EXata 5.1
LTE Model Library

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1 Overview of Model Library

1.1 Overview

The Long Term Evolution (LTE) Model Library provides high fidelity simulation of 4G cellular networks based on the 3GPP Release 9 standards. It provides system-level scalability, fast execution speeds and detailed MAC and PHY modeling. It includes models of nodes called eNodeB (Base Station) and UE (Mobile Station).

1.2 List of Models in the Library

Table 1-1 lists the models included in the LTE Model Library.

TABLE 1-1. LTE Library Models

Model Name	Model Type	Section Number
LTE Evolved Packet Core (EPC) Model	Network Layer	Section 4.1
LTE Layer 2 Model	Layer 2	Section 3.1
LTE PHY Model	Physical Layer	Section 2.1

1.3 Limitations

The LTE Model Library has not been tested on parallel and distributed architectures.

1.4 Conventions Used

1.4.1 Format for Command Line Configuration

This section describes the general format for specifying parameters in input files, the precedence rules for parameters, and the conventions used in the description of command line configuration for each model.

1.4.1.1 General Format of Parameter Declaration

The general format for specifying a parameter in an input file is:

```
[<Qualifier>] <Parameter Name> [<Index>] <Parameter Value>
```

where

`<Qualifier>` The qualifier is optional and defines the scope of the parameter declaration. The scope can be one of the following: Global, Node, Subnet, and Interface. Multiple instances of a parameter with different qualifiers can be included in an input file. Precedence rules (see Section 1.4.1.2) determine the parameter value for a node or interface.

Global: The parameter declaration is applicable to the entire scenario (to all nodes and interfaces), subject to precedence rules. The scope of a parameter declaration is global if the qualifier is not included in the declaration.

Example:

```
MAC-PROTOCOL            MACDOT11
```

Node: The parameter declaration is applicable to specified nodes, subject to precedence rules. The qualifier for a node-level declaration is a list of space-separated node IDs or a range of node IDs (specified by using the keyword `thru`) enclosed in square brackets.

Example:

```
[5 thru 10] MAC-PROTOCOL            MACDOT11
```

Subnet: The parameter declaration is applicable to all interfaces in specified subnets, subject to precedence rules. The qualifier for a subnet-level declaration is a space-separated list of subnet addresses enclosed in square brackets. A subnet address can be specified in the IP dot notation or in the EXata N syntax.

Example:

```
[N8-1.0 N2-1.0] MAC-PROTOCOL      MACDOT11
```

Interface: The parameter declaration is applicable to specified interfaces. The qualifier for an interface-level declaration is a space-separated list of subnet addresses enclosed in square brackets.

Example:

```
[192.168.2.1 192.168.2.4] MAC-PROTOCOL MACDOT11
```

`<Parameter Name>`	Name of the parameter.
`<Index>`	Instance of the parameter to which this parameter declaration is applicable, enclosed in square brackets. This should be in the range 0 to *n* -1, where *n* is the number of instances of the parameter. The instance specification is optional in a parameter declaration. If an instance is not included, then the parameter declaration is applicable to all instances of the parameter, unless otherwise specified.
`<Parameter Value>`	Value of the parameter.

Note: There should not be any spaces between the parameter name and the index.

Examples of parameter declarations in input files are:

```
PHY-MODEL                                        PHY802.11b
[1] PHY-MODEL                                    PHY802.11a
[N8-1.0] PHY-RX-MODEL                            BER-BASED
[8 thru 10] ROUTING-PROTOCOL                     RIP
[192.168.2.1 192.168.2.4] MAC-PROTOCOL           GENERICMAC
NODE-POSITION-FILE                               ./default.nodes
PROPAGATION-CHANNEL-FREQUENCY[0]                 2.4e9
[1 2] QUEUE-WEIGHT[1]                            0.3
```

Note In the rest of this document, we will not use the qualifier or the index in a parameter's description. Users should use a qualifier and/or index to restrict the scope of a parameter, as appropriate.

1.4.1.2 Precedence Rules

Parameters without Instances

If the parameter declarations do not include instances, then the following rules of precedence apply when determining the parameter values for specific nodes and interfaces:

Interface > Subnet > Node > Global

This can be interpreted as follows:

- The value specified for an interface takes precedence over the value specified for a subnet, if any.
- The value specified for a subnet takes precedence over the value specified for a node, if any.
- The value specified for a node takes precedence over the value specified for the scenario (global value), if any.

Parameters with Instances

If the parameter declarations are a combination of declarations with and without instances, then the following precedence rules apply (unless otherwise stated):

Interface[i] > Subnet[i] > Node[i] > Global[i] > Interface > Subnet > Node > Global

This can be interpreted as follows:

- Values specified for a specific instance (at the interface, subnet, node, or global level) take precedence over values specified without the instance.

- For values specified for the same instance at different levels, the following precedence rules apply:
  - The value specified for an interface takes precedence over the value specified for a subnet, if any, if both declarations are for the same instance.
  - The value specified for a subnet takes precedence over the value specified for a node, if any, if both declarations are for the same instance.
  - The value specified for a node takes precedence over the value specified for the scenario (global value), if any, if both declarations are for the same instance.

1.4.1.3 Parameter Description Format

In the Model Library, most parameters are described using a tabular format described below. The parameter description tables have three columns labeled “Parameter”, “Values”, and “Description”. Table 1-2 shows the format of parameter tables. Table 1-4 shows examples of parameter descriptions in this format.

TABLE 1-2. Parameter Table Format

Parameter	Values	Description
<Parameter Name> <Designation> <Scope> [<Instances>]	*<Type>* [<Range>] [<Default Value>] [<Unit>]	*<Description>*

Parameter Column

The first column contains the following entries:

- ***<Parameter Name>*:** The first entry is the parameter name (this is the exact name of the parameter to be used in the input files).

- ***<Designation>:*** This entry can be *Optional* or *Required*. These terms are explained below.
  - ***Optional***: This indicates that the parameter is optional and may be omitted from the configuration file. (If applicable, the default value for this parameter is included in the second column.)
  - ***Required***: This indicates that the parameter is mandatory and must be included in the configuration file.

- ***<Scope>:*** This entry specifies the possible scope of the parameter, i.e., if the parameter can be specified at the global, node, subnet, or interface levels. Any combination of these levels is possible.If the parameter can be specified at all four levels, the keyword “All” is used to indicate that.

  Examples of scope specification are:

  Scope: All

  Scope: Subnet, Interface

  Scope: Global, Node

- ***<Instances>:*** If the parameter can have multiple instances, this entry indicates the type of index. If the parameter can not have multiple instances, then this entry is omitted.

Examples of instance specification are:

Instances: channel number

Instances: interface index

Instances: queue index

Values Column

The second column contains the following information:

- ***<Type>*:** The first entry is the parameter type and can be one of the following: Integer, Real, String, Time, Filename, IP Address, Coordinates, Node-list, or List. If the type is a List, then all possible values in the list are enumerated below the word “List”. (In some cases, the values are listed in a separate table and a reference to that table is included in place of the enumeration.)

  Table 1-3 shows the values a parameter can take for each type.

TABLE 1-3. Parameter Types

Type	Description
Integer	Integer value Examples: `2`, `10`
Real	Real value Examples: `15.0`, `-23.5`, `2.0e9`
String	String value Examples: `TEST`, `SWITCH1`
Time	Time value expressed in EXata time syntax (refer to *EXata User's Guide*) Examples: `1.5S`, `200MS`, `10US`
Filename	Name of a file in EXata filename syntax (refer to *EXata User's Guide*) Examples: `../../data/terrain/los-angeles-w` (For Windows and UNIX) `C:\scalable\exata\5.1\scenarios\WF\WF.nodes` (For Windows) `/root/scalable/exata/5.1/scenarios/WF/WF.nodes` (For UNIX)
Path	Path to a directory in EXata path syntax (refer to *EXata User's Guide*) Examples: `../../data/terrain` (For Windows and UNIX) `C:\scalable\exata\5.1\scenarios\default` (For Windows) `/root/scalable/exata/5.1/scenarios/default` (For UNIX)
IP Address	IPv4 or IPv6 address Examples: `192.168.2.1`, `2000:0:0:0::1`

TABLE 1-3. Parameter Types (Continued)

Type	Description
IPv4 Address	IPv4 address Examples: `192.168.2.1`
IPv6 Address	IPv6 address Examples: `2000:0:0:0::1`
Coordinates	Coordinates in Cartesian or Lat-Lon-Alt system. The altitude is optional. Examples: `(100, 200, 2.5)`, `(-25.3478, 25.28976)`
Node-list	List of node IDs separated by commas and enclosed in "`{`" and "`}`". Examples: `{2, 5, 10}`, `{1, 3 thru 6}`
List	One of the enumerated values. Example: See the parameter `MOBILITY` in Table 1-4.

Note: If the parameter type is List, then options for the parameter available in EXata and the commonly used model libraries are enumerated. Additional options for the parameter may be available if some other model libraries or addons are installed. These additional options are not listed in this document but are described in the corresponding model library or addon documentation.

- ***<Range>*:** This is an optional entry and is used if the range of values that a parameter can take is restricted. The permissible range is listed after the label "*Range:*" The range can be specified by giving the minimum value, the maximum value, or both. If the range of values is not restricted, then this entry is omitted.

  If both the minimum and maximum values are specified, then the following convention is used to indicate whether the minimum and maximum values are included in the range:

`(min, max)`	`min` < parameter value < `max`
`[min, max)`	`min` ≤ parameter value < `max`
`(min, max]`	`min` < parameter value ≤ `max`
`[min, max]`	`min` ≤ parameter value ≤ `max`

`min` (or `max`) can be a parameter name, in which case it denotes the value of that parameter.

Examples of range specification are:

Range: ≥ `0`

Range: `(0.0, 1.0]`

Range: `[1, MAX-COUNT]`

Range: `[1S, 200S]`

Note: If an upper limit is not specified in the range, then the maximum value that the parameter can take is the largest value of the type (integer, real, time) that can be stored in the system.

- ***<Default>*:** This is an optional entry which specifies the default value of an optional or conditional-optional parameter. The default value is listed after the label "*Default:*"
- ***<Unit>*:** This is an optional entry which specifies the unit for the parameter, if applicable. The unit is listed after the label "*Unit:*". Examples of units are: meters, dBm, slots.

Description Column

The third column contains a description of the parameter. The significance of different parameter values is explained here, where applicable. In some cases, references to notes, other tables, sections in the User's Guide, or to other model libraries may be included here.

Table 1-4 shows examples of parameter descriptions using the format described above.

TABLE 1-4. Example Parameter Table

Parameter	Values	Description
`MOBILITY` Optional *Scope:* Global, Node	List: • `NONE` • `FILE` • `GROUP-MOBILITY` • `RANDOM-WAYPOINT` Default: `NONE`	Mobility model used for the node. If `MOBILITY` is set to `NONE`, then the nodes remain fixed in one place for the duration of the simulation. See Table 7-11 for a description of mobility models.
`BACKOFF-LIMIT` Required *Scope:* Subnet, Interface	Integer *Range:* `[4,10)` *Unit:* slots	Upper limit of backoff interval after collision. A backoff interval is randomly chosen between 1 and this number following a collision.
`IP-QUEUE-PRIORITY-QUEUE-SIZE` Required *Scope:* All *Instances:* queue index	Integer *Range:* `[1, 65535]` *Unit:* bytes	Size of the output priority queue.
`MAC-DOT11-DIRECTIONAL-ANTENNA-MODE` Optional *Scope:* All	List • `YES` • `NO` *Default:* `NO`	Indicates whether the radio is to use a directional antenna for transmission and reception.

1.4.2 Format for GUI Configuration

The GUI configuration section for a model outlines the steps to configure the model using the GUI. The following conventions are used in the GUI configuration sections:

Path to a Parameter Group

As a shorthand, the location of a parameter group in a properties editor is represented as a path consisting of the name of the properties editor, name of the tab within the properties editor, name of the parameter group within the tab (if applicable), name of the parameter sub-group (if applicable), and so on.

Example

The following statement:

Go to **Default Device Properties Editor > Interfaces > Interface # > MAC Layer**

is equivalent to the following sequence of steps:

1. Open the Default Device Properties Editor for the node.
2. Click the **Interfaces** tab.
3. Expand the applicable Interface group.
4. Click the **MAC Layer** parameter group.

The above path is shown in Figure 1-1.

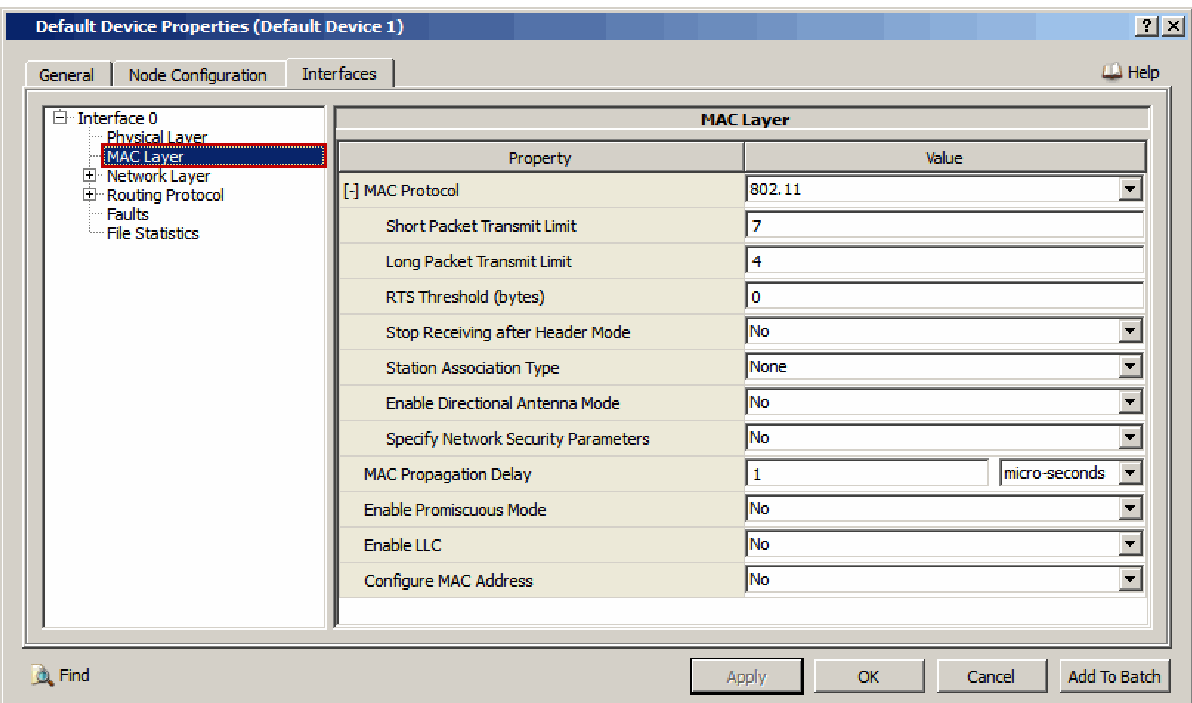

FIGURE 1-1. Path to a Parameter Group

Path to a Specific Parameter

As a shorthand, the location of a specific parameter within a parameter group is represented as a path consisting of all ancestor parameters and their corresponding values starting from the top-level parameter. The value of an ancestor parameter is enclosed in square brackets after the parameter name.

Example

The following statement:

> Set **MAC Protocol** *[= 802.11]* **> Station Association Type** *[= Dynamic]* **> Set Access Point** *[= Yes]* **>** *Enable Power Save Mode* to *Yes*

is equivalent to the following sequence of steps:

1. Set **MAC Protocol** to *802.11*.
2. Set **Station Association Type** to *Dynamic.*
3. Set **Set Access Point** to *Yes*.
4. Set **Enable Power Save Mode** to *Yes*.

The above path is shown in Figure 1-2.

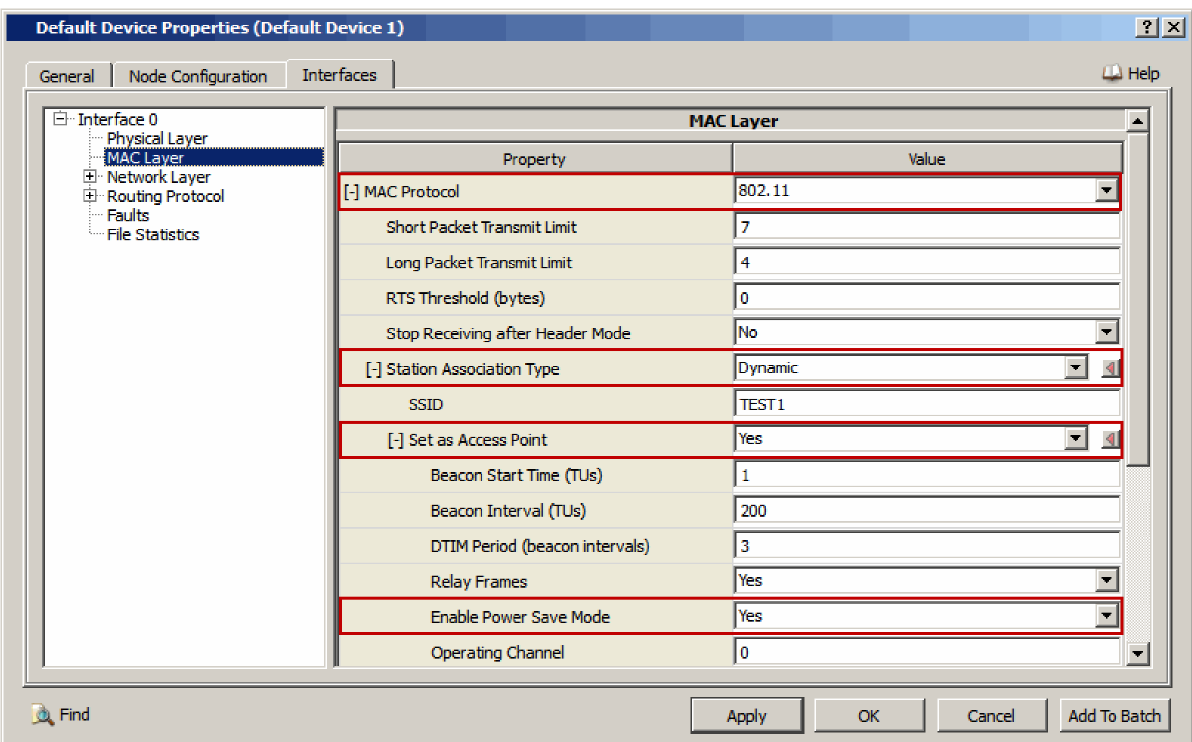

FIGURE 1-2. Path to a Specific Parameter

Parameter Table

GUI configuration of a model is described as a series of a steps. Each step describes how to configure one or more parameters. Since the GUI display name of a parameter may be different from the name in the configuration file, each step also includes a table that shows the mapping between the GUI names and command line names of parameters configured in that step. For a description of a GUI parameter, see the description of the equivalent command line parameter in the command line configuration section.

The format of a parameter mapping table is shown in Table 1-5.

TABLE 1-5. Mapping Table

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
<GUI Display Name>	*<Scope>*	*<Command Line Parameter Name>*

The first column, labeled "GUI Parameter", lists the name of the parameter as it is displayed in the GUI.

The second column, labeled "Scope of GUI Parameter", lists the level(s) at which the parameter can be configured. *<Scope>* can be any combination of: Global, Node, Subnet, Wired Subnet, Wireless Subnet, Point-to-point Link, and Interface.

Table 1-6 lists the Properties Editors where parameters with different scopes can be set.

Notes: **1.** Unless otherwise stated, the "Subnet" scope refers to "Wireless Subnet".

2. The scope column can also refer to Properties Editors for special devices and network components (such as ATM Device Properties Editor) which are not included in Table 1-6.

TABLE 1-6. Properties Editors for Different Scopes

Scope of GUI Parameter	Properties Editor
Global	Scenario Properties Editor
Node	Default Device Properties Editor (General and Node Configuration tabs)
Subnet Wireless Subnet	Wireless Subnet Properties Editor
Wired Subnet	Wired Subnet Properties Editor
Point-to-point Link	Point-to-point Link Properties Editor
Interface	Interface Properties Editor, Default Device Properties Editor (Interfaces tab)

The third column, labeled "Command Line Parameter", lists the equivalent command line parameter.

Note: For some parameters, the scope may be different in command line and GUI configurations (a parameter may be configurable at fewer levels in the GUI than in the command line).

Table 1-7 is an example of a parameter mapping table.

TABLE 1-7. Example Mapping Table

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Define Area	Node	`OSPFv2-DEFINE-AREA`
OSPFv2 Configuration File	Node	`OSPFv2-CONFIG-FILE`
Specify Autonomous System	Node	N/A
Configure as Autonomous System Boundary Router	Node	`AS-BOUNDARY-ROUTER`
Inject External Route	Node	N/A
Enable Stagger Start	Node	`OSPFv2-STAGGER-START`

2 PHY Layer Models

This chapter describes features, configuration requirements and parameters, statistics, and scenarios for the PHY Layer models in the LTE Model Library, and consists of the following section:

- LTE PHY Model

2.1 LTE PHY Model

The EXata LTE PHY model is based on the 3GPP 36.3XX architecture, and specifies E-UTRAN physical layer models.

2.1.1 Description

The main functions of the E-UTRAN PHY module are:

- Downlink transmission/reception using OFDMA
- Uplink transmission/reception using SC-FDMA
- Coding/decoding, modulation/demodulation
- Multi antenna operation (MIMO)
- CQI/RI/PMI reporting
- Power Control
- Cell Selection
- Random Access
- Measurements

Figure 2-1 shows the LTE Physical layer architecture.

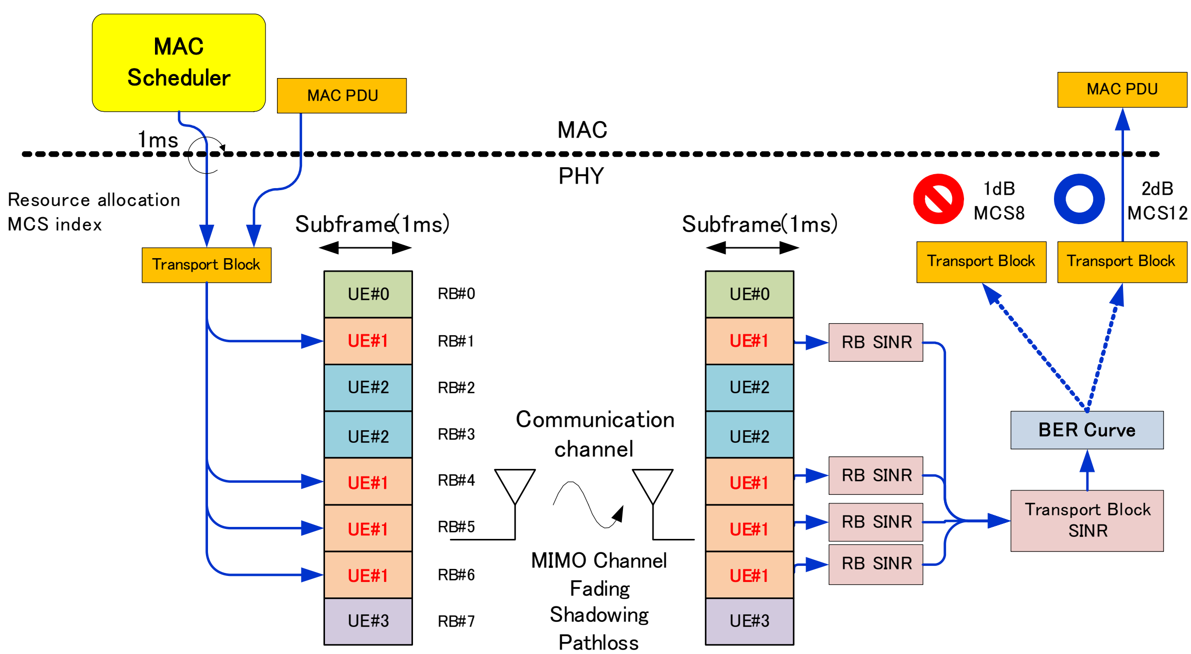

FIGURE 2-1. LTE Physical Layer

The LTE Physical layer transmits a MAC PDU from the sender to the receiver as follows:

1. For every TTI (1 ms interval), the MAC Scheduler allocates resources to the connected UEs in units of Resource Block (RB) and Modulation and Coding Scheme (MCS).

2. The PHY layer retrieves the MAC PDU from the MAC layer and creates Transport Block(s), which are transmitted using the indicated MCS for UE (DL) and eNB (UL) over allocated RBs.
3. Signals undergo attenuation due to pathloss, shadowing, and fading and arrive at the receiver.
4. The receiver calculates the SINR for each RB and Transport Block, and retrieves the Bit Error Rate (BER) looking up BER curves prepared for each MCS.
5. The received Transport Block is evaluated for errors and is forwarded to MAC layer if it is error-free.

Note that considerations of link level processes such as turbo coding /decoding, modulation/demodulation, OFDM/SC-FDMA, SC-FDMA signal generations are all included in BER curves, which are derived from the link level simulation in advance. The Physical layer in EXata does not implement link level processes, but sends transport block(s) with information of allocated RBs and MCS indices.

There are 32 MCS indices defined in the E-UTRAN specification for both DL and UL. Combinations of coding rate and modulation such as QPSK, 16QAM, 64QAM are assigned to each MCS index. Therefore, various data rates are available (MCS 29, 30, 31 are used for HARQ retransmission).

The maximum data rate depends on the bandwidth configuration. There are several bandwidth configurations specified in E-UTRAN. The number of RBs (which are the unit of resource allocations) also depend on the bandwidth configuration. EXata supports all of available bandwidth configurations specified in E-UTRAN specification. The maximum PHY throughput for various bandwidths and number of RBs is listed in Table 2-1.

TABLE 2-1. Maximum PHY Throughput

Bandwidth	Number of RBs	Max. PHY Throughput (Mbps) (approx.)	
		SIMO/ SFBC	OLSM
1.4 MHz	6	4	8
3 MHz	15	11	22
5 MHz	25	18	36
10 MHz	50	36	73
15 MHz	75	55	110
20 MHz	100	75	150

MIMO operation is an important feature of E-UTRAN PHY. EXata currently supports:

- Single antenna transmission (SIMO)
- Transmit diversity (SFBC)
- Open Loop Spatial Multiplexing (OLSM)

For the transmission scheme, uplink can only use SIMO because the maximum number of transmission antennas is 1. For downlink, various transmission schemes are available.

The maximum data rate for OLSM is double that of SIMO or SFBC. The transmission scheme depends on the transmission mode number. Table 2-2 shows the transmission scheme used for each transmission mode number.

TABLE 2-2. Transmission Mode and Transmission Scheme

Mode Number	Transmission Scheme
1	Single antenna transmission
2	Transmit diversity (SFBC)
3	RI = 2: Open loop spatial multiplexing (without CDD) RI = 1: Transmit diversity (SFBC) (Switched dynamically depending on RI)

The available transmission mode depends on the number of antennas at eNB and UE. The following tables show the possible combinations for numbers of antennas and transmission modes for downlink and uplink transmission.

- Downlink (Transmission mode 1)

		eNB Tx Antennas	
		1	2
UE Rx Antennas	1	x	–
	2	x	–

- Downlink (Transmission mode 2)

		eNB Tx Antennas	
		1	2
UE Rx Antennas	1	–	x
	2	–	x

- Downlink (Transmission mode 3)

		eNB Tx Antennas	
		1	2
UE Rx Antennas	1	–	x (SFBC only)
	2	–	x

- Uplink

		UE Tx Antennas	
		1	**2**
eNB Rx Antennas	**1**	x	–
	2	x	–

2.1.2 Features and Assumptions

This section describes the implemented features, omitted features, assumptions, and limitations of the LTE PHY model.

2.1.2.1 Implemented Features

- PHY/MAC and Upper Layer protocols based on 3GPP Release 9 (LTE) standards
- IPv4 support for Network Layer
- Open-Loop MIMO model with 2x2 antenna
- OFDMA/SC-FDMA PHY high-fidelity model
- FDD support
- MIMO channel model to support multi-antenna operation

2.1.2.2 Omitted Features

- TDD frame structure
- Support for 3 or more antennas
- CDD matrix
- Closed-Loop MIMO
- Multi-user MIMO
- PMI, Subband CQI
- PBCH, PMCH, PCFICH, and PHICH
- Details of primary synchronization signal, secondary synchronization signal, reference signals
- PUCCH
- DMRS Frequency selectivity
- SCM channel model
- Closed-loop UL power control

2.1.2.3 Assumptions and Limitations

- PDCCH does not consume any radio resource
- No reception error for control information (CQI/RI).
- PRACH does not interfere with other signals
- RSRQ can be measured only in a channel, which is used by UE for DL reception
- System information from an eNB is sent once every 10 ms to UEs
- Interference signals do not experience fading
- Only one LTE interface is supported
- The LTE models can be enabled only on the first interface of a node

2.1.3 Command Line Configuration

To select LTE PHY as the PHY model, include the following parameter in the scenario configuration (.config) file:

```
[<Qualifier>] PHY-MODEL    PHY-LTE
```

The scope of this parameter declaration can be Global, Node, Subnet, or Interface. See Section 1.4.1.1 for a description of `<Qualifier>` for each scope.

LTE PHY Parameters

Table 2-3 lists the PHY parameters used by both eNB and UE nodes. Table 2-4 lists the additional PHY parameters used only by eNB nodes. Table 2-5 lists the additional PHY parameters used only by UE nodes.

> **Note:** Station type for an LTE node (eNB or UE) is configured by means of the LTE MAC parameter, `MAC-LTE-STATION-TYPE` (see Section 3.1.3).

See Section 1.4.1.3 for a description of the format used for the parameter tables.

TABLE 2-3. LTE PHY Parameters Common to eNB and UE Nodes

Parameter	Value	Description
`PHY-LTE-TX-POWER` *Optional* *Scope:* All	Real *Range:* `[-1000.0, 1000.0]` *Default:* `23.0` *Unit:* dBm	Maximum transmission power.
`PHY-LTE-NUM-TX-ANTENNAS` *Optional* *Scope:* All	Integer *Range:* see description *Default:* `1`	Number of transmission antennas. The value of this parameter can be 1 or 2 for eNB nodes, and 1 for UE nodes.
`PHY-LTE-NUM-RX-ANTENNAS` *Optional* *Scope:* All	Integer *Range:* `[1, 2]` *Default:* `1`	Number of receive antennas.
`PHY-RX-MODEL` *Required* *Scope:* All	List • `PHY-LTE-BER-BASED`	PHY receive model. This parameter must be set to `PHY-LTE-BER-BASED`.

TABLE 2-3. LTE PHY Parameters Common to eNB and UE Nodes (Continued)

Parameter	Value	Description
PHY-RX-BER-TABLE-FILE *Required* *Scope:* All *Instances:* file number	Filename	File containing the BER table. • PHY-RX-BER-TABLE-FILE[0] to PHY-RX-BER-TABLE-FILE[28] specify the DL MCS BER table files 0 to 28. • PHY-RX-BER-TABLE-FILE[32] to PHY-RX-BER-TABLE-FILE[60] specify the UL MCS BER table files 0 to 28.
PHY-LTE-RX-SENSITIVITY *Optional* *Scope:* All	Real *Range:* [-1000.0, 1000.0] *Default:* -1000.0 *Unit:* dBm	Minimum strength of the received signal to be accepted as a valid signal.
PHY-LTE-PATHLOSS-FILTER-COEFFICIENT *Optional* *Scope:* All	Real *Range:* ≥ 0.0 *Default:* 40.0	Coefficient for filtering path loss.
PHY-LTE-INTERFERENCE-FILTER-COEFFICIENT *Optional* *Scope:* All	Real *Range:* ≥ 0.0 *Default:* 40.0	Filtering coefficient for interference signal power.
PHY-LTE-CHANNEL-BANDWIDTH *Optional* *Scope:* Subnet	List: • 1400000 • 3000000 • 5000000 • 10000000 • 15000000 • 20000000 *Default:* 10000000 *Unit:* Hz	Channel bandwidth.

TABLE 2-3. LTE PHY Parameters Common to eNB and UE Nodes (Continued)

Parameter	Value	Description
`PHY-LTE-DL-CQI-SNR-TABLE` *Optional* *Scope:* Subnet *Instance:* entry number	Real *Default:* See description *Unit:* dB	Channel Quality Indicator (CQI) SNR table entries. CQI represents the DL channel quality reported by the UE to the eNB. The default values for the table entries are listed below. Index — Default Value 0 — -5.00 1 — -4.42 2 — -3.40 3 — -1.70 4 — -0.19 5 — 1.34 6 — 2.64 7 — 5.16 8 — 6.71 9 — 8.18 10 — 10.43 11 — 11.84 12 — 13.32 13 — 15.53 14 — 16.20 15 — 22.38

TABLE 2-4. Additional PHY Parameters for eNB Nodes

Parameter	Value	Description
`PHY-LTE-DL-CHANNEL` *Optional* *Scope:* Subnet, Interface	Integer or string *Range:* ≥ `0` (if channel index is used) *Default:* `0`	Channel index or name of the downlink (transmission) channel. If a channel index is used to specify the downlink channel, then it must correspond to the index of the parameter `PROPAGATION-CHANNEL-FREQUENCY`, which is used to configure the channel frequency.
`PHY-LTE-UL-CHANNEL` *Optional* *Scope:* Subnet, Interface	Integer or string *Range:* ≥ `0` (if channel index is used) *Default:* `1`	Channel index or name of the uplink (receiving) channel. If a channel index is used to specify the uplink channel, then it must correspond to the index of the parameter `PROPAGATION-CHANNEL-FREQUENCY`, which is used to configure the channel frequency.
`PHY-LTE-PUCCH-OVERHEAD` *Optional* *Scope:* Subnet, Interface	Integer *Range:* `[0, 100]` *Default:* `0` *Unit:* PRB (see description)	UL control channel overhead. The control channel overhead is in units of Physical Resource Block (PRB).

TABLE 2-4. Additional PHY Parameters for eNB Nodes (Continued)

Parameter	Value	Description
PHY-LTE-TPC-P_O_PUSCH *Optional* *Scope:* All	Real *Range:* [-1000.0, 1000.0] *Default:* -90.0 *Unit:* dBm	Target Rx power used for UL Transmission Power Control (TPC) per Resource Block (RB), P_{O_PUSCH}.
PHY-LTE-TPC-ALPHA *Optional* *Scope:* All	Real *Range:* [0.0, 1.0] *Default:* 1.0	Coefficient for the pathloss value for UL TPC.
PHY-LTE-CELL-SELECTION-RX-LEVEL-MIN *Optional* *Scope:* All	Real *Range:* [-1000.0, 1000.0] *Default:* -140.0 *Unit:* dBm	Minimum Reference Signal Receive Power (RSRP). This is the conditional parameter, $Q_{rxlevmin}$, for cell selection.
PHY-LTE-CELL-SELECTION-RX-LEVEL-MIN-OFFSET *Optional* *Scope:* All	Real *Range:* [-1000.0, 1000.0] *Default:* 0.0 *Unit:* dB	Minimum RSRP offset. This is the conditional parameter, $Q_{rxlevminoffset}$, for cell selection.
PHY-LTE-CELL-SELECTION-QUAL-LEVEL-MIN *Optional* *Scope:* All	Real *Range:* [-1000,0, 1000.0] *Default:* -19.5 *Unit:* dB	Minimum Reference Signal Receive Quality (RSRQ). This is the conditional parameter, $Q_{qualmin}$, for cell selection.
PHY-LTE-CELL-SELECTION-QUAL-LEVEL-MIN-OFFSET *Optional* *Scope:* All	Real *Range:* [-1000.0, 1000.0] *Default:* 0.0 *Unit:* dB	Minimum RSRQ offset. This is the conditional parameter, $Q_{qualminoffset}$, for cell selection.

TABLE 2-4. Additional PHY Parameters for eNB Nodes (Continued)

Parameter	Value	Description
`PHY-LTE-RA-DETECTION-THRESHOLD` *Optional* *Scope:* All	Real *Range:* `[-1000.0, 1000.0]` *Default:* `-100.0` *Unit:* dBm	Random access preamble detection threshold.
`PHY-LAYER-STATISTICS` *Optional* *Scope:* All	List: • `YES` • `NO` *Default:* `NO`	Indicates whether statistics are collected for the Physical layer protocols, including LTE PHY.

TABLE 2-5. Additional PHY Parameters for UE Nodes

Parameter	Value	Description
`PHY-LTE-CQI-REPORTING-INTERVAL` *Optional* *Scope:* All	Integer *Range:* ≥ `1` *Default:* `10` *Unit:* TTI	Channel Quality Indicator (CQI) report period. See description of `PHY-LTE-CQI-REPORTING-OFFSET`.
`PHY-LTE-CQI-REPORTING-OFFSET` *Optional* *Scope:* All	Integer *Range:* ≥ `0` *Default:* `0` *Unit:* TTI	CQI report offset. A CQI report is sent when (*TTI_count* + *CQI_report_offset*) % *CQI_report_period* = 0, where *TTI_count* : Number of TTIs elapsed since the beginning of simulation *CQI_report_offset* : CQI report offset (specified by parameter `PHY-LTE-CQI-REPORTING-OFFSET`) *CQI_report_period* : CQI report period (specified by parameter `PHY-LTE-CQI-REPORTING-INTERVAL`)
`PHY-LTE-RI-REPORTING-INTERVAL` *Optional* *Scope:* All	Integer *Range:* ≥ `1` *Default:* `10` *Unit:* TTI	Rank Indicator (RI) report period. See description of `PHY-LTE-RI-REPORTING-OFFSET`.

TABLE 2-5. Additional PHY Parameters for UE Nodes

Parameter	Value	Description
PHY-LTE-RI-REPORTING-OFFSET *Optional* *Scope:* All	Integer *Range:* ≥ 1 *Default:* 1 *Unit:* TTI	RI report offset. A RI report is sent when (*TTI_count* + *RI_report_offset*) % *RI_report_period* = 0, where *TTI_count* : Number of TTIs elapsed since the beginning of simulation *RI_report_offset* : RI report offset (specified by parameter PHY-LTE-RI-REPORTING-OFFSET) *RI_report_period* : RI report period (specified by parameter PHY-LTE-RI-REPORTING-INTERVAL) **Note:** If both RI and CQI reports are configured to be sent at the same time, only the RI report is sent. To ensure that both RI and CQI reports are sent, configure different offsets or intervals for CQI and RI reports.
PHY-LTE-SRS-TRANSMISSION-INTERVAL *Optional* *Scope:* All	Integer *Range:* ≥ 1 *Default:* 10 *Unit:* TTI	Sounding Reference Signal (SRS) transmission period. See description of PHY-LTE-SRS-TRANSMISSION-OFFSET.
PHY-LTE-SRS-TRANSMISSION-OFFSET *Optional* *Scope:* All	Integer *Range:* ≥ 0 *Default:* 0 *Unit:* TTI	SRS transmission offset. An SRS transmission is sent when A RI report is sent when (*TTI_count* + *SRS_transmission_offset*) % *SRS_report_period* = 0, where *TTI_count* : Number of TTIs elapsed since the beginning of simulation *SRS_transmission_offset* : RI report offset (specified by parameter PHY-LTE-SRS-TRANSMISSION-OFFSET) *SRS_transmission_period* : RI report period (specified by parameter PHY-LTE-SRS-TRANSMISSION-INTERVAL)

TABLE 2-5. Additional PHY Parameters for UE Nodes

Parameter	Value	Description
PHY-LTE-NON-SERVING-CELL-MEASUREMENT-PERIOD *Optional* *Scope:* All	Time *Range:* ≥ 0S *Default:* 200MS	Measurement period for detecting a non-serving cell.
PHY-LTE-CELL-SELECTION-MIN-SERVING-DURATION *Optional* *Scope:* All	Time *Range:* ≥ 0S *Default:* 1S	Minimum serving duration for cell selection.

2.1.4 GUI Configuration

This section describes how to configure the LTE PHY model using the GUI.

Configuring LTE PHY Parameters

To configure the LTE PHY model, perform the following steps:

1. Go to one of the following locations:

- To set properties for a specific subnet, go to **Wireless Subnet Properties Editor > Physical Layer**.
- To set properties a specific interface of a node, go to one of the following locations:
  - **Interface Properties Editor > Interfaces > Interface # > Physical Layer**.
  - **Default Device Properties Editor > Interfaces > Interface # > Physical Layer**.

In this section, we show how to configure LTE PHY parameters for a specific subnet using the Wireless Subnet Properties Editor. Parameters can be set in the other properties editors in a similar way.

2. Set **Radio Type** to *LTE* PHY and set the dependent parameters listed in Table 2-6.

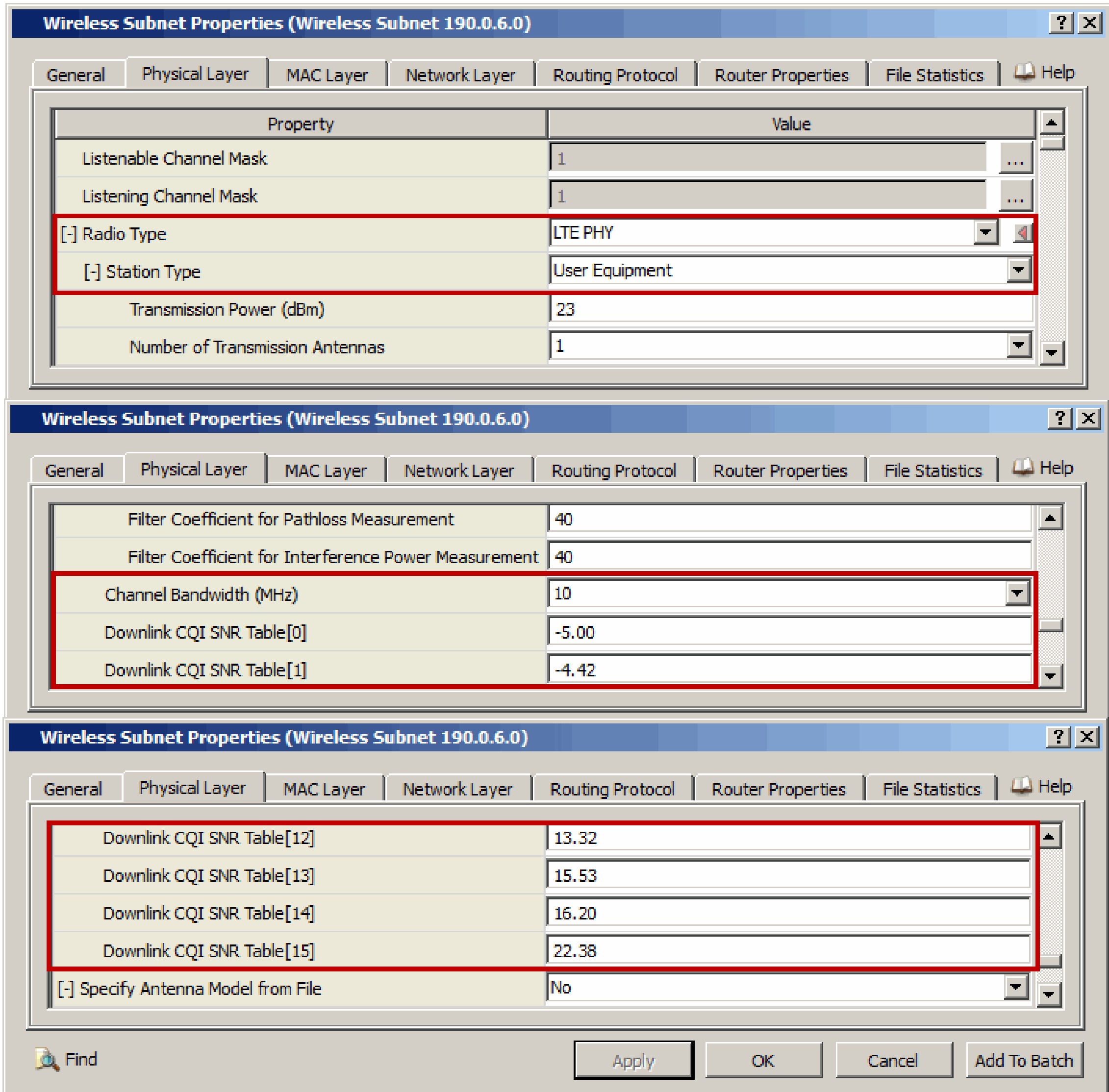

FIGURE 2-2. Setting LTE PHY Parameters

TABLE 2-6. Command Line Equivalent of LTE PHY Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Station Type	Subnet, Interface	N/A
Channel Bandwidth	Subnet	`PHY-LTE-CHANNEL-BANDWIDTH`
Downlink CQI SNR Table[*i*]	Subnet	`PHY-LTE-DL-CQI-SNR-TABLE[i]`

Setting Parameters

- Set **Station Type** to the same value as the MAC Layer parameter **Station Type** (see Section 3.1.4.2).

3. If **Station Type** is set to *User Equipment*, then set the parameters listed in Table 2-7.

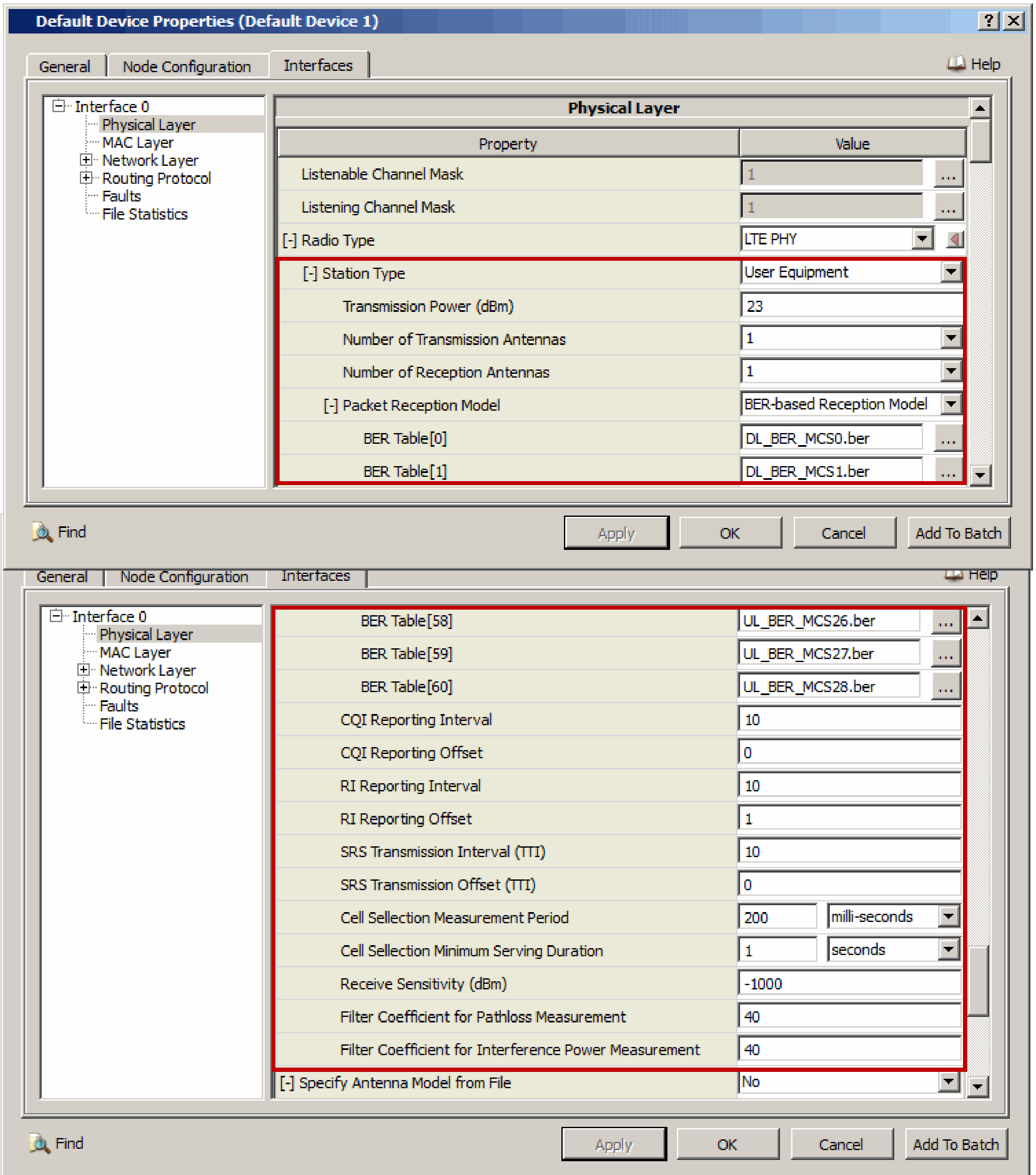

FIGURE 2-3. Setting UE Node Parameters

TABLE 2-7. Command Line Equivalent of UE Node Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Transmission Power	Subnet, Interface	`PHY-LTE-TX-POWER`
Number of Transmission Antennas	Subnet, Interface	`PHY-LTE-NUM-TX-ANTENNAS`
Number of Reception Antennas	Subnet, Interface	`PHY-LTE-NUM-RX-ANTENNAS`
Packet Reception Model	Subnet, Interface	`PHY-RX-MODEL`
BER Table[*i*]	Subnet, Interface	`PHY-RX-BER-TABLE-FILE[i]`
CQI Reporting Interval	Subnet, Interface	`PHY-LTE-CQI-REPORTING-INTERVAL`
CQI Reporting Offset	Subnet, Interface	`PHY-LTE-CQI-REPORTING-OFFSET`
RI Reporting Interval	Subnet, Interface	`PHY-LTE-RI-REPORTING-INTERVAL`
RI Reporting Offset	Subnet, Interface	`PHY-LTE-RI-REPORTING-OFFSET`
SRS Transmission Interval	Subnet, Interface	`PHY-LTE-SRS-TRANSMISSION-INTERVAL`
SRS Transmission Offset	Subnet, Interface	`PHY-LTE-SRS-TRANSMISSION-OFFSET`
Cell Selection Measurement Period	Subnet, Interface	`PHY-LTE-NON-SERVING-CELL-MEASUREMENT-PERIOD`
Cell Selection Minimum Serving Duration	Subnet, Interface	`PHY-LTE-CELL-SELECTION-MIN-SERVING-DURATION`
Receive Sensitivity	Subnet, Interface	`PHY-LTE-RX-SENSITIVITY`
Filter Coefficient for Pathloss Measurement	Subnet, Interface	`PHY-LTE-PATHLOSS-FILTER-COEFFICIENT`
Filter Coefficient for Interference Power Measurement	Subnet, Interface	`PHY-LTE-INTERFERENCE-FILTER-COEFFICIENT`

4. If **Station Type** is set to *evolved Node B*, then set the parameters listed in Table 2-8.

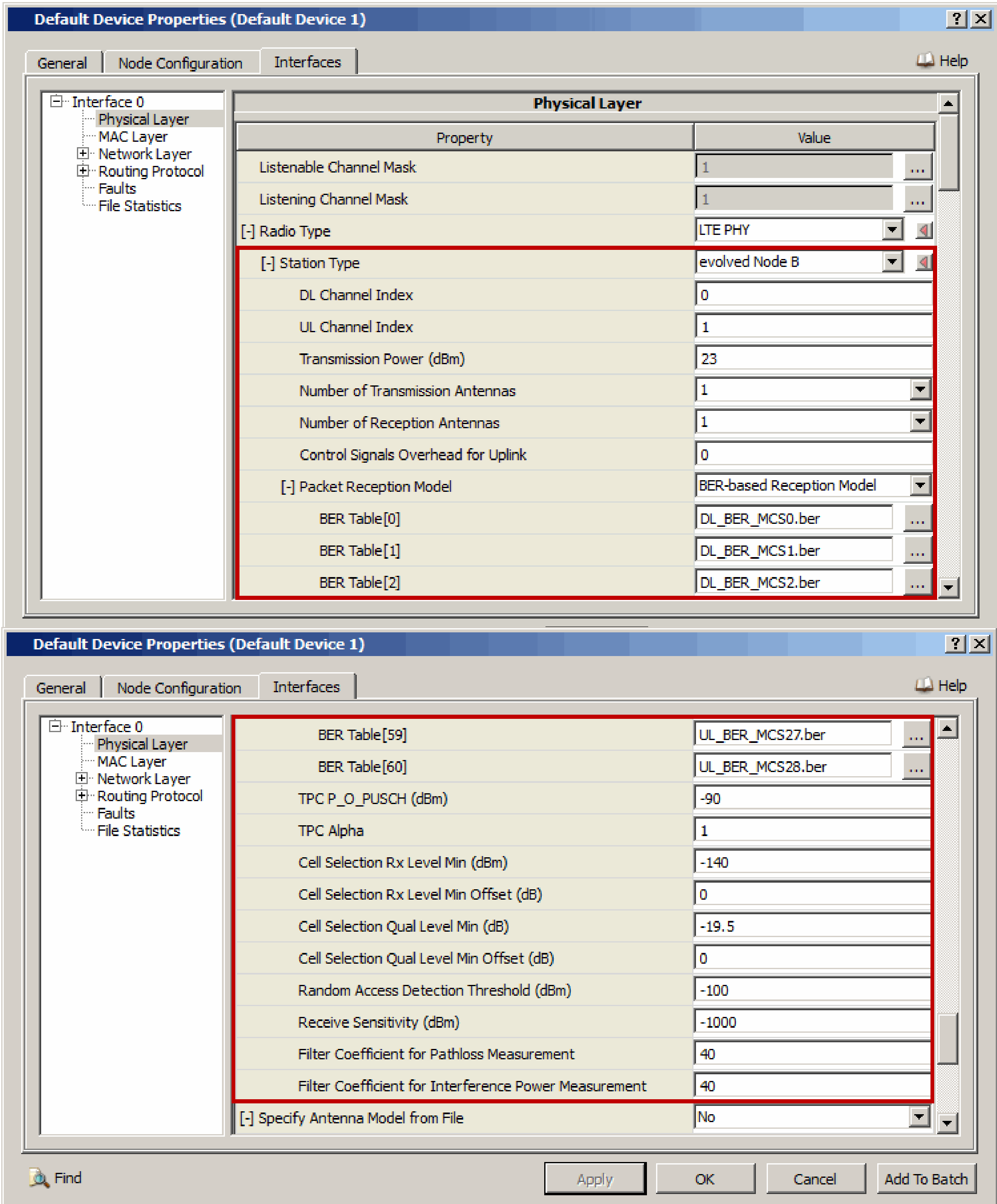

FIGURE 2-4. Setting eNB Node Parameters

TABLE 2-8. Command Line Equivalent of eNB Node Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
DL Channel Index	Subnet, Interface	`PHY-LTE-DL-CHANNEL`
UL Channel Index	Subnet, Interface	`PHY-LTE-UL-CHANNEL`
Transmission Power	Subnet, Interface	`PHY-LTE-TX-POWER`
Number of Transmission Antennas	Subnet, Interface	`PHY-LTE-NUM-TX-ANTENNAS`
Number of Reception Antennas	Subnet, Interface	`PHY-LTE-NUM-RX-ANTENNAS`
Control Signals Overhead for Uplink	Subnet, Interface	`PHY-LTE-PUCCH-OVERHEAD`
Packet Reception Model	Subnet, Interface	`PHY-RX-MODEL`
BER Table[*i*]	Subnet, Interface	`PHY-RX-BER-TABLE-FILE[i]`
TPC P_O_PUSCH	Subnet, Interface	`PHY-LTE-TPC-P_O_PUSCH`
TPC Alpha	Subnet, Interface	`PHY-LTE-TPC-ALPHA`
Cell Selection Rx Level Min	Subnet, Interface	`PHY-LTE-CELL-SELECTION-RX-LEVEL-MIN`
Cell Selection Rx Level Min Offset	Subnet, Interface	`PHY-LTE-CELL-SELECTION-RX-LEVEL-MIN-OFFSET`
Cell Selection Qual Level Min	Subnet, Interface	`PHY-LTE-CELL-SELECTION-QUAL-LEVEL-MIN`
Cell Selection Qual Level Min Offset	Subnet, Interface	`PHY-LTE-CELL-SELECTION-QUAL-LEVEL-MIN-OFFSET`
Random Access Detection Threshold	Subnet, Interface	`PHY-LTE-RA-DETECTION-THRESHOLD`
Receive Sensitivity	Subnet, Interface	`PHY-LTE-RX-SENSITIVITY`
Filter Coefficient for Pathloss Measurement	Subnet, Interface	`PHY-LTE-PATHLOSS-FILTER-COEFFICIENT`
Filter Coefficient for Interference Power Measurement	Subnet, Interface	`PHY-LTE-INTERFERENCE-FILTER-COEFFICIENT`

Configuring Statistics Parameters

Statistics for the LTE PHY model can be collected at the global, node, subnet, and interface levels. See Section 4.2.9 of *EXata User's Guide* for details of configuring statistics parameters.

To enable statistics collection for LTE PHY, check the box labeled **PHY/Radio** in the appropriate properties editor.

TABLE 2-9. Command Line Equivalent of Statistics Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
PHY/Radio	Global, Node, Subnet, Interface	`PHY-LAYER-STATISTICS`

2.1.5 Statistics

This section describes the file, database, and dynamic statistics of the LTE PHY model.

2.1.5.1 File Statistics

Table 2-10 lists the LTE PHY statistics that are output to the statistics (.stat) file at the end of simulation.

TABLE 2-10. LTE PHY Statistics

Statistics	Description
Signals transmitted	Total number of signals transmitted by the node.
Signals locked on by PHY	Total number of signals locked on by PHY for the node
Transport blocks received and forwarded to MAC	Total number of transport blocks received and forwarded to MAC for the node.
Transport blocks received but with errors	Total number of transport blocks received in errors for the node.
Interference signals received	Total number of interference signals received by the node.
Total bits sent to MAC	Total number of bits sent to MAC.

2.1.5.2 Database Statistics

In addition to the file statistics, the LTE PHY model also enters statistics in various scenario statistics database tables. Refer to *EXata Statistics Database User's Guide* for details.

2.1.5.3 Dynamic Statistics

No dynamic statistics are supported for the LTE PHY model.

2.1.6 Sample Scenario

See Section 4.1.6 for a sample scenario that uses LTE PHY.

2.1.7 References

The LTE model is based on the following 3GPP UMTS Technical Specifications Release 9 standards:

1. 3GPP TS 36.423, “Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)”

2. 3GPP TS 36.413 “Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)”

3. 3GPP TS 36.300, “Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description”

4. 3GPP TS 36.331 “Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification”

3 Layer 2 Models

This chapter describes features, configuration requirements and parameters, statistics, and scenarios for Layer 2 models in the LTE Model Library, and consists of the following sections:

- LTE Layer 2 Model

3.1 LTE Layer 2 Model

The EXata LTE Layer 2 model is based on the 3GPP 36.3XX architecture which specifies E-UTRAN MAC and higher layer models.

3.1.1 Description

The main functions of the E-UTRAN Layer 2 are:

- RRC sublayer
  - Establishment of RRC connection
- PDCP sublayer
  - Maintenance of PDCP SNs
- RLC sublayer
  - ARQ (RLC Acknowledge mode)
  - Segmentation, Concatenation, and Reassembly
  - Resegmentation
  - Reordering
- MAC sublayer
  - Buffer Status Report
  - Random Access
  - Multiplexing and Demultiplexing
  - Scheduling

Figure 3-1 shows the data PDUs for each sublayer.

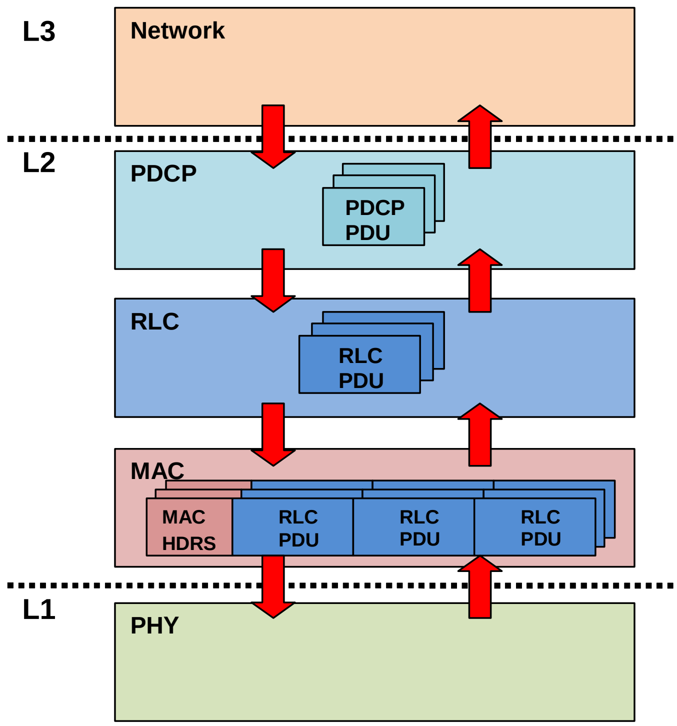

FIGURE 3-1. Layer 2 Data PDUs

3.1.2 Features and Assumptions

This section describes the implemented features, omitted features, and assumptions and limitations of the LTE Layer 2 model.

3.1.2.1 Implemented Features

- RRC sublayer
  - Establishment of RRC connections
- PDCP sublayer
  - Maintenance of PDCP SNs
- RLC sublayer
  - ARQ (RLC acknowledge mode)
  - Segmentation, Concatenation, and Reassembly
  - Resegmentation
  - Reordering
- MAC sublayer
  - Buffer Status Report
  - Random Access
  - Multiplexing and Demultiplexing

- Scheduling
  - Round Robin
  - Proportional Fair

3.1.2.2 Omitted Features

- E-UTRAN
  - Mobility and handover
- RRC sublayer
  - Modification/release of RRC connection
  - MBMS
- PDCP sublayer
  - Header compression
  - Ciphering
  - Discarding data
- RLC sublayer
  - TM/UM
  - Error correction
  - Protocol error detection
- MAC sublayer
  - H-ARQ

3.1.2.3 Assumptions and Limitations

- Only static routes are supported.
- Only one radio bearer is supported.
- Only one LTE interface is supported.
- The LTE models can be enabled only on the first interface of a node.
- If RLC status PDU size is more than the sendable size on MAC sublayer, it is not sent at its subframe.
- If RLC transmission window is stopped, RLC cannot send after that.
- Only X2 handover is implemented.
- Only A3 event is implemented as the measurement report trigger. A1, A2, A4 and A5 events are not available.
- RSRQ measurements are available only for intra-frequency neighbor cells (eNB nodes which are using the same channel).
- The effect of the layer 3 filtering coefficient (specified by the parameter `RRC-LTE-MEAS-FILTER-COEFFICIENT`) does not fit the expectation derived from the description in the specification. This is because the layer 1 filtering is not implemented in LTE models. It shortens the average period and results in a more frequent evaluation than expected in layer 3 filtering.

3.1.3 Command Line Configuration

To use the LTE Layer 2 model in a scenario, include the following parameter in the scenario configuration (.config) file:

```
<Qualifier> MAC-PROTOCOL    MAC-LTE
```

The scope of this parameter declaration can be Global, Node, Subnet, or Interface. See Section 1.4.1.1 for a description of `<Qualifier>` for each scope.

LTE Layer 2 Parameters

Table 3-1 describe the LTE Layer 2 parameters. Table 3-2 describes the RRC sublayer measurement parameters. Table 3-3 and Table 3-6 list the configuration parameters for the RRC and MAC sublayers, respectively, for UE nodes. Table 3-4, Table 3-5, and Table 3-7 list the configuration parameters for the RRC, RLC, and MAC sublayers, respectively, for eNodeB nodes.

There are no configuration parameters for the LTE PDCP sublayer.

See Section 1.4.1.3 for a description of the format used for the parameter tables.

TABLE 3-1. Layer 2 Parameters

Parameter	Value	Description
`MAC-LTE-STATION-TYPE` *Required* *Scope:* All	List: • `eNB` • `UE`	Type of the node. `eNB`: evolved Node B `UE`: User Equipment If this parameter is set to `eNB`, then set the parameters listed in Table 3-7, Table 3-5, and Table 3-4. If this parameter is set to `UE`, then set the parameters listed in Table 3-6 and Table 3-3.

TABLE 3-2. RRC Sublayer Measurement Parameters

Parameter	Value	Description
`RRC-LTE-MEAS-OBSERVING-EVENT-MASK-RSRP` *Optional* *Scope:* Global, Subnet	Striking of 0's and 1's *Default:* `00000`	Observing event mask for RSRP. The observing event mask is a string of five 0's and 1's. Each bit in the mask corresponds to an event. The left-most bit corresponds to event A1, while the right-most bit corresponds to event A5. If the bit in the mask is set to 1, then the corresponding event is observed; otherwise, that event is not observed. **Note:** In the LTE model, only the A3 event is observable. Therefore, this mask can be set only to `00000` or `00100`.

TABLE 3-2. RRC Sublayer Measurement Parameters (Continued)

Parameter	Value	Description
RRC-LTE-MEAS-OBSERVING-EVENT-MASK-RSRQ *Optional* *Scope:* Global, Subnet	Striking of 0's and 1's *Default:* 00000	Observing event mask for RSRQ. The observing event mask is a string of five 0's and 1's. Each bit in the mask corresponds to an event. The left-most bit corresponds to event A1, while the right-most bit corresponds to event A5. If the bit in the mask is set to 1, then the corresponding event is observed; otherwise, that event is not observed. **Note:** In the LTE model, only the A3 event is observable. Therefore, this mask can be set only to 00000 or 00100.
RRC-LTE-MEAS-EVENT-A3-RSRP-OFF *Optional* *Scope:* Global, Subnet	Real *Range:* [-1000.0, 1000.0] *Default:* 0.0 *Units:* dB	Reference Signal Receive Power (RSRP) offset of event A3.
RRC-LTE-MEAS-EVENT-A3-RSRP-HYS *Optional* *Scope:* Global, Subnet	Real *Range:* [-1000.0, 1000.0] *Default:* 0.0 *Units:* dB	RSRP hysteresis of event A3.
RRC-LTE-MEAS-EVENT-A3-RSRQ-OFF *Optional* *Scope:* Global, Subnet	Real *Range:* [-1000.0, 1000.0] *Default:* 0.0 *Units:* dB	Reference Signal Receive Quality (RSRQ) offset of event A3.
RRC-LTE-MEAS-EVENT-A3-RSRQ-HYS *Optional* *Scope:* Global, Subnet	Real *Range:* [-1000.0, 1000.0] *Default:* 0.0 *Units:* dB	RSRQ hysteresis of event A3.
RRC-LTE-MEAS-EVENT-A5-RSRQ-TH2 *Optional* *Scope:* Global	Real *Range:* [-1000.0, 1000.0] *Default:* 0.0 *Units:* dBm	Threshold2 of event A5 (RSRQ). **Note:** This parameter is reserved for future release.

TABLE 3-2. RRC Sublayer Measurement Parameters (Continued)

Parameter	Value	Description
`RRC-LTE-MEAS-EVENT-A5-RSRQ-HYS` *Optional* *Scope:* Global	Real *Range:* `[-1000.0, 1000.0]` *Default:* `0.0` *Units:* `dB`	Hysteresis of event A5 (RSRQ). **Note:** This parameter is reserved for future release.
`RRC-LTE-MEAS-REPORT-INTERVAL` *Optional* *Scope:* Global, Subnet	Time *Range:* `> 0S` *Default:* `120MS`	Interval for sending periodic measurement reports.
`RRC-LTE-MEAS-REPORT-AMOUNT` *Optional* *Scope:* Global, Subnet	Integer *Range:* ≥ `1` *Default:* `1`	Number of measurement reports sent.
`RRC-LTE-MEAS-QUANTITY-CONFIG-FILTER-COEF-RSRP` *Optional* *Scope:* Global, Subnet	Integer *Range:* `[0, 100]` *Default:* `4`	Coefficient to filter measured RSRP value.
`RRC-LTE-MEAS-QUANTITY-CONFIG-FILTER-COEF-RSRQ` *Optional* *Scope:* Global, Subnet	Integer *Range:* `[0, 100]` *Default:* `4`	Coefficient to filter measured RSRQ value.
`RRC-LTE-MEAS-GAP-CONFIG-TYPE` *Optional* *Scope:* Global, Subnet	List: • `0` • `1` *Default:* `0`	Specifies the measurement gap. This value determines the frequency of inter-frequency measurement. 0: Once every 40 subframes 1: Once every 80 subframes

TABLE 3-3. RRC Sublayer Parameters for UE Nodes

Parameter	Value	Description
RRC-LTE-WAIT-RRC-CONNECTED-TIME *Optional* *Scope:* All	Time *Range:* ≥ 0S *Default:* 10MS	Waiting period after the Random Access has finished before transitioning to the RRC_CONNECTED state. The UE changes its state to RRC_CONNECTED and sends a RRC Connection Setup Complete Message when this timer expires. The eNB changes its state to RRC_CONNECTED when it receives a RRC Connection Setup Complete Message from the UE.
RRC-LTE-WAIT-RRC-CONNECTED-RECONF-TIME *Optional* *Scope:* All	Time *Range:* ≥ 0S *Default:* 10MS	Waiting period after the Random Access has finished during the handover process before transitioning to the state of RRC_CONNECTED. The UE changes its state to RRC_CONNECTED and sends a RRC Connection Reconfiguration Complete Message when this timer expires. The eNB changes its state to RRC_CONNECTED when it receives a RRC Connection Reconfiguration Complete Message from the UE.

TABLE 3-4. RRC Sublayer Parameters for eNB Nodes

Parameter	Value	Description
RRC-LTE-MEAS-FILTER-COEFFICIENT *Optional* *Scope:* All	Real *Range:* ≥ 0 *Default:* 40	Coefficient for the exponential average of measurement data. It is identical to *filterCoefficient* in the following formula. filteredValue = (1 - a) x filteredValue + a x value where $a = \frac{1}{2^{(filterCoefficient)/4}}$

TABLE 3-5. RLC Sublayer Parameters for eNB Nodes

Parameter	Value	Description
RLC-LTE-MAX-RETX-THRESHOLD *Optional* *Scope:* All	Integer *Range:* ≥ 0 *Default:* 8	Maximum number of retransmissions at the RLC.
RLC-LTE-POLL-PDU *Optional* *Scope:* All	Integer *Range:* ≥ 0 *Default:* 16	Number of PDUs that can be transmitted after the previous polling and until the next polling. The next polling happens just after the number of transmitted PDUs exceeds this value or the number of transmitted bytes of PDUs exceeds the value specified by the parameter RLC-LTE-POLL-BYTE.
RLC-LTE-POLL-BYTE *Optional* *Scope:* All	Integer *Range:* ≥ 0 *Default:* 250 *Unit:* kilobytes	Maximum data size after the previous polling and until the next polling. The next polling happens just after the number of transmitted bytes of PDUs exceeds this value or the number of transmitted PDUs exceeds the value specified by the parameter RLC-LTE-POLL-PDU.
RLC-LTE-T-POLL-RETRANSMIT *Optional* *Scope:* All	Time *Range:* ≥ 1MS *Default:* 100MS	t-PollRetransmit timer period.
RLC-LTE-T-REORDERING *Optional* *Scope:* All	Time *Range:* ≥ 1MS *Default:* 100MS	t-Reordering timer period.
RLC-LTE-T-STATUS-PROHIBIT *Optional* *Scope:* All	Time *Range:* ≥ 1MS *Default:* 12MS	t-StatusProhibit timer period.

TABLE 3-6. MAC Sublayer Parameters for UE Nodes

Parameter	Value	Description
`MAC-LTE-UE-SCHEDULER-TYPE` *Optional* *Scope:* All	List • `SIMPLE-SCHEDULER` *Default:* `SIMPLE-SCHEDULER`	Type of scheduler at the UE.

TABLE 3-7. MAC Sublayer Parameters for eNB Nodes

Parameter	Value	Description
`MAC-LTE-RA-BACKOFF-TIME` *Optional* *Scope:* All	Time *Range:* ≥ `0S` *Default:* `10MS`	Maximum backoff time for retransmission of the random access preamble. The backoff time is selected according to a uniform distribution between 0 and this value. This corresponds to “raBackoffParameterValue“ in the 3GPP specification.
`MAC-LTE-RA-PREAMBLE-INITIAL-RECEIVED-TARGET-POWER` *Optional* *Scope:* All	Real *Range:* `[-1000.0, 1000.0]` *Default:* `-90.0` *Unit:* dBm	Initial target received power of the random access preamble. This corresponds to “preambleInitialReceivedTargetPower “ in the 3GPP specification.
`MAC-LTE-RA-POWER-RAMPING-STEP` *Optional* *Scope:* All	Integer *Range:* `[0, 1000]` *Default:* `2` *Unit:* dB	Ramping step of the target received power of the random access preamble. The target received power of the preamble is increased by this value after every retransmission. This corresponds to “powerRampingStep” in the 3GPP specification.
`MAC-LTE-RA-PREAMBLE-TRANS-MAX` *Optional* *Scope:* All	Integer *Range:* ≥ `0` *Default:* `4`	Maximum number of retransmissions of the Random Access Preamble. This corresponds to “preambleTransMax” in the 3GPP specification.
`MAC-LTE-RA-RESPONSE-WINDOW-SIZE` *Optional* *Scope:* All	Integer *Range:* ≥ `3` *Default:* `10`	Number of subframes with RA Grant.

TABLE 3-7. MAC Sublayer Parameters for eNB Nodes (Continued)

Parameter	Value	Description
MAC-LTE-RA-PRACH-CONFIG-INDEX *Optional* *Scope:* All	Integer *Range:* [3, 14] *Default:* 14	Value for PRACH configuration index during Random Access.
MAC-LTE-PERIODIC-BSR-TTI *Optional* *Scope:* All	Integer *Range:* ≥ 1 *Default:* 1 *Unit:* TTI	Interval of periodic BSR transmission.
MAC-LTE-ENB-SCHEDULER-TYPE *Optional* *Scope:* All	List: • ROUND-ROBIN • PROPORTIONAL-FAIRNESS *Default:* ROUND-ROBIN	Type of scheduler at the eNB.
MAC-LTE-TRANSMISSION-MODE *Optional* *Scope:* All	List: • 1 • 2 • 3 *Default:* 1	Initial transmission mode. 1: Single antenna scheme 2: Transmission diversity (SFBC) 3: Transmission diversity/open-loop spatial multiplexing
MAC-LTE-TARGET-BLER *Optional* *Scope:* All	Real *Range:* [0.0, 1.0] *Default:* 0.01	Target Block Error Rate (BLER) used by the scheduler.
MAC-LTE-PF-FILTER-COEFFICIENT *Optional* *Scope:* All	Real *Range:* ≥ 0.0 *Default:* 36.0	Coefficient value for filtering average throughput used when calculating the PF Metric value. This value should be the same as the filtering coefficient value defined by RRC-LTE-MEAS-FILTER-COEFFICIENT.
MAC-LTE-PF-UL-RB-ALLOCATION-UNIT *Optional* *Scope:* All	Integer *Range:* [1, 100] *Default:* 1	Allocation unit of the number of resource blocks that are used by PF and UL schedulers.

3.1.4 GUI Configuration

This section describes how to configure the LTE Layer 2 model using the GUI.

Section 3.1.4.1 describes how to configure the LTE Layer 2 measurement parameters. Section 3.1.4.2 describes how to configure LTE Layer 2 parameters for stations (UE and eNB nodes). Section 3.1.4.3 describes how to configure statistics parameters for the LTE layer 2 model.

3.1.4.1 Configuring Layer 2 Measurement Parameters

To configure the LTE Layer 2 measurement parameters, perform the following steps:

1. Go to **Wireless Subnet Properties Editor > MAC Layer**.
2. Set **MAC Protocol** to *LTE MAC.*
3. Set **Specify Measurement Parameters** to *YES* and set the parameters listed in Table 3-8.

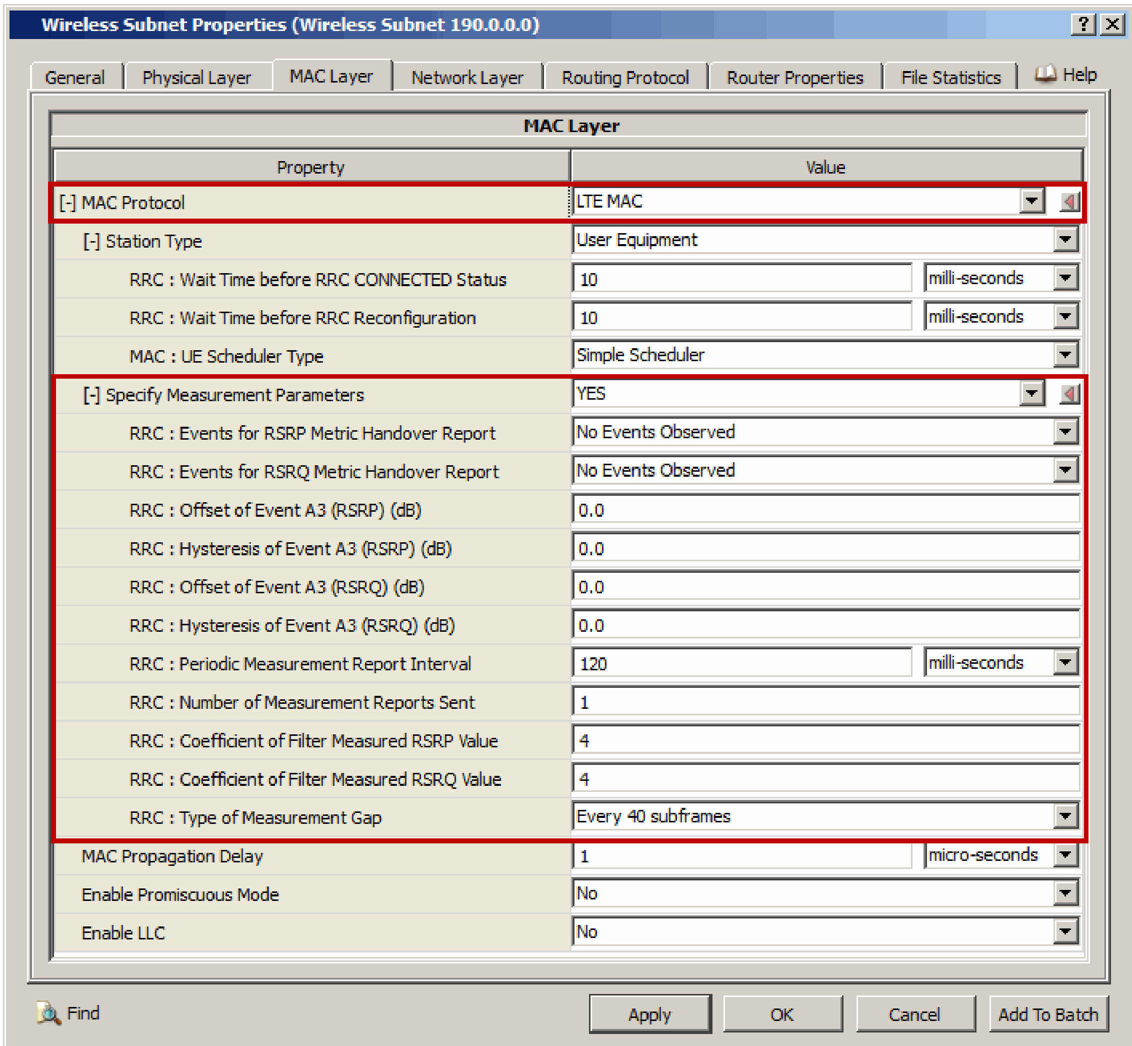

FIGURE 3-2. Setting Measurement Parameters

TABLE 3-8. Command Line Equivalent of Measurement Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
RRC: Events for RSRP Metric Handover Report	Subnet	`RRC-LTE-MEAS-OBSERVING-EVENT-MASK-RSRP`
RRC: Events for RSRQ Metric Handover Report	Subnet	`RRC-LTE-MEAS-OBSERVING-EVENT-MASK-RSRQ`
RRC: Offset of Event A3 (RSRP)	Subnet	`RRC-LTE-MEAS-EVENT-A3-RSRP-OFF`
RRC: Hysteresis of Event A3 (RSRP)	Subnet	`RRC-LTE-MEAS-EVENT-A3-RSRP-HYS`
RRC: Offset of Event A3 (RSRQ)	Subnet	`RRC-LTE-MEAS-EVENT-A3-RSRQ-OFF`
RRC: Hysteresis of Event A3 (RSRQ)	Subnet	`RRC-LTE-MEAS-EVENT-A3-RSRQ-HYS`
RRC: Periodical Measurement Report Interval	Subnet	`RRC-LTE-MEAS-REPORT-INTERVAL`
RRC: Number of Measurement Reports Sent	Subnet	`RRC-LTE-MEAS-REPORT-AMOUNT`
RRC: Coefficient to Filter Measured RSRP Value	Subnet	`RRC-LTE-MEAS-QUANTITY-CONFIG-FILTER-COEF-RSRP`
RRC: Coefficient to Filter Measured RSRQ Value	Subnet	`RRC-LTE-MEAS-QUANTITY-CONFIG-FILTER-COEF-RSRQ`
RRC: Type of Measurement Gap	Subnet	`RRC-LTE-MEAS-GAP-CONFIG-TYPE`

TABLE 3-9. Command Line Equivalent of Gap Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Type of Measurement Gap	Global	`RRC-LTE-MEAS-GAP-CONFIG-TYPE`

3.1.4.2 Configuring Layer 2 Parameters for Stations

To configure the LTE Layer 2 parameters for stations, perform the following steps:

1. Go to one of the following locations:
   - To set properties for a specific subnet, go to **Wireless Subnet Properties Editor > MAC Layer**.
   - To set properties a specific interface of a node, go to one of the following locations:
     - **Interface Properties Editor > Interfaces > Interface # > MAC Layer**.
     - **Default Device Properties Editor > Interfaces > Interface # > MAC Layer**.

   In this section, we show how to configure LTE Layer 2 parameters for a subnet using the Wireless Subnet Properties Editor. Parameters can be set in the other properties editors in a similar way.

2. Set **MAC Protocol** to *LTE MAC* and set the dependent parameters listed in Table 3-10.

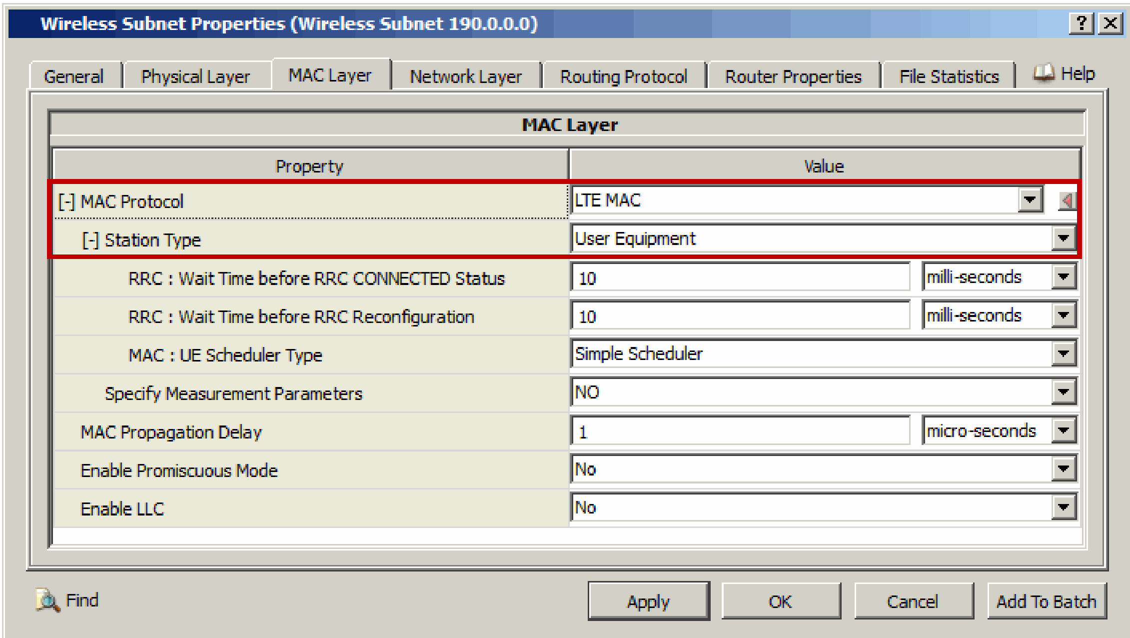

FIGURE 3-3. Configuring Station Type

TABLE 3-10. Command Line Equivalent of Station Type Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Station Type	Subnet, Interface	`MAC-LTE-STATION-TYPE`

3. If **Station Type** is set to *User Equipment*, then set the parameters listed in Table 3-11.

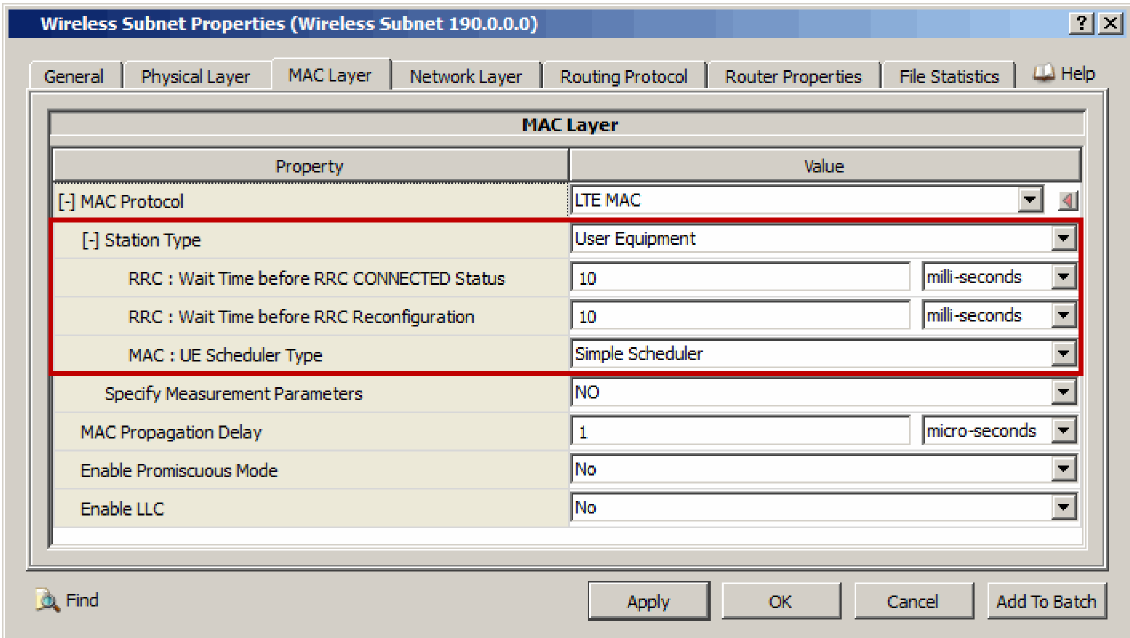

FIGURE 3-4. Setting UE Node Layer 2 Parameters

TABLE 3-11. Command Line Equivalent of UE Node Layer 2 Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
RRC: Wait Time before RRC CONNECTED Status	Subnet, Interface	`RRC-LTE-WAIT-RRC-CONNECTED-TIME`
RRC: Wait Time before RRC Reconfiguration	Subnet, Interface	`RRC-LTE-WAIT-RRC-CONNECTED-RECONF-TIME`
MAC: UE Scheduler Type	Subnet, Interface	`MAC-LTE-UE-SCHEDULER-TYPE`

4. If **Station Type** is set to *evolved Node B*, then set the parameters listed in Table 3-12.

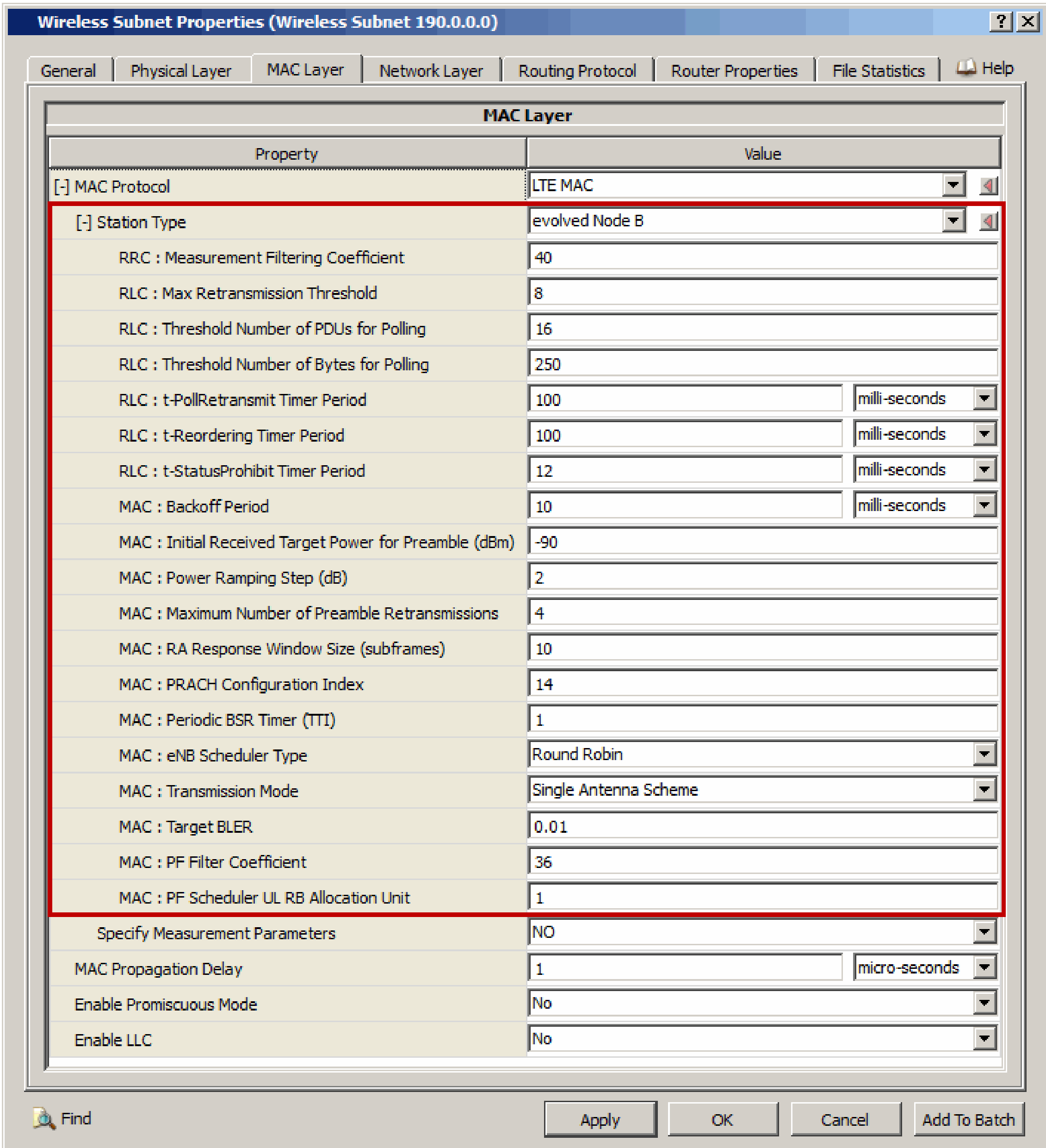

FIGURE 3-5. Setting eNB Node Layer 2 Parameters

TABLE 3-12. Command Line Equivalent of eNB Node Layer 2 Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
RRC: Measurement Filtering Coefficient	Subnet, Interface	`RRC-LTE-MEAS-FILTER-COEFFICIENT`
RLC: Max Retransmission Threshold	Subnet, Interface	`RLC-LTE-MAX-RETX-THRESHOLD`

TABLE 3-12. Command Line Equivalent of eNB Node Layer 2 Parameters (Continued)

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
RLC: Threshold Number of PDUs for Polling	Subnet, Interface	`RLC-LTE-POLL-PDU`
RLC: Threshold Number of Bytes for Polling	Subnet, Interface	`RLC-LTE-POLL-BYTE`
RLC: t-PollRetransmit Timer Period	Subnet, Interface	`RLC-LTE-T-POLL-RETRANSMIT`
RLC: t-Reordering Timer Period	Subnet, Interface	`RLC-LTE-T-REORDERING`
RLC: t-StatusProhibit Timer Period	Subnet, Interface	`RLC-LTE-T-STATUS-PROHIBIT`
MAC: Backoff Period	Subnet, Interface	`MAC-LTE-RA-BACKOFF-TIME`
MAC: Initial Received Target Power for Preamble	Subnet, Interface	`MAC-LTE-RA-PREAMBLE-INITIAL-RECEIVED-TARGET-POWER`
MAC: Power Ramping Step	Subnet, Interface	`MAC-LTE-RA-POWER-RAMPING-STEP`
MAC: Maximum Number of Preamble Retrasnsmissions	Subnet, Interface	`MAC-LTE-RA-PREAMBLE-TRANS-MAX`
MAC: RA Response Window Size	Subnet, Interface	`MAC-LTE-RA-RESPONSE-WINDOW-SIZE`
MAC: PRACH Configuration Index	Subnet, Interface	`MAC-LTE-RA-PRACH-CONFIG-INDEX`
MAC: Periodic BSR Timer	Subnet, Interface	`MAC-LTE-PERIODIC-BSR-TTI`
MAC: eNB Scheduler Type	Subnet, Interface	`MAC-LTE-ENB-SCHEDULER-TYPE`
MAC: Transmission Mode	Subnet, Interface	`MAC-LTE-TRANSMISSION-MODE`
MAC: Target BLER	Subnet, Interface	`MAC-LTE-TARGET-BLER`
MAC: PF Filter Coefficient	Subnet, Interface	`MAC-LTE-PF-FILTER-COEFFICIENT`
MAC: Scheduler UL RB Allocation Unit	Subnet, Interface	`MAC-LTE-PF-UL-RB-ALLOCATION-UNIT`

3.1.4.3 Configuring Statistics Parameters

Statistics for the LTE Layer 2 model can be collected at the global, node, subnet, and interface levels. See Section 4.2.9 of *EXata User's Guide* for details of configuring statistics parameters.

To enable statistics collection for the LTE Layer 2 model, check the box labeled **MAC** in the appropriate properties editor.

TABLE 3-13. Command Line Equivalent of Statistics Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
MAC	Global, Node, Subnet, Interface	`MAC-LAYER-STATISTICS`

3.1.5 Statistics

This section describes the file, database, and dynamic statistics of the LTE Layer 2 model.

3.1.5.1 File Statistics

This section describes the LTE Layer 2 statistics that are output to the statistics (.stat) file at the end of simulation.

Table 3-14 through Table 3-17 list the statistics collected for the RRC, PDCP, RLC, and MAC sublayers, respectively.

Note: Unless otherwise stated, the statistics are collected for both eNB and UE nodes.

TABLE 3-14. RRC Sublayer Statistics

Statistic	Description
Number of RRC Connection Establishment	The number of RRC Connection Establishment. eNB: The number of RRC Connected notified to the PHY layer. UE: The number of RRC Connected notified from the PHY layer.
Average count of Retry RRC Connection Establishment	The average number of RRC Connection Establishment retries (not including the first transmission). **Note:** This statistic is collected only for UE nodes.
Average time of RRC Connection Establishment	The average time for RRC Connection Establishment (duration between the Power-On time to the time when RRC Connected is notified from eNB). **Note:** This statistic is collected only for UE nodes.

TABLE 3-15. PDCP Sublayer Statistics

Statistic	Description
Number of packets from Upper Layer	The number of PDCP SDUs received from the upper layer.
Number of packets from Upper Layer but discard	The number of PDCP SDUs received from the upper layer, but can be discarded with the following reasons: • Not connected. • Broadcast packet (not supported).
Number of packets to Lower Layer	The number of PDCP PDUs transmitted to the lower layer.
Number of packets from Lower Layer	The number of PDCP PDUs received from the lower layer.
Number of packets to Upper Layer	The number of PDCP PDUs transmitted to the upper layer.
Number of data packets enqueued in retransmission buffer	The number of PDCP PDUs enqueued in retransmission buffer
Number of data packets discarded due to retransmission buffer overflow	The number of PDCP PDU/SDUs discarded due to retransmission buffer overflow
Number of data packets discarded from retransmission buffer due to discard timer expired	The number of PDCP PDUs discarded from retransmission buffer due to discard timer expired

TABLE 3-15. PDCP Sublayer Statistics (Continued)

Statistic	Description
Number of data packets dequeued from retransmission buffer	The number of PDCP PDUs dequeued from retransmission buffer
Number of data packets discarded due to ack received	The number of PDCP PDUs discarded due to ack received
Number of data packets enqueued in reordering buffer	The number of PDCP PDUs enqueued in reordering buffer
Number of data packets discarded due to already received	The number of PDCP PDUs discarded due to already received
Number of data packets dequeued from reordering buffer	The number of PDCP PDUs dequeued from reordering buffer
Number of data packets discarded from reordering buffer	The number of PDCP PDUs discarded from reordering buffer due to invalid PDCP SN received

TABLE 3-16. RLC Sublayer Statistics

Statistic	Description
Number of SDUs received from the upper layer	The number of SDUs transferred from the PDCP layer.
Number of SDUs discarded by overflow	The number of SDUs discarded by buffer overflow.
Number of SDUs sent to the upper layer	The number of SDUs passed to the PDCP layer.
Number of data PDUs sent to the MAC sublayer	The number of data PDUs passed to the MAC layer.
Number of data PDUs discarded by Retransmission threshold	The number of abandoned data PDUs that exceeded maximum retransmission times.
Number of data PDUs received from the MAC sublayer	The number of PDUs received from the MAC layer.
Number of data PDUs received from MAC sublayer but discarded by RESET	The number of PDUs received from the MAC layer but discarded by Reset.
Number of AM STATUS PDUs sent to the MAC sublayer	The number of Status PDUs passed to the MAC layer.
Number of AM STATUS PDUs received from the MAC sublayer	The number of Status PDUs received from the MAC layer.
Number of AM STATUS PDUs received from MAC sublayer but discarded by RESET	The number of Status PDUs received from the MAC layer but discarded by reset.

TABLE 3-17. MAC Sublayer Statistics

Statistic	Description
Statistics for UE nodes only	
Number of sending Random Access Preamble	The number of transmission requests of Random Access Preamble.
Number of receiving Random Access Grant	The number of receiving notification of Random Access Grant.

TABLE 3-17. MAC Sublayer Statistics (Continued)

Statistic	Description
Average count of PREAMBLE_TRANSMISSION_COUNTER	Average count of transmission of RA preamble.
Statistics for eNB nodes only	
Number of receiving Random Access Preamble	The number of receiving notifications of Random Access Preamble.
Number of sending Random Access Grant	The number of transmission request of Random Access Grant.
Statistics for both UE and eNB nodes	
Number of MAC SDU from Upper Layer	The number of MAC SDUs received from the upper layer.
Number of MAC PDU to Lower Layer	The number of MAC PDUs transmitted to the lower layer.
Number of MAC PDU from Upper Layer	The number of MAC PDUs received from the upper layer.
Number of MAC PDU from Lower Layer with Error	The number of MAC PDUs reported with errors from the lower layer.
Number of MAC SDU to Upper Layer	The number of MAC SDUs transmitted to the upper layer.

3.1.5.2 Database Statistics

In addition to the file statistics, the LTE Layer 2 model also enters statistics in various scenario statistics database tables. Refer to *EXata Statistics Database User's Guide* for details.

3.1.5.3 Dynamic Statistics

No dynamic statistics are supported for the LTE Layer 2 model.

3.1.6 Sample Scenario

See Section 4.1.6 for a sample scenario that uses LTE Layer 2.

3.1.7 References

The LTE model is based on the following 3GPP UMTS Technical Specifications Release 9 standards:

1. 3GPP TS 36.423, "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)"
2. 3GPP TS 36.413 "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)"
3. 3GPP TS 36.300, "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description"
4. 3GPP TS 36.331 "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification"

4 Network Layer Models

This chapter describes features, configuration requirements and parameters, statistics, and scenarios for Network Layer models in the LTE Model Library, and consists of the following section(s):

- LTE Evolved Core Packet (EPC) Model

4.1 LTE Evolved Packet Core (EPC) Model

The EXata Evolved Packet Core (EPC) model is based on the 3GPP 36.423 and 3GPP 36.413 architecture that specifies X2 Application Protocol (X2AP) and S1 Application Part (S1AP).

4.1.1 Description

Evolved Packet Core is a framework for providing converged voice and data on a 4G LTE network.

The main functions of the EPC are:

- Handover Decision
- Admission Control
- Management downlink data path (from SGW/MME to UE)
- X2AP: Messages exchanged on the X2 interface between eNBs
- S1AP: Messages exchanged on the S1 interface between eNB and SGW/MME

The source eNB makes decisions based on Measurement Reports before handing over control to the UE. In this model, the source eNB always decides the starting handover. The target eNB performs admission control that is based on the Handover Request. In this model the resources are always granted to the UE.

The SGW/MME switches the downlink data path to the target side after receiving a Path Switch Request. The serving gateway sends one or more "end marker" packets on the old path to the source eNB and then can release any U-plane/TNL resource towards the source eNB.

All control messages for X2 handover are exchanged by the X2 interface or the S1 interface. Two eNBs are inter-connected via the X2 interface. The primary functions of the X2 interface are to provide intra-LTE-access-system mobility support for UE in LTE_ACTIVE state and inter-cell interference coordination functionality.

The S1AP protocol primarily supports general E-UTRAN procedures from the EPC, transfers transparent non-access signaling, and performs the mobility function. It is also capable of carrying messages transparently between the EPC and the UE over the S1 interface.

4.1.2 Features and Assumptions

This section describes the implemented features, omitted features, and assumptions and limitations of the LTE EPC model.

4.1.2.1 Implemented Features

- X2AP: Implement X2AP on UDP instead of GTP-U
- S1AP: Implement S1AP on UDP instead of GTP-U

4.1.2.2 Omitted Features

- C-Plane handover procedure
  - Handover Preparation Failure
  - Handover Cancel
- U-Plane handover procedure
  - Handling of unknown, unforeseen and erroneous protocol data

- PDCP Control PDU
- FMS

- Measurement
  - Timers
    - T321 timer
    - TperiodicalReport timer
  - Measurement Events
    - Event A1 (Serving becomes better than threshold)
    - Event A2 (Serving becomes worse than threshold)
    - Event A4 (Neighbor becomes better than threshold)
    - Event A5 (Serving becomes worse than threshold1 and neighbor becomes better)
- S1 Attach procedure
  - Create Route Acknowledge
  - Create Route Failure
  - Path Switch Request Failure
  - Timers
    - Twait_attach_response timer
    - Twait_create_route_ack timer

4.1.2.3 Assumptions and Limitations

- SGW and MME are assumed to exist on the same node.

4.1.3 Command Line Configuration

To configure a subnet as an EPC subnet, include the following parameter in the scenario configuration (.config) file:

```
[<Qualifier>] IS-EPC-SUBNET   YES
```

The scope of this parameter declaration can be Global, Node, Subnet, or Interface. See Section 1.4.1.1 for a description of `<Qualifier>` for each scope.

Note: The default value of `IS-EPC-SUBNET` is `NO`.

LTE EPC Parameters

Table 4-1 lists the configuration parameters for the EPC model. See Section 1.4.1.3 for a description of the format used for the parameter table.

TABLE 4-1. EPC Parameters

Parameter	Value	Description
`EPC-SGWMME-NODE-ID` *Optional* *Scope:* Subnet	Integer *Default:* `1`	Node ID of SGW / MME node.
`EPC-SGWMME-INTERFACE-INDEX` *Optional* *Scope:* Subnet	Integer *Default:* `0`	Index of the EPC subnet interface of SGW / MME node.

4.1.4 GUI Configuration

This section describes how to configure the LTE EPC model using the GUI.

4.1.4.1 Configuring LTE EPC

To configure the LTE EPC model, perform the following steps:

1. Place a Hub and eNBs on the canvas.
2. Create a link between the eNBs and the Hub.
3. Go to **Wired Subnet Properties Editor > General**.

4. Set **Is EPC Subnet** to *Yes* and set the dependent parameters listed in Table 4-2.

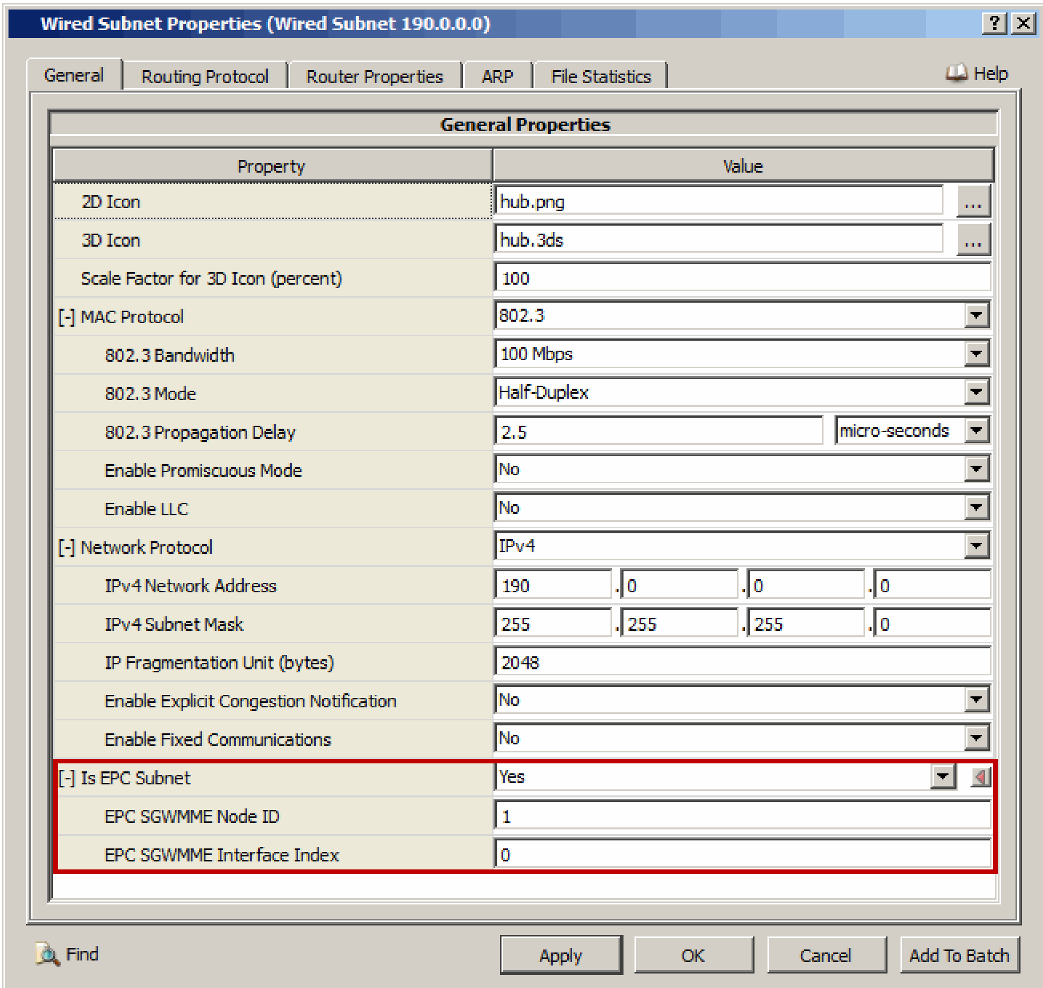

FIGURE 4-1. Configuring EPC Subnet

TABLE 4-2. Command Line Equivalent of Station Type Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Is EPC Subnet	Subnet	`IS-EPC-SUBNET`
EPC SGWMME Node ID	Subnet	`EPC-SGWMME-NODE-ID`
EPC SGWMME Interface Index	Subnet	`EPC-SGWMME-INTERFACE-INDEX`

4.1.5 Statistics

Table 4-3 lists the statistics collected for the LTE EPC model that are output to the statistics (.stat) file at the end of simulation.

Note: Unless otherwise stated, the statistics are collected for both eNB and UE nodes.

TABLE 4-3. EPC Statistics

Statistic	Description
Number of handover request sent	The number of Handover Requests sent. This statistic is collected only for eNB nodes.
Number of handover request received	The number of Handover Requests received. This statistic is collected only for eNB nodes.
Number of handover request acknowledgement sent	The number of Handover Requests Ack sent. This statistic is collected only for eNB nodes.
Number of handover request acknowledgement received	The number of Handover Requests Ack received. This statistic is collected only for eNB nodes.
Number of SN Status Transfer sent	The number of SN Status Transfers sent. This statistic is collected only for eNB nodes.
Number of SN Status Transfer received	The number of SN Status Transfers received. This statistic is collected only for eNB nodes.
Number of Path Switch Request sent	The number of Path Switch Requests sent. This statistic is collected only for eNB and SGWMME nodes.
Number of Path Switch Request received	The number of Path Switch Requests received. This statistic is collected only for eNB and SGWMME nodes.
Number of Path Switch Request Acknowledgment sent	The number of Path Switch Requests Acknowledgment sent. This statistic is collected only for eNB and SGWMME nodes.
Number of Path Switch Request Acknowledgment received	The number of Path Switch Requests Acknowledgment received. This statistic is collected only for eNB and SGWMME nodes.
Number of End Marker sent	The number of End Markers sent. This statistic is collected only for eNB and SGWMME nodes.
Number of End Marker received	The number of End Markers received. This statistic is collected only for eNB and SGWMME nodes.
Number of UE Context Release sent	The number of UE Context Releases sent. This statistic is collected only for eNB nodes.

TABLE 4-3. EPC Statistics (Continued)

Statistic	Description
Number of UE Context Release received	The number of UE Context Releases received. This statistic is collected only for eNB nodes.
Number of handovers completed	The number of completed handovers. This statistic is collected only for eNB nodes.
Number of handovers failed	The number of handovers that failed. This statistic is collected only for eNB nodes.

4.1.6 Sample Scenario

The purpose of this scenario is to test the simple inter-channel handover.

4.1.6.1 Scenario Description

The scenario consists of one EPC subnet with two base stations (eNBs) and one user equipment (UE). Node 4 is the UE. Node 2 and 3 are eNBs (Figure 4-2).

The UE is attached with eNB1 initially, then it moves away from eNB1 to eNB2. The UE performs a handover from eNB1 (using channel 0 for DL, 1 for UL) to eNB2 (using channel 2 for DL, 3 for UL) as it moves away from eNB1 and closer to eNB2. CBR traffic is configured between the UE and the CN.

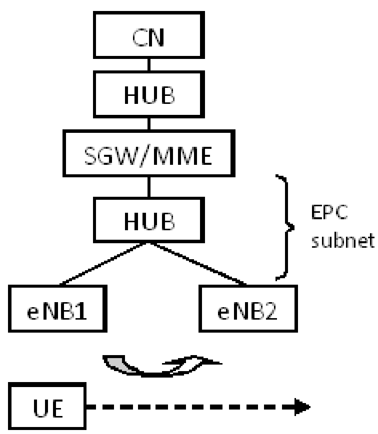

FIGURE 4-2. Simple Inter-channel Handover Scenario

4.1.6.2 Command Line Configuration

To configure the sample scenario in the command line, include the following lines in the scenario configuration file. (Default values are used for most of the parameters. Only the mandatory LTE Configuration parameters are listed here.)

Note: Default BER table files are included in EXATA_HOME/data/modulation/lte. Copy the *.ber files into your scenario directory, at the same level as the scenario configuration (.config) file.

```
APP-CONFIG-FILE   EPC-scenario.app

# Node 1 is the CN, node 2 is the SGW/MME, node 3 is eNB 2,
# node 4 is eNB 1, and node 5 is the UE.

# Point-to-point link between the CN and the SGW/MME.
LINK N8-190.0.1.0   {1, 2}

# Wired subnet connecting the SGW/MME and the two eNBs.
SUBNET N8-190.2.0 {2, 3, 4}

# Wireless subnet connecting the two eNBs and the UE.
SUBNET N8-190.0.3.0 {3, 4, 5}

# Observing event mask configuration. 00100 means observation of
# A3 event.
RRC-LTE-MEAS-OBSERVING-EVENT-MASK-RSRP 00100

# LTE parameters for LTE wireless subnet.
[ N8-190.0.3.0 ] PHY-MODEL PHY-LTE
[ N8-190.0.3.0 ] MAC-PROTOCOL MAC-LTE
[190.0.3.1 190.0.3.2] MAC-LTE-STATION-TYPE  eNB
[190.0.3.3 ] MAC-LTE-STATION-TYPE UE

[ N8-190.0.3.0 ] PHY-RX-MODEL PHY-LTE-BER-BASED
[ N8-190.0.3.0 ] PHY-RX-BER-TABLE-FILE[0] DL_BER_MCS0.ber
[ N8-190.0.3.0 ] PHY-RX-BER-TABLE-FILE[1] DL_BER_MCS1.ber

# The remaining DL BER tables are configured in a similar way.
[ N8-190.0.3.0 ] PHY-RX-BER-TABLE-FILE[28] DL_BER_MCS28.ber

[ N8-190.0.3.0 ] PHY-RX-BER-TABLE-FILE[32] UL_BER_MCS0.ber
[ N8-190.0.3.0 ] PHY-RX-BER-TABLE-FILE[33] UL_BER_MCS1.ber

# The remaining DL BER tables are configured in a similar way.
[ N8-190.0.3.0 ] PHY-RX-BER-TABLE-FILE[60] UL_BER_MCS28.ber
```

```
# Configure channel frequencies and names.
PROPAGATION-CHANNEL-FREQUENCY[0] 2.4e6
PROPAGATION-CHANNEL-NAME[0] channel-1
PROPAGATION-CHANNEL-FREQUENCY[1] 2.5e6
PROPAGATION-CHANNEL-NAME[1]  channel-2
PROPAGATION-CHANNEL-FREQUENCY[2] 2.6e6
PROPAGATION-CHANNEL-NAME[2]  channel-3
PROPAGATION-CHANNEL-FREQUENCY[2] 2.6e6
PROPAGATION-CHANNEL-NAME[3]  channel-4

# eNB 1 channel configuration.
[190.0.3.1] PHY-LISTENABLE-CHANNELS  channel-2
[190.0.3.1] PHY-LISTENING-CHANNELS  channel-2
[190.0.3.1] PHY-LTE-DL-CHANNEL  0
[190.0.3.1] PHY-LTE-UL-CHANNEL  1

# eNB 2 channel configuration.
[190.0.3.2] PHY-LISTENABLE-CHANNELS  channel-4
[190.0.3.2] PHY-LISTENING-CHANNELS  channel-4
[190.0.3.2] PHY-LTE-DL-CHANNEL  2
[190.0.3.2] PHY-LTE-UL-CHANNEL  3

# UE channel configuration.
[190.0.3.3] PHY-LISTENABLE-CHANNELS  channel-1, channel-3
[190.0.3.3] PHY-LISTENING-CHANNELS   channel-1

# Wired Subnet configuration.
# Interface 1 of the SGW/MME is connected to the eNBs.
[ N8-190.0.2.0 ] IS-EPC-SUBNET YES
[ N8-190.0.2.0 ] EPC-SGWMME-NODE-ID 2
[ N8-190.0.2.0 ] EPC-SGWMME-INTERFACE-INDEX 1
```

In the applications configuration file, EPC-scenario.app, set up a CBR session between node 5 and node 1 as follows:

```
CBR 5 1 100 512 1S 1S 25S PRECEDENCE 0
```

4.1.6.3 GUI Configuration

To configure the sample scenario in the GUI, perform the following steps:

1. Create the scenario topology as follows (seeFigure 4-3):

   a. Place five nodes of the default device type on the canvas. Node 1 is the CN, node 2 is the SGW/ MME, node 3 is eNB 1, node 4 is eNB 2, and node 5 is the UE.

   b. Create a point-to-point link between Nodes 1 and 2.

   c. Place a wired subnet and connect nodes 2, 3, and 4 to it.

   d. Place a wireless subnet and connect nodes 3, 4, and 5 to it.

   e. Place a waypoint for node 5 close to node 3. The UE should reach this waypoint at time 20 seconds.

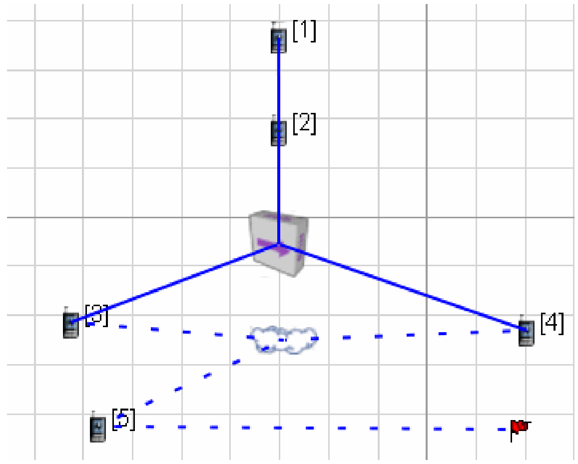

FIGURE 4-3. Sample Scenario in GUI

2. Default BER table files are included in EXATA_HOME/data/modulation/lte. Copy the *.ber files into your scenario directory, at the same level as the scenario configuration (.config) file.
3. Go to **Wireless Subnet Properties > Physical Layer** and set **Radio Type** to *LTE PHY*. Use default values for all PHY parameters. See Figure 2-2.
4. Go to **Wireless Subnet Properties > MAC Layer** and set **MAC Protocol** to *LTE MAC*.
   a. Set **Specify Measurement Parameters** to *YES* and then set **RRC: Events for RSRP Metric Handover Report** to *Observe A3 Events*. See Figure 3-2.
   b. Use default values for all other MAC parameters.
5. Go to **Scenario Properties Editor > Channel Properties**. Set **Number of Channels** to *4*.
6. For node 3 (eNB 1), go to **Default Device Properties > Interfaces > Interface 1**. (Make sure that Interface 1 corresponds to the wireless interface of node 3.)
   a. Select the **Physical Layer** group.
      i. Set **Station Type** to *evolved Node B*.
      ii. Set **Listenable Channels** and **Listening Channels** to *channel-2*.
   b. Select the **MAC Layer** group and set **Station Type** to *evolved Node B*.
3. For node 4 (eNB 2), go to **Default Device Properties > Interfaces > Interface 1**. (Make sure that Interface 1 corresponds to the wireless interface of node 4.)
   a. Select the **Physical Layer** group.
      i. Set **Station Type** to *evolved Node B*.
      ii. Set **DL Channel Index** to *2* and **UL CHannel Index** to *3*.
      iii. Set **Listenable Channels** and **Listening Channels** to *channel-4.*
   b. Select the **MAC Layer** group and set **Station Type** to *evolved Node B*.
4. For node 5 (UE node), go to **Default Device Properties > Interfaces > Interface 0 > Physical Layer** and set **Listenable Channels** to *channel1, channel-3* and **Listening Channels** to *channel-1*.
5. Select the wired subnet and go to **Wired Subnet Properties > General** (see Figure 4-1).
   a. Set **EPC Subnet** to *Yes*.
   b. Set **EPC SGWMME Node ID** to *2*.

   c. Set **SGWMME Interface Index** to *1*.

6. Set up a CBR session between node 5 and node 1.

4.1.7 References

The LTE model is based on the following 3GPP UMTS Technical Specifications Release 9 standards:

1. 3GPP TS 36.423, "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)"
2. 3GPP TS 36.413 "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)"
3. 3GPP TS 36.300, "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description"
4. 3GPP TS 36.331 "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification"