LTE RF Optimization Guide V1.0

LTE RNPS

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Change History

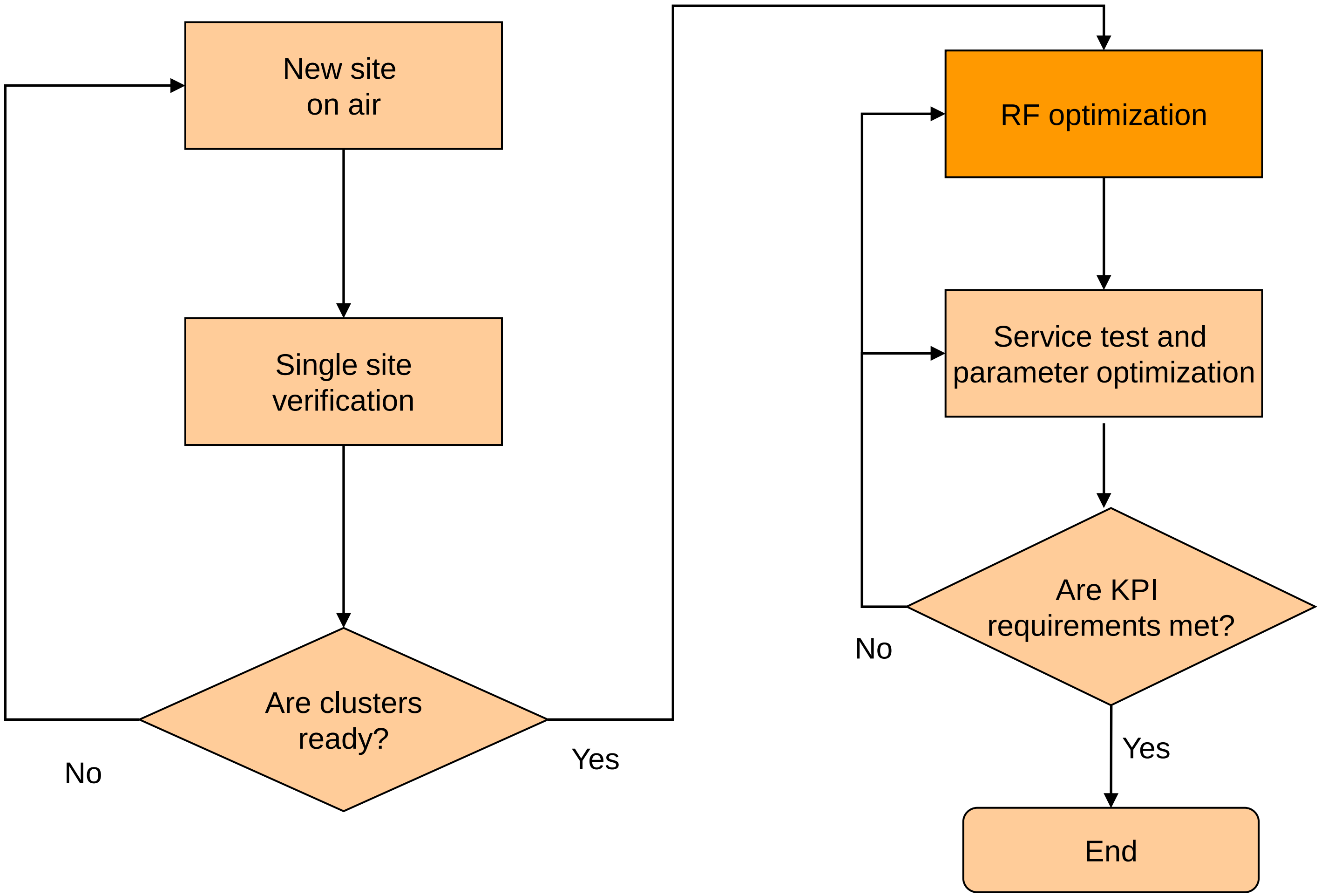
Date	Version	Description	Author
	0.5		LTE RNPS
	1.0		LTE RNPS

Preface

To meet customers' requirements for high-quality networks, LTE trial networks must be optimized during and after project implementation. Radio frequency (RF) optimization is necessary in the entire optimization process. This document provides guidelines on network optimization for network planning and optimization personnel.

Contents

Network Optimization Flowchart



Network Optimization Process

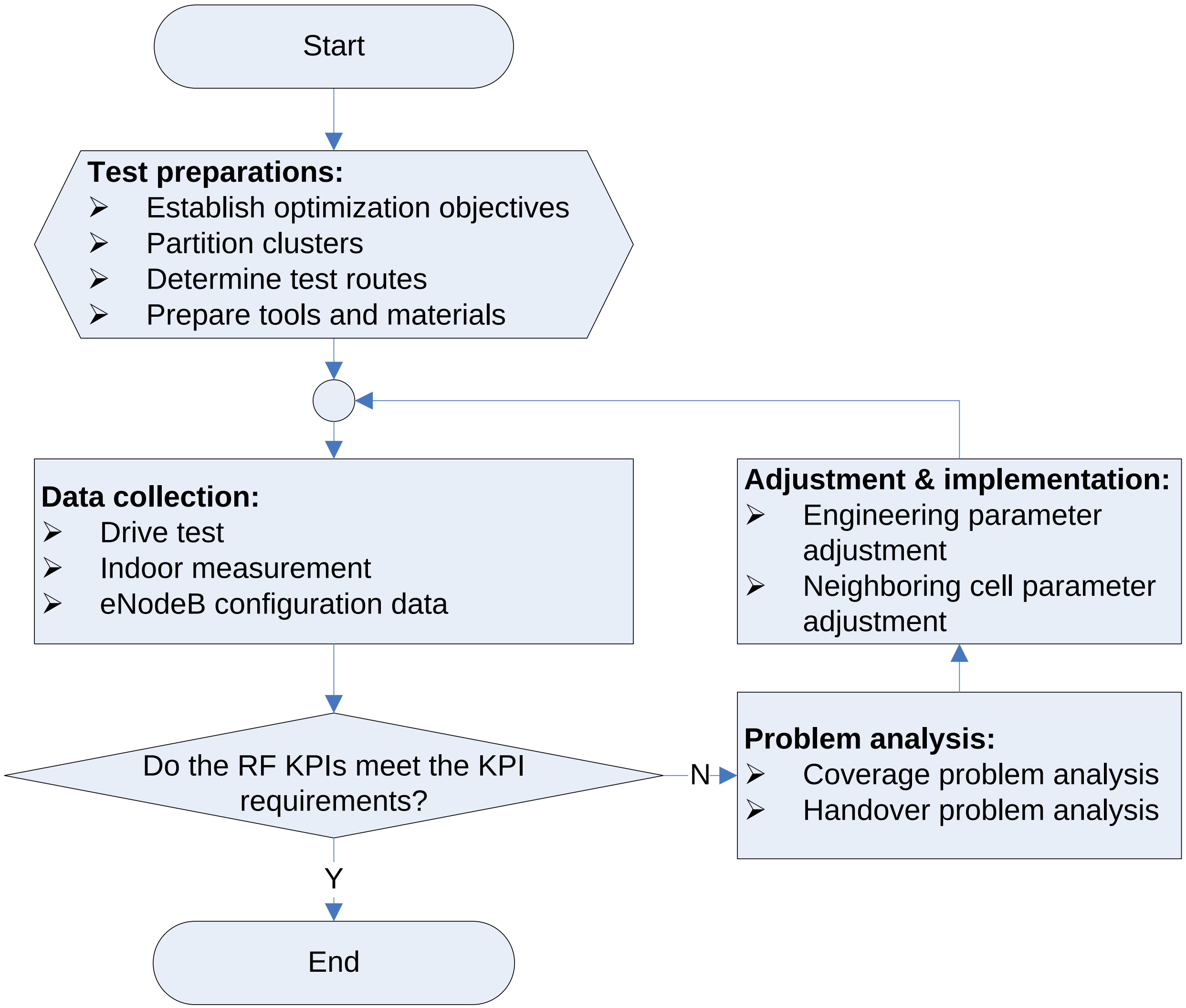
- **Single site verification**

  Single site verification, the first phase of network optimization, involves function verification at each new site. Single site verification aims to ensure that each site is properly installed and that parameters are correctly configured.

- **RF optimization**

  RF (or cluster) optimization starts after all sites in a planned area are installed and verified. RF optimization aims to control pilot pollution while optimizing signal coverage, increase handover success rates, and ensure normal distribution of radio signals before parameter optimization. RF optimization involves optimization and adjustment of antenna system hardware and neighbor lists. The first RF optimization test must traverse all cells in an area to rectify hardware faults.

RF Optimization Flowchart



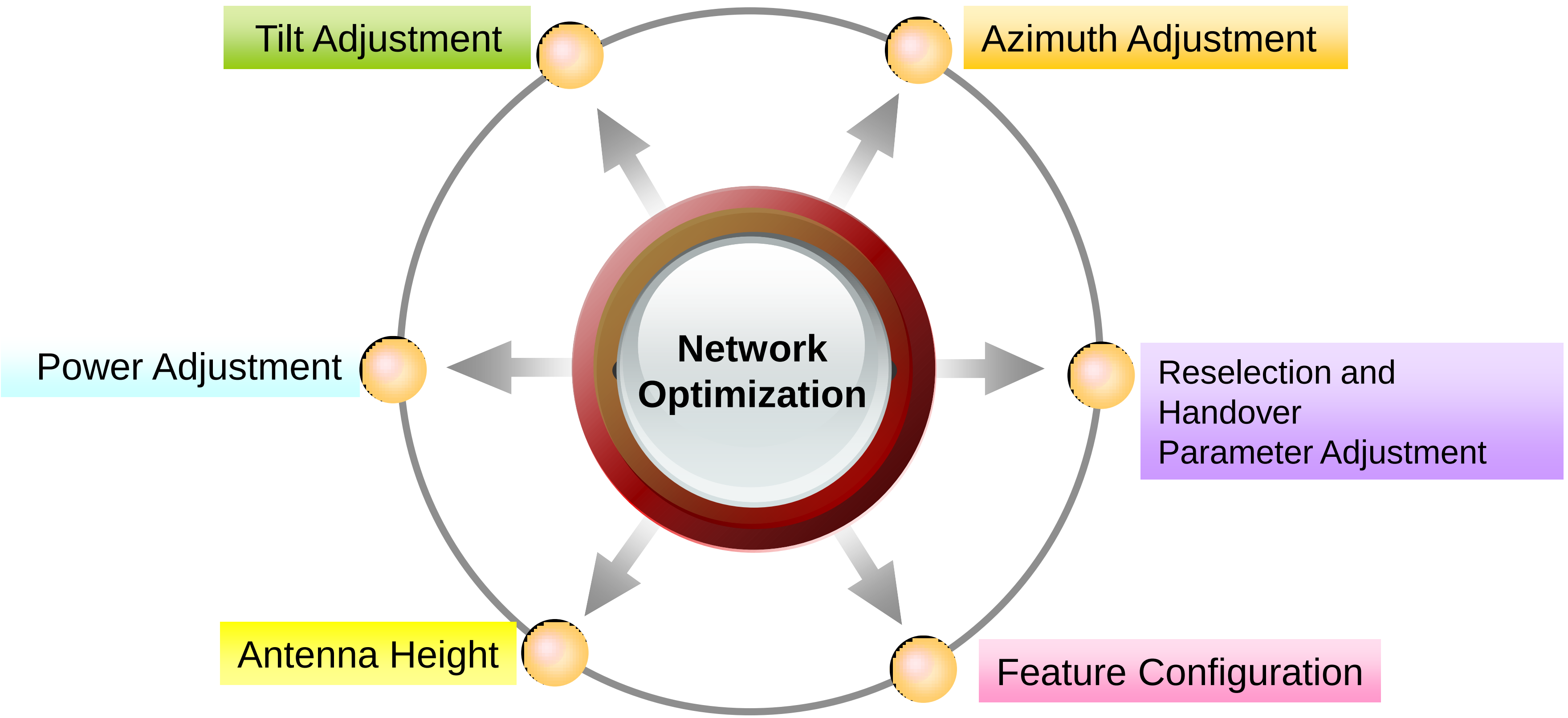
Preparations for RF Optimization

Checklist

- Network plan, network structure diagram, site distribution, site information, and engineering parameters
- Drive test results (such as service drop points and handover failure points) in the current area
- Reference signal received power (RSRP) coverage diagram
- Signal to interference plus noise ratio (SINR) distribution diagram
- Measured handover success rates

➢ Areas to be optimized can be determined by comparing the distribution of RSRPs, SINRs, and handover success rates with the optimization baseline.

Network Optimization Methods



RF optimization involves adjustment of azimuths, tilts, antenna height, eNodeB transmit power, feature algorithms, and performance parameters. Optimization methods in different standards are similar, but each standard has its own measurement definition.

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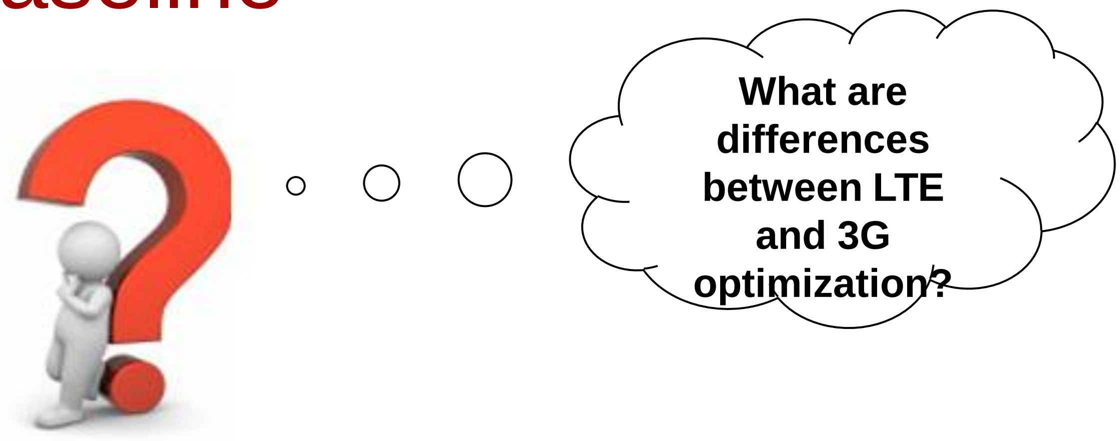
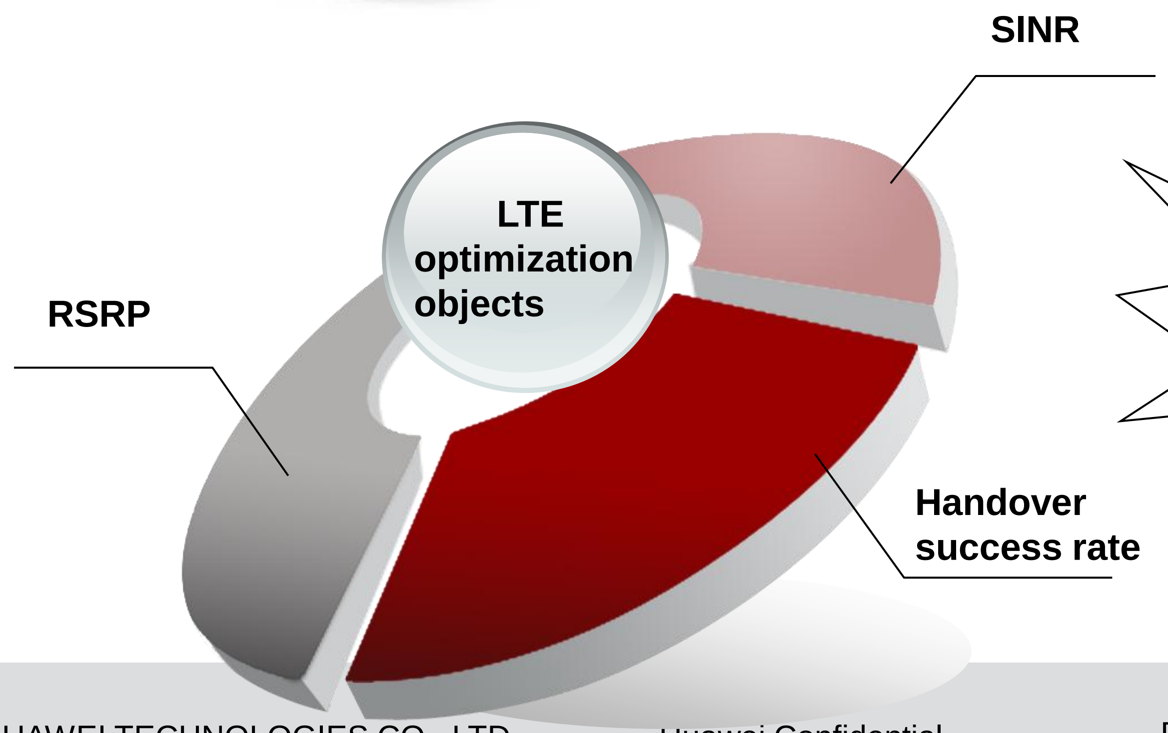
LTE RF Optimization Objects and Target Baseline





How are these counters defined?

RSRP

3GPP definition

Reference signal received power (RSRP), is determined for a considered cell as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth.

- **Note: Different from GSM or TD-SCDMA systems, TD-LTE systems have multiple subcarriers multiplexed. Therefore, the measured pilot signal strength is the RSRP of a single subcarrier (15 kHz) not the total bandwidth power of the frequency.**

The RSRPs near a cell, in the middle of a cell, and at the edge of a cell are determined based on the distribution of signals on the entire network. Generally, the RSRP near a cell is -85 dBm, the RSRP in the middle of a cell is -95 dBm, and the RSRP at the edge of a cell is -105 dBm.

Currently, the minimum RSRP for UEs to camp on a cell is -120 dBm.

- **Empirical RSRP at the edge of a cell:**

The RSRP is greater than -110 dBm in 99% areas at the TD-LTE site in Norway.

The RSRP is greater than -110 dBm in 98.09% areas in the Huayang field in Chengdu.

SINR

The SINR is not specifically defined in 3GPP specifications. A common formula is as follows:

SINR = S/(I + N)

- **S: indicates the power of measured usable signals. Reference signals (RS) and physical downlink shared channels (PDSCHs) are mainly involved.**
- **I: indicates the power of measured signals or channel interference signals from other cells in the current system and from inter-RAT cells.**
- **N: indicates background noise, which is related to measurement bandwidths and receiver noise coefficients.**

- **Empirical SINR at the edge of a cell:**

The SINR is greater than -3 dB in 99% areas in Norway.

The SINR is greater than -3 dB in 99.25% areas in the Huayang field in Chengdu.

Handover Success Rate

According to the signaling process in 3GPP TS 36.331,

- eNodeB statistics

(1) Handover success rate = Number of handovers/Number of handover attempts x 100%

(2) Number of handover attempts: indicates the number of eNodeB-transmitted RRCConnectionReconfiguration messages for handovers.

(3) Number of handovers: indicates the number of eNodeB-received RRCConnectionReconfigurationComplete messages for handovers.

- Handover success rate

The handover success rate is greater than 97% at the TD-LTE site in Norway.

The handover success rate is 100% in the Huayang field in Chengdu.

Power Adjustment Method

Definitions in 3GPP specifications

Subcarriers share the transmit power of an eNodeB, and therefore the transmit power of each subcarrier depends on the configured system bandwidth (such as 5 MHz and 10 MHz). A larger bandwidth will result in lower power of each subcarrier. LTE uses PA and PB parameters to adjust power.

ρA: indicates the ratio of the data subcarrier power of OFDM symbols excluding pilot symbols to the pilot subcarrier power.

ρB: indicates the ratio of the data subcarrier power of OFDM symbols including pilot symbols to the pilot subcarrier power.

◆**Service power configuration (calculating PDSCH power based on RS power)**

RS power PA and PB are delivered using RRC signaling. For two antennas, PA is ρA and **ρB is calculated based on the right table. PDSCH power is calculated based on PA and PB. Currently, it is recommended that PB be set to 1 dB and PA be set to -3 dB. That is, the pilot power for symbols including pilot symbols accounts for 1/3. This setting optimizes network performance and ensures that the pilot power for Type A and Type B symbols is equivalent to the service channel power. In scenarios with special requirements, for example, in rural scenarios requiring low edge rates, PB can be set to 2 or 3 dB to enhance coverage.**

P_B	ρ_B / ρ_A	
	One Antenna Port	Two and Four Antenna Ports
0	1	5/4
1	4/5	1
2	3/5	3/4
3	2/5	1/2

◆**Control channels**

Power of PDCCHs, PHICHs, PCFICHs, PBCHs, primary synchronization channels, and secondary synchronization channels is set using an offset from RS power.

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- **Network and RF Optimization Processes**
- **LTE RF Optimization Objects**
- **Troubleshooting**
  - Coverage
  - Signal quality
  - Handover success rate

Classification of Coverage Problems (RSRP is mainly involved)

Weak coverage and coverage holes	Cross coverage	Imbalance between uplink and downlink	Lack of a dominant cell
Continuous coverage must be ensured.	The actual coverage must be consistent with the planned one to prevent service drops caused by isolated islands during handovers.	Uplink and downlink losses must be balanced to resolve uplink and downlink coverage problems.	Each cell on a network must have a dominant coverage area to prevent frequent reselections or handovers caused by signal changes.

Factors Affecting Coverage

1

Downlink:
- Equivalent isotropic radiated power (EIRP)
- Total transmit power
- Combining loss
- Path loss (PL)
- Frequency band
- Distance between a receive point and an eNodeB
- Scenarios (urban and suburban areas) and terrains (plains, mountains, and hills) of electric wave propagation
- Antenna gain
- Antenna height
- Antenna parameters (antenna pattern)
- Antenna tilt
- Antenna azimuth

2

Uplink:
- eNodeB receiver sensitivity
- Antenna diversity gain
- UE transmit power
- Propagation loss of uplink radio signals
- Impact of tower-mounted amplifiers (TMAs) on uplink

Weak Coverage and Coverage Holes

Weak coverage

The signal quality in cells is poorer than the optimization baseline in an area. As a result, UEs cannot be registered with the network or accessed services cannot meet QoS requirements.

Coverage holes

If there is no network coverage or coverage levels are excessively low in an area, the area is called a weak coverage area. The receive level of a UE is less than its minimum access level (RXLEV_ACCESS_MIN) because downlink receive levels in a weak coverage area are unstable. In this situation, the UE is disconnected from the network. After entering a weak coverage area, UEs in connected mode cannot be handed over to a high-level cell, and even service drops occur because of low levels and signal quality.

Resolving Weak Coverage Problems

- **Analyze geographical environments and check the receive levels of adjacent eNodeBs.**
- **Analyze the EIRP of each sector based on parameter configurations and ensure EIRPs can reach maximum values if possible.**
- **Increase pilot power.**
- **Adjust antenna azimuths and tilts, increase antenna height, and use high-gain antennas.**

- **Deploy new eNodeBs if coverage hole problems cannot be resolved by adjusting antennas.**
- **Increase coverage by adjacent eNodeBs to achieve large coverage overlapping between two eNodeBs and ensure a moderate handover area.**

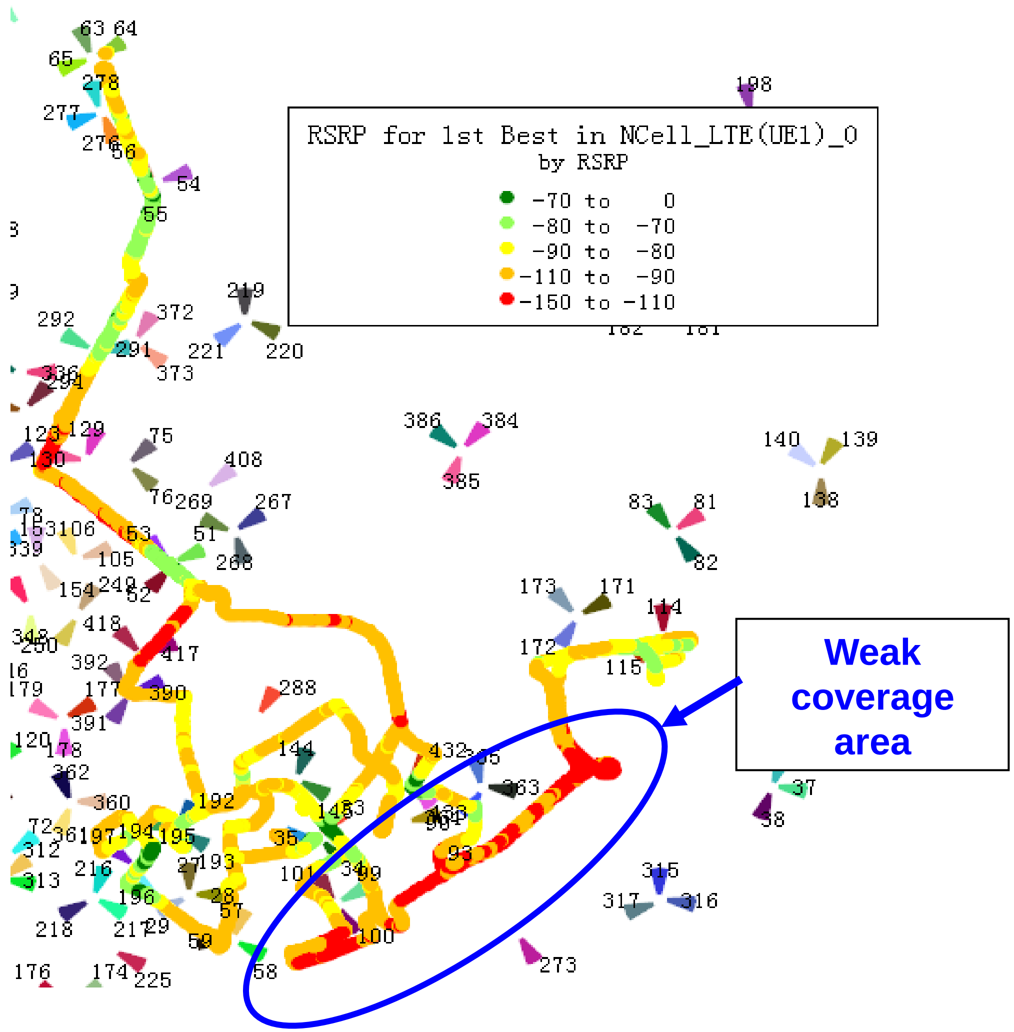
Note: Increasing coverage may lead to co-channel and adjacent-channel interference.

- **Use RRUs, indoor distribution systems, leaky feeders, and directional antennas to resolve the problem with blind spots in elevator shafts, tunnels, underground garages or basements, and high buildings.**
- **Analyze the impact of scenarios and terrains on coverage.**

Case: Searching for a Weak Coverage Area by Using a Scanner or Performing Drive Tests on UEs

Perform drive tests in zero-load environments to obtain the distribution of signals on test routes. Then, find a weak coverage area based on the distribution, as shown in the figure.

Adjust RF parameters of the eNodeB covering the area.



Lack of a Dominant Cell

Lack of a dominant cell

In an area without a dominant cell, the receive level of the serving cell is similar to the receive levels of its neighboring cells and the receive levels of downlink signals between different cells are close to cell reselection thresholds. Receive levels in an area without a dominant cell are also unsatisfactory. The SINR of the serving cell becomes unstable because of frequency reuse, and even receive quality becomes unsatisfactory. In this situation, a dominant cell is frequently reselected and changed in idle mode. As a result, frequent handovers or service drops occur on UEs in connected mode because of poor signal quality. An area without a dominant cell can also be regarded as a weak coverage area.

Resolving Problems with Lack of a Dominant Cell

- **Determine cells covering an area without a dominant cell during network planning, and adjust antenna tilts and azimuths to increase coverage by a cell with strong signals and decrease coverage of other cells with weak signals.**

- **Adjust engineering parameters of a cell that can optimally cover the area as required.**

Case: Searching for an Area Without a Dominant Cell

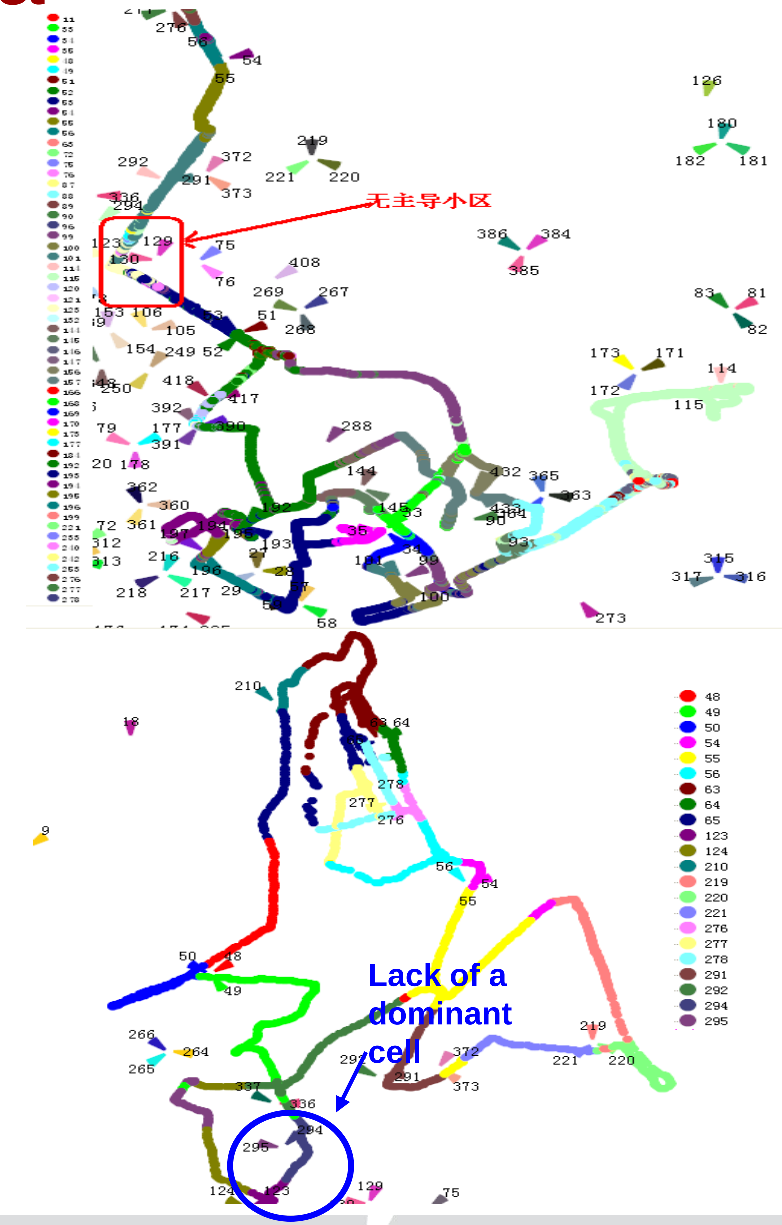
- Symptom

  UEs frequently perform cell reselections or handovers between identical cells.
- Analysis

  Analysis can be based on signaling procedures and PCI distribution.

  According to PCI distribution shown in the figure, PCIs alternate in two or more colors if there is no dominant cell.
- Solution

  According to the coverage plan, cell 337 is a dominant cell covering the area and cell 49 also has strong signals. To ensure handovers between cells 337 and 49 at crossroads, increase tilts in cell 49.



1.PCI distribution in cluster xx

Cross Coverage

Cross coverage

Cross coverage means that the coverage scope of an eNodeB exceeds the planned one and generates discontinuous dominant areas in the coverage scope of other eNodeBs. For example, if the height of a site is much higher than the average height of surrounding buildings, its transmit signals propagate far along hills or roads and form dominant coverage in the coverage scope of other eNodeBs. This is an "island" phenomenon. If a call is connected to an island that is far away from an eNodeB but is still served by the eNodeB, and cells around the island are not configured as neighboring cells of the current cell when cell handover parameters are configured, call drops may occur immediately once UEs leave the island. If neighboring cells are configured but the island is excessively small, call drops may also occur because UEs are not promptly handed over. In addition, cross coverage occurs on two sides of a bay because a short distance between the two sides. Therefore, eNodeBs on two sides of a bay must be specifically designed.

Resolving Cross Coverage Problems

- **Adjust antenna azimuths properly so that the direction of the main lobe slightly obliques from the direction of a street. This reduces excessively far coverage by electric waves because of reflection from buildings on two sides of the street.**

- **Adjust antenna tilts or replace antennas with large-tilt antennas while ensuring proper antenna azimuths. Tilt adjustment is the most effective approach to control coverage. Tilts are classified into electrical tilts and mechanical tilts. Electrical tilts are preferentially adjusted if possible.**

- **Decrease the antenna height for a high site.**
- **Decrease transmit power of carriers when cell performance is not affected.**

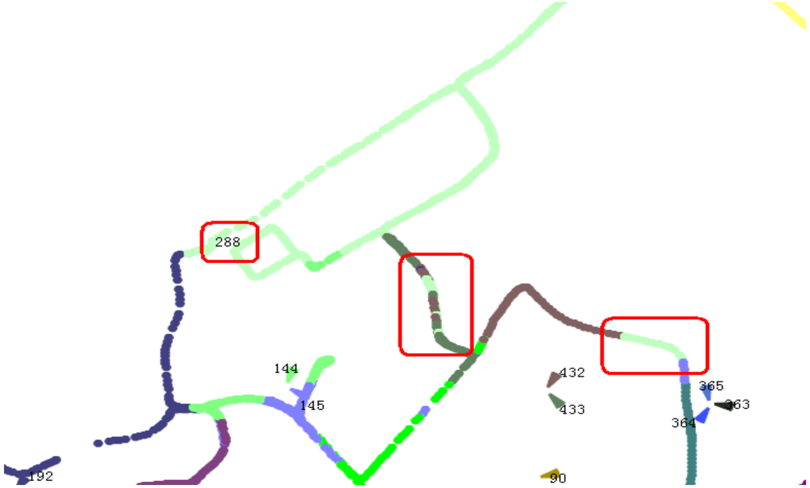
Case: Cross Coverage Caused by Improper Tilt Settings

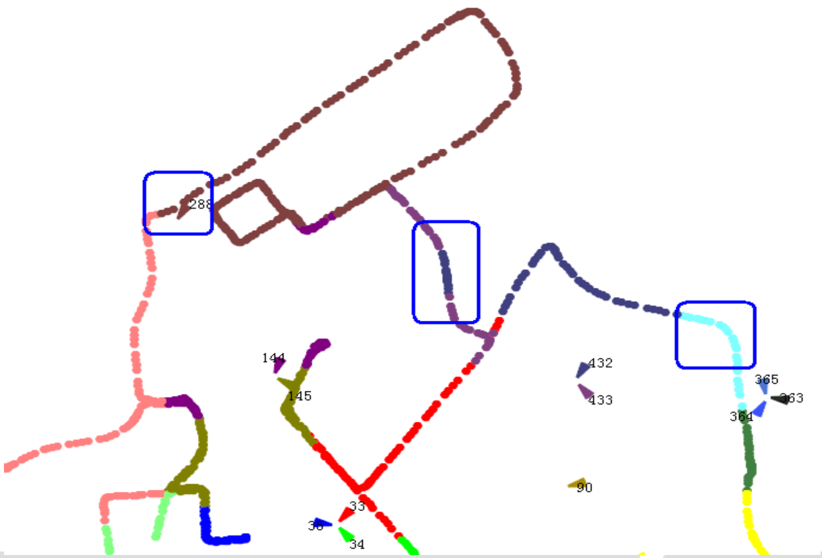
- Symptom

  As shown in the upper right figure, cross coverage occurs in a cell whose PCI is 288. Therefore, the cell interferes with other cells, which increases the probability of service drops.
- Analysis

  The most possible cause for cross coverage is excessively antenna height or improper tilt settings. According to a check on the current engineering parameter settings, the tilt is set to an excessively small value. Therefore, it is recommended that the tilt be increased.
- Solution

  Adjust the tilt of cell 288 from 3 to 6. As shown in the lower right figure, cross coverage of cell 288 is significantly reduced after the tilt is adjusted.





Case: Inverse Connections Involved in the Antenna System

- **Symptom**

  The RSRPs of cells 0 and 2 at the Expo Village site are low and high respectively in the red area shown in the figure. The signal quality of cells 0 and 2 is satisfactory in the areas covered by cells 2 and 0 respectively.

- **Analysis**

  After installation and commissioning are complete, the RSRP in the direction of the main lobe in cell 0 is low. After cell 0 is disabled and cell 2 is enabled, the RSRP in cell 2 is normal and the SINR is higher than that tested in cell 0. Therefore, this problem may occur because the antenna systems in the two cells are connected inversely. Test results are as expected after optical fibers on the baseband board are swapped.

- **Solution**

  Swap optical fibers on the baseband board or adjust feeders and antennas properly. It is recommended that optical fibers on the baseband board be swapped because this operation can be performed in the equipment room.

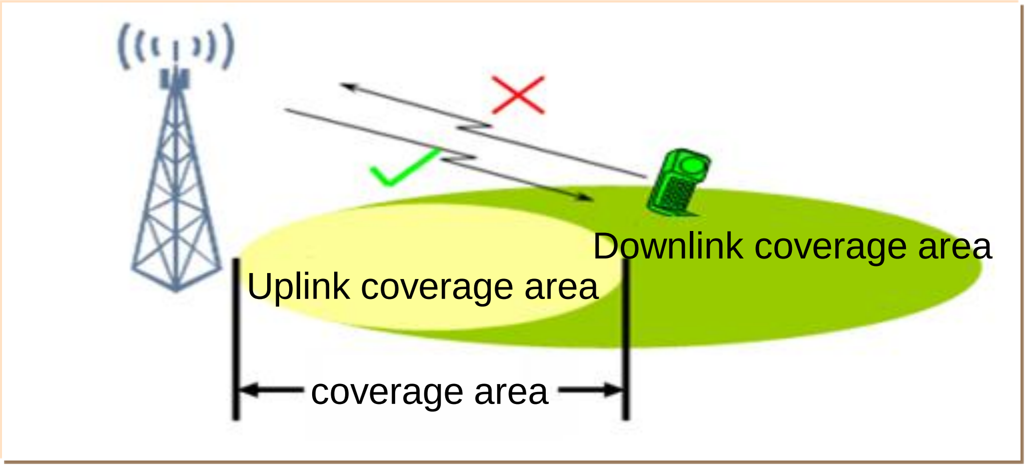
- **Suggestions**

  Network planning personnel must participate in installation. Alternatively, customer service personnel have detailed network planning materials and strictly supervise project constructors for installation. After installation is complete, labels must be attached and installation materials must be filed.

Imbalance Between Uplink and Downlink

Imbalance between uplink and downlink

When UE transmit power is less than eNodeB transmit power, UEs in idle mode may receive eNodeB signals and successfully register in cells. However, the eNodeB cannot receive uplink signals because of limited power when UEs perform random access or upload data. In this situation, the uplink coverage distance is less than the downlink coverage distance. Imbalance between uplink and downlink involves limited uplink or downlink coverage. In limited uplink coverage, UE transmit power reaches its maximum but still cannot meet the requirement for uplink BLERs. In limited downlink coverage, the downlink DCH transmit code power reaches its maximum but still cannot meet the requirement for the downlink BLER. Imbalance between uplink and downlink leads to service drops. The most common cause is limited uplink coverage.



Resolving Problems with Imbalance Between Uplink and Downlink

- If no performance data is available for RF optimization, trace a single user in the OMC equipment room to obtain uplink measurement reports on the Uu interface, and then analyze the measurement reports and drive test files.
- If performance data is available, check each carrier in each cell for imbalance between uplink and downlink based on uplink and downlink balance measurements.

- If uplink interference leads to imbalance between uplink and downlink, monitor eNodeB alarms to check for interference.
- Check whether equipment works properly and whether alarms are generated if imbalance between uplink and downlink is caused by other factors, for example, uplink and downlink gains of repeaters and trunk amplifiers are set incorrectly, the antenna system for receive diversity is faulty when reception and transmission are separated, or power amplifiers are faulty. If equipment works properly or alarms are generated, take measures such as replacement, isolation, and adjustment.

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Signal Quality (SINR is mainly involved)

① Frequency plan

② Cell layout

③ Site selection

④ Antenna height

⑤ Antenna azimuths

⑥ Antenna tilts

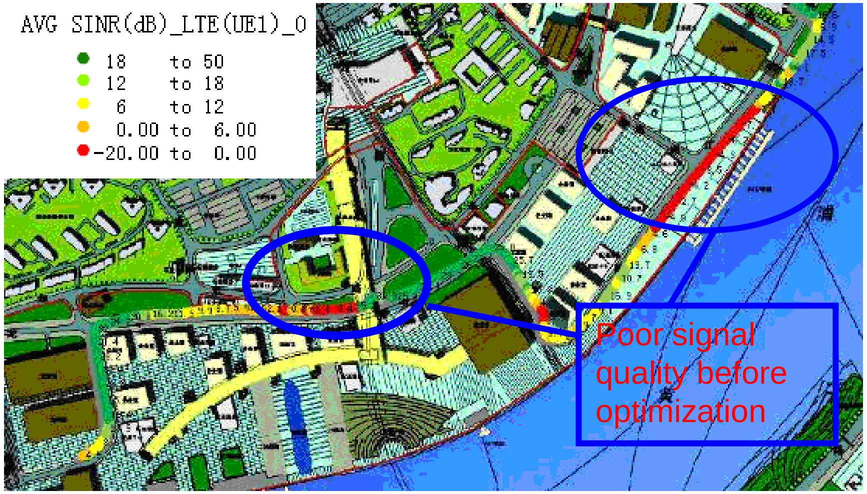
Process of analyzing SINR problems

Resolving Signal Quality Problems Caused by Improper Parameter Settings

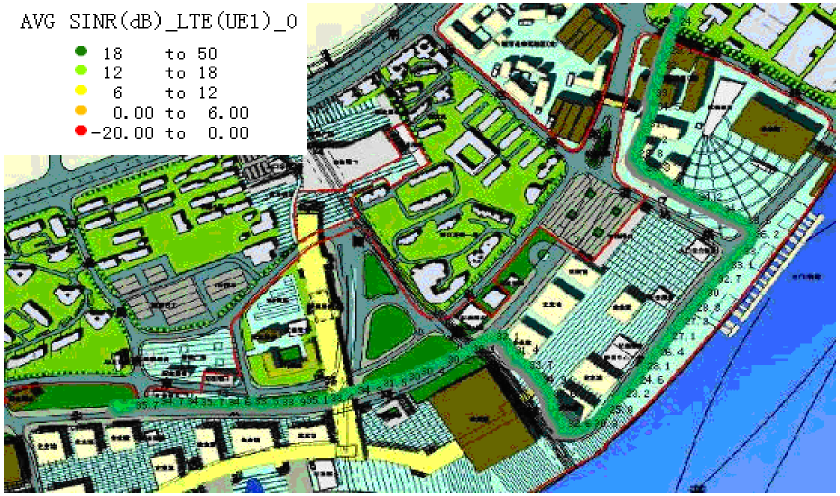
Optimizing frequencies	Change and optimize frequencies based on drive test and performance measurement data.
Adjusting the antenna system	Adjust antenna azimuths and tilts to change the distribution of signals in an interfered area by increasing the level of a dominant sector and decreasing levels of other sectors.
Adding dominant coverage	Increase power of a cell and decrease power of other cells to form a dominant cell.
Adjusting power	Decrease RS power to reduce coverage if the antenna pattern is distorted because of a large antenna tilt. Power adjustment and antenna system adjustment can be used together.

Case: Adjusting Antenna Azimuths and Tilts to Reduce Interference

- **Symptom**
  Cross coverage occurs at sites 1, 2, 3, 7, 8, 9, 10, 11, and 12, and co-channel interference occurs in many areas.
- **Analysis**
  According to the analysis of engineering parameters and drive test data, cell density is large in coverage areas. Coverage by each cell can be reduced by adjusting antenna azimuths and tilts.
- **Solution**
  Change the tilt in cell 28 from 2 degrees to 4 degrees so that the direction points to a demonstration route. Change the tilt in cell 33 from 3 degrees to 6 degrees so that the direction points to the Wanke Pavilion. Change the tilt in cells 50 and 51 from 3 degrees to 6 degrees so that the direction points to the Communication Pavilion. Decrease the transmit power in cell 33 by 3 dB to reduce its interference to overhead footpaths near China Pavilion.



SINR before optimization in Puxi



SINR after optimization in Puxi

Case: Changing PCIs of Intra-frequency Cells to Reduce Interference

- **Symptom**

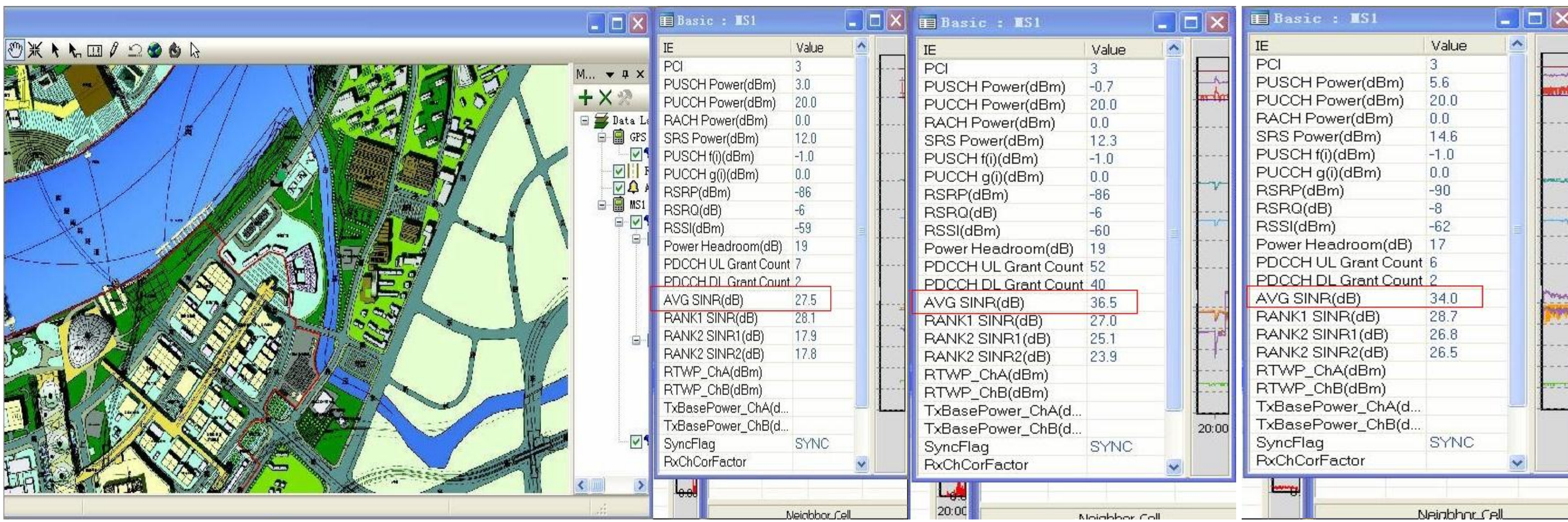
  Near Japan Pavilion, UEs access a cell whose PCI is 3 and SINRs are low. UEs are about 200 m away from the eNodeB. This problem may be caused by co-channel interference.

- **Analysis**

  This problem is not caused by co-channel interference because no neighboring cell has the same frequency as the current cell. Cell 6 interferes with cell 3. SINRs increase after cell 6 is disabled. In theory, staggered PCIs can reduce interference.

- **Solution**

  Change PCI 6 to PCI 8. Test results show that SINRs increase by about 10 dB.



IE	Value
PCI	3
PUSCH Power(dBm)	3.0
PUCCH Power(dBm)	20.0
RACH Power(dBm)	0.0
SRS Power(dBm)	12.0
PUSCH f(i)(dBm)	-1.0
PUCCH g(i)(dBm)	0.0
RSRP(dBm)	-86
RSRQ(dB)	-6
RSSI(dBm)	-59
Power Headroom(dB)	19
PDCCH UL Grant Count	7
PDCCH DL Grant Count	2
AVG SINR(dB)	27.5
RANK1 SINR(dB)	28.1
RANK2 SINR1(dB)	17.9
RANK2 SINR2(dB)	17.8
RTWP_ChA(dBm)	
RTWP_ChB(dBm)	
TxBasePower_ChA(d...	
TxBasePower_ChB(d...	
SyncFlag	SYNC
RxChCorFactor	

IE	Value
PCI	3
PUSCH Power(dBm)	-0.7
PUCCH Power(dBm)	20.0
RACH Power(dBm)	0.0
SRS Power(dBm)	12.3
PUSCH f(i)(dBm)	-1.0
PUCCH g(i)(dBm)	0.0
RSRP(dBm)	-86
RSRQ(dB)	-6
RSSI(dBm)	-60
Power Headroom(dB)	19
PDCCH UL Grant Count	52
PDCCH DL Grant Count	40
AVG SINR(dB)	36.5
RANK1 SINR(dB)	27.0
RANK2 SINR1(dB)	25.1
RANK2 SINR2(dB)	23.9
RTWP_ChA(dBm)	
RTWP_ChB(dBm)	
TxBasePower_ChA(d...	
TxBasePower_ChB(d...	
SyncFlag	SYNC
RxChCorFactor	

IE	Value
PCI	3
PUSCH Power(dBm)	5.6
PUCCH Power(dBm)	20.0
RACH Power(dBm)	0.0
SRS Power(dBm)	14.6
PUSCH f(i)(dBm)	-1.0
PUCCH g(i)(dBm)	0.0
RSRP(dBm)	-90
RSRQ(dB)	-8
RSSI(dBm)	-62
Power Headroom(dB)	17
PDCCH UL Grant Count	6
PDCCH DL Grant Count	2
AVG SINR(dB)	34.0
RANK1 SINR(dB)	28.7
RANK2 SINR1(dB)	26.8
RANK2 SINR2(dB)	26.5
RTWP_ChA(dBm)	
RTWP_ChB(dBm)	
TxBasePower_ChA(d...	
TxBasePower_ChB(d...	
SyncFlag	SYNC
RxChCorFactor	

SINR when cell 6 is enabled **SINR when cell 6 is disabled** **SINR when PCI 6 is changed to PCI 8**

Case: Handover Failure Caused by Severe Interference

- **Symptom**

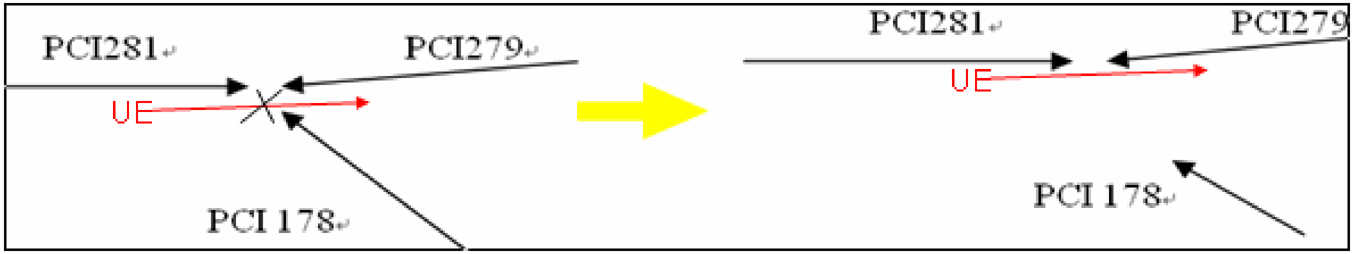
  During a test, handovers from PCI 281 to PCI 279 fail.

- **Analysis**

  Cell 281 is a source cell and is interfered by cells 279 and 178. Delivered handover commands always fail and cannot be received correctly by UEs. Cell 279 is a target cell for handover, and its coverage is not adjusted preferentially because the signal strength in the handover area can ensure signal quality after handovers. Therefore, cell 178 must be adjusted to reduce its interference to cell 281.

- **Solution**

  Adjust antenna tilts to decrease coverage by cell 178.



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Analysis of Handover Success Rate Problems

Poor handovers

Handover validity
1. Neighboring cell validity
2. Average receive level for handovers
3. Average receive quality for handovers
4. Ratio of the number of handovers to the number of calls
5. Measurements on neighboring cell handovers not defined

Interference
1. Uplink interference bands
2. Receive level and quality of carriers
3. Number of handovers because of poor uplink and downlink quality
4. Average receive level and power level for handovers

Coverage
1. Cross coverage
2. Imbalance between uplink and downlink
3. Receive level measurements
4. Receive quality measurements
5. Receive levels of neighboring cells
6. Average level and TA when service drops occur

Neighboring cell optimization must be performed to ensure that UEs in idle or connected mode can promptly perform reselection to or be handed over to optimal serving cells. This helps achieve continuous coverage. In addition, problems with delay, ping-pong, and non-logical handovers can be resolved by optimizing coverage, interference, and handover parameters.

Handover Problem Analysis

- Checking handover validity

Obtain source and target cells using drive test software and then check whether handovers are performed between two cells that are geographically far using Mapinfo.

- Checking interference

Check interference in both source and target cells because handover failures may be caused by uplink or downlink interference.

- Checking coverage

Check source and target cells for cross coverage, imbalance between uplink and downlink, and carrier-level receive quality and level.

- Check contents

Check handovers based on RSRPs measured in UE drive tests.

1. Verify that RSRPs in the expected source and target cells are maximum.
2. Verify that the absolute RSRPs in the source and target cells are reasonable at a handover point. In other words, handovers are not allowed if signal quality is excessively poor. Specific RSRPs are determined based on the entire RSRPs on a network.

Case: Service Drops Caused by Missing Neighboring Cell Configuration

- **Symptom**

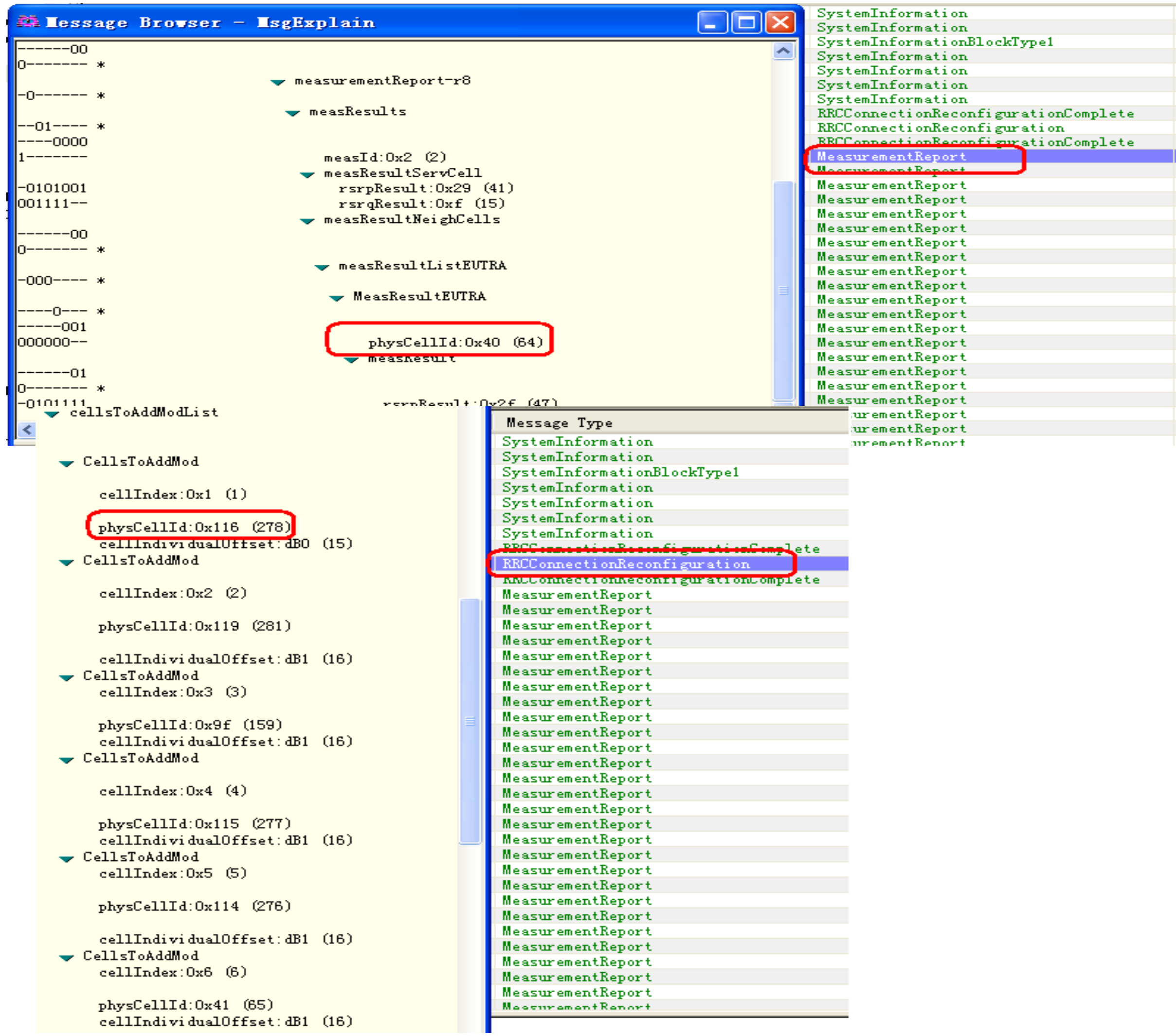
  As shown in the upper right figure, a UE sends multiple measurement reports but is not handed over, which may be caused by missing neighboring cell configuration.

- **Analysis**

  According to measurement reports, the UE sends an A3 report of cell 64. However, the RRCConnectionReconfiguration message in the lower right figure shows that the current cell is cell 278 (the first cell) and cell 64 is not included in the message. This indicates that cells 278 and 64 are not configured as neighboring cells. Neighboring cell configuration on live networks can be checked for further confirmation.

- **Solution**

  Configure cells 278 and 64 as neighboring cells.



Summary

RF optimization involves adjustment of neighboring cell lists and engineering parameters.

Most coverage and interference problems can be resolved by taking the following measures (sorted in descending order by priority):

- **Adjusting antenna tilts**
- **Adjusting antenna azimuths**
- **Adjusting antenna height**
- **Adjusting antenna position**
- **Adjusting antenna types**
- **Adding TMAs**
- **Adjusting site position**
- **Adding sites or RRUs**

This document describes what are involved in the RF optimization phase of network optimization. RF optimization focuses on improvement of signal distribution and provides a good radio signal environment for subsequent service parameter optimization. RF optimization mainly use drive tests, which can be supplemented by other tests. RF optimization focuses on coverage and handover problems, which can be supplemented by other problems. RF optimization aims to resolve handover, service drop, access, and interference problems caused by these problems. Engineering parameters and neighboring cell lists are adjusted in the RF optimization phase, while cell parameters are adjusted in the parameter optimization phase.

Thank you

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