.3 Strategy: One SYNC_DL Code per Site

Since the restrictions of neighbourhood only apply to co-sites, therefore, every site has the same priority. Cluster allocation to sites is performed in an alphanumeric order.

Without "Use a Maximum of Code"	With "Use a Maximum of Code"
	
In this strategy, a cluster of codes is limited to be used at just one site at a time unless all codes and clusters have been allocated and there are still sites remaining to be allocated. In this case, **9955** reuses the cluster as far as possible at another site.	When it is possible to use a maximum of codes, **9955** can allocate different codes from a reused cluster at another site.

8.8.2.1.4 Strategy: Distributed per Site

Since the restrictions of neighbourhood only apply to co-sites, therefore, every site has the same priority. Cluster allocation to sites is performed in an alphanumeric order.

Without "Use a Maximum of Code"	With "Use a Maximum of Code"
	
A group of adjacent clusters is allocated to one site at a time, unless all the codes and groups of adjacent clusters have been allocated but there are still sites remaining to be allocated. In this case (here only one group of adjacent clusters 0, 1, and 2 is available), **9955** reuses the group as far as possible at another site.	When it is possible to use a maximum of codes, **9955** can allocate different codes from a reused groups of adjacent clusters at another site.

8.8.2.2 Multi Carrier Network

If you have a multi carrier network, i.e., transmitters with more than one cells using different carriers, and you run scrambling code allocation on "all" the carriers, **9955** allocates the same scrambling code to each carrier of a transmitter.

Let Site0, Site1, Site2, and Site3 be four sites with 3 cells using carrier 0 and 3 cells using carrier 1. Scrambling codes have to be allocated out of 6 clusters consisted of 4 scrambling codes. This implies that the domain of scrambling codes for the four sites is from 0 to 23 (cluster 0 to cluster 5). The reuse distance is supposed to be less than the inter-site distance. Only co-site neighbours exist. Every site has the same priority and the cluster allocation to sites is performed in an alphanumeric order.

9955 allocates one cluster at each site and then, one code to each transmitter. Then, the same code is given to each cell of the transmitter.

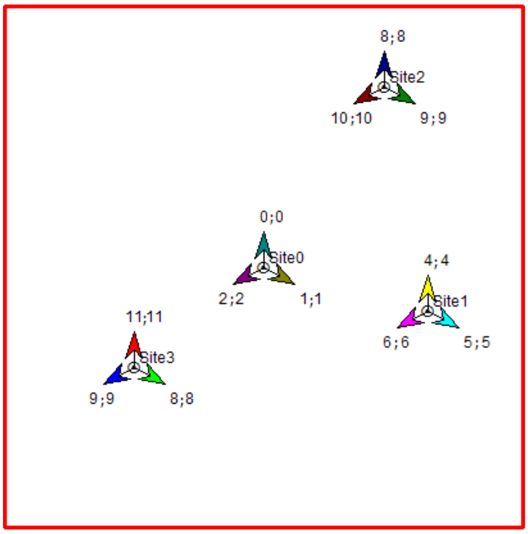


Figure 8.16: Scrambling Code Allocation to All Carriers

8.9 Automatic GSM/TD-SCDMA Neighbour Allocation

It is possible to automatically calculate and allocate neighbours between GSM and TD-SCDMA networks. In **9955**, it is called inter-technology neighbour allocation.

Inter-technology handover is used in two cases:

- When the TD-SCDMA coverage is not continuous. In this case, the TD-SCDMA coverage is extended by TD-SCDMA to GSM handovers.
- In order to balance traffic and service distribution between both networks.

9955's automatic inter-technology neighbour allocation algorithm takes into account both cases.

In order to be able to use the inter-technology neighbour allocation algorithm, you must have:

- An .atl document containing the GSM network, GSM.atl, and another one containing the TD-SCDMA network, TD-SCDMA.atl,
- An existing link on the Transmitters folder of GSM.atl into TD-SCDMA.atl.

The external neighbour allocation algorithm takes into account all the GSM TBC transmitters. It means that all the TBC transmitters of GSM.atl are potential neighbours. The TD-SCDMA cells, in TD-SCDMA.atl, to be allocated neighbours are called TBA cells which fulfill following conditions:

- They are active
- They satisfy the filter criteria applied to Transmitters folder
- They are located inside the focus zone
- They belong to the folder for which allocation has been executed. This folder can be either the Transmitters folder or one of its subfolders.

Only TD-SCDMA TBA cells can be assigned neighbours.

8.9.1 Automatic Allocation Description

The allocation algorithm takes into account criteria listed below:

- The inter-transmitter distance
- The maximum number of neighbours
- Allocation options
- The selected allocation strategy

Two allocation strategies are available: the first one is based on distance and the second one on coverage overlapping.

We assume we have a TD-SCDMA reference cell, A, and a GSM candidate neighbour transmitter, B.

8.9.1.1 Algorithm Based on Distance

When automatic allocation starts, **9955** checks following conditions:

1. The distance between the TD-SCDMA reference cell and the GSM neighbour must be less than the user-defined maximum inter-site distance. If the distance between the TD-SCDMA reference cell and the GSM neighbour is greater than this value, then the candidate neighbour is discarded.

   9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Appendix: Calculation of the Inter-Transmitter Distance" on page 608.

2. The calculation options:

   Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

   Force co-site cells as neighbours: It enables you to automatically include GSM transmitters located on the same site than the reference TD-SCDMA cell in the candidate neighbour list. This option is automatically selected.

   Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a GSM transmitter to be candidate neighbour of the reference TD-SCDMA cell.

   Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, existing neighbours are kept.

3. The importance of neighbours.

   Next, **9955** calculates the importance of the automatically allocated neighbours. **9955** sorts the neighbours by decreasing importance in order to keep the ones with high importance. If the maximum number of neighbours to be allocated to each cell is exceeded, **9955** keeps the ones with high importance.

   As indicated in the table below, the neighbour importance depends on the distance and on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter	If the Force co-site cells as neighbours option is selected	100 %
Neighbourhood relationship that fulfils distance conditions	If the maximum distance is not exceeded	$1 - \frac{d}{d_{max}}$

   Where d is the effective distance between the TD-SCDMA reference cell and the GSM neighbour and d_{max} is the maximum inter-site distance.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site, or distance. For neighbours accepted for distance reasons, **9955** displays the distance from the reference cell (m). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

8.9.1.2 Algorithm Based on Coverage Overlapping

When automatic allocation starts, **9955** checks following conditions:

1. The distance between the TD-SCDMA reference cell and the GSM neighbour must be less than the user-defined maximum inter-site distance. If the distance between the TD-SCDMA reference cell and the GSM neighbour is greater than this value, then the candidate neighbour is discarded.

   9955 calculates the effective distance, which corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Appendix: Calculation of the Inter-Transmitter Distance" on page 608.

2. The calculation options:

   Carriers: This option enables you to select the carrier(s) on which you want to run the allocation. You may choose one or more carriers. **9955** will allocate neighbours to cells using the selected carriers.

   Force co-site cells as neighbours: It enables you to automatically include GSM transmitters located on the same site than the reference TD-SCDMA cell in the candidate neighbour list. This option is automatically selected.

   Force exceptional pairs: This option enables you to force/forbid some neighbourhood relationships. Therefore, you may force/forbid a GSM transmitter to be candidate neighbour of the reference TD-SCDMA cell.

Delete existing neighbours: When selecting the Delete existing neighbours option, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, existing neighbours are kept.

3. There must be an overlapping zone ($S_A \cap S_B$) with a given cell edge coverage probability.

Two different cases may be considered for S_A:

- 1st case: S_A is the area where the cell A is the best serving cell of the TD-SCDMA network.
  - The pilot signal received from A is greater than the minimum pilot signal level and is the highest one.
  - The margin is set to 0 dB.
- 2nd case: The margin is different from 0 dB and S_A is the area where:
  - The pilot signal level received from A exceeds the user-defined minimum pilot signal level and is within a margin from the highest signal level.

Two different cases may be considered for S_B:

- 1st case: S_B is the area where the cell B is the best serving transmitter of the GSM network.

  In this case, the margin must be set to 0 dB.

  - The signal level received from B on the BCCH TRX type exceeds the user-defined minimum threshold and is the highest one.
- 2nd case: The margin is different from 0 dB and S_B is the area where:
  - The signal level received from B on the BCCH TRX type exceeds the user-defined minimum threshold and is within a margin from the best BCCH signal level.

9955 calculates the percentage of covered area ($\frac{S_A \cap S_B}{S_A} \times 100$) and compares this value to the % minimum covered area. If this percentage is less than the minimum, the candidate neighbour B is discarded.

Candidate neighbours fulfilling coverage conditions are sorted in descending order with respect to percentage of covered area.

4. The importance of neighbours.

Next, **9955** calculates the importance of the automatically allocated neighbours. **9955** sorts the neighbours by decreasing importance in order to keep the ones with high importance. If the maximum number of neighbours to be allocated to each cell is exceeded, **9955** keeps the ones with high importance.

As indicated in the table below, the neighbour importance depends on the distance and on the neighbourhood cause; this value varies between 0 to 100%.

Neighbourhood reason	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter	If the Force co-site cells as neighbours option is selected	IF
Neighbourhood relationship that fulfils coverage conditions	If the % minimum covered area is exceeded	IF

Except the case of forced neighbours (importance = 100%), priority assigned to each neighbourhood cause is determined using the Importance Function (IF). The IF considers the following factors for calculating the importance:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas. For information on the effective distance calculation, see "Appendix: Calculation of the Inter-Transmitter Distance" on page 608.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.
- The co-site factor (C): a Boolean,
- The overlapping factor (O): the percentage of overlapping.

The IF is user-definable using the Min importance and Max importance fields.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The IF evaluates importance as follows:

Co-site Neighbourhood cause	IF	Resulting IF using the default values from the table above
No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+50%{10%(Di)+90%(O)}
Yes	Min(C)+Delta(C){Max(Di)(Di)/(Max(Di)+Max(O))+ Max(O)(O)/(Max(Di)+Max(O))}	60%+40%{1/7%(Di)+6/7%(O)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.

In the **Results** part, **9955** provides the list of neighbours, the number of neighbours and the maximum number of neighbours allowed for each cell. In addition, it indicates the importance (in %) of each neighbour and the allocation reason. Therefore, a neighbour may be marked as exceptional pair, co-site or coverage. For neighbours accepted for co-site and coverage reasons, **9955** displays the percentage of area meeting the coverage conditions and the corresponding surface area (km^2). Finally, if cells have previous allocations in the list, neighbours are marked as existing.

- No prediction study is needed to perform an automatic neighbour allocation. When starting an automatic neighbour allocation, 9955 automatically calculates the path loss matrices if not found.
- A forbidden neighbour must not be listed as neighbour except if the neighbourhood relationship already exists and the Delete existing neighbours option is unchecked when you start the new allocation. In this case, 9955 displays a warning in the Event viewer indicating that the constraint on the forbidden neighbour will be ignored by algorithm because the neighbour already exists.
- In the Results, 9955 displays only the cells for which it finds new neighbours. Therefore, if a TBA cell has already reached its maximum number of neighbours before starting the new allocation, it will not appear in the Results table.

8.9.1.3 Appendices

8.9.1.3.1 Delete Existing Neighbours Option

As explained above, **9955** keeps the existing inter-technology neighbours when the Delete existing neighbours option is not selected. If a new TBA cell *i* is created in TD-SCDMA.atl, you can run the automatic allocation with the Delete existing neighbours option not selected, in order to allocate neighbours to the new cell *i* only.

If you change some allocation criteria (e.g., increase the maximum number of neighbours or create a new GSM TBC transmitter) and start a new allocation without selecting the Delete existing neighbours option, **9955** examines the neighbour list of the TBA cells and checks allocation criteria only if there is still space left in their neighbour lists. A new GSM TBC transmitter can enter the TBA cell neighbour list if allocation criteria are satisfied. It will be the first one in the neighbour list.

Chapter 9

WiMAX BWA Networks

This chapter describes WiMAX calculations.

In this chapter, the following are explained:

- "Definitions" on page 625
- "Calculation Quick Reference" on page 629
- "Available Calculations" on page 641
- "Coverage Predictions" on page 642
- "Effective Signal Analysis Coverage Predictions" on page 643
- "C/(I+N)-based Coverage Predictions" on page 644
- "Calculations on Subscriber Lists" on page 646
- "Monte Carlo Simulations" on page 646
- "Calculation Details" on page 653
- "Automatic Planning Algorithms" on page 708

9 WiMAX BWA Networks

This chapter describes all the calculations performed in **9955** WiMAX documents. The first part of this chapter lists all the input parameters in the WiMAX BWA documents, their significance, location in the **9955** GUI, and their usage. It also contains the lists of the formulas used for the calculations.

The second part describes all the calculation processes, i.e., signal level coverage predictions, point analysis calculations, signal quality coverage predictions, calculations on subscriber lists, and Monte Carlo simulations. The calculation algorithms used by these calculation processes are available in the next part.

The third part describes all the calculation algorithms used in all the calculations. These algorithms include the calculation of signal levels, noise, and interference for downlink and uplink considering the effects of smart antennas, power control, subchannelisation, MIMO etc., and the radio resource management algorithms used by the different available schedulers.

If you are new to WiMAX, you can also see the *Glossary of WiMAX Terms* in the *User Manual* for information on WiMAX terms and concepts, especially in the context of their user in **9955**.

- All the calculations are performed on TBC (to be calculated) transmitters. For the definition of TBC transmitters please refer to "Path Loss Matrices" on page 98.
- A cell refers to a transmitter-carrier (TX-c) pair. The cell being studied during a calculation is referred to as $TX_i(ic)$ in this chapter.
- All the calculation algorithms in this section are described for two types of cells.
    - A *studied cell* (represented by the subscript "*i*") comprising the studied transmitter TX_i and its carrier *ic*. It is the cell which is currently the focus of the calculation. For example, a victim cell when calculating the interference it is receiving from other cells.
    - *Other cells* (represented by the subscript "*j*") comprising the other transmitter TX_j and its carrier *jc*. The other cells in the network can be interfering cells (downlink) or the serving cells of interfering mobiles (uplink).
- All the calculation algorithms in this section are described for two types of receivers.
    - M_i: A pixel (coverage predictions), subscriber (calculations on subscriber lists), or mobile (Monte Carlo simulations) covered/served by the studied cell $TX_i(ic)$.
    - M_j: A mobile (Monte Carlo simulations) covered/served by any other cell $TX_j(jc)$.
- Logarithms used in this chapter (Log function) are base-10 unless stated otherwise.

9.1 Definitions

This table lists the input to calculations, coverage predictions, and simulations.

Name	Value	Unit	Description
K	1.38×10^{-23}	J/K	Boltzmann's constant
T	290	K	Ambient temperature
n_0	Calculation result ($10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$)	dBm/Hz	Power spectral density of thermal noise
D_{Frame}	Global parameter	ms	Frame Duration Choice List: 2, 2.5, 4, 5, 8, 10, 12.5, 20
r_{CP}	Global parameter	None	Cyclic Prefix Ratio Choice List: 1/4, 1/8, 1/16, 1/32
O^{DL}_{Fixed}	Global parameter	SD	Fixed time-domain overhead (DL)
O^{UL}_{Fixed}	Global parameter	SD	Fixed time-domain overhead (UL)
$O^{DL}_{Variable}$	Global parameter	%	Variable time-domain overhead (DL)
$O^{UL}_{Variable}$	Global parameter	%	Variable time-domain overhead (UL)
$r^{TDD}_{DL\text{-}Frame}$	Global parameter	%	Ratio of the DL subframe to the entire frame (TDD only)

Name	Value	Unit	Description
N_{SD-DL}^{TDD}	Global parameter	None	Number of symbol durations per frame that corresponds to the DL subframe (TDD only)
N_{SD-UL}^{TDD}	Global parameter	None	Number of symbol durations per frame that corresponds to the UL subframe (TDD only)
D_{TTG}^{TDD}	Global parameter	ms	Transmit Time Guard (TDD only)
D_{RTG}^{TDD}	Global parameter	ms	Receive Time Guard (TDD only)
M_{PC}	Global parameter	dB	Uplink power control margin
CNR_{Min}	Global parameter[a]	dB	Minimum signal to thermal noise threshold (interferer cutoff)
N_{SC-UL}^{PZ}	Permutation zone parameter	None	Number of subchannels per channel in UL subframe
N_{SC-DL}^{PZ}	Permutation zone parameter	None	Number of subchannels per channel in DL subframe
$N_{SCa-Total}$	Frame configuration parameter	None	Total number of subcarriers per channel (FFT size)
$N_{SCa-Preamble}$	Frame configuration parameter	None	Number of subcarriers used by the preamble
$N_{SCa-Used}^{PZ}$	Permutation zone parameter	None	Number of used subcarriers per channel
$N_{SCa-Data}^{PZ}$	Permutation zone parameter	None	Number of subcarriers per channel used for data transfer
N_{SCa-DC}	Hard-coded parameter ($N_{SCa-DC} = 1$)	None	Number of DC subcarriers per channel
$N_{SCa-Pilot}^{PZ}$	Calculation result ($N_{SCa-Pilot}^{PZ} = N_{SCa-Used}^{PZ} - N_{SCa-Data}^{PZ}$)	None	Number of pilot subcarriers per channel
$N_{SCa-Guard}^{PZ}$	Calculation result ($N_{SCa-Guard}^{PZ} = N_{SCa-Total} - N_{SCa-Used}^{PZ} - N_{SCa-DC}$)	None	Number of guard subcarriers per channel
PZ_{UL}	Permutation zone parameter	None	Uplink permutation zone
PZ_{DL}	Permutation zone parameter	None	Downlink permutation zone
QT_{PZ}	Permutation zone parameter	dB	Quality threshold: Required preamble C/N or C/(I+N) for accessing a zone
$Speed_{Max-PZ}$	Permutation zone parameter	Km/hr	Speed limit for mobiles trying to access a permutation zone
d_{Max-PZ}	Permutation zone parameter	m	Maximum distance from the transmitter covered by a zone
p_{PZ}	Permutation zone parameter	None	Permutation zone priority
$W_{Channel}$	Frequency band parameter	MHz	Channel bandwidth
$N_{Channel}^{First}$	Frequency band parameter	None	First channel number of the frequency band
$N_{Channel}^{Last}$	Frequency band parameter	None	Last channel number of the frequency band
$F_{Start-FB-TDD}$	Frequency band parameter	MHz	Start frequency of the TDD frequency band
$F_{Start-FB-FDD-DL}$	Frequency band parameter	MHz	DL Start frequency of the FDD frequency band
$F_{Start-FB-FDD-UL}$	Frequency band parameter	MHz	UL Start frequency of the FDD frequency band

Alcatel·Lucent

Name	Value	Unit	Description
$f_{Sampling}$	Frequency band parameter	None	Sampling factor
f_{ACS-FB}	Frequency band parameter	dB	Adjacent Channel Suppression Factor
$f_{IRF}^{Inter-Tech}$	Network parameter	dB	Inter-technology interference reduction factor
B	Bearer parameter	None	Bearer index
Mod_B	Bearer parameter	None	Modulation used by the bearer
CR_B	Bearer parameter	None	Coding rate of the bearer
η_B	Bearer parameter	bits/ symbol	Bearer Efficiency
T_B	Bearer parameter	dB	Bearer selection threshold
nf^{TX}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	dB	Transmitter noise figure
N_{Ant-TX}	Transmitter parameter	None	Number of antennas used for MIMO in transmission
N_{Ant-RX}	Transmitter parameter	None	Number of antennas used for MIMO in reception
G^{TX}	Antenna parameter	dB	Transmitter antenna gain
L^{TX}	Transmitter parameter (user-defined or calculated from transmitter equipment characteristics)	dB	Transmitter loss
E_{SA}^{TX}	Smart antenna parameter	None	Number of smart antenna elements
ΔG_{SA}^{Array}	Smart antenna parameter	dB	Array gain offset
$\Delta G_{SA}^{Combining}$	Smart antenna parameter	dB	Power combining gain offset
G_{SA}^{Div}	Smart antenna parameter	dB	Diversity gain (cross-polarisation)
$N_{Channel}$	Cell parameter	None	Cell's channel number
$P_{Preamble}$	Cell parameter	dBm	Preamble power
$\Delta P_{Traffic}$	Cell parameter $P_{Traffic} = P_{Preamble} - \Delta P_{Traffic}$ in dB $\Delta P_{Traffic}^{Ratio} = 10^{\frac{\Delta P_{Traffic}}{10}}$ in %	dB	Traffic power reduction
ΔP_{Pilot}	Cell parameter $P_{Pilot} = P_{Preamble} - \Delta P_{Pilot}$ in dB $\Delta P_{Pilot}^{Ratio} = 10^{\frac{\Delta P_{Pilot}}{10}}$ in %	dB	Pilot power reduction
$\Delta P_{Idle-Pilot}$	Cell parameter $P_{Idle-Pilot} = P_{Preamble} - \Delta P_{Idle-Pilot}$ in dB $\Delta P_{Idle-Pilot}^{Ratio} = 10^{\frac{\Delta P_{Idle-Pilot}}{10}}$ in %	dB	Idle pilot power reduction
TL_{DL}	Cell parameter	%	Downlink traffic load
TL_{UL}	Cell parameter	%	Uplink traffic load
TL_{DL-Max}	Cell parameter	%	Maximum downlink traffic load
TL_{UL-Max}	Cell parameter	%	Maximum uplink traffic load
NR_{UL}	Cell parameter	dB	Uplink noise rise
NR_{UL-Seg}	Cell parameter	dB	Segmented zone uplink noise rise
$N_{Users-Max}$	Cell parameter	None	Maximum number of users per cell

Name	Value	Unit	Description
SU_{DL}	Cell parameter	%	Downlink segmentation usage ratio
AU_{DL}	Cell parameter	%	Downlink AAS usage ratio
T_{AMS}	Cell parameter	dB	Adaptive MIMO switch threshold
$T_{MU-MIMO}$	Cell parameter	dB	Multi-user MIMO threshold
PI	Cell parameter	None	Preamble index
$T_{Preamble}$	Cell parameter	dB	Preamble C/N threshold
D_{Reuse}	Cell parameter	m	Channel and preamble index reuse distance
$G_{MU-MIMO}$	Cell parameter	None	Uplink MU-MIMO gain
$NR_{DL}^{Inter-Tech}$	Cell parameter	dB	Inter-technology downlink noise rise
$NR_{UL}^{Inter-Tech}$	Cell parameter	dB	Inter-technology uplink noise rise
ZPB_{DL}	Cell parameter	None	Downlink zone permbase
ZPB_{UL}	Cell parameter	None	Uplink zone permbase
$G_{MUG-DL}^{TX_i(ic)}$	Proportional Fair scheduler parameter	None	Downlink multi-user diversity gain (MUG)
$G_{MUG-UL}^{TX_i(ic)}$	Proportional Fair scheduler parameter	None	Uplink multi-user diversity gain (MUG)
$CINR_{MUG}^{Max}$	Proportional Fair scheduler parameter	dB	Maximum C/(I+N) above which no MUG gain is applied
$G_{SU-MIMO}^{Max}$	Cell WiMAX equipment parameter	None	Maximum SU-MIMO gain
G_{STTD}^{UL}	Cell WiMAX equipment parameter	dB	Uplink STTD/MRC gain
f_{Bias}^{QoS}	Scheduler parameter	%	QoS class bias factor
QoS	Service parameter	None	QoS class of the service
p	Service parameter	None	Service priority
$B_{DL-Highest}$	Service parameter	None	Highest bearer used by a service in the downlink
$B_{UL-Highest}$	Service parameter	None	Highest bearer used by a service in the uplink
$B_{DL-Lowest}$	Service parameter	None	Lowest bearer used by a service in the downlink
$B_{UL-Lowest}$	Service parameter	None	Lowest bearer used by a service in the uplink
f_{Act}^{UL}	Service parameter	%	Uplink activity factor
f_{Act}^{DL}	Service parameter	%	Downlink activity factor
TPD_{Min-UL}	Service parameter	kbps	Minimum throughput demand in the uplink
TPD_{Min-DL}	Service parameter	kbps	Minimum throughput demand in the downlink
TPD_{Max-UL}	Service parameter	kbps	Maximum throughput demand in the uplink
TPD_{Max-DL}	Service parameter	kbps	Maximum throughput demand in the downlink
$TP_{Average}^{UL}$	Service parameter	kbps	Average requested throughput in the uplink

Name	Value	Unit	Description
$TP^{DL}_{Average}$	Service parameter	kbps	Average requested throughput in the downlink
TP_{Offset}	Service parameter	kbps	Throughput offset
$f_{TP-Scaling}$	Service parameter	%	Scaling factor
L_{Body}	Service parameter	dB	Body loss
P_{Min}	Terminal parameter	dBm	Minimum terminal power allowed
P_{Max}	Terminal parameter	dBm	Maximum terminal power allowed
nf	Terminal parameter	dB	Terminal noise figure
G	Terminal parameter	dB	Terminal antenna gain
L	Terminal parameter	dB	Terminal loss
N_{Ant-TX}	Terminal parameter	None	Number of antennas used for MIMO in transmission
N_{Ant-RX}	Terminal parameter	None	Number of antennas used for MIMO in reception
$G^{Max}_{SU-MIMO}$	Terminal WiMAX equipment parameter	None	Maximum SU-MIMO gain
G^{DL}_{STTD}	Terminal WiMAX equipment parameter	dB	Downlink STTD/MRC gain
ΔG^{UL}_{STTD}	Clutter parameter	dB	Additional uplink STTD/MRC gain
ΔG^{DL}_{STTD}	Clutter parameter	dB	Additional downlink STTD/MRC gain
$f_{SU-MIMO}$	Clutter parameter	None	SU-MIMO gain factor
L_{Indoor}	Clutter parameter	dB	Indoor loss
L_{Path}	Propagation model result	dB	Path loss
$M_{Shadowing-Model}$	Monte Carlo simulations: Random result calculated from model standard deviation Coverage Predictions: Result calculated from cell edge coverage probability and model standard deviation	dB	Model shadowing margin
$M_{Shadowing-C/I}$	Coverage Predictions: Result calculated from cell edge coverage probability and C/I standard deviation	dB	C/I shadowing margin

a. *Any interfering cell whose signal to thermal noise ratio is less than* CNR_{Min} *will be discarded.*

9.2 Calculation Quick Reference

The following tables list the formulas used in calculations.

9.2.1 Co- and Adjacent Channel Overlaps Calculation

Name	Value	Unit	Description
$F^{TX_i(ic)}_{Start}$	$F^{TX_i(ic)}_{Start-FB} + W^{TX_i(ic)}_{Channel} \times \left(N^{TX_i(ic)}_{Channel} - N^{First}_{Channel}\right)$	MHz	Start frequency for the channel number assigned to a cell
$F^{TX_i(ic)}_{End}$	$F^{TX_i(ic)}_{Start-FB} + W^{TX_i(ic)}_{Channel} \times \left(N^{TX_i(ic)}_{Channel} - N^{First}_{Channel} + 1\right)$	MHz	End frequency for the channel number assigned to a cell
$W^{TX_i(ic)-TX_j(jc)}_{CCO}$	$Min\left(F^{TX_j(jc)}_{End}, F^{TX_i(ic)}_{End}\right) - Max\left(F^{TX_j(jc)}_{Start}, F^{TX_i(ic)}_{Start}\right)$	MHz	Co-channel overlap bandwidth

Name	Value	Unit	Description
$r_{CCO}^{TX_i(ic)-TX_j(jc)}$	$\dfrac{W_{CCO}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Co-channel overlap ratio
$W_{ACO_L}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)}\right)$	MHz	Bandwidth of the lower-frequency adjacent channel overlap
$r_{ACO_L}^{TX_i(ic)-TX_j(jc)}$	$\dfrac{W_{ACO_L}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Lower-frequency adjacent channel overlap ratio
$W_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right)$	MHz	Bandwidth of the higher-frequency adjacent channel overlap
$r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	$\dfrac{W_{ACO_H}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Higher-frequency adjacent channel overlap ratio
$r_{ACO}^{TX_i(ic)-TX_j(jc)}$	$r_{ACO_L}^{TX_i(ic)-TX_j(jc)} + r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	None	Adjacent channel overlap ratio
$r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)}$	$\dfrac{r_{DL-Frame}^{TDD}}{100}$ if interferer uses a TDD frequency band and victim uses an FDD frequency band, 1 otherwise	None	FDD – TDD overlap ratio
$r_O^{TX_i(ic)-TX_j(jc)}$	$\left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}}\right) \times r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)}$ if $W_{Channel}^{TX_i(ic)} \geq W_{Channel}^{TX_j(jc)}$ $\left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}}\right) \times r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)} \times \dfrac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ if $W_{Channel}^{TX_i(ic)} < W_{Channel}^{TX_j(jc)}$	None	Total overlap ratio

9.2.2 Preamble Signal Level Calculation

Name	Value	Unit	Description
$C_{Preamble}^{TX_i(ic)}$	$EIRP_{Preamble}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$	dBm	Received preamble signal level
$EIRP_{Preamble}^{TX_i(ic)}$	Without smart antennas: $P_{Preamble}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$ With smart antennas: $P_{Preamble}^{TX_i(ic)} + G^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$	dBm	Preamble EIRP of a cell
L_{Path}	$L_{Model} + L_{Ant}^{TX_i}$	dB	Path loss
L_{Total}	$L_{Path} + L^{TX_i} + L_{Indoor} + M_{Shadowing-Model} - G^{TX_i} + L^{M_i} - G^{M_i} + L_{Ant}^{M_i} + L_{Body}^{M_i}$	dB	Total losses

9.2.3 Preamble Noise Calculation

Name	Value	Unit	Description
$n_{0-Preamble}^{TX_i(ic)}$	$n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Preamble}^{TX_i(ic)}}{N_{SCa-Total}^{TX_i(ic)}} \times f_{Segment}^{Preamble}\right)$	dBm	Preamble thermal noise for a cell
$f_{Segment}^{Preamble}$	$\frac{1}{3}$	None	Preamble segmenting factor
$n_{Preamble}^{TX_i(ic)}$	$n_{0-Preamble}^{TX_i(ic)} + nf^{M_i}$	dBm	Preamble noise for a cell

9.2.4 Preamble Interference Calculation

Name	Value	Unit	Description
$I_{Preamble}^{TX_j(jc)}$	$C_{Preamble}^{TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)} + f_{Seg-Preamble}^{TX_i(ic)-TX_j(jc)} + I_{DL}^{Inter-Tech}$	dBm	Total interference generated by an interfering cell
$f_O^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to the co- and adjacent channel overlap
$f_{Seg-Preamble}^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(p_{Collision}^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to segmentation
$p_{Collision}^{TX_i(ic)-TX_j(jc)}$	1 if $N_{Seg}^{TX_i(ic)} = N_{Seg}^{TX_j(jc)}$ and 0 if $N_{Seg}^{TX_i(ic)} \neq N_{Seg}^{TX_j(jc)}$	None	Preamble subcarrier collision probability

9.2.5 Preamble C/N Calculation

Name	Value	Unit	Description
$CNR_{Preamble}^{TX_i(ic)}$	$C_{Preamble}^{TX_i(ic)} - n_{Preamble}^{TX_i(ic)}$	dB	Preamble C/N for a cell

9.2.6 Preamble C/(I+N) Calculation

Name	Value	Unit	Description
$CINR_{Preamble}^{TX_i(ic)}$	$C_{Preamble}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{Preamble}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Preamble}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$	dB	Preamble C/(I+N) for a cell
$(I+N)_{Preamble}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{Preamble}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Preamble}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}$	dBm	Preamble Total Noise (I+N) for a cell

9.2.7 Traffic and Pilot Signal Level Calculation (DL)

Name	Value	Unit	Description
$C_{Traffic}^{TX_i(ic)}$	$EIRP_{Traffic}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$	dBm	Received traffic signal level

Name	Value	Unit	Description
$C_{Pilot}^{TX_i(ic)}$	$EIRP_{Pilot}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$	dBm	Received pilot signal level
$EIRP_{Traffic}^{TX_i(ic)}$	$P_{Traffic}^{TX_i(ic)} + G^{TX_i} + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$	dBm	Traffic EIRP of a cell
$EIRP_{Pilot}^{TX_i(ic)}$	$P_{Pilot}^{TX_i(ic)} + G^{TX_i} + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$	dBm	Pilot EIRP of a cell
$P_{Traffic}^{TX_i(ic)}$	$P_{Preamble}^{TX_i(ic)} - \Delta P_{Traffic}^{TX_i(ic)}$	dBm	Traffic transmission power of a cell
$P_{Pilot}^{TX_i(ic)}$	$P_{Preamble}^{TX_i(ic)} - \Delta P_{Pilot}^{TX_i(ic)}$	dBm	Pilot transmission power of a cell

9.2.8 Traffic and Pilot Noise Calculation (DL)

Name	Value	Unit	Description
$n_{0-DL}^{TX_i(ic)}$	$n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Used}^{PZ_{DL}^{M_i}}}{N_{SCa-Total}^{TX_i(ic)}}\right)$ With Segmentation: $n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Used}^{PZ_{DL}^{M_i}}}{N_{SCa-Total}^{TX_i(ic)}} \times f_{Segment-DL}\right)$	dBm	Thermal noise for a cell
$f_{Segment-DL}$	1 without and $\frac{3 \times PSG + 2 \times SSG}{15}$ with downlink segmentation	None	Downlink segmenting factor
$n_{DL}^{TX_i(ic)}$	$n_{0-DL}^{TX_i(ic)} + nf^{M_i}$	dBm	Downlink noise for a cell

9.2.9 Traffic and Pilot Interference Calculation (DL)

Name	Value	Unit	Description
$I_{Total}^{TX_j(jc)}$	Monte Carlo Simulations: $10 \times Log\left(10^{\frac{I_{Non-AAS}^{TX_j(jc)}}{10}} + 10^{\frac{I_{Idle}^{TX_j(jc)}}{10}}\right)$ without smart antennas, or $10 \times Log\left(10^{\frac{I_{AAS}^{TX_j(jc)}}{10}}\right)$ with smart antennas Coverage Predictions: $10 \times Log\left(10^{\frac{I_{Non-AAS}^{TX_j(jc)}}{10}} + 10^{\frac{I_{Idle}^{TX_j(jc)}}{10}} + 10^{\frac{I_{AAS}^{TX_j(jc)}}{10}}\right)$	dBm	Total interference generated by an interfering cell

Name	Value	Unit	Description
$I^{TX_j(jc)}_{Traffic}$	Monte Carlo Simulations: $EIRP^{TX_j(jc)}_{Traffic} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$ Coverage Predictions: $EIRP^{TX_j(jc)}_{Traffic} - L_{Path} - M_{Shadowing-Model} + M_{Shadowing-C/I} - L_{Indoor}$ $+ G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$	dBm	Traffic interference power of an interfering cell
$I^{TX_j(jc)}_{Pilot}$	Monte Carlo Simulations: $EIRP^{TX_j(jc)}_{Pilot} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$ Coverage Predictions: $EIRP^{TX_j(jc)}_{Pilot} - L_{Path} - M_{Shadowing-Model} + M_{Shadowing-C/I} - L_{Indoor}$ $+ G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$	dBm	Pilot interfering power of an interfering cell
$EIRP^{TX_j(jc)}_{Traffic}$	$P^{TX_j(jc)}_{Traffic} + G^{TX_j} - L^{TX_j}$	dBm	Traffic EIRP of an interfering cell
$EIRP^{TX_j(jc)}_{Pilot}$	$P^{TX_j(jc)}_{Pilot} + G^{TX_j} - L^{TX_j}$	dBm	Pilot EIRP of an interfering cell
$I^{TX_j(jc)}_{Non-AAS}$	$10 \times Log\left(TL^{TX_j(jc)}_{DL} \times \left(1 - AU^{TX_j(jc)}_{DL}\right) \times \left(10^{\frac{I^{TX_j(jc)}_{Traffic}}{10}} \times \frac{N^{TX_j(jc)}_{SCa-Data}}{N^{TX_j(jc)}_{SCa-Used}} + 10^{\frac{I^{TX_j(jc)}_{Pilot}}{10}} \times \left(1 - \frac{N^{TX_j(jc)}_{SCa-Data}}{N^{TX_j(jc)}_{SCa-Used}}\right)\right)\right)$	dBm	Interference from the loaded part of the frame transmitted using the transmitter antenna of an interfering cell
$I^{TX_j(jc)}_{AAS}$	Monte Carlo Simulations: $EIRP^{TX_j(jc)}_{AAS} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$ Coverage Predictions: $EIRP^{TX_j(jc)}_{AAS} - L_{Path} - M_{Shadowing-Model} + M_{Shadowing-C/I} - L_{Indoor}$ $+ G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$	dBm	Interference power of an interfering cell transmitted using smart antenna
$EIRP^{TX_j(jc)}_{AAS}$	$P^{TX_j(jc)}_{Traffic} + G^{TX_j} - L^{TX_j}$	dBm	Traffic EIRP of an interfering cell using smart antenna
$I^{TX_j(jc)}_{Idle-Pilot}$	$EIRP^{TX_j(jc)}_{Idle-Pilot} - L_{Path} - L_{Indoor} + G^{M_i} - L^{M_i} - L^{M_i}_{Ant} - L^{M_i}_{Body}$	dBm	Interference from empty part of the frame transmitted using the transmitter antenna of an interfering cell
$EIRP^{TX_j(jc)}_{Idle-Pilot}$	$P^{TX_j(jc)}_{Idle-Pilot} + G^{TX_j} - L^{TX_j}$	dBm	Idle pilot EIRP of an interfering cell
$I^{TX_j(jc)}_{Idle}$	$10 \times Log\left(\left(1 - TL^{TX_j(jc)}_{DL}\right) \times \left(10^{\frac{I^{TX_j(jc)}_{Idle-Pilot}}{10}} \times \left(1 - \frac{N^{TX_j(jc)}_{SCa-Data}}{N^{TX_j(jc)}_{SCa-Used}}\right)\right)\right)$	dBm	Interference from the empty part of the frame transmitted using the transmitter antenna of an interfering cell
$f_O^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to the co- and adjacent channel overlap
$f_{Seg-DL}^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(p_{Collision-DL}^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to downlink segmentation

9.2.10 Traffic and Pilot C/N Calculation (DL)

Name	Value	Unit	Description
$CNR_{Traffic}^{TX_i(ic)}$	$C_{Traffic}^{TX_i(ic)} - n_{DL}^{TX_i(ic)}$ With MIMO (STTD/MRC): $CNR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$ With MIMO (AMS) if $CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CNR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$	dB	Traffic C/N for a cell
$CNR_{Pilot}^{TX_i(ic)}$	$C_{Pilot}^{TX_i(ic)} - n_{DL}^{TX_i(ic)}$ With MIMO (STTD/MRC): $CNR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$ With MIMO (AMS) if $CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CNR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$	dB	Pilot C/N for a cell

9.2.11 Traffic and Pilot C/(I+N) Calculation (DL)

Name	Value	Unit	Description
$CINR_{Traffic}^{TX_i(ic)}$	$C_{Traffic}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$ With MIMO (STTD/MRC): $CINR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$ With MIMO (AMS) if $CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CINR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$	dB	Traffic C/(I+N) for a cell
$CINR_{Pilot}^{TX_i(ic)}$	$C_{Pilot}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$ With MIMO (STTD/MRC): $CINR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$ With MIMO (AMS) if $CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CINR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$	dB	Pilot C/(I+N) for a cell
$(I+N)_{DL}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}$	dBm	Traffic Total Noise (I+N) for a cell

9.2.12 Traffic Signal Level Calculation (UL)

Name	Value	Unit	Description
$C_{UL}^{M_i}$	$EIRP_{UL}^{M_i} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{TX_i}$ $- L^{TX_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$	dBm	Received uplink signal level

Name	Value	Unit	Description
$EIRP_{UL}^{M_i}$	$P^{M_i} + G^{M_i} - L^{M_i}$ With $P^{M_i} = P_{Max}^{M_i}$ without power control and $P^{M_i} = P_{Eff}^{M_i}$ after power control	dBm	Uplink EIRP of a user equipment

9.2.13 Traffic Noise Calculation (UL)

Name	Value	Unit	Description
$n_{0-UL}^{TX_i(ic)}$	$n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Used}^{PZ_{UL}^{M_i}}}{N_{SCa-Total}^{TX_i(ic)}}\right)$	dBm	Thermal noise for a cell
$n_{UL}^{TX_i(ic)}$	$n_{0-UL}^{TX_i(ic)} + nf^{TX_i(ic)}$	dBm	Uplink noise for a cell

9.2.14 Traffic Interference Calculation (UL)

Name	Value	Unit	Description
$I_{UL}^{M_j}$	$C_{UL}^{M_j} + f_O^{TX_i(ic)-TX_j(jc)} + f_{TL-UL}^{M_j} + f_{Seg-UL}^{TX_i(ic)-TX_j(jc)}$	dBm	Uplink interference received at a cell
$f_O^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to the co- and adjacent channel overlap
$f_{TL-UL}^{M_j}$	$10 \times Log\left(TL_{UL}^{M_j}\right)$	dB	Interference reduction factor due to the interfering mobile's uplink traffic load
$f_{Seg-UL}^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(p_{Collision-UL}^{TX_i(ic)-TX_j(jc)}\right)$	db	Interference reduction factor due to uplink segmentation
$p_{Collision-UL}^{TX_i(ic)-TX_j(jc)}$	$\frac{SC_{Com}}{SC^{TX_i(ic)}}$	None	Uplink segmentation collision probability
$NR_{UL}^{TX_i(ic)}$	$10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}} \left(10^{\frac{I_{UL}^{M_j}\big\vert_{\forall\ non\text{-}seg\ M_j}}{10}}\right) + 10^{\frac{n_{UL}^{TX_i(ic)}}{10}}\right) + NR_{UL}^{Inter-Tech} - n_{UL}^{TX_i(ic)}$	dB	Non-segmented zone uplink noise at a cell without smart antennas
$NR_{UL-Seg}^{TX_i(ic)}$	$10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}} \left(10^{\frac{I_{UL}^{M_j}\big\vert_{\forall\ seg\ M_j}}{10}}\right) + 10^{\frac{n_{UL}^{TX_i(ic)}}{10}}\right) + NR_{UL}^{Inter-Tech} - n_{UL}^{TX_i(ic)}$	dB	Segmented zone uplink noise at a cell without smart antennas
$(I + N)_{UL}^{TX_i(ic)}$	$NR_{UL}^{TX_i(ic)} + n_{UL}^{TX_i(ic)}$ or $NR_{UL-Seg}^{TX_i(ic)} + n_{UL}^{TX_i(ic)}$	dBm	Total Noise (I+N) for a cell
$NR_{UL}(\varphi)$	$\frac{I_{UL}(\varphi) + \sigma_n^2 \cdot I}{\sigma_n^2 \cdot I}$	dB	Uplink noise at a cell with smart antenna
$(I + N)_{UL}^{TX_i(ic)}(\varphi)$	$I_{UL}(\varphi) + \sigma_n^2 \cdot I$	dBm	Total Noise (I+N) for a cell in case of smart antennas

9.2.15 Traffic C/N Calculation (UL)

Name	Value	Unit	Description
$CNR_{UL}^{M_i}$	$C_{UL}^{M_i} - n_{UL}^{TX_i(ic)}$ With MIMO (STTD/MRC): $CNR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$ With MIMO (AMS) if $CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CNR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$	dB	Uplink C/N at a cell

9.2.16 Traffic C/(I+N) Calculation (UL)

Name	Value	Unit	Description
$CINR_{UL}^{M_i}$	Without smart antennas: $CNR_{UL}^{M_i} - NR_{UL}^{TX_i(ic)}$ or $CNR_{UL}^{M_i} - NR_{UL-Seg}^{TX_i(ic)}$ With smart antennas: $CNR_{UL}^{M_i} - NR_{UL}^{TX_i(ic)}(\varphi)$ With MIMO (STTD/MRC): $CINR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$ With MIMO (AMS) if $CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CINR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$	dB	Uplink C/(I+N) at a cell

9.2.17 Calculation of Total Cell Resources

Name	Value	Unit	Description
$F_{Sampling}^{TX_i(ic)}$	$Floor\left(f_{Sampling} \times \frac{W_{Channel}^{TX_i(ic)} \times 10^6}{8000}\right) \times 8000$	Hz	Sampling frequency
$\Delta F^{TX_i(ic)}$	$\frac{F_{Sampling}^{TX_i(ic)} \times 10^{-3}}{N_{SCa-Total}^{TX_i(ic)}}$	kHz	Inter-subcarrier distance
$D_{Sym-Useful}^{TX_i(ic)}$	$\frac{1}{\Delta F^{TX_i(ic)}}$	ms	Useful symbol duration
D_{CP}	$\frac{r_{CP}}{\Delta F}$	ms	Cyclic prefix duration
$D_{Symbol}^{TX_i(ic)}$	$D_{Sym-Useful}^{TX_i(ic)} + D_{CP}$	ms	Symbol duration
D_{Frame}^{Used}	$D_{Frame} - D_{TTG}^{TDD} - D_{RTG}^{TDD}$	ms	Used frame duration
$N_{(SD-Used)/Frame}^{TX_i(ic)}$	$Floor\left(\frac{D_{Frame}^{Used}}{D_{Symbol}^{TX_i(ic)}}\right)$	SD	Frame duration in terms of symbol durations
$N_{(SD-DL)/Subframe}^{TX_i(ic)}$	If DL:UL ratio is defined in percentage: $RoundUp\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times r_{DL-Frame}^{TDD}\right) - O_{Fixed}^{DL}$ If DL:UL ratio is defined in fraction: $RoundUp\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times \frac{N_{SD-DL}^{TDD}}{N_{SD-DL}^{TDD} + N_{SD-UL}^{TDD}}\right) - O_{Fixed}^{DL}$	SD	Downlink subframe duration in terms of symbol durations

Name	Value	Unit	Description
$R_{DL}^{TX_i(ic)} =$ $N_{(Sym-DL)/Subframe}^{TX_i(ic)}$	$Floor\left\{N_{(SD-DL)/Subframe}^{TX_i(ic)} \times N_{SCa-Data}^{PZ_{DL}^{M_i}} \times \left(1 - \frac{O_{Variable}^{DL}}{100}\right)\right\}$	Symbols	Total downlink cell resources, i.e., the number of symbols in the downlink subframe
$N_{(SD-UL)/Subframe}^{TX_i(ic)}$	If DL:UL ratio is defined in percentage: $RoundDown\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times (1 - r_{DL-Frame}^{TDD})\right) - O_{Fixed}^{UL}$ If DL:UL ratio is defined in fraction: $RoundDown\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times \frac{N_{SD-UL}^{TDD}}{N_{SD-DL}^{TDD} + N_{SD-UL}^{TDD}}\right) - O_{Fixed}^{UL}$	SD	Uplink subframe duration in terms of symbol durations
$R_{UL}^{TX_i(ic)} =$ $N_{(Sym-UL)/Subframe}^{TX_i(ic)}$	$Floor\left\{N_{(SD-UL)/Subframe}^{TX_i(ic)} \times N_{SCa-Data}^{PZ_{UL}^{M_i}} \times \left(1 - \frac{O_{Variable}^{UL}}{100}\right)\right\}$	Symbols	Total uplink cell resources, i.e., the number of symbols in the uplink subframe

9.2.18 Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation

Name	Value	Unit	Description
$CTP_{P-DL}^{M_i}$	Without downlink segmentation: $\frac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}}{D_{Frame}}$ With downlink segmentation: $\frac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}}{D_{Frame}} \times f_{Segment-DL}$ With MIMO (SU-MIMO): $\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ With MIMO (AMS): $\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ if $CNR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$	kbps	Downlink peak MAC channel throughput
$CTP_{E-DL}^{M_i}$	$CTP_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$	kbps	Downlink effective MAC channel throughput
$CTP_{A-DL}^{M_i}$	$CTP_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Downlink application channel throughput
$Cap_{P-DL}^{M_i}$	$CTP_{P-DL}^{M_i} \times TL_{DL-Max}^{TX_i(ic)}$	kbps	Downlink peak MAC cell capacity
$Cap_{E-DL}^{M_i}$	$Cap_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$	kbps	Downlink effective MAC cell capacity
$Cap_{A-DL}^{M_i}$	$Cap_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Downlink application cell capacity

Name	Value	Unit	Description
$CTP_{P-UL}^{M_i}$	$\frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}}$ With MIMO (SU-MIMO): $\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ With MIMO (AMS): $\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ if $CNR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ With MIMO (MU-MIMO) in uplink throughput coverage predictions: $\frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}} \times G_{MU-MIMO}^{TX_i(ic)}$	kbps	Uplink peak MAC channel throughput
$CTP_{E-UL}^{M_i}$	$CTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$	kbps	Uplink effective MAC channel throughput
$CTP_{A-UL}^{M_i}$	$CTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Uplink application channel throughput
$Cap_{P-UL}^{M_i}$	$CTP_{P-UL}^{M_i} \times TL_{UL-Max}^{TX_i(ic)}$	kbps	Uplink peak MAC cell capacity
$Cap_{E-UL}^{M_i}$	$Cap_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$	kbps	Uplink effective MAC cell capacity
$Cap_{A-UL}^{M_i}$	$Cap_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Uplink application cell capacity
$ABTP_{P-UL}^{M_i}$	$CTP_{P-UL}^{M_i} \times \frac{N_{SC-UL}^{M_i}}{N_{SC}^{PZ_{UL}^{M_i}}}$	kbps	Uplink peak MAC allocated bandwidth throughput
$ABTP_{E-UL}^{M_i}$	$ABTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$	kbps	Uplink effective MAC allocated bandwidth throughput
$ABTP_{A-UL}^{M_i}$	$ABTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Uplink application allocated bandwidth throughput

9.2.19 Scheduling and Radio Resource Management

Name	Value	Unit	Description
$R_{Min-DL}^{M_i^{Sel}}$	$\frac{TPD_{Min-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}}$	None	Resources allocated to a mobile to satisfy its minimum throughput demand in downlink
$R_{Min-UL}^{M_i^{Sel}}$	$\frac{TPD_{Min-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$	None	Resources allocated to a mobile to satisfy its minimum throughput demand in uplink
$R_{Rem-DL}^{TX_i(ic)}$	$TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}}$	None	Remaining downlink cell resources after allocation for minimum throughput demands

Name	Value	Unit	Description
$R_{Rem-UL}^{TX_i(ic)}$	$TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}}$	None	Remaining uplink cell resources after allocation for minimum throughput demands
$TPD_{Rem-DL}^{M_i^{Sel}}$	$TPD_{Max-DL}^{M_i^{Sel}} - TPD_{Min-DL}^{M_i^{Sel}}$	kbps	Remaining throughput demand for a mobile in downlink
$TPD_{Rem-UL}^{M_i^{Sel}}$	$TPD_{Max-UL}^{M_i^{Sel}} - TPD_{Min-UL}^{M_i^{Sel}}$	kbps	Remaining throughput demand for a mobile in uplink
$CTP_{P-DL}^{M_i^{Sel}}$	$CTP_{P-DL}^{M_i^{Sel}}\Big\|_{Without\ MUG} \times G_{MUG-DL}^{TX_i(ic)}$	kbps	Downlink peak channel throughput with multi-user diversity gain (Proportional Fair)
$CTP_{P-UL}^{M_i^{Sel}}$	$CTP_{P-UL}^{M_i^{Sel}}\Big\|_{Without\ MUG} \times G_{MUG-UL}^{TX_i(ic)}$	kbps	Uplink peak channel throughput with multi-user diversity gain (Proportional Fair)
$RD_{Rem-DL}^{M_i^{Sel}}$	$\frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}}$	None	Remaining resource demand for a mobile in downlink
$RD_{Rem-UL}^{M_i^{Sel}}$	$\frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$	None	Remaining resource demand for a mobile in uplink
$R_{Max-DL}^{M_i^{Sel}}$	Proportional Fair: $Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right)$ Proportional Demand: $R_{Eff-Rem-DL}^{TX_i(ic)} \times \frac{RD_{Rem-DL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}}$ Biased (QoS Class): $Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{QoS-DL}^{TX_i(ic)}}{N_{QoS}}\right)$ Max Aggregate Throughput: $\frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}}$ Round Robin: $Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right)$	None	Resources allocated to a mobile to satisfy its maximum throughput demand in downlink

Name	Value	Unit	Description
$R_{Max-UL}^{M_i^{Sel}}$	Proportional Fair: $Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$ Proportional Demand: $R_{Eff-Rem-UL}^{TX_i(ic)} \times \frac{RD_{Rem-UL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}}$ Biased (QoS Class): $Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{QoS-UL}^{TX_i(ic)}}{N_{QoS}}\right)$ Max Aggregate Throughput: $\frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$ Round Robin: $Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$	None	Resources allocated to a mobile to satisfy its maximum throughput demand in uplink
$R_{Eff-Rem-DL}^{TX_i(ic)}$	$Min\left(R_{Rem-DL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}\right)$	None	Effective remaining downlink resources in a cell (Proportional Demand)
$R_{Eff-Rem-UL}^{TX_i(ic)}$	$Min\left(R_{Rem-UL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}\right)$	None	Effective remaining uplink resources in a cell (Proportional Demand)
β	$1 + \frac{f_{Bias}^{QoS}}{100} = \frac{R_{Max-ErtPS}^{M_i^{Sel}}}{R_{Max-rtPS}^{M_i^{Sel}}} = \frac{R_{Max-rtPS}^{M_i^{Sel}}}{R_{Max-nrtPS}^{M_i^{Sel}}} = \frac{R_{Max-nrtPS}^{M_i^{Sel}}}{R_{Max-BE}^{M_i^{Sel}}}$	None	QoS class bias (Biased (QoS Class))
$R_{QoS-DL}^{TX_i(ic)}$	$R_{Rem-DL}^{TX_i(ic)} \times \frac{N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}}{\sum_{All\ QoS}\left[N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}\right]}$	None	Remaining downlink cell resources after allocation for minimum throughput demands for a QoS class (Biased (QoS Class))
$R_{QoS-UL}^{TX_i(ic)}$	$R_{Rem-UL}^{TX_i(ic)} \times \frac{N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}}{\sum_{All\ QoS}\left[N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}\right]}$	None	Remaining downlink cell resources after allocation for minimum throughput demands for a QoS class (Biased (QoS Class))
$TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}}$	$R_{Min-DL}^{M_i^{Sel}} + R_{Max-DL}^{M_i^{Sel}}$	None	Total resources assigned to a mobile in downlink (Downlink traffic load of the mobile)
$TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}}$	$R_{Min-UL}^{M_i^{Sel}} + R_{Max-UL}^{M_i^{Sel}}$	None	Total resources assigned to a mobile in uplink (Uplink traffic load of the mobile)

9.2.20 User Throughput Calculation

Name	Value	Unit	Description
$UTP_{P-DL}^{M_i^{Sel}}$	$R_{DL}^{M_i^{Sel}} \times CTP_{P-DL}^{M_i^{Sel}}$	kbps	Downlink peak MAC user throughput

Name	Value	Unit	Description
$UTP_{E-DL}^{M_i^{Sel}}$	$UTP_{P-DL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)$	kbps	Downlink effective MAC user throughput
$UTP_{A-DL}^{M_i^{Sel}}$	$UTP_{E-DL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$	kbps	Downlink application user throughput
$UTP_{P-UL}^{M_i^{Sel}}$	$R_{UL}^{M_i^{Sel}} \times CTP_{P-UL}^{M_i^{Sel}}$	kbps	Uplink peak MAC user throughput
$UTP_{E-UL}^{M_i^{Sel}}$	$UTP_{P-UL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)$	kbps	Uplink effective MAC user throughput
$UTP_{A-UL}^{M_i^{Sel}}$	$UTP_{E-UL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$	kbps	Uplink application user throughput

9.3 Available Calculations

9.3.1 Point Analysis

9.3.1.1 Profile View

The point analysis profile view displays the following calculation results for the selected transmitter based on the calculation algorithm described in "Preamble Signal Level Calculation" on page 658.

- Preamble signal level $C_{Preamble}^{TX_i(ic)}$
- Path loss L_{Path}
- Total losses L_{Total}

L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$ are not used in the calculations performed for the profile view.

9.3.1.2 Reception View

Analysis provided in the reception view is based on path loss matrices. So, you can display received signal levels from the cells for which calculated path loss matrices are available. For each cell, **9955** displays the received preamble, pilot, or traffic signal level or C/N.

Reception level bar graphs show the signal levels or C/N in decreasing order. The maximum number of bars in the graph depends on the preamble signal level of the best server. The bar graph displays cells whose received preamble signal levels are higher than their preamble C/N thresholds and are within a 30 dB margin from the highest preamble signal level.

You can use a value other than 30 dB for the margin from the highest preamble signal level, for example a smaller value for improving the calculation speed. For more information on defining a different value for this margin, see the *Administrator Manual*.

The reception viewcalculates:

- The preamble signal level as explained in "Preamble Signal Level Calculation" on page 658.
- The preamble C/N as explained in "Preamble C/N Calculation" on page 662.
- The preamble C/(I+N) and total noise (I+N) as explained in "Preamble C/(I+N) Calculation" on page 662.
- The best server as explained in "Best Server Determination" on page 663.
- The service availability as explained in "Service Area Calculation" on page 664.
- The permutation zone as explained in "Permutation Zone Selection" on page 665.
- The downlink traffic and pilot signal levels as explained in "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- The downlink traffic and pilot C/N as explained in "Traffic and Pilot C/N Calculation (DL)" on page 676.
- The downlink traffic and pilot C/(I+N) and the traffic total noise (I+N) as explained in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- The uplink signal level as explained in "Traffic Signal Level Calculation (UL)" on page 680.
- The uplink C/(I+N) and total noise (I+N) as explained in "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.

- The downlink and uplink bearers as explained in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678 and "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.
- The different throughputs as explained in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

9.3.1.3 Interference View

Analysis provided in the interference view is based on path loss matrices. So, you can display the received signal level from the best server and interfering signal levels from other cells for which calculated path loss matrices are available. For each cell, **9955** displays the best server preamble, pilot, or traffic signal level, and interference from other cells.

Ten interferer bar graphs are displayed by default. This number can be changed through the Atoll.ini file. For more information on defining a different number of interferers, see the *Administrator Manual*.

The interference view calculates:

- The preamble signal level as explained in "Preamble Signal Level Calculation" on page 658.
- The preamble C/(I+N) and total noise (I+N) as explained in "Preamble C/(I+N) Calculation" on page 662.
- The best server as explained in "Best Server Determination" on page 663.
- The service availability as explained in "Service Area Calculation" on page 664.
- The permutation zone as explained in "Permutation Zone Selection" on page 665.
- The downlink traffic and pilot signal levels as explained in "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- The downlink traffic and pilot C/(I+N) and the traffic total noise (I+N) as explained in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- The channel overlap as explained in "Co- and Adjacent Channel Overlaps Calculation" on page 629.
- The collision probability due to downlink segmentation as explained in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- The interference reduction due to the downlink traffic load as explained in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.

9.3.2 Coverage Predictions

9.3.2.1 Preamble Signal Level Coverage Predictions

The following coverage predictions are based on the received preamble signal levels:

- Coverage by Transmitter
- Coverage by Signal Level
- Overlapping Zones

For these calculations, **9955** calculates the received preamble signal level. Then, **9955** determines the selected display parameter on each pixel inside the cell's calculation area. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver. For these calculations, the best server calculation is always based on preamble signal level.

These coverage predictions do not depend on the traffic input. Therefore, these calculations are of special interest before and during the deployment stage of the network to study the coverage footprint of the system.

L^{M_i}, G^{M_i}, $L^{M_i}_{Ant}$, and $L^{M_i}_{Body}$ are not considered in the calculations performed for the preamble signal level based coverage predictions.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on preamble signal level calculations, see "Preamble Signal Level Calculation" on page 658

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 642.
- "Coverage Display Types" on page 643.

Coverage Area Determination

9955 uses parameters entered in the Condition tab of the coverage prediction properties dialogue to determine coverage areas to display. There are three possibilities.

- All Servers

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C_{Preamble}^{TX_i(ic)}\left(or\ L_{Total}^{TX_i(ic)}\ or\ L_{Path}^{TX_i(ic)}\right) < MaximumThreshold$$

- Best Signal Level and a Margin

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C_{Preamble}^{TX_i(ic)}\left(or\ L_{Total}^{TX_i(ic)}\ or\ L_{Path}^{TX_i(ic)}\right) < MaximumThreshold$$

  AND

$$C_{Preamble}^{TX_i(ic)} \ge \underset{j \ne i}{Best}\left(C_{Preamble}^{TX_j(jc)}\right) - M$$

  Where *M* is the specified margin (dB). The *Best* function considers the highest value from a list of values.

  - If *M* = 0 dB, **9955** considers pixels where the received preamble signal level from $TX_i(ic)$ is the highest.
  - If *M* = 2 dB, **9955** considers pixels where the received preamble signal level from $TX_i(ic)$ is either the highest or within a 2 dB margin from the highest.
  - If *M* = -2 dB, **9955** considers pixels where the received preamble signal level from $TX_i(ic)$ is 2 dB higher than the received preamble signal levels from the cells which are 2nd best servers.

- Second Best Signal Level and a Margin

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C_{Preamble}^{TX_i(ic)}\left(or\ L_{Total}^{TX_i(ic)}\ or\ L_{Path}^{TX_i(ic)}\right) < MaximumThreshold$$

  AND

$$C_{Preamble}^{TX_i(ic)} \ge \underset{j \ne i}{2^{nd}Best}\left(C_{Preamble}^{TX_j(jc)}\right) - M$$

  Where *M* is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

  - If *M* = 0 dB, **9955** considers pixels where the received preamble signal level from $TX_i(ic)$ is the second highest.
  - If *M* = 2 dB, **9955** considers pixels where the received preamble signal level from $TX_i(ic)$ is either the second highest or within a 2 dB margin from the second highest.
  - If *M* = -2 dB, **9955** considers pixels where the received preamble signal level from $TX_i(ic)$ is 2 dB higher than the received preamble signal levels from the cells which are 3rd best servers.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the coverage predictions with colours depending on any transmitter or cell attribute, and other criteria such as:

- Signal Level (dBm, dBµV, dBµV/m)
- Best Signal Level (dBm, dBµV, dBµV/m): Where cell coverage areas overlap, 9955 keeps the highest value of the signal level.
- Path Loss (dB)
- Total Losses (dB)
- Best Server Path Loss (dB): Where cell coverage areas overlap, 9955 determines the best cell (i.e., the cell with the highest preamble signal level) and evaluates the path loss from this cell.
- Best Server Total Losses (dB): Where cell coverage areas overlap, 9955 determines the best cell (i.e., the cell with the highest preamble signal level) and evaluates the total losses from this cell.
- Number of Servers: 9955 evaluates the number of cells that cover a pixel (i.e., the pixel falls within the coverage areas of these cells).

9.3.2.2 Effective Signal Analysis Coverage Predictions

The following coverage predictions are based on the received preamble, traffic, or pilot signal levels and noise, and take into account the receiver characteristics (L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$) when calculating the required parameter:

- Effective Signal Analysis (DL)

- Effective Signal Analysis (UL)

For these calculations, **9955** calculates the received signal level or C/N level at each pixel for the channel type being studied, i.e., preamble, traffic, or pilot. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver. The properties of the non-interfering probe receiver are set by selecting a terminal, a mobility type, and a service.

These coverage predictions do not depend on the traffic input. Therefore, these calculations are of special interest before and during the deployment stage of the network to study the coverage footprint of the system.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on signal level calculations, see:

- "Preamble Signal Level Calculation" on page 658.
- "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- "Traffic Signal Level Calculation (UL)" on page 680

For more information on permutation zone selection, see "Permutation Zone Selection" on page 665.

For more information on C/N level calculations, see:

- "Preamble C/N Calculation" on page 662.
- "Traffic and Pilot C/N Calculation (DL)" on page 676
- "Traffic C/N Calculation (UL)" on page 685.

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 644.
- "Coverage Display Types" on page 644.

Coverage Area Determination

These coverage predictions are all best server coverage predictions, i.e., the coverage area of each cell comprises the pixels where the cell is the best server. Best server for each pixel is calculated as explained in "Best Server Determination" on page 663.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display type parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the Effective Signal Analysis (DL) coverage prediction with colours depending on the following display options:

- Preamble Signal Level (DL) (dBm)
- Pilot Signal Level (DL) (dBm)
- Traffic Signal Level (DL) (dBm)
- Preamble C/N Level (DL) (dB)
- Pilot C/N Level (DL) (dB)
- Traffic C/N Level (DL) (dB)
- Permutation Zone (DL)
- Segment

It is possible to display the Effective Signal Analysis (UL) coverage prediction with colours depending on the following display options:

- Signal Level (UL) (dBm)
- C/N Level (UL) (dB)
- Permutation Zone (UL)

9.3.2.3 C/(I+N)-based Coverage Predictions

The following coverage predictions are based on the received signal levels, total noise, and interference.

- Coverage by C/(I+N) Level (DL)
- Service Area Analysis (DL)
- Coverage by Throughput (DL)
- Coverage by Quality Indicator (DL)
- Coverage by C/(I+N) Level (UL)
- Service Area Analysis (UL)
- Coverage by Throughput (UL)
- Coverage by Quality Indicator (UL)

These coverage predictions take into account the receiver characteristics (L^{M_i}, G^{M_i}, $L^{M_i}_{Ant}$, and $L^{M_i}_{Body}$) when calculating the required parameter. For these calculations, **9955** calculates the received signal level, noise, and interference at each pixel. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver. The properties of the non-interfering probe receiver are set by selecting a terminal, a mobility type, and a service.

The downlink coverage predictions are based on the downlink traffic loads of the cells, and the uplink coverage predictions are based on the uplink noise rise values. These parameters can either be calculated by **9955** during the Monte Carlo simulations, or set manually by the user for all the cells.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on C/(I+N), (I+N), and bearer calculations, see:

- "Preamble C/(I+N) Calculation" on page 662.
- "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.
- "Noise Rise Calculation (UL)" on page 684

For more information on thoughput calculations, see:

- "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 645.
- "Coverage Display Types" on page 645.

Coverage Area Determination

These coverage predictions are all best server coverage predictions, i.e., the coverage area of each cell comprises the pixels where the cell is the best server. Best server for each pixel is calculated as explained in "Best Server Determination" on page 663.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display type parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the Coverage by C/(I+N) Level (DL) coverage prediction with colours depending on the following display options:

- Preamble C/(I+N) Level (DL) (dB)
- Preamble Total Noise (I+N) (DL) (dBm)
- Traffic C/(I+N) Level (DL) (dB)
- Traffic Total Noise (I+N) (DL) (dBm)
- Pilot C/(I+N) Level (DL) (dB)

It is possible to display the Service Area Analysis (DL) coverage prediction with colours depending on the following display options:

- Bearer (DL)
- Modulation (DL): Modulation used by the bearer
- Service

It is possible to display the Coverage by Throughput (DL) coverage prediction with colours depending on the following display options:

- Peak MAC Channel Throughput (DL) (kbps)
- Effective MAC Channel Throughput (DL) (kbps)
- Application Channel Throughput (DL) (kbps)
- Peak MAC Cell Capacity (DL) (kbps)
- Effective MAC Channel Throughput (DL) (kbps)
- Application Channel Throughput (DL) (kbps)

It is possible to display the Coverage by Quality Indicator (DL) coverage prediction with colours depending on the following display options:

- Quality indicators available in the document (Quality Indicators table): 9955 calculates the downlink traffic C/(I+N) levels received from the best serving cells at each pixel of their coverage areas. From the C/(I+N), 9955 determines the best bearer available on each pixel. Then, for the calculated C/(I+N) and bearer, it determines the value of the selected quality indicator from the quality graphs defined in the WiMAX equipment of the selected terminal.

It is possible to display the Coverage by C/(I+N) Level (UL) coverage prediction with colours depending on the following display options:

- C/(I+N) Level (UL) (dB)
- Total Noise (I+N) (UL) (dBm)
- Allocated Bandwidth (UL) (No. of Subchannels)
- C/(I+N) Level for 1 Subchannel (UL) (dB)
- Transmission Power (UL) (dBm)

It is possible to display the Service Area Analysis (UL) coverage prediction with colours depending on the following display options:

- Bearer (UL)
- Modulation (UL): Modulation used by the bearer
- Service

It is possible to display the Coverage by Throughput (UL) coverage prediction with colours depending on the following display options:

- Peak MAC Channel Throughput (UL) (kbps)
- Effective MAC Channel Throughput (UL) (kbps)
- Application Channel Throughput (UL) (kbps)
- Peak MAC Cell Capacity (UL) (kbps)
- Effective MAC Channel Throughput (UL) (kbps)
- Application Channel Throughput (UL) (kbps)
- Peak MAC Allocated Bandwidth Throughput (UL) (kbps)
- Effective MAC Allocated Bandwidth Throughput (UL) (kbps)
- Application Allocated Bandwidth Throughput (UL) (kbps)

It is possible to display the Coverage by Quality Indicator (UL) coverage prediction with colours depending on the following display options:

- Quality indicators available in the document (Quality Indicators table): **9955** calculates the uplink traffic C/(I+N) levels received at the best serving cells from each pixel of their coverage areas. From the C/(I+N), **9955** determines the best bearer available on each pixel. Then, for the calculated C/(I+N) and bearer, it determines the value of the selected quality indicator from the quality graphs defined in the WiMAX equipment of the best serving cell.

9.3.3 Calculations on Subscriber Lists

When calculations are performed on a list of subscribers by running the Automatic Server Allocation, **9955** calculates the path loss again for the subscriber locations and heights because the subscriber heights can be different from the default receiver height used for calculating the path loss matrices.

9955 calculates the following parameters for each subscriber in the list whose **Lock Status** is set to **None**.

- **Serving Base Station** and **Reference Cell** as described in "Best Server Determination" on page 663.

9955 calculates the following parameters for each subscriber in the list that has a serving base station assigned and whose **Lock Status** is set to **None** or **Server**.

- **Azimuth (°)**: Angle with respect to the north for pointing the subscriber terminal antenna towards its serving base station.
- **Mechanical Downtilt (°)**: Angle with respect to the horizontal for pointing the subscriber terminal antenna towards its serving base station.

9955 calculates the remaining parameters for each subscriber in the list that has a serving base station assigned, using the properties of the default terminal and service. For more information, see:

- "Preamble Signal Level Calculation" on page 658.
- "Preamble C/(I+N) Calculation" on page 662.
- "Permutation Zone Selection" on page 665.
- "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- "Traffic Signal Level Calculation (UL)" on page 680.
- "Noise Rise Calculation (UL)" on page 684.
- "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.
- "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

9.3.4 Monte Carlo Simulations

The simulation process is divided into two steps.

- Generating a realistic user distribution as explained in "User Distribution" on page 647.

9955 generates user distributions as part of the Monte Carlo algorithm based on traffic data. The resulting user distribution complies with the traffic database and maps selected when creating simulations.

- Scheduling and Radio Resource Management as explained under "Simulation Process" on page 650.

9.3.4.1 User Distribution

During each simulation, **9955** performs two random trials. The first random trial generates the number of users and their activity status as explained in the following sections depending on the type of traffic input.

- "Simulations Based on User Profile Traffic Maps and Subscriber Lists" on page 647.
- "Simulations Based on Sector Traffic Maps" on page 649.

Once all the user characteristics have been determined, a second random trial is performed to obtain their geographical locations weighted according to the clutter classes, and whether they are indoor or outdoor according to the percentage of indoor users per clutter class.

9955 determines the total number of users attempting connection in each simulation based on the Poisson distribution. This may lead to slight variations in the total numbers of users in different simulations. To have the same total number of users in each simulation of a group, add the following lines in the Atoll.ini file:
[Simulation]
RandomTotalUsers=0

9.3.4.1.1 Simulations Based on User Profile Traffic Maps and Subscriber Lists

User profile environment based traffic maps: Each pixel of the map is assigned an environment class which contains a list of user profiles with an associated mobility type and a given density, i.e., number of users of a user profile per km².

User profile traffic maps: Each polygon or line of the map is assigned a density of users with a given user profile and mobility type. If the map is composed of points, each point is assigned a number of users with given user profile and mobility type.

Fixed subscribers listed in subscriber lists have a user profile assigned to each of them.

User profiles model the behaviour of the different user categories. Each user profile contains a list of services and parameters describing how these services are accessed by the user.

The number of users of each user profile is calculated from the surface area (S_{Env}) of each environment class map (or each polygon) and the user profile density (D_{UP}).

$$N_{Users} = S_{Env} \times D_{UP}$$

- In case of user profile traffic maps composed of lines, the number of users of each user profile is calculated from the line length (L) and the user profile density (D_{UP}) (users per km): $N_{Users} = L \times D_{UP}$
- The number of users is a direct input when a user profile traffic map is composed of points.

9955 calculates the probability for a user being active at a given instant in the uplink and in the downlink according to the service usage characteristics described in the user profiles, i.e., the number of voice calls or data sessions, the average duration of each voice call, or the volume of the data transfer in the uplink and the downlink in each data session.

Voice Service (*v*)

User profile parameters for voice type services are:

- The user terminal equipment used for the service (from the Terminals table).
- The average number of calls per hour N_{Call}.
- The average duration of a call (seconds) D_{Call}.

Calculation of the service usage duration per hour (p_0 : probability of an active call): $p_0 = \frac{N_{Call} \times D_{Call}}{3600}$

Calculation of the number of users trying to access the service *v* (n_v): $n_v = N_{Users} \times p_0$

The activity status of each user depends on the activity periods during the call, i.e., the uplink and downlink activity factors defined for the voice type service v, f_{Act}^{UL} and f_{Act}^{DL}.

Calculation of activity probabilities:

Probability of being inactive: $p_{Inactive} = (1 - f_{Act}^{UL}) \times (1 - f_{Act}^{DL})$

Probability of being active in the uplink: $p_{Active}^{UL} = f_{Act}^{UL} \times (1 - f_{Act}^{DL})$

Probability of being active in the downlink: $p_{Active}^{DL} = f_{Act}^{DL} \times (1 - f_{Act}^{UL})$

Probability of being active in the uplink and downlink both: $p_{Active}^{UL+DL} = f_{Act}^{UL} \times f_{Act}^{DL}$

Calculation of number of users per activity status:

Number of inactive users: $n_{v-Inactive} = n_v \times p_{Inactive}$

Number of users active in the uplink: $n_{v-Active}^{UL} = n_v \times p_{Active}^{UL}$

Number of users active in the downlink: $n_{v-Active}^{DL} = n_v \times p_{Active}^{DL}$

Number of users active in the uplink and downlink both: $n_{v-Active}^{UL+DL} = n_v \times p_{Active}^{UL+DL}$

Therefore, a user can be either active on both links, inactive on both links, active on UL only, or active on DL only.

Data Service (*d*)

User profile parameters for data type services are:

- The user terminal equipment used for the service (from the Terminals table).
- The average number of data sessions per hour $N_{Session}$.
- The average data volume (in kBytes) transferred in the downlink V^{DL} and the uplink V^{UL} during a session.
- The average throughputs in the downlink $TP_{Average}^{DL}$ and the uplink $TP_{Average}^{UL}$ for the service *d*.

Calculation of activity probabilities: $f^{UL} = \frac{N_{Session} \times V^{UL} \times 8}{TP_{Average}^{UL} \times 3600}$ and $f^{DL} = \frac{N_{Session} \times V^{DL} \times 8}{TP_{Average}^{DL} \times 3600}$

Probability of being inactive: $p_{Inactive} = (1 - f^{UL}) \times (1 - f^{DL})$

Probability of being active in the uplink: $p_{Active}^{UL} = f^{UL} \times (1 - f^{DL})$

Probability of being active in the downlink: $p_{Active}^{DL} = f^{DL} \times (1 - f^{UL})$

Probability of being active in the uplink and downlink both: $p_{Active}^{UL+DL} = f^{UL} \times f^{DL}$

Calculation of number of users:

Number of inactive users: $n_{d-Inactive} = N_{Users} \times p_{Inactive}$

Number of users active in the uplink: $n_{d-Active}^{UL} = N_{Users} \times p_{Active}^{UL}$

Number of users active in the downlink: $n_{d-Active}^{DL} = N_{Users} \times p_{Active}^{DL}$

Number of users active in the uplink and downlink both: $n_{d-Active}^{UL+DL} = N_{Users} \times p_{Active}^{UL+DL}$

Calculation of the number of active users trying to access the service *d* (n_d):

$$n_d = n_{d-Active}^{UL} + n_{d-Active}^{DL} + n_{d-Active}^{UL+DL}$$

The user distribution per service and the activity status distribution between the users are average distributions. The service and the activity status of each user are randomly drawn in each simulation. Therefore, if you calculate several simulations at once, the average number of users per service and average numbers of inactive, active on UL, active on DL and active on UL and DL users, respectively, will correspond to calculated distributions. But if you check each simulation, the user distribution between services as well as the activity status distribution between users can be different in each of them.

9.3.4.1.2 Simulations Based on Sector Traffic Maps

Sector traffic maps per sector are also referred to as live traffic maps. Live traffic data from the OMC is spread over the best server coverage areas of the transmitters included in the traffic map. Either throughput demands per service or the number of active users per service are assigned to the coverage areas of each transmitter.

For each transmitter TX_i and each service *s*,

- **Sector Traffic Maps (Throughputs)**

  9955 calculates the number of active users of each service *s* on UL and DL in the coverage area of TX_i as follows:

  $$N^{UL} = \frac{TP^{UL}_{Cell}}{TP^{UL}_{Average}} \text{ and } N^{DL} = \frac{TP^{DL}_{Cell}}{TP^{DL}_{Average}}$$

  Where TP^{UL}_{Cell} is the total uplink throughput demand defined in the map for any service *s* for the coverage area of the transmitter, TP^{DL}_{Cell} is the total downlink throughput demand defined in the map for any service *s* for the coverage area of the transmitter, $TP^{UL}_{Average}$ is the average uplink requested throughput of the service *s*, and $TP^{DL}_{Average}$ is the average downlink requested throughput of the service *s*.

- **Sector Traffic Maps (# Active Users)**

  9955 directly uses the defined N^{UL} and N^{DL} values, i.e., the number of active users on UL and DL in the transmitter coverage area using the service *s*.

At any given instant, **9955** calculates the probability for a user being active in the uplink and in the downlink as follows:

Users active in the uplink and downlink both are included in the N^{UL} and N^{DL} values. Therefore, it is necessary to accurately determine the number of active users in the uplink (n^{UL}_{Active}), in the downlink (n^{DL}_{Active}), and both (n^{UL+DL}_{Active}). As for the other types of traffic maps, **9955** considers both active and inactive users.

The activity status of each user depends on the activity periods during the call, i.e., the uplink and downlink activity factors defined for the service, f^{UL}_{Act} and f^{DL}_{Act}.

Calculation of activity probabilities:

Probability of being inactive: $p_{Inactive} = (1 - f^{UL}_{Act}) \times (1 - f^{DL}_{Act})$

Probability of being active in the uplink: $p^{UL}_{Active} = f^{UL}_{Act} \times (1 - f^{DL}_{Act})$

Probability of being active in the downlink: $p^{DL}_{Active} = f^{DL}_{Act} \times (1 - f^{UL}_{Act})$

Probability of being active in the uplink and downlink both: $p^{UL+DL}_{Active} = f^{UL}_{Act} \times f^{DL}_{Act}$

Calculation of the number of active users trying to access the service:

We have: $N^{UL} = (p^{UL}_{Active} + p^{UL+DL}_{Active}) \times n$ and $N^{DL} = (p^{DL}_{Active} + p^{UL+DL}_{Active}) \times n$

Where, *n* is the total number of active users in the transmitter coverage area using the service.

Calculation of number of users per activity status:

Number of users active in the uplink and downlink both: $n^{UL+DL}_{Active} = Min\left(\frac{N^{UL} \times p^{UL+DL}_{Active}}{p^{UL}_{Active} + p^{UL+DL}_{Active}}, \frac{N^{DL} \times p^{UL+DL}_{Active}}{p^{DL}_{Active} + p^{UL+DL}_{Active}}\right)$ or simply, $n^{UL+DL}_{Active} = Min(N^{UL} \times f^{DL}_{Act}, N^{DL} \times f^{UL}_{Act})$

Number of users active in the uplink: $n^{UL}_{Active} = N^{UL} - n^{UL+DL}_{Active}$

Number of users active in the downlink: $n^{DL}_{Active} = N^{DL} - n^{UL+DL}_{Active}$

And, $n = n^{UL}_{Active} + n^{DL}_{Active} + n^{UL+DL}_{Active}$

Calculation of the number of inactive users attempting to access the service:

Number of inactive users: $n_{Inactive} = \frac{n_v}{1 - p_{Inactive}} \times p_{Inactive}$

> The activity status distribution between users is an average distribution. In fact, in each simulation, the activity status of each user is randomly drawn. Therefore, if you calculate several simulations at once, average numbers of inactive, active on UL, active on DL and active on UL and DL users correspond to the calculated distribution. But if you check each simulation, the activity status distribution between users can be different in each of them.

9.3.4.2 Simulation Process

WiMAX cells include intelligent schedulers and radio resource management features for regulating network traffic loads, optimising spectral efficiency, and satisfying the QoS demands of the users. Each Monte Carlo simulation in the **9955** WiMAX BWA module is a snap-shot of the network with resource allocation carried out over a duration of *1* second. The number of WiMAX frames in *1* second depends on the selected frame duration, D_{Frame}. The steps of this algorithm are listed below.

The simulation process can be summed up into the following iterative steps.

For each simulation, the simulation process,

1. Generates mobiles according to the input traffic data as explained in "User Distribution" on page 647.
2. Sets initial values for the following parameters:
   - Cell transmission powers and reductions ($P_{Preamble}^{TX_i(ic)}$, $\Delta P_{Traffic}^{TX_i(ic)}$, $\Delta P_{Pilot}^{TX_i(ic)}$, and $\Delta P_{Idle-Pilot}^{TX_i(ic)}$) are set to the values defined by the user.
   - Mobile transmission power is set to the maximum mobile power ($P_{Max}^{M_i}$).
   - Cell loads ($TL_{DL}^{TX_i(ic)}$, $TL_{UL}^{TX_i(ic)}$, $NR_{UL}^{TX_i(ic)}$, $NR_{UL-Seg}^{TX_i(ic)}$, $SU_{DL}^{TX_i(ic)}$, and $AU_{DL}^{TX_i(ic)}$) are set to their current values in the Cells table.
3. Determines the best servers for all the mobiles generated for the simulation as explained in "Best Server Determination" on page 663.

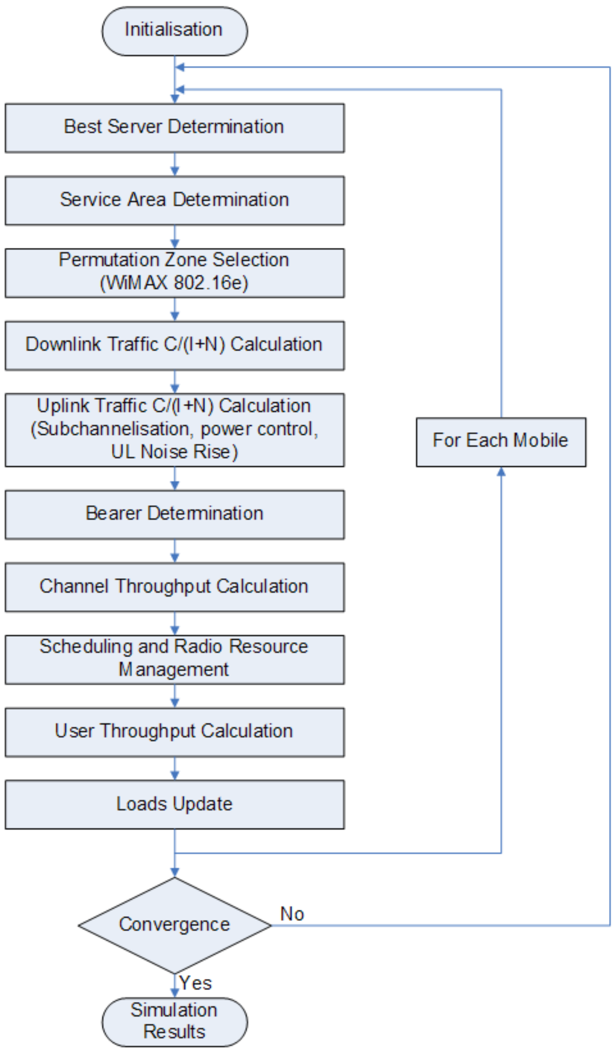


Figure 9.1: WiMAX Simulation Algorithm

For each iteration *k*, the simulation process,

4. Determines the mobiles which are within the service areas of their best serving cells as explained in "Service Area Calculation" on page 664.
5. Determines the permutation zone assigned to each mobile as explained in "Permutation Zone Selection" on page 665.
6. Determines the downlink and uplink traffic C/(I+N) and bearers for each of these mobiles as explained in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678 and "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687 respectively.
7. Determines the channel throughputs at the mobile as explained in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.
8. Performs radio resource management and scheduling to determine the amount of resources to allocate to each mobile according to the QoS and throughput demands of each mobile using the selected scheduler as explained in "Scheduling and Radio Resource Allocation" on page 698.
9. Calculates the user throughputs after allocating resources to each mobile as explained in "User Throughput Calculation" on page 707.
10. Updates the traffic loads, and noise rise values of all the cells according to the resources in use and the total resources as follows:

Calculation of Traffic Loads:

9955 calculates the traffic loads for all the cells $TX_i(ic)$.

$$TL_{DL}^{TX_i(ic)} = \sum_{M_i} R_{DL}^{M_i} \text{ and } TL_{UL}^{TX_i(ic)} = \sum_{M_i} R_{UL}^{M_i}$$

For uplink MU-MIMO, $TL_{UL}^{TX_i(ic)} = \sum_{M_i^{MU-MIMO}} RC_{UL}^{M_i^{MU-MIMO}}$

Calculation of Uplink Noise Rise:

For each victim cell $TX_i(ic)$, the uplink noise rise is calculated and updated by considering each interfering mobile M_j as explained in "Noise Rise Calculation (UL)" on page 684.

Calculation of Downlink Segmentation Usage:

9955 calculates the segmentation usages for all the cells as follows:

$$SU_{DL}^{TX_i(ic)} = \frac{\sum_{M_i|_{PZ_{DL}^{M_i} = Seg}} R_{DL}^{M_i}\Big|_{PZ_{DL}^{M_i} = Seg}}{TL_{DL}^{TX_i(ic)}}$$

Where $\sum_{M_i|_{PZ_{DL}^{M_i} = Seg}} R_{DL}^{M_i}\Big|_{PZ_{DL}^{M_i} = Seg}$ is the sum of the percentages of the downlink cell resources allocated to mobiles served by the downlink segmented permutation zone.

Calculation of Downlink AAS Usage:

9955 calculates the downlink AAS usages for all the cells as follows:

$$AU_{DL}^{TX_i(ic)} = \frac{\sum_{M_i|_{AAS}} R_{DL}^{M_i}\Big|_{AAS}}{TL_{DL}^{TX_i(ic)}}$$

Where $\sum_{M_i|_{AAS}} R_{DL}^{M_i}\Big|_{AAS}$ is the sum of the percentages of the downlink cell resources allocated to mobiles served by the smart antennas.

Calculation of Uplink MU-MIMO Gain:

9955 calculates the uplink MU-MIMO gain for all the cells as follows:

$$G_{MU-MIMO}^{TX_i(ic)} = \frac{\sum_{M_i^{MU-MIMO}} R_{UL}^{M_i^{MU-MIMO}}}{\sum_{M_i^{MU-MIMO}} RC_{UL}^{M_i^{MU-MIMO}}}$$

Where $\sum_{M_i^{MU-MIMO}} R_{UL}^{M_i^{MU-MIMO}}$ is the sum of the percentages of the uplink cell resources allocated to MU-MIMO mobiles and $\sum_{M_i^{MU-MIMO}} RC_{UL}^{M_i^{MU-MIMO}}$ is the sum of the real resource consumption of MU-MIMO mobiles.

11. Performs the convergence test to see whether the differences between the current and the new loads are within the convergence thresholds.

The convergence criteria are evaluated at the end of each iteration k, and can be written as follows:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(TL_{DL}^{TX_i(ic)}\Big|_k - TL_{DL}^{TX_i(ic)}\Big|_{k-1}\right)$$

$$\Delta TL_{UL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(TL_{UL}^{TX_i(ic)}\Big|_k - TL_{UL}^{TX_i(ic)}\Big|_{k-1}\right)$$

$$\Delta NR_{UL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(NR_{UL}^{TX_i(ic)}\Big|_k - NR_{UL}^{TX_i(ic)}\Big|_{k-1}\right)$$

If $\Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}$, $\Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}$, and $\Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$ are the simulation convergence thresholds defined when creating the simulation, **9955** stops the simulation in the following cases.

Convergence: Simulation has converged between iteration *k - 1* and *k* if:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k \le \Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}\ AND\ \Delta TL_{UL}^{TX_i(ic)}\Big|_k \le \Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}\ AND\ \Delta NR_{UL}^{TX_i(ic)}\Big|_k \le \Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$$

No convergence: Simulation has not converged even after the last iteration, i.e., *k* = Max Number of Iterations defined when creating the simulation, if:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k > \Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}\ OR\ \Delta TL_{UL}^{TX_i(ic)}\Big|_k > \Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}\ OR\ \Delta NR_{UL}^{TX_i(ic)}\Big|_k > \Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$$

12. Repeats the above steps (from step 3.) for the iteration *k+1* using the new calculated loads as the current loads.

Simulation Results

At the end of the simulation process, the main results obtained are:

- Downlink traffic loads
- Uplink traffic loads
- Uplink noise rise received at the main antenna
- Ssegmented zone uplink noise rise received at the main antenna
- Angular distributions of downlink traffic power density for cells with smart antennas
- Angular distributions of uplink noise rise for cells with smart antennas
- Downlink AAS usage
- Downlink segmentation usage
- Uplink MU-MIMO capacity gain

These results can be used as input for C/(I+N)-based coverage predictions.

In addition to the above parameters, the simulations also list the connection status of each mobile. Mobiles can be rejected due to:

- **No Coverage:** If the mobile does not have any best serving cell (step 3.) or if the mobile is not within the service area of its best server (step 4.).
- **No Service:** If the mobile is not able to access a bearer in the direction of its activity (step 6.), i.e., UL, DL, or DL+UL.
- **Scheduler Saturation:** If the mobile is not in the list of mobiles selected for scheduling (step 8.)
- **Resource Saturation:** If all the cell resources are used up before allocation to the mobile or if, for a user active in uplink, the minimum uplink throughput demand is higher than the uplink allocated bandwidth throughput (step 8.)

Connected mobiles (step 8.) can be:

- **Connected UL:** If a mobile active in UL is allocated resources in UL.
- **Connected DL:** If a mobile active in DL is allocated resources in DL.
- **Connected DL+UL:** If a mobile active in DL+UL is allocated resources in DL+UL.

9.4 Calculation Details

The following sections describe all the calculation algorithms used in point analysis, calculation of coverage predictions, calculations on subscriber lists, and Monte Carlo simulations.

9.4.1 Co- and Adjacent Channel Overlaps Calculation

A WiMAX network can consist of cells that use different channel bandwidths. Therefore, the start and end frequencies of all the channels may not exactly coincide. Channel bandwidths of cells can overlap each other with different ratios.

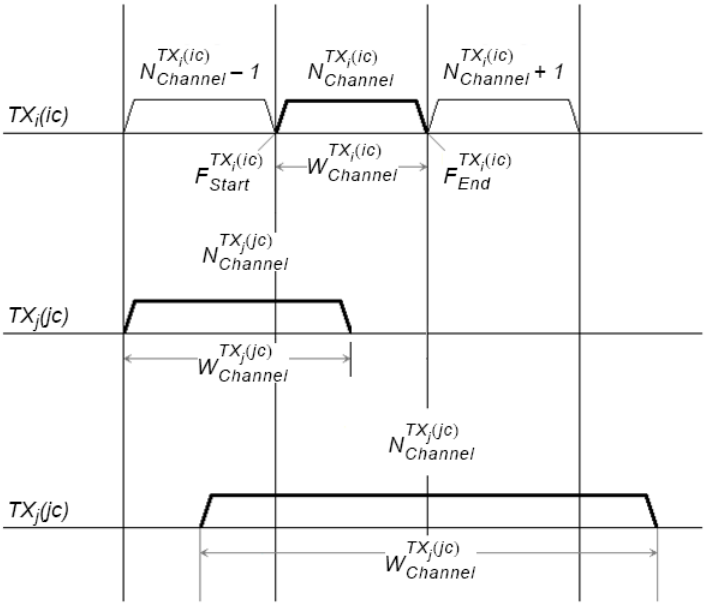


Figure 9.2: Co-Channel and Adjacent Channel Overlaps

The following sections describe how the co- and adjacent channel overlaps are calculated between the channels used by any studied cell $TX_i(ic)$ and any other cell $TX_j(jc)$ of the network. In terms of interference calculation, the studied cell can be considered a victim of interference received from the other cells that might be interfering the studied cell.

If the studied cell is assigned a channel number $N_{Channel}^{TX_i(ic)}$, it receives co-channel interference on the channel bandwidth of $N_{Channel}^{TX_i(ic)}$, and adjacent channel interference on the adjacent channel bandwidths, i.e., corresponding to $N_{Channel}^{TX_i(ic)} - 1$ and $N_{Channel}^{TX_i(ic)} + 1$.

In order to calculate the co- and adjacent channel overlaps between two channels, it is necessary to calculate the start and end frequencies of both channels (explained in "Conversion From Channel Numbers to Start and End Frequencies" on page 654). Once the start and end frequencies are known for the studied and other cells, the co- and adjacent overlaps and the total overlap ratio are calculated as respectively explained in:

- "Co-Channel Overlap Calculation" on page 655.
- "Adjacent Channel Overlap Calculation" on page 655.
- "Total Overlap Ratio Calculation" on page 657.

9.4.1.1 Conversion From Channel Numbers to Start and End Frequencies

Input

- $F_{Start-FB}^{TX_i(ic)}$ and $F_{Start-FB}^{TX_j(jc)}$: Start frequency of the frequency band assigned to the cells *$TX_i(ic)$ and $TX_j(jc)$.*

  $F_{Start-FB}$ can be the start frequency of a TDD frequency band ($F_{Start-FB-TDD}$), or the uplink or the downlink start frequency of an FDD frequency band ($F_{Start-FB-FDD-UL}$ or $F_{Start-FB-FDD-DL}$).

- $N_{Channel}^{First-TX_i(ic)}$ and $N_{Channel}^{First-TX_j(jc)}$: First channel numbers the frequency band assigned to the cells *$TX_i(ic)$ and $TX_j(jc)$.*
- $N_{Channel}^{TX_i(ic)}$ and $N_{Channel}^{TX_j(jc)}$: Channel numbers assigned to cells *$TX_i(ic)$ and $TX_j(jc)$.*

  For FDD networks, **9955** considers that the same channel number is assigned to a cell in the downlink and uplink, i.e., the channel number you assign to a cell is considered for uplink and downlink both.

- $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$: Bandwidths of the channels assigned to cells $TX_i(ic)$ and $TX_j(jc)$.

Calculations

Channel numbers are converted into start and end frequencies as follows:

For cell $TX_i(ic)$:

$$F_{Start}^{TX_i(ic)} = F_{Start-FB}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)}\right)$$

$$F_{End}^{TX_i(ic)} = F_{Start-FB}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)} + 1\right)$$

For cell $TX_j(jc)$:

$$F_{Start}^{TX_j(jc)} = F_{Start-FB}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times \left(N_{Channel}^{TX_j(jc)} - N_{Channel}^{First-TX_j(jc)}\right)$$

$$F_{End}^{TX_j(jc)} = F_{Start-FB}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times \left(N_{Channel}^{TX_j(jc)} - N_{Channel}^{First-TX_j(jc)} + 1\right)$$

Output

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$.
- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$.

9.4.1.2 Co-Channel Overlap Calculation

Input

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 654.
- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 654.
- $W_{Channel}^{TX_i(ic)}$: Bandwidth of the channel assigned to the studied cell $TX_i(ic)$.

Calculations

9955 first verifies that co-channel overlap exists between the cells $TX_i(ic)$ and $TX_j(jc)$.

Co-channel overlap exists if:

$$F_{Start}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \text{ AND } F_{End}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Otherwise there is no co-channel overlap.

9955 calculates the bandwidth of the co-channel overlap as follows:

$$W_{CCO}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right)$$

The co-channel overlap ratio is given by:

$$r_{CCO}^{TX_i(ic)-TX_j(jc)} = \frac{W_{CCO}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

Output

- $r_{CCO}^{TX_i(ic)-TX_j(jc)}$: Co-channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

9.4.1.3 Adjacent Channel Overlap Calculation

Input

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 654.

- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 654.
- $W_{Channel}^{TX_i(ic)}$: Bandwidth of the channel assigned to the studied cell $TX_i(ic)$.

Calculations

9955 first verifies that adjacent channel overlaps exist between (the lower-frequency and the higher-frequency adjacent channels of) the cells $TX_i(ic)$ and $TX_j(jc)$.

Adjacent channel overlap exists on the lower-frequency adjacent channel if:

$$F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \quad AND \quad F_{Start}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Adjacent channel overlap exists on the higher-frequency adjacent channel if:

$$F_{End}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \quad AND \quad F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Otherwise there is no adjacent channel overlap.

9955 determines the adjacent channel overlap ratio as follows:

Bandwidth of the lower-frequency adjacent channel overlap:

$$W_{ACO_L}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)}\right)$$

The lower-frequency adjacent channel overlap ratio is given by:

$$r_{ACO_L}^{TX_i(ic)-TX_j(jc)} = \frac{W_{ACO_L}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

Bandwidth of the higher-frequency adjacent channel overlap:

$$W_{ACO_H}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right)$$

The higher-frequency adjacent channel overlap ratio is given by:

$$r_{ACO_H}^{TX_i(ic)-TX_j(jc)} = \frac{W_{ACO_H}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

The adjacent channel overlap ratio is given by:

$$r_{ACO}^{TX_i(ic)-TX_j(jc)} = r_{ACO_L}^{TX_i(ic)-TX_j(jc)} + r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$$

Output

- $r_{ACO}^{TX_i(ic)-TX_j(jc)}$: Adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

9.4.1.4 FDD – TDD Overlap Ratio Calculation

There are many different interference scenarios possible in a WiMAX network depending on the type of duplexing used by the cells of the network. The most common interference scenarios are FDD-only and TDD-only interferences. However, co-existing FDD and TDD cells may also exist and interfere each other. **9955** models the co-existence of FDD and TDD cells in a network by determining the FDD – TDD overlap ratio as follows:

Input

- $r_{DL-Frame}^{TDD}$: Downlink subframe ratio defined in the Global Parameters.

Calculations

The FDD – TDD overlap ratio is calculated as follows depending on the frequency bands assigned to the cells $TX_i(ic)$ and $TX_j(jc)$:

Frequency Band		Overlap Ratio $r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)}$
$TX_i(ic)$	**$TX_j(jc)$**	
TDD	TDD	1
TDD	FDD	1
FDD	TDD	$\frac{r_{DL-Frame}^{TDD}}{100}$
FDD	FDD	1

Output

- $r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)}$: FDD – TDD overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

9.4.1.5 Total Overlap Ratio Calculation

Input

- $r_{CCO}^{TX_i(ic)-TX_j(jc)}$: Co-channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co-Channel Overlap Calculation" on page 655.
- $r_{ACO}^{TX_i(ic)-TX_j(jc)}$: Adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Adjacent Channel Overlap Calculation" on page 655.
- $r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)}$: FDD – TDD overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "FDD – TDD Overlap Ratio Calculation" on page 656.
- $f_{ACS-FB}^{TX_i(ic)}$: Adjacent channel suppression factor defined for the frequency band of the cell $TX_i(ic)$.
- $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$: Bandwidths of the channels assigned to the cells $TX_i(ic)$ and $TX_j(jc)$.

Calculations

The total overlap ratio is:

$$r_O^{TX_i(ic)-TX_j(jc)} = \begin{cases} \left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}} \right) \times r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)} & \text{if} \quad W_{Channel}^{TX_i(ic)} \geq W_{Channel}^{TX_j(jc)} \\ \left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}} \right) \times r_{FDD-TDD}^{TX_i(ic)-TX_j(jc)} \times \frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}} & \text{if} \quad W_{Channel}^{TX_i(ic)} < W_{Channel}^{TX_j(jc)} \end{cases}$$

The multiplicative factor $\frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ is used to normalise the transmission power of the interfering cell $TX_j(jc)$. This means that if the interfering cell transmits at *X* dBm over a bandwidth of $W_{Channel}^{TX_j(jc)}$, and it interferes over a bandwidth less than $W_{Channel}^{TX_j(jc)}$, the interference from this cell should not be considered at *X* dBm but less than that. The factor $\frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ converts *X* dBm over $W_{Channel}^{TX_j(jc)}$ to *Y* dBm (which is less than *X* dBm) over less than $W_{Channel}^{TX_j(jc)}$.

Output

- $r_O^{TX_i(ic)-TX_j(jc)}$: Total co- and adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

9.4.2 Preamble Signal Level and Quality Calculations

These calculations include the calculation of the received preamble signal level, and the noise and interference on the preamble. The following sections also describe how the received preamble signal level, the noise and interference, C/N, and C/(I+N) ratios are calculated in **9955**:

- "Preamble Signal Level Calculation" on page 658.
- "Preamble Noise Calculation" on page 659.
- "Preamble C/N Calculation" on page 662.
- "Preamble Interference Calculation" on page 660.
- "Preamble C/(I+N) Calculation" on page 662.

9.4.2.1 Preamble Signal Level Calculation

Input

- $P_{Preamble}^{TX_i(ic)}$: Preamble transmission power of the cell $TX_i(ic)$.
- $E_{SA}^{TX_i}$: Number of antenna elements defined for the smart antenna equipment used by the transmitter TX_i.
- $\Delta G_{SA}^{Combining}$: Smart power combining gain offset defined per clutter class.
- G_{SA}^{Div} : Smart antenna diversity gain (for cross-polarised smart antennas) defined per clutter class.
- G^{TX_i} : Transmitter antenna gain for the antenna used by the transmitter TX_i.
- L^{TX_i} : Total transmitter losses for the transmitter TX_i ($L^{TX_i} = L_{Total-DL}$).
- L_{Model} : Loss on the transmitter-receiver path (path loss) calculated using a propagation model.
- $L_{Ant}^{TX_i}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_i.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.
- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.
- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.
- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  For calculating the useful signal level from the best serving cell, $L_{Ant}^{M_i}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L_{Ant}^{M_i}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.
- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.

> L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$ are not used in the calculations performed for the point analysis tool's profile tab and the preamble signal level based coverage predictions.

Calculations

The received preamble signal level (dBm) from any cell $TX_i(ic)$ is calculated for a pixel, subscriber, or mobile M_i as follows:

$$C_{Preamble}^{TX_i(ic)} = EIRP_{Preamble}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the cell calculated as follows:

- Without smart antennas: $EIRP_{Preamble}^{TX_i(ic)} = P_{Preamble}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$
- With smart antennas: $EIRP_{Preamble}^{TX_i(ic)} = P_{Preamble}^{TX_i(ic)} + G^{TX_i} - L^{TX_i} + 10 \cdot Log\left(E_{SA}^{TX_i}\right) + \Delta G_{SA}^{Combining} + G_{SA}^{Div}$

L_{Path} is the path loss (dB) calculated as follows:

$$L_{Path} = L_{Model} + L_{Ant}^{TX_i}$$

Furthermore, the total losses between the cell and the pixel, subscriber, or mobile M_i can be calculated as follows:

$$L_{Total} = L_{Path} + L^{TX_i} + L_{Indoor} + M_{Shadowing-Model} - G^{TX_i} + L^{M_i} - G^{M_i} + L_{Ant}^{M_i} + L_{Body}^{M_i}$$

> If you wish to exclude the the energy corresponding to the cyclic prefix part of the total symbol duration from the useful signal level, you must add the following lines in the Atoll.ini file:
>
> ```
> [WiMAX]
> ExcludeCPFromUsefulPower = 1
> ```
>
> When this option is active, the cyclic prefix energy is excluded from $C_{Preamble}^{TX_i(ic)}$. In other words, the factor $10 \times Log(1 - r_{CP})$ is added to $C_{Preamble}^{TX_i(ic)}$.
>
> Independant of the option, interference levels are calculated for the total symbol durations, i.e., the energy of the useful symbol duration and the cyclic prefix energy.

Output

- $C_{Preamble}^{TX_i(ic)}$: Received preamble signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- L_{Path}: Path loss between the cell $TX_i(ic)$ and the pixel, subscriber, or mobile M_i.
- L_{Total}: Total losses between the cell $TX_i(ic)$ and the pixel, subscriber, or mobile M_i.

9.4.2.2 Preamble Noise Calculation

For determining the preamble C/N and C/(I+N), **9955** calculates the preamble noise over the bandwidth used by the cell. The used bandwidth depends on the number of subcarriers used by the preamble.The number of subcarriers used by the preamble can be different from the number of subcarriers used by the permutation zones.

The preamble noise comprises thermal noise and the noise figure of the equipment. The thermal noise density depends on the temperature, i.e., it remains constant for a given temperature. However, the value of the thermal noise varies with the used bandwidth.

Input

- *K*: Boltzmann's constant.
- *T*: Temperature in Kelvin.
- $N_{SCa-Preamble}^{TX_i(ic)}$: Number of subcarriers used by the preamble defined for the frame configuration of the cell $TX_i(ic)$.
- $N_{SCa-Total}^{TX_i(ic)}$: Total number of subcarriers defined for the frame configuration of the cell $TX_i(ic)$.
- $F_{Sampling}^{TX_i(ic)}$: Sampling frequency for the cell $TX_i(ic)$ as calculated in "Calculation of Sampling Frequency" on page 691.
- nf^{M_i}: Noise figure of the terminal used for calculations by the pixel, subscriber, or mobile M_i.

Calculations

The power spectral density of thermal noise is calculated as follows:

$$n_0 = 10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$$

The thermal noise over the preamble for a cell is calculated as:

$$n_{0-Preamble}^{TX_i(ic)} = n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Preamble}^{TX_i(ic)}}{N_{SCa-Total}^{TX_i(ic)}} \times f_{Segment}^{Preamble}\right)$$

Effect of Segmentation:

The preamble is segmented and one of the three preamble carrier sets is used for transmission. Each preamble carrier set uses 1/3rd of the total number of preamble subcarriers. The power transmitted over the preamble has higher spectral density than the power transmitted over the entire channel bandwidth. This power concentration due to segmentation on the C/N and C/(I+N) results in an increase in the coverage footprint of the preamble. Hence, the thermal noise at the pixel, subscriber, or mobile M_i covered by the preamble is reduced by a factor of $f_{Segment}^{Preamble} = \frac{1}{3}$.

The following table shows the different types of subcarriers and their numbers for preamble transmission in WiMAX.

$N_{SCa-Total}$	Segment	Guard Subcarriers			DC Subcarrier	$N_{SCa-Preamble}$	$f_{Segment}^{Preamble}$
		Left	Right	Total			
128	All	10	10	20	1 (54)	107	1
	0				1 (54)	35	0.3271
	1				None	36	0.3364
	2				None	36	0.3364
512	All	42	41	83	1 (214)	428	1
	0				None	143	0.3341
	1				1 (214)	142	0.3318
	2				None	143	0.3341
1024	All	86	86	172	1 (426)	851	1
	0				1 (426)	283	0.3325
	1				None	284	0.3337
	2				None	284	0.3337
2048	All	172	172	344	1 (852)	1703	1
	0				1 (852)	567	0.3329
	1				None	568	0.3335
	2				None	568	0.3335

The preamble noise is the sum of the thermal noise and the noise figure of the terminal used for the calculations by the pixel, subscriber, or mobile M_i.

$$n_{Preamble}^{TX_i(ic)} = n_{0-Preamble}^{TX_i(ic)} + nf^{M_i}$$

Output

- $n_{Preamble}^{TX_i(ic)}$: Preamble noise for the cell $TX_i(ic)$.

9.4.2.3 Preamble Interference Calculation

The interference received by any pixel, subscriber, or mobile, served by a cell $TX_i(ic)$ from other cells $TX_j(jc)$ can be defined as the preamble signal levels received from interfering cells $TX_j(jc)$ depending on the overlap that exists between the channels used by the cells $TX_i(ic)$ and $TX_j(jc)$ and which preamble carrier sets are used by the two cells.

Input

- $C_{Preamble}^{TX_j(jc)}$: Preamble signal level received from an interfering cell $TX_j(jc)$ as calculated in "Preamble Signal Level Calculation" on page 658 at the pixel, subscriber, or mobile M_i covered by the cell $TX_i(ic)$.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.
- $M_{Shadowing-C/I}$: Shadowing margin based on the C/I standard deviation.

In Monte Carlo simulations, interfering signal levels already include $M_{Shadowing-Model}$, as explained in "Preamble Signal Level Calculation" on page 630.

In coverage predictions, the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$ is applied to the interfering signals (for more information, see "Shadow Fading Model" on page 85). As the received interfering signal levels already include $M_{Shadowing-Model}$, $M_{Shadowing-C/I}$ is added to the received interfering signal levels in order to achieve the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$:

$$C_{Preamble}^{TX_j(jc)} = C_{Preamble}^{TX_j(jc)} + M_{Shadowing-C/I}$$

In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.

- $r_O^{TX_i(ic)-TX_j(jc)}$: Total channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 653.
- $N_{Seg}^{TX_i(ic)}$ and $N_{Seg}^{TX_j(jc)}$: Segment numbers assigned to the cells $TX_i(ic)$ and $TX_j(jc)$ calculated from their respective preamble indexes ($n_{Preamble}^{TX_i(ic)}$ and $n_{Preamble}^{TX_j(jc)}$) as follows:

$n_{Preamble}$	N_{Seg}
0 to 31, 96, 99, 102, 105, 108, 111	0
32 to 63, 97, 100, 103, 106, 109, 112	1
64 to 95, 98, 101, 104, 107, 110, 113	2

- $f_{IRF}^{Inter-Tech}$: Inter-technology interference reduction factor.

Calculations

The received preamble interference (dBm) from any cell $TX_j(jc)$ is calculated for a pixel, subscriber, or mobile M_i as follows:

$$I_{Preamble}^{TX_j(jc)} = C_{Preamble}^{TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)} + f_{Seg-Preamble}^{TX_i(ic)-TX_j(jc)} + I_{DL}^{Inter-Tech}$$

Where $f_O^{TX_i(ic)-TX_j(jc)}$ is the interference reduction factor due to channel overlap between the cells $TX_i(ic)$ and $TX_j(jc)$, calculated as follows:

$$f_O^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$$

$f_{Seg-Preamble}^{TX_i(ic)-TX_j(jc)}$ is the interference reduction factor due to preamble segmentation, calculated as follows:

$$f_{Seg-Preamble}^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(p_{Collision}^{TX_i(ic)-TX_j(jc)}\right)$$

The probability of preamble subcarrier collision $p_{Collision}^{TX_i(ic)-TX_j(jc)}$ between the cells $TX_i(ic)$ and $TX_j(jc)$ is 0 if $N_{Seg}^{TX_i(ic)} \neq N_{Seg}^{TX_j(jc)}$ and 1 if $N_{Seg}^{TX_i(ic)} = N_{Seg}^{TX_j(jc)}$.

In case of smart antennas, $C_{Preamble}^{TX_j(jc)}$ in $I_{Preamble}^{TX_j(jc)}$ already includes the effect of the number of antenna elements ($E_{SA}^{TX_j}$). If you wish to include the effect of the number of antennas in case of MIMO, you must add the following lines in the Atoll.ini file:

```
[WiMAX]
MultiAntennaInterference
```

When the multi-antenna interference option is active, and $TX_j(jc)$ does not have a smart antenna equipment assigned, the interference is incremented by $+ 10 \times Log\left(N_{Ant-TX}^{TX_j(jc)}\right)$.

Where $N_{Ant-TX}^{TX_j(jc)}$ is the number of MIMO transmission (downlink) antennas defined for the cell $TX_j(jc)$.

$I_{DL}^{Inter-Tech}$ is the inter-technology downlink interference from transmitters of an external network (linked document of any technology) calculated as follows:

$$I_{DL}^{Inter-Tech} = \sum_{All\ External\ TXs} EIRP_{DL}^{TX-External} - L_{Path} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} - f_{IRF}^{Inter-Tech}$$

Where $EIRP_{DL}^{TX-External}$ is the downlink EIRP of the external transmitter, L_{Path} is the path loss from the external transmitters to the pixel, subscriber, or mobile location, L_{Indoor} is the indoor losses taken into account when the option "Indoor coverage" is selected, L^{M_i} is the receiver terminal losses for the pixel, subscriber, or mobile M_i, G^{M_i} is the receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i, $L_{Ant}^{M_i}$ is the receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i, and $L_{Body}^{M_i}$ is the body loss defined for the service used by the pixel, subscriber, or mobile M_i.

Output

- $I_{Preamble}^{TX_j(jc)}$: Preamble interference received from any interfering cell $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.

9.4.2.4 Preamble C/N Calculation

Input

- $C_{Preamble}^{TX_i(ic)}$: Received preamble signal level from the cell $TX_i(ic)$ as calculated in "Preamble Signal Level Calculation" on page 658.
- $n_{Preamble}^{TX_i(ic)}$: Preamble noise for the cell $TX_i(ic)$ as calculated in "Preamble Noise Calculation" on page 659.

Calculations

The preamble C/N for a cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CNR_{Preamble}^{TX_i(ic)} = C_{Preamble}^{TX_i(ic)} - n_{Preamble}^{TX_i(ic)}$$

Output

- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N from the cell $TX_i(ic)$ at any pixel, subscriber, or mobile M_i.

9.4.2.5 Preamble C/(I+N) Calculation

The carrier signal to interference and noise ratio is calculated in three steps. First **9955** calculates the received preamble signal level from the studied cell (as explained in "Preamble Signal Level Calculation" on page 658) at the pixel, subscriber or mobile under study. Next, **9955** calculates the interference received at the same studied pixel, subscriber, or mobile from all the interfering cells (as explained in "Preamble Interference Calculation" on page 660). Interference from each cell is weighted according to the co- and adjacent channel overlap between the studied and the interfering cells, and the probabilities of subcarrier collision. Finally, **9955** takes the ratio of the preamble signal level, and the sum of the total interference from all interfering cells and the noise (as calculated in "Preamble Noise Calculation" on page 659).

The receiver terminal is always considered to be oriented towards its best server, except when the "Lock Status" is set to "Server+Orientation" for a subscriber in a subscriber list and its azimuth and tilt manually edited. In the case of NLOS between the receiver and the best server, **9955** does not try to find the direction of the strongest signal, the receiver is oriented towards the best server just as in the case of LOS.

Input

- $C_{Preamble}^{TX_i(ic)}$: Preamble signal level received from the cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i as calculated in "Preamble Signal Level Calculation" on page 658.
- $n_{Preamble}^{TX_i(ic)}$: Preamble noise for the cell $TX_i(ic)$ as calculated in "Preamble Noise Calculation" on page 659.
- $I_{Preamble}^{TX_j(jc)}$: Preamble interference received from any cell $TX_j(jc)$ at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ as calculated in "Preamble Interference Calculation" on page 660.
- $NR_{DL}^{Inter-Tech}$: Inter-technology downlink noise rise.

Calculations

The preamble C/(I+N) for a cell $TX_i(ic)$ is calculated as follows at any pixel, subscriber, or mobile M_i:

$$CINR_{Preamble}^{TX_i(ic)} = C_{Preamble}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{I_{Preamble}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Preamble}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

The preamble total noise (I+N) for a cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$(I+N)_{Preamble}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{I_{Preamble}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{Preamble}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}$$

Output

- $CINR_{Preamble}^{TX_i(ic)}$: Preamble C/(I+N) from the cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i.
- $(I+N)_{Preamble}^{TX_i(ic)}$: Preamble total noise from the interfering cells $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.

9.4.3 Best Server Determination

In WiMAX, best server refers to a cell ("serving transmitter"-"reference cell" pair) from which a pixel, subscriber, or mobile M_i gets the highest preamble signal level or preamble C/(I+N). This calculation also determines whether the pixel, subscriber, or mobile M_i is within the coverage area of any transmitter or not.

Input

- $C_{Preamble}^{TX_i(ic)}$: Preamble signal level received from any cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i as calculated in "Preamble Signal Level Calculation" on page 658 using the terminal and service parameters (L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$) of M_i. "Preamble C/(I+N) Calculation" on page 662
- $CINR_{Preamble}^{TX_i(ic)}$: Preamble C/(I+N) received from any cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i as calculated in "Preamble C/(I+N) Calculation" on page 662 using the terminal and service parameters (L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$) of M_i.

Calculations

The best server of any pixel, subscriber, or mobile M_i, BS_{M_i}, is the cell from which the received preamble signal level or C/(I+N) is the highest among all the cells. The best server is determined as follows:

$$BS_{M_i} = TX_i(ic)\Big|_{C_{Preamble}^{TX_i(ic)} = \underset{All\ TX_i(ic)}{Best}\left\{C_{Preamble}^{TX_i(ic)}\right\}} \quad \text{or } BS_{M_i} = TX_i(ic)\Big|_{CINR_{Preamble}^{TX_i(ic)} = \underset{All\ TX_i(ic)}{Best}\left\{CINR_{Preamble}^{TX_i(ic)}\right\}}$$

Here *ic* is the cell of the transmitter TX_i with the highest preamble power. However, if more than one cell of the same transmitter covers the pixel, subscriber, or mobile, the final reference cell *ic* might be different from the initial cell *ic* (the one with the highest power) depending on the serving cell selection method:

- **Random:** In coverage prediction calculations and in calculations on subsriber lists, the cell of the highest layer is selected as the serving (reference) cell. In Monte Carlo simulations, a random cell is selected as the serving (reference) cell.
- **Distributive:** In coverage prediction calculations and in calculations on subsriber lists, the cell of the highest layer is selected as the serving (reference) cell. In Monte Carlo simulations, mobiles are distributed among cell layers one by one, i.e., if more than one cell layer covers a set of mobiles, the first mobile is assigned to the highest cell layer, the 2nd mobile to the second highest cell layer, and so on.

  When using either the **Random** or the **Distributive** cell selection method, the reference cell once assigned to a mobile does not change during Monte Carlo simulations.

Output

- BS_{M_i} : Best serving cell of the pixel, subscriber, or mobile M_i.

9.4.4 Service Area Calculation

In WiMAX, a pixel, subscriber, or mobile M_i can be covered by a cell (as calculated in "Best Server Determination" on page 663) but can be outside the service area. A pixel, subscriber, or mobile M_i is said to be within the service area of its best serving cell $TX_i(ic)$ if the preamble C/N from the cell at the pixel, subscriber, or mobile is greater than or equal to the preamble C/N threshold defined for the cell.

Input

- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N from the cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i as calculated in "Preamble C/N Calculation" on page 662.
- $T_{Preamble}^{TX_i(ic)}$: Preamble C/N threshold defined for the cell $TX_i(ic)$.

Calculations

A pixel, subscriber, or mobile M_i is within the service area of its best serving cell $TX_i(ic)$ if:

$$CNR_{Preamble}^{TX_i(ic)} \geq T_{Preamble}^{TX_i(ic)}$$

Output

- *True*: If the calculation criterion is satisfied.

- *False*: Otherwise.

9.4.5 Permutation Zone Selection

In order to be able to calculate the traffic C/(I+N) and the throughputs, a permutation zone is assigned to each pixel, subscriber, or mobile M_i located within the service area (as calculated in "Service Area Calculation" on page 664) of its best serving cell. The permutation zone assigned to M_i is one which covers M_i in terms of distance and preamble C/N or C/(I+N), and accepts user speeds equal to or higher than M_i's speed selected for the calculation.

A pixel, subscriber, or mobile M_i which is unable to get a permutation zone is considered to be outside the service area.

Input

- $d_{Max-PZ}^{TX_i(ic)}$: Maximum distance covered by a permutation zone of a cell $TX_i(ic)$.
- $QT_{PZ}^{TX_i(ic)}$: Minimum preamble C/N or C/(I+N) required at the pixel, subscriber, or mobile M_i to connect to a permutation zone of a cell $TX_i(ic)$.
- $Speed_{Max-PZ}^{TX_i(ic)}$: Maximum speed supported by a permutation zone of a cell $TX_i(ic)$.
- $d^{M_i-TX_i(ic)}$: Distance between the pixel, subscriber, or mobile M_i and a cell $TX_i(ic)$.
- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N from the cell $TX_i(ic)$ as calculated in "Preamble C/N Calculation" on page 662.
- $CINR_{Preamble}^{TX_i(ic)}$: Preamble C/(I+N) from the cell $TX_i(ic)$ as calculated in "Preamble C/(I+N) Calculation" on page 662.
- $Mobility(M_i)$: Speed of the pixel, subscriber, or mobile M_i.

Calculations

M_i is assigned the permutation zone with the highest priority among the permutation zones whose selection criteria M_i satisfies. M_i satisfies the selection criteria of a permutation zone if:

- The distance between M_i and $TX_i(ic)$ is less than or equal to the maximum distance covered by the permutation zone:

  $$d^{M_i-TX_i(ic)} \le d_{Max-PZ}^{TX_i(ic)}$$

- The preamble C/N or C/(I+N) at M_i is better than or equal to the quality threshold defined for the permutation zone:

  $$CNR_{Preamble}^{TX_i(ic)} \ge QT_{PZ}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} \ge QT_{PZ}^{TX_i(ic)}$$

- The mobility of M_i is less than or equal to the maximum mobile speed supported by the permutation zone:

  $$Mobility(M_i) \le Speed_{Max-PZ}^{TX_i(ic)}$$

Therefore, the permutation zones assigned to a pixel, subscriber, or mobile M_i in the downlink and uplink are:

$$PZ_{DL}^{M_i} = Highest\ Priority\left(PZ_{DL}^{TX_i(ic)} \middle| \left(d^{M_i-TX_i(ic)} \le d_{Max-PZ}^{TX_i(ic)}\right) AND \begin{pmatrix} CNR_{Preamble}^{TX_i(ic)} \ge QT_{PZ}^{TX_i(ic)} \\ OR \\ CINR_{Preamble}^{TX_i(ic)} \ge QT_{PZ}^{TX_i(ic)} \end{pmatrix} AND \left(Mobility(M_i) \le Speed_{Max-PZ}^{TX_i(ic)}\right) \right)$$

$$PZ_{UL}^{M_i} = Highest\ Priority\left(PZ_{UL}^{TX_i(ic)} \middle| \left(d^{M_i-TX_i(ic)} \le d_{Max-PZ}^{TX_i(ic)}\right) AND \begin{pmatrix} CNR_{Preamble}^{TX_i(ic)} \ge QT_{PZ}^{TX_i(ic)} \\ OR \\ CINR_{Preamble}^{TX_i(ic)} \ge QT_{PZ}^{TX_i(ic)} \end{pmatrix} AND \left(Mobility(M_i) \le Speed_{Max-PZ}^{TX_i(ic)}\right) \right)$$

If more than 1 permutation zone satisfies the distance, speed, and quality threshold criteria, and all have the same priority, the permutation zone assigned to the pixel, subscriber, or mobile will be the first in the list of permutation zones (frame configuration) among these zones.

Output

- $PZ_{DL}^{M_i}$ and $PZ_{UL}^{M_i}$: Downlink and uplink permutation zones assigned to the pixel, subscriber, or mobile M_i.

9.4.6 Traffic and Pilot Signal Level and Quality Calculations

Traffic and pilot subcarriers can be transmitted with different transmission powers than the preamble power of a cell, and do not suffer the same interference and noise as the preamble. The following sections describe how traffic and pilot signal levels, noise and interference, C/N, and C/(I+N) ratios are calculated on the downlink and uplink.

- "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- "Traffic and Pilot Noise Calculation (DL)" on page 667.
- "Traffic and Pilot Interference Calculation (DL)" on page 669.
- "Traffic and Pilot C/N Calculation (DL)" on page 676.
- "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- "Traffic Signal Level Calculation (UL)" on page 680.
- "Traffic Noise Calculation (UL)" on page 681.
- "Traffic Interference Calculation (UL)" on page 682.
- "Traffic C/N Calculation (UL)" on page 685.
- "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.

9.4.6.1 Traffic and Pilot Signal Level Calculation (DL)

Input

- $P_{Preamble}^{TX_i(ic)}$: Preamble transmission power of the cell $TX_i(ic)$.
- $\Delta P_{Traffic}^{TX_i(ic)}$: Traffic power reduction of the cell $TX_i(ic)$.
- $\Delta P_{Pilot}^{TX_i(ic)}$: Pilot power reduction of the cell $TX_i(ic)$.
- G^{TX_i} : Transmitter antenna gain for the antenna used by the transmitter TX_i.
  - **Without smart antennas:** G^{TX_i} is the transmitter antenna gain, i.e., $G^{TX_i} = G_{Ant}^{TX_i}$.
  - **With smart antennas:** G^{TX_i} is the smart antenna gain in the direction of the pixel, subscriber, or mobile M_i, i.e., $G^{TX_i} = G_{SA}(\theta)$. Where θ is the direction in which M_i is located. For more information on the calculation of $G_{SA}(\theta)$, refer to section "Beamforming Smart Antenna Models" on page 41.
- ΔG_{SA}^{Array} : Smart antenna array gain offset defined per clutter class.
- $\Delta G_{SA}^{Combining}$: Smart power combining gain offset defined per clutter class.
- G_{SA}^{Div} : Smart antenna diversity gain (for cross-polarised smart antennas) defined per clutter class.
- L^{TX_i} : Total transmitter losses for the transmitter TX_i ($L^{TX_i} = L_{Total-DL}$).
- L_{Path} : Path loss ($L_{Path} = L_{Model} + L_{Ant}^{TX_i}$).
- L_{Model} : Loss on the transmitter-receiver path (path loss) calculated using a propagation model.
- $L_{Ant}^{TX_i}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_i.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.
- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.

- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.
- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  For calculating the useful signal level from the best serving cell, $L_{Ant}^{M_i}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L_{Ant}^{M_i}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.

- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.

Calculations

The received traffic and pilot signal levels (dBm) from any cell $TX_i(ic)$ are calculated for a pixel, subscriber, or mobile M_i as follows:

$$C_{Traffic}^{TX_i(ic)} = EIRP_{Traffic}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$ and

$$C_{Pilot}^{TX_i(ic)} = EIRP_{Pilot}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the cell calculated as follows:

$$EIRP_{Traffic}^{TX_i(ic)} = P_{Traffic}^{TX_i(ic)} + G^{TX_i} + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$$ and

$$EIRP_{Pilot}^{TX_i(ic)} = P_{Pilot}^{TX_i(ic)} + G^{TX_i} + \Delta G_{SA}^{Array} + \Delta G_{SA}^{Combining} + G_{SA}^{Div} - L^{TX_i}$$

With $P_{Traffic}^{TX_i(ic)}$ and $P_{Pilot}^{TX_i(ic)}$ being the traffic and pilot transmission powers of the cell $TX_i(ic)$ calculated as follows:

$P_{Traffic}^{TX_i(ic)} = P_{Preamble}^{TX_i(ic)} - \Delta P_{Traffic}^{TX_i(ic)}$ and $P_{Pilot}^{TX_i(ic)} = P_{Preamble}^{TX_i(ic)} - \Delta P_{Pilot}^{TX_i(ic)}$

> If you wish to exclude the the energy corresponding to the cyclic prefix part of the total symbol duration from the useful signal level, you must add the following lines in the Atoll.ini file:
>
> ```
> [WiMAX]
> ExcludeCPFromUsefulPower = 1
> ```
>
> When this option is active, the cyclic prefix energy is excluded from $C_{Preamble}^{TX_i(ic)}$. In other words, the factor $10 \times Log(1 - r_{CP})$ is added to $C_{Preamble}^{TX_i(ic)}$.
>
> Independant of the option, interference levels are calculated for the total symbol durations, i.e., the energy of the useful symbol duration and the cyclic prefix energy.

Output

- $C_{Traffic}^{TX_i(ic)}$: Received traffic signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $C_{Pilot}^{TX_i(ic)}$: Received pilot signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.

9.4.6.2 Traffic and Pilot Noise Calculation (DL)

For determining the traffic and pilot C/N and C/(I+N), **9955** calculates the downlink noise over the channel bandwidth used by the cell. The used bandwidth depends on the number of used subcarriers. The numbers of subcarriers used by different permutation zones can be different.

The downlink noise comprises thermal noise and the noise figure of the equipment. The thermal noise density depends on the temperature, i.e., it remains constant for a given temperature. However, the value of the thermal noise varies with the used bandwidth.

Input

- K: Boltzmann's constant.
- T: Temperature in Kelvin.
- $N_{SCa-Used}^{PZ_{DL}^{M_i}}$: Number of subcarriers used by the downlink permutation zone of a cell $TX_i(ic)$ assigned to M_i.
- $N_{SCa-Total}^{TX_i(ic)}$: Total number of subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- $F_{Sampling}^{TX_i(ic)}$: Sampling frequency for the cell $TX_i(ic)$ as calculated in "Calculation of Sampling Frequency" on page 691.
- nf^{M_i} : Noise figure of the terminal used for calculations by the pixel, subscriber, or mobile M_i.

Calculations

The power spectral density of thermal noise is calculated as follows:

$$n_0 = 10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$$

The thermal noise for a cell is calculated as:

$$n_{0-DL}^{TX_i(ic)} = n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Used}^{PZ_{DL}^{M_i}}}{N_{SCa-Total}^{TX_i(ic)}} \right)$$

The downlink noise is the sum of the thermal noise and the noise figure of the terminal used for the calculations by the pixel, subscriber, or mobile M_i.

$$n_{DL}^{TX_i(ic)} = n_{0-DL}^{TX_i(ic)} + nf^{M_i}$$

Effect of Segmentation:

If you select downlink segmentation support for the frame configuration used by the cell, it means that the first downlink PUSC permutation zone is segmented. All other zones are pooled together to form a non-segmented zone.

The downlink segmenting factor, $f_{Segment-DL}$, is calculated from the number of secondary subchannel groups assigned to the permutation zone in the Permutation Zones table.

$$f_{Segment-DL} = \frac{3 \times PSG + 2 \times SSG}{15}$$

Where, PSG is the number of primary subchannel groups and SSG is the number of used secondary subchannel groups.

> The multiplicative coefficients of *3* and *2* are derived from the ratio of the numbers of subchannels that belong to the primary and to the secondary subchannel gourps. For example, for the FFT size of *1024* (or *2048*), each primary subchannel group contains *6* (or *12*) subchannels, and each secondary subchannel group contains *4* (or *8*) subchannels, which gives the ratio of *3*:*2*. And, the denominator of *15* = *3* x *3* + *2* x *3*.

$f_{Segment-DL}$ represents the fraction of the channel bandwidth used by a downlink segment. The power transmitted over a segment has $\frac{1}{f_{Segment-DL}}$ times the spectral density of the power transmitted over the entire channel bandwidth. When calculating the downlink C/N and C/(I+N) ratios, the increase in power by $\frac{1}{f_{Segment-DL}}$ due to this power concentration is equivalent to a reduction in the noise level by $f_{Segment-DL}$. Hence, if downlink segmentation is used, the thermal noise power at the pixel, subscriber, or mobile M_i covered by the downlink segmented permutation zone is reduced by the factor $f_{Segment-DL}$. Which means that the thermal noise for the a segment of the channel used by a cell is calculated as:

$$n_{0-DL}^{TX_i(ic)} = n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Used}^{PZ_{DL}^{M_i}}}{N_{SCa-Total}^{TX_i(ic)}} \times f_{Segment-DL} \right)$$

Output

- $n_{DL}^{TX_i(ic)}$: Downlink noise for the cell $TX_i(ic)$.

9.4.6.3 Traffic and Pilot Interference Calculation (DL)

The interference received by any pixel, subscriber, or mobile, served by a cell $TX_i(ic)$ from other cells $TX_j(jc)$ can be defined as the traffic and pilot signal levels received from interfering cells $TX_j(jc)$ depending on the overlap that exists between the channels used by the cells $TX_i(ic)$ and $TX_j(jc)$, on the traffic loads of the interfering cells $TX_j(jc)$, and whether the cells use downlink segmentation or not. Moreover, the interference can come from cells using simple as well as smart antennas.

The calculation can be divided into the two parts.

- "Traffic and Pilot Interference Signal Levels Calculation (DL)" on page 669.
- "Effective Traffic and Pilot Interference Calculation (DL)" on page 672.

9.4.6.3.1 Traffic and Pilot Interference Signal Levels Calculation (DL)

The traffic and pilot signal levels received from interfering cells $TX_j(jc)$ at a pixel, subscriber, or mobile M_i, covered by a cell $TX_i(ic)$, are calculated in a different manner than the traffic and pilot signal levels from the studied cell $TX_i(ic)$. This section explains how these interfering signals are calculated.

Input

- $P_{Preamble}^{TX_j(jc)}$: Preamble transmission power of the cell $TX_j(jc)$.
- $\Delta P_{Pilot}^{TX_j(jc)}$: Pilot power reduction of the interfering cell $TX_j(jc)$.
- $\Delta P_{Traffic}^{TX_j(jc)}$: Traffic power reduction of the interfering cell $TX_j(jc)$.
- $\Delta P_{Idle-Pilot}^{TX_j(jc)}$: Idle pilot power reduction of the interfering cell $TX_j(jc)$.
- L^{TX_j} : Total transmitter losses for the transmitter TX_j ($L^{TX_j} = L_{Total-DL}$).
- L_{Path} : Path loss ($L_{Path} = L_{Model} + L_{Ant}^{TX_j}$).
- L_{Model} : Loss on the transmitter-receiver path (path loss) calculated using a propagation model.
- $L_{Ant}^{TX_j}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_j.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.
- $M_{Shadowing-C/I}$: Shadowing margin based on the C/I standard deviation.

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.

- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.
- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.
- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  $L_{Ant}^{M_i}$ is determined in the direction of $TX_j(jc)$ from the antenna patterns of the antenna used by M_i while the antenna is pointed towards $TX_i(ic)$.

- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.
- $TL_{DL}^{TX_j(jc)}$: Downlink traffic load of the interfering cell $TX_j(jc)$.

  Traffic loads can either be calculated using Monte Carlo simulations, or entered manually for each cell. Calculation of traffic loads is explained in "Simulation Process" on page 650.

- $AU_{DL}^{TX_j(jc)}$: Downlink AAS usage ratio of the interfering cell $TX_j(jc)$.

Downlink AAS usage ratios are calculated using Monte Carlo simulations as explained in "Simulation Process" on page 650.

- $N_{SCa-Used}^{TX_j(jc)}$: Number of used subcarriers defined for the first downlink permutation zone in the frame configuration assigned to the interfering cell $TX_j(jc)$.
- $N_{SCa-Data}^{TX_j(jc)}$: Number of data subcarriers defined for the first downlink permutation zone in the frame configuration assigned to the interfering cell $TX_j(jc)$.

Calculations

WiMAX cells can transmit different powers on pilot ($N_{Used} - N_{Data}$) and data (N_{Data}) subcarriers for the part of the frame with traffic, and a different pilot power for the part of the frame that does not have traffic bursts. Data subcarriers are off during the empty part of the frame. Therefore, the interference received from a cell depends on the traffic load and the different powers of the cell, i.e., pilot, traffic, and idle pilot powers.

Monte Carlo simulations and coverage prediction calculations present different scenarios for interference calculations in the case of smart antennas.

- **Monte Carlo Simulations:**

  In the case of Monte Carlo simulations, the interferer is either using the transmitter antenna or the smart antenna at any given moment. So, for each interfered pixel, subscriber, or mobile, **9955** already knows the type of the interference source. Therefore, the interference received from any cell $TX_j(jc)$ can be given by:

  Without smart antennas: $I_{Total}^{TX_j(jc)} = 10 \times Log\left(10^{\frac{I_{Non-AAS}^{TX_j(jc)}}{10}} + 10^{\frac{I_{Idle}^{TX_j(jc)}}{10}}\right)$

  With smart antennas: $I_{Total}^{TX_j(jc)} = 10 \times Log\left(10^{\frac{I_{AAS}^{TX_j(jc)}}{10}}\right)$

- **Coverage Predictions:**

  In the case of coverage prediction calculations, the interferer could either be transmitting using the transmitter antenna, or using the smart antenna, or it could be empty, or not transmitting.Therefore, the interference received from any cell $TX_j(jc)$ can be given by:

$$I_{Total}^{TX_j(jc)} = 10 \times Log\left(10^{\frac{I_{Non-AAS}^{TX_j(jc)}}{10}} + 10^{\frac{I_{Idle}^{TX_j(jc)}}{10}} + 10^{\frac{I_{AAS}^{TX_j(jc)}}{10}}\right)$$

Where, the three components of the interference are:

- $I_{Non-AAS}^{TX_j(jc)}$: Interference from the loaded part of the frame transmitted using the main antenna,
- $I_{AAS}^{TX_j(jc)}$: Interference from the loaded part of the frame transmitted using the smart antenna,
- $I_{Idle}^{TX_j(jc)}$: Interference from the empty, or idle, part of the frame.

The above components of the interference are calculated as follows:

The interference from the loaded part of the frame transmitted using the main antenna is calculated as follows:

The received interfering traffic and pilot signal levels (dBm) from any cell $TX_j(jc)$ are calculated for a pixel, subscriber, or mobile M_i as follows:

In Monte Carlo simulations:

$$I_{Traffic}^{TX_j(jc)} = EIRP_{Traffic}^{TX_j(jc)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

$$I_{Pilot}^{TX_j(jc)} = EIRP_{Pilot}^{TX_j(jc)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

In coverage prediction:

$$I_{Traffic}^{TX_j(jc)} = EIRP_{Traffic}^{TX_j(jc)} - L_{Path} - M_{Shadowing-Model} + M_{Shadowing-C/I} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

$$I_{Pilot}^{TX_j(jc)} = EIRP_{Pilot}^{TX_j(jc)} - L_{Path} - M_{Shadowing-Model} + M_{Shadowing-C/I} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the cell calculated as follows:

$$EIRP_{Traffic}^{TX_j(jc)} = P_{Traffic}^{TX_j(jc)} + G^{TX_j} - L^{TX_j} \text{ and } EIRP_{Pilot}^{TX_j(jc)} = P_{Pilot}^{TX_j(jc)} + G^{TX_j} - L^{TX_j}$$

With $P_{Traffic}^{TX_j(jc)}$ and $P_{Pilot}^{TX_j(jc)}$ being the traffic and pilot transmission powers of the cell $TX_j(jc)$ calculated as follows:

$$P_{Traffic}^{TX_j(jc)} = P_{Preamble}^{TX_j(jc)} - \Delta P_{Traffic}^{TX_j(jc)} \text{ and } P_{Pilot}^{TX_j(jc)} = P_{Preamble}^{TX_j(jc)} - \Delta P_{Pilot}^{TX_j(jc)}$$

And $G^{TX_j} = G_{Ant}^{TX_j}$, i.e., the transmitter antenna gain for the antenna used by the transmitter TX_j.

The interference from the loaded part of the frame transmitted using the main antenna is given as:

$$I_{Non-AAS}^{TX_j(jc)} = 10 \times Log\left(TL_{DL}^{TX_j(jc)} \times \left(1 - AU_{DL}^{TX_j(jc)}\right) \times \left(10^{\frac{I_{Traffic}^{TX_j(jc)}}{10}} \times \frac{N_{SCa-Data}^{TX_j(jc)}}{N_{SCa-Used}^{TX_j(jc)}} + 10^{\frac{I_{Pilot}^{TX_j(jc)}}{10}} \times \left(1 - \frac{N_{SCa-Data}^{TX_j(jc)}}{N_{SCa-Used}^{TX_j(jc)}}\right)\right)\right)$$

If you wish to include the effect of the number of antennas in case of MIMO, you must add the following lines in the Atoll.ini file:

```
[WiMAX]
MultiAntennaInterference = 1
```

When the multi-antenna interference option is active, the interference is incremented by $+ 10 \times Log\left(N_{Ant-TX}^{TX_j(jc)}\right)$. Where $N_{Ant-TX}^{TX_j(jc)}$ is the number of MIMO transmission (downlink) antennas defined for the cell $TX_j(jc)$.

The interference from the loaded part of the frame transmitted using the smart antenna is calculated as follows:

The received interfering traffic signal level (dBm) from any cell $TX_j(jc)$ is calculated for a pixel, subscriber, or mobile M_i as follows:

In Monte Carlo simulations:

$$I_{AAS}^{TX_j(jc)} = EIRP_{AAS}^{TX_j(jc)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

In coverage prediction:

$$I_{AAS}^{TX_j(jc)} = EIRP_{AAS}^{TX_j(jc)} - L_{Path} - M_{Shadowing-Model} + M_{Shadowing-C/I} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the cell calculated as follows:

$$EIRP_{AAS}^{TX_j(jc)} = P_{Traffic}^{TX_j(jc)} + G^{TX_j} - L^{TX_j}$$

With $P_{Traffic}^{TX_j(jc)}$ being the traffic transmission power of the cell $TX_j(jc)$ calculated as follows:

$$P_{Traffic}^{TX_j(jc)} = P_{Preamble}^{TX_j(jc)} - \Delta P_{Traffic}^{TX_j(jc)}$$

And, $G^{TX_j} = G_{SA}(\varphi)$ is the smart antenna gain in the direction of the victim mobile M_i, calculated from the angular distributions of the downlink traffic power density of the interfering cells. The angular distribution of the downlink traffic power density is determined from the array correlation matrices calculated during Monte Carlo simulations.

φ is the direction in which the victim pixel, subscriber, or mobile M_i is located. For more information on the calculation of $G_{SA}(\varphi)$, see "Beamforming Smart Antenna Models" on page 41.

The gain of the interfering signal, $G_{SA}(\varphi)$, transmitted in the direction of each pixel φ is given by:

$$G_{SA}(\varphi) = g_n(\varphi) \cdot \vec{S}_{\varphi}^{H} \cdot \vec{R}_{Avg} \cdot \vec{S}_{\varphi}$$

Where $\vec{S}_{\varphi}$ is the steering vector in the direction φ (probe mobile/pixel), *H* denotes the Hilbert transform, $\vec{R}_{Avg}$ is the average array correlation matrix, and $g_n(\varphi)$ is the gain of the n^{th} antenna element in the direction φ.

The interference from the empty, or idle, part of the frame transmitted using the transmitter antenna is calculated as follows:

The received interfering pilot signal level (dBm) from any cell $TX_j(jc)$ is calculated for a pixel, subscriber, or mobile M_i as follows:

$$I_{Idle-Pilot}^{TX_j(jc)} = EIRP_{Idle-Pilot}^{TX_j(jc)} - L_{Path} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the cell calculated as follows:

$$EIRP_{Idle-Pilot}^{TX_j(jc)} = P_{Idle-Pilot}^{TX_j(jc)} + G^{TX_j} - L^{TX_j}$$

With $P_{Idle-Pilot}^{TX_j(jc)}$ being the idle pilot transmission power of the cell $TX_j(jc)$ calculated as follows:

$$P_{Idle-Pilot}^{TX_j(jc)} = P_{Preamble}^{TX_j(jc)} - \Delta P_{Idle-Pilot}^{TX_j(jc)}$$

And, $G^{TX_j} = G_{Ant}^{TX_j}$, i.e., the transmitter antenna gain for the antenna used by the transmitter TX_j.

The interference from the empty, or idle, part of the frame transmitted using the transmitter antenna is given as:

$$I_{Idle}^{TX_j(jc)} = 10 \times Log\left(\left(1 - TL_{DL}^{TX_j(jc)}\right) \times \left(10^{\frac{I_{Idle-Pilot}^{TX_j(jc)}}{10}} \times \left(1 - \frac{N_{SCa-Data}^{TX_j(jc)}}{N_{SCa-Used}^{TX_j(jc)}}\right)\right)\right)$$

If you wish to include the effect of the number of antennas in case of MIMO, you must add the following lines in the Atoll.ini file:

```
[WiMAX]
MultiAntennaInterference = 1
```

When the multi-antenna interference option is active, the interference is incremented by $+ 10 \times Log\left(N_{Ant-TX}^{TX_j(jc)}\right)$. Where $N_{Ant-TX}^{TX_j(jc)}$ is the number of MIMO transmission (downlink) antennas defined for the cell $TX_j(jc)$.

Output

- $I_{Total}^{TX_j(jc)}$: Interference received at the pixel, subscriber, or mobile M_i from any interfering cell $TX_j(jc)$.

9.4.6.3.2 Effective Traffic and Pilot Interference Calculation (DL)

The effective downlink traffic and pilot interference received at a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ from interfering cells $TX_j(jc)$ depends on the co- and adjacent channel overlap that exists between the channel used by the studied cell and the interfering cells, and the downlink segmentation parameters of the studied and interfering cells. The first downlink PUSC zone can be segmented at the studied and the interfering cells. The probability of subcarrier collision depends on the lengths of the segmented zones and on the subchannel groups used at both sides.

Input

- $I_{Total}^{TX_j(jc)}$: Interference received at the pixel, subscriber, or mobile M_i from any interfering cell $TX_j(jc)$ as calculated in "Traffic and Pilot Interference Signal Levels Calculation (DL)" on page 669.
- $r_O^{TX_i(ic) - TX_j(jc)}$: Total channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 653.

- $SU_{DL}^{TX_i(ic)}$ and $SU_{DL}^{TX_j(jc)}$: Downlink segmentation usage ratios defined for cells $TX_i(ic)$ and $TX_j(jc)$.

Calculations

The total traffic and pilot interference (dBm) from any cell $TX_j(jc)$ is calculated for a pixel, subscriber, or mobile M_i as follows:

$$I_{DL}^{TX_j(jc)} = I_{Total}^{TX_j(jc)} + f_O^{TX_i(ic) - TX_j(jc)} + f_{Seg-DL}^{TX_i(ic) - TX_j(jc)} + I_{DL}^{Inter-Tech}$$

Calculations for the interference reduction factors due to channel overlapping and downlink segmentation are explained below:

Interference reduction due to the co- and adjacent channel overlap between the studied and the interfering cells:

Interference reduction due to the co- and adjacent channel overlap between the cells $TX_i(ic)$ and $TX_j(jc)$ is calculated as follows:

$$f_O^{TX_i(ic) - TX_j(jc)} = 10 \times Log\left(r_O^{TX_i(ic) - TX_j(jc)}\right)$$

Interference reduction due to downlink segmentation:

If you select downlink segmentation support for the frame configuration that you are using, it means that the first zone in the downlink, i.e., the DL PUSC zone, is segmented. All other zones are pooled together to form a group of non-segmented zones. There are two effects of segmentation:

1. Power concentration, which means that the spectral density of the power transmitted over one segment is higher than the spectral density of the same power transmitted over the entire channel bandwidth. The effect of power concentration is visible when calculating the downlink C/(I+N). The power transmitted over a segmented zone has $\frac{1}{f_{Segment-DL}}$ times the spectral density of the power transmitted over the entire channel bandwidth. When calculating the C/(I+N) ratio, the increase in power by $\frac{1}{f_{Segment-DL}}$ is equivalent to decreasing the noise and interference by $f_{Segment-DL}$. Hence, if downlink segmentation is used, the interference received at the pixel, subscriber, or mobile M_i covered by the segmented zone is reduced by a factor of $f_{Segment-DL}$.
2. Collision probability between the subcarriers used by the subchannels belonging to the segment of the studied cell and the subcarriers used by other sectors, segmented or not. The following paragraphs explain how the collision probability is calculated.

   The downlink segmentation usage (*SU*) ratio is the percentage of the total downlink traffic load present in the segmented downlink PUSC zone. For example, if the downlink traffic load is 80 %, and the downlink segmentation usage ratio is 50 %, then this means that the downlink traffic load of the segmented zone is 40 % (i.e., 50 % of 80 %), and the downlink traffic load of the non-segmented zones is 40 %.

   In coverage predictions, **9955** uses the downlink segmentation usage ratios stored in the cell properties for determining the interference. In simulations, **9955** resets the downlink segmentation usage ratios for all the cells to 0, and then calculates the downlink segmentation usage ratios according to the traffic loads of the mobiles allocated to the segmented zone and in the non-segmented zones.

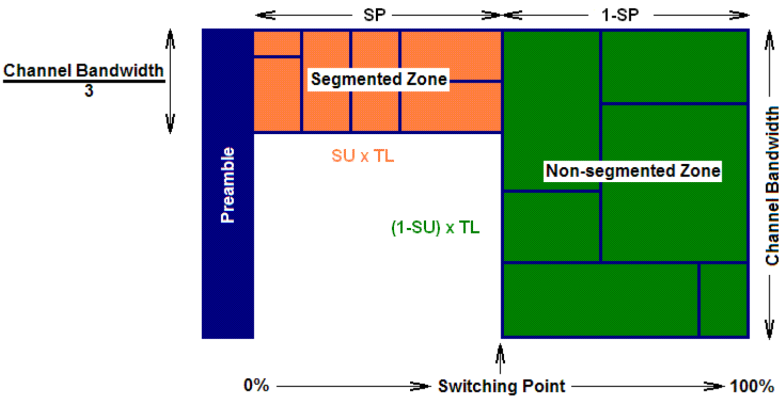


Figure 9.3: Downlink Segmentation

9955 determines the switching point between the segmented and the non-segmented zones using the downlink segmentation usage ratio. The switching points between the segmented and non-segmented zones of the victim and interfering cells, $TX_i(ic)$ and $TX_j(jc)$ respectively, are calculated as follows:

$$SP^{TX_i(ic)} = \frac{SU_{DL}^{TX_i(ic)}}{SU_{DL}^{TX_i(ic)} + f_{Segment-DL} \times \left(1 - SU_{DL}^{TX_i(ic)}\right)}$$ and

$$SP^{TX_j(jc)} = \frac{SU_{DL}^{TX_j(jc)}}{SU_{DL}^{TX_j(jc)} + f_{Segment-DL} \times \left(1 - SU_{DL}^{TX_j(jc)}\right)}$$

Where, *SP* is the switching point between the segmented and the non-segmented zones, *SU* is the downlink segmentation usage ratios of the cells, and $f_{Segment-DL}$ is downlink segmenting factor, which gives the bandwidth used by a segment.

The downlink segmenting factor, $f_{Segment-DL}$, is calculated from the number of secondary subchannel groups assigned to the first downlink PUSC permutation zone in the Permutation Zones table.

$$f_{Segment-DL} = \frac{3 \times PSG + 2 \times SSG}{15}$$

Where, *PSG* is the number of primary subchannel groups and *SSG* is the number of secondary subchannel groups.

> The multiplicative coefficients of *3* and *2* are derived from the ratio of the numbers of subchannels that belong to the primary and to the secondary subchannel gourps. For example, for the FFT size of *1024* (or *2048*), each primary subchannel group contains *6* (or *12*) subchannels, and each secondary subchannel group contains *4* (or *8*) subchannels, which gives the ratio of *3:2*. And, the denominator of *15* = *3* x *3* + *2* x *3*.

If the downlink segmentation usage ratio is set to 0, it means that the segmented zone does not exist. Setting *SU* to 0 gives *SP* = 0, and setting *SU* to 1 gives *SP* = 1 (or 100%), which shows how the switching point varies with the downlink segmentation usage ratio.

> Derivation of the switching point formula: The downlink segmentation usage ratio is used to partition the total downlink traffic load into segmented and non-segmented zones. Therefore, the switching point formula is derived from the equation:
>
> $$\frac{SU_{DL} \times TL_{DL}}{SP \times f_{Segment-DL} \times W_{Channel}} = \frac{(1 - SU_{DL}) \times TL_{DL}}{(1 - SP) \times W_{Channel}}$$

With cells using downlink segmentation, there can be four different interference scenarios.

- Between the segmented zone of the victim and the segmented zone of the interferer.
- Between the segmented zone of the victim and the non-segmented zone of the interferer.
- Between the non-segmented zone of the victim and the segmented zone of the interferer.
- Between the non-segmented zone of the victim and the non-segmented zone of the interferer.

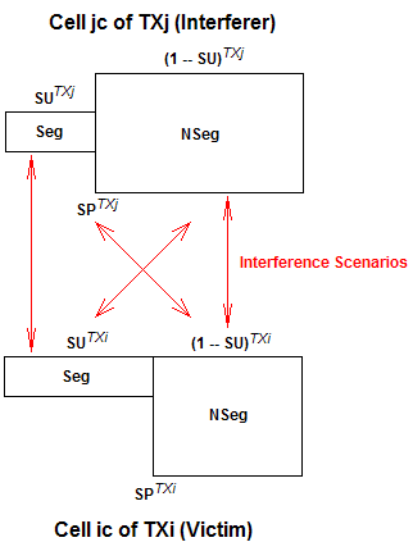


Figure 9.4: Downlink Segmentation Interference Scenarios

Therefore, **9955** calculates the probabilities of collision for each scenario and weights the total interference according to the total collision probability. The probability of collision p_{Coll} for each scenario is given by the following formula:

$$p_{Coll} = \frac{3 \times PSG_{Com} + 2 \times SSG_{Com}}{3 \times PSG^{TX_i(ic)} + 2 \times SSG^{TX_i(ic)}}$$

Where, PSG_{Com} is the number of primary subchannel groups common in $TX_i(ic)$ and $TX_j(jc)$, SSG_{Com} is the number of secondary subchannel groups common in $TX_i(ic)$ and $TX_j(jc)$, $PSG^{TX_i(ic)}$ is the number of primary subchannel groups in the cell $TX_i(ic)$, and $SSG^{TX_i(ic)}$ is the number of secondary subchannel groups in the cell $TX_i(ic)$.

The segment numbers and the cell permutation base numbers (Cell PermBase) are determined from the cell's preamble index. The mapping between the preamble index, the segment number, and Cell PermBase is available in the IEEE specifications. This mapping is performed in **9955** as follows:

Preamble Index (PI) **Range: 0 to 113**	$PI < 96$	$96 \le PI < 114$
Cell PermBase (PB) **Range: 0 to 31**	$PI \;\; Modulo \;\; 32$	$PI - 96$
Segment Number (N_{Seg}) **Range: 0, 1, 2**	$Floor\left(\frac{PI}{32}\right)$	$(PI - 96) \;\; Modulo \;\; 3$

There can be 2 cases for calculating the total probability of collision.

- **Case 1:** If the pixel, subscriber, or mobile M_i is covered by the segmented zone of $TX_i(ic)$, the total collision probability for the pixel, subscriber, or mobile M_i is calculated as follows:

$$p_{Collision-DL}^{TX_i(ic)-TX_j(jc)} = \begin{cases} p_{Coll}^{SS} & If \;\; SP^{TX_j(jc)} \ge SP^{TX_i(ic)} \\ \dfrac{p_{Coll}^{SS} \times SP^{TX_j(jc)} + p_{Coll}^{SN} \times \left(SP^{TX_i(ic)} - SP^{TX_j(jc)}\right)}{SP^{TX_i(ic)}} & If \;\; SP^{TX_j(jc)} < SP^{TX_i(ic)} \end{cases}$$

- **Case 2:** If the pixel, subscriber, or mobile M_i is covered by the non-segmented zone of $TX_i(ic)$, the total collision probability for the pixel, subscriber, or mobile M_i is calculated as follows:

$$p_{Collision-DL}^{TX_i(ic)-TX_j(jc)} = \begin{cases} p_{Coll}^{NN} & If \;\; SP^{TX_j(jc)} \le SP^{TX_i(ic)} \\ \dfrac{p_{Coll}^{NN} \times \left(1 - SP^{TX_j(jc)}\right) + p_{Coll}^{NS} \times \left(SP^{TX_j(jc)} - SP^{TX_i(ic)}\right)}{\left(1 - SP^{TX_i(ic)}\right)} & If \;\; SP^{TX_j(jc)} > SP^{TX_i(ic)} \end{cases}$$

The interference reduction factor due to downlink segmentation for the pixel, subscriber, or mobile M_i is calculated as follows:

$$f_{Seg-DL}^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(p_{Collision-DL}^{TX_i(ic)-TX_j(jc)}\right)$$

$I_{DL}^{Inter-Tech}$ is the inter-technology downlink interference from transmitters of an external network (linked document of any technology) calculated as follows:

$$I_{DL}^{Inter-Tech} = \sum_{All\ External\ TXs} EIRP_{DL}^{TX-External} - L_{Path} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} - f_{IRF}^{Inter-Tech}$$

Where $EIRP_{DL}^{TX-External}$ is the downlink EIRP of the external transmitter, L_{Path} is the path loss from the external transmitters to the pixel, subscriber, or mobile location, L_{Indoor} is the indoor losses taken into account when the option "Indoor coverage" is selected, L^{M_i} is the receiver terminal losses for the pixel, subscriber, or mobile M_i, G^{M_i} is the receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i, $L_{Ant}^{M_i}$ is the receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i, and $L_{Body}^{M_i}$ is the body loss defined for the service used by the pixel, subscriber, or mobile M_i.

Output

- $I_{DL}^{TX_j(jc)}$: Effective downlink traffic and pilot interference received at the pixel, subscriber, or mobile M_i from any interfering cell $TX_j(jc)$.

9.4.6.4 Traffic and Pilot C/N Calculation (DL)

Input

- $C_{Traffic}^{TX_i(ic)}$: Received traffic signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- $C_{Pilot}^{TX_i(ic)}$: Received pilot signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- $n_{DL}^{TX_i(ic)}$: Downlink noise for the cell $TX_i(ic)$ as calculated in "Traffic and Pilot Noise Calculation (DL)" on page 667.
- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Preamble C/N Calculation" on page 662.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the WiMAX equipment used by M_i's terminal.
- $B_{DL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{DL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{TX_i(ic)}$: Number of MIMO transmission (downlink) antennas defined for the cell $TX_i(ic)$.
- $N_{Ant-RX}^{M_i}$: Number of MIMO reception (downlink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- Subchannel allocation mode used by the downlink permutation zone $PZ_{DL}^{M_i}$ assigned to the pixel, subscriber, or mobile M_i as calculated in "Permutation Zone Selection" on page 665.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the WiMAX equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.

Calculations

The traffic and pilot C/N for a cell $TX_i(ic)$ are calculated as follows for any pixel, subscriber, or mobile M_i:

$$CNR_{Traffic}^{TX_i(ic)} = C_{Traffic}^{TX_i(ic)} - n_{DL}^{TX_i(ic)}$$

$$CNR_{Pilot}^{TX_i(ic)} = C_{Pilot}^{TX_i(ic)} - n_{DL}^{TX_i(ic)}$$

Bearer Determination:

The bearers available for selection in the pixel, subscriber, or mobile M_i's WiMAX equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.

- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the traffic or pilot C/N at M_i: $T_B^{M_i} < CNR_{Traffic}^{TX_i(ic)}$ or $T_B^{M_i} < CNR_{Pilot}^{TX_i(ic)}$

  If the cell supports STTD/MRC or AMS, the STTD/MRC gain, G_{STTD}^{DL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the WiMAX equipment assigned to the pixel, subscriber, or mobile M_i for $N_{Ant-TX}^{TX_i(ic)}$, $N_{Ant-RX}^{M_i}$, the subchannel allocation mode of $PZ_{DL}^{M_i}$, $Mobility(M_i)$, $BLER\left(B_{DL}^{M_i}\right)$.

  The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{DL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the WiMAX equipment for which the following is true:

  In case of STTD/MRC:

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CNR_{Traffic}^{TX_i(ic)}$$

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CNR_{Pilot}^{TX_i(ic)}$$

  In case of AMS:

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CNR_{Traffic}^{TX_i(ic)} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CNR_{Pilot}^{TX_i(ic)} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell *$TX_i(ic)$*.

- Bearer Index

  From among the bearers available for selection, the selected bearer is the one with the highest index.
- Peak MAC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest downlink peak MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.
- Effective MAC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest downlink effective MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

MIMO – STTD/MRC Gain:

Once the bearer is known, the traffic and pilot C/N calculated above become:

In case of STTD/MRC:

$$CNR_{Traffic}^{TX_i(ic)} = CNR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$$

$$CNR_{Pilot}^{TX_i(ic)} = CNR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$$

In case of AMS:

$$CNR_{Traffic}^{TX_i(ic)} = CNR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

$$CNR_{Pilot}^{TX_i(ic)} = CNR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{DL} is the STTD/MRC gain corresponding to the selected bearer.

Output

- $CNR_{Traffic}^{TX_i(ic)}$: Traffic C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $CNR_{Pilot}^{TX_i(ic)}$: Pilot C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.

9.4.6.5 Traffic and Pilot C/(I+N) and Bearer Calculation (DL)

The carrier signal to interference and noise ratio is calculated in three steps. First **9955** calculates the received signal level from the studied cell (as explained in "Traffic and Pilot Signal Level Calculation (DL)" on page 666) at the pixel, subscriber, or mobile under study. Next, **9955** calculates the interference received at the same studied pixel, subscriber, or mobile from all the interfering cells (as explained in "Traffic and Pilot Interference Calculation (DL)" on page 669). Interference from each cell is weighted according to the co- and adjacent channel overlap between the studied and the interfering cells, the traffic loads of the interfering cells, and the probabilities of subcarrier collision if downlink segmentation is used. Finally, **9955** takes the ratio of the signal level and the sum of the total interference from other cells and the downlink noise (as calculated in "Traffic and Pilot Noise Calculation (DL)" on page 667).

The receiver terminal is always considered to be oriented towards its best server, except when the "Lock Status" is set to "Server+Orientation" for a subscriber in a subscriber list and its azimuth and tilt manually edited. In the case of NLOS between the receiver and the best server, **9955** does not try to find the direction of the strongest signal, the receiver is oriented towards the best server just as in the case of LOS.

Input

- $C_{Traffic}^{TX_i(ic)}$: Received traffic signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- $C_{Pilot}^{TX_i(ic)}$: Received pilot signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Traffic and Pilot Signal Level Calculation (DL)" on page 666.
- $n_{DL}^{TX_i(ic)}$: Downlink noise for the cell $TX_i(ic)$ as calculated in "Traffic and Pilot Noise Calculation (DL)" on page 667.
- $I_{DL}^{TX_j(jc)}$: Effective downlink traffic and pilot interference from any cell $TX_j(jc)$ calculated for a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ as explained in "Traffic and Pilot Interference Calculation (DL)" on page 669.
- $NR_{DL}^{Inter-Tech}$: Inter-technology downlink noise rise.
- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Preamble C/N Calculation" on page 662.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the WiMAX equipment used by M_i's terminal.
- $B_{DL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{DL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{TX_i(ic)}$: Number of MIMO transmission (downlink) antennas defined for the cell $TX_i(ic)$.
- $N_{Ant-RX}^{M_i}$: Number of MIMO reception (downlink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- Subchannel allocation mode used by the downlink permutation zone $PZ_{DL}^{M_i}$ assigned to the pixel, subscriber, or mobile M_i as calculated in "Permutation Zone Selection" on page 665.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the WiMAX equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.

Calculations

The traffic and pilot C/(I+N) for a cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CINR_{Traffic}^{TX_i(ic)} = C_{Traffic}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right) \text{ and}$$

$$CINR_{Pilot}^{TX_i(ic)} = C_{Pilot}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

The Traffic Total Noise (I+N) for a cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$(I+N)_{DL}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)} \left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}$$

Bearer Determination:

The bearers available for selection in the pixel, subscriber, or mobile M_i's WiMAX equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the traffic or pilot C/(I+N) at M_i: $T_B^{M_i} < CINR_{Traffic}^{TX_i(ic)}$ or $T_B^{M_i} < CINR_{Pilot}^{TX_i(ic)}$

  If the cell supports STTD/MRC or AMS, the STTD/MRC gain, G_{STTD}^{DL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the WiMAX equipment assigned to the pixel, subscriber, or mobile M_i for $N_{Ant-TX}^{TX_i(ic)}$, $N_{Ant-RX}^{M_i}$, the subchannel allocation mode of $PZ_{DL}^{M_i}$, $Mobility(M_i)$, $BLER\left(B_{DL}^{M_i}\right)$.

  The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{DL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the WiMAX equipment for which the following is true:

  In case of STTD/MRC:

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CINR_{Traffic}^{TX_i(ic)}$$

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CINR_{Pilot}^{TX_i(ic)}$$

  In case of AMS:

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CINR_{Traffic}^{TX_i(ic)} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CINR_{Pilot}^{TX_i(ic)} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$.

- Bearer Index

  From among the bearers available for selection, the selected bearer is the one with the highest index.
- Peak MAC Throughput

From among the bearers available for selection, the selected bearer is the one with the highest downlink peak MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

- Effective MAC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest downlink effective MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

MIMO – STTD/MRC Gain:

Once the bearer is known, the traffic and pilot C/(I+N) calculated above become:

In case of STTD/MRC:

$$CINR_{Traffic}^{TX_i(ic)} = CINR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$$

$$CINR_{Pilot}^{TX_i(ic)} = CINR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$$

In case of AMS:

$$CINR_{Traffic}^{TX_i(ic)} = CINR_{Traffic}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

$$CINR_{Pilot}^{TX_i(ic)} = CINR_{Pilot}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{DL} is the STTD/MRC gain corresponding to the selected bearer.

Output

- $CINR_{Traffic}^{TX_i(ic)}$: Traffic C/(I+N) from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $CINR_{Pilot}^{TX_i(ic)}$: Pilot C/(I+N) from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $(I+N)_{DL}^{TX_i(ic)}$: Traffic Total noise from the interfering cells $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $B_{DL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the downlink.

9.4.6.6 Traffic Signal Level Calculation (UL)

Input

- $P_{Max}^{M_i}$: Maximum transmission power of the terminal used by the pixel, subscriber, or mobile M_i without power control.
- $P_{Eff}^{M_i}$: Effective transmission power of the terminal used by the pixel, subscriber, or mobile M_i after power control as calculated in "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.
- $E_{SA}^{TX_i}$: Number of antenna elements defined for the smart antenna equipment used by the transmitter TX_i.
- G^{TX_i} : Transmitter antenna gain for the antenna used by the transmitter TX_i.
  - **Without smart antennas:** G^{TX_i} is the transmitter antenna gain, i.e., $G^{TX_i} = G_{Ant}^{TX_i}$.
  - **With smart antennas:** G^{TX_i} is the uplink smart antenna beamforming gain, i.e., $G^{TX_i} = G_{SA} = 10 \times Log\left(E_{SA}^{TX_i}\right)$.

    For more information on the calculation of G_{SA}, refer to section "Beamforming Smart Antenna Models" on page 41.
- L^{TX_i} : Total transmitter losses for the transmitter TX_i ($L^{TX_i} = L_{Total-UL}$).
- L_{Path} : Path loss ($L_{Path} = L_{Model} + L_{Ant}^{TX_i}$).
- L_{Model} : Loss on the transmitter-receiver path (path loss) calculated using a propagation model.

- $L_{Ant}^{TX_i}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_i.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.
- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.
- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.
- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  For calculating the useful signal level from the best serving cell, $L_{Ant}^{M_i}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L_{Ant}^{M_i}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.
- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.

Calculations

The received traffic signal level (dBm) from a pixel, subscriber, or mobile M_i at its serving cell $TX_i(ic)$ is calculated as follows:

$$C_{UL}^{M_i} = EIRP_{UL}^{M_i} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{TX_i} - L^{TX_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the terminal calculated as follows:

$$EIRP_{UL}^{M_i} = P^{M_i} + G^{M_i} - L^{M_i}$$

With $P^{M_i} = P_{Max}^{M_i}$ without power control at the start of the calculations, and is the $P^{M_i} = P_{Eff}^{M_i}$ after power control.

Output

- $C_{UL}^{M_i}$: Received uplink signal level from the pixel, subscriber, or mobile M_i at a cell $TX_i(ic)$.

9.4.6.7 Traffic Noise Calculation (UL)

For determining the uplink C/N and C/(I+N), **9955** calculates the uplink noise over the channel bandwidth used by the cell. The used bandwidth depends on the number of used subcarriers. The numbers of subcarriers used by different permutation zones can be different.

The uplink noise comprises thermal noise and the noise figure of the equipment. The thermal noise density depends on the temperature, i.e., it remains constant for a given temperature. However, the value of the thermal noise varies with the used bandwidth.

Input

- *K*: Boltzmann's constant.
- *T*: Temperature in Kelvin.
- $N_{SCa-Used}^{PZ_{UL}^{M_i}}$: Number of subcarriers used by the uplink permutation zone of a cell $TX_i(ic)$ assigned to M_i.
- $N_{SCa-Total}^{TX_i(ic)}$: Total number of subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- $F_{Sampling}^{TX_i(ic)}$: Sampling frequency for the cell $TX_i(ic)$ as calculated in "Calculation of Sampling Frequency" on page 691.
- $nf^{TX_i(ic)}$: Noise figure of the cell $TX_i(ic)$.

Calculations

The power spectral density of thermal noise is calculated as follows:

$$n_0 = 10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$$

The thermal noise for a cell is calculated as:

$$n_{0-UL}^{TX_i(ic)} = n_0 + 10 \times Log\left(F_{Sampling}^{TX_i(ic)} \times \frac{N_{SCa-Used}^{PZ_{UL}^{M_i}}}{N_{SCa-Total}^{TX_i(ic)}}\right)$$

The uplink noise is the sum of the thermal noise and the noise figure of the cell $TX_i(ic)$.

$$n_{UL}^{TX_i(ic)} = n_{0-UL}^{TX_i(ic)} + nf^{TX_i(ic)}$$

Output

- $n_{UL}^{TX_i(ic)}$: Uplink noise for the cell $TX_i(ic)$.

9.4.6.8 Traffic Interference Calculation (UL)

The uplink traffic interference is only calculated during Monte Carlo simulations. In coverage predictions, the uplink noise rise values already available in simulation results or in the Cells table are used.

The interference received by a cell $TX_i(ic)$ from an interfering mobile covered by a cell $TX_j(jc)$ can be defined as the uplink signal level received from interfering mobiles M_j depending on the overlap that exists between the channels used by the cells $TX_i(ic)$ and $TX_j(jc)$, on the traffic loads of the interfering mobile M_j.

The calculation of uplink interference can be divided into two parts:

- Calculation of the uplink interference from each individual interfering mobile as explained in "Traffic Interference Signal Levels Calculation (UL)" on page 682.
- Calculation of the uplink noise rise which represents the total uplink interference from all the interfering mobiles as explained in "Noise Rise Calculation (UL)" on page 684.

9.4.6.8.1 Traffic Interference Signal Levels Calculation (UL)

Input

- $C_{UL}^{M_j}$: Uplink signal level received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$ as calculated in "Traffic Signal Level Calculation (UL)" on page 680.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.
- $M_{Shadowing-C/I}$: Shadowing margin based on the C/I standard deviation.

  In Monte Carlo simulations, interfering signal levels already include $M_{Shadowing-Model}$, as explained in "Traffic Signal Level Calculation (UL)" on page 680.

  In coverage predictions, the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$ is applied to the interfering signals (for more information, see "Shadow Fading Model" on page 85). As the interfering signal levels already include $M_{Shadowing-Model}$, $M_{Shadowing-C/I}$ is added to the received interfering signal levels in order to achieve the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$:

  $$C_{UL}^{M_j} = C_{UL}^{M_j} + M_{Shadowing-C/I}$$

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.

- $r_O^{TX_i(ic) - TX_j(jc)}$: Total channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 653.
- $TL_{UL}^{M_j}$: Uplink traffic load of the interfering mobile M_j.

  Traffic loads are calculated during Monte Carlo simulations as explained in "Scheduling and Radio Resource Allocation" on page 698.

Calculations

The uplink interference received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$ is calculated as follows:

$$I_{UL}^{M_j} = C_{UL}^{M_j} + f_O^{TX_i(ic)-TX_j(jc)} + f_{TL-UL}^{M_j} + f_{Seg-UL}^{TX_i(ic)-TX_j(jc)}$$

Calculations for the interference reduction factors due to channel overlapping, uplink traffic load, and uplink segmentation are explained below:

Interference reduction due to the co- and adjacent channel overlap between the studied and the interfering cells:

Interference reduction due to the co- and adjacent channel overlap between the cells $TX_i(ic)$ and $TX_j(jc)$ is calculated as follows:

$$f_O^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$$

Interference reduction due to interfering mobile's traffic load:

The interference reduction factor due to the interfering mobile's uplink traffic load is calculated as follows:

$$f_{TL-UL}^{M_j} = 10 \times Log\left(TL_{UL}^{M_j}\right)$$

Interference reduction due to uplink segmentation:

If you select uplink segmentation support for the frame configuration that you are using, it means that the first zone in the uplink, i.e., the UL PUSC zone, is segmented. All other zones are pooled together to form a group of non-segmented zones. The interference reduction factor due to uplink segmentation is calculated as follows:

$$f_{Seg-UL}^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(p_{Collision-UL}^{TX_i(ic)-TX_j(jc)}\right)$$

Where $p_{Collision-UL}^{TX_i(ic)-TX_j(jc)}$ is the collision probability between the subcarriers of the uplink segments being used by the interfered and interfering cells. It is determined during Monte Carlo simulations as follows:

$$p_{Collision-UL}^{TX_i(ic)-TX_j(jc)} = \frac{SC_{Com}}{SC^{TX_i(ic)}}$$

Where, SC_{Com} is the number of subchannels common in $TX_i(ic)$ and $TX_j(jc)$, $SC^{TX_i(ic)}$ is the number of subchannels in the cell $TX_i(ic)$.

The segment numbers and the cell permutation base numbers (Cell PermBase) are determined from the cell's preamble index. The mapping between the preamble index, the segment number, and Cell PermBase is available in the IEEE specifications. This mapping is performed in **9955** as follows:

Preamble Index (PI) **Range: 0 to 113**	$PI < 96$	$96 \le PI < 114$
Cell PermBase (PB) **Range: 0 to 31**	$PI \quad Modulo \quad 32$	$PI - 96$
Segment Number (N_{Seg}) **Range: 0, 1, 2**	$Floor\left(\frac{PI}{32}\right)$	$(PI - 96) \quad Modulo \quad 3$

In Monte Carlo simulations, **9955** calculates two separate noise rise values; for the mobiles served by the segmented zone of the interfered cell **9955** calculates the uplink segmented noise rise, and for the mobiles served by the non-segmented zones of the interfered cell **9955** calculates the uplink noise rise.

In coverage predictions, point analysis, and calculations on subscriber lists, according to the zone, segmented or non-segmented, that covers the pixel, receiver, or subscriber, **9955** uses either the uplink segmented noise rise or the uplink noise rise to calculate the C/(I+N). For more information on the calculation of the uplink noise rise, see "Noise Rise Calculation (UL)" on page 684.

Output

- $I_{UL}^{M_j}$: Uplink interference signal level received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$.

9.4.6.8.2 Noise Rise Calculation (UL)

The uplink noise rise is defined as the ratio of the total uplink interference received by any cell $TX_i(ic)$ from interfering mobiles M_j present in the coverage areas of other cells $TX_j(jc)$ to the uplink noise of the cell $TX_i(ic)$. In other words, it is the ratio (I+N)/N.

Input

- $I_{UL}^{M_j}$: Uplink interference signal levels received at a cell $TX_i(ic)$ from interfering mobiles M_j covered by other cells $TX_j(jc)$ as calculated in "Traffic Interference Signal Levels Calculation (UL)" on page 682.
- $n_{UL}^{TX_i(ic)}$: Uplink noise for the cell $TX_i(ic)$ as calculated in "Traffic Noise Calculation (UL)" on page 681.
- $NR_{UL}^{Inter-Tech}$: Inter-technology uplink noise rise.

Calculations

The uplink noise rise and total noise (I+N) for the cell $TX_i(ic)$ are calculated as follows:

- **Without smart antennas:**

  For any mobile M_i covered by a non-segmented zone in the interfered cell $TX_i(ic)$, **9955** calculates the UL noise rise as follows:

$$NR_{UL}^{TX_i(ic)} = 10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}}\left(10^{\frac{I_{UL}^{M_j}\big|_{\forall\ non\text{-}seg\ M_i}}{10}}\right) + 10^{\frac{n_{UL}^{TX_i(ic)}}{10}}\right) + NR_{UL}^{Inter-Tech} - n_{UL}^{TX_i(ic)}$$

  For any pixel, subscriber, or mobile M_i covered by the non-segmented zone in the interfered cell $TX_i(ic)$, **9955** calculates the uplink total noise (I+N) as follows:

$$(I+N)_{UL}^{TX_i(ic)} = NR_{UL}^{TX_i(ic)} + n_{UL}^{TX_i(ic)}$$

  For any mobile M_i covered by the segmented zone in the interfered cell $TX_i(ic)$, **9955** calculates the segmented zone UL noise rise as follows:

$$NR_{UL-Seg}^{TX_i(ic)} = 10 \times Log\left(\sum_{\substack{All\ M_j \\ All\ TX_j(jc)}}\left(10^{\frac{I_{UL}^{M_j}\big|_{\forall\ seg\ M_i}}{10}}\right) + 10^{\frac{n_{UL}^{TX_i(ic)}}{10}}\right) + NR_{UL}^{Inter-Tech} - n_{UL}^{TX_i(ic)}$$

  For any pixel, subscriber, or mobile M_i covered by the segmented zone in the interfered cell $TX_i(ic)$, **9955** calculates the uplink total noise (I+N) as follows:

$$(I+N)_{UL}^{TX_i(ic)} = NR_{UL-Seg}^{TX_i(ic)} + n_{UL}^{TX_i(ic)}$$

- **With smart antennas:**

  The angular distribution of the uplink noise rise is calculated during Monte Carlo simulations and can be stored in the Cells table in order to be used in coverage predictions. The angular distribution of the uplink noise rise is given by:

$$NR_{UL}(\varphi) = \frac{I_{UL}(\varphi) + \sigma_n^2 \cdot I}{\sigma_n^2 \cdot I}$$

$$(I+N)_{UL}^{TX_i(ic)}(\varphi) = I_{UL}(\varphi) + \sigma_n^2 \cdot I$$

Output

- $NR_{UL}^{TX_i(ic)}$: Non-segmented uplink noise rise for the cell $TX_i(ic)$.
- $NR_{UL-Seg}^{TX_i(ic)}$: Segmented uplink noise rise for the cell $TX_i(ic)$.

- $NR_{UL}^{TX_i(ic)}(\varphi)$: Angular distribution of the uplink noise rise for the cell *TX$_i$(ic).*
- $(I+N)_{UL}^{TX_i(ic)}$ or $(I+N)_{UL}^{TX_i(ic)}(\varphi)$: Total Noise for a cell *TX$_i$(ic)* calculated for any pixel, subscriber, or mobile *M$_i$*.

9.4.6.9 Traffic C/N Calculation (UL)

Input

- $C_{UL}^{M_i}$: Received uplink signal level from the pixel, subscriber, or mobile *M$_i$* at its serving cell *TX$_i$(ic)* as calculated in "Traffic Signal Level Calculation (UL)" on page 680.
- $n_{UL}^{TX_i(ic)}$: Uplink noise for the cell *TX$_i$(ic)* as calculated in "Traffic Noise Calculation (UL)" on page 681.
- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N from the cell *TX$_i$(ic)* at the pixel, subscriber, or mobile *M$_i$* as calculated in "Preamble C/N Calculation" on page 662.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell *TX$_i$(ic).*
- $T_{B-Lowest}^{TX_i(ic)}$: Bearer selection threshold of the lowest bearer in the WiMAX equipment assigned to the cell *TX$_i$(ic).*
- $N_{SC}^{PZ_{UL}^{M_i}}$: Number of subchannels per channel defined for the uplink permutation zone assigned to the pixel, subscriber, or mobile *M$_i$* as calculated in "Permutation Zone Selection" on page 665.
- $N_{SC/Seg}^{PZ_{UL}^{M_i}=8}$: Number of subchannels per segment for the first uplink PUSC permutation zone.
- $P_{Max}^{M_i}$: Maximum transmission power of the terminal used by the pixel, subscriber, or mobile *M$_i$*.
- $P_{Min}^{M_i}$: Minimum transmission power of the terminal used by the pixel, subscriber, or mobile *M$_i$*.
- M_{PC} : Power control margin defined in the Global Parameters.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the WiMAX equipment used bythe cell *TX$_i$(ic)*.
- $B_{UL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile *M$_i$*.
- $B_{UL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile *M$_i$*.
- $N_{Ant-TX}^{M_i}$: Number of MIMO transmission (uplink) antennas defined for the terminal used by the pixel, subscriber, or mobile *M$_i$*.
- $N_{Ant-RX}^{TX_i(ic)}$: Number of MIMO reception (uplink) antennas defined for the cell *TX$_i$(ic).*
- $Mobility(M_i)$: Mobility used for the calculations.
- Subchannel allocation mode used by the uplink permutation zone $PZ_{UL}^{M_i}$ assigned to the pixel, subscriber, or mobile *M$_i$* as calculated in "Permutation Zone Selection" on page 665.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the WiMAX equipment assigned to the cell *TX$_i$(ic)*.

Calculations

The uplink C/N from a pixel, subscriber, or mobile *M$_i$* at its serving cell *TX$_i$(ic)* is calculated as follows:

$$CNR_{UL}^{M_i} = C_{UL}^{M_i} - n_{UL}^{TX_i(ic)}$$

Bearer Determination:

The bearers available for selection in the cell *TX$_i$(ic)*'s WiMAX equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the uplink C/N at M_i: $T_B^{M_i} < CNR_{UL}^{M_i}$

  If the cell supports STTD/MRC or AMS, the STTD/MRC gain, G_{STTD}^{UL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the WiMAX equipment assigned to the cell $TX_i(ic)$ for $N_{Ant-TX}^{M_i}$, $N_{Ant-RX}^{TX_i(ic)}$, the subchannel allocation mode of $PZ_{UL}^{M_i}$, $Mobility(M_i)$, $BLER\left(B_{UL}^{M_i}\right)$.

  The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{UL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the WiMAX equipment for which the following is true:

  In case of STTD/MRC:

  $$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CNR_{UL}^{M_i}$$

  In case of AMS:

  $$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CNR_{UL}^{M_i} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$.

- Bearer Index

  From among the bearers available for selection, the selected bearer is the one with the highest index.
- Peak MAC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest uplink peak MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.
- Effective MAC Throughput

  From among the bearers available for selection, the selected bearer is the one with the highest uplink effective MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

MIMO – STTD/MRC Gain:

Once the bearer is known, the uplink C/N calculated above become:

In case of STTD/MRC:

$$CNR_{UL}^{M_i} = CNR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$$

In case of AMS:

$$CNR_{UL}^{M_i} = CNR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{UL} is the STTD/MRC gain corresponding to the selected bearer.

Uplink Subchannelisation:

The uplink subchannelisation depends on the uplink bandwidth allocation target defined for the scheduler used by the cell $TX_i(ic)$. The uplink C/N calculated above is given for the total number of subchannels associated with the permutation zone, i.e., $N_{SC}^{PZ_{UL}^{M_i}}$. Subchannelisation is performed for all the pixels, subscribers, or mobiles in the uplink, and may reduce the number of used subchannels in order to satisfy the selected target.

- Full Bandwidth

  Full channel width is used by each mobile in the uplink. As there is no reduction in the bandwidth used for transmission, there is no gain in the uplink C/N.

- Maintain Connection

  The bandwidth used for transmission by a mobile is reduced only if the uplink C/N is not enough to even access the lowest bearer. For example, as a mobile moves from good to bad radio conditions, the number of subchannels used by it for transmission in uplink are reduced one by one in order to improve the uplink C/N. The calculation of the gain introduced by the subchannelisation is explained below.

- Best Bearer

  The bandwidth used for transmission by a mobile is reduced in order to improve the uplink C/N enough to access the best bearer. For example, if using 5 subchannels, a mobile is able to access the best bearer, and using 6 it would only get access to the second best, it will be assigned 5 subchannels as the used uplink bandwidth. Although using 4 subchannels, its uplink C/N will be better than when using 5, the uplink bandwidth is not reduced to 4 because it does not provide any gain in terms of the bearer, i.e., the mobile already has the best bearer using 5 subchannels. The calculation of the gain introduced by the bandwidth reduction is explained below.

  The definition of the best bearer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$, i.e., bearer with the highest index, with the highest peak MAC throughput, or with the highest effective MAC throughput.

The uplink subchannelisation may result in the use of a number of subchannels which is less than the total number of subchannels associated with the permutation zone. The gain related to this bandwidth reduction is applied to the uplink C/N:

$$CNR_{UL_{Final}}^{M_i} = CNR_{UL_{All\ SC}}^{M_i} + 10 \times Log\left(\frac{N_{SC}^{PZ_{UL}^{M_i}}}{N_{SC-UL}^{M_i}}\right)$$

Where $N_{SC-UL}^{M_i} < N_{SC}^{PZ_{UL}^{M_i}}$ for any pixel, subscriber, or mobile M_i covered by a non-segmented permutation zone in the interfered cell $TX_i(ic)$, and $N_{SC-UL}^{M_i} < N_{SC/Seg}^{PZ_{UL}^{M_i} = 8}$ for any pixel, subscriber, or mobile M_i covered by the segmented uplink PUSC zone in the interfered cell $TX_i(ic)$.

Uplink Power Control:

Once the subchannelisation is performed, **9955** continues to work with the C/N given by the subchannelisation, i.e., $CNR_{UL}^{M_i} = CNR_{UL_{Final}}^{M_i}$.

The pixel, subscriber, or mobile M_i reduces its transmission power so that the uplink C/N from it at its cell is just enough to get the selected bearer.

If with $P^{M_i} = P_{Max}^{M_i}$ AND $CNR_{UL}^{M_i} > T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}$, where $T_{B_{UL}^{M_i}}^{TX_i(ic)}$ is the bearer selection threshold, from the WiMAX equipment assigned to the cell $TX_i(ic)$, for the bearer selected for the pixel, subscriber, or mobile M_i.

The transmission power of M_i is reduced to determine the effective transmission power from the pixel, subscriber, or mobile M_i as follows:

$$P_{Eff}^{M_i} = Max\left(P_{Max}^{M_i} - \left(CNR_{UL}^{M_i} - \left(T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}\right)\right), P_{Min}^{M_i}\right)$$

$CNR_{UL}^{M_i}$ is calculated again using $P_{Eff}^{M_i}$.

Output

- $CNR_{UL}^{M_i}$: Uplink C/N from a pixel, subscriber, or mobile M_i at it serving cell $TX_i(ic)$.

9.4.6.10 Traffic C/(I+N) and Bearer Calculation (UL)

The carrier signal to interference and noise ratio is calculated in three steps. First, **9955** calculates the received signal level from each pixel, subscriber, or mobile at its serving cell using the effective power of the terminal used by the pixel, subscriber, or mobile as explained in "Traffic Signal Level Calculation (UL)" on page 680. Next, **9955** calculates the uplink carrier to noise ratio as explained in "Traffic C/N Calculation (UL)" on page 685. Finally, determines the uplink C/(I+N) by dividing the previously calculated uplink C/N by the uplink noise rise value of the cell as calculated in "Noise Rise Calculation (UL)" on page 684.

The uplink noise rise can be set by the user manually for each cell or calculated using Monte Carlo simulations.

The receiver terminal is always considered to be oriented towards its best server, except when the "Lock Status" is set to "Server+Orientation" for a subscriber in a subscriber list and its azimuth and tilt manually edited. In the case of NLOS between the receiver and the best server, **9955** does not try to find the direction of the strongest signal, the receiver is oriented towards the best server just as in the case of LOS.

Input

- $CNR_{UL}^{M_i}$: Uplink C/N from a pixel, subscriber, or mobile M_i at it serving cell $TX_i(ic)$ as calculated in "Traffic C/N Calculation (UL)" on page 685.
- $NR_{UL}^{TX_i(ic)}$: Non-segmented uplink noise rise for the cell $TX_i(ic)$ as calculated in "Noise Rise Calculation (UL)" on page 684.
- $NR_{UL-Seg}^{TX_i(ic)}$: Segmented uplink noise rise for the cell $TX_i(ic)$ as calculated in "Noise Rise Calculation (UL)" on page 684.
- $NR_{UL}^{TX_i(ic)}(\varphi)$: Angular distribution of the uplink noise rise for the cell $TX_i(ic)$ as calculated in "Noise Rise Calculation (UL)" on page 684.
- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Preamble C/N Calculation" on page 662.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_{B-Lowest}^{TX_i(ic)}$: Bearer selection threshold of the lowest bearer in the WiMAX equipment assigned to the cell $TX_i(ic)$.
- $N_{SC}^{PZ_{UL}^{M_i}}$: Number of subchannels per channel defined for the uplink permutation zone assigned to the pixel, subscriber, or mobile M_i as calculated in "Permutation Zone Selection" on page 665.
- $N_{SC/Seg}^{PZ_{UL}^{M_i} = 8}$: Number of subchannels per segment for the first uplink PUSC permutation zone.
- $P_{Max}^{M_i}$: Maximum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- $P_{Min}^{M_i}$: Minimum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- M_{PC} : Power control margin defined in the Global Parameters.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the WiMAX equipment used bythe cell $TX_i(ic)$.
- $B_{UL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{UL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{M_i}$: Number of MIMO transmission (uplink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-RX}^{TX_i(ic)}$: Number of MIMO reception (uplink) antennas defined for the cell $TX_i(ic)$.
- $Mobility(M_i)$: Mobility used for the calculations.
- Subchannel allocation mode used by the uplink permutation zone $PZ_{UL}^{M_i}$ assigned to the pixel, subscriber, or mobile M_i as calculated in "Permutation Zone Selection" on page 665.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the WiMAX equipment assigned to the cell $TX_i(ic)$.

Calculations

The uplink C/(I+N) for any pixel, subscriber, or mobile M_i at a cell $TX_i(ic)$ is calculated as follows:

- **Without smart antennas:**

  For any pixel, subscriber, or mobile M_i covered by the non-segmented zone in the interfered cell $TX_i(ic)$:

  $$CINR_{UL}^{M_i} = CNR_{UL}^{M_i} - NR_{UL}^{TX_i(ic)}$$

  For any pixel, subscriber, or mobile M_i covered by the segmented zone in the interfered cell $TX_i(ic)$:

  $$CINR_{UL}^{M_i} = CNR_{UL}^{M_i} - NR_{UL-Seg}^{TX_i(ic)}$$

- **With smart antennas:**
  - **Monte Carlo simulations:** The uplink C/(I+N) is calculated as described in the section "Beamforming Smart Antenna Models" on page 41. Victim and interfering mobiles are generated by a time-slot scenario as explained in "Simulation Process" on page 650.
  - **Coverage predictions:** $CINR_{UL}^{M_i}(\varphi) = CNR_{UL}^{M_i} - NR_{UL}^{TX_i(ic)}(\varphi)$

  Bearer Determination:

  The bearers available for selection in the cell $TX_i(ic)$'s WiMAX equipment are the ones:

  - Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
  - Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
  - Whose selection thresholds are less than the uplink C/(I+N) at M_i: $T_B^{M_i} < CINR_{UL}^{M_i}$ and $T_B^{M_i} < CINR_{UL}^{M_i}(\varphi)$

    If the cell supports STTD/MRC or AMS, the STTD/MRC gain, G_{STTD}^{UL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the WiMAX equipment assigned to the cell $TX_i(ic)$ for $N_{Ant-TX}^{M_i}$, $N_{Ant-RX}^{TX_i(ic)}$, the subchannel allocation mode of $PZ_{UL}^{M_i}$, $Mobility(M_i)$, $BLER\left(B_{UL}^{M_i}\right)$.

    The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{UL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the WiMAX equipment for which the following is true:

    In case of STTD/MRC:

    $$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CINR_{UL}^{M_i} \text{ and}$$

    $$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CINR_{UL}^{M_i}(\varphi)$$

    In case of AMS:

    $$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CINR_{UL}^{M_i} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

    and

    $$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CINR_{UL}^{M_i}(\varphi) \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

  The bearer selected for data transfer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$.

  - Bearer Index

    From among the bearers available for selection, the selected bearer is the one with the highest index.

  - Peak MAC Throughput

    From among the bearers available for selection, the selected bearer is the one with the highest uplink peak MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

  - Effective MAC Throughput

From among the bearers available for selection, the selected bearer is the one with the highest uplink effective MAC channel throughput as calculated in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

MIMO – STTD/MRC Gain:

Once the bearer is known, the uplink C/(I+N) calculated above become:

In case of STTD/MRC:

$$CINR_{UL}^{M_i} = CINR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL} \text{ and}$$

$$CINR_{UL}^{M_i}(\varphi) = CINR_{UL}^{M_i}(\varphi) + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$$

In case of AMS:

$$CINR_{UL}^{M_i} = CINR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

and

$$CINR_{UL}^{M_i}(\varphi) = CINR_{UL}^{M_i}(\varphi) + G_{STTD}^{UL} + \Delta G_{STTD}^{UL} \text{ if } CNR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)} \text{ or } CINR_{Preamble}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{UL} is the STTD/MRC gain corresponding to the selected bearer.

Uplink Subchannelisation:

The uplink subchannelisation depends on the uplink bandwidth allocation target defined for the scheduler used by the cell $TX_i(ic)$. The uplink C/(I+N) calculated above is given for the total number of subchannels associated with the permutation zone, i.e., $N_{SC}^{PZ_{UL}^{M_i}}$. Subchannelisation is performed for all the pixels, subscribers, or mobiles in the uplink, and may reduce the number of used subchannels in order to satisfy the selected target.

- Full Bandwidth

  Full channel width is used by each mobile in the uplink. As there is no reduction in the bandwidth used for transmission, there is no gain in the uplink C/(I+N).

- Maintain Connection

  The bandwidth used for transmission by a mobile is reduced only if the uplink C/(I+N) is not enough to even access the lowest bearer. For example, as a mobile moves from good to bad radio conditions, the number of subchannels used by it for transmission in uplink are reduced one by one in order to improve the uplink C/(I+N). The calculation of the gain introduced by the subchannelisation is explained below.

- Best Bearer

  The bandwidth used for transmission by a mobile is reduced in order to improve the uplink C/(I+N) enough to access the best bearer. For example, if using 5 subchannels, a mobile is able to access the best bearer, and using 6 it would only get access to the second best, it will be assigned 5 subchannels as the used uplink bandwidth. Although using 4 subchannels, its uplink C/(I+N) will be better than when using 5, the uplink bandwidth is not reduced to 4 because it does not provide any gain in terms of the bearer, i.e., the mobile already has the best bearer using 5 subchannels. The calculation of the gain introduced by the bandwidth reduction is explained below.

  The definition of the best bearer depends on the bearer selection criterion of the scheduler used by the cell $TX_i(ic)$, i.e., bearer with the highest index, with the highest peak MAC throughput, or with the highest effective MAC throughput.

The uplink subchannelisation may result in the use of a number of subchannels which is less than the total number of subchannels associated with the permutation zone. The gain related to this bandwidth reduction is applied to the uplink C/(I+N):

$$CINR_{UL_{Final}}^{M_i} = CINR_{UL_{All\ SC}}^{M_i} + 10 \times Log\left(\frac{N_{SC}^{PZ_{UL}^{M_i}}}{N_{SC-UL}^{M_i}}\right)$$

Where $N_{SC-UL}^{M_i} < N_{SC}^{PZ_{UL}^{M_i}}$ for any pixel, subscriber, or mobile M_i covered by a non-segmented permutation zone in the interfered cell $TX_i(ic)$, and $N_{SC-UL}^{M_i} < N_{SC/Seg}^{PZ_{UL}^{M_i} = 8}$ for any pixel, subscriber, or mobile M_i covered by the segmented uplink PUSC zone in the interfered cell $TX_i(ic)$.

Uplink Power Control:

Once the subchannelisation is performed, **9955** continues to work with the C/(I+N) given by the subchannelisation, i.e., $CINR_{UL}^{M_i} = CINR_{UL_{Final}}^{M_i}$.

The pixel, subscriber, or mobile M_i reduces its transmission power so that the uplink C/(I+N) from it at its cell is just enough to get the selected bearer.

If with $P^{M_i} = P_{Max}^{M_i}$ AND $CINR_{UL}^{M_i} > T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}$, where $T_{B_{UL}^{M_i}}^{TX_i(ic)}$ is the bearer selection threshold, from the WiMAX equipment assigned to the cell $TX_i(ic)$, for the bearer selected for the pixel, subscriber, or mobile M_i.

The transmission power of M_i is reduced to determine the effective transmission power from the pixel, subscriber, or mobile M_i as follows:

$$P_{Eff}^{M_i} = Max\left(P_{Max}^{M_i} - \left(CINR_{UL}^{M_i} - \left(T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}\right)\right), P_{Min}^{M_i}\right)$$

$CINR_{UL}^{M_i}$ is calculated again using $P_{Eff}^{M_i}$.

Output

- $CINR_{UL}^{M_i}$ or $CINR_{UL}^{M_i}(\varphi)$: Uplink C/(I+N) from a pixel, subscriber, or mobile M_i at it serving cell $TX_i(ic)$.
- $N_{SC-UL}^{M_i}$: Number of subchannels used by the pixel, subscriber, or mobile M_i in the uplink after subchannelisation.
- $P_{Eff}^{M_i}$: Effective transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- $B_{UL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the uplink.

9.4.7 Throughput Calculation

Throughputs are calculated in two steps.

- Calculation of uplink and downlink total resources in a cell as explained in "Calculation of Total Cell Resources" on page 691.
- Calculation of throughputs as explained in "Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation" on page 694.

9.4.7.1 Calculation of Total Cell Resources

The total amount of resources in a cell is the number of modulation symbols that can be used for data transfer in each frame. The total cell resources can be calculated separately for the downlink and the uplink subframes. The following sections describe how the cell capacities are calculated for TDD and FDD networks.

9.4.7.1.1 Calculation of Sampling Frequency

Input

- $f_{Sampling}^{TX_i(ic)}$: Sampling factor defined for the frequency band of the cell $TX_i(ic)$.
- $W_{Channel}^{TX_i(ic)}$: Channel bandwidth of the cell $TX_i(ic)$.

Calculations

9955 determines the sampling frequency as follows:

$$F_{Sampling}^{TX_i(ic)} = Floor\left(f_{Sampling} \times \frac{W_{Channel}^{TX_i(ic)} \times 10^6}{8000}\right) \times 8000$$

Output

- $F_{Sampling}^{TX_i(ic)}$: Sampling frequency for the cell $TX_i(ic)$.

9.4.7.1.2 Calculation of Symbol Duration

Input

- $F_{Sampling}^{TX_i(ic)}$: Sampling frequency for the cell $TX_i(ic)$ as calculated in "Calculation of Sampling Frequency" on page 691.
- $N_{SCa-Total}^{TX_i(ic)}$: Total number of subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- r_{CP} : Cyclic prefix ratio defined for the network in the Global Parameters.

Calculations

From the sampling frequency, **9955** determines the inter-subcarrier spacing.

$$\Delta F^{TX_i(ic)} = \frac{F_{Sampling}^{TX_i(ic)} \times 10^{-3}}{N_{SCa-Total}^{TX_i(ic)}}$$

9955 calculates the useful symbol duration.

$$D_{Sym-Useful}^{TX_i(ic)} = \frac{1}{\Delta F^{TX_i(ic)}}$$

And, the duration of the cyclic prefix.

$$D_{CP} = \frac{r_{CP}}{\Delta F}$$

Adding the Cyclic prefix ratio to the useful symbol duration, **9955** determines the total symbol duration.

$$D_{Symbol}^{TX_i(ic)} = D_{Sym-Useful}^{TX_i(ic)} + D_{CP}$$

Output

- $D_{Symbol}^{TX_i(ic)}$: Total symbol duration of one modulation symbol for a cell $TX_i(ic)$.

9.4.7.1.3 Calculation of Total Cell Resources - TDD Networks

Input

- D_{Frame} : Frame duration.
- D_{TTG}^{TDD} : TTG duration.
- D_{RTG}^{TDD} : RTG duration.
- $D_{Symbol}^{TX_i(ic)}$: Total symbol duration of one modulation symbol for a cell $TX_i(ic)$ as calculated in "Calculation of Symbol Duration" on page 692.
- $r_{DL-Frame}^{TDD}$: DL ratio.
- N_{SD-DL}^{TDD} : Number of symbol durations that correspond to the downlink subframe.
- N_{SD-UL}^{TDD} : Number of symbol durations that correspond to the uplink subframe.
- O_{Fixed}^{DL} : Downlink fixed overhead.
- $O_{Variable}^{DL}$: Downlink variable overhead.
- O_{Fixed}^{UL} : Uplink fixed overhead.

- $O_{Variable}^{UL}$: Uplink variable overhead.
- $N_{SCa-Data}^{PZ_{DL}^{M_i}}$: Number of data subcarriers of the downlink permutation zone of a cell $TX_i(ic)$ assigned to M_i.
- $N_{SCa-Data}^{PZ_{UL}^{M_i}}$: Number of data subcarriers of the uplink permutation zone of a cell $TX_i(ic)$ assigned to M_i.

Calculations

The downlink and the uplink subframes of a TDD frame are separated in time by the TTG and the RTG time guards.

First of all, **9955** calculates the useful frame duration by removing the TTG and RTG from the frame duration:

$$D_{Frame}^{Used} = D_{Frame} - D_{TTG}^{TDD} - D_{RTG}^{TDD}$$

Then, **9955** calculates the frame duration in terms of number of symbol durations:

$$N_{(SD-Used)/Frame}^{TX_i(ic)} = Floor\left(\frac{D_{Frame}^{Used}}{D_{Symbol}^{TX_i(ic)}}\right)$$

Next, **9955** calculates the downlink and uplink cell capacities as follows:

Downlink Subframe:

9955 calculates the number of symbol durations in the downlink subframe excluding the fixed overhead defined in the Global Parameters:

$$N_{(SD-DL)/Subframe}^{TX_i(ic)} = RoundUp\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times r_{DL-Frame}^{TDD}\right) - O_{Fixed}^{DL}$$ if DL:UL ratio is defined in percentage.

Or $N_{(SD-DL)/Subframe}^{TX_i(ic)} = RoundUp\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times \frac{N_{SD-DL}^{TDD}}{N_{SD-DL}^{TDD} + N_{SD-UL}^{TDD}}\right) - O_{Fixed}^{DL}$ if DL:UL ratio is defined in fraction.

The *RoundUp* function rounds a float value up to the nearest integer value.

The total number of symbols in the downlink subframe after removing the variable overhead is:

$$R_{DL}^{TX_i(ic)} = N_{(Sym-DL)/Subframe}^{TX_i(ic)} = Floor\left\{N_{(SD-DL)/Subframe}^{TX_i(ic)} \times N_{SCa-Data}^{PZ_{DL}^{M_i}} \times \left(1 - \frac{O_{Variable}^{DL}}{100}\right)\right\}$$

Uplink Subframe:

9955 calculates the number of symbol durations in the uplink subframe excluding the fixed overhead defined in the Global Parameters:

$$N_{(SD-UL)/Subframe}^{TX_i(ic)} = RoundDown\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times (1 - r_{DL-Frame}^{TDD})\right) - O_{Fixed}^{UL}$$ if DL:UL ratio is defined in percentage.

Or $N_{(SD-UL)/Subframe}^{TX_i(ic)} = RoundDown\left(N_{(SD-Used)/Frame}^{TX_i(ic)} \times \frac{N_{SD-UL}^{TDD}}{N_{SD-DL}^{TDD} + N_{SD-UL}^{TDD}}\right) - O_{Fixed}^{UL}$ if DL:UL ratio is defined in fraction.

The *RoundDown* function rounds a float value down to the nearest integer value.

The total number of symbols in the uplink subframe after removing the variable overhead is:

$$R_{UL}^{TX_i(ic)} = N_{(Sym-UL)/Subframe}^{TX_i(ic)} = Floor\left\{N_{(SD-UL)/Subframe}^{TX_i(ic)} \times N_{SCa-Data}^{PZ_{UL}^{M_i}} \times \left(1 - \frac{O_{Variable}^{UL}}{100}\right)\right\}$$

Output

- $R_{DL}^{TX_i(ic)} = N_{(Sym-DL)/Subframe}^{TX_i(ic)}$: Amount of downlink resources in the cell $TX_i(ic)$.
- $R_{UL}^{TX_i(ic)} = N_{(Sym-UL)/Subframe}^{TX_i(ic)}$: Amount of uplink resources in the cell $TX_i(ic)$.

9.4.7.1.4 Calculation of Total Cell Resources - FDD Networks

The total cell resources calculation is the same for downlink and uplink subframes in FDD networks. Therefore, the symbol *X* is used to represent *DL* or *UL* in the expressions below.

Input

- D_{Frame} : Frame duration.
- $D_{Symbol}^{TX_i(ic)}$: Total symbol duration of one modulation symbol for a cell $TX_i(ic)$ as calculated in "Calculation of Symbol Duration" on page 692.
- O_{Fixed}^{X} : Downlink or uplink fixed overhead.
- $O_{Variable}^{X}$: Downlink or uplink variable overhead.
- $N_{SCa-Data}^{PZ_X^{M_i}}$: Number of data subcarriers of the downlink or uplink permutation zone of a cell $TX_i(ic)$ assigned to M_i.

Calculations

There are no transmit and receive time guards in FDD systems. Therefore, the downlink and the uplink subframe durations are the same as the frame duration.

$$D_{Subframe}^{X} = D_{Frame}$$

The subframe durations in terms of the number of symbol durations excluding the fixed overheads are:

$$N_{(SD-X)/Subframe}^{TX_i(ic)} = Floor\left(\frac{D_{Subframe}^{X}}{D_{Symbol}^{TX_i(ic)}}\right) - O_{Fixed}^{X}$$

The total numbers of symbols in the downlink or uplink subframes after removing the variable overheads are:

$$R_X^{TX_i(ic)} = N_{(Sym-X)/Subframe}^{TX_i(ic)} = Floor\left\{N_{(SD-X)/Subframe}^{TX_i(ic)} \times N_{SCa-Data}^{PZ_X^{M_i}} \times \left(1 - \frac{O_{Variable}^{X}}{100}\right)\right\}$$

Output

- $R_X^{TX_i(ic)} = N_{(Sym-X)/Subframe}^{TX_i(ic)}$: Amount of downlink or uplink resources in the cell $TX_i(ic)$.

9.4.7.2 Channel Throughput, Cell Capacity, and Allocated Bandwidth Throughput Calculation

Channel throughputs are calculated for the entire channel resources allocated to the pixel, subscriber, or mobile M_i. Cell capacities are similar to channel throughputs but upper-bound by the maximum downlink and uplink traffic loads. Allocated bandwidth throughputs are calculated for the number of used subchannels in uplink allocated to the pixel, subscriber, or mobile M_i.

Input

- $TL_{DL-Max}^{TX_i(ic)}$: Maximum downlink traffic load for the cell $TX_i(ic)$.
- $TL_{UL-Max}^{TX_i(ic)}$: Maximum uplink traffic load for the cell $TX_i(ic)$.
- $R_{DL}^{TX_i(ic)}$: Amount of downlink resources in the cell $TX_i(ic)$ as calculated in "Calculation of Total Cell Resources" on page 691.

- $R_{UL}^{TX_i(ic)}$: Amount of uplink resources in the cell $TX_i(ic)$ as calculated in "Calculation of Total Cell Resources" on page 691.
- $\eta_{B_{DL}^{M_i}}$: Bearer efficiency (bits/symbol) of the bearer assigned to the pixel, subscriber, or mobile M_i in the downlink in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- $\eta_{B_{UL}^{M_i}}$: Bearer efficiency (bits/symbol) of the bearer assigned to the pixel, subscriber, or mobile M_i in the uplink in "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.
- D_{Frame} : Frame duration.
- $f_{Segment-DL}$: Downlink segmenting factor for the first downlink PUSC zone as calculated in "Effective Traffic and Pilot Interference Calculation (DL)" on page 672.
- $CNR_{Preamble}^{TX_i(ic)}$: Preamble C/N the cell $TX_i(ic)$ as calculated in "Preamble C/N Calculation" on page 662.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_{MU-MIMO}^{TX_i(ic)}$: MU-MIMO threshold defined for the cell $TX_i(ic)$.
- $G_{MU-MIMO}^{TX_i(ic)}$: MU-MIMO gain defined for the cell $TX_i(ic)$.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the BLER vs. $CINR_{Traffic}^{TX_i(ic)}$ graph available in the WiMAX equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the BLER vs. $CINR_{UL}^{M_i}$ graph available in the WiMAX equipment assigned to the cell $TX_i(ic)$.
- $f_{TP-Scaling}^{M_i}$: Throughput scaling factor defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $TP_{Offset}^{M_i}$: Throughput offset defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{SC}^{PZ_{UL}^{M_i}}$: Number of subchannels per channel defined for the uplink permutation zone assigned to the pixel, subscriber, or mobile M_i as calculated in "Permutation Zone Selection" on page 665.
- $N_{SC-UL}^{M_i}$: Number of uplink subchannels after subchannelisation with which the pixel, subscriber, or mobile M_i can get the highest available bearer, as calculated in "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.

Calculations

Downlink:

- **Peak MAC Channel Throughput:** $CTP_{P-DL}^{M_i} = \dfrac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}}{D_{Frame}}$

  In the above formula, the actual value of D_{Frame} is used to calculate the channel throughput for coverage predictions, while $D_{Frame} = 1\ sec$ for Monte Carlo simulations.

  Downlink Segmentation:

  If the permutation zone assigned to the pixel, subscriber, or mobile M_i is the first downlink PUSC zone ($PZ_{DL}^{M_i} = 0$) and it is segmented, the channel throughput is calculated as:

$$CTP_{P-DL}^{M_i} = \frac{R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}}{D_{Frame}} \times f_{Segment-DL}$$

  MIMO – SU-MIMO Gain:

If the permutation zone assigned to the pixel, subscriber, or mobile M_i supports SU-MIMO or AMS, SU-MIMO gain $G_{SU-MIMO}^{Max}$ is applied to the bearer efficiency. The gain is read from the properties of the WiMAX equipment assigned to the pixel, subscriber, or mobile M_i for:

- $N_{Ant-TX}^{TX_i(ic)}$: Number of MIMO transmission (downlink) antennas defined for the cell $TX_i(ic)$.
- $N_{Ant-RX}^{M_i}$: Number of MIMO reception (downlink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- Subchannel allocation mode used by the downlink permutation zone $PZ_{DL}^{M_i}$ assigned to the pixel, subscriber, or mobile M_i as calculated in "Permutation Zone Selection" on page 665.
- $B_{DL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the downlink as explained in "Traffic and Pilot C/(I+N) and Bearer Calculation (DL)" on page 678.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the WiMAX equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i. BLER is determined for $CINR_{Traffic}^{TX_i(ic)}$.

9955 also takes into account the SU-MIMO Gain Factor $f_{SU-MIMO}$ defined for the clutter class where the pixel, subscriber, or mobile M_i is located.

In case of SU-MIMO: $\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$

In case of AMS: $\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ if $CNR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$

If the Max SU-MIMO Gain for the exact value of the C/(I+N) is not availabe in the table, it is interpolated from the gain values available for the C/(I+N) just less than and just greater than the actual C/(I+N).

- **Effective MAC Channel Throughput:** $CTP_{E-DL}^{M_i} = CTP_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$
- **Application Channel Throughput:** $CTP_{A-DL}^{M_i} = CTP_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak MAC Cell Capacity:** $Cap_{P-DL}^{M_i} = CTP_{P-DL}^{M_i} \times TL_{DL-Max}^{TX_i(ic)}$
- **Effective MAC Cell Capacity:** $Cap_{E-DL}^{M_i} = Cap_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$
- **Application Cell Capacity:** $Cap_{A-DL}^{M_i} = Cap_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$

Uplink:

- **Peak MAC Channel Throughput:** $CTP_{P-UL}^{M_i} = \frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}}$

  In the above formula, the actual value of D_{Frame} is used to calculate the channel throughput for coverage predictions, while $D_{Frame} = 1\ sec$ for Monte Carlo simulations.

  MIMO – SU-MIMO Gain:

  If the permutation zone assigned to the pixel, subscriber, or mobile M_i supports SU-MIMO or AMS, SU-MIMO gain $G_{SU-MIMO}^{Max}$ is applied to the bearer efficiency. The gain is read from the properties of the WiMAX equipment assigned to the cell $TX_i(ic)$ for:

  - $N_{Ant-TX}^{M_i}$: Number of MIMO transmission (uplink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.

- $N_{Ant-RX}^{TX_i(ic)}$: Number of MIMO reception (uplink) antennas defined for the cell $TX_i(ic)$.
- $Mobility(M_i)$: Mobility used for the calculations.
- Subchannel allocation mode used by the uplink permutation zone $PZ_{UL}^{M_i}$ assigned to the pixel, subscriber, or mobile M_i as calculated in "Permutation Zone Selection" on page 665.
- $B_{UL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the uplink as explained in "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the WiMAX equipment assigned to the cell $TX_i(ic)$. BLER is determined for $CINR_{UL}^{M_i}$.

9955 also takes into account the SU-MIMO Gain Factor $f_{SU-MIMO}$ defined for the clutter class where the pixel, subscriber, or mobile M_i is located.

In case of SU-MIMO: $\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$

In case of AMS: $\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ if $CNR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$ or $CINR_{Preamble}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$

If the Max SU-MIMO Gain for the exact value of the C/(I+N) is not availabe in the table, it is interpolated from the gain values available for the C/(I+N) just less than and just greater than the actual C/(I+N).

MIMO – MU-MIMO Gain (for uplink throughput coverage predictions only):

If the permutation zone assigned to the pixel, subscriber, or mobile M_i supports MU-MIMO and $CNR_{Preamble}^{TX_i(ic)} > T_{MU-MIMO}^{TX_i(ic)}$ and $N_{Ant-RX}^{TX_i(ic)} \geq 2$, the MU-MIMO gain $G_{MU-MIMO}^{TX_i(ic)}$ is applied to the channel throughput. The MU-MIMO gain is read from the properties of the cell $TX_i(ic)$.

$$CTP_{P-UL}^{M_i} = \frac{R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}}{D_{Frame}} \times G_{MU-MIMO}^{TX_i(ic)}$$

- **Effective MAC Channel Throughput:** $CTP_{E-UL}^{M_i} = CTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Channel Throughput:** $CTP_{A-UL}^{M_i} = CTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak MAC Cell Capacity:** $Cap_{P-UL}^{M_i} = CTP_{P-UL}^{M_i} \times TL_{UL-Max}^{TX_i(ic)}$
- **Effective MAC Cell Capacity:** $Cap_{E-UL}^{M_i} = Cap_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Cell Capacity:** $Cap_{A-UL}^{M_i} = Cap_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak MAC Allocated Bandwidth Throughput:** $ABTP_{P-UL}^{M_i} = CTP_{P-UL}^{M_i} \times \frac{N_{SC-UL}^{M_i}}{N_{SC}^{PZ_{UL}^{M_i}}}$
- **Effective MAC Allocated Bandwidth Throughput:** $ABTP_{E-UL}^{M_i} = ABTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Allocated Bandwidth Throughput:** $ABTP_{A-UL}^{M_i} = ABTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$

Output

- $CTP_{P-DL}^{M_i}$: Downlink peak MAC channel throughput at the pixel, subscriber, or mobile M_i.

- $CTP_{E-DL}^{M_i}$: Downlink effective MAC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{A-DL}^{M_i}$: Downlink application channel throughput at the pixel, subscriber, or mobile M_i.
- $Cap_{P-DL}^{M_i}$: Downlink peak MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{E-DL}^{M_i}$: Downlink effective MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{A-DL}^{M_i}$: Downlink application cell capacity at the pixel, subscriber, or mobile M_i.
- $CTP_{P-UL}^{M_i}$: Uplink peak MAC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{E-UL}^{M_i}$: Uplink effective MAC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{A-UL}^{M_i}$: Uplink application channel throughput at the pixel, subscriber, or mobile M_i.
- $Cap_{P-UL}^{M_i}$: Uplink peak MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{E-UL}^{M_i}$: Uplink effective MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{A-UL}^{M_i}$: Uplink application cell capacity at the pixel, subscriber, or mobile M_i.
- $ABTP_{P-UL}^{M_i}$: Uplink peak MAC allocated bandwidth throughput at the pixel, subscriber, or mobile M_i.
- $ABTP_{E-UL}^{M_i}$: Uplink effective MAC allocated bandwidth throughput at the pixel, subscriber, or mobile M_i.
- $ABTP_{A-UL}^{M_i}$: Uplink application allocated bandwidth throughput at the pixel, subscriber, or mobile M_i.

9.4.8 Scheduling and Radio Resource Management

9955 WiMAX BWA module includes a number of scheduling methods which can be used for scheduling and radio resource allocation during Monte Carlo simulations. These resource allocation algorithms are explained in "Scheduling and Radio Resource Allocation" on page 698 and the calculation of user throughputs is explained in "User Throughput Calculation" on page 707.

9.4.8.1 Scheduling and Radio Resource Allocation

Input

- $TL_{DL-Max}^{TX_i(ic)}$: Maximum downlink traffic load for the cell $TX_i(ic)$.
- $TL_{UL-Max}^{TX_i(ic)}$: Maximum uplink traffic load for the cell $TX_i(ic)$.
- $N_{Users-Max}^{TX_i(ic)}$: Maximum number of users defined for the cell $TX_i(ic)$.
- QoS^{M_i} : QoS class of the service (UGS, ErtPS, rtPS, nrtPS, or Best Effort) accessed by a mobile M_i.
- p^{M_i} : Priority of the service accessed by a mobile M_i.
- $TPD_{Min-DL}^{M_i}$: Downlink minimum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Min-UL}^{M_i}$: Uplink minimum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Max-DL}^{M_i}$: Downlink maximum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Max-UL}^{M_i}$: Uplink maximum throughput demand for the service accessed by a mobile M_i.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the BLER vs. $CINR_{Traffic}^{TX_i(ic)}$ graph available in the WiMAX equipment assigned to the terminal used by the mobile M_i.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the BLER vs. $CINR_{UL}^{M_i}$ graph available in the WiMAX equipment assigned to the cell $TX_i(ic)$.

- $f_{TP-Scaling}^{M_i}$: Throughput scaling factor defined in the properties of the service used by the mobile M_i.
- $TP_{Offset}^{M_i}$: Throughput offset defined in the properties of the service used by the mobile M_i.
- $CTP_{P-DL}^{M_i}$: Downlink peak MAC channel throughput at the mobile M_i as calculated in "Throughput Calculation" on page 691.
- $CTP_{P-UL}^{M_i}$: Uplink peak MAC channel throughput at the mobile M_i as calculated in "Throughput Calculation" on page 691.
- $ABTP_{P-UL}^{M_i}$: Uplink peak MAC allocated bandwidth throughput at the mobile M_i as calculated in "Throughput Calculation" on page 691.
- f_{Bias}^{QoS} : Bias factor defined for the Biased (QoS Class) scheduling method.

Calculations

The following calculations are described for any cell $TX_i(ic)$ containing the users M_i for which it is the best server.

Mobile Selection:

The scheduler selects $N_{Users}^{TX_i(ic)}$ mobiles for the scheduling and RRM process. If the Monte Carlo user distribution has generated a number of users which is less than $N_{Users-Max}^{TX_i(ic)}$, the scheduler keeps all the mobiles generated for the cell $TX_i(ic)$.

$$N_{Users}^{TX_i(ic)} = Min\left(N_{Users-Max}^{TX_i(ic)}, N_{Users-Generated}^{TX_i(ic)}\right)$$

For a cell, mobiles $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ are selected for RRM by the scheduler.

Calculation of Actual Minimum and Maximum Throughput Demands:

Depending on the selected target throughput of the scheduler assigned to the cell $TX_i(ic)$, the actual minimum and maximum throughput demands can be considered as the peak MAC, effective MAC, or application throughput. Therefore:

- **Target Throughput = Peak MAC Throughput**

  Downlink: $TPD_{Min-DL}^{M_i^{Sel}}$, $TPD_{Max-DL}^{M_i^{Sel}}$

  Uplink: $TPD_{Min-UL}^{M_i^{Sel}}$, $Min\left(TPD_{Max-UL}^{M_i^{Sel}}, ABTP_{P-UL}^{M_i}\right)$

- **Target Throughput = Effective MAC Throughput**

  Downlink: $TPD_{Min-DL}^{M_i^{Sel}} = \dfrac{TPD_{Min-DL}^{M_i^{Sel}}}{\left(1-BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)}$, $TPD_{Max-DL}^{M_i^{Sel}} = \dfrac{TPD_{Max-DL}^{M_i^{Sel}}}{\left(1-BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)}$

  Uplink: $TPD_{Min-UL}^{M_i^{Sel}} = \dfrac{TPD_{Min-UL}^{M_i^{Sel}}}{\left(1-BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)}$, $TPD_{Max-UL}^{M_i^{Sel}} = \dfrac{Min\left(TPD_{Max-UL}^{M_i^{Sel}}, ABTP_{P-UL}^{M_i}\right)}{\left(1-BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)}$

- **Target Throughput = Application Throughput**

  Downlink: $TPD_{Min-DL}^{M_i^{Sel}} = \dfrac{TPD_{Min-DL}^{M_i^{Sel}} + TP_{Offset}^{M_i}}{\left(1-BLER\left(B_{DL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$, $TPD_{Max-DL}^{M_i^{Sel}} = \dfrac{TPD_{Max-DL}^{M_i^{Sel}} + TP_{Offset}^{M_i}}{\left(1-BLER\left(B_{DL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$

Uplink: $TPD_{Min-UL}^{M_i^{Sel}} = \dfrac{TPD_{Min-UL}^{M_i^{Sel}} + TP_{Offset}^{M_i}}{\left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$,

$$TPD_{Max-UL}^{M_i^{Sel}} = \frac{Min\left(TPD_{Max-UL}^{M_i^{Sel}}, ABTP_{P-UL}^{M_i}\right) + TP_{Offset}^{M_i}}{\left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right) \times f_{TP-Scaling}^{M_i}}$$

The *Min()* function selects the lower of the two values. This calculation is performed in order to limit the maximum uplink throughput demand to the maximum throughput that a user can get in uplink using the allocated bandwidth (number of used subchannels) calculated for it in "Traffic C/(I+N) and Bearer Calculation (UL)" on page 687.

Resource Allocation for Minimum Throughput Demands:

1. For the QoS classes UGS, ErtPS, rtPS, and nrtPS, **9955** sorts the $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ in order of decreasing service priority, $p^{M_i^{Sel}}$:

M_i^{Sel}	$QoS^{M_i^{Sel}}$	$p^{M_i^{Sel}}$
1	UGS	$p^{M_i^{Sel}} = n$
2		$... n > p^{M_i^{Sel}} > 0 ...$
:		$p^{M_i^{Sel}} = 0$
:	ErtPS	$p^{M_i^{Sel}} = n$
:		$... n > p^{M_i^{Sel}} > 0 ...$
:		$p^{M_i^{Sel}} = 0$
:	rtPS	$p^{M_i^{Sel}} = n$
:		$... n > p^{M_i^{Sel}} > 0 ...$
:		$p^{M_i^{Sel}} = 0$
:	nrtPS	$p^{M_i^{Sel}} = n$
$N-1$		$... n > p^{M_i^{Sel}} > 0 ...$
N		$p^{M_i^{Sel}} = 0$

Where $N < N_{Users}^{TX_i(ic)}$, if there are some Best Effort users, or $N = N_{Users}^{TX_i(ic)}$ if there are no Best Effort users selected.

2. Starting with $M_i^{Sel} = 1$ up to $M_i^{Sel} = N$, **9955** allocates the downlink and uplink resources required to satisfy each user's minimum throughput demands in downlink and uplink as follows:

$$R_{Min-DL}^{M_i^{Sel}} = \frac{TPD_{Min-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } R_{Min-UL}^{M_i^{Sel}} = \frac{TPD_{Min-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

3. **9955** stops the resource allocation in downlink or uplink,
   - When/If in downlink $\sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} = TL_{DL-Max}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the minimum throughput demands of the mobiles.
   - When/If in uplink $\sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} = TL_{UL-Max}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the minimum throughput demands of the mobiles.
4. Mobiles which are active DL+UL must be able to get their minimum throughput demands in both UL and DL in order to be considered connected DL+UL. If an active DL+UL mobile is only able to get its minimum throughput demand in one direction, it is rejected, and the resources, that were allocated to it in the one direction in which it was able to get a throughput, are allocated to other mobiles.
5. Mobiles which are active UL and whose minimum throughput demand in UL is higher than the uplink allocated bandwidth throughput ($TPD_{Min-UL}^{M_i^{Sel}} > ABTP_{P-UL}^{M_i^{Sel}}$) are rejected due to Resource Saturation.
6. If $\sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} < TL_{DL-Max}^{TX_i(ic)}$ or $\sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} < TL_{UL-Max}^{TX_i(ic)}$, and all the minimum throughput resources demanded by the mobiles have been allocated, **9955** goes to the next step for allocating resources to satisfy the maximum throughput demands.

The remaining cell resources available for the next step are:

Downlink: $R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}}$

Uplink: $R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}}$

Resource Allocation for Maximum Throughput Demands:

For each mobile, the throughput demands remaining once the minimum throughput demands have been satisfied are the difference between the maximum and the minimum throughput demands:

Downlink: $TPD_{Rem-DL}^{M_i^{Sel}} = TPD_{Max-DL}^{M_i^{Sel}} - TPD_{Min-DL}^{M_i^{Sel}}$

Uplink: $TPD_{Rem-UL}^{M_i^{Sel}} = TPD_{Max-UL}^{M_i^{Sel}} - TPD_{Min-UL}^{M_i^{Sel}}$

For the remaining throughput demands of the mobiles belonging to the QoS classes ErtPS, rtPS, nrtPS, and Best Effort, the following resource allocation methods are available:

1. **Proportional Fair:**

   The goal of this scheduling method is to distribute resources among users fairly in such a way that, on the average, each user gets the highest possible throughput that it can get under the radio conditions at its location.

Let the total number of users belonging to the QoS classes ErtPS, rtPS, nrtPS, and Best Effort, be $N \in M_i^{Sel}$.

a. Each user's channel throughput is increased by the multi-user diversity gain $G_{MUG-DL}^{TX_i(ic)}$ or $G_{MUG-UL}^{TX_i(ic)}$ read from the scheduler properties for the $Mobility(M_i)$ assigned to mobile M_i^{Sel} and the number of connected users, DL or UL, in the cell $TX_i(ic)$ in the iteration *k-1*.

$$CTP_{P-DL}^{M_i^{Sel}} = CTP_{P-DL}^{M_i^{Sel}}\Big|_{Without\ MUG} \times G_{MUG-DL}^{TX_i(ic)} \text{ and } CTP_{P-UL}^{M_i^{Sel}} = CTP_{P-UL}^{M_i^{Sel}}\Big|_{Without\ MUG} \times G_{MUG-UL}^{TX_i(ic)}$$

$$G_{MUG-DL}^{TX_i(ic)} = 1 \text{ if } CINR_{Traffic}^{M_i^{Sel}} \geq CINR_{MUG}^{Max} \text{ and } G_{MUG-UL}^{TX_i(ic)} = 1 \text{ if } CINR_{UL}^{M_i^{Sel}} \geq CINR_{MUG}^{Max}.$$

If the multi-user diversity gain for the exact value of the number of connected users is not availabe in the graph, it is interpolated from the gain values available for the numbers of users just less than and just greater than the actual number of users.

b. **9955** divides the remaining resources in the cell into equal parts for each user:

$$\frac{R_{Rem-DL}^{TX_i(ic)}}{N} \text{ and } \frac{R_{Rem-UL}^{TX_i(ic)}}{N}$$

c. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

$$RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

d. The resources allocated to each user by the Proportional Fair scheduling method for satisfying its maximum throughput demands are:

$$R_{Max-DL}^{M_i^{Sel}} = Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right) \text{ and } R_{Max-UL}^{M_i^{Sel}} = Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$$

Each user gets either the resources it needs to achieve its maximum throughput demands or an equal share from the remaining resources of the cell, whichever is smaller.

e. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{Rem-DL}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the maximum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{Rem-UL}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the maximum throughput demands of the mobiles.

f. If the resources allocated to a user satisfy its maximum throughput demands, this user is removed from the list of remaining users.

g. **9955** recalculates the remaining resources as follows:

$$R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} \text{ and}$$

$$R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}}$$

h. **9955** repeats the all the above steps for the users whose maximum throughput demands have not been satisfied until either $R_{Rem-DL}^{TX_i(ic)} = 0$ and $R_{Rem-UL}^{TX_i(ic)} = 0$, or all the maximum throughput demands are satisfied.

2. **Proportional Demand:**

The goal of this scheduling method is to allocate resources to users weighted according to their remaining throughput demands. Therefore, the user throughputs for users with high throughput demands will be higher than those with low throughput demands. In other words, this scheduler distributes channel throughput between users proportionally to their demands.

a. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

$$RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

b. **9955** calculates the amount effective remaining resources for the cell of each user to distribute among the users as follows:

$$R_{Eff-Rem-DL}^{TX_i(ic)} = Min\left(R_{Rem-DL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}\right) \text{ and } R_{Eff-Rem-UL}^{TX_i(ic)} = Min\left(R_{Rem-UL}^{TX_i(ic)}, \sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}\right)$$

c. The resources allocated to each user by the Proportional Demand scheduling method for satisfying its maximum throughput demands are:

$$R_{Max-DL}^{M_i^{Sel}} = R_{Eff-Rem-DL}^{TX_i(ic)} \times \frac{RD_{Rem-DL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-DL}^{M_i^{Sel}}} \text{ and } R_{Max-UL}^{M_i^{Sel}} = R_{Eff-Rem-UL}^{TX_i(ic)} \times \frac{RD_{Rem-UL}^{M_i^{Sel}}}{\sum_{M_i^{Sel}} RD_{Rem-UL}^{M_i^{Sel}}}$$

3. **Biased (QoS Class):**

The goal of this scheduling method is to distribute resources among users of each QoS class fairly in such a way that, on the average, each user gets the highest possible throughput that it can get under the radio conditions at its location. The resources available for allocation to users of each QoS class depend on a bias factor. The QoS Class Bias Factor controls the amount of resources available for each QoS class.

Calculation of the Remaining Resources per QoS Class:

The bias factor f_{Bias}^{QoS} represents the bias in terms of resources allocated to *1* user of a QoS class with rank *r* to the resources allocated to *1* user of a QoS class with rank *r–1*:

$$\beta = 1 + \frac{f_{Bias}^{QoS}}{100} = \frac{R_{Max-ErtPS}^{M_i^{Sel}}}{R_{Max-rtPS}^{M_i^{Sel}}} = \frac{R_{Max-rtPS}^{M_i^{Sel}}}{R_{Max-nrtPS}^{M_i^{Sel}}} = \frac{R_{Max-nrtPS}^{M_i^{Sel}}}{R_{Max-BE}^{M_i^{Sel}}}$$

The ranks of QoS classes are:

QoS Class	QoS Class Rank r_{QoS}
ErtPS	1
rtPS	2
nrtPS	3
Best Effort	4

The resources available for the users of each QoS class from among the remaining resources is calculated as follows:

$$R_{QoS-DL}^{TX_i(ic)} = R_{Rem-DL}^{TX_i(ic)} \times \frac{N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}}{\sum_{All\,QoS}\left[N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}\right]} \text{ and } R_{QoS-UL}^{TX_i(ic)} = R_{Rem-UL}^{TX_i(ic)} \times \frac{N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}}{\sum_{All\,QoS}\left[N_{QoS} \times \left(\frac{1}{\beta}\right)^{r_{QoS}}\right]}$$

Resource Allocation:

Once the remaining resources available for the users of each QoS class have been determined, the allocation of resources within each QoS class is performed as for the proportional fair scheduler.

Let the number of users belonging to a QoS class $N_{QoS} \in M_i^{Sel}$.

a. **9955** divides the remaining resources of the QoS class into equal parts for each user:

$$\frac{R_{QoS-DL}^{TX_i(ic)}}{N_{QoS}} \text{ and } \frac{R_{QoS-UL}^{TX_i(ic)}}{N_{QoS}}$$

b. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

$$RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

c. The resources allocated to each user by the Biased scheduling method for satisfying its maximum throughput demands are:

$$R_{Max-DL}^{M_i^{Sel}} = Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{QoS-DL}^{TX_i(ic)}}{N_{QoS}}\right) \text{ and } R_{Max-UL}^{M_i^{Sel}} = Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{QoS-UL}^{TX_i(ic)}}{N_{QoS}}\right)$$

Each user gets either the resources it needs to achieve its maximum throughput demands or an equal share from the remaining resources of the QoS class, whichever is smaller.

d. **9955** stops the resource allocation for a QoS class in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{QoS-DL}^{TX_i(ic)}$, i.e., the resources available in downlink for the QoS class have been used up for satisfying the maximum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{QoS-UL}^{TX_i(ic)}$, i.e., the resources available in uplink for the QoS class have been used up for satisfying the maximum throughput demands of the mobiles.

e. If the resources allocated to a user satisfy its maximum throughput demands, this user is removed from the list of remaining users.

f. **9955** recalculates the remaining resources as follows:

$$R_{QoS-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} \text{ and}$$

$$R_{QoS-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}}$$

g. **9955** repeats the all the above steps for the users of the QoS class whose maximum throughput demands have not been satisfied until either $R_{QoS-DL}^{TX_i(ic)} = 0$ and $R_{QoS-UL}^{TX_i(ic)} = 0$, or all the maximum throughput demands are satisfied.

4. **Max Aggregate Throughput:**

The goal of this scheduling method is to achieve the maximum aggregate throughput for the cells. This is done by allocating as much resources as needed to mobiles with high C/(I+N) conditions. As mobiles with high C/(I+N) can get higher bearers, and therefore require less amount of resources, more mobiles can therefore be allocated resources in the same frame, and the end-throughput for each cell will be the highest compared to other types of schedulers.

a. **9955** sorts the $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ in order of decreasing downlink or uplink traffic C/(I+N), depending on whether the allocation is being performed for the downlink or for the uplink.

b. Starting with the mobile with the highest rank, **9955** allocates the downlink and uplink resources required to satisfy each user's remaining throughput demands in downlink and uplink as follows:

$$R_{Max-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } R_{Max-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

c. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{Rem-DL}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the maximum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{Rem-UL}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the maximum throughput demands of the mobiles.

5. Round Robin:

The goal of this scheduling method is to allocate equal resources to users fairly.

Let the total number of users belonging to the QoS classes ErtPS, rtPS, nrtPS, and Best Effort, be $N \in M_i^{Sel}$.

a. **9955** divides the remaining resources in the cell into equal parts for each user:

$$\frac{R_{Rem-DL}^{TX_i(ic)}}{N} \text{ and } \frac{R_{Rem-UL}^{TX_i(ic)}}{N}$$

b. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

$$RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

c. The resources allocated to each user by the Round Robin scheduling method for satisfying its maximum throughput demands are:

$$R_{Max-DL}^{M_i^{Sel}} = Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right) \text{ and } R_{Max-UL}^{M_i^{Sel}} = Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$$

Each user gets either the resources it needs to achieve its maximum throughput demands or an equal share from the remaining resources of the cell, whichever is smaller.

d. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{Rem-DL}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the maximum throughput demands of the mobiles.

- When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{Rem-UL}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the maximum throughput demands of the mobiles.

e. If the resources allocated to a user satisfy its maximum throughput demands, this user is removed from the list of remaining users.

f. **9955** recalculates the remaining resources as follows:

$$R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}}$$ and

$$R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}}$$

g. **9955** repeats the all the above steps for the users whose maximum throughput demands have not been satisfied until either $R_{Rem-DL}^{TX_i(ic)} = 0$ and $R_{Rem-UL}^{TX_i(ic)} = 0$, or all the maximum throughput demands are satisfied.

Spatial Multiplexing with Uplink Multi-User MIMO:

MU-MIMO lets the system/scheduler work with two parallel WiMAX frames (1 for each antenna). Therefore, a mobile connected to antenna 1 creates a corresponding resource availability on antenna 2. This resources made available on antenna 2 can then be assigned to another mobile without any effect on the overall load of the cell. When the second mobile is assigned to antenna 2, the resources allocated to it overlap with the resources made available by the first mobile on antenna 1. If the second mobile is allocated more resources than the first one made available, the second mobile will create resource availability on antenna 1. Each new mobile is either connected to antenna 1 or antenna 2. The part of the mobile's resources which are not coupled with resources allocated to another mobile on the other antenna is called the real resource consumption. The part of the mobile's resources which are coupled with the resources allocated to another mobile on the other antenna is called the virtual resource consumption.

MU-MIMO can be used if the permutation zone assigned to the pixel, subscriber, or mobile M_i supports MU-MIMO, $CNR_{Preamble}^{TX_i(ic)} > T_{MU-MIMO}^{TX_i(ic)}$, and $N_{Ant-RX}^{TX_i(ic)} \geq 2$.

Let i be the index of connected MU-MIMO mobiles: $i = 1 \text{ to } N$

Each mobile $M_i^{MU-MIMO}$ has a corresponding traffic load $TL_{UL}^{M_i^{MU-MIMO}}$. The scheduling starts with available real resources $RR_{UL}^{M_{i=0}^{MU-MIMO}} = 100\ \%$ and available virtual resources $\Delta V_{UL}^{M_{i=0}^{MU-MIMO}} = 0\ \%$. $i = 0$ means no MU-MIMO mobile has yet been scheduled.

The virtual resource consumption of a mobile $M_i^{MU-MIMO}$ is given by: $VC_{UL}^{M_i^{MU-MIMO}} = Min\left(TL_{UL}^{M_i^{MU-MIMO}}, \Delta V_{UL}^{M_{i-1}^{MU-MIMO}}\right)$

The real resource consumption of a mobile $M_i^{MU-MIMO}$ is given by: $RC_{UL}^{M_i^{MU-MIMO}} = TL_{UL}^{M_i^{MU-MIMO}} - VC_{UL}^{M_i^{MU-MIMO}}$

The virtual resources made available by the mobile $M_i^{MU-MIMO}$ are given by:

$$\Delta V_{UL}^{M_i^{MU-MIMO}} = \Delta V_{UL}^{M_{i-1}^{MU-MIMO}} - VC_{UL}^{M_i^{MU-MIMO}} + RC_{UL}^{M_i^{MU-MIMO}}$$

Saturation occurs when $\sum RC_{UL}^{M_i^{MU-MIMO}} = TL_{UL-Max}^{TX_i(ic)}$.

The following table gives an example:

Mobile	$TL_{UL}^{M_i^{MU-MIMO}}$ (%)	$VC_{UL}^{M_i^{MU-MIMO}}$ (%)	$RC_{UL}^{M_i^{MU-MIMO}}$ (%)	$\Delta V_{UL}^{M_i^{MU-MIMO}}$ (%)
M_1	10	0	10	10
M_2	5	5	0	5

Mobile	$TL_{UL}^{M_i^{MU-MIMO}}$ (%)	$VC_{UL}^{M_i^{MU-MIMO}}$ (%)	$RC_{UL}^{M_i^{MU-MIMO}}$ (%)	$\Delta V_{UL}^{M_i^{MU-MIMO}}$ (%)
M_3	20	5	15	15
M_4	40	15	25	25
...	...	...	...	...

Total Amount of Resources Assigned to Each Selected Mobile:

9955 calculates the amounts of downlink and uplink resources allocated to each individual mobile M_i^{Sel} (which can also be referred to as the traffic loads of the mobiles) as follows:

Downlink: $TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}} = R_{Min-DL}^{M_i^{Sel}} + R_{Max-DL}^{M_i^{Sel}}$

Uplink: $TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}} = R_{Min-UL}^{M_i^{Sel}} + R_{Max-UL}^{M_i^{Sel}}$ or $TL_{UL}^{M_i^{Sel}} = RC_{UL}^{M_i^{MU-MIMO}}$ for MU-MIMO mobiles for cell traffic load calculation

Output

- $TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}}$: Downlink traffic load or the amount of downlink resources allocated to the mobile M_i^{Sel}.
- $TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}}$: Uplink traffic load or the amount of uplink resources allocated to the mobile M_i^{Sel}.

9.4.8.2 User Throughput Calculation

User throughputs are calculated for the percentage of resources allocated to each mobile selected by the scheduling for RRM during the Monte Carlo simulations, M_i^{Sel}.

Input

- $R_{DL}^{M_i^{Sel}}$: Amount of downlink resources allocated to the mobile M_i^{Sel} as calculated in "Scheduling and Radio Resource Allocation" on page 698.
- $R_{UL}^{M_i^{Sel}}$: Amount of uplink resources allocated to the mobile M_i^{Sel} as calculated in "Scheduling and Radio Resource Allocation" on page 698.
- $CTP_{P-DL}^{M_i^{Sel}}$: Downlink peak MAC channel throughput at the mobile M_i^{Sel} as calculated in "Throughput Calculation" on page 691.
- $CTP_{P-UL}^{M_i^{Sel}}$: Uplink peak MAC channel throughput at the mobile M_i^{Sel} as calculated in "Throughput Calculation" on page 691.
- $BLER\left(B_{DL}^{M_i^{Sel}}\right)$: Downlink block error rate read from the BLER vs. $CINR_{Traffic}^{TX_i(ic)}$ graph available in the WiMAX equipment assigned to the terminal used by the mobile M_i^{Sel}.
- $BLER\left(B_{UL}^{M_i^{Sel}}\right)$: Uplink block error rate read from the BLER vs. $CINR_{UL}^{M_i}$ graph available in the WiMAX equipment assigned to the cell $TX_i(ic)$.
- $f_{TP-Scaling}^{M_i^{Sel}}$: Throughput scaling factor defined in the properties of the service used by the mobile M_i^{Sel}.
- $TP_{Offset}^{M_i^{Sel}}$: Throughput offset defined in the properties of the service used by the mobile M_i^{Sel}.

Calculations

Downlink:

- **Peak MAC User Throughput:** $UTP_{P-DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}} \times CTP_{P-DL}^{M_i^{Sel}}$
- **Effective MAC User Throughput:** $UTP_{E-DL}^{M_i^{Sel}} = UTP_{P-DL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)$
- **Application User Throughput:** $UTP_{A-DL}^{M_i^{Sel}} = UTP_{E-DL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$

Uplink:

- **Peak MAC User Throughput:** $UTP_{P-UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}} \times CTP_{P-UL}^{M_i^{Sel}}$
- **Effective MAC User Throughput:** $UTP_{E-UL}^{M_i^{Sel}} = UTP_{P-UL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)$
- **Application User Throughput:** $UTP_{A-UL}^{M_i^{Sel}} = UTP_{E-UL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$

Output

- $UTP_{P-DL}^{M_i^{Sel}}$: Downlink peak MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel} .
- $UTP_{E-DL}^{M_i^{Sel}}$: Downlink effective MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel} .
- $UTP_{A-DL}^{M_i^{Sel}}$: Downlink application user throughput at the pixel, subscriber, or mobile M_i^{Sel} .
- $UTP_{P-UL}^{M_i^{Sel}}$: Uplink peak MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel} .
- $UTP_{E-UL}^{M_i^{Sel}}$: Uplink effective MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel} .
- $UTP_{A-UL}^{M_i^{Sel}}$: Uplink application user throughput at the pixel, subscriber, or mobile M_i^{Sel} .

9.5 Automatic Planning Algorithms

The following sections describe the algorithms for:

- "Automatic Neighbour Planning" on page 708.
- "Automatic Inter-technology Neighbour Planning" on page 712.
- "Automatic Frequency Planning Using the AFP" on page 715.
- "Automatic Preamble Index Planning Using the AFP" on page 717.
- "Automatic Zone PermBase Planning Using the AFP" on page 721.

9.5.1 Automatic Neighbour Planning

The intra-technology neighbour planning algorithm takes into account the cells of all the TBC transmitters. It means that the cells of all the TBC transmitters of your ATL document are potential neighbours.

The cells to be allocated will be called TBA cells. They must fulfil the following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which the allocation has been executed. This can be the Transmitters folder or a group of transmitters (subfolder).

Only TBA cells are assigned neighbours.

> If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

We assume a reference cell $TX_i(ic)$ and a candidate neighbour cell $TX_j(jc)$. When automatic planning starts, **9955** checks the following conditions:

1. The distance between both cells must be less than the user-definable maximum inter-site distance. If the distance between the reference cell and the candidate neighbour is greater than this value, then the candidate neighbour is discarded.

   9955 calculates the effective distance between the reference cell and its candidate neighbour from the real distance between them and the azimuths of their antennas:

   $$Dist(CellA, CellB) = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

   Where x = 0.3% so that the maximum variation in *D* does not to exceed 1%. D is stated in m.

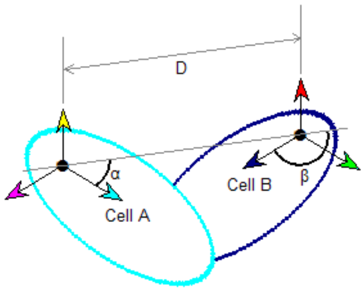


Figure 9.5: Inter-Transmitter Distance Calculation

   The formula above implies that two cells facing each other have a smaller effective distance than the actual distance. Candidate neighbours are ranked in the order of increasing effective distance from the reference cell.

2. The calculation options,

   - **Force Co-site Cells as Neighbours:** If selected, **9955** adds all the cells located on the same site as the reference cell to the candidate neighbour list. The weight of this constraint can be defined. It is used to calculate the rank of each neighbour, and its importance.
   - **Force Adjacent Cells as Neighbours:** If selected, **9955** adds all the cells geographically adjacent to the reference cell to the candidate neighbour list. The weight of this constraint can be defined. It is used to calculate the rank of each neighbour, and its importance.

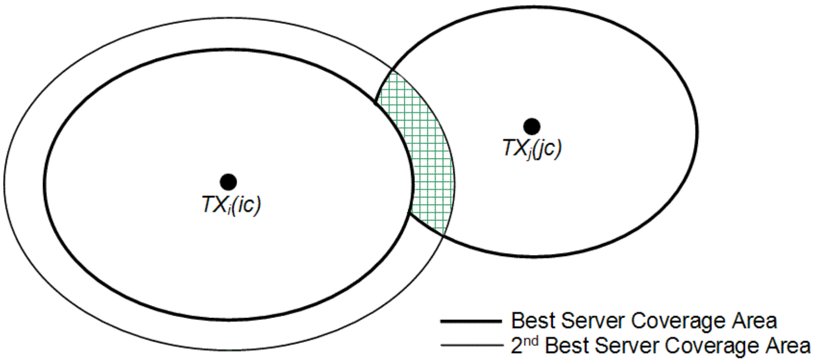


Figure 9.6: Determination of Adjacent Cells

   Determination of Adjacent Cells: Geographically adjacent cells are determined on the basis of their best server coverage areas. A candidate neighbour cell $TX_i(ic)$ is considered adjacent to the reference cell $TX_i(ic)$ if there exists at least one pixel of $TX_j(jc)$'s best server coverage area where $TX_i(ic)$ is the second best server. The ranking of adjacent neighbour cells increases with the number of such pixels. Adjacent cells are sorted in the order of decreasing rank.

   - **Force Neighbour Symmetry:** If selected, **9955** adds the reference cell to the candidate neighbour list of the its candidate neighbour.

     A symmetric neighbour relation is allowed only if the neighbour list of the reference cell is not already full. If $TX_j(jc)$ is a neighbour of $TX_i(ic)$ but $TX_i(ic)$ is not a neighbour of $TX_j(jc)$, there can be two possibilities:

i. The neighbour list of $TX_j(jc)$ is not full, **9955** will add $TX_i(ic)$ to the end of the list.

ii. The neighbour list of $TX_j(jc)$ is full, **9955** will not be able to add $TX_i(ic)$ to the list, so it will also remove $TX_j(jc)$ from the neighbour list of $TX_i(ic)$.

- **Force Exceptional Pairs:** This option enables you to force/forbid some neighbour relations. Exceptional pairs are pairs of cells which will always or never be neighbours of each other.

  If you select "Force exceptional pairs" and "Force symmetry", **9955** considers the constraints between exceptional pairs in both directions so as to respect symmetry condition. On the other hand, if neighbourhood relationship is forced in one direction and forbidden in the other, symmetry cannot be respected. In this case, **9955** displays a warning in the Event viewer.
- **Delete Existing Neighbours:** If selected, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept in the list.

3. The coverage areas of $TX_i(ic)$ and $TX_j(jc)$ must have an overlap ($S_{TX_i(ic)} \cap S_{TX_j(jc)}$).

- Here $S_{TX_i(ic)}$ is the surface area covered by the cell $TX_i(ic)$ that comprises all the pixels where:
  - The received preamble signal level is greater than or equal to the preamble signal level threshold. The received preamble signal level ($C^{TX_i(ic)}_{Preamble}$) and the preamble signal level threshold are calculated from $CNR^{TX_i(ic)}_{Preamble}$ and $T^{TX_i(ic)}_{Preamble}$, respectively, by adding the value of the noise ($n^{TX_i(ic)}_{Preamble}$) to them.
  - $S_{TX_i(ic)}$ is the surface area covered by $TX_i(ic)$ within $C^{TX_i(ic)}_{Preamble} + HO_{Start}$ and $C^{TX_i(ic)}_{Preamble} + HO_{End}$, or $CINR^{TX_i(ic)}_{Preamble} + HO_{Start}$ and $CINR^{TX_i(ic)}_{Preamble} + HO_{End}$. HO_{Start} is the margin with respect to the best preamble signal level or C/(I+N) at which the handover starts, and HO_{End} is the margin with respect to the best preamble signal level or C/(I+N) at which the handover ends.
- $S_{TX_j(jc)}$ is the coverage area where the candidate cell $TX_j(jc)$ is the best server.

> - If a global value of the preamble C/N threshold ($T^{TX_i(ic)}_{Preamble}$) is set in the coverage conditions dialogue, for each cell, **9955** uses the higher of the two values, i.e., global value and the value defined for that cell.
> - For calculating the overlapping coverage areas, **9955** uses the service with the lowest body loss, the terminal that has the highest difference between gain and losses, and the shadowing margin calculated using the defined cell edge coverage probability, if the option is selected. The service and terminal are selected such that the selection gives the largest possible preamble C/N coverage areas for the cells.
> -

When the above conditions are met, **9955** calculates the percentage of the coverage area overlap ($\frac{S_{TX_i(ic)} \cap S_{TX_j(jc)}}{S_{TX_i(ic)}} \times 100$), and compares this value with the % Min Covered Area.

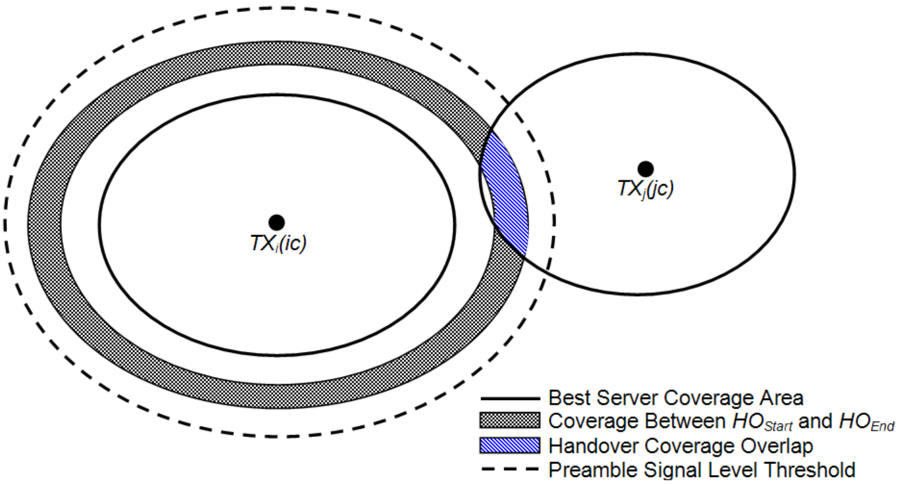


Figure 9.7: Overlapping Zones

$TX_j(jc)$ is considered a neighbour of $TX_i(ic)$ if $\frac{S_{TX_i(ic)} \cap S_{TX_j(jc)}}{S_{TX_i(ic)}} \times 100 \geq \%\ Min\ Coverage\ Area$.

Next, **9955** calculates the importance of the automatically allocated neighbours. **9955** sorts the neighbours by decreasing importance in order to keep the ones with high importance. If the maximum number of neighbours to be allocated to each cell is exceeded, **9955** keeps the ones with high importance.

The neighbour importance depends on the distance from the reference transmitter and on the neighbourhood cause (cf. table below); this value varies between 0 and 100%.

Neighbourhood cause	When	Importance value
Existing neighbour	Only if the Delete Existing Neighbours option is not selected and in case of a new allocation	Existing importance
Exceptional pair	Only if the Force Exceptional Pairs option is selected	100 %
Co-site cell	Only if the Force Co-site Cells as Neighbours option is selected	Importance Function (IF)
Adjacent cell	Only if the Force Adjacent Cells as Neighbours option is selected	Importance Function (IF)
Neighbourhood relationship that fulfils coverage conditions	Only if the % Min Covered Area is exceeded	Importance Function (IF)
Symmetric neighbourhood relationship	Only if the Force Neighbour Symmetry option is selected	Importance Function (IF)

The importance is evaluated using an Importance Function (IF), which takes into account the following factors:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

  $$(Di) = 1 - \frac{d}{d_{max}}$$

  d is the effective distance (in m). It corresponds to the real inter-transmitter distance (D in m) weighted by the azimuths of antennas.

  d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The adjacency factor (A): the percentage of adjacency,
- The overlapping factor (O): the percentage of overlapping.

The minimum and maximum importance assigned to each of the above factors can be defined.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	30%
Adjacency factor (A)	Min(A)	30%	Max(A)	60%

Factor	Min importance	Default value	Max importance	Default value
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The Importance Function is evaluated as follows:

Neighbourhood cause		Importance Function	Resulting IF using the default values from the table above
Co-site	Adjacent		
No	No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+20%{10%(Di)+90%(O)}
No	Yes	Min(A)+Delta(A){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	30%+30%{10%(Di)+30%(O) +60%(A)}
Yes	Yes	Min(C)+Delta(C){Max(Di)(Di)+Max(O)(O)+ (100%-Max(Di)-Max(O))(A)}	60%+40%{10%(Di)+30%(O) +60%(A)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours, adjacent neighbours, and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- The default value of Min(O) = 1% ensures that neighbours selected for symmetry will have an importance greater than 0%. With a value of Min(O) = 0%, neighbours selected for symmetry will have an importance field greater than 0% only if there is some coverage overlapping.If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.
- By adding an option in the atoll.ini file, the neighbour planning and importance calculation can be based on the distance criterion only. For more information, see the *Administrator Manual*.

In the results, **9955** lists only the cells for which it finds new neighbours. Cells whose channels have the same start frequency, the same channel width, and the same total number of subcarriers are listed as intra-carrier neighbours. Otherwise, neighbour cells are listed as inter-carrier neighbours.

9.5.2 Automatic Inter-technology Neighbour Planning

The inter-technology neighbour planning algorithm takes into account all the TBC transmitters (if the other technology is GSM) or the cells of all the TBC transmitters (for any other technology than GSM). This means that all the TBC transmitters (GSM) or the cells of all the TBC transmitters (all other technologies) of the linked document are potential neighbours.

The cells to be allocated in the main document will be called TBA cells. They must fulfil the following conditions:

- They are active,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone,
- They belong to the folder on which allocation has been executed. This can be the Transmitters folder or a group of transmitters (subfolder).

Only TBA cells are assigned neighbours.

If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

We assume a reference cell A and a candidate neighbour B. When automatic planning starts, **9955** checks following conditions:

1. The distance between reference cell and the candidate neighbour must be less than the user-definable maximum inter-site distance. If the distance is greater than this value, the candidate neighbour is discarded.

9955 calculates the effective distance between the reference cell and its candidate neighbour from the real distance between them and the azimuths of their antennas:

$$Dist(CellA, CellB) = D \times (1 + x \times \cos\beta - x \times \cos\alpha)$$

Where x = 0.3% so that the maximum variation in *D* does not to exceed 1%. D is stated in m.

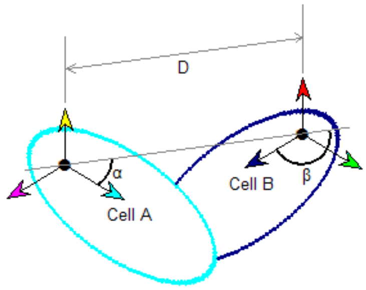


Figure 9.8: Inter-Transmitter Distance Calculation

The formula above implies that two cells facing each other have a smaller effective distance than the actual distance. Candidate neighbours are ranked in the order of increasing effective distance from the reference cell.

2. The calculation options:
   - **CDMA Carriers:** This option is available when an WiMAX network is being co-planned with a UMTS, CDMA, or TD-SCDMA network. This option enables you to select the CDMA carrier(s) that you want **9955** to consider as potential neighbours of WiMAX cells. You may choose one or more carriers. **9955** will allocate only the cells using the selected carriers as neighbours.
   - **Force co-site cells as neighbours:** If selected, **9955** adds all the transmitters/cells located on the same site as the reference cell in its candidate neighbour list. The weight of this constraint can be defined. It is used to calculate the rank of each neighbour and its importance.
   - **Force exceptional pairs:** This option enables you to force/forbid some neighbour relations. Exceptional pairs are pairs of cells which will always or never be neighbours of each other.
   - **Delete existing neighbours:** If selected, **9955** deletes all the current neighbours and carries out a new neighbour allocation. If not selected, the existing neighbours are kept in the list.
3. Neighbour relation criterion:
   - **Allocation based on distance:**

     The allocation algorithm is based on the effective distance between the reference cell and its candidate neighbour.
   - **Algorithm based on coverage overlapping:**

     The coverage areas of the reference cell A and the candidate neighbour B must overlap ($S_A \cap S_B$).

     Two cases may exist for S_A:

     - 1st case: S_A is the area where the cell A is the best serving cell, with a 0dB margin.

       This means that the preamble signal received from A is greater than the minimum required (calculated from the preamble C/N threshold), and is the highest one. .
     - 2nd case: The margin is other than 0dB. S_A is the area where:

       The preamble signal level received from A exceeds the minimum required (calculated from the preamble C/N threshold) and is within a margin from the highest signal level.

     Two cases may exist for S_B:

     - 1st case: S_B is the area where the candidate neighbour is the best server. In this case, the margin must be set to 0dB.

       The signal level received from B exceeds the minimum required, and is the highest one.
     - 2nd case: The margin is other than 0dB. S_B is the area where:

       The signal level received from B exceeds the minimum required and is within a margin from the best signal level.

9955 calculates the percentage of the coverage area overlap ($\frac{S_A \cap S_B}{S_A} \times 100$) and compares this value with the % Min Covered Area. B is considered a neighbour of A if $\frac{S_A \cap S_B}{S_A} \times 100 \geq \%\ Min\ Covered\ Area$.

Candidate neighbours are ranked in the order of decreasing coverage area overlap percentages.

Next, **9955** calculates the importance of the automatically allocated neighbours. **9955** sorts the neighbours by decreasing importance in order to keep the ones with high importance. If the maximum number of neighbours to be allocated to each cell is exceeded, **9955** keeps the ones with high importance.

The importance (%) of neighbours depends on the distance and on the reason of allocation:

- **For allocation based on distance:**

Neighbour cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter/cell	If the Force co-site cells as neighbours option is selected	100 %
Neighbour relation that fulfils distance conditions	If the maximum distance is not exceeded	$1 - \frac{d}{d_{max}}$

d is the effective distance between the reference cell and the neighbour and d_{max} is the maximum inter-site distance.

- **For allocation based on coverage overlapping:**

Neighbour cause	When	Importance value
Existing neighbour	If the Delete existing neighbours option is not selected	Existing importance
Exceptional pair	If the Force exceptional pairs option is selected	100 %
Co-site transmitter/cell	If the Force co-site cells as neighbours option is selected	IF
Neighbourhood relationship that fulfils coverage conditions	If the % minimum covered area is exceeded	IF

The importance is evaluated using an Importance Function (IF), which takes into account the following factors:

- The distance factor (Di) denoting the distance between the possible neighbour transmitter and the reference transmitter.

$$(Di) = 1 - \frac{d}{d_{max}}$$

d is the effective distance (in m). It corresponds to the real inter-transmitter distance weighted by the azimuths of antennas.

d_{max} is the maximum distance between the reference transmitter and a possible neighbour.

- The co-site factor (C): a Boolean,
- The overlapping factor (O): the percentage of overlapping.

The IF is user-definable using the Min importance and Max importance fields.

Factor	Min importance	Default value	Max importance	Default value
Distance factor (Di)	Min(Di)	1%	Max(Di)	10%
Overlapping factor (O)	Min(O)	10%	Max(O)	60%
Co-site factor (C)	Min(C)	60%	Max(C)	100%

The IF evaluates importance as follows:

Co-site Neighbourhood cause	IF	Resulting IF using the default values from the table above
No	Min(O)+Delta(O){Max(Di)(Di)+(100%-Max(Di))(O)}	10%+50%{10%(Di)+90%(O)}
Yes	Min(C)+Delta(C){Max(Di)(Di)/(Max(Di)+Max(O))+ Max(O)(O)/(Max(Di)+Max(O))}	60%+40%{1/7%(Di)+6/7%(O)}

Where

Delta(X)=Max(X)-Min(X)

- Set Min(Di) and Max(Di) to 0% if you do not want to take into account the distance factor in the importance calculation.
- If the Min and Max value ranges of the importance function factors do not overlap, the neighbours will be ranked by neighbour cause. With the default values for minimum and maximum importance fields, neighbours will be ranked in this order: co-site neighbours and neighbours allocated based on coverage overlapping.
- If the Min and Max value ranges of the importance function factors overlap, the neighbours may be ranked differently. There can be a mix of the neighbourhood causes.

In the results, **9955** displays only the cells for which it finds new neighbours.

9.5.3 Automatic Frequency Planning Using the AFP

The role of an Automatic Frequency Planning (AFP) tool is to assign frequencies (channels) to cells of a network such that the overall network performance is optimised. In other words, the interference within the network is reduced as much as possible. Co-channel interference is the main reason for overall network quality degradation in WiMAX. In order to improve network performance, the WiMAX AFP tries to minimise co- and adjacent channel interference as much as possible while respecting any constraints input to it. The main constraints are the resources available for allocation, i.e., the number of frequencies with which the AFP can work, and the relationships to take into account, i.e., interference matrices, neighbours, and distance between transmitters.

The AFP is based on a cost function which represents the interference level in the network. The aim of the AFP is to minimise the cost. The best, or optimum, frequency plan is the one which corresponds to the lowest cost.

The following describes the AFP's automatic planning method for frequencies in WiMAX networks, which takes into account interference matrices, neighbour relations, and distance between transmitters.

The AFP takes into account the cells of all the TBC transmitters. The cells to be allocated will be called TBA cells. They must fulfil the following conditions:

- They are active,
- Their channel allocation status is not set to locked,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone.

If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

9.5.3.1 Constraint and Relationship Weights

The AFP is based on a cost function which takes into account the following separation constraint:

- Required channel separation Λ_{Req} for co-site cells: 2 channel bandwidths of the TBA cell.
- Required channel separation Λ_{Req} for neighbour cells: 1 channel bandwidth of the TBA cell.

The above separation constraint is studied between each TBA cell and its related cells. **9955** calculates the cost between each individual TBA and related cell, and then the overall cost for the TBA cell.

Related cells of a TBA cell are:

- Its neighbours, if the check box "Existing neighbours" is selected,

  Assigned weight $\omega_{Neighbour} = 0.5$

- Cells that are listed in the interference matrix of the TBA cell,

  Assigned weight $\omega_{IM} = 0.3$

- Cells within the cell's (or the default) minimum reuse distance, if the check box "Reuse distance" is selected,

  Assigned weight $\omega_{Distance} = 0.2$

The sum of the weights assigned to the above relations is 1.

You can modify these weights in your WiMAX document. The absolute values of the constraint weights are calculated from the relative weights (%) defined in the **Constraint Weights** dialogue as follows:

$$\omega_{Neighbour} = \frac{\%\omega_{Neighbour}}{\%\omega_{Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{IM} = \frac{\%\omega_{IM}}{\%\omega_{Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{Distance} = \frac{\%\omega_{Distance}}{\%\omega_{Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

9.5.3.2 Cost Calculation

9955 calculates the separation constraint violation level between the TBA cell $TX_i(ic)$ and its related cell $TX_j(jc)$ as follows:

$$VL_{Sep}^{TX_i(ic)-TX_j(jc)} = \begin{cases} \left(\dfrac{\Lambda_{Req}^{TX_i(ic)-TX_j(jc)} - \Lambda^{TX_i(ic)-TX_j(jc)}}{\Lambda_{Req}^{TX_i(ic)-TX_j(jc)}}\right)^2 & if\ \ \Lambda^{TX_i(ic)-TX_j(jc)} < \Lambda_{Req}^{TX_i(ic)-TX_j(jc)} \\ 0 & Otherwise \end{cases}$$

Where $\Lambda_{Req}^{TX_i(ic)-TX_j(jc)}$ is the required separation, and $\Lambda^{TX_i(ic)-TX_j(jc)}$ is the actual separation between channels used by $TX_i(ic)$ and $TX_j(jc)$ calculated as follows:

$$\Lambda^{TX_i(ic)-TX_j(jc)} = \left|\frac{F_{Start}^{TX_j(jc)} - F_{Start}^{TX_i(ic)}}{W_{Channel}^{TX_i(ic)}}\right|$$

Where $F_{Start}^{TX_j(jc)}$ is the start frequency of the channel used by $TX_j(jc)$ calculated as follows:

$$F_{Start}^{TX_j(jc)} = F_{Start-FB}^{TX_j(jc)} + N_{Channel}^{TX_j(jc)} \times W_{Channel}^{TX_j(jc)}$$

$F_{Start}^{TX_i(ic)}$ is the start frequency of the channel used by $TX_i(ic)$ calculated as follows:

$$F_{Start}^{TX_i(ic)} = F_{Start-FB}^{TX_i(ic)} + N_{Channel}^{TX_i(ic)} \times W_{Channel}^{TX_i(ic)}$$

Where $F_{Start-FB}^{TX_i(ic)}$ and $F_{Start-FB}^{TX_j(jc)}$ are the start frequencies of the frequency bands assigned to the cells $TX_i(ic)$ *and* $TX_j(jc)$ respectively. $F_{Start-FB}$ can be the start frequency of a TDD frequency band ($F_{Start-FB-TDD}$), or the downlink start frequency of an FDD frequency band ($F_{Start-FB-FDD-DL}$). $N_{Channel}^{TX_i(ic)}$ and $N_{Channel}^{TX_j(jc)}$ are the channel numbers assigned to cells $TX_i(ic)$ *and* $TX_j(jc)$ respectively. For FDD networks, **9955** considers that the same channel number is assigned to a cell in the downlink and uplink, i.e., the channel number you assign to a cell is considered for uplink and downlink both. And, $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$ are the bandwidths of the channels assigned to cells $TX_i(ic)$ and $TX_j(jc)$ respectively.

The cost of the relation between the TBA cell and its related cell is calculated next:

$$\$^{TX_i(ic)-TX_j(jc)} = VL_{Sep}^{TX_i(ic)-TX_j(jc)} \times \left(\omega_{Neighbour} \times \iota_{Neighbour}^{TX_i(ic)-TX_j(jc)} + \omega_{Distance} \times \iota_{Distance}^{TX_i(ic)-TX_j(jc)}\right) + \omega_{IM} \times \iota_{IM}^{TX_i(ic)-TX_j(jc)}$$

Where $\iota_{Neighbour}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related neighbour cell. $\iota_{Neighbour}^{TX_i(ic)-TX_j(jc)}$ is calculated during automatic neighbour planning by **9955** as explained in "Automatic Neighbour Planning" on page 708. For manual neighbour planning, this value is equal to 1.

$\iota_{IM}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related interfering cell. $\iota_{IM}^{TX_i(ic)-TX_j(jc)}$ is calculated during interference matrix calculation as explained in "Interference Matrix Calculation" on page 723.

$\iota_{Distance}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA and its related cell with respect to the distance between them. $\iota_{Distance}^{TX_i(ic)-TX_j(jc)}$ is calculated as explained in "Distance Importance Calculation" on page 724.

9955 calculates the quality reduction factor for the TBA cell and its related cell from the cost calculated above as follows:

$$QRF^{TX_i(ic)-TX_j(jc)} = 1 - \$^{TX_i(ic)-TX_j(jc)}$$

The quality reduction factor is a measure of the cost of an individual relation.

The total cost of the current frequency plan for any TBA cell is given as follows, considering all the cells with which the TBA cell has relations:

$$\$_{Total}^{TX_i(ic)} = 1 - \prod_{TX_j(jc)} QRF^{TX_i(ic)-TX_j(jc)}$$

And, the total cost of the current frequency plan for the entire network is simply the sum of the total TBA cell costs calculated above, i.e.,

$$\$_{Total} = \sum_{TX_i(ic)} \$_{Total}^{TX_i(ic)}$$

9.5.3.3 AFP Algorithm

The AFP algorithm is an iterative algorithm which:

- Calculates the cost (as described above) of the initial frequency plan,
- Tries different frequency plans in order to reduce the cost,
- Memorises the different frequency plans in order to determine the best one, i.e., the frequency plan which provides the lowest total cost,
- Stops when it is unable to improve the cost of the network, and proposes the last known best frequency plan as the solution.

9.5.4 Automatic Preamble Index Planning Using the AFP

IEEE 802.16e defines 114 preamble indexes. Each preamble index, from 0 to 113, contains the following information:

- Segment number (0, 1, or 2),
- DL PermBase (0 to 31) for the obligatory first DL PUSC zone, and
- A pseudo-noise sequence transmitted using the subcarriers corresponding to the preamble carrier set.

The downlink subframe can be divided into a 3-segment structure, and includes a preamble which begins the transmission (the first symbol of the downlink transmission). The preamble subcarriers are divided into 3 carrier sets. There are three possible groups consisting of a carrier set each which may be used by any segment. These are defined by allocation of different subcarriers to each one of them. The subcarriers are modulated using a BPSK modulation with a specific Pseudo-Noise (PN) sequence.

Preamble carrier sets are defined using equation below:

$$PreambleCarrierSet_n = n + k \times 3$$

Where $PreambleCarrierSet_n$ gives the subcarriers used by the preamble, n is the number of the preamble carrier set indexed 0, 1, or 2, k is a running index from 0 to 567 for FFT 2048, from 0 to 283 for FFT 1024, from 0 to 142 for FFT 512, and from 0 to 35 for FFT 128.

In a WiMAX network, each base station transmits a different PN sequence, out of the 114 available, on the preamble carrier set. A mobile trying to connect to the network scans all the preamble subcarriers, listens to all the preambles (i.e., PN sequences) from all the base stations it can receive, and compares the PN sequences it is receiving with the 114 stored in its memory in order to detect the preamble index from the PN sequence.

It selects the base station as its server whose preamble it receives with either the highest signal level or the highest C/(I+N). Once the best server is known, its PN sequence is used to identify its transmission. The PN sequence of the best server gives the preamble index, which in turn gives the segment number, and the IDCell (DL PermBase of the first DL PUSC zone, referred to as Cell PermBase in **9955**). Therefore, the mobile knows which subcarriers to listen to for the FCH, DCD, UCD, DL-MAP, and UL-MAP.

As can be understood from the above description, if all the cells in the network transmit the same preamble index, the network will have 100% interference on downlink preambles, and it will be impossible for a mobile to identify different cells. Cell search and selection will be impossible. Therefore, it is important to intelligently plan preamble indexes to cells so as to reduce preamble interference, and allow easy recognition of cells by mobiles.

The following describes the AFP's automatic planning method for preamble indexes in a WiMAX network, which takes into account interference matrices, neighbour relations (first-order neighbours, first-order neighbours of a common WiMAX cell, and optionally second-order neighbours), distance between transmitters, and the frequency plan of the network.

The AFP takes into account the cells of all the TBC transmitters. The cells to be allocated will be called TBA cells. They must fulfil the following conditions:

- They are active,
- Their preamble index status or segment is not set to locked,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone.

> If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

9.5.4.1 Constraint and Relationship Weights

The AFP is based on a cost-based function which takes into account the following constraints, in the order of priority:

1. Same preamble index,

   Assigned weight $\omega_{PI} = 0.75$

2. Same segment number,

   Assigned weight $\omega_{Seg} = 0$

3. Same cell permbase,

   Assigned weight $\omega_{PB} = 0.25$

> The sum of the weights assigned to the above constraints is 1.

You can modify these weights in your WiMAX document. The absolute values of the constraint weights are calculated from the relative weights (%) defined in the **Constraint Weights** dialogue as follows:

$$\omega_{PI} = \frac{\%\omega_{PI}}{\%\omega_{PI} + \%\omega_{Seg} + \%\omega_{PB}}$$

$$\omega_{Seg} = \frac{\%\omega_{Seg}}{\%\omega_{PI} + \%\omega_{Seg} + \%\omega_{PB}}$$

$$\omega_{PB} = \frac{\%\omega_{PB}}{\%\omega_{PI} + \%\omega_{Seg} + \%\omega_{PB}}$$

The above constraints are studied between each TBA cell and its related cells. **9955** calculates the cost between each individual TBA and related cell, and then the overall cost for the TBA cell.

Related cells of a TBA cell are:

- Its neighbours, if the check box "Existing neighbours" is selected,

  Assigned weight $\omega_{Neighbour} = 0.35$

  TBA cells which are first-order neighbours of a common cell are also related to each other through that cell. This relation is also taken into account,

  Assigned weight $\omega_{Inter-Neighbour} = 0.15$

  You can choose to not take into account the preamble index collision between neighbours of a common cell by adding an option in the Atoll.ini file (see the *Administrator Manual*). If the collision between neighbours of a common cell is not taken into account, the weight assigned to the direct first-order neighbour relation alone is $\omega_{Neighbour} = 0.5$ and that of the collision between neighbours of a common cell is of course $\omega_{Inter-Neighbour} = 0$.

By adding an option in the Atoll.ini file (see the *Administrator Manual*), second-order neighbours can also be taken into account. In this case, the assigned weights are: $\omega_{Neighbour} = 0.25$, $\omega_{2nd-Neighbour} = 0.15$, and $\omega_{Inter-Neighbour} = 0.10$.

- Cells that are listed in the interference matrix of the TBA cell,

  Assigned weight $\omega_{IM} = 0.3$

- Cells within the cell's (or the default) minimum reuse distance, if the check box "Reuse distance" is selected,

  Assigned weight $\omega_{Distance} = 0.2$

> The sum of the weights assigned to the above relations is 1.

You can modify these weights in your WiMAX document. The absolute values of the constraint weights are calculated from the relative weights (%) defined in the **Constraint Weights** dialogue as follows:

$$\omega_{Neighbour} = \frac{\%\omega_{Neighbour}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{Inter-Neighbour} = \frac{\%\omega_{Inter-Neighbour}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{2nd-Neighbour} = \frac{\%\omega_{2nd-Neighbour}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{IM} = \frac{\%\omega_{IM}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

$$\omega_{Distance} = \frac{\%\omega_{Distance}}{\%\omega_{Neighbour} + \%\omega_{Inter-Neighbour} + \%\omega_{2nd-Neighbour} + \%\omega_{IM} + \%\omega_{Distance}}$$

9.5.4.2 Cost Calculation

9955 calculates the constraint violation levels between the TBA cell $TX_i(ic)$ and its related cell $TX_j(jc)$ as follows:

$$VL_1^{TX_i(ic)-TX_j(jc)} = r_O^{TX_i(ic)-TX_j(jc)} \times (\omega_{PI} \times p_{Coll}^{PI} + \omega_{PB} \times p_{Penalty}^{PB})$$

$$VL_2^{TX_i(ic)-TX_j(jc)} = r_O^{TX_i(ic)-TX_j(jc)} \times (\omega_{Seg} \times p_{Coll}^{Seg})$$

If $TX_i(ic)$ and $TX_i(jc)$ are co-transmitter cells, and the option Allocate Same Segment to Co-transmitter Cells has been selected, and $N_{Seg}^{TX_i(ic)} \neq N_{Seg}^{TX_i(jc)}$, then $VL_1^{TX_i(ic)-TX_j(jc)} + VL_2^{TX_i(ic)-TX_j(jc)} = 1$.

Where $r_O^{TX_i(ic)-TX_j(jc)}$ is the total channel overlap ratio between the $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 653, ω_{PI}, ω_{Seg}, and ω_{PB} are the weights assigned to the preamble index, segment number, and cell permbase constraints.

p_{Coll}^{PI} is the preamble index collision probability given by $p_{Coll}^{PI} = \begin{cases} 1 & \text{if } PI^{TX_i(ic)} = PI^{TX_j(jc)} \\ 0 & \text{if } PI^{TX_i(ic)} \neq PI^{TX_j(jc)} \end{cases}$.

p_{Coll}^{Seg} is the segment number collision probability. If $TX_i(ic)$ and $TX_j(jc)$ are co-transmitter cells, and the option Allocate Same Segment to Co-transmitter Cells has been selected, p_{Coll}^{Seg} is given by $p_{Coll}^{Seg} = \begin{cases} 0 & if\ N_{Seg}^{TX_i(ic)} = N_{Seg}^{TX_j(jc)} \\ 1 & if\ N_{Seg}^{TX_i(ic)} \neq N_{Seg}^{TX_j(jc)} \end{cases}$. Otherwise,

$$p_{Coll}^{Seg} = \begin{cases} 1 & if\ N_{Seg}^{TX_i(ic)} = N_{Seg}^{TX_j(jc)} \\ 0 & if\ N_{Seg}^{TX_i(ic)} \neq N_{Seg}^{TX_j(jc)} \end{cases}.$$

$p_{Penalty}^{PB}$ is the cell permbase penalty given by $p_{Penalty}^{PB} = \begin{cases} 1 & if\ PB^{TX_i(ic)} \neq PB^{TX_j(jc)}\ AND\ Site^{TX_i(ic)} = Site^{TX_j(jc)} \\ 0.001 & if\ PB^{TX_i(ic)} \neq PB^{TX_j(jc)}\ AND\ Site^{TX_i(ic)} \neq Site^{TX_j(jc)} \\ 0 & Otherwise \end{cases}$ if the cell permbase planning strategy is set to "Same per site", and by $p_{Penalty}^{PB} = 0$ if the cell permbase planning strategy is set to "Free". The cell permbase penalty models the cell permbase constraint.

Next, **9955** calculates the importance of the neighbour relations between the TBA cell and its related cell.

$$\iota_{\Sigma Neighbours}^{TX_i(ic)-TX_j(jc)} = \omega_{Neighbour} \times \iota_{Neighbour}^{TX_i(ic)-TX_j(jc)} + \omega_{Inter-Neighbour} \times \iota_{Inter-Neighbour} + \omega_{2nd-Neighbour} \times \iota_{2nd-Neighbour}$$

Where $\iota_{Neighbour}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related neighbour cell. $\iota_{Neighbour}^{TX_i(ic)-TX_j(jc)}$ is calculated during automatic neighbour planning by **9955** as explained in "Automatic Neighbour Planning" on page 708. For manual neighbour planning, this value is equal to 1.

$\iota_{Inter-Neighbour}$ is calculated from the neighbour relationship importance values calculated during automatic neighbour planning. If two cells are neighbours of a common cell and have the same preamble index assigned, the importance of the preamble index collision is the average of their neighbour importance values with the common neighbour cell. If more than one pair of neighbours of the TBA cell has the same preamble index assigned, then the importance is the highest value among all the averages:

$$\iota_{Inter-Neighbour} = \underset{\substack{All\ Neighbour\ Pairs \\ with\ PI\ Collisions}}{Max} \left(\frac{\iota_{Neighbour}^{TX_i(ic)-TX_{j1}(j1c)} + \iota_{Neighbour}^{TX_i(ic)-TX_{j2}(j2c)}}{2} \right)$$

Where $TX_{j1}(j1c)$ and $TX_{j2}(j2c)$ are two neighbours of the TBA cell $TX_i(ic)$ that have the same preamble index assigned.

$\iota_{2nd-Neighbour}$ is calculated from the neighbour relationship importance values calculated during automatic neighbour planning. If the TBA cell has the same preamble index assigned as one of its second-order neighbours, the importance of the preamble index collision is the multiple of the importance values of the first order neighbour relations between the TBA cell and its second order neighbour. If the TBA cell is related to its second order neighbour through more than one first order neighbour, the importance is the highest value among all the multiples:

$$\iota_{2nd-Neighbour} = \underset{\substack{All\ Neighbour\ Pairs \\ with\ PI\ Collisions}}{Max} \left(\iota_{Neighbour}^{TX_i(ic)-TX_j(jc)} \times \iota_{Neighbour}^{TX_j(jc)-TX_k(kc)} \right)$$

Where $TX_k(kc)$ is the second-order neighbour of $TX_i(ic)$ through $TX_j(jc)$.

Next, **9955** calculates the importance of the interference relations between the TBA cell and its related cell.

$$\iota_{Interference}^{TX_i(ic)-TX_j(jc)} = \omega_{IM} \times \iota_{IM}^{TX_i(ic)-TX_j(jc)} + \omega_{Distance} \times \iota_{Distance}^{TX_i(ic)-TX_j(jc)}$$

$\iota_{IM}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related interfering cell. $\iota_{IM}^{TX_i(ic)-TX_j(jc)}$ is calculated during interference matrix calculation as explained in "Interference Matrix Calculation" on page 723.

$\iota_{Distance}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA and its related cell with respect to the distance between them. $\iota_{Distance}^{TX_i(ic)-TX_j(jc)}$ is calculated as explained in "Distance Importance Calculation" on page 724.

From the constraint violation levels and the importance values of the relations between the TBA and its related cell, **9955** calculates the quality reduction factor for the pair as follows:

$$QRF^{TX_i(ic) - TX_j(jc)} = 1 - \left\{ \left(VL_1^{TX_i(ic) - TX_j(jc)} + VL_2^{TX_i(ic) - TX_j(jc)} \right) \times \iota_{Interference}^{TX_i(ic) - TX_j(jc)} + VL_1^{TX_i(ic) - TX_j(jc)} \times \iota_{\Sigma Neighbours}^{TX_i(ic) - TX_j(jc)} \right\}$$

The quality reduction factor is a measure of the cost of an individual relation.

The total cost of the current preamble index plan for any TBA cell is given as follows, considering all the cells with which the TBA cell has relations:

$$\$_{Total}^{TX_i(ic)} = 1 - \prod_{TX_j(jc)} QRF^{TX_i(ic) - TX_j(jc)}$$

And, the total cost of the current preamble index plan for the entire network is simply the sum of the total TBA cell costs calculated above, i.e.,

$$\$_{Total} = \sum_{TX_i(ic)} \$_{Total}^{TX_i(ic)}$$

9.5.4.3 AFP Algorithm

The AFP algorithm is an iterative algorithm which:

- Calculates the cost (as described above) of the initial preamble index plan,
- Tries different preamble index plans in order to reduce the cost,
- Memorises the different plans in order to determine the best one, i.e., which provides the lowest total cost,
- Stops when it is unable to improve the cost of the network, and proposes the last known best preamble index plan as the solution.

9.5.5 Automatic Zone PermBase Planning Using the AFP

PermBases are numbers which are used as seeds in the permutation of subcarriers (mapping between physical and logical subcarrier numbers) and their allocation to subchannels. Subchannels in a channel contain different physical subcarriers when different permbases are used as seeds.

Downlink PUSC permutation zones use 2 permbases:

1. The first DL PUSC permutation zone uses the cell permbase (mapped to the preamble index of the cell). It is called IDCell in the IEEE specifications. It is a number from 0 to 31.
2. The second DL PUSC permutation zone uses the zone permbase, also a number from 0 to 31.

Other downlink permutation zones only use zone permbases.

Uplink permutation zones also use only zone permbases. However, the uplink zone permbase is a number from 0 to 69.

The following describes the AFP's automatic planning method for zone permbases in a WiMAX network, which takes into account interference matrices, neighbour relations (first-order neighbours, first-order neighbours of a common WiMAX cell, and optionally second-order neighbours), distance between transmitters, and the frequency plan of the network.

The AFP takes into account the cells of all the TBC transmitters. The cells to be allocated will be called TBA cells. They must fulfil the following conditions:

- They are active,
- Their zone permbase status is not set to locked,
- They satisfy the filter criteria applied to the Transmitters folder,
- They are located inside the focus zone.

> - In the following description, ZPB is used for the downlink zone permbases (ZPB_{DL}) and uplink zone permbases (ZPB_{UL}) without distinction.
> - If no focus zone exists in the ATL document, **9955** takes into account the computation zone.

9.5.5.1 Constraint and Relationship Weights

The AFP is based on a cost-based function which takes into account the following constraint:

- Same zone permbase,

  Assigned weight $\omega_{ZPB} = 1$

The above constraint is studied between each TBA cell and its related cells. **9955** calculates the cost between each individual TBA and related cell, and then the overall cost for the TBA cell.

Related cells of a TBA cell are:

- Its neighbours, if the check box "Existing neighbours" is selected,

  Assigned weight $\omega_{Neighbour} = 0.35$

  TBA cells which are first-order neighbours of a common cell are also related to each other through that cell. This relation is also taken into account,

  Assigned weight $\omega_{Inter-Neighbour} = 0.15$

  You can choose to not take into account the zone permbase collision between neighbours of a common cell by adding an option in the Atoll.ini file (see the *Administrator Manual*). If the collision between neighbours of a common cell is not taken into account, the weight assigned to the direct first-order neighbour relation alone is $\omega_{Neighbour} = 0.5$ and that of the collision between neighbours of a common cell is of course $\omega_{Inter-Neighbour} = 0$.

  By adding an option in the Atoll.ini file (see the *Administrator Manual*), second-order neighbours can also be taken into account. In this case, the assigned weights are: $\omega_{Neighbour} = 0.25$, $\omega_{2nd-Neighbour} = 0.10$, and $\omega_{Inter-Neighbour} = 0.15$.

- Cells that are listed in the interference matrix of the TBA cell,

  Assigned weight $\omega_{IM} = 0.3$

- Cells within the cell’s (or the default) minimum reuse distance, if the check box "Reuse distance" is selected,

  Assigned weight $\omega_{Distance} = 0.2$

> The sum of the weights assigned to the above relations is 1.

9.5.5.2 Cost Calculation

9955 calculates the constraint violation level between the TBA cell $TX_i(ic)$ and its related cell $TX_j(jc)$ as follows:

$$VL^{TX_i(ic)-TX_j(jc)} = r_O^{TX_i(ic)-TX_j(jc)} \times (\omega_{ZPB} \times p_{Coll}^{ZPB})$$

Where $r_O^{TX_i(ic)-TX_j(jc)}$ is the total channel overlap ratio between the $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 653, and ω_{ZPB} is the weight assigned to the zone permbase constraint.

p_{Coll}^{ZPB} is the zone permbase collision probability given by $p_{Coll}^{ZPB} = \begin{cases} 1 & \text{if } ZPB^{TX_i(ic)} = ZPB^{TX_j(jc)} \\ 0 & \text{if } ZPB^{TX_i(ic)} \neq ZPB^{TX_j(jc)} \end{cases}$.

Next, **9955** calculates the importance of the relation between the TBA cell and its related cell.

$$\iota_{Total}^{TX_i(ic)-TX_j(jc)} = \omega_{Neighbour} \times \iota_{Neighbour}^{TX_i(ic)-TX_j(jc)} + \omega_{Inter-Neighbour} \times \iota_{Inter-Neighbour} + \omega_{2nd-Neighbour} \times \iota_{2nd-Neighbour} + \omega_{IM} \times \iota_{IM}^{TX_i(ic)-TX_j(jc)} + \omega_{Distance} \times \iota_{Distance}^{TX_i(ic)-TX_j(jc)}$$

Where $\iota_{Neighbour}^{TX_i(ic)-TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related neighbour cell. $\iota_{Neighbour}^{TX_i(ic)-TX_j(jc)}$ is calculated during automatic neighbour planning by **9955** as explained in "Automatic Neighbour Planning" on page 708. For manual neighbour planning, this value is equal to 1.

$\iota_{Inter-Neighbour}$ is calculated from the neighbour relationship importance values calculated during automatic neighbour planning. If two cells are neighbours of a common cell and have the same zone permbase assigned, the importance of the zone permbase collision is the average of their neighbour importance values with the common neighbour cell. If more than one pair of neighbours of the TBA cell has the same zone permbase assigned, then the importance is the highest value among all the averages:

$$\iota_{Inter-Neighbour} = \underset{\substack{\text{All Neighbour Pairs} \\ \text{with ZPB Collisions}}}{Max} \left(\frac{\iota_{Neighbour}^{TX_i(ic) - TX_{j1}(j1c)} + \iota_{Neighbour}^{TX_i(ic) - TX_{j2}(j2c)}}{2} \right)$$

Where $TX_{j1}(j1c)$ and $TX_{j2}(j2c)$ are two neighbours of the TBA cell $TX_i(ic)$ that have the same zone permbase assigned.

$\iota_{2nd-Neighbour}$ is calculated from the neighbour relationship importance values calculated during automatic neighbour planning. If the TBA cell has the same zone permbase assigned as one of its second-order neighbours, the importance of the zone permbase collision is the multiple of the importance values of the first order neighbour relations between the TBA cell and its second order neighbour. If the TBA cell is related to its second order neighbour through more than one first order neighbour, the importance is the highest value among all the multiples:

$$\iota_{2nd-Neighbour} = \underset{\substack{\text{All Neighbour Pairs} \\ \text{with ZPB Collisions}}}{Max} \left(\iota_{Neighbour}^{TX_i(ic) - TX_j(jc)} \times \iota_{Neighbour}^{TX_j(jc) - TX_k(kc)} \right)$$

Where $TX_k(kc)$ is the second-order neighbour of $TX_i(ic)$ through $TX_j(jc)$.

$\iota_{IM}^{TX_i(ic) - TX_j(jc)}$ is the importance of the relationship between the TBA cell and its related interfering cell. $\iota_{IM}^{TX_i(ic) - TX_j(jc)}$ is calculated during interference matrix calculation as explained in "Interference Matrix Calculation" on page 723.

$\iota_{Distance}^{TX_i(ic) - TX_j(jc)}$ is the importance of the relationship between the TBA and its related cell with respect to the distance between them. $\iota_{Distance}^{TX_i(ic) - TX_j(jc)}$ is calculated as explained in "Distance Importance Calculation" on page 724.

From the constraint violation level and the total importance of the relation between the TBA and its related cell, **9955** calculates the quality reduction factor for the pair as follows:

$$QRF^{TX_i(ic) - TX_j(jc)} = 1 - VL^{TX_i(ic) - TX_j(jc)} \times \iota_{Total}^{TX_i(ic) - TX_j(jc)}$$

The quality reduction factor is a measure of the cost of an individual relation.

The total cost of the current zone permbase plan for any TBA cell is given as follows, considering all the cells with which the TBA cell has relations:

$$\$_{Total}^{TX_i(ic)} = 1 - \prod_{TX_j(jc)} QRF^{TX_i(ic) - TX_j(jc)}$$

And, the total cost of the current zone permbase plan for the entire network is simply the sum of the total TBA cell costs calculated above, i.e.,

$$\$_{Total} = \sum_{TX_i(ic)} \$_{Total}^{TX_i(ic)}$$

9.5.5.3 AFP Algorithm

The AFP algorithm is an iterative algorithm which:

- Calculates the cost (as described above) of the initial zone permbase plan,
- Tries different zone permbase plans in order to reduce the cost,
- Memorises the different plans in order to determine the best one, i.e., which provides the lowest total cost,
- Stops when it is unable to improve the cost of the network, and proposes the last known best zone permbase plan as the solution.

9.5.6 Appendices

9.5.6.1 Interference Matrix Calculation

The importance of an interference matrix entry ($\iota_{IM}^{TX_i(ic) - TX_j(jc)}$) is equal to the co- or adjacent chanenl interference probability calculated by taking the ratio of the interfered surface area to the total surface area of a cell.

The co-channel interference probability is calculated as follows:

$$\frac{S_{TX_i(ic)}\Bigg|_{C_{Preamble}^{TX_i(ic)} - 10 \times Log\left(10^{\frac{C_{Preamble}^{TX_j(jc)} + M_{Quality}}{10}} + 10^{\frac{n_{Preamble}^{TX_i(ic)}}{10}}\right) < T_{Preamble}^{TX_i(ic)}}}{S_{TX_i(ic)}}$$

The adjacent channel interference probability is calculated as follows:

$$\frac{S_{TX_i(ic)}\Bigg|_{C_{Preamble}^{TX_i(ic)} - 10 \times Log\left(10^{\frac{C_{Preamble}^{TX_j(jc)} + M_{Quality} + f_{ACS-FB}^{TX_i(ic)}}{10}} + 10^{\frac{n_{Preamble}^{TX_i(ic)}}{10}}\right) < T_{Preamble}^{TX_i(ic)}}}{S_{TX_i(ic)}}$$

For frequencies farther than the adjacent channel, $\iota_{IM}^{TX_i(ic) - TX_j(jc)} = 0$.

Here $S_{TX_i(ic)}$ is the best server coverage area of the cell $TX_i(ic)$, that comprises all the pixels where $CNR_{Preamble}^{TX_i(ic)} \geq T_{Preamble}^{TX_i(ic)}$ as calculated in "Service Area Calculation" on page 664. $S_{TX_i(ic)}\Big|_{Condition}$ is the best server coverage area of the cell $TX_i(ic)$ where the given condition is true. $C_{Preamble}^{TX_i(ic)}$ and $C_{Preamble}^{TX_j(jc)}$ are the received preamble signal levels from the cells $TX_i(ic)$ and $TX_j(jc)$ respectively, $n_{Preamble}^{TX_i(ic)}$ the preamble noise for the cell $TX_i(ic)$ as calculated in "Preamble Noise Calculation" on page 659, $M_{Quality}$ is the quality margin used for the interference matrices calculation, and $f_{ACS-FB}^{TX_i(ic)}$ is the adjacent channel suppression factor defined for the frequency band of the cell $TX_i(ic)$.

9.5.6.2 Distance Importance Calculation

The distance importance between two cells ($\iota_{Distance}^{TX_i(ic) - TX_j(jc)}$) is calculated as follows:

$$\iota_{Distance}^{TX_i(ic) - TX_j(jc)} = \begin{cases} 1 & \text{if } D^{TX_i(ic) - TX_j(jc)} < 1 \\ \dfrac{Log\left(\left(\dfrac{D_{Reuse}}{D^{TX_i(ic) - TX_j(jc)}}\right)^2\right)}{Log(D_{Reuse}^2)} & \text{Otherwise} \end{cases}$$

Where D_{Reuse} is the minimum reuse distance, either defined for each TBA cell individually or set for all the TBA cells in the AFP dialogue, and $D^{TX_i(ic) - TX_j(jc)}$ is the weighted distance between the TBA cell $TX_i(ic)$ and its related cell $TX_j(jc)$ calculated as follows:

$$D^{TX_i(ic) - TX_j(jc)} = d^{TX_i(ic) - TX_j(jc)} \times (1 + x \times (cos(\beta) - cos(\alpha) - 2))$$

$D^{TX_i(ic) - TX_j(jc)}$ is weighted according to the azimuths of the TBA cell and its related cell with respect to the straight line joining them. $d^{TX_i(ic) - TX_j(jc)}$ is the distance between the two cells considering any offsets with respect to the site locations. x is set to 15 % so that the maximum variation in $D^{TX_i(ic) - TX_j(jc)}$ due to the azimuths does not exceed 60 %. α and β are calculated from the azimuths of the two cells as shown in Figure 9.9 on page 725.

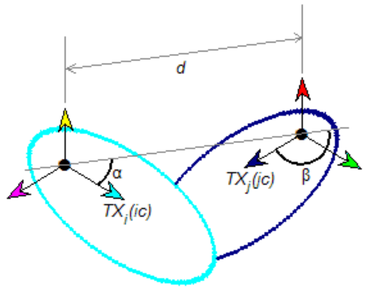


Figure 9.9: Weighted Distance Between Cells

The above formula implies that two cells facing each other will have a shorter effective distance between them than the real distance, and two cells pointing in opposite directions will have a greater effective distance.

The importance of the distance relation is explained in Figure 9.10 on page 725. This figure shows that cells that are located near (based on the effective distance which is weighted by the orientations of the cells) have high importance, which is interpreted as a high cost, and cells that are located far have low importance. Cells that are further than the reuse distance do not have any cost related to the distance relation.

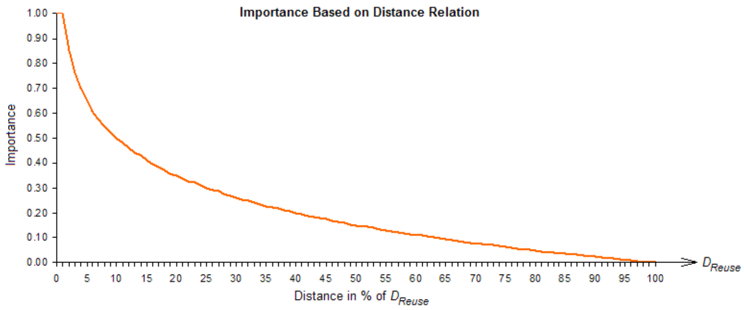


Figure 9.10: Importance Based on Distance Relation

Chapter 9

Wi-Fi Networks

This chapter describes Wi-Fi calculations

In this chapter, the following are explained:

- "Definitions" on page 729
- "Calculation Quick Reference" on page 732
- "Available Calculations" on page 737
- "Calculation Details" on page 747

10 Wi-Fi Networks

This chapter describes all the calculations performed in **9955** Wi-Fi documents. The first part of this chapter lists all the input parameters in the Wi-Fi documents, their significance, location in the **9955** GUI, and their usage. It also contains the lists of the formulas used for the calculations.

The second part describes all the calculation processes, i.e., signal level coverage predictions, point analysis calculations, signal quality coverage predictions, calculations on subscriber lists, and Monte Carlo simulations. The calculation algorithms used by these calculation processes are available in the next part.

The third part describes all the calculation algorithms used in all the calculations. These algorithms include the calculation of signal levels, noise, and interference for downlink and uplink, and the radio resource management algorithms used in Monte Carlo simulations.

- All the calculations are performed on TBC (to be calculated) transmitters. For the definition of TBC transmitters please refer to "Path Loss Matrices" on page 98.
- A cell refers to a transmitter-carrier (TX-c) pair. The cell being studied during a calculation is referred to as $TX_i(ic)$ in this chapter.
- All the calculation algorithms in this section are described for two types of cells.
  - A *studied cell* (represented by the subscript "*i*") comprising the studied transmitter TX_i and its carrier *ic*. It is the cell which is currently the focus of the calculation. For example, a victim cell when calculating the interference it is receiving from other cells.
  - *Other cells* (represented by the subscript "*j*") comprising the other transmitter TX_j and its carrier *jc*. The other cells in the network can be interfering cells (downlink) or the serving cells of interfering mobiles (uplink).
- All the calculation algorithms in this section are described for two types of receivers.
  - M_i: A pixel (coverage predictions), subscriber (calculations on subscriber lists), or mobile (Monte Carlo simulations) covered/served by the studied cell $TX_i(ic)$.
  - M_j: A mobile (Monte Carlo simulations) covered/served by any other cell $TX_j(jc)$.
- Logarithms used in this chapter (Log function) are base-10 unless stated otherwise.

10.1 Definitions

This table lists the input to calculations, coverage predictions, and simulations.

Name	Value	Unit	Description
K	1.38×10^{-23}	J/K	Boltzmann's constant
T	290	K	Ambient temperature
n_0	Calculation result ($10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$)	dBm/Hz	Power spectral density of thermal noise
r_{CP}	Global parameter	None	Cyclic Prefix Ratio (guard interval) Choice List: 1/4 (long), 1/8 (short)
M_{PC}	Global parameter	dB	Uplink power control margin
CNR_{Min}	Global parameter[a]	dB	Minimum signal to thermal noise threshold (interferer cutoff)
$N_{SCa-Total}$	Frame configuration parameter	None	Total number of subcarriers per channel (FFT size)
$N_{SCa-Used}$	Frame configuration parameter	None	Number of used subcarriers per channel
$N_{SCa-Data}$	Frame configuration zone parameter	None	Number of subcarriers per channel used for data transfer
N_{SCa-DC}	Hard-coded parameter ($N_{SCa-DC} = 1$)	None	Number of DC subcarriers per channel
$N_{SCa-Pilot}$	Calculation result ($N_{SCa-Pilot} = N_{SCa-Used} - N_{SCa-Data}$)	None	Number of pilot subcarriers per channel

Name	Value	Unit	Description
$N_{SCa-Guard}$	Calculation result ($N_{SCa-Guard} = N_{SCa-Total} - N_{SCa-Used} - N_{SCa-DC}$)	None	Number of guard subcarriers per channel
$W_{Channel}$	Frequency band parameter	MHz	Channel bandwidth
$N_{Channel}^{First}$	Frequency band parameter	None	First channel number of the frequency band
$N_{Channel}^{Last}$	Frequency band parameter	None	Last channel number of the frequency band
$F_{Start-FB-DL}$	Frequency band parameter	MHz	DL Start frequency of the frequency band
$F_{Start-FB-UL}$	Frequency band parameter	MHz	UL Start frequency of the frequency band
f_{ACS-FB}	Frequency band parameter	dB	Adjacent Channel Suppression Factor
$f_{IRF}^{Inter-Tech}$	Network parameter	dB	Inter-technology interference reduction factor
B	Bearer parameter	None	Bearer index
Mod_B	Bearer parameter	None	Modulation used by the bearer
CR_B	Bearer parameter	None	Coding rate of the bearer
η_B	Bearer parameter	bits/ symbol	Bearer Efficiency
T_B	Bearer parameter	dB	Bearer selection threshold
nf^{TX}	Transmitter parameter	dB	Transmitter noise figure
N_{Ant-TX}	Transmitter parameter	None	Number of antennas used for MIMO in transmission
N_{Ant-RX}	Transmitter parameter	None	Number of antennas used for MIMO in reception
G^{TX}	Antenna parameter	dB	Transmitter antenna gain
L^{TX}	Transmitter parameter	dB	Transmitter loss
$N_{Channel}$	Cell parameter	None	Cell’s channel number
P_{DL}	Cell parameter	dBm	Power
TL_{DL}	Cell parameter	%	Downlink traffic load
TL_{UL}	Cell parameter	%	Uplink traffic load
TL_{DL-Max}	Cell parameter	%	Maximum downlink traffic load
TL_{UL-Max}	Cell parameter	%	Maximum uplink traffic load
NR_{UL}	Cell parameter	dB	Uplink noise rise
$N_{Users-Max}$	Cell parameter	None	Maximum number of users per cell
T_{AMS}	Cell parameter	dB	Adaptive MIMO switch threshold
T_{Min}	Cell parameter	dB	Minimum C/N threshold
$NR_{DL}^{Inter-Tech}$	Cell parameter	dB	Inter-technology downlink noise rise
$NR_{UL}^{Inter-Tech}$	Cell parameter	dB	Inter-technology uplink noise rise
$G_{SU-MIMO}^{Max}$	Cell Wi-Fi equipment parameter	None	Maximum SU-MIMO gain
G_{STTD}^{UL}	Cell Wi-Fi equipment parameter	dB	Uplink STTD/MRC gain

Name	Value	Unit	Description
p	Service parameter	None	Service priority
$B_{DL-Highest}$	Service parameter	None	Highest bearer used by a service in the downlink
$B_{UL-Highest}$	Service parameter	None	Highest bearer used by a service in the uplink
$B_{DL-Lowest}$	Service parameter	None	Lowest bearer used by a service in the downlink
$B_{UL-Lowest}$	Service parameter	None	Lowest bearer used by a service in the uplink
f_{Act}^{UL}	Service parameter	%	Uplink activity factor
f_{Act}^{DL}	Service parameter	%	Downlink activity factor
TPD_{Min-UL}	Service parameter	kbps	Minimum throughput demand in the uplink
TPD_{Min-DL}	Service parameter	kbps	Minimum throughput demand in the downlink
TPD_{Max-UL}	Service parameter	kbps	Maximum throughput demand in the uplink
TPD_{Max-DL}	Service parameter	kbps	Maximum throughput demand in the downlink
$TP_{Average}^{UL}$	Service parameter	kbps	Average requested throughput in the uplink
$TP_{Average}^{DL}$	Service parameter	kbps	Average requested throughput in the downlink
TP_{Offset}	Service parameter	kbps	Throughput offset
$f_{TP-Scaling}$	Service parameter	%	Scaling factor
L_{Body}	Service parameter	dB	Body loss
P_{Min}	Terminal parameter	dBm	Minimum terminal power allowed
P_{Max}	Terminal parameter	dBm	Maximum terminal power allowed
nf	Terminal parameter	dB	Terminal noise figure
G	Terminal parameter	dB	Terminal antenna gain
L	Terminal parameter	dB	Terminal loss
N_{Ant-TX}	Terminal parameter	None	Number of antennas used for MIMO in transmission
N_{Ant-RX}	Terminal parameter	None	Number of antennas used for MIMO in reception
$G_{SU-MIMO}^{Max}$	Terminal Wi-Fi equipment parameter	None	Maximum SU-MIMO gain
G_{STTD}^{DL}	Terminal Wi-Fi equipment parameter	dB	Downlink STTD/MRC gain
ΔG_{STTD}^{UL}	Clutter parameter	dB	Additional uplink STTD/MRC gain
ΔG_{STTD}^{DL}	Clutter parameter	dB	Additional downlink STTD/MRC gain
$f_{SU-MIMO}$	Clutter parameter	None	SU-MIMO gain factor
L_{Indoor}	Clutter parameter	dB	Indoor loss
L_{Path}	Propagation model result	dB	Path loss

Name	Value	Unit	Description
$M_{Shadowing-Model}$	Monte Carlo simulations: Random result calculated from model standard deviation Coverage Predictions: Result calculated from cell edge coverage probability and model standard deviation	dB	Model shadowing margin
$M_{Shadowing-C/I}$	Coverage Predictions: Result calculated from cell edge coverage probability and C/I standard deviation	dB	C/I shadowing margin

a. *Any interfering cell whose signal to thermal noise ratio is less than* CNR_{Min} *will be discarded.*

10.2 Calculation Quick Reference

The following tables list the formulas used in calculations.

10.2.1 Co- and Adjacent Channel Overlaps Calculation

Name	Value	Unit	Description
$F_{Start}^{TX_i(ic)}$	$F_{Start-FB}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First}\right)$	MHz	Start frequency for the channel number assigned to a cell
$F_{End}^{TX_i(ic)}$	$F_{Start-FB}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First} + 1\right)$	MHz	End frequency for the channel number assigned to a cell
$W_{CCO}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right)$	MHz	Co-channel overlap bandwidth
$r_{CCO}^{TX_i(ic)-TX_j(jc)}$	$\dfrac{W_{CCO}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Co-channel overlap ratio
$W_{ACO_L}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)}\right)$	MHz	Bandwidth of the lower-frequency adjacent channel overlap
$r_{ACO_L}^{TX_i(ic)-TX_j(jc)}$	$\dfrac{W_{ACO_L}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Lower-frequency adjacent channel overlap ratio
$W_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	$Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right)$	MHz	Bandwidth of the higher-frequency adjacent channel overlap
$r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	$\dfrac{W_{ACO_H}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$	None	Higher-frequency adjacent channel overlap ratio
$r_{ACO}^{TX_i(ic)-TX_j(jc)}$	$r_{ACO_L}^{TX_i(ic)-TX_j(jc)} + r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$	None	Adjacent channel overlap ratio
$r_O^{TX_i(ic)-TX_j(jc)}$	$\left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}}\right)$ $if \quad W_{Channel}^{TX_i(ic)} \geq W_{Channel}^{TX_j(jc)}$ $\left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}}\right) \times \dfrac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ $if \quad W_{Channel}^{TX_i(ic)} < W_{Channel}^{TX_j(jc)}$	None	Total overlap ratio

10.2.2 Signal Level Calculation (DL)

Name	Value	Unit	Description
$C_{DL}^{TX_i(ic)}$	$EIRP_{Traffic}^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$	dBm	Received signal level
$EIRP^{TX_i(ic)}$	$P_{DL}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$	dBm	EIRP of a cell

10.2.3 Noise Calculation (DL)

Name	Value	Unit	Description
$n_{0-DL}^{TX_i(ic)}$	$n_0 + 10 \times Log\left(\frac{N_{SCa-Used}^{TX_i(ic)}}{N_{SCa-Total}^{TX_i(ic)}}\right)$	dBm	Thermal noise for a cell
$n_{DL}^{TX_i(ic)}$	$n_{0-DL}^{TX_i(ic)} + nf^{M_i}$	dBm	Downlink noise for a cell

10.2.4 Interference Calculation (DL)

Name	Value	Unit	Description
$I_{DL}^{TX_j(jc)}$	$C_{DL}^{TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)} + f_{TL-DL}^{TX_j(jc)} + I_{DL}^{Inter-Tech}$	dBm	Interference generated by an interfering cell
$f_O^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to the co- and adjacent channel overlap
$f_{TL-DL}^{TX_j(jc)}$	$10 \times Log\left(TL_{DL}^{TX_j(jc)}\right)$	dB	Interference reduction factor due to downlink traffic load

10.2.5 C/N Calculation (DL)

Name	Value	Unit	Description
$CNR_{DL}^{TX_i(ic)}$	$C_{DL}^{TX_i(ic)} - n_{DL}^{TX_i(ic)}$ With MIMO (AMS) if $CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CNR_{DL}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$	dB	Downlink C/N for a cell

10.2.6 C/(I+N) Calculation (DL)

Name	Value	Unit	Description
$CINR_{DL}^{TX_i(ic)}$	$C_{DL}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$ With MIMO (AMS) if $CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CINR_{DL}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL}$	dB	Downlink C/(I+N) for a cell

Name	Value	Unit	Description
$(I+N)_{DL}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}$	dBm	Total Noise (I+N) for a cell

10.2.7 Signal Level Calculation (UL)

Name	Value	Unit	Description
$C_{UL}^{M_i}$	$EIRP_{UL}^{M_i} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{TX_i} - L^{TX_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$	dBm	Received uplink signal level
$EIRP_{UL}^{M_i}$	$P^{M_i} + G^{M_i} - L^{M_i}$ With $P^{M_i} = P_{Max}^{M_i}$ without power control and $P^{M_i} = P_{Eff}^{M_i}$ after power control	dBm	Uplink EIRP of a user equipment

10.2.8 Noise Calculation (UL)

Name	Value	Unit	Description
$n_{0-UL}^{TX_i(ic)}$	$n_0 + 10 \times Log\left(\frac{N_{SCa-Used}^{TX_i(ic)}}{N_{SCa-Total}^{TX_i(ic)}}\right)$	dBm	Thermal noise for a cell
$n_{UL}^{TX_i(ic)}$	$n_{0-UL}^{TX_i(ic)} + nf^{TX_i(ic)}$	dBm	Uplink noise for a cell

10.2.9 Interference Calculation (UL)

Name	Value	Unit	Description
$I_{UL}^{M_j}$	$C_{UL}^{M_j} + f_O^{TX_i(ic)-TX_j(jc)} + f_{TL-UL}^{M_j}$	dBm	Uplink interference received at a cell
$f_O^{TX_i(ic)-TX_j(jc)}$	$10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$	dB	Interference reduction factor due to the co- and adjacent channel overlap
$f_{TL-UL}^{M_j}$	$10 \times Log\left(TL_{UL}^{M_j}\right)$	dB	Interference reduction factor due to the interfering mobile's uplink traffic load
$NR_{UL}^{TX_i(ic)}$	$10 \times Log\left(\sum_{All\ TX_j(jc)}\sum_{All\ M_j}\left(10^{\frac{I_{UL}^{M_j}\big\vert_{\forall\ non\text{-}seg\ M_i}}{10}}\right) + 10^{\frac{n_{UL}^{TX_i(ic)}}{10}}\right) + NR_{UL}^{Inter-Tech} - n_{UL}^{TX_i(ic)}$	dB	Uplink noise at a cell
$(I+N)_{UL}^{TX_i(ic)}$	$NR_{UL}^{TX_i(ic)} + n_{UL}^{TX_i(ic)}$	dBm	Total Noise (I+N) for a cell

10.2.10 C/N Calculation (UL)

Name	Value	Unit	Description
$CNR_{UL}^{M_i}$	$C_{UL}^{M_i} - n_{UL}^{TX_i(ic)}$ With MIMO (AMS) if $CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CNR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$	dB	Uplink C/N at a cell

10.2.11 C/(I+N) Calculation (UL)

Name	Value	Unit	Description
$CINR_{UL}^{M_i}$	$CNR_{UL}^{M_i} - NR_{UL}^{TX_i(ic)}$ With MIMO (AMS) if $CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$: $CINR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL}$	dB	Uplink C/(I+N) at a cell

10.2.12 Calculation of Total Cell Resources

Name	Value	Unit	Description
$\Delta F^{TX_i(ic)}$	$\dfrac{W_{Channel}^{TX_i(ic)} \times 10^6}{N_{SCa-Total}^{TX_i(ic)}}$	kHz	Inter-subcarrier distance
$D_{Sym-Useful}^{TX_i(ic)}$	$\dfrac{1}{\Delta F^{TX_i(ic)}}$	sec	Useful symbol duration
D_{CP}	$\dfrac{r_{CP}}{\Delta F}$	sec	Cyclic prefix duration
$D_{Symbol}^{TX_i(ic)}$	$D_{Sym-Useful}^{TX_i(ic)} + D_{CP}$	sec	Symbol duration
$R_{DL}^{TX_i(ic)}$	$Floor\left(\dfrac{1}{D_{Symbol}^{TX_i(ic)}}\right) \times N_{SCa-Data}^{TX_i(ic)}$	Symbols	Total cell resources

10.2.13 Channel Throughput and Cell Capacity

Name	Value	Unit	Description
$CTP_{P-DL}^{M_i}$	$R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}$ With MIMO (AMS): $\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1))$ if $CNR_{DL}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$	kbps	Downlink peak MAC channel throughput
$CTP_{E-DL}^{M_i}$	$CTP_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$	kbps	Downlink effective MAC channel throughput
$CTP_{A-DL}^{M_i}$	$CTP_{E-DL}^{M_i} \times \dfrac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$	kbps	Downlink application channel throughput
$Cap_{P-DL}^{M_i}$	$CTP_{P-DL}^{M_i} \times TL_{DL-Max}^{TX_i(ic)}$	kbps	Downlink peak MAC cell capacity
$Cap_{E-DL}^{M_i}$	$Cap_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$	kbps	Downlink effective MAC cell capacity

Name	Value	Unit	Description
$Cap^{M_i}_{A-DL}$	$Cap^{M_i}_{E-DL} \times \frac{f^{M_i}_{TP-Scaling}}{100} - TP^{M_i}_{Offset}$	kbps	Downlink application cell capacity
$CTP^{M_i}_{P-UL}$	$R^{TX_i(ic)}_{UL} \times \eta_{B^{M_i}_{UL}}$ With MIMO (AMS): $\eta_{B^{M_i}_{UL}} = \eta_{B^{M_i}_{UL}} \times (1 + f_{SU-MIMO}(G^{Max}_{SU-MIMO} - 1))$ if $CNR^{TX_i(ic)}_{DL} > T^{TX_i(ic)}_{AMS}$	kbps	Uplink peak MAC channel throughput
$CTP^{M_i}_{E-UL}$	$CTP^{M_i}_{P-UL} \times \left(1 - BLER\left(B^{M_i}_{UL}\right)\right)$	kbps	Uplink effective MAC channel throughput
$CTP^{M_i}_{A-UL}$	$CTP^{M_i}_{E-UL} \times \frac{f^{M_i}_{TP-Scaling}}{100} - TP^{M_i}_{Offset}$	kbps	Uplink application channel throughput
$Cap^{M_i}_{P-UL}$	$CTP^{M_i}_{P-UL} \times TL^{TX_i(ic)}_{UL-Max}$	kbps	Uplink peak MAC cell capacity
$Cap^{M_i}_{E-UL}$	$Cap^{M_i}_{P-UL} \times \left(1 - BLER\left(B^{M_i}_{UL}\right)\right)$	kbps	Uplink effective MAC cell capacity
$Cap^{M_i}_{A-UL}$	$Cap^{M_i}_{E-UL} \times \frac{f^{M_i}_{TP-Scaling}}{100} - TP^{M_i}_{Offset}$	kbps	Uplink application cell capacity

10.2.14 Scheduling and Radio Resource Management

Name	Value	Unit	Description
$R^{M_i^{Sel}}_{Min-DL}$	$\frac{TPD^{M_i^{Sel}}_{Min-DL}}{CTP^{M_i^{Sel}}_{P-DL}}$	None	Resources allocated to a mobile to satisfy its minimum throughput demand in downlink
$R^{M_i^{Sel}}_{Min-UL}$	$\frac{TPD^{M_i^{Sel}}_{Min-UL}}{CTP^{M_i^{Sel}}_{P-UL}}$	None	Resources allocated to a mobile to satisfy its minimum throughput demand in uplink
$R^{TX_i(ic)}_{Rem-DL}$	$TL^{TX_i(ic)}_{DL-Max} - \sum_{M_i^{Sel}} R^{M_i^{Sel}}_{Min-DL}$	None	Remaining downlink cell resources after allocation for minimum throughput demands
$R^{TX_i(ic)}_{Rem-UL}$	$TL^{TX_i(ic)}_{DL-Max} - \sum_{M_i^{Sel}} R^{M_i^{Sel}}_{Min-UL}$	None	Remaining uplink cell resources after allocation for minimum throughput demands
$TPD^{M_i^{Sel}}_{Rem-DL}$	$TPD^{M_i^{Sel}}_{Max-DL} - TPD^{M_i^{Sel}}_{Min-DL}$	kbps	Remaining throughput demand for a mobile in downlink
$TPD^{M_i^{Sel}}_{Rem-UL}$	$TPD^{M_i^{Sel}}_{Max-UL} - TPD^{M_i^{Sel}}_{Min-UL}$	kbps	Remaining throughput demand for a mobile in uplink
$RD^{M_i^{Sel}}_{Rem-DL}$	$\frac{TPD^{M_i^{Sel}}_{Rem-DL}}{CTP^{M_i^{Sel}}_{P-DL}}$	None	Remaining resource demand for a mobile in downlink

Name	Value	Unit	Description
$RD_{Rem-UL}^{M_i^{Sel}}$	$\frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$	None	Remaining resource demand for a mobile in uplink
$R_{Max-DL}^{M_i^{Sel}}$	$Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right)$	None	Resources allocated to a mobile to satisfy its maximum throughput demand in downlink
$R_{Max-UL}^{M_i^{Sel}}$	$Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$	None	Resources allocated to a mobile to satisfy its maximum throughput demand in uplink
$TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}}$	$R_{Min-DL}^{M_i^{Sel}} + R_{Max-DL}^{M_i^{Sel}}$	None	Total resources assigned to a mobile in downlink (Downlink traffic load of the mobile)
$TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}}$	$R_{Min-UL}^{M_i^{Sel}} + R_{Max-UL}^{M_i^{Sel}}$	None	Total resources assigned to a mobile in uplink (Uplink traffic load of the mobile)

10.2.15 User Throughput Calculation

Name	Value	Unit	Description
$UTP_{P-DL}^{M_i^{Sel}}$	$R_{DL}^{M_i^{Sel}} \times CTP_{P-DL}^{M_i^{Sel}}$	kbps	Downlink peak MAC user throughput
$UTP_{E-DL}^{M_i^{Sel}}$	$UTP_{P-DL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)$	kbps	Downlink effective MAC user throughput
$UTP_{A-DL}^{M_i^{Sel}}$	$UTP_{E-DL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$	kbps	Downlink application user throughput
$UTP_{P-UL}^{M_i^{Sel}}$	$R_{UL}^{M_i^{Sel}} \times CTP_{P-UL}^{M_i^{Sel}}$	kbps	Uplink peak MAC user throughput
$UTP_{E-UL}^{M_i^{Sel}}$	$UTP_{P-UL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)$	kbps	Uplink effective MAC user throughput
$UTP_{A-UL}^{M_i^{Sel}}$	$UTP_{E-UL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$	kbps	Uplink application user throughput

10.3 Available Calculations

10.3.1 Point Analysis

10.3.1.1 Profile View

The point analysis profile view displays the following calculation results for the selected transmitter based on the calculation algorithm described in "Signal Level Calculation (DL)" on page 751.

- Downlink signal level $C_{DL}^{TX_i(ic)}$
- Path loss L_{Path}
- Total losses L_{Total}

L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$ are not used in the calculations performed for the profile view.

10.3.1.2 Reception View

Analysis provided in the reception view is based on path loss matrices. So, you can display received signal levels from the cells for which calculated path loss matrices are available.

Reception level bar graphs show the signal levels or C/N in decreasing order. The maximum number of bars in the graph depends on the downlink signal level of the best server. The bar graph displays cells whose received signal levels are higher than their C/N thresholds and are within a 30 dB margin from the highest signal level.

You can use a value other than 30 dB for the margin from the highest signal level, for example a smaller value for improving the calculation speed. For more information on defining a different value for this margin, see the *Administrator Manual*.

The reception view calculates:

- The downlink signal levels as explained in "Signal Level Calculation (DL)" on page 751.
- The downlink C/N as explained in "C/N Calculation (DL)" on page 754.
- The uplink signal level as explained in "Signal Level Calculation (UL)" on page 757.
- The downlink and uplink C/(I+N) and bearers as explained in "C/(I+N) and Bearer Calculation (DL)" on page 755 and "C/(I+N) and Bearer Calculation (UL)" on page 761.
- The best server as explained in "Best Server Determination" on page 763.
- The service availability as explained in "Service Area Calculation" on page 764.
- The different throughputs as explained in "Channel Throughput and Cell Capacity Calculation" on page 765.

10.3.1.3 Interference View

Analysis provided in the interference view is based on path loss matrices. So, you can display the received signal level from the best server and interfering signal levels from other cells for which calculated path loss matrices are available. For each cell, **9955** displays the best server signal level, and interference from other cells.

Ten interferer bar graphs are displayed by default. This number can be changed through the Atoll.ini file. For more information on defining a different number of interferers, see the *Administrator Manual*.

The interference view calculates:

- The downlink signal levels as explained in "Signal Level Calculation (DL)" on page 751.
- The downlink C/(I+N) and total noise (I+N) as explained in "C/(I+N) and Bearer Calculation (DL)" on page 755.
- The best server as explained in "Best Server Determination" on page 763.
- The service availability as explained in "Service Area Calculation" on page 764.

10.3.2 Coverage Predictions

10.3.2.1 Signal Level Coverage Predictions

The following coverage predictions are based on the received signal levels:

- Coverage by Transmitter
- Coverage by Signal Level
- Overlapping Zones

For these calculations, **9955** calculates the received signal level, then determines the selected display parameter on each pixel inside the cell's calculation area. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver.

L^{M_i}, G^{M_i}, $L^{M_i}_{Ant}$, and $L^{M_i}_{Body}$ are not considered in the calculations performed for the signal level based coverage predictions.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on signal level calculations, see "Signal Level Calculation (DL)" on page 751

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 738.
- "Coverage Display Types" on page 739.

Coverage Area Determination

9955 uses parameters entered in the Condition tab of the coverage prediction properties dialogue to determine coverage areas to display. There are three possibilities.

- All Servers

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C_{DL}^{TX_i(ic)}\left(or\ L_{Total}^{TX_i(ic)}\ or\ L_{Path}^{TX_i(ic)}\right) < MaximumThreshold$$

- Best Signal Level and a Margin

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C_{DL}^{TX_i(ic)}\left(or\ L_{Total}^{TX_i(ic)}\ or\ L_{Path}^{TX_i(ic)}\right) < MaximumThreshold$$

  AND

$$C_{DL}^{TX_i(ic)} \ge \underset{j \ne i}{Best}\left(C_{DL}^{TX_j(jc)}\right) - M$$

  Where M is the specified margin (dB). The *Best* function considers the highest value from a list of values.

  - If M = 0 dB, **9955** considers pixels where the received signal level from $TX_i(ic)$ is the highest.
  - If M = 2 dB, **9955** considers pixels where the received signal level from $TX_i(ic)$ is either the highest or within a 2 dB margin from the highest.
  - If M = -2 dB, **9955** considers pixels where the received signal level from $TX_i(ic)$ is 2 dB higher than the received signal levels from the cells which are 2nd best servers.

- Second Best Signal Level and a Margin

  The coverage area of each cell $TX_i(ic)$ corresponds to the pixels where.

$$MinimumThreshold \le C_{DL}^{TX_i(ic)}\left(or\ L_{Total}^{TX_i(ic)}\ or\ L_{Path}^{TX_i(ic)}\right) < MaximumThreshold$$

  AND

$$C_{DL}^{TX_i(ic)} \ge \underset{j \ne i}{2^{nd}Best}\left(C_{DL}^{TX_j(jc)}\right) - M$$

  Where M is the specified margin (dB). The *2nd Best* function considers the second highest value from a list of values.

  - If M = 0 dB, **9955** considers pixels where the received signal level from $TX_i(ic)$ is the second highest.
  - If M = 2 dB, **9955** considers pixels where the received signal level from $TX_i(ic)$ is either the second highest or within a 2 dB margin from the second highest.
  - If M = -2 dB, **9955** considers pixels where the received signal level from $TX_i(ic)$ is 2 dB higher than the received signal levels from the cells which are 3rd best servers.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the coverage predictions with colours depending on any transmitter or cell attribute, and other criteria such as:

- Signal Level (dBm, dBµV, dBµV/m)
- Best Signal Level (dBm, dBµV, dBµV/m): Where cell coverage areas overlap, **9955** keeps the highest value of the signal level.
- Path Loss (dB)
- Total Losses (dB)
- Best Server Path Loss (dB): Where cell coverage areas overlap, **9955** determines the best cell (i.e., the cell with the highest signal level) and evaluates the path loss from this cell.
- Best Server Total Losses (dB): Where cell coverage areas overlap, **9955** determines the best cell (i.e., the cell with the highest signal level) and evaluates the total losses from this cell.
- Number of Servers: **9955** evaluates the number of cells that cover a pixel (i.e., the pixel falls within the coverage areas of these cells).

10.3.2.2 Effective Signal Analysis Coverage Predictions

The following coverage predictions are based on the received signal levels and noise, and take into account the receiver characteristics (L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$) when calculating the required parameter:

- Effective Signal Analysis (DL)

- Effective Signal Analysis (UL)

For these calculations, **9955** calculates the received signal level or C/N level at each pixel. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver. The properties of the non-interfering probe receiver are set by selecting a terminal, a mobility type, and a service.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on signal level calculations, see:

- "Signal Level Calculation (DL)" on page 751.
- "Signal Level Calculation (UL)" on page 757.

For more information on C/N level calculations, see:

- "C/N Calculation (DL)" on page 754.
- "C/N Calculation (UL)" on page 760.

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 740.
- "Coverage Display Types" on page 740.

Coverage Area Determination

These coverage predictions are all best server coverage predictions, i.e., the coverage area of each cell comprises the pixels where the cell is the best server. Best server for each pixel is calculated as explained in "Best Server Determination" on page 763.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display type parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the Effective Signal Analysis (DL) coverage prediction with colours depending on the following display options:

- Signal Level (DL) (dBm)
- C/N Level (DL) (dB)

It is possible to display the Effective Signal Analysis (UL) coverage prediction with colours depending on the following display options:

- Signal Level (UL) (dBm)
- C/N Level (UL) (dB)

10.3.2.3 C/(I+N)-based Coverage Predictions

The following coverage predictions are based on the received signal levels, total noise, and interference.

- Coverage by C/(I+N) Level (DL)
- Service Area Analysis (DL)
- Coverage by Throughput (DL)
- Coverage by Quality Indicator (DL)
- Coverage by C/(I+N) Level (UL)
- Service Area Analysis (UL)
- Coverage by Throughput (UL)
- Coverage by Quality Indicator (UL)

These coverage predictions take into account the receiver characteristics (L^{M_i}, G^{M_i}, $L^{M_i}_{Ant}$, and $L^{M_i}_{Body}$) when calculating the required parameter. For these calculations, **9955** calculates the received signal level, noise, and interference at each pixel. Each pixel within the calculation area of $TX_i(ic)$ is considered a non-interfering receiver. The properties of the non-interfering probe receiver are set by selecting a terminal, a mobility type, and a service.

The downlink coverage predictions are based on the downlink traffic loads of the cells, and the uplink coverage predictions are based on the uplink noise rise values. These parameters can either be calculated by **9955** during the Monte Carlo simulations, or set manually by the user for all the cells.

The resolution of the coverage prediction does not depend on the resolutions of the path loss matrices or the geographic data and can be defined separately for each coverage prediction. Coverage predictions are generated using a bilinear interpolation method from multi-resolution path loss matrices (similar to the one used to calculate site altitudes, see "Path Loss Calculation Prerequisites" on page 53 for more information).

For more information on C/(I+N), (I+N), and bearer calculations, see:

- "C/(I+N) and Bearer Calculation (DL)" on page 755.
- "C/(I+N) and Bearer Calculation (UL)" on page 761.
- "Noise Rise Calculation (UL)" on page 759

For more information on throughput calculations, see:

- "Channel Throughput and Cell Capacity Calculation" on page 765.

For more information on coverage area determination and available display options, see:

- "Coverage Area Determination" on page 741.
- "Coverage Display Types" on page 741.

Coverage Area Determination

These coverage predictions are all best server coverage predictions, i.e., the coverage area of each cell comprises the pixels where the cell is the best server. Best server for each pixel is calculated as explained in "Best Server Determination" on page 763.

Coverage Display Types

A pixel of a coverage area is coloured if the calculated value of the selected display type parameter is greater than or equal to the defined thresholds values. Coverage consists of several independent layers that can be displayed and hidden on the map.

It is possible to display the Coverage by C/(I+N) Level (DL) coverage prediction with colours depending on the following display options:

- C/(I+N) Level (DL) (dB)
- Total Noise (I+N) (DL) (dBm)

It is possible to display the Service Area Analysis (DL) coverage prediction with colours depending on the following display options:

- Bearer (DL)
- Modulation (DL): Modulation used by the bearer
- Service

It is possible to display the Coverage by Throughput (DL) coverage prediction with colours depending on the following display options:

- Peak MAC Channel Throughput (DL) (kbps)
- Effective MAC Channel Throughput (DL) (kbps)
- Application Channel Throughput (DL) (kbps)
- Peak MAC Cell Capacity (DL) (kbps)
- Effective MAC Channel Throughput (DL) (kbps)
- Application Channel Throughput (DL) (kbps)

It is possible to display the Coverage by Quality Indicator (DL) coverage prediction with colours depending on the following display options:

- Quality indicators available in the document (Quality Indicators table): **9955** calculates the downlink C/(I+N) levels received from the best serving cells at each pixel of their coverage areas. From the C/(I+N), **9955** determines the best bearer available on each pixel. Then, for the calculated C/(I+N) and bearer, it determines the value of the selected quality indicator from the quality graphs defined in the Wi-Fi equipment of the selected terminal.

It is possible to display the Coverage by C/(I+N) Level (UL) coverage prediction with colours depending on the following display options:

- C/(I+N) Level (UL) (dB)
- Total Noise (I+N) (UL) (dBm)
- Transmission Power (UL) (dBm)

It is possible to display the Service Area Analysis (UL) coverage prediction with colours depending on the following display options:

- Bearer (UL)
- Modulation (UL): Modulation used by the bearer
- Service

It is possible to display the Coverage by Throughput (UL) coverage prediction with colours depending on the following display options:

- Peak MAC Channel Throughput (UL) (kbps)
- Effective MAC Channel Throughput (UL) (kbps)
- Application Channel Throughput (UL) (kbps)
- Peak MAC Cell Capacity (UL) (kbps)

- Effective MAC Channel Throughput (UL) (kbps)
- Application Channel Throughput (UL) (kbps)

It is possible to display the Coverage by Quality Indicator (UL) coverage prediction with colours depending on the following display options:

- Quality indicators available in the document (Quality Indicators table): **9955** calculates the uplink C/(I+N) levels received at the best serving cells from each pixel of their coverage areas. From the C/(I+N), **9955** determines the best bearer available on each pixel. Then, for the calculated C/(I+N) and bearer, it determines the value of the selected quality indicator from the quality graphs defined in the Wi-Fi equipment of the best serving cell.

10.3.3 Calculations on Subscriber Lists

When calculations are performed on a list of subscribers by running the Automatic Server Allocation, **9955** calculates the path loss again for the subscriber locations and heights because the subscriber heights can be different from the default receiver height used for calculating the path loss matrices.

9955 calculates the following parameters for each subscriber in the list whose **Lock Status** is set to **None**.

- **Serving Base Station** and **Reference Cell** as described in "Best Server Determination" on page 763.

9955 calculates the following parameters for each subscriber in the list that has a serving base station assigned and whose **Lock Status** is set to **None** or **Server**.

- **Azimuth (°)**: Angle with respect to the north for pointing the subscriber terminal antenna towards its serving base station.
- **Mechanical Downtilt (°)**: Angle with respect to the horizontal for pointing the subscriber terminal antenna towards its serving base station.

9955 calculates the remaining parameters for each subscriber in the list that has a serving base station assigned, using the properties of the default terminal and service. For more information, see:

- "Signal Level Calculation (DL)" on page 751.
- "C/(I+N) and Bearer Calculation (DL)" on page 755.
- "Signal Level Calculation (UL)" on page 757.
- "Noise Rise Calculation (UL)" on page 759.
- "C/(I+N) and Bearer Calculation (UL)" on page 761.
- "Throughput Calculation" on page 764.

10.3.4 Monte Carlo Simulations

The simulation process is divided into two steps.

- Generating a realistic user distribution as explained in "User Distribution" on page 742.

  9955 generates user distributions as part of the Monte Carlo algorithm based on traffic data. The resulting user distribution complies with the traffic database and maps selected when creating simulations.

- Scheduling and Radio Resource Management as explained under "Simulation Process" on page 745.

10.3.4.1 User Distribution

During each simulation, **9955** performs two random trials. The first random trial generates the number of users and their activity status as explained in the following sections depending on the type of traffic input.

- "Simulations Based on User Profile Traffic Maps and Subscriber Lists" on page 743.
- "Simulations Based on Sector Traffic Maps" on page 744.

Once all the user characteristics have been determined, a second random trial is performed to obtain their geographical locations weighted according to the clutter classes, and whether they are indoor or outdoor according to the percentage of indoor users per clutter class.

> **9955** determines the total number of users attempting connection in each simulation based on the Poisson distribution. This may lead to slight variations in the total numbers of users in different simulations. To have the same total number of users in each simulation of a group, add the following lines in the Atoll.ini file:
> [Simulation]
> RandomTotalUsers=0

10.3.4.1.1 Simulations Based on User Profile Traffic Maps and Subscriber Lists

User profile environment based traffic maps: Each pixel of the map is assigned an environment class which contains a list of user profiles with an associated mobility type and a given density, i.e., number of users of a user profile per km².

User profile traffic maps: Each polygon or line of the map is assigned a density of users with a given user profile and mobility type. If the map is composed of points, each point is assigned a number of users with given user profile and mobility type.

Fixed subscribers listed in subscriber lists have a user profile assigned to each of them.

User profiles model the behaviour of the different user categories. Each user profile contains a list of services and parameters describing how these services are accessed by the user.

The number of users of each user profile is calculated from the surface area (S_{Env}) of each environment class map (or each polygon) and the user profile density (D_{UP}).

$$N_{Users} = S_{Env} \times D_{UP}$$

- In case of user profile traffic maps composed of lines, the number of users of each user profile is calculated from the line length (L) and the user profile density (D_{UP}) (users per km): $N_{Users} = L \times D_{UP}$
- The number of users is a direct input when a user profile traffic map is composed of points.

9955 calculates the probability for a user being active at a given instant in the uplink and in the downlink according to the service usage characteristics described in the user profiles, i.e., the number of voice calls or data sessions, the average duration of each voice call, or the volume of the data transfer in the uplink and the downlink in each data session.

Voice Service (*v*)

User profile parameters for voice type services are:

- The user terminal equipment used for the service (from the Terminals table).
- The average number of calls per hour N_{Call}.
- The average duration of a call (seconds) D_{Call}.

Calculation of the service usage duration per hour (p_0 : probability of an active call): $p_0 = \frac{N_{Call} \times D_{Call}}{3600}$

Calculation of the number of users trying to access the service *v* (n_v): $n_v = N_{Users} \times p_0$

The activity status of each user depends on the activity periods during the call, i.e., the uplink and downlink activity factors defined for the voice type service *v*, f_{Act}^{UL} and f_{Act}^{DL}.

Calculation of activity probabilities:

Probability of being inactive: $p_{Inactive} = (1 - f_{Act}^{UL}) \times (1 - f_{Act}^{DL})$

Probability of being active in the uplink: $p_{Active}^{UL} = f_{Act}^{UL} \times (1 - f_{Act}^{DL})$

Probability of being active in the downlink: $p_{Active}^{DL} = f_{Act}^{DL} \times (1 - f_{Act}^{UL})$

Probability of being active in the uplink and downlink both: $p_{Active}^{UL+DL} = f_{Act}^{UL} \times f_{Act}^{DL}$

Calculation of number of users per activity status:

Number of inactive users: $n_{v-Inactive} = n_v \times p_{Inactive}$

Number of users active in the uplink: $n_{v-Active}^{UL} = n_v \times p_{Active}^{UL}$

Number of users active in the downlink: $n_{v-Active}^{DL} = n_v \times p_{Active}^{DL}$

Number of users active in the uplink and downlink both: $n_{v-Active}^{UL+DL} = n_v \times p_{Active}^{UL+DL}$

Therefore, a user can be either active on both links, inactive on both links, active on UL only, or active on DL only.

Data Service (*d*)

User profile parameters for data type services are:

- The user terminal equipment used for the service (from the Terminals table).
- The average number of data sessions per hour $N_{Session}$.
- The average data volume (in kBytes) transferred in the downlink V^{DL} and the uplink V^{UL} during a session.
- The average throughputs in the downlink $TP^{DL}_{Average}$ and the uplink $TP^{UL}_{Average}$ for the service *d*.

Calculation of activity probabilities: $f^{UL} = \frac{N_{Session} \times V^{UL} \times 8}{TP^{UL}_{Average} \times 3600}$ and $f^{DL} = \frac{N_{Session} \times V^{DL} \times 8}{TP^{DL}_{Average} \times 3600}$

Probability of being inactive: $p_{Inactive} = (1 - f^{UL}) \times (1 - f^{DL})$

Probability of being active in the uplink: $p^{UL}_{Active} = f^{UL} \times (1 - f^{DL})$

Probability of being active in the downlink: $p^{DL}_{Active} = f^{DL} \times (1 - f^{UL})$

Probability of being active in the uplink and downlink both: $p^{UL+DL}_{Active} = f^{UL} \times f^{DL}$

Calculation of number of users:

Number of inactive users: $n_{d-Inactive} = N_{Users} \times p_{Inactive}$

Number of users active in the uplink: $n^{UL}_{d-Active} = N_{Users} \times p^{UL}_{Active}$

Number of users active in the downlink: $n^{DL}_{d-Active} = N_{Users} \times p^{DL}_{Active}$

Number of users active in the uplink and downlink both: $n^{UL+DL}_{d-Active} = N_{Users} \times p^{UL+DL}_{Active}$

Calculation of the number of active users trying to access the service *d* (n_d):

$$n_d = n^{UL}_{d-Active} + n^{DL}_{d-Active} + n^{UL+DL}_{d-Active}$$

The user distribution per service and the activity status distribution between the users are average distributions. The service and the activity status of each user are randomly drawn in each simulation. Therefore, if you calculate several simulations at once, the average number of users per service and average numbers of inactive, active on UL, active on DL and active on UL and DL users, respectively, will correspond to calculated distributions. But if you check each simulation, the user distribution between services as well as the activity status distribution between users can be different in each of them.

10.3.4.1.2 Simulations Based on Sector Traffic Maps

Sector traffic maps per sector are also referred to as live traffic maps. Live traffic data from the OMC is spread over the best server coverage areas of the transmitters included in the traffic map. Either throughput demands per service or the number of active users per service are assigned to the coverage areas of each transmitter.

For each transmitter TX_i and each service *s*,

- **Sector Traffic Maps (Throughputs)**

  9955 calculates the number of active users of each service *s* on UL and DL in the coverage area of TX_i as follows:

  $$N^{UL} = \frac{TP^{UL}_{Cell}}{TP^{UL}_{Average}} \text{ and } N^{DL} = \frac{TP^{DL}_{Cell}}{TP^{DL}_{Average}}$$

  Where TP^{UL}_{Cell} is the total uplink throughput demand defined in the map for any service *s* for the coverage area of the transmitter, TP^{DL}_{Cell} is the total downlink throughput demand defined in the map for any service *s* for the coverage area of the transmitter, $TP^{UL}_{Average}$ is the average uplink requested throughput of the service *s*, and $TP^{DL}_{Average}$ is the average downlink requested throughput of the service *s*.

- **Sector Traffic Maps (# Active Users)**

9955 directly uses the defined N^{UL} and N^{DL} values, i.e., the number of active users on UL and DL in the transmitter coverage area using the service *s*.

At any given instant, **9955** calculates the probability for a user being active in the uplink and in the downlink as follows:

Users active in the uplink and downlink both are included in the N^{UL} and N^{DL} values. Therefore, it is necessary to accurately determine the number of active users in the uplink (n^{UL}_{Active}), in the downlink (n^{DL}_{Active}), and both (n^{UL+DL}_{Active}). As for the other types of traffic maps, **9955** considers both active and inactive users.

The activity status of each user depends on the activity periods during the call, i.e., the uplink and downlink activity factors defined for the service, f^{UL}_{Act} and f^{DL}_{Act}.

Calculation of activity probabilities:

Probability of being inactive: $p_{Inactive} = (1 - f^{UL}_{Act}) \times (1 - f^{DL}_{Act})$

Probability of being active in the uplink: $p^{UL}_{Active} = f^{UL}_{Act} \times (1 - f^{DL}_{Act})$

Probability of being active in the downlink: $p^{DL}_{Active} = f^{DL}_{Act} \times (1 - f^{UL}_{Act})$

Probability of being active in the uplink and downlink both: $p^{UL+DL}_{Active} = f^{UL}_{Act} \times f^{DL}_{Act}$

Calculation of the number of active users trying to access the service:

We have: $N^{UL} = (p^{UL}_{Active} + p^{UL+DL}_{Active}) \times n$ and $N^{DL} = (p^{DL}_{Active} + p^{UL+DL}_{Active}) \times n$

Where, *n* is the total number of active users in the transmitter coverage area using the service.

Calculation of number of users per activity status:

Number of users active in the uplink and downlink both: $n^{UL+DL}_{Active} = Min\left(\frac{N^{UL} \times p^{UL+DL}_{Active}}{p^{UL}_{Active} + p^{UL+DL}_{Active}}, \frac{N^{DL} \times p^{UL+DL}_{Active}}{p^{DL}_{Active} + p^{UL+DL}_{Active}}\right)$ or simply, $n^{UL+DL}_{Active} = Min(N^{UL} \times f^{DL}_{Act}, N^{DL} \times f^{UL}_{Act})$

Number of users active in the uplink: $n^{UL}_{Active} = N^{UL} - n^{UL+DL}_{Active}$

Number of users active in the downlink: $n^{DL}_{Active} = N^{DL} - n^{UL+DL}_{Active}$

And, $n = n^{UL}_{Active} + n^{DL}_{Active} + n^{UL+DL}_{Active}$

Calculation of the number of inactive users attempting to access the service:

Number of inactive users: $n_{Inactive} = \frac{n_v}{1 - p_{Inactive}} \times p_{Inactive}$

The activity status distribution between users is an average distribution. In fact, in each simulation, the activity status of each user is randomly drawn. Therefore, if you calculate several simulations at once, average numbers of inactive, active on UL, active on DL and active on UL and DL users correspond to the calculated distribution. But if you check each simulation, the activity status distribution between users can be different in each of them.

10.3.4.2 Simulation Process

Each Monte Carlo simulation in **9955** Wi-Fi is a snap-shot of the network with resource allocation carried out over a duration of *1* second. The steps of this algorithm are listed below.

The simulation process can be summed up into the following iterative steps.

For each simulation, the simulation process,

1. Generates mobiles according to the input traffic data as explained in "User Distribution" on page 742.
2. Sets initial values for the following parameters:

- Cell transmission power ($P_{DL}^{TX_i(ic)}$) is set to the value defined by the user.
- Mobile transmission power is set to the maximum mobile power ($P_{Max}^{M_i}$).
- Cell loads ($TL_{DL}^{TX_i(ic)}$, $TL_{UL}^{TX_i(ic)}$, and $NR_{UL}^{TX_i(ic)}$) are set to their current values in the Cells table.

3. Determines the best servers for all the mobiles generated for the simulation as explained in "Best Server Determination" on page 763.

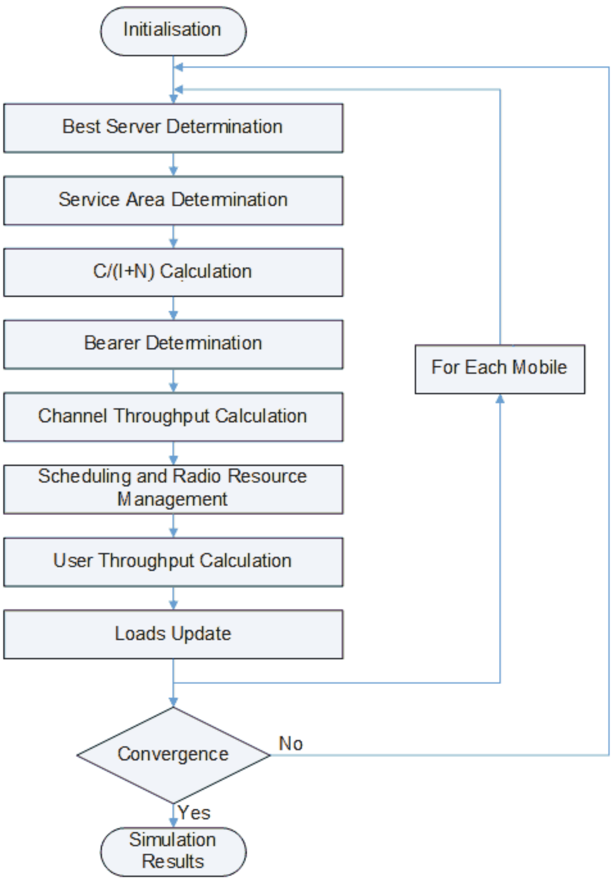


Figure 10.1: Wi-Fi Simulation Algorithm

For each iteration *k*, the simulation process,

4. Determines the mobiles which are within the service areas of their best serving cells as explained in "Service Area Calculation" on page 764.

5. Determines the downlink and uplink C/(I+N) and bearers for each of these mobiles as explained in "C/(I+N) and Bearer Calculation (DL)" on page 755 and "C/(I+N) and Bearer Calculation (UL)" on page 761 respectively.

6. Determines the channel throughputs at the mobile as explained in "Channel Throughput and Cell Capacity Calculation" on page 765.

7. Performs radio resource management and scheduling to determine the amount of resources to allocate to each mobile according to the throughput demands of each mobile using the selected scheduler as explained in "Scheduling and Radio Resource Allocation" on page 768.

8. Calculates the user throughputs after allocating resources to each mobile as explained in "User Throughput Calculation" on page 770.

9. Updates the traffic loads, and noise rise values of all the cells according to the resources in use and the total resources as follows:

Calculation of Traffic Loads: 9955 calculates the traffic loads for all the cells *TX$_i$(ic)*.

$$TL_{DL}^{TX_i(ic)} = \sum_{M_i} R_{DL}^{M_i} \text{ and } TL_{UL}^{TX_i(ic)} = \sum_{M_i} R_{UL}^{M_i}$$

Calculation of Uplink Noise Rise: For each victim cell *TX$_i$(ic)*, the uplink noise rise is calculated and updated by considering each interfering mobile M_j as explained in "Noise Rise Calculation (UL)" **on page 759**.

10. Performs the convergence test to see whether the differences between the current and the new loads are within the convergence thresholds.

The convergence criteria are evaluated at the end of each iteration *k*, and can be written as follows:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(TL_{DL}^{TX_i(ic)}\Big|_k - TL_{DL}^{TX_i(ic)}\Big|_{k-1}\right)$$

$$\Delta TL_{UL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(TL_{UL}^{TX_i(ic)}\Big|_k - TL_{UL}^{TX_i(ic)}\Big|_{k-1}\right)$$

$$\Delta NR_{UL}^{TX_i(ic)}\Big|_k = \underset{All\ TX_i(ic)}{Max}\left(NR_{UL}^{TX_i(ic)}\Big|_k - NR_{UL}^{TX_i(ic)}\Big|_{k-1}\right)$$

If $\Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}$, $\Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}$, and $\Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$ are the simulation convergence thresholds defined when creating the simulation, **9955** stops the simulation in the following cases.

Convergence: Simulation has converged between iteration *k - 1* and *k* if:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k \le \Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}\ AND\ \Delta TL_{UL}^{TX_i(ic)}\Big|_k \le \Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}\ AND\ \Delta NR_{UL}^{TX_i(ic)}\Big|_k \le \Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$$

No convergence: Simulation has not converged even after the last iteration, i.e., *k* = Max Number of Iterations defined when creating the simulation, if:

$$\Delta TL_{DL}^{TX_i(ic)}\Big|_k > \Delta TL_{DL}^{TX_i(ic)}\Big|_{Req}\ OR\ \Delta TL_{UL}^{TX_i(ic)}\Big|_k > \Delta TL_{UL}^{TX_i(ic)}\Big|_{Req}\ OR\ \Delta NR_{UL}^{TX_i(ic)}\Big|_k > \Delta NR_{UL}^{TX_i(ic)}\Big|_{Req}$$

11. Repeats the above steps (from step 3.) for the iteration *k+1* using the new calculated loads as the current loads.

Simulation Results

At the end of the simulation process, the main results obtained are:

- Downlink traffic load
- Uplink traffic load
- Uplink noise rise

These results can be used as input for C/(I+N)-based coverage predictions.

In addition to the above parameters, the simulations also list the connection status of each mobile. Mobiles can be rejected due to:

- **No Coverage:** If the mobile does not have any best serving cell (step 3.) or if the mobile is not within the service area of its best server (step 4.).
- **No Service:** If the mobile is not able to access a bearer in the direction of its activity (step 5.), i.e., UL, DL, or DL+UL.
- **Scheduler Saturation:** If the mobile is not in the list of mobiles selected for scheduling (step 7.)
- **Resource Saturation:** If all the cell resources are used up before allocation to the mobile or if, for a user active in uplink, the minimum uplink throughput demand is higher than the uplink allocated bandwidth throughput (step 7.)

Connected mobiles (step 7.) can be:

- **Connected UL:** If a mobile active in UL is allocated resources in UL.
- **Connected DL:** If a mobile active in DL is allocated resources in DL.
- **Connected DL+UL:** If a mobile active in DL+UL is allocated resources in DL+UL.

10.4 Calculation Details

The following sections describe all the calculation algorithms used in point analysis, calculation of coverage predictions, calculations on subscriber lists, and Monte Carlo simulations.

10.4.1 Co- and Adjacent Channel Overlaps Calculation

A Wi-Fi network can consist of cells that use different channel bandwidths. Therefore, the start and end frequencies of all the channels may not exactly coincide. Channel bandwidths of cells can overlap each other with different ratios.

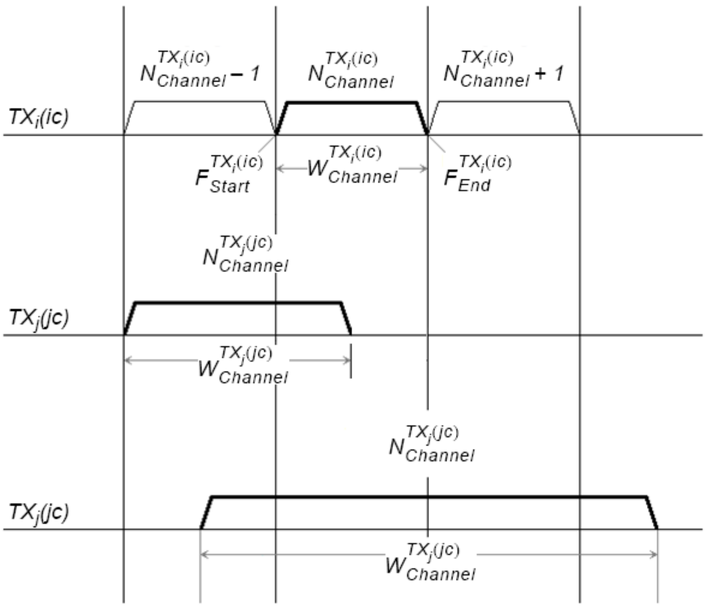


Figure 10.2: Co-Channel and Adjacent Channel Overlaps

The following sections describe how the co- and adjacent channel overlaps are calculated between the channels used by any studied cell $TX_i(ic)$ and any other cell $TX_j(jc)$ of the network. In terms of interference calculation, the studied cell can be considered a victim of interference received from the other cells that might be interfering the studied cell.

If the studied cell is assigned a channel number $N_{Channel}^{TX_i(ic)}$, it receives co-channel interference on the channel bandwidth of $N_{Channel}^{TX_i(ic)}$, and adjacent channel interference on the adjacent channel bandwidths, i.e., corresponding to $N_{Channel}^{TX_i(ic)} - 1$ and $N_{Channel}^{TX_i(ic)} + 1$.

In order to calculate the co- and adjacent channel overlaps between two channels, it is necessary to calculate the start and end frequencies of both channels (explained in "Conversion From Channel Numbers to Start and End Frequencies" on page 748). Once the start and end frequencies are known for the studied and other cells, the co- and adjacent overlaps and the total overlap ratio are calculated as respectively explained in:

- "Co-Channel Overlap Calculation" on page 749.
- "Adjacent Channel Overlap Calculation" on page 749.
- "Total Overlap Ratio Calculation" on page 750.

10.4.1.1 Conversion From Channel Numbers to Start and End Frequencies

Input

- $F_{Start-FB}^{TX_i(ic)}$ and $F_{Start-FB}^{TX_j(jc)}$: Start frequency of the frequency band assigned to the cells *$TX_i(ic)$ and $TX_j(jc)$.*

  $F_{Start-FB}$ can represent the uplink or the downlink start frequencies ($F_{Start-FB-UL}$ or $F_{Start-FB-DL}$).
- $N_{Channel}^{First-TX_i(ic)}$ and $N_{Channel}^{First-TX_j(jc)}$: First channel numbers the frequency band assigned to the cells *$TX_i(ic)$ and $TX_j(jc)$.*
- $N_{Channel}^{TX_i(ic)}$ and $N_{Channel}^{TX_j(jc)}$: Channel numbers assigned to cells *$TX_i(ic)$ and $TX_j(jc)$.*

  9955 considers that the same channel number is assigned to a cell in the downlink and uplink, i.e., the channel number you assign to a cell is considered for uplink and downlink both.
- $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$: Bandwidths of the channels assigned to cells *$TX_i(ic)$* and *$TX_j(jc)$.*

Calculations

Channel numbers are converted into start and end frequencies as follows:

For cell *$TX_i(ic)$*:

$$F_{Start}^{TX_i(ic)} = F_{Start-FB}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)}\right)$$

$$F_{End}^{TX_i(ic)} = F_{Start-FB}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} \times \left(N_{Channel}^{TX_i(ic)} - N_{Channel}^{First-TX_i(ic)} + 1\right)$$

For cell $TX_j(jc)$:

$$F_{Start}^{TX_j(jc)} = F_{Start-FB}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times \left(N_{Channel}^{TX_j(jc)} - N_{Channel}^{First-TX_j(jc)}\right)$$

$$F_{End}^{TX_j(jc)} = F_{Start-FB}^{TX_j(jc)} + W_{Channel}^{TX_j(jc)} \times \left(N_{Channel}^{TX_j(jc)} - N_{Channel}^{First-TX_j(jc)} + 1\right)$$

Output

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$.
- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$.

10.4.1.2 Co-Channel Overlap Calculation

Input

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 748.
- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 748.
- $W_{Channel}^{TX_i(ic)}$: Bandwidth of the channel assigned to the studied cell $TX_i(ic)$.

Calculations

9955 first verifies that co-channel overlap exists between the cells $TX_i(ic)$ and $TX_j(jc)$.

Co-channel overlap exists if:

$$F_{Start}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \text{ AND } F_{End}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Otherwise there is no co-channel overlap.

9955 calculates the bandwidth of the co-channel overlap as follows:

$$W_{CCO}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right)$$

The co-channel overlap ratio is given by:

$$r_{CCO}^{TX_i(ic)-TX_j(jc)} = \frac{W_{CCO}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

Output

- $r_{CCO}^{TX_i(ic)-TX_j(jc)}$: Co-channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

10.4.1.3 Adjacent Channel Overlap Calculation

Input

- $F_{Start}^{TX_i(ic)}$ and $F_{Start}^{TX_j(jc)}$: Start frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 748.

- $F_{End}^{TX_i(ic)}$ and $F_{End}^{TX_j(jc)}$: End frequencies for the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Conversion From Channel Numbers to Start and End Frequencies" on page 748.
- $W_{Channel}^{TX_i(ic)}$: Bandwidth of the channel assigned to the studied cell $TX_i(ic)$.

Calculations

9955 first verifies that adjacent channel overlaps exist between (the lower-frequency and the higher-frequency adjacent channels of) the cells $TX_i(ic)$ and $TX_j(jc)$.

Adjacent channel overlap exists on the lower-frequency adjacent channel if:

$$F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \quad AND \quad F_{Start}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Adjacent channel overlap exists on the higher-frequency adjacent channel if:

$$F_{End}^{TX_i(ic)} < F_{End}^{TX_j(jc)} \quad AND \quad F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)} > F_{Start}^{TX_j(jc)}$$

Otherwise there is no adjacent channel overlap.

9955 determines the adjacent channel overlap ratio as follows:

Bandwidth of the lower-frequency adjacent channel overlap:

$$W_{ACO_L}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{Start}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{Start}^{TX_i(ic)} - W_{Channel}^{TX_i(ic)}\right)$$

The lower-frequency adjacent channel overlap ratio is given by:

$$r_{ACO_L}^{TX_i(ic)-TX_j(jc)} = \frac{W_{ACO_L}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

Bandwidth of the higher-frequency adjacent channel overlap:

$$W_{ACO_H}^{TX_i(ic)-TX_j(jc)} = Min\left(F_{End}^{TX_j(jc)}, F_{End}^{TX_i(ic)} + W_{Channel}^{TX_i(ic)}\right) - Max\left(F_{Start}^{TX_j(jc)}, F_{End}^{TX_i(ic)}\right)$$

The higher-frequency adjacent channel overlap ratio is given by:

$$r_{ACO_H}^{TX_i(ic)-TX_j(jc)} = \frac{W_{ACO_H}^{TX_i(ic)-TX_j(jc)}}{W_{Channel}^{TX_i(ic)}}$$

The adjacent channel overlap ratio is given by:

$$r_{ACO}^{TX_i(ic)-TX_j(jc)} = r_{ACO_L}^{TX_i(ic)-TX_j(jc)} + r_{ACO_H}^{TX_i(ic)-TX_j(jc)}$$

Output

- $r_{ACO}^{TX_i(ic)-TX_j(jc)}$: Adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

10.4.1.4 Total Overlap Ratio Calculation

Input

- $r_{CCO}^{TX_i(ic)-TX_j(jc)}$: Co-channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co-Channel Overlap Calculation" on page 749.
- $r_{ACO}^{TX_i(ic)-TX_j(jc)}$: Adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Adjacent Channel Overlap Calculation" on page 749.
- $f_{ACS-FB}^{TX_i(ic)}$: Adjacent channel suppression factor defined for the frequency band of the cell $TX_i(ic)$.
- $W_{Channel}^{TX_i(ic)}$ and $W_{Channel}^{TX_j(jc)}$: Bandwidths of the channels assigned to the cells $TX_i(ic)$ and $TX_j(jc)$.

Calculations

The total overlap ratio is:

$$r_O^{TX_i(ic)-TX_j(jc)} = \begin{cases} \left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}} \right) & if \quad W_{Channel}^{TX_i(ic)} \geq W_{Channel}^{TX_j(jc)} \\ \left(r_{CCO}^{TX_i(ic)-TX_j(jc)} + r_{ACO}^{TX_i(ic)-TX_j(jc)} \times 10^{\frac{-f_{ACS-FB}^{TX_i(ic)}}{10}} \right) \times \frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}} & if \quad W_{Channel}^{TX_i(ic)} < W_{Channel}^{TX_j(jc)} \end{cases}$$

The multiplicative factor $\frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ is used to normalise the transmission power of the interfering cell $TX_j(jc)$. This means that if the interfering cell transmits at X dBm over a bandwidth of $W_{Channel}^{TX_j(jc)}$, and it interferes over a bandwidth less than $W_{Channel}^{TX_j(jc)}$, the interference from this cell should not be considered at X dBm but less than that. The factor $\frac{W_{Channel}^{TX_i(ic)}}{W_{Channel}^{TX_j(jc)}}$ converts X dBm over $W_{Channel}^{TX_j(jc)}$ to Y dBm (which is less than X dBm) over less than $W_{Channel}^{TX_j(jc)}$.

Output

- $r_O^{TX_i(ic)-TX_j(jc)}$: Total co- and adjacent channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$.

10.4.2 Signal Level and Quality Calculations

The following sections describe how signal levels, noise and interference, C/N, and C/(I+N) ratios are calculated on the downlink and uplink.

- "Signal Level Calculation (DL)" on page 751.
- "Noise Calculation (DL)" on page 752.
- "Interference Calculation (DL)" on page 753.
- "C/N Calculation (DL)" on page 754.
- "C/(I+N) and Bearer Calculation (DL)" on page 755.
- "Signal Level Calculation (UL)" on page 757.
- "Noise Calculation (UL)" on page 758.
- "Interference Calculation (UL)" on page 759.
- "C/N Calculation (UL)" on page 760.
- "C/(I+N) and Bearer Calculation (UL)" on page 761.

10.4.2.1 Signal Level Calculation (DL)

Input

- $P_{DL}^{TX_i(ic)}$: Transmission power of the cell $TX_i(ic)$.
- G^{TX_i}: Transmitter antenna gain for the antenna used by the transmitter TX_i. ($G^{TX_i} = G_{Ant}^{TX_i}$).
- L^{TX_i}: Total transmitter losses for the transmitter TX_i ($L^{TX_i} = L_{Total-DL}$).
- L_{Path}: Path loss ($L_{Path} = L_{Model} + L_{Ant}^{TX_i}$).
- L_{Model}: Loss on the transmitter-receiver path (path loss) calculated using a propagation model.
- $L_{Ant}^{TX_i}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_i.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.

In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.

- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.
- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.
- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  For calculating the useful signal level from the best serving cell, $L_{Ant}^{M_i}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L_{Ant}^{M_i}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.

- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.

Calculations

The received signal levels (dBm) from any cell $TX_i(ic)$ are calculated for a pixel, subscriber, or mobile M_i as follows:

$$C_{DL}^{TX_i(ic)} = EIRP^{TX_i(ic)} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the cell calculated as follows:

$$EIRP^{TX_i(ic)} = P_{DL}^{TX_i(ic)} + G^{TX_i} - L^{TX_i}$$

> If you wish to exclude the energy corresponding to the cyclic prefix (guard interval) in the total symbol duration from the useful signal level, you must add the following lines in the Atoll.ini file:
>
> ```
> [WiMAX]
> ExcludeCPFromUsefulPower = 1
> ```
>
> When this option is active, the cyclic prefix energy is excluded from $C_{DL}^{TX_i(ic)}$. In other words, the factor $10 \times Log(1 - r_{CP})$ is added to $C_{DL}^{TX_i(ic)}$.
>
> Independant of the option, interference levels are calculated for the total symbol durations, i.e., the energy of the useful symbol duration and the cyclic prefix energy.

Output

- $C_{DL}^{TX_i(ic)}$: Received signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.

10.4.2.2 Noise Calculation (DL)

For determining the C/N and C/(I+N), **9955** calculates the downlink noise over the channel bandwidth used by the cell. The used bandwidth depends on the number of used subcarriers. The downlink noise comprises thermal noise and the noise figure of the equipment. The thermal noise density depends on the temperature, i.e., it remains constant for a given temperature. However, the value of the thermal noise varies with the used bandwidth.

Input

- K: Boltzmann's constant.
- T: Temperature in Kelvin.
- $N_{SCa-Used}^{TX_i(ic)}$: Number of used subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- $N_{SCa-Total}^{TX_i(ic)}$: Total number of subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- nf^{M_i} : Noise figure of the terminal used for calculations by the pixel, subscriber, or mobile M_i.

Calculations

The power spectral density of thermal noise is calculated as follows:

$$n_0 = 10 \times Log(K \times T \times 1000) = -174\ dBm/Hz$$

The thermal noise for a cell is calculated as:

$$n_{0-DL}^{TX_i(ic)} = n_0 + 10 \times Log\left(\frac{N_{SCa-Used}^{TX_i(ic)}}{N_{SCa-Total}^{TX_i(ic)}}\right)$$

The downlink noise is the sum of the thermal noise and the noise figure of the terminal used for the calculations by the pixel, subscriber, or mobile M_i.

$$n_{DL}^{TX_i(ic)} = n_{0-DL}^{TX_i(ic)} + nf^{M_i}$$

Output

- $n_{DL}^{TX_i(ic)}$: Downlink noise for the cell $TX_i(ic)$.

10.4.2.3 Interference Calculation (DL)

The interference received by any pixel, subscriber, or mobile, served by a cell $TX_i(ic)$ from other cells $TX_j(jc)$ can be defined as the signal levels received from interfering cells $TX_j(jc)$ depending on the overlap that exists between the channels used by the cells $TX_i(ic)$ and $TX_j(jc)$, and on the traffic loads of the interfering cells $TX_j(jc)$.

Input

- $C_{DL}^{TX_j(jc)}$: Received signal level from the cell $TX_i(ic)$ as explained in "Signal Level Calculation (DL)" on page 751.
- $M_{Shadowing-C/I}$: Shadowing margin based on the C/I standard deviation.

  In Monte Carlo simulations, the received signal levels from interferers already include $M_{Shadowing-Model}$, as explained in "Signal Level Calculation (DL)" on page 751.

  In coverage predictions, the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$ is applied to the interfering signals (for more information, see "Shadow Fading Model" on page 85). As the received signal levels from interferers already include $M_{Shadowing-Model}$, $M_{Shadowing-C/I}$ is added to the signal levels from interferers in order to achieve the ratio $M_{Shadowing-Model} - M_{Shadowing-C/I}$:

  $$C_{DL}^{TX_j(jc)} = C_{DL}^{TX_j(jc)} + M_{Shadowing-C/I}$$

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.

- $TL_{DL}^{TX_j(jc)}$: Downlink traffic load of the interfering cell $TX_j(jc)$.

  Traffic loads can either be calculated using Monte Carlo simulations, or entered manually for each cell. Calculation of traffic loads is explained in "Simulation Process" on page 745.

- $r_O^{TX_i(ic)-TX_j(jc)}$: Total channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 747.

Calculations

Interference (dBm) from any cell $TX_j(jc)$ is calculated for a pixel, subscriber, or mobile M_i as follows:

$$I_{DL}^{TX_j(jc)} = C_{DL}^{TX_j(jc)} + f_O^{TX_i(ic)-TX_j(jc)} + f_{TL-DL}^{TX_j(jc)} + I_{DL}^{Inter-Tech}$$

If you wish to exclude the energy corresponding to the cyclic prefix (guard interval) in the total symbol duration from the useful signal level, you must add the following lines in the Atoll.ini file:

```
[WiMAX]
ExcludeCPFromUsefulPower = 1
```

When this option is active, the cyclic prefix energy is excluded from $C_{DL}^{TX_i(ic)}$. In other words, the factor $10 \times Log(1 - r_{CP})$ is added to $C_{DL}^{TX_i(ic)}$.

Independent of the option, interference levels are calculated for the total symbol durations, i.e., the energy of the useful symbol duration and the cyclic prefix energy.

Calculations for the interference reduction factors due to channel overlapping and traffic load are explained below:

Interference reduction due to the co- and adjacent channel overlap between the studied and the interfering cells:

Interference reduction due to the co- and adjacent channel overlap between the cells $TX_i(ic)$ and $TX_j(jc)$ is calculated as follows:

$$f_O^{TX_i(ic) - TX_j(jc)} = 10 \times Log\left(r_O^{TX_i(ic) - TX_j(jc)}\right)$$

Interference reduction due to interfering cell's traffic load:

The interference reduction factor due to the interfering cell's traffic load is calculated as follows:

$$f_{TL-DL}^{TX_j(jc)} = 10 \times Log\left(TL_{DL}^{TX_j(jc)}\right)$$

$I_{DL}^{Inter-Tech}$ is the inter-technology downlink interference from transmitters of an external network (linked document of any technology) calculated as follows:

$$I_{DL}^{Inter-Tech} = \sum_{All\ External\ TXs} EIRP_{DL}^{TX-External} - L_{Path} - L_{Indoor} + G^{M_i} - L^{M_i} - L_{Ant}^{M_i} - L_{Body}^{M_i} - f_{IRF}^{Inter-Tech}$$

Where $EIRP_{DL}^{TX-External}$ is the downlink EIRP of the external transmitter, L_{Path} is the path loss from the external transmitters to the pixel, subscriber, or mobile location, L_{Indoor} is the indoor losses taken into account when the option "Indoor coverage" is selected, L^{M_i} is the receiver terminal losses for the pixel, subscriber, or mobile M_i, G^{M_i} is the receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i, $L_{Ant}^{M_i}$ is the receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i, and $L_{Body}^{M_i}$ is the body loss defined for the service used by the pixel, subscriber, or mobile M_i.

Output

- $I_{DL}^{TX_j(jc)}$: Downlink interference received at the pixel, subscriber, or mobile M_i from any interfering cell $TX_j(jc)$.

10.4.2.4 C/N Calculation (DL)

Input

- $C_{DL}^{TX_i(ic)}$: Received signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 751.
- $n_{DL}^{TX_i(ic)}$: Downlink noise for the cell $TX_i(ic)$ as calculated in "Noise Calculation (DL)" on page 752.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the Wi-Fi equipment used by M_i's terminal.
- $B_{DL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.

- $B_{DL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{TX_i(ic)}$: Number of MIMO transmission (downlink) antennas defined for the cell $TX_i(ic)$.
- $N_{Ant-RX}^{M_i}$: Number of MIMO reception (downlink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the Wi-Fi equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.

Calculations

The C/N for a cell $TX_i(ic)$ are calculated as follows for any pixel, subscriber, or mobile M_i:

$$CNR_{DL}^{TX_i(ic)} = C_{DL}^{TX_i(ic)} - n_{DL}^{TX_i(ic)}$$

Bearer Determination:

The bearers available for selection in the pixel, subscriber, or mobile M_i's Wi-Fi equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the C/N at M_i: $T_B^{M_i} < CNR_{DL}^{TX_i(ic)}$

  If the cell's frame configuration supports AMS, the STTD/MRC gain, G_{STTD}^{DL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the Wi-Fi equipment assigned to the pixel, subscriber, or mobile M_i for $N_{Ant-TX}^{TX_i(ic)}$, $N_{Ant-RX}^{M_i}$, $Mobility(M_i)$, $BLER\left(B_{DL}^{M_i}\right)$.

  The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{DL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the Wi-Fi equipment for which the following is true:

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CNR_{DL}^{TX_i(ic)} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

The bearer selected for data transfer is the one with the highest index.

MIMO – STTD/MRC Gain:

Once the bearer is known, the C/N calculated above become:

$$CNR_{DL}^{TX_i(ic)} = CNR_{DL}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{DL} is the STTD/MRC gain corresponding to the selected bearer.

Output

- $CNR_{DL}^{TX_i(ic)}$: C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.

10.4.2.5 C/(I+N) and Bearer Calculation (DL)

The carrier signal to interference and noise ratio is calculated in three steps. First **9955** calculates the received signal level from the studied cell (as explained in "Signal Level Calculation (DL)" on page 751) at the pixel, subscriber, or mobile under study. Next, **9955** calculates the interference received at the same studied pixel, subscriber, or mobile from all the interfering cells (as explained in "Interference Calculation (DL)" on page 753). Interference from each cell is weighted according to the co- and adjacent channel overlap between the studied and the interfering cells, and the traffic loads of the interfering cells. Finally,

9955 takes the ratio of the signal level and the sum of the total interference from other cells and the downlink noise (as calculated in "Noise Calculation (DL)" on page 752).

The receiver terminal is always considered to be oriented towards its best server, except when the "Lock Status" is set to "Server+Orientation" for a subscriber in a subscriber list and its azimuth and tilt manually edited. In the case of NLOS between the receiver and the best server, **9955** does not try to find the direction of the strongest signal, the receiver is oriented towards the best server just as in the case of LOS.

Input

- $C_{DL}^{TX_i(ic)}$: Received signal level from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 751.
- $n_{DL}^{TX_i(ic)}$: Downlink noise for the cell $TX_i(ic)$ as calculated in "Noise Calculation (DL)" on page 752.
- $I_{DL}^{TX_j(jc)}$: Interference from any cell $TX_j(jc)$ calculated for a pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$ as explained in "Interference Calculation (DL)" on page 753.
- $NR_{DL}^{Inter-Tech}$: Inter-technology downlink noise rise.
- $CNR_{DL}^{TX_i(ic)}$: C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 754.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the Wi-Fi equipment used by M_i's terminal.
- $B_{DL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{DL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{TX_i(ic)}$: Number of MIMO transmission (downlink) antennas defined for the cell $TX_i(ic)$.
- $N_{Ant-RX}^{M_i}$: Number of MIMO reception (downlink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the Wi-Fi equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.

Calculations

The downlink C/(I+N) for a cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$CINR_{DL}^{TX_i(ic)} = C_{DL}^{TX_i(ic)} - \left(10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}\right)$$

The Total Noise (I+N) for a cell $TX_i(ic)$ is calculated as follows for any pixel, subscriber, or mobile M_i:

$$(I+N)_{DL}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)}\left(10^{\frac{I_{DL}^{TX_j(jc)}}{10}}\right) + 10^{\frac{n_{DL}^{TX_i(ic)}}{10}}\right) + NR_{DL}^{Inter-Tech}$$

Bearer Determination:

The bearers available for selection in the pixel, subscriber, or mobile M_i's Wi-Fi equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.

- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the downlink C/(I+N) at M_i: $T_B^{M_i} < CINR_{DL}^{TX_i(ic)}$

  If the cell supports AMS, the STTD/MRC gain, G_{STTD}^{DL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the Wi-Fi equipment assigned to the pixel, subscriber, or mobile M_i for $N_{Ant-TX}^{TX_i(ic)}$, $N_{Ant-RX}^{M_i}$, $Mobility(M_i)$, $BLER\left(B_{DL}^{M_i}\right)$.

  The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{DL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the Wi-Fi equipment for which the following is true:

  $$T_B^{M_i} - G_{STTD}^{DL} - \Delta G_{STTD}^{DL} < CINR_{DL}^{TX_i(ic)} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

The bearer selected for data transfer is the one with the highest index.

MIMO – STTD/MRC Gain:

Once the bearer is known, the C/(I+N) calculated above become:

$$CINR_{DL}^{TX_i(ic)} = CINR_{DL}^{TX_i(ic)} + G_{STTD}^{DL} + \Delta G_{STTD}^{DL} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{DL} is the STTD/MRC gain corresponding to the selected bearer.

Output

- $CINR_{DL}^{TX_i(ic)}$: Downlink C/(I+N) from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i.
- $(I+N)_{DL}^{TX_i(ic)}$: Total noise from the interfering cells $TX_j(jc)$ at the pixel, subscriber, or mobile M_i covered by a cell $TX_i(ic)$.
- $B_{DL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the downlink.

10.4.2.6 Signal Level Calculation (UL)

Input

- $P_{Max}^{M_i}$: Maximum transmission power of the terminal used by the pixel, subscriber, or mobile M_i without power control.
- $P_{Eff}^{M_i}$: Effective transmission power of the terminal used by the pixel, subscriber, or mobile M_i after power control as calculated in "C/(I+N) and Bearer Calculation (UL)" on page 761.
- G^{TX_i} : Transmitter antenna gain for the antenna used by the transmitter TX_i ($G^{TX_i} = G_{Ant}^{TX_i}$).
- L^{TX_i} : Total transmitter losses for the transmitter TX_i ($L^{TX_i} = L_{Total-UL}$).
- L_{Path} : Path loss ($L_{Path} = L_{Model} + L_{Ant}^{TX_i}$).
- L_{Model} : Loss on the transmitter-receiver path (path loss) calculated using a propagation model.
- $L_{Ant}^{TX_i}$: Antenna attenuation (from antenna patterns) calculated for the antenna used by the transmitter TX_i.
- $M_{Shadowing-Model}$: Shadowing margin based on the model standard deviation.

  In coverage predictions, shadowing margins are taken into account when the option "Shadowing taken into account" is selected.
- L_{Indoor} : Indoor losses taken into account when the option "Indoor coverage" is selected.
- L^{M_i} : Receiver terminal losses for the pixel, subscriber, or mobile M_i.
- G^{M_i} : Receiver terminal's antenna gain for the pixel, subscriber, or mobile M_i.

- $L_{Ant}^{M_i}$: Receiver terminal's antenna attenuation calculated for the pixel, subscriber, or mobile M_i.

  For calculating the useful signal level from the best serving cell, $L_{Ant}^{M_i}$ is determined in the direction (H,V) = (0,0) from the antenna patterns of the antenna used by M_i. For calculating the interfering signal level from any interferer, $L_{Ant}^{M_i}$ is determined in the direction of the interfering cell from the antenna patterns of the antenna used by M_i, while the antenna is pointed towards M_i's best serving cell.

- $L_{Body}^{M_i}$: Body loss defined for the service used by the pixel, subscriber, or mobile M_i.

Calculations

The received traffic signal level (dBm) from a pixel, subscriber, or mobile M_i at its serving cell $TX_i(ic)$ is calculated as follows:

$$C_{UL}^{M_i} = EIRP_{UL}^{M_i} - L_{Path} - M_{Shadowing-Model} - L_{Indoor} + G^{TX_i} - L^{TX_i} - L_{Ant}^{M_i} - L_{Body}^{M_i}$$

Where *EIRP* is the effective isotropic radiated power of the terminal calculated as follows:

$$EIRP_{UL}^{M_i} = P^{M_i} + G^{M_i} - L^{M_i}$$

With $P^{M_i} = P_{Max}^{M_i}$ without power control at the start of the calculations, and is the $P^{M_i} = P_{Eff}^{M_i}$ after power control.

Output

- $C_{UL}^{M_i}$: Received uplink signal level from the pixel, subscriber, or mobile M_i at a cell $TX_i(ic)$.

10.4.2.7 Noise Calculation (UL)

For determining the uplink C/N and C/(I+N), **9955** calculates the uplink noise over the channel bandwidth used by the cell. The used bandwidth depends on the number of used subcarriers. The uplink noise comprises thermal noise and the noise figure of the equipment. The thermal noise density depends on the temperature, i.e., it remains constant for a given temperature. However, the value of the thermal noise varies with the used bandwidth.

Input

- *K*: Boltzmann's constant.
- *T*: Temperature in Kelvin.
- $N_{SCa-Used}^{TX_i(ic)}$: Number of used subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- $N_{SCa-Total}^{TX_i(ic)}$: Total number of subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- $nf^{TX_i(ic)}$: Noise figure of the cell $TX_i(ic)$.

Calculations

The power spectral density of thermal noise is calculated as follows:

$$n_0 = 10 \times Log(K \times T \times 1000) = -174 \text{ dBm/Hz}$$

The thermal noise for a cell is calculated as:

$$n_{0-UL}^{TX_i(ic)} = n_0 + 10 \times Log\left(\frac{N_{SCa-Used}^{TX_i(ic)}}{N_{SCa-Total}^{TX_i(ic)}}\right)$$

The uplink noise is the sum of the thermal noise and the noise figure of the cell $TX_i(ic)$.

$$n_{UL}^{TX_i(ic)} = n_{0-UL}^{TX_i(ic)} + nf^{TX_i(ic)}$$

Output

- $n_{UL}^{TX_i(ic)}$: Uplink noise for the cell $TX_i(ic)$.

10.4.2.8 Interference Calculation (UL)

The uplink interference is only calculated during Monte Carlo simulations. In coverage predictions, the uplink noise rise values already available in simulation results or in the Cells table are used.

The interference received by a cell $TX_i(ic)$ from an interfering mobile covered by a cell $TX_j(jc)$ can be defined as the uplink signal level received from interfering mobiles M_j depending on the overlap that exists between the channels used by the cells $TX_i(ic)$ and $TX_j(jc)$, on the traffic loads of the interfering mobile M_j.

The calculation of uplink interference can be divided into two parts:

- Calculation of the uplink interference from each individual interfering mobile as explained in "Interference Signal Levels Calculation (UL)" on page 759.
- Calculation of the uplink noise rise which represents the total uplink interference from all the interfering mobiles as explained in "Noise Rise Calculation (UL)" on page 759.

10.4.2.8.1 Interference Signal Levels Calculation (UL)

Input

- $C_{UL}^{M_j}$: Uplink signal level received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$ as calculated in "Signal Level Calculation (UL)" on page 757.
- $r_O^{TX_i(ic)-TX_j(jc)}$: Total channel overlap ratio between the cells $TX_i(ic)$ and $TX_j(jc)$ as calculated in "Co- and Adjacent Channel Overlaps Calculation" on page 747.
- $TL_{UL}^{M_j}$: Uplink traffic load of the interfering mobile M_j.

  Traffic loads are calculated during Monte Carlo simulations as explained in "Scheduling and Radio Resource Allocation" on page 768.

Calculations

The uplink interference received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$ is calculated as follows:

$$I_{UL}^{M_j} = C_{UL}^{M_j} + f_O^{TX_i(ic)-TX_j(jc)} + f_{TL-UL}^{M_j}$$

Calculations for the interference reduction factors due to channel overlapping and uplink traffic load are explained below:

Interference reduction due to the co- and adjacent channel overlap between the studied and the interfering cells:

Interference reduction due to the co- and adjacent channel overlap between the cells $TX_i(ic)$ and $TX_j(jc)$ is calculated as follows:

$$f_O^{TX_i(ic)-TX_j(jc)} = 10 \times Log\left(r_O^{TX_i(ic)-TX_j(jc)}\right)$$

Interference reduction due to interfering mobile's traffic load:

The interference reduction factor due to the interfering mobile's uplink traffic load is calculated as follows:

$$f_{TL-UL}^{M_j} = 10 \times Log\left(TL_{UL}^{M_j}\right)$$

Output

- $I_{UL}^{M_j}$: Uplink interference signal level received at a cell $TX_i(ic)$ from an interfering mobile M_j covered by a cell $TX_j(jc)$.

10.4.2.8.2 Noise Rise Calculation (UL)

The uplink noise rise is defined as the ratio of the total uplink interference received by any cell $TX_i(ic)$ from interfering mobiles M_j present in the coverage areas of other cells $TX_j(jc)$ to the uplink noise of the cell $TX_i(ic)$. In other words, it is the ratio (I+N)/N.

Input

- $I_{UL}^{M_j}$: Uplink interference signal levels received at a cell $TX_i(ic)$ from interfering mobiles M_j covered by other cells $TX_j(jc)$ as calculated in "Interference Signal Levels Calculation (UL)" on page 759.

- $n_{UL}^{TX_i(ic)}$: Uplink noise for the cell $TX_i(ic)$ as calculated in "Noise Calculation (UL)" on page 758.
- $NR_{UL}^{Inter-Tech}$: Inter-technology uplink noise rise.

Calculations

The uplink noise rise and total noise (I+N) for the cell $TX_i(ic)$ are calculated as follows:

$$NR_{UL}^{TX_i(ic)} = 10 \times Log\left(\sum_{All\ TX_j(jc)}\left(\sum_{All\ M_j}\left(10^{\frac{I_{UL}^{M_j}}{10}}\right) + 10^{\frac{n_{UL}^{TX_i(ic)}}{10}}\right)\right) + NR_{UL}^{Inter-Tech} - n_{UL}^{TX_i(ic)}$$

For any pixel, subscriber, or mobile M_i in the interfered cell $TX_i(ic)$, **9955** calculates the uplink total noise (I+N) as follows:

$$(I+N)_{UL}^{TX_i(ic)} = NR_{UL}^{TX_i(ic)} + n_{UL}^{TX_i(ic)}$$

Output

- $NR_{UL}^{TX_i(ic)}$: Uplink noise rise for the cell $TX_i(ic)$.
- $(I+N)_{UL}^{TX_i(ic)}$: Total noise for a cell $TX_i(ic)$ calculated for any pixel, subscriber, or mobile M_i.

10.4.2.9 C/N Calculation (UL)

Input

- $C_{UL}^{M_i}$: Received uplink signal level from the pixel, subscriber, or mobile M_i at its serving cell $TX_i(ic)$ as calculated in "Signal Level Calculation (UL)" on page 757.
- $n_{UL}^{TX_i(ic)}$: Uplink noise for the cell $TX_i(ic)$ as calculated in "Noise Calculation (UL)" on page 758.
- $CNR_{DL}^{TX_i(ic)}$: Downlink C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 754.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $P_{Max}^{M_i}$: Maximum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- $P_{Min}^{M_i}$: Minimum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- M_{PC} : Power control margin defined in the Global Parameters.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the Wi-Fi equipment used bythe cell $TX_i(ic)$.
- $B_{UL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{UL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{M_i}$: Number of MIMO transmission (uplink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-RX}^{TX_i(ic)}$: Number of MIMO reception (uplink) antennas defined for the cell $TX_i(ic)$.
- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the Wi-Fi equipment assigned to the cell $TX_i(ic)$.

Calculations

The uplink C/N from a pixel, subscriber, or mobile M_i at its serving cell $TX_i(ic)$ is calculated as follows:

$$CNR_{UL}^{M_i} = C_{UL}^{M_i} - n_{UL}^{TX_i(ic)}$$

Bearer Determination:

The bearers available for selection in the cell $TX_i(ic)$'s Wi-Fi equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the uplink C/N at M_i: $T_B^{M_i} < CNR_{UL}^{M_i}$

  If the cell supports AMS, the STTD/MRC gain, G_{STTD}^{UL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the Wi-Fi equipment assigned to the cell $TX_i(ic)$ for $N_{Ant-TX}^{M_i}$, $N_{Ant-RX}^{TX_i(ic)}$, $Mobility(M_i)$, and $BLER\left(B_{UL}^{M_i}\right)$.

  The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{UL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the Wi-Fi equipment for which the following is true:

  $$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CNR_{UL}^{M_i} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

MIMO – STTD/MRC Gain:

Once the bearer is known, the uplink C/N calculated above become:

$$CNR_{UL}^{M_i} = CNR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{UL} is the STTD/MRC gain corresponding to the selected bearer.

Uplink Power Control:

The pixel, subscriber, or mobile M_i reduces its transmission power so that the uplink C/N from it at its cell is just enough to get the selected bearer.

If with $P^{M_i} = P_{Max}^{M_i}$ AND $CNR_{UL}^{M_i} > T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}$, where $T_{B_{UL}^{M_i}}^{TX_i(ic)}$ is the bearer selection threshold, from the Wi-Fi equipment assigned to the cell $TX_i(ic)$, for the bearer selected for the pixel, subscriber, or mobile M_i.

The transmission power of M_i is reduced to determine the effective transmission power from the pixel, subscriber, or mobile M_i as follows:

$$P_{Eff}^{M_i} = Max\left(P_{Max}^{M_i} - \left(CNR_{UL}^{M_i} - \left(T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}\right)\right), P_{Min}^{M_i}\right)$$

$CNR_{UL}^{M_i}$ is calculated again using $P_{Eff}^{M_i}$.

Output

- $CNR_{UL}^{M_i}$: Uplink C/N from a pixel, subscriber, or mobile M_i at it serving cell $TX_i(ic)$.

10.4.2.10 C/(I+N) and Bearer Calculation (UL)

The carrier signal to interference and noise ratio is calculated in three steps. First, **9955** calculates the received signal level from each pixel, subscriber, or mobile at its serving cell using the effective power of the terminal used by the pixel, subscriber, or mobile as explained in "Signal Level Calculation (UL)" on page 757. Next, **9955** calculates the uplink carrier to noise ratio as explained in "C/N Calculation (UL)" on page 760. Finally, determines the uplink C/(I+N) by dividing the previously calculated uplink C/N by the uplink noise rise value of the cell as calculated in "Noise Rise Calculation (UL)" on page 759.

The uplink noise rise can be set by the user manually for each cell or calculated using Monte Carlo simulations.

The receiver terminal is always considered to be oriented towards its best server, except when the "Lock Status" is set to "Server+Orientation" for a subscriber in a subscriber list and its azimuth and tilt manually edited. In the case of NLOS between the receiver and the best server, **9955** does not try to find the direction of the strongest signal, the receiver is oriented towards the best server just as in the case of LOS.

Input

- $CNR_{UL}^{M_i}$: Uplink C/N from a pixel, subscriber, or mobile M_i at it serving cell $TX_i(ic)$ as calculated in "C/N Calculation (UL)" on page 760.
- $NR_{UL}^{TX_i(ic)}$: Uplink noise rise for the cell $TX_i(ic)$ as calculated in "Noise Rise Calculation (UL)" on page 759.
- $CNR_{DL}^{TX_i(ic)}$: Downlink C/N from the cell $TX_i(ic)$ at the pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 754.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $P_{Max}^{M_i}$: Maximum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- $P_{Min}^{M_i}$: Minimum transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- M_{PC} : Power control margin defined in the Global Parameters.
- $T_B^{M_i}$: Bearer selection thresholds of the bearers defined in the Wi-Fi equipment used bythe cell $TX_i(ic)$.
- $B_{UL-Highest}^{M_i}(Service)$: Highest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $B_{UL-Lowest}^{M_i}(Service)$: Lowest downlink bearer defined in the properties of the service used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-TX}^{M_i}$: Number of MIMO transmission (uplink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
- $N_{Ant-RX}^{TX_i(ic)}$: Number of MIMO reception (uplink) antennas defined for the cell $TX_i(ic)$.
- $Mobility(M_i)$: Mobility used for the calculations.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the Wi-Fi equipment assigned to the cell $TX_i(ic)$.

Calculations

The uplink C/(I+N) for any pixel, subscriber, or mobile M_i at a cell $TX_i(ic)$ is calculated as follows:

$$CINR_{UL}^{M_i} = CNR_{UL}^{M_i} - NR_{UL}^{TX_i(ic)}$$

Bearer Determination:

The bearers available for selection in the cell $TX_i(ic)$'s Wi-Fi equipment are the ones:

- Which are common between M_i's and $TX_i(ic)$'s equipment (bearer indexes for which selection thresholds are defined in both equipment), if the corresponding option has been set in the Atoll.ini file. For more information, see the *Administrator Manual*.
- Whose indexes are within the range defined by the lowest and the highest bearer indexes defined for the service being accessed by M_i.
- Whose selection thresholds are less than the uplink C/(I+N) at M_i: $T_B^{M_i} < CINR_{UL}^{M_i}$

If the cell supports AMS, the STTD/MRC gain, G_{STTD}^{UL}, corresponding to the bearer is applied to its selection threshold. The gain is read from the properties of the Wi-Fi equipment assigned to the cell *TX$_i$(ic)* for $N_{Ant-TX}^{M_i}$, $N_{Ant-RX}^{TX_i(ic)}$, $Mobility(M_i)$, and $BLER\left(B_{UL}^{M_i}\right)$.

The additional STTD/MRC gain defined for the clutter class of the pixel, subscriber, or mobile M_i ΔG_{STTD}^{UL} is also applied. Therefore, the bearers available for selection are all the bearers defined in the Wi-Fi equipment for which the following is true:

$$T_B^{M_i} - G_{STTD}^{UL} - \Delta G_{STTD}^{UL} < CINR_{UL}^{M_i} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

MIMO – STTD/MRC Gain:

Once the bearer is known, the uplink C/(I+N) calculated above become:

$$CINR_{UL}^{M_i} = CINR_{UL}^{M_i} + G_{STTD}^{UL} + \Delta G_{STTD}^{UL} \text{ if } CNR_{DL}^{TX_i(ic)} < T_{AMS}^{TX_i(ic)}$$

Where G_{STTD}^{UL} is the STTD/MRC gain corresponding to the selected bearer.

Uplink Power Control:

The pixel, subscriber, or mobile M_i reduces its transmission power so that the uplink C/(I+N) from it at its cell is just enough to get the selected bearer.

If with $P^{M_i} = P_{Max}^{M_i}$ AND $CINR_{UL}^{M_i} > T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}$, where $T_{B_{UL}^{M_i}}^{TX_i(ic)}$ is the bearer selection threshold, from the Wi-Fi equipment assigned to the cell *TX$_i$(ic)*, for the bearer selected for the pixel, subscriber, or mobile M_i.

The transmission power of M_i is reduced to determine the effective transmission power from the pixel, subscriber, or mobile M_i as follows:

$$P_{Eff}^{M_i} = Max\left(P_{Max}^{M_i} - \left(CINR_{UL}^{M_i} - \left(T_{B_{UL}^{M_i}}^{TX_i(ic)} + M_{PC}\right)\right), P_{Min}^{M_i}\right)$$

$CINR_{UL}^{M_i}$ is calculated again using $P_{Eff}^{M_i}$.

Output

- $CINR_{UL}^{M_i}$: Uplink C/(I+N) from a pixel, subscriber, or mobile M_i at it serving cell *TX$_i$(ic).*
- $P_{Eff}^{M_i}$: Effective transmission power of the terminal used by the pixel, subscriber, or mobile M_i.
- $B_{UL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the uplink.

10.4.3 Best Server Determination

In Wi-Fi, best server refers to a cell ("serving transmitter"-"reference cell" pair) from which a pixel, subscriber, or mobile M_i gets the highest signal level. This calculation also determines whether the pixel, subscriber, or mobile M_i is within the coverage area of any transmitter or not.

Input

- $C_{DL}^{TX_i(ic)}$: Downlink signal level received from any cell *TX$_i$(ic)* at a pixel, subscriber, or mobile M_i as calculated in "Signal Level Calculation (DL)" on page 751 using the terminal and service parameters (L^{M_i}, G^{M_i}, $L_{Ant}^{M_i}$, and $L_{Body}^{M_i}$) of M_i.

Calculations

The best server of any pixel, subscriber, or mobile M_i, BS_{M_i}, is the cell from which the received downlink signal level is the highest among all the cells. The best server is determined as follows:

$$BS_{M_i} = TX_i(ic)\Big|_{C_{DL}^{TX_i(ic)} = \underset{All\ TX_i(ic)}{Best}\left\{C_{DL}^{TX_i(ic)}\right\}}$$

Here *ic* is the cell of the transmitter TX_i with the highest power. However, if more than one cell of the same transmitter covers the pixel, subscriber, or mobile, the final reference cell *ic* might be different from the initial cell *ic* (the one with the highest power). In coverage prediction calculations and in calculations on subsriber lists, the cell of the highest layer is selected as the serving (reference) cell. In Monte Carlo simulations, a random cell is selected as the serving (reference) cell.

Output

- BS_{M_i} : Best serving cell of the pixel, subscriber, or mobile M_i.

10.4.4 Service Area Calculation

In Wi-Fi, a pixel, subscriber, or mobile M_i can be covered by a cell (as calculated in "Best Server Determination" on page 763) but can be outside the service area. A pixel, subscriber, or mobile M_i is said to be within the service area of its best serving cell $TX_i(ic)$ if the downlink C/N from the cell at the pixel, subscriber, or mobile is greater than or equal to the minimum C/N threshold defined for the cell.

Input

- $CNR_{DL}^{TX_i(ic)}$: Downlink C/N from the cell $TX_i(ic)$ at a pixel, subscriber, or mobile M_i as calculated in "C/N Calculation (DL)" on page 754.
- $T_{Min}^{TX_i(ic)}$: Min C/N threshold defined for the cell $TX_i(ic)$.

Calculations

A pixel, subscriber, or mobile M_i is within the service area of its best serving cell $TX_i(ic)$ if:

$$CNR_{DL}^{TX_i(ic)} \geq T_{Min}^{TX_i(ic)}$$

Output

- *True*: If the calculation criterion is satisfied.
- *False*: Otherwise.

10.4.5 Throughput Calculation

Throughputs are calculated in two steps.

- Calculation of uplink and downlink total resources in a cell as explained in "Calculation of Total Cell Resources" on page 764.
- Calculation of throughputs as explained in "Channel Throughput and Cell Capacity Calculation" on page 765.

10.4.5.1 Calculation of Total Cell Resources

The total amount of resources in a cell is the number of modulation symbols that can be used for data transfer per second.

Input

- $W_{Channel}^{TX_i(ic)}$: Channel bandwidth of the cell $TX_i(ic)$.
- $N_{SCa-Total}^{TX_i(ic)}$: Total number of subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- $N_{SCa-Data}^{TX_i(ic)}$: Number of data subcarriers defined for the frame configuration of a cell $TX_i(ic)$.
- r_{CP} : Cyclic prefix ratio defined for the network in the Global Parameters.

Calculations

9955 determines the inter-subcarrier spacing.

$$\Delta F^{TX_i(ic)} = \frac{W_{Channel}^{TX_i(ic)} \times 10^6}{N_{SCa-Total}^{TX_i(ic)}}$$

9955 calculates the useful symbol duration.

$$D_{Sym-Useful}^{TX_i(ic)} = \frac{1}{\Delta F^{TX_i(ic)}}$$

And, the duration of the cyclic prefix (guard interval).

$$D_{CP} = \frac{r_{CP}}{\Delta F}$$

Adding the cyclic prefix ratio to the useful symbol duration, **9955** determines the total symbol duration.

$$D_{Symbol}^{TX_i(ic)} = D_{Sym-Useful}^{TX_i(ic)} + D_{CP}$$

The total number of modulation symbols in the downlink and uplink are:

$$R_{DL}^{TX_i(ic)} = R_{UL}^{TX_i(ic)} = Floor\left(\frac{1}{D_{Symbol}^{TX_i(ic)}}\right) \times N_{SCa-Data}^{TX_i(ic)}$$

Output

- $R_{DL}^{TX_i(ic)}$ and $R_{UL}^{TX_i(ic)}$: Amount of downlink and uplink resources in the cell $TX_i(ic)$.

10.4.5.2 Channel Throughput and Cell Capacity Calculation

Channel throughputs are calculated for the entire channel resources allocated to the pixel, subscriber, or mobile M_i. Cell capacities are similar to channel throughputs but upper-bound by the maximum downlink and uplink traffic loads.

Input

- $TL_{DL-Max}^{TX_i(ic)}$: Maximum downlink traffic load for the cell $TX_i(ic)$.
- $TL_{UL-Max}^{TX_i(ic)}$: Maximum uplink traffic load for the cell $TX_i(ic)$.
- $R_{DL}^{TX_i(ic)}$: Amount of downlink resources in the cell $TX_i(ic)$ as calculated in "Calculation of Total Cell Resources" on page 764.
- $R_{UL}^{TX_i(ic)}$: Amount of uplink resources in the cell $TX_i(ic)$ as calculated in "Calculation of Total Cell Resources" on page 764.
- $\eta_{B_{DL}^{M_i}}$: Bearer efficiency (bits/symbol) of the bearer assigned to the pixel, subscriber, or mobile M_i in the downlink in "C/(I+N) and Bearer Calculation (DL)" on page 755.
- $\eta_{B_{UL}^{M_i}}$: Bearer efficiency (bits/symbol) of the bearer assigned to the pixel, subscriber, or mobile M_i in the uplink in "C/(I+N) and Bearer Calculation (UL)" on page 761.
- $CNR_{DL}^{TX_i(ic)}$: Downlink C/N the cell $TX_i(ic)$ as calculated in "C/N Calculation (DL)" on page 754.
- $T_{AMS}^{TX_i(ic)}$: AMS threshold defined for the cell $TX_i(ic)$.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the BLER vs. $CNR_{DL}^{TX_i(ic)}$ graph available in the Wi-Fi equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the BLER vs. $CINR_{UL}^{M_i}$ graph available in the Wi-Fi equipment assigned to the cell $TX_i(ic)$.
- $f_{TP-Scaling}^{M_i}$: Throughput scaling factor defined in the properties of the service used by the pixel, subscriber, or mobile M_i.

- $TP_{Offset}^{M_i}$: Throughput offset defined in the properties of the service used by the pixel, subscriber, or mobile M_i.

Calculations

Downlink:

- **Peak MAC Channel Throughput:** $CTP_{P-DL}^{M_i} = R_{DL}^{TX_i(ic)} \times \eta_{B_{DL}^{M_i}}$

  MIMO – SU-MIMO Gain:

  If the frame configuration supports AMS, SU-MIMO gain $G_{SU-MIMO}^{Max}$ is applied to the bearer efficiency. The gain is read from the properties of the Wi-Fi equipment assigned to the pixel, subscriber, or mobile M_i for:

  - $N_{Ant-TX}^{TX_i(ic)}$: Number of MIMO transmission (downlink) antennas defined for the cell $TX_i(ic)$.
  - $N_{Ant-RX}^{M_i}$: Number of MIMO reception (downlink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
  - $Mobility(M_i)$: Mobility used for the calculations.
  - $B_{DL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the downlink as explained in "C/(I+N) and Bearer Calculation (DL)" on page 755.
  - $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the graphs available in the Wi-Fi equipment assigned to the terminal used by the pixel, subscriber, or mobile M_i. BLER is determined for $CINR_{DL}^{TX_i(ic)}$.

  9955 also takes into account the SU-MIMO Gain Factor $f_{SU-MIMO}$ defined for the clutter class where the pixel, subscriber, or mobile M_i is located.

$$\eta_{B_{DL}^{M_i}} = \eta_{B_{DL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1)) \text{ if } CNR_{DL}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$$

  If the Max SU-MIMO Gain for the exact value of the C/(I+N) is not available in the table, it is interpolated from the gain values available for the C/(I+N) just less than and just greater than the actual C/(I+N).

- **Effective MAC Channel Throughput:** $CTP_{E-DL}^{M_i} = CTP_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$
- **Application Channel Throughput:** $CTP_{A-DL}^{M_i} = CTP_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak MAC Cell Capacity:** $Cap_{P-DL}^{M_i} = CTP_{P-DL}^{M_i} \times TL_{DL-Max}^{TX_i(ic)}$
- **Effective MAC Cell Capacity:** $Cap_{E-DL}^{M_i} = Cap_{P-DL}^{M_i} \times \left(1 - BLER\left(B_{DL}^{M_i}\right)\right)$
- **Application Cell Capacity:** $Cap_{A-DL}^{M_i} = Cap_{E-DL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$

Uplink:

- **Peak MAC Channel Throughput:** $CTP_{P-UL}^{M_i} = R_{UL}^{TX_i(ic)} \times \eta_{B_{UL}^{M_i}}$

  MIMO – SU-MIMO Gain:

  If the frame configuration supports AMS, SU-MIMO gain $G_{SU-MIMO}^{Max}$ is applied to the bearer efficiency. The gain is read from the properties of the Wi-Fi equipment assigned to the cell $TX_i(ic)$ for:

  - $N_{Ant-TX}^{M_i}$: Number of MIMO transmission (uplink) antennas defined for the terminal used by the pixel, subscriber, or mobile M_i.
  - $N_{Ant-RX}^{TX_i(ic)}$: Number of MIMO reception (uplink) antennas defined for the cell $TX_i(ic)$.

- $Mobility(M_i)$: Mobility used for the calculations.
- $B_{UL}^{M_i}$: Bearer assigned to the pixel, subscriber, or mobile M_i in the uplink as explained in "C/(I+N) and Bearer Calculation (UL)" on page 761.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the graphs available in the Wi-Fi equipment assigned to the cell $TX_i(ic)$. BLER is determined for $CINR_{UL}^{M_i}$.

9955 also takes into account the SU-MIMO Gain Factor $f_{SU-MIMO}$ defined for the clutter class where the pixel, subscriber, or mobile M_i is located.

$$\eta_{B_{UL}^{M_i}} = \eta_{B_{UL}^{M_i}} \times (1 + f_{SU-MIMO}(G_{SU-MIMO}^{Max} - 1)) \text{ if } CNR_{DL}^{TX_i(ic)} > T_{AMS}^{TX_i(ic)}$$

If the Max SU-MIMO Gain for the exact value of the C/(I+N) is not available in the table, it is interpolated from the gain values available for the C/(I+N) just less than and just greater than the actual C/(I+N).

- **Effective MAC Channel Throughput:** $CTP_{E-UL}^{M_i} = CTP_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Channel Throughput:** $CTP_{A-UL}^{M_i} = CTP_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$
- **Peak MAC Cell Capacity:** $Cap_{P-UL}^{M_i} = CTP_{P-UL}^{M_i} \times TL_{UL-Max}^{TX_i(ic)}$
- **Effective MAC Cell Capacity:** $Cap_{E-UL}^{M_i} = Cap_{P-UL}^{M_i} \times \left(1 - BLER\left(B_{UL}^{M_i}\right)\right)$
- **Application Cell Capacity:** $Cap_{A-UL}^{M_i} = Cap_{E-UL}^{M_i} \times \frac{f_{TP-Scaling}^{M_i}}{100} - TP_{Offset}^{M_i}$

Output

- $CTP_{P-DL}^{M_i}$: Downlink peak MAC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{E-DL}^{M_i}$: Downlink effective MAC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{A-DL}^{M_i}$: Downlink application channel throughput at the pixel, subscriber, or mobile M_i.
- $Cap_{P-DL}^{M_i}$: Downlink peak MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{E-DL}^{M_i}$: Downlink effective MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{A-DL}^{M_i}$: Downlink application cell capacity at the pixel, subscriber, or mobile M_i.
- $CTP_{P-UL}^{M_i}$: Uplink peak MAC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{E-UL}^{M_i}$: Uplink effective MAC channel throughput at the pixel, subscriber, or mobile M_i.
- $CTP_{A-UL}^{M_i}$: Uplink application channel throughput at the pixel, subscriber, or mobile M_i.
- $Cap_{P-UL}^{M_i}$: Uplink peak MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{E-UL}^{M_i}$: Uplink effective MAC cell capacity at the pixel, subscriber, or mobile M_i.
- $Cap_{A-UL}^{M_i}$: Uplink application cell capacity at the pixel, subscriber, or mobile M_i.

10.4.6 Scheduling and Radio Resource Management

Wi-Fi scheduling and RRM algorithms are explained in "Scheduling and Radio Resource Allocation" on page 768 and the calculation of user throughputs is explained in "User Throughput Calculation" on page 770.

10.4.6.1 Scheduling and Radio Resource Allocation

Input

- $TL_{DL-Max}^{TX_i(ic)}$: Maximum downlink traffic load for the cell *TX*$_i$*(ic).*
- $TL_{UL-Max}^{TX_i(ic)}$: Maximum uplink traffic load for the cell *TX*$_i$*(ic).*
- $N_{Users-Max}^{TX_i(ic)}$: Maximum number of users defined for the cell *TX*$_i$*(ic).*
- p^{M_i} : Priority of the service accessed by a mobile M_i.
- $TPD_{Min-DL}^{M_i}$: Downlink minimum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Min-UL}^{M_i}$: Uplink minimum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Max-DL}^{M_i}$: Downlink maximum throughput demand for the service accessed by a mobile M_i.
- $TPD_{Max-UL}^{M_i}$: Uplink maximum throughput demand for the service accessed by a mobile M_i.
- $BLER\left(B_{DL}^{M_i}\right)$: Downlink block error rate read from the BLER vs. $CINR_{DL}^{TX_i(ic)}$ graph available in the Wi-Fi equipment assigned to the terminal used by the mobile M_i.
- $BLER\left(B_{UL}^{M_i}\right)$: Uplink block error rate read from the BLER vs. $CINR_{UL}^{M_i}$ graph available in the Wi-Fi equipment assigned to the cell *TX*$_i$*(ic)*.
- $f_{TP-Scaling}^{M_i}$: Throughput scaling factor defined in the properties of the service used by the mobile M_i.
- $TP_{Offset}^{M_i}$: Throughput offset defined in the properties of the service used by the mobile M_i.
- $CTP_{P-DL}^{M_i}$: Downlink peak MAC channel throughput at the mobile M_i as calculated in "Throughput Calculation" on page 764.
- $CTP_{P-UL}^{M_i}$: Uplink peak MAC channel throughput at the mobile M_i as calculated in "Throughput Calculation" on page 764.

Calculations

The following calculations are described for any cell *TX*$_i$*(ic)* containing the users M_i for which it is the best server.

Mobile Selection:

The scheduler selects $N_{Users}^{TX_i(ic)}$ mobiles for the scheduling and RRM process. If the Monte Carlo user distribution has generated a number of users which is less than $N_{Users-Max}^{TX_i(ic)}$, the scheduler keeps all the mobiles generated for the cell *TX*$_i$*(ic)*.

$$N_{Users}^{TX_i(ic)} = Min\left(N_{Users-Max}^{TX_i(ic)}, N_{Users-Generated}^{TX_i(ic)}\right)$$

For a cell, mobiles $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ are selected for RRM by the scheduler.

Resource Allocation for Minimum Throughput Demands:

1. **9955** sorts the $M_i^{Sel} \in N_{Users}^{TX_i(ic)}$ in order of decreasing service priority, $p^{M_i^{Sel}}$:
2. Starting with $M_i^{Sel} = 1$ up to $M_i^{Sel} = N$, **9955** allocates the downlink and uplink resources required to satisfy each user's minimum throughput demands in downlink and uplink as follows:

$$R_{Min-DL}^{M_i^{Sel}} = \frac{TPD_{Min-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}} \text{ and } R_{Min-UL}^{M_i^{Sel}} = \frac{TPD_{Min-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$$

3. **9955** stops the resource allocation in downlink or uplink,

- When/If in downlink $\sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} = TL_{DL-Max}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the minimum throughput demands of the mobiles.
- When/If in uplink $\sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} = TL_{UL-Max}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the minimum throughput demands of the mobiles.

4. Mobiles which are active DL+UL must be able to get their minimum throughput demands in both UL and DL in order to be considered connected DL+UL. If an active DL+UL mobile is only able to get its minimum throughput demand in one direction, it is rejected, and the resources, that were allocated to it in the one direction in which it was able to get a throughput, are allocated to other mobiles.

5. If $\sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} < TL_{DL-Max}^{TX_i(ic)}$ or $\sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} < TL_{UL-Max}^{TX_i(ic)}$, and all the minimum throughput resources demanded by the mobiles have been allocated, **9955** goes to the next step for allocating resources to satisfy the maximum throughput demands.

The remaining cell resources available for the next step are:

Downlink: $R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}}$

Uplink: $R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}}$

Resource Allocation for Maximum Throughput Demands:

For each mobile, the throughput demands remaining once the minimum throughput demands have been satisfied are the difference between the maximum and the minimum throughput demands:

Downlink: $TPD_{Rem-DL}^{M_i^{Sel}} = TPD_{Max-DL}^{M_i^{Sel}} - TPD_{Min-DL}^{M_i^{Sel}}$

Uplink: $TPD_{Rem-UL}^{M_i^{Sel}} = TPD_{Max-UL}^{M_i^{Sel}} - TPD_{Min-UL}^{M_i^{Sel}}$

Let the total number of users with remaining throughput demands greater than 0 be $N \in M_i^{Sel}$.

1. **9955** divides the remaining resources in the cell into equal parts for each user:

   $\frac{R_{Rem-DL}^{TX_i(ic)}}{N}$ and $\frac{R_{Rem-UL}^{TX_i(ic)}}{N}$

2. **9955** converts the remaining throughput demands of all the users to their respective remaining resource demands:

   $RD_{Rem-DL}^{M_i^{Sel}} = \frac{TPD_{Rem-DL}^{M_i^{Sel}}}{CTP_{P-DL}^{M_i^{Sel}}}$ and $RD_{Rem-UL}^{M_i^{Sel}} = \frac{TPD_{Rem-UL}^{M_i^{Sel}}}{CTP_{P-UL}^{M_i^{Sel}}}$

   Remaining resource demands of a user are given by the ratio between its remaining throughput demands and the peak channel throughputs at the user's location.

3. The resources allocated to each user for satisfying its maximum throughput demands are:

   $R_{Max-DL}^{M_i^{Sel}} = Min\left(RD_{Rem-DL}^{M_i^{Sel}}, \frac{R_{Rem-DL}^{TX_i(ic)}}{N}\right)$ and $R_{Max-UL}^{M_i^{Sel}} = Min\left(RD_{Rem-UL}^{M_i^{Sel}}, \frac{R_{Rem-UL}^{TX_i(ic)}}{N}\right)$

   Each user gets either the resources it needs to achieve its maximum throughput demands or an equal share from the remaining resources of the cell, whichever is smaller.

4. **9955** stops the resource allocation in downlink or uplink,
   - When/If in downlink $\sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} = R_{Rem-DL}^{TX_i(ic)}$, i.e., the resources available in downlink have been used up for satisfying the maximum throughput demands of the mobiles.
   - When/If in uplink $\sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}} = R_{Rem-UL}^{TX_i(ic)}$, i.e., the resources available in uplink have been used up for satisfying the maximum throughput demands of the mobiles.
5. If the resources allocated to a user satisfy its maximum throughput demands, this user is removed from the list of remaining users.
6. **9955** recalculates the remaining resources as follows:

$$R_{Rem-DL}^{TX_i(ic)} = TL_{DL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-DL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-DL}^{M_i^{Sel}} \text{ and}$$

$$R_{Rem-UL}^{TX_i(ic)} = TL_{UL-Max}^{TX_i(ic)} - \sum_{M_i^{Sel}} R_{Min-UL}^{M_i^{Sel}} - \sum_{M_i^{Sel}} R_{Max-UL}^{M_i^{Sel}}$$

7. **9955** repeats the all the above steps for the users whose maximum throughput demands have not been satisfied until either $R_{Rem-DL}^{TX_i(ic)} = 0$ and $R_{Rem-UL}^{TX_i(ic)} = 0$, or all the maximum throughput demands are satisfied.

Total Amount of Resources Assigned to Each Selected Mobile:

9955 calculates the amounts of downlink and uplink resources allocated to each individual mobile M_i^{Sel} (which can also be referred to as the traffic loads of the mobiles) as follows:

Downlink: $TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}} = R_{Min-DL}^{M_i^{Sel}} + R_{Max-DL}^{M_i^{Sel}}$

Uplink: $TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}} = R_{Min-UL}^{M_i^{Sel}} + R_{Max-UL}^{M_i^{Sel}}$

Output

- $TL_{DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}}$: Downlink traffic load or the amount of downlink resources allocated to the mobile M_i^{Sel}.
- $TL_{UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}}$: Uplink traffic load or the amount of uplink resources allocated to the mobile M_i^{Sel}.

10.4.6.2 User Throughput Calculation

User throughputs are calculated for the percentage of resources allocated to each mobile selected by the scheduling for RRM during the Monte Carlo simulations, M_i^{Sel}.

Input

- $R_{DL}^{M_i^{Sel}}$: Amount of downlink resources allocated to the mobile M_i^{Sel} as calculated in "Scheduling and Radio Resource Allocation" on page 768.
- $R_{UL}^{M_i^{Sel}}$: Amount of uplink resources allocated to the mobile M_i^{Sel} as calculated in "Scheduling and Radio Resource Allocation" on page 768.
- $CTP_{P-DL}^{M_i^{Sel}}$: Downlink peak MAC channel throughput at the mobile M_i^{Sel} as calculated in "Throughput Calculation" on page 764.

- $CTP_{P-UL}^{M_i^{Sel}}$: Uplink peak MAC channel throughput at the mobile M_i^{Sel} as calculated in "Throughput Calculation" on page 764.
- $BLER\left(B_{DL}^{M_i^{Sel}}\right)$: Downlink block error rate read from the BLER vs. $CINR_{Traffic}^{TX_i(ic)}$ graph available in the Wi-Fi equipment assigned to the terminal used by the mobile M_i^{Sel}.
- $BLER\left(B_{UL}^{M_i^{Sel}}\right)$: Uplink block error rate read from the BLER vs. $CINR_{UL}^{M_i}$ graph available in the Wi-Fi equipment assigned to the cell $TX_i(ic)$.
- $f_{TP-Scaling}^{M_i^{Sel}}$: Throughput scaling factor defined in the properties of the service used by the mobile M_i^{Sel}.
- $TP_{Offset}^{M_i^{Sel}}$: Throughput offset defined in the properties of the service used by the mobile M_i^{Sel}.

Calculations

Downlink:

- **Peak MAC User Throughput:** $UTP_{P-DL}^{M_i^{Sel}} = R_{DL}^{M_i^{Sel}} \times CTP_{P-DL}^{M_i^{Sel}}$
- **Effective MAC User Throughput:** $UTP_{E-DL}^{M_i^{Sel}} = UTP_{P-DL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{DL}^{M_i^{Sel}}\right)\right)$
- **Application User Throughput:** $UTP_{A-DL}^{M_i^{Sel}} = UTP_{E-DL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$

Uplink:

- **Peak MAC User Throughput:** $UTP_{P-UL}^{M_i^{Sel}} = R_{UL}^{M_i^{Sel}} \times CTP_{P-UL}^{M_i^{Sel}}$
- **Effective MAC User Throughput:** $UTP_{E-UL}^{M_i^{Sel}} = UTP_{P-UL}^{M_i^{Sel}} \times \left(1 - BLER\left(B_{UL}^{M_i^{Sel}}\right)\right)$
- **Application User Throughput:** $UTP_{A-UL}^{M_i^{Sel}} = UTP_{E-UL}^{M_i^{Sel}} \times \frac{f_{TP-Scaling}^{M_i^{Sel}}}{100} - TP_{Offset}^{M_i^{Sel}}$

Output

- $UTP_{P-DL}^{M_i^{Sel}}$: Downlink peak MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{E-DL}^{M_i^{Sel}}$: Downlink effective MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{A-DL}^{M_i^{Sel}}$: Downlink application user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{P-UL}^{M_i^{Sel}}$: Uplink peak MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{E-UL}^{M_i^{Sel}}$: Uplink effective MAC user throughput at the pixel, subscriber, or mobile M_i^{Sel}.
- $UTP_{A-UL}^{M_i^{Sel}}$: Uplink application user throughput at the pixel, subscriber, or mobile M_i^{Sel}.

Technical Reference Guide

Release V7.1.2

3DF 01955 7181 RKZZA ED.02
29 June 2012

Alcatel-Lucent Romania
Gh. LAZAR, no. 9
300081 Timisoara, Romania

9955 User Support:

We are always interested in meeting our customers' needs, in continuously improving our software and giving you the support you need in order to successfully master your network planning.

If you encounter any problems with the *9955* software, please contact the Alcatel-Lucent hotline support (available during Romanian working days from 8:00 a.m. to 5:00 p.m. CET):

Tel:	+40 256 303 135
Fax:	+40 256 303413
e-mail:	radiotools.support@alcatel-lucent.com

Please help *us* in helping *you* –by being as precise as possible in describing your specific problems. Thank you.