EXata 5.1
Advanced Wireless Model Library

August 2013

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Table of Contents

1 Overview of Model Library

1.1 List of Models in the Library

The models described in the Advanced Wireless Model Library are listed in Table 1-1.

TABLE 1-1. Advanced Wireless Library Models

Model Name	Model Type	Section Number
802.16 MAC and 802.16e MAC	MAC Layer	Section 3.1
802.16 PHY	PHY Layer	Section 2.1

1.2 Conventions Used

1.2.1 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.

1.2.1.1 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 1.2.1.2) 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.

1.2.1.2 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.

1.2.1.3 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.

1.2.2 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.

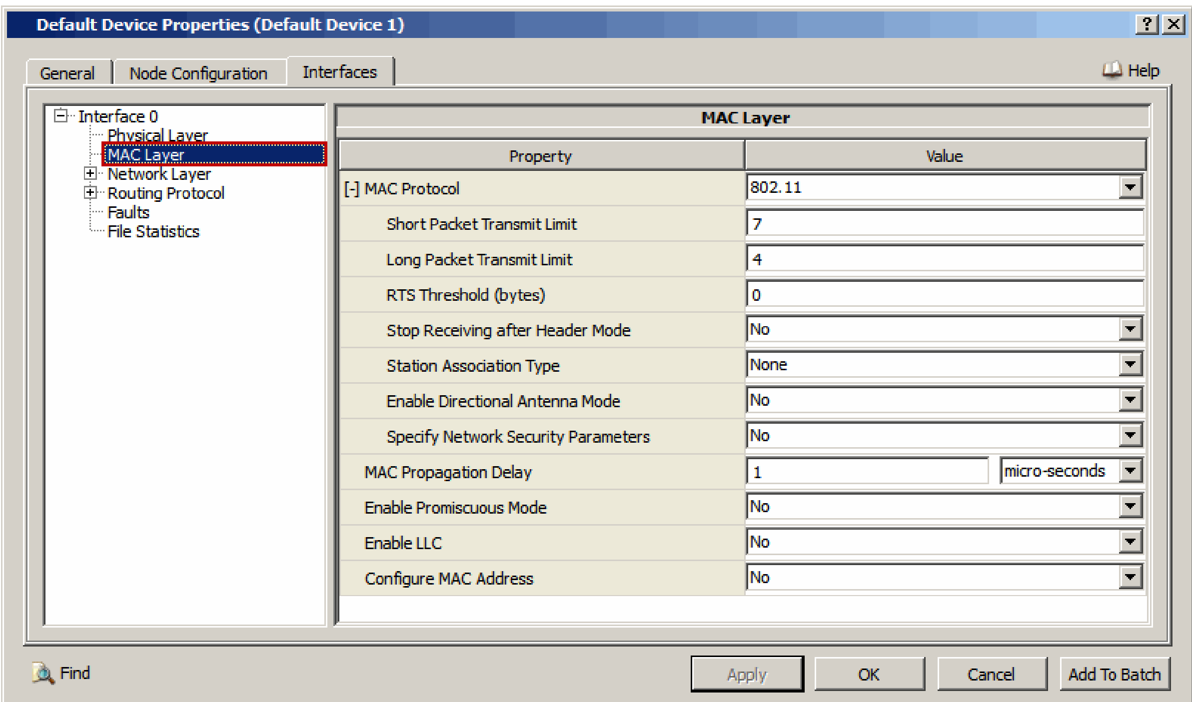


FIGURE 1-1. Path to a Parameter Group

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.

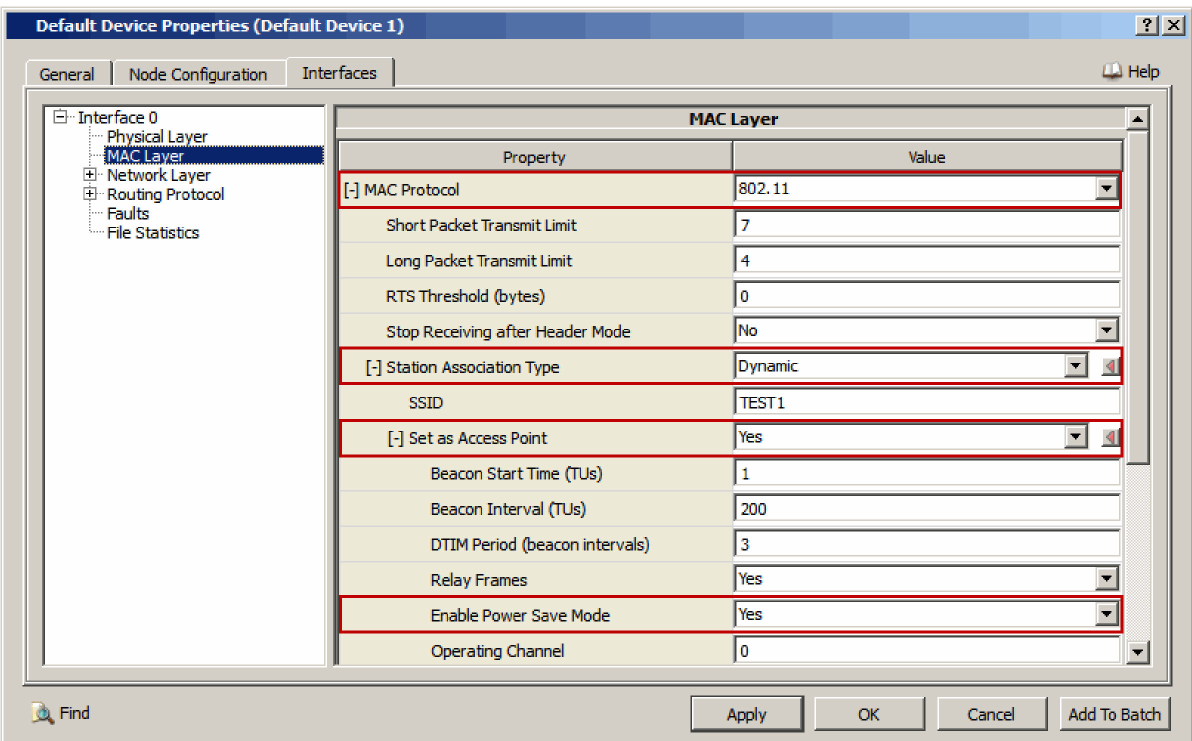


FIGURE 1-2. Path to a Specific Parameter

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

TABLE 1-7. Example Mapping Table (Continued)

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
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 PHY Layer Models, and consists of the following section:

- 802.16 PHY

2.1 802.16 PHY

2.1.1 Description

IEEE 802.16 specifies multiple physical specifications including SC, SCa, OFDM and OFDMA. EXata PHY802.16 only implemented the OFDMA PHY. OFDMA is similar to OFDM using multiple subcarriers to transmit data. However, while OFDM uses all available subcarriers in each transmission, different subcarriers could be arranged to different subscribers in downlink and each transmission could use a subset of the available subcarriers in uplink in OFDMA.

The mandatory features are implemented in current implementation. It supports variable channel bandwidth, different FFT sizes, multiple cyclic prefix time, and different modulation schemes such as QPSK, 16QAM, and 64QAM with convolutional encoding at variety encoding rates.

The raw data rates of the OFDMA are functions of several parameters such as channel bandwidths, FFT size, sampling factor, cyclic prefix time, modulation scheme, encoding scheme and encoding rate. It can be up to 70 Mbps by using high grade modulation scheme with other suitable parameters. In general, the raw data rate can be obtained by using the following equation:

```
R = N * b *  c / T
```

where

`N`	Number of used subcarriers
`b`	Number of bits per modulation symbol
`c`	Coding rate
`T`	OFDM symbol duration

In general, the number of used data subcarriers (N) is the function of the FFT size. Table 2-1 lists the values of N used in the implementation.

TABLE 2-1. Number of Used Data Subcarriers as a Function of FFT Size

FFT Size	Number of Used Data Subcarriers
2048	1440
1024	720
512	360
128	72

The number of bits per modulation symbol (b) is a function of the modulation scheme. Table 2-2 lists the values of b used in the implementation.

TABLE 2-2. Number of Bits per Modulation Symbol as a Function of Modulation Scheme

Modulation Scheme	Number of Bits per Modulation Symbol (b)
QPSK	2
16QAM	4
64QAM	6

In this implementation, the following three coding rates are supported: 1/2, 2/3, and 3/4. OFDM symbol duration can be obtained by using the following formulas:

- Sampling frequency, `Fs`, is obtained by using the following formula:

  `Fs = floor(Sampling-factor * Channel-Bandwidth / 8000) * 8000`

  where

`Sampling-Factor`	Sampling Factor. This is set to 8/7 in the implementation.
`Channel-Bandwidth`	Channel bandwidth, in Hz

- Useful symbol time, `Tb`, is calculated by using the following formula:

  `Tb = FFT-size / Fs`

  where

`FFT-size`	FFT size
`Fs`	Sampling Frequency

- Cyclic prefix time, `Tg`, is obtained by using the following formula:

  `Tg = G * Tb`

  where

`G`	Ratio of cyclic prefix time to useful symbol time. The following values are supported in the implementation: 1/32, 1/16, 1/8, and 1/4.
`Tb`	Useful symbol time

- OFDMA symbol time, T, is calculated by using the following formula:

  `T = Tb + Tg`

  where

`Tb`	Useful symbol time
`Tg`	Cycle prefix time

As an example, assume the following parameters:

`Channel bandwidth` = 20 MHz
`Sampling factor` = 8/7
`FFT size` = 2048
`G` = 1/8

Using the above formulas, `Tb` and `Tg` are 89.6 and 11.2 microseconds, respectively. This results in an OFDMA symbol time of 100.8 microseconds.

Table 2-3 lists the raw data rates for different modulation schemes and coding rates in convolutional encoding using the above parameters.

TABLE 2-3. Raw Data Rates for Different Modulation Schemes and Encoding Rates

Modulation Scheme	Encoding Rate	Raw Data Rate (Mbps)
QPSK	1/2	14.2857
QPSK	3/4	21.4285

TABLE 2-3. Raw Data Rates for Different Modulation Schemes and Encoding Rates

Modulation Scheme	Encoding Rate	Raw Data Rate (Mbps)
16QAM	1/2	28.5714
16QAM	3/4	42.8570
64QAM	1/2	42.8470
64QAM	2/3	57.1428
64QAM	3/4	64.2857

2.1.2 Features and Assumptions

This section describes the implemented features, omitted features, assumptions and limitations of the 802.16 PHY model.

2.1.2.1 Implemented Features

- OFDMA physical model.
- Variety channel bandwidth support.
- Multiple FFT size support.
- Multiple cyclic prefix time support.
- Multiple data rates support.
- BER-based reception quality estimation.
- Subchannel SINR representation.
- Data rate and transmission range estimation.

2.1.2.2 Omitted Features

None.

2.1.2.3 Assumptions and Limitations

- The 802.16 PHY model supports only the omnidirectional antenna model.

2.1.3 Command Line Configuration

To select the 802.16 PHY protocol, specify the following parameter in the scenario configuration (.config) file:

```
[<Qualifier>]  PHY-MODEL     PHY802.16
```

The scope of this parameter declaration can be Global, Node, Subnet, or Interface. See Section 1.2.1.1 for a description of `<Qualifier>` for each scope.

Configuration Requirements

To use 802.16 PHY as the radio model 802.16 MAC be selected as the MAC protocol. See Section 3.1 for details of configuring 802.16 MAC.

802.16 PHY Parameters

Table 2-4 lists the 802.16 PHY configuration parameters. See Section 1.2.1.3 for a description of the format used for the parameter table.

In addition to 802.16 PHY parameters listed in Table 2-4, several other parameters have a significant effect on the performance. For example, noise factor, antenna gain, frequency, pathloss, shadowing model, and fading model. These parameters should be set to values suitable for the scenario.

TABLE 2-4. 802.16 PHY Parameters

Parameter	Value	Explanation
PHY802.16-MAX_TX-POWER *Optional* *Scope:* All	Real *Default:* 50.0 *Unit:* dBm	Maximum transmission power.
PHY802.16-TX-POWER *Optional* *Scope:* All	Real *Range:* ≤ PHY802.16-MAX_TX-POWER *Default:* 20.0 *Unit:* dBm	Transmission power.
PHY802.16-CHANNEL-BANDWIDTH *Optional* *Scope:* All	Real *Range:* > 10.0 *Default:* 20.0 *Unit:* MHz	Channel bandwidth of the physical model.
PHY802.16-FFT-SIZE *Optional* *Scope:* All	List: • 128 • 512 • 1024 • 2048 *Default:* 2048	FFT size used in the device. The FFT size determines the number of available subcarriers and OFDM symbol duration. In general, for a given bandwidth, a larger FFT size results in a greater number of available subcarriers and a longer OFDM symbol duration.
PHY802.16-CYCLIC-PREFIX *Optional* *Scope:* All	List: • 4 • 8 • 16 • 32 *Default:* 8	Ratio of useful symbol time to cyclic prefix time. This parameter is inverse of the variable G described in Section 2.1.1.

TABLE 2-4. 802.16 PHY Parameters (Continued)

Parameter	Value	Explanation
`PHY-RX-MODEL` *Required* *Scope:* All	List: • `PHY802.16`	Packet reception model.
`PHY-LAYER-STATISTICS` *Optional* *Scope:* All	List: • `YES` • `NO` *Default:* `NO`	Indicates whether statistics are collected for the physical layer protocols, including 802.16 PHY.

2.1.4 GUI Configuration

This section describes how to configure the 802.16 PHY in the GUI.

Configuration Requirements

To use 802.16 PHY as the radio model 802.16 MAC be selected as the MAC protocol. See Section 3.1 for details of configuring 802.16 MAC.

Configuring 802.16 PHY Model Parameters

To configure the general 802.16 PHY parameters, perform the following steps:

1. Go to one of the following locations:
   - To set properties at the subnet level, go to **Wireless Subnet Properties Editor > Physical Layer**.
   - To set properties for 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 the 802.16 parameters in the Wireless Subnet Properties Editor. Parameters can be set in the Interface properties editor in a similar way.

2. Set **Radio Type** to *802.16 Radio,* as shown in Figure 2-1 and set the dependent parameters as listed in Table 2-5.

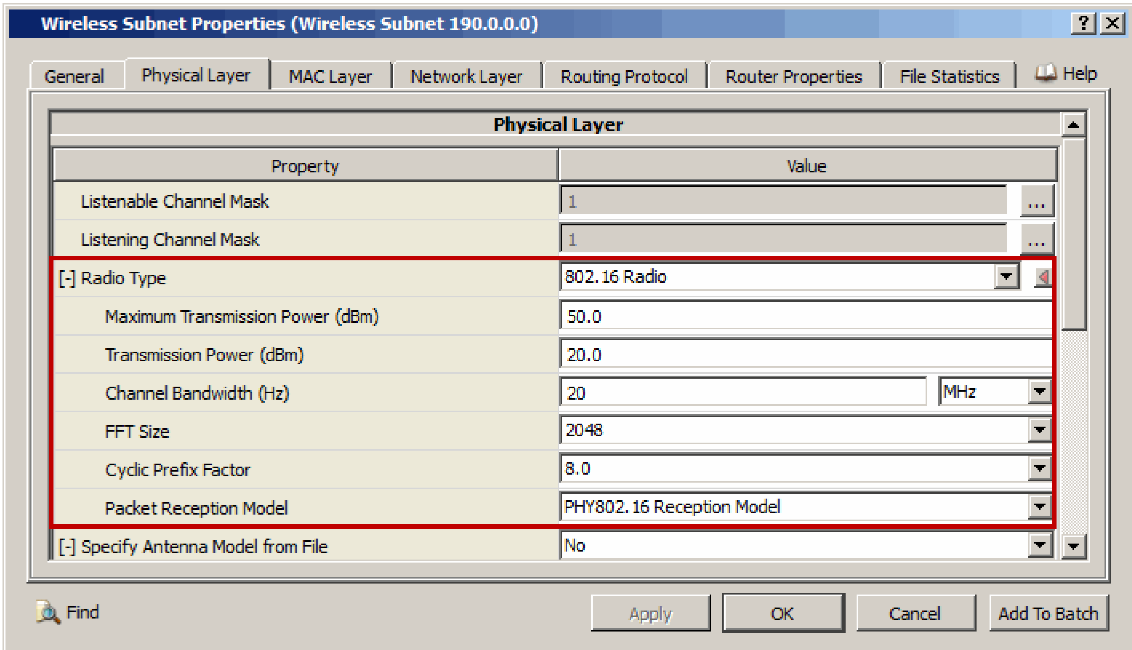


FIGURE 2-1. Configuring 802.16 PHY Parameters

TABLE 2-5. Command Line Equivalent of 802.16 PHY Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Maximum Transmission Power	Subnet, Interface	`PHY802.16-MAX-TX-POWER`
Transmission Power	Subnet, Interface	`PHY802.16-TX-POWER`
Channel Bandwidth	Subnet, Interface	`PHY802.16-CHANNEL-BANDWIDTH`
FFT Size	Subnet, Interface	`PHY802.16-FFT-SIZE`
Cyclic Prefix Factor	Subnet, Interface	`PHY802.16-CYCLIC-PREFIX`
Packet Reception Model	Subnet, Interface	`PHY-RX-MODEL`

Configuring Statistics Parameters

Statistics for the 802.16 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 802.16 PHY, check the box labeled **PHY/Radio** in the appropriate properties editor.

TABLE 2-6. 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 and dynamic statistics of the 802.16 PHY model.

2.1.5.1 File Statistics

Table 2-7 lists 802.16 PHY model statistics that are output to the statistics (.stat) file at the end of simulation.

TABLE 2-7. 802.16 PHY Statistics

Statistic	Description
Signals transmitted	Total number of signals transmitted by the node.
Signals received and forwarded to MAC	Total number of signals received and forward to MAC by the node.
Signals locked on by PHY	Total number of signals locked on by PHY for the node
Signals received but with errors	Total number of signals in errors for the node.
OFDMA bursts received and forwarded to MAC	Total number of OFDMA bursts received and forwarded to MAC for the node.
OFDMA bursts received but with errors	Total number of OFDMA bursts received in errors for the node.

2.1.5.2 Dynamic Statistics

The following dynamic statistics are enabled for the 802.16 PHY model (refer to Chapter 6 of *EXata User's Guide* for details of viewing dynamic statistics in the GUI during the simulation):

- Number of OFDMA Bursts Received

2.1.6 Sample Scenario

In this section, we use an example to show how you can configure a scenario with 802.16 MAC.

2.1.6.1 Scenario Description

Assume the scenario contains two subnets. Subnet 1 contains node 1 to node 10 and subnet 2 contains node 11 to node 20. Both subnets run 802.16 MAC with node 1 as the BS of subnet 1 and node 15 as the BS of subnet 2. The two base stations, node 1 and node 15, are connected via a wired point-to-point link, as shown in Figure 2-2.

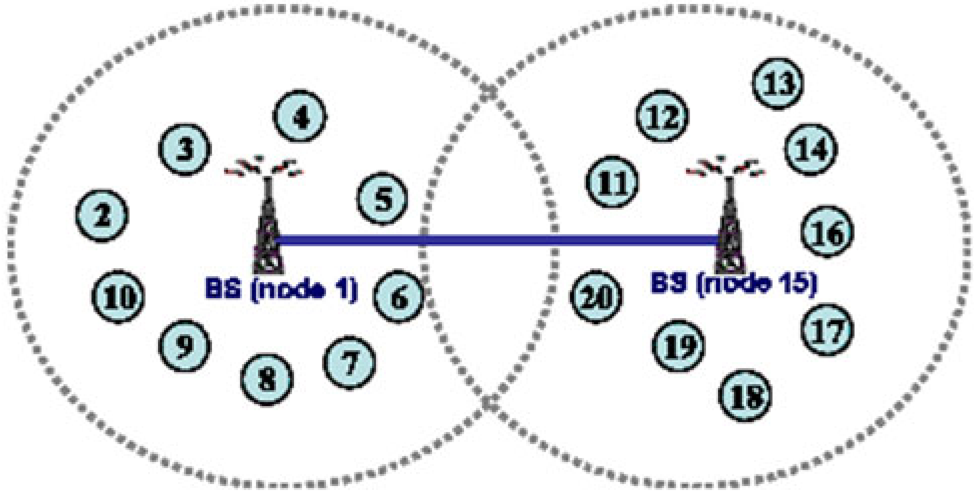


FIGURE 2-2. Topology of Sample Scenario

2.1.6.2 Command Line Configuration

1. Define the two subnets and a point-to-point link between node 1 and node 15.

```
SUBNET N8-0.0 {1 thru 10}
SUBNET N8-1.0 {11 thru 20}
LINK N2-2.0 {1, 15}
```

2. Create two wireless channels.

```
PROPAGATION-CHANNEL-FREQUENCY[0] 10.0e9
PROPAGATION-CHANNEL-FREQUENCY[1] 10.1e9
PROPAGATION-CHANNEL-NAME[0] channel-0
PROPAGATION-CHANNEL-NAME[1] channel-1
```

3. Assign channel 0 to subnet 1 and channel 1 to subnet 2.

```
[N8-0.0] PHY-LISTENABLE-CHANNELS channel-0, channel-1
[N8-0.0] PHY-LISTENING-CHANNELS  channel-0

[N8-1.0] PHY-LISTENABLE-CHANNELS channel-0, channel-1
[N8-1.0] PHY-LISTENING-CHANNELS  channel-1
```

4. Specify 802.16 MAC as the MAC protocol for both subnets.

```
[N8-0.0] MAC-PROTOCOL MAC802.16
[N8-1.0] MAC-PROTOCOL MAC802.16
```

5. Specify node 1 as BS of subnet 1 and node 15 as the BS of subnet 2.

```
[0.0.0.1] MAC-802.16-STATION-TYPE    BS    // node 1
[0.0.1.5] MAC-802.16-STATION-TYPE    BS    // node 15
```

6. Enable mobility for all nodes in the subnet.

```
[N8-0.0] MAC-802.16-MOBILITY-SUPPORT YES
[N8-0.1] MAC-802.16-MOBILITY-SUPPORT YES
```

7. Enable ARQ for all the nodes in the subnet.

```
[N8-0.0.0.0] MAC-802.16-ARQ-ENABLED YES
[N8-0.0.1.0] MAC-802.16-ARQ-ENABLED YES
```

8. Specify 802.16 PHY as the radio type for both subnets.

```
[N8-0.0] PHY-MODEL         PHY802.16
[N8-0.0] PHY-RX-MODEL      PHY802.16
[N8-1.0] PHY-MODEL         PHY802.16
[N8-1.0] PHY-RX-MODEL      PHY802.16
```

2.1.6.3 GUI Configuration

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

1. Create two wireless subnets. Subnet 1 contains nodes 1 to 10 and subnet 2 contains nodes 11 to 20. Connect nodes 1 and 15 using a point-to-point link.

2. Go to **Scenario Properties Editor > Channel Properties**, set the **Number of Channels** to *2*.

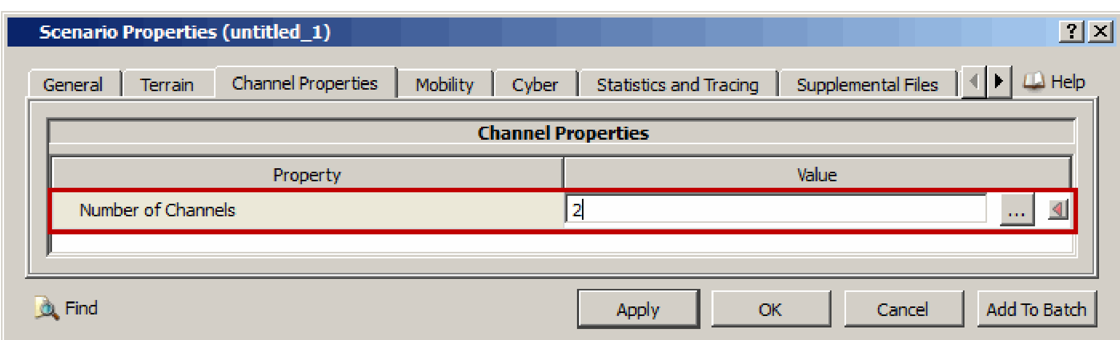
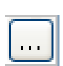


FIGURE 2-3. Setting Number of Channels

3. To configure the properties for the number of channels, do the following:

a. Click the **Open Array Editor**  button in the **Value** column. This opens the Array Editor (Figure 2-4).

b. Set the parameters for each channel index.

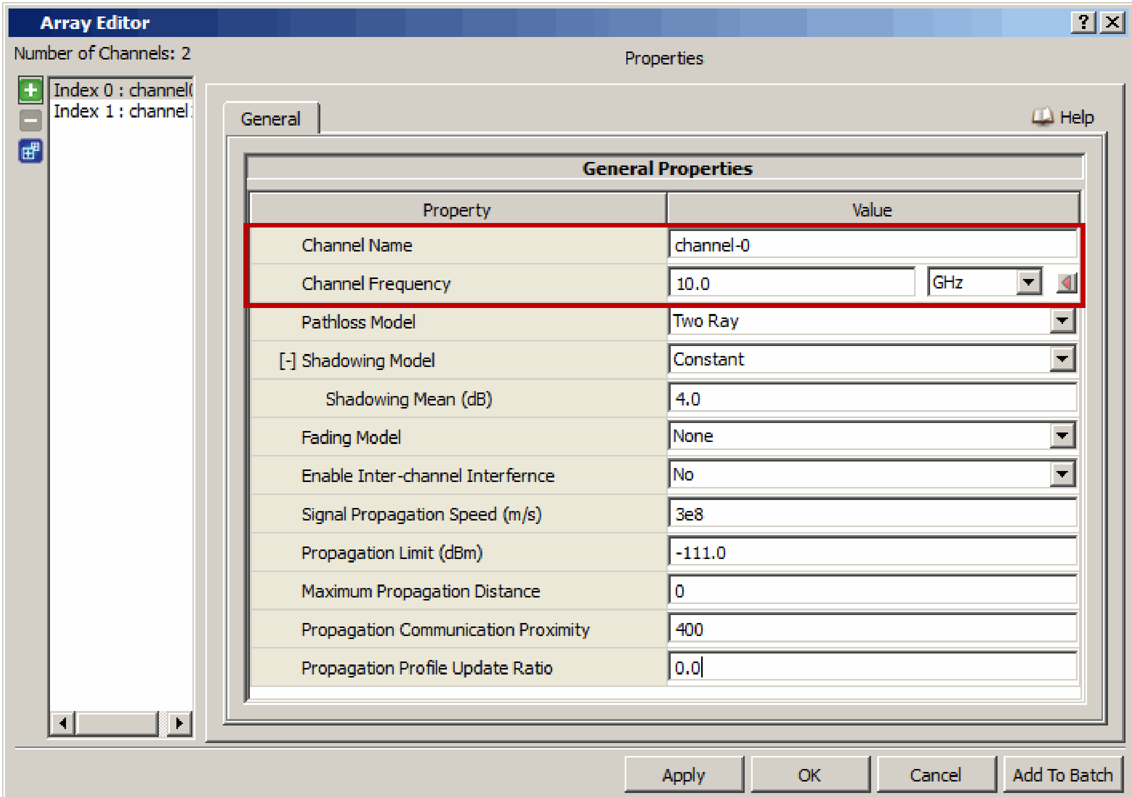


FIGURE 2-4. Setting Channel Parameters

4. Go to **Wireless Subnet Properties Editor > Physical Layer** for subnet 1. Set **Listenable Channels** to *channel-0, channel-1* and **Listening Channels** to *channel-0,* as shown in Figure 2-5.

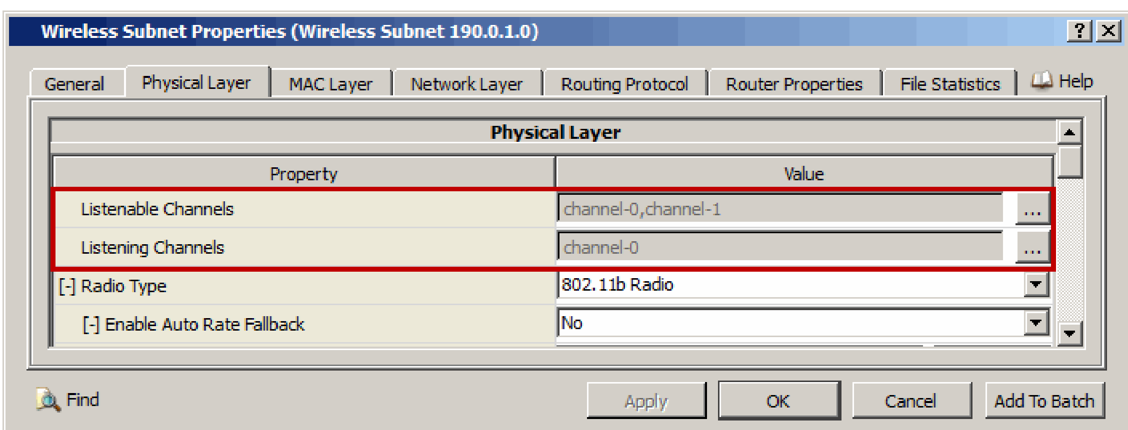


FIGURE 2-5. Setting Listenable and Listening Channels

5. Similarly, for subnet 2 set **Listenable Channels** to *channel-0, channel-1* and **Listening Channels** to *channel-1*.

6. For both subnets, go to **Group Wireless Subnet Properties Editor > Physical Layer** and set **Radio Type** to *802.16 Radio*, as shown in the Figure 2-1**.**
7. For both subnets, go to **Group Wireless Subnet Properties Editor > MAC Layer** and set **MAC Protocol** to *802.16*, as shown in Figure 2-6.

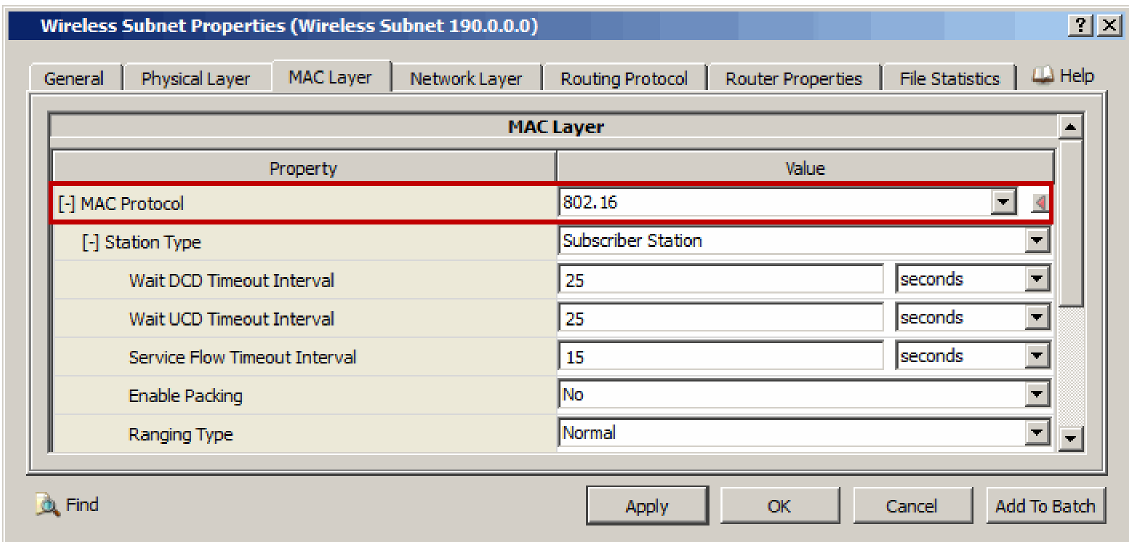


FIGURE 2-6. Setting the MAC Protocol

8. Set **Enable Mobility Mode (802.16e)** to *Yes and* set the dependent parameters as shown in Figure 3-5*.*
9. Set **Enable ARQ** to *Yes* and set the dependent parameters as shown in Figure 3-6**.**
10. For node 1 and node 15, go to **Default Device Properties Editor > Interfaces > MAC Layer**, set **MAC Protocol** *[= 802.16]* **> Station Type** to *Base Station* as shown in Figure 2-7.

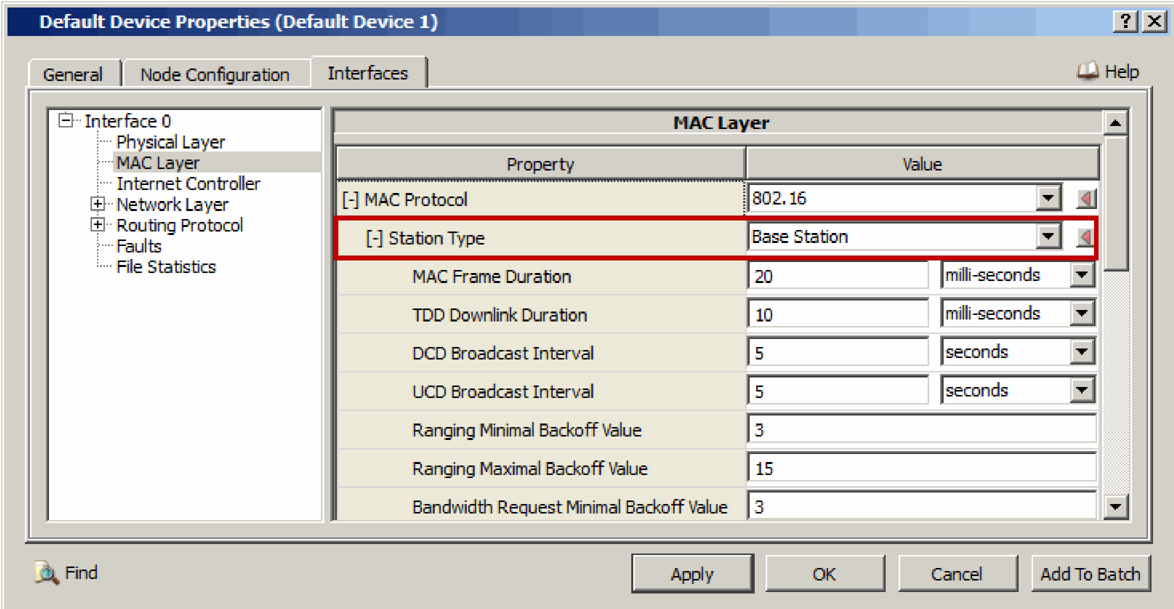


FIGURE 2-7. Setting Base Station Parameters

2.1.7 Scenarios Included in EXata

The EXata distribution includes several sample scenarios for the 802.16 PHY model. All scenarios are located in the directory EXATA_HOME/scenarios/advanced_wireless/802.16. Table 2-8 lists the sub-directory where each scenario is located.

TABLE 2-8. IEEE 802.16 PHY Scenarios Included in EXata

Scenario	Description
Admission-Control	Shows an example of Admission control scheme procedure for 802.16 network.
ARQ	Show the functionality of ARP for 802.16 network
Cdma	Shows the functionality of CDMA based ranging and bandwidth request process for 802.16 network.
dualIP	Shows the functionality of IEEE 802.16 when ruining with Dual IP.
Fragmentation	Shows an example of Fragmentation functionality for 802.16 network.
Idle-Mode	Shows an example of IDLE-MODE functionality for 802.16 network.
IPv6-routing-protocol	Shows an example of functionality of IEEE 802.16 when running IPv6 routing protocols.
mobility_two_cell	Shows the functionality of basic handover of IEEE 802.16e.
multicast	Shows the functionality of IEEE 802.16 when running with multicast and unicast applications.
multi-cell	Shows an example of the interoperability between 802.16 and wired 802.3 subnet as well as wireless 802.11 hot spots.

TABLE 2-8. IEEE 802.16 PHY Scenarios Included in EXata (Continued)

Scenario	Description
multicell-high-mobility	Shows an example of the basic handover functionality of IEEE 802.16e in multicell environment and with high mobility.
multi-rates	Shows an example of the multiple rates capability of 802.16 using different coding and modulation combinations. The rates are properly chosen based on signal strengths. In this sample, the signal strength is mainly decided by the distance between the BS and SS.
packing	Shows an example of the Packing functionality for 802.16 network.
service-types	Shows an example of the four service types, namely UGS, ertPs, rtPS, nrtPS and BE. Five flows are defined with different service types. They will get different quality of service based on their service types
single-cell	Shows an example of the basic functionality of a single cell 802.16 network with IPv4.
single-cell-ipv6	Shows an example of the basic functionality of a single cell 802.16 network with IPv6.
SleepMode	Shows an example of the sleep mode functionality for 802.16 wireless network.
two-cell-backbone	Shows an example of two separated 802.16 subnets operating on different channels. The BSs of the two subnets are connected via a wired point-to-point link.
UrbanEnv	Shows an example of a WiMAX system working in urban environment, i.e., urban terrain and urban propagation.

2.1.8 References

1. IEEE Std 802.16-2004, “Part 16: Air Interface for Fixed Broadband Wireless Access Systems,” IEEE Standard for Local and metropolitan area networks, Oct. 2004.
2. IEEE Std 802.16e-2005, "Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems: Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1," Feb 2006.

3 MAC Layer Models

This chapter describes features, configuration requirements and parameters, statistics, and scenarios for MAC Layer Models, and consists of the following section:

- 802.16 MAC and 802.16e MAC

3.1 802.16 MAC and 802.16e MAC

3.1.1 Description

The IEEE 802.16 standard, including MAC layer and PHY layer specifications, defines the air interface and associated functions of the broadband wireless access system supporting multimedia services. It is designed for high-range and high-bandwidth wireless access, or Wireless Metropolitan Area Network (Wireless MAN). The bandwidth is up to 70 Mbps and radio range can go up to 50 kilometers (31 miles). Its major advantages include:

- High bandwidth and large coverage range
- Multiple service with different QoS guarantees
- Built-in security
- Cost-effective and fast-to-deploy first mile access to public networking
- A cost effective alternative that replaces WiFi and 3G/4G

The IEEE 802.16 is also known as WiMAX, which is a certification mark for products that pass conformity and interoperability tests for IEEE 802.16 standards.

The basic components of an 802.16 network are Base Stations (BS) and Subscriber Stations (SS) (or Mobile Stations (MS) in 802.16e). The BSs connect to the public networks and serve their registered subscriber stations. The SSs typically serve a building (commercial or residential, or WiFi hot spots). Both BSs and SSs are assumed to be static in an 802.16 network (mobility support is added in 802.16e standard). The basic operation mode of an 802.16 network is called Point to Multi-Point (PMP) where each SS is only one-hop away from the BS and can only communicate with its BS, not other neighboring SSs.

An optional operational mode called Mesh mode, has no clear distinction between SSs and BSs. Stations can talk directly to each other and be more than one-hop away from the BS, and the BS is defined as the station that provides access to the public network, such as the Internet.

Figure 3-1 shows an illustration of an 802.16 network running under the basic PMP mode.

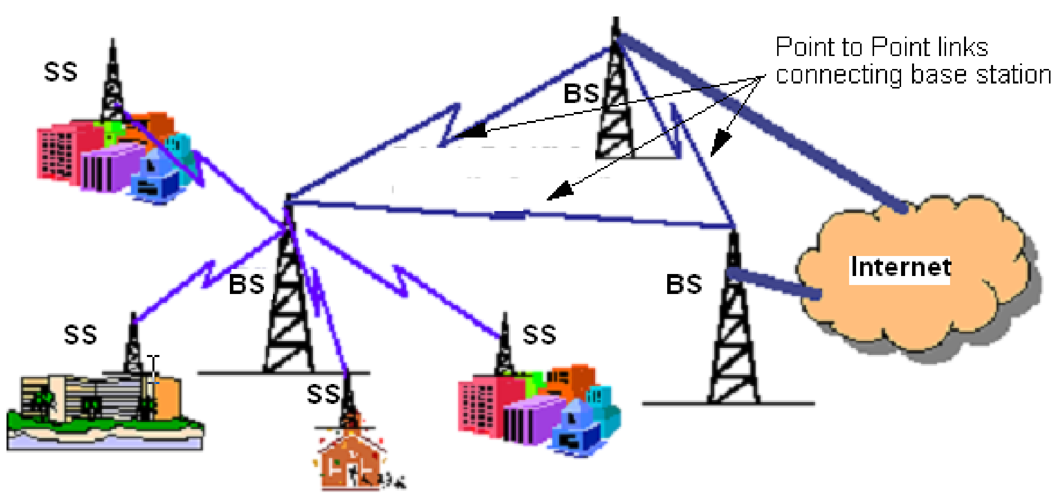


FIGURE 3-1. IEEE 802.16 MAC with PMP Mode

IEEE 802.16e adds mobility support to IEEE 802.16. It can support mixed fixed and mobile broadcast wireless access networks. In the 802.16e specification, Subscriber Stations (SS) are also referred to as Mobile Stations (MS). Under 802.16e, the MS can handover from one BS to another BS.

1. Neighbor BS information advertisement: The serving BS periodically broadcasts information about neighboring BSs. This information is then used by the MS to guide the neighbor BS scanning. In addition, the BS also indicates to MSs the thresholds that will trigger neighbor BS scan or handover actions.
2. Neighbor BS scanning: When the signal quality/QoS of the serving BS is below a certain threshold, the MS starts the neighbor BS scanning procedure, seeking available BSs and determining their suitability as targets for handover. During neighbor BS scanning, the MS may also associate with neighboring BSs to reduce delay in handover.
3. Handover: An MS may perform handover under two conditions, a) when the signal quality of the serving BS is too low, and b) when the QoS capability of the serving BS cannot fulfill the requirements. Both MS and BS can initiate the handover.
4. Sleep mode: When MS is inactive, it can go to sleep mode in order to save power.
5. Paging: Paging is used to reach an MS in idle or sleep mode.
6. Idle mode: An MS can go into idle mode where it periodically listens to the Down Link (DL) broadcast traffic without ranging and registration. This can save overhead on handover when the MS traverses an air-link environment populated by multiple BSs.
7. Authentication and Service Authorization (ASA) server: Provides access control to MSs.
8. Backbone functionalities: The BSs can use the backbone to communicate with each other to exchange some information for services such as network/BS assisted handovers.

Figure 3-2 shows the IEEE 802.16e Access Network supporting mobility.

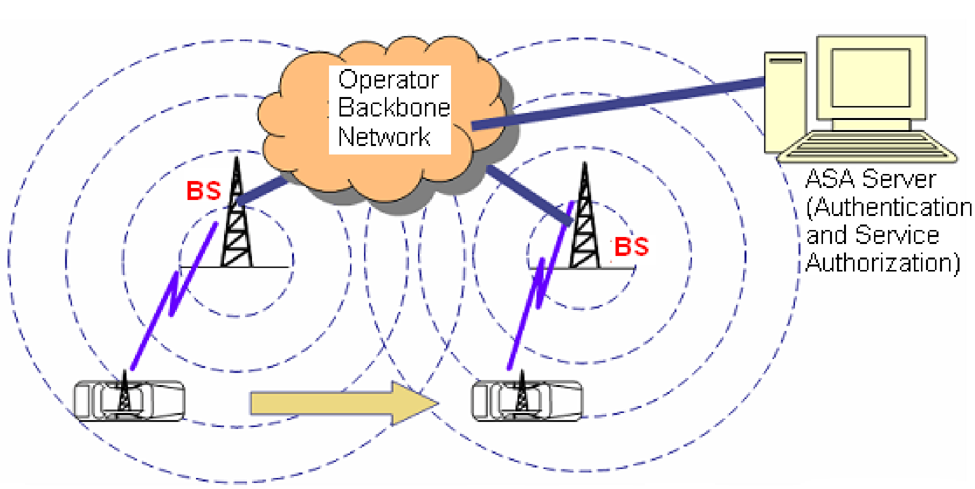


FIGURE 3-2. IEEE 802.16e Access Network with Mobility Support

The IEEE 802.16 MAC is basically a TDMA type of medium access control protocol. The medium is first divided into MAC frames, then each MAC frame is divided into a downlink subframe and an uplink subframe. In the downlink subframe, the BS transmits different bursts to different SSs in TDD way. For the uplink, different SSs transmit in different uplink bursts that are primarily TDMA. The scheduling of downlink and uplink bursts is controlled by the BS. AN SS needs to request bandwidth based on its need. Thus, the uplink access is usually referred to as TDMA + DAMA.

IEEE 802.16 MAC supports three duplex modes. They are Time Division Duplex (TDD), Frequency Division Duplex (FDD) Half-Duplex, and FDD Full-Duplex. The IEEE 802.16 also defines four PHY types including SC, SCa, OFDM, and OFDMA.

A distinctive feature of 802.16 is its QoS support. It has five service classes to support real-time and non-real-time communications, as described below. Unsolicited Grant Service (UGS): UGS supports real-time service flows that generate a fixed-size data packet on a periodic basis, e.g., VoIP without silence suppression.

- Extended Real-time Polling Service (ertPS): ertPS supports features of UGS with variable-size data packets, such as VoIP with silence suppression.
- Real-Time Polling Service (rtPS): rtPS supports real-time service flows that generate variable-size data packets on a periodic basis, such as MPEG video or VoIP with silence suppression.
- Non-real-time Polling Service (nrtPS): nrtPS supports delay-tolerant data streams consisting of variable-sized data packets for which a minimum data rate is required, such as FTP or HTTP (web browsing).
- Best Effort (BE): BE service supports data streams for which no minimum service level is required and therefore may be handled on a space-available basis.

3.1.2 Features and Assumptions

This section describes the implemented features, omitted features, assumptions and limitations of the 802.16 MAC model.

3.1.2.1 Implemented Features

The MAC802.16 model has implemented features defined in both IEEE 802.16 and IEEE 802.16e. The detailed list of implemented features is:

- Point to Multi-Point (PMP) mode.
- Time Division Duplex (TDD) mode:
  - MAC frame is divided into downlink subframe and uplink subframe.
  - DL-MAP and UL-MAP supporting subchannels of OFDMA PHY.
- Network entry and initialization:
  - Channel scan and synchronization with DL channel. Channel lost detection and network re-entry.
  - Downlink Channel Descriptor (DCD) and Uplink Channel Descriptor (UCD) messages for obtaining and maintaining Downlink (DL)/Uplink (UL) parameters.
  - Initial (contention) ranging and periodic ranging.
  - Negotiation of basic capability and registration.
  - CDMA-based ranging.
- Dynamic flow management including service flow addition, deletion, and change.
- Bandwidth management:
  - Five service types: UGS, ertPS, rtPS, nrtPS and BE.

    - Polling-based bandwidth requests.
    - Contention-based bandwidth requests.
    - CDMA-based bandwidth requests.
- Scheduling service at the base station:
    - Strict priority-based scheduling for different service types where management messages > UGS > ertPS > rtPS > nrtPS > BE.
    - Within each service type, Weighted Fair Queuing (WFQ) scheduling is used for fairness.
- MAC frame construction:
    - Downlink (DL) subframe construction.
    - Uplink (UL) burst construction.
    - PDU concatenation, fragmentation, packing, and CRC.
- Adaptive Modulation and Coding (AMC):
    - Signal strength monitoring (UL/DL) and reporting (DL).
    - Seven burst profiles for both downlink and uplink transmissions using different coding and modulation combinations.
    - Dynamic switch of burst profiles based on CINR.
    - Support for broadcast and multicast flows.
- Convergence Sublayer (CS):
    - Classify flows to different service types based on their priority.
    - Retrieve accurate QoS parameters of UGS flows.
    - Support both IPv4 and IPv6.
- IEEE 802.16e Mobility Support:
    - Neighbor information exchange among configured BSs.
    - Neighbor BS scanning at SS.
    - MS initiated and BS initiated hard handoff.
    - Flow disconnection and reconnection.
    - Idle mode and paging.
    - Sleep mode.
- Interface other networks, such as ATM, 802.3, and 802.11, at network layer.
- Support 802.16 OFDMA PHY.
- Simple admission control.
- ARQ.

3.1.2.2 Omitted Features

- Mesh mode.
- Frequency Division Duplex (FDD) mode.
- Transmission power adjustment during ranging.
- PKM (Privacy Key Management) security feature.
- Convergence sublayer doesn't support ATM. No packet header compression.
- SC, SCa, and OFDM 802.16 PHYs.
- Only CBR and VBR traffic generators have been modified to provide correct QoS parameters. For other types of traffic generators, some default QoS parameters are used.
- Association level 1, 2, and soft handoff.

3.1.2.3 Assumptions and Limitations

None.

3.1.3 Supplemental Information

To use the 802.16 MAC QoS support capability, the IP protocol's precedence field should be set appropriately. Table 3-1 specifies the mapping implemented between precedence values and service classes which ensures that traffic is directed to a specific service class.

TABLE 3-1. MAC Layer Service Flow Mapping

MAC Layer Services	Precedence
Unsolicited Grant Service	7, 5
Extended Real-time Polling Service	4
Real-time Polling Service	3
Non-real-time Polling Service	6,2,1
Best Effort	0

Note: Precedence 6, 2, 1 are all mapped to nrtPS service type. This allows different priorities for nrtPS flows. However, in the current implementation, the scheduling doesn't support multiple priorities inside one service type. WFQ is used for scheduling and its weight is based on the bandwidth need of the flow.

CBR Application Example

```
CBR  2  5  0  512  1S  20S  0S  PRECEDENCE 0   # assign traffic as BE flow
CBR  2  5  0  512  1S  20S  0S  PRECEDENCE 1 # assign traffic as nrtPS flow
CBR  2  5  0  512  1S  20S  0S  PRECEDENCE 3  # assign traffic as rtPS flow
CBR  2  5  0  512  1S  20S  0S  PRECEDENCE 4 # assign traffic as ertPS flow
CBR  2  5  0  512  1S  20S  0S  PRECEDENCE 7   # assign traffic as UGS flow
```

Note: In EXata, routing traffic uses precedence 6, which is classified as nrtPS flow. Also, the Network layer may affect the QoS if it has fewer queues than eight, as it queues packets of different service types into one queue. The value of the parameter `IP-QUEUE-NUM-PRIORITIES` should be larger or equal to eight, otherwise, the application sets a high precedence for its packets and they may be blocked by lower precedence packets in network queues. Therefore, to fully guarantee the service types, configure eight queues at the network layer, as follows:

```
IP-QUEUE-NUM-PRIORITIES 8
```

3.1.4 Command Line Configuration

To select the 802.16 MAC protocol, specify the following parameter in the scenario configuration (.config) file:

```
[<Qualifier>] MAC-PROTOCOL    MAC802.16
```

The 802.16e MAC protocol provides mobility support. To enable 802.16e MAC, specify the following parameter in the scenario configuration (.config) file:

```
[<Qualifier>] MAC-802.16-SUPPORT-MOBILITY   YES
```

The scope of these parameters declaration can be Global, Node, Subnet, or Interface. See Section 1.2.1.1 for a description of `<Qualifier>` for each scope.

Note: The default value of the parameter `MAC-802.16-SUPPORT-MOBILITY` is `NO`.

Configuration Requirements

To use 802.16 MAC as the MAC protocol, 802.16 PHY must be selected as the radio model. See Section 2.1 for details of configuring 802.16 PHY.

802.16 MAC and 802.16e MAC Parameters

The 802.16 MAC parameters are described in Table 3-2. Table 3-3 lists the 802.16e MAC configuration parameters. See Section 1.2.1.3 for a description of the format used for the parameter tables.

Parameters with the prefix `MAC-802.16-BS-` and `MAC-802.16e-BS-` are applicable to only by base stations. Subscriber station specific parameters have the prefix `MAC-802.16-SS-` or `MAC-802.16e-SS-`. In general, parameters without these prefixes are applicable to both base and subscriber stations. Most parameters are configured for base stations. Subscriber stations learn the related parameters from their currently associated base stations.

TABLE 3-2. 802.16 MAC Parameters

Parameter	Value	Description
`MAC-802.16-STATION-TYPE` *Optional* *Scope:* All	List: • `BS` • `SS` *Default:* `SS`	Type of the 802.16 station. BS: Base Station SS: Subscriber Station (or Mobile Station in 802.16e)
`MAC-802.16-BS-FRAME-DURATION` *Optional* *Scope:* All	Time *Range:* `> 0` *Default:* `20MS`	Duration of the MAC frame. The BS schedules transmission on a MAC frame basis. A MAC frame is divided into downlink (DL link) and uplink (UL link) under TDD. This parameter specifies the length of a MAC frame.
`MAC-802.16-BS-TDD-DL-DURATION` *Optional* *Scope:* All	Time *Range:* `> 0` *Default:* `10MS`	Length of the DL link part of a MAC frame. It indicates how the MAC frame is divided between downlink transmissions and uplink transmissions.
`MAC-802.16-BS-TTG` *Optional* *Scope:* All	Time *Range:* `> 0S` *Default:* `100NS`	Transmit/receive Transition Gap (TTG). This is the gap between the DL part and UL part of a MAC frame provided in order to give the BS enough time to transit from transmission mode to receiving mode.

TABLE 3-2. 802.16 MAC Parameters (Continued)

Parameter	Value	Description
`MAC-802.16-BS-RTG` *Optional* *Scope:* All	Time *Range:* `> 100NS` *Default:* `10US`	Receive/transmit Transition Gap RTG). This gap is necessary for a BS to switch from receiving mode to transmitting mode. This gap is inserted between two MAC frames.
`MAC-802.16-BS-SSTG` *Optional* *Scope:* All	Time *Range:* `> 100NS` *Default:* `4US`	Transition gap for a subscriber station to switch from transmitting mode to receiving mode or vice versa. Note that this is a parameter for BS. The BS schedules uplink bursts for different SSs. This gap should be inserted between different uplink bursts to guarantee correct transition from one SS to the next and avoid interferences.
`MAC-802.16-BS-DCD-BROADCAST-INTERVAL` *Optional* *Scope:* All	Time *Range:* `[MAC-802.16-BS-FRAME-DURATION, 10S]` *Default:* `5S`	DCD packet interval. The DCD management packet contains the DL parameters. An SS must receive at least one DCD packet to acquire the DL parameters before it can synchronize with the downlink channel. The DCD packet interval determines how fast an SS can synchronize with the DL channel. The shorter this interval, the faster the SS synchronizes with the DL channel. On the other hand, DCD messages are overhead. Too short DCD intervals may consume a lot of downlink bandwidth.
`MAC-802.16-BS-UCD-BROADCAST-INTERVAL` *Optional* *Scope:* All	Time *Range:* `[MAC-802.16-BS-FRAME-DURATION, 10S]` *Default:* `5S`	UCD packet interval. The UCD management message contains a description of the uplink channel. An SS must receive at least one UCD message to acquire uplink channel parameters before it can synchronize with the UL channel. The UCD packet interval affects how fast an SS can synchronize with the UL channel. The shorter this interval, the faster the SS synchronizes with the UL channel. On the other hand, UCD messages are overhead. Too short UCD intervals may consume a lot of downlink bandwidth.

TABLE 3-2. 802.16 MAC Parameters (Continued)

Parameter	Value	Description
`MAC-802.16-BS-RANGING-BACKOFF-MIN` *Optional* *Scope:* All	Integer *Range:* ≥ `0` *Default:* 3	Minimum backoff counter used for contention-based ranging (initial ranging). The maximum backoff counter is specified by the parameter `MAC-802.16-BS-RANGING-BACKOFF-MAX`. When an SS performs the initial ranging, it performs a random backoff before selecting a contention ranging slot to transmit the ranging requests. The SS randomly selects a backoff value within its current backoff window. The size of the backoff window is from 0 to $2^{backoff\text{-}count}$, where *backoff-count* is bounded by the minimum and maximum value specified by the parameters `MAC-802.16-BS-RANGING-BACKOFF-MIN` and `MAC-802.16-BS-RANGING-BACKOFF-MAX`. When a collision happens (SS does not get range reply for its ranging request after a timeout interval), the SS doubles its backoff count until it reaches the maximum value. This is also known as binary backoff. Thus, the backoff value affects the speed of network entry. When there are many SSs in one cell, a short backoff value may result in a large number of collisions. However, long backoff values may waste bandwidth. The backoff is in terms of contention ranging slot. For example, if a SS has a backoff value as n, it will use the $(n+1)^{th}$ contention ranging slot to transmit the ranging request. In this implementation, a BS will allocate 3 contention ranging slots in each DL-MAP. A SS will retry 16 times for the ranging requests before it gives up the current DL channel.
`MAC-802.16-BS-RANGING-BACKOFF-MAX` *Optional* *Scope:* All	Integer *Range:* ≥ `MAC-802.16-BS-RANGING-BACKOFF-MIN` *Default:* 15	Maximum backoff counter used for contention-based ranging (initial ranging). See the description of `MAC-802.16-BS-RANGING-BACKOFF-MIN`.

TABLE 3-2. 802.16 MAC Parameters (Continued)

Parameter	Value	Description
`MAC-802.16-BS-BANDWIDTH-REQUEST-BACKOFF-MIN` *Optional* *Scope:* All	Integer *Range:* ≥ `0` *Default:* 3	Specifies the minimum backoff counter used for contention-based bandwidth requests. The maximum backoff counter is specified by the parameter `MAC-802.16-BS-BANDWIDTH-REQUEST-BACKOFF-MAX`. The backoff scheme works in the same as the binary backoff for ranging requests. Bandwidth requests are per service flow based. For UGS flows, there is no need for explicit bandwidth requests. The BS will allocate enough bandwidth periodically based on the QoS parameters of the UGS service flow. Similar to UGS, the BS will allocate enough bandwidth periodically to ertPS flow. However, SS is able to send a bandwidth request to adjust the bandwidth requirement when data grant is too much or not enough for its flow requirement. For rtPS service flow, the BS will also allocate unicast polling specific to the SS for performing bandwidth request. The interval of unicast polling is the smaller of the maximal latency of the rtPS flow and 1 second. For nrtPS, the BS will allocate periodic unicast polling, too. However, the interval is fixed as 2 seconds. For best effort (BE) flows, no unicast polling will be allocated. Only contention based bandwidth requests are used for BE flows.
`MAC-802.16-BS-BANDWIDTH-REQUEST-BACKOFF-MAX` *Optional* *Scope:* All	Integer *Range:* ≥ `MAC-802.16-BS-BANDWIDTH-REQUEST-BACKOFF-MIN` *Default:* 15	Specifies the maximum backoff counter used for contention-based bandwidth requests. See the description of `MAC-802.16-BS-BANDWIDTH-REQUEST-BACKOFF-MIN`.
`MAC-802.16-BS-MAX-ALLOWED-UPLINK-LOAD-LEVEL` *Optional* *Scope:* All	Real *Range:* `[0.0, 1.0]` *Default:* `0.7`	Upper limit of the load that BS can handle in the uplink direction. BS reserves some bandwidth for control messages and handoffs of existing applications. If you specify the value 0.9, the remaining 10% of the total capacity will be allocated for management message and handoffs exclusively.
`MAC-802.16-BS-MAX-ALLOWED-DOWNLINK-LOAD-LEVEL` *Optional* *Scope:* All	Real *Range:* `[0.0, 1.0]` *Default:* `0.7`	Upper limit of the load that BS can handle in the downlink direction. BS reserves some bandwidth for control messages and handoffs of existing applications. If you specify the value 0.9, the remaining 10% of the total capacity will be allocated for management message and handoffs exclusively.

TABLE 3-2. 802.16 MAC Parameters (Continued)

Parameter	Value	Description
MAC-802.16-SS-WAIT-DCD-TIMEOUT-INTERVAL *Optional* *Scope:* All	Time *Range:* [0S, 50S] *Default:* 25S	Specifies how long SS will wait for the DCD message before it decides that it has lost the synchronization of the downlink channel. After timeout, the SS will give up the current DL channel and move to scan the next available channel. If the DCD interval is configured, this parameter may also need to be configured. In the worst case, if this parameter is shorter than the DCD interval, the SS may frequently lose DL synchronization and restart. **Note:** The default value is 25 seconds, which is 5 times of the default value of DCD interval (MAC-802.16-BS-DCD-BROADCAST-INTERVAL).
MAC-802.16-SS-WAIT-UCD-TIMEOUT-INTERVAL *Optional* *Scope:* All	Time *Range:* [0S, 50S] *Default:* 25S	Specifies how long a SS will wait for the UCD message before it decides that it has lost the synchronization of the uplink channel. After timeout, the SS will give up the current UL channel, and move to scan the next available channel. If the UCD interval is configured, this parameter may also need to be configured. In the worst case, if this parameter is shorter than the UCD interval, the SS may frequently lose UL synchronization and restart. **Note:** The default value is 25 seconds, which is 5 times of the default value of UCD interval (MAC-802.16-BS-UCD-BROADCAST-INTERVAL).
MAC-802.16-STATION-CLASS *Optional* *Scope:* All	List: • GOLD • SILVER • BRONZE *Default:* BRONZE	Provisioning class of the SS. The data to and from the station will be throttled according to the assigned class. The three values are assigned as: GOLD 3000000 (bps) SILVER 1500000 (bps) BRONZE 512000 (bps)

TABLE 3-2. 802.16 MAC Parameters (Continued)

Parameter	Value	Description
Note: The following parameters apply to both BS and SS nodes.		
MAC-802.16-SERVICE-FLOW-TIMEOUT-INTERVAL *Optional* *Scope:* All	Time *Range:* > 0S *Default:* 15S	Specifies how long the BS or SS will wait before it times out a service flow. When an application flow ends, the MAC protocol doesn't get notified due to the lack of the QoS framework. Thus, the BS or SS relies on this timeout to detect finished flows. When the queue of a service flow has been idle for longer than this timeout value, the node times out the service flow and performs flow deletion. This parameter is important for releasing resources. If it is shorter than the packet interval of an application flow, the node may frequently time out the flow and perform flow addition again when the next packet of the flow arrives, which may result in poor bandwidth performance. On the other hand, if this time out value is too long, then the node will not be able to detect the end of service flows in time. Thus, the BS may waste bandwidth to allocate unicast polling to the service flow.
MAC-802.16-CONTENTION-BASED-BWREQ-TYPE *Optional* *Scope:* All	List: • NORMAL • CDMA *Default:* NORMAL	Indicates the type of contention-based bandwidth request. NORMAL Subscriber Station sends the bandwidth request header CDMA Subscriber Station uses the CDMA based mechanism.
MAC-802.16-RANGING-TYPE *Optional* *Scope:* All	List: • NORMAL • CDMA *Default:* NORMAL	Indicates the initial and periodic ranging type. Ranging is the process of acquiring correct timing offset and power adjustments such that the SS transmissions are aligned with the BS receive frame and received within the appropriate reception thresholds.
MAC-802.16-PACKING-ENABLED *Optional* *Scope:* All	List: • YES • NO *Default:* NO	Indicates whether packing/unpacking is enabled.
MAC-802.16-ARQ-ENABLED *Optional* *Scope:* All	List: • YES • NO *Default:* NO	Indicates whether the ARQ mechanism is enabled. The ARQ mechanism may be enabled on a per-connection basis. The per-connection ARQ is specified and negotiated during connection creation. A connection cannot have a mixture of ARQ and non-ARQ traffic.
MAC-802.16-ARQ-WINDOW-SIZE *Optional* *Scope:* All	Integer *Range:* see note *Default:* 256	Maximum number of unacknowledged ARQ blocks at any given time. An ARQ block is unacknowledged if it has been transmitted but no acknowledgement has been received. **Note:** The range of this parameter is 1 to 2^{11}.

TABLE 3-2. 802.16 MAC Parameters (Continued)

Parameter	Value	Description
`MAC-802.16-ARQ-RETRY-TIMEOUT` *Optional* *Scope:* All	Integer *Range:* `> 0` *Default:* 2 *Unit:* frames	Transmitter and receiver delay. The transmitter delay includes sending (MAC PDUs) and receiving (ARQ feedback) delays and other implementation dependent delays. If the transmitter is BS, then it also includes other delays such as scheduling and propagation delay. The receiver delay includes receiving (MAC PDUs) and sending (ARQ feedback) delays and other implementation dependent delays. If the receiver is BS, the receiver delay also includes other delays like scheduling and propagation delay. **Note:** If this parameter is 0, `MAC-802.16-ARQ-RETRY-TIMEOUT` value is considered infinite. The value of (`MAC-802.16-ARQ-RETRY-TIMEOUT` * `MAC-802.16-BS-FRAME-DURATION`) must lie between 0 and (655350 * 2) microseconds.
`MAC-802.16-ARQ-RETRY-COUNT` *Optional* *Scope:* All	Integer *Range:* `[0, 655350]` *Default:* `2`	Maximum number of times an ARQ block is resent by the sender before it is discarded. Using this variable the value of ARQ block life time can be calculated as (`MAC-802.16-ARQ-RETRY-COUNT` * `MAC-802.16-ARQ-RETRY-TIMEOUT`). **Note:** If this parameter is set to `0`, ARQ block life time is considered infinite.
`MAC-802.16-ARQ-SYNC-LOSS-INTERNAL` *Optional* *Scope:* All	Integer *Range:* `[0, 655350]` *Default:* `32` *Unit:* frames	Maximum time interval that the lower edge of the ARQ transmit or receive window shall be allowed to remain at the same value before declaring a loss of synchronization of the sender and receiver state machines when data transfer is known to be active. **Note:** If this parameter is set to `0`, then ARQ sync loss value is considered infinite.
`MAC-802.16-ARQ-RX-PURGE-TIMEOUT` *Optional* *Scope:* All	Integer *Range:* `[0, 655350]` *Default:* `28` *Unit:* frames	Time interval that the receiver must wait after successful reception of a block that does not result in advancement of the lower edge of the ARQ receive window. **Note:** If this parameter is set to `0`, then it waits for an infinite time.

TABLE 3-2. 802.16 MAC Parameters (Continued)

Parameter	Value	Description
MAC-802.16-ARQ-BLOCK-SIZE *Optional* *Scope:* All	Integer *Range:* [1, 2040] *Default:* 64 *Unit:* bytes	Specifies the length used for portioning an SDU into a sequence of ARQ blocks prior to transmission.
MAC-LAYER-STATISTICS *Optional* *Scope:* All	List • Yes • NO *Default:* NO	Indicates whether statistics are collected for MAC layer protocols, including 802.16 MAC.

Table 3-3 lists the 802.16e MAC configuration parameters.

TABLE 3-3. 802.16e MAC Parameters

Parameter	Value	Description
MAC-802.16e-BS-PAGING-GROUP-ID *Optional* *Scope:* All	Integer *Range:* ≥ 0 *Default:* 1	ID of the paging group to which the BS belongs. By default, all BSs are part of paging group 1. This parameter can be used to place BSs in different paging groups.
MAC-802.16e-BS-IS-PAGING-CONTROLLER *Optional* *Scope:* All	List: • YES • NO *Default:* NO	Specifies whether the BS is configured as a paging controller.
MAC-802.16e-BS-PAGING-CONTROLLER *Optional* *Scope:* All	IP Address	IP address of the paging controller which is responsible for carrying out paging related tasks for this BS.
MAC-802.16e-BS-PAGING-INTERVAL-LENGTH *Optional* *Scope:* All	Integer *Range:* [1, 5] *Default:* 5 *Unit:* frames	Length of the BS Paging interval. During this time, the BS can send Paging Advertisement messages.
MAC-802.16e-BS-PAGING-CYCLE *Optional* *Scope:* All	Integer *Range:* ≥ 1 *Default:* 200 *Unit:* frames	Length of the BS Paging cycle. This is the cycle in which the paging message is transmitted within the paging group.

TABLE 3-3. 802.16e MAC Parameters (Continued)

Parameter	Value	Description
`MAC-802.16e-BS-PAGING-OFFSET` *Optional* *Scope:* All	Integer *Range:* `[1, MAC-802.16e-BS-PAGING-CYCLE)` *Default:* `5` *Unit:* frames	Specifies the frame within the cycle in which the paging message is transmitted.
`MAC-802.16e-PAGING-HASHSKIP-THRESHOLD` *Optional* *Scope:* All	Integer *Range:* `[0, 255]` *Default:* `0`	Number of successive MOB_PAG-ADV messages that may be sent from a BS without individual notification for an MS.
`MAC-802.16-BS-NEIGHBOR` *Optional* *Scope:* All	String (see note)	Specifies the neighboring BSs of this BS. **Note:** The neighbor BS list could be in the form of {`nodeId1,nodeId2…`} or {`nodeId1 thru nodeId2`} or a combination.

TABLE 3-3. 802.16e MAC Parameters (Continued)

Parameter	Value	Description
MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER *Optional* *Scope:* All	Real *Default:* -76 *Unit:* dBm	This parameter, along with parameters MAC-802.16e-HANDOVER-RSS-TRIGGER and MAC-802.16e-HANDOVER-RSS-MARGIN, is used to perform neighbor BS scanning or handover. Currently, only the Receive Signal Strength metric is used. BS also uses these parameters to decide whether to start a BS-initiated handover process. MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER specifies the threshold to trigger the neighbor BS scanning. This parameter is read by the BS. The BS sends the threshold values that trigger BS scan to the MS. When the MS detects that the RSS of the current serving BS is lower than this threshold, it tries to perform neighbor BS scanning. MAC-802.16e-HANDOVER-RSS-TRIGGER specifies the threshold to trigger the handover. When the MS detects that the RSS of the serving BS is lower than this threshold, it will try to select a neighbor BS and perform handover. MAC-802.16e-HANDOVER-RSS-MARGIN is used for selecting the target BS to perform handover. When selecting the neighbor BS to perform handover, MS considers only those neighbor BSs whose RSS is larger than the RSS of the current serving BS, and that has at least this margin value. This eliminates frequent handovers. To make the handover work properly, you might need to adjust the values of MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER and MAC-802.16e-HANDOVER-RSS-TRIGGER. If the values of the two triggers are too large, then the MS may spend a lot of time on neighbor BS scanning or handover. If they are too small, then the MS may move out of range of serving BS before performing a handover to a new BS, resulting in the MS to lose connection.
MAC-802.16e-HANDOVER-RSS-TRIGGER *Optional* *Scope:* All	Real *Default:* -78 *Unit:* dBm	This parameter, along with parameters MAC-MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER and MAC-802.16e-HANDOVER-RSS-MARGIN, is for SS to perform neighbor BS scanning or handover. This parameter is read by both BS and MS. See the description of MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER.
MAC-802.16e-HANDOVER-RSS-MARGIN *Optional* *Scope:* All	Real *Default:* 1 *Unit:* dB	This parameter, along with parameters MAC-MAC-MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER and MAC-802.16e-HANDOVER-RSS-TRIGGER, is for SS to perform neighbor BS scanning or handover. This parameter is read by both BS and MS. See the description of MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER.

TABLE 3-3. 802.16e MAC Parameters (Continued)

Parameter	Value	Description
`MAC-802.16e-SS-SUPPORT-IDLE-MODE` *Optional* *Scope:* All	List: • `YES` • `NO` *Default:* `NO`	Specifies whether or not SS supports idle mode. Paging would only be enabled if value of this parameter is configured as `YES`.
`MAC-802.16e-SS-SUPPORT-SLEEP-MODE` *Optional* *Scope:* All	List: • `YES` • `NO` *Default:* `NO`	Specifies whether or not SS supports sleep mode.
`MAC-LAYER-STATISTICS` *Optional* *Scope:* All	List • `Yes` • `NO` *Default:* `NO`	Indicates whether statistics are collected for MAC layer protocols, including 802.16e MAC.

3.1.5 GUI Configuration

This section describes how to configure 802.16 MAC and 802.16e MAC in the GUI.

Configuration Requirements

To use 802.16 MAC as the MAC protocol, 802.16 PHY must be selected as the radio model. See Section 2.1 for details of configuring 802.16 PHY.

General Configuration

To configure the 802.16 MAC and 802.16e MAC parameters, perform the following steps:

1. Go to one of the following locations:
   - To set properties at the subnet level, go to **Wireless Subnet Properties Editor > MAC Layer**.
   - To set properties for 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 the 802.16 and 802.16e MAC parameters in the Wireless Subnet Properties Editor. Parameters can be set in the Interface Properties editor and Default Device Properties Editor in a similar way.

2. Set **MAC Protocol** to *802.16* and set the dependent parameters listed in Table 3-4.

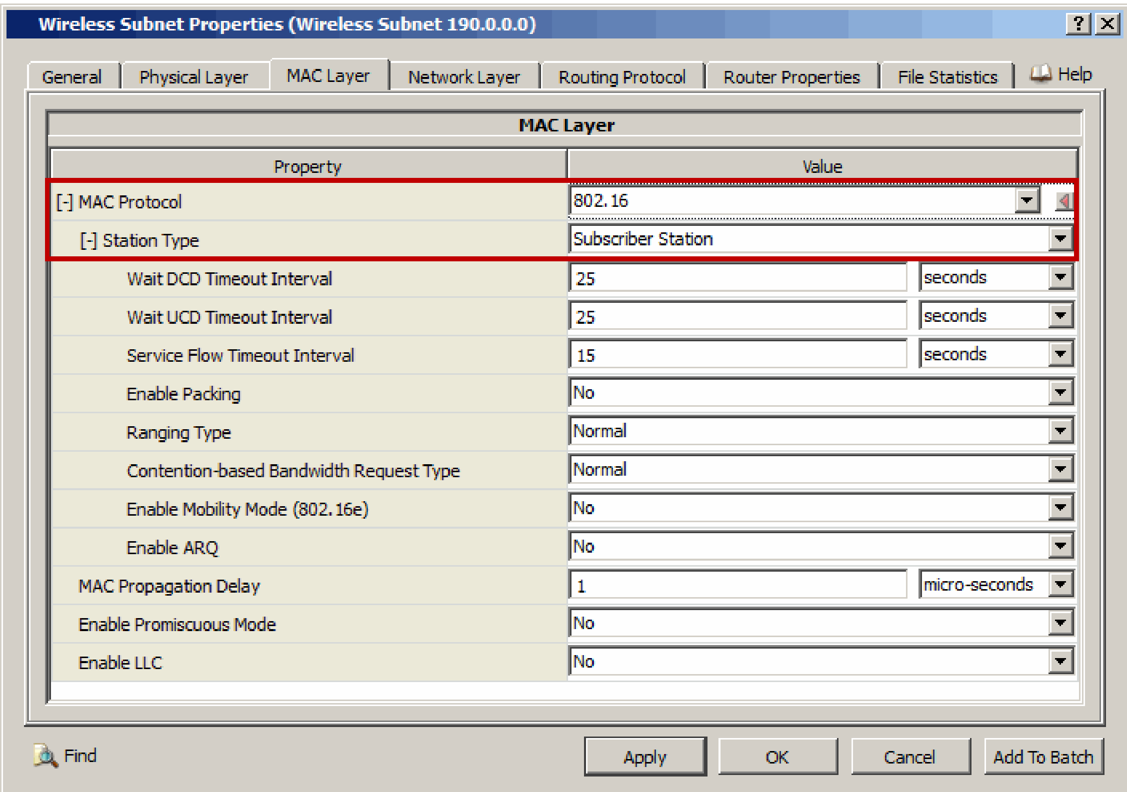


FIGURE 3-3. Setting 802.16 General Parameters

TABLE 3-4. Command Line Equivalent of 802.16 General Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Station Type	Subnet, Interface	`MAC-802.16-STATION-TYPE`

Setting Parameters

- To configure the node as a subscriber station, set **Station Type** to *Subscriber Station* and configure the subscriber station parameters as described below.
- To configure the node as a base station, set **Station Type** to *Base Station* and configure the base station parameters as described below.

Subscriber Station Configuration

To configure subscriber station parameters, perform the following steps:

1. Set **MAC Protocol** *[=802.16]* **> Station Type** to *Subscriber Station* and set the dependent parameters listed in Table 3-5.

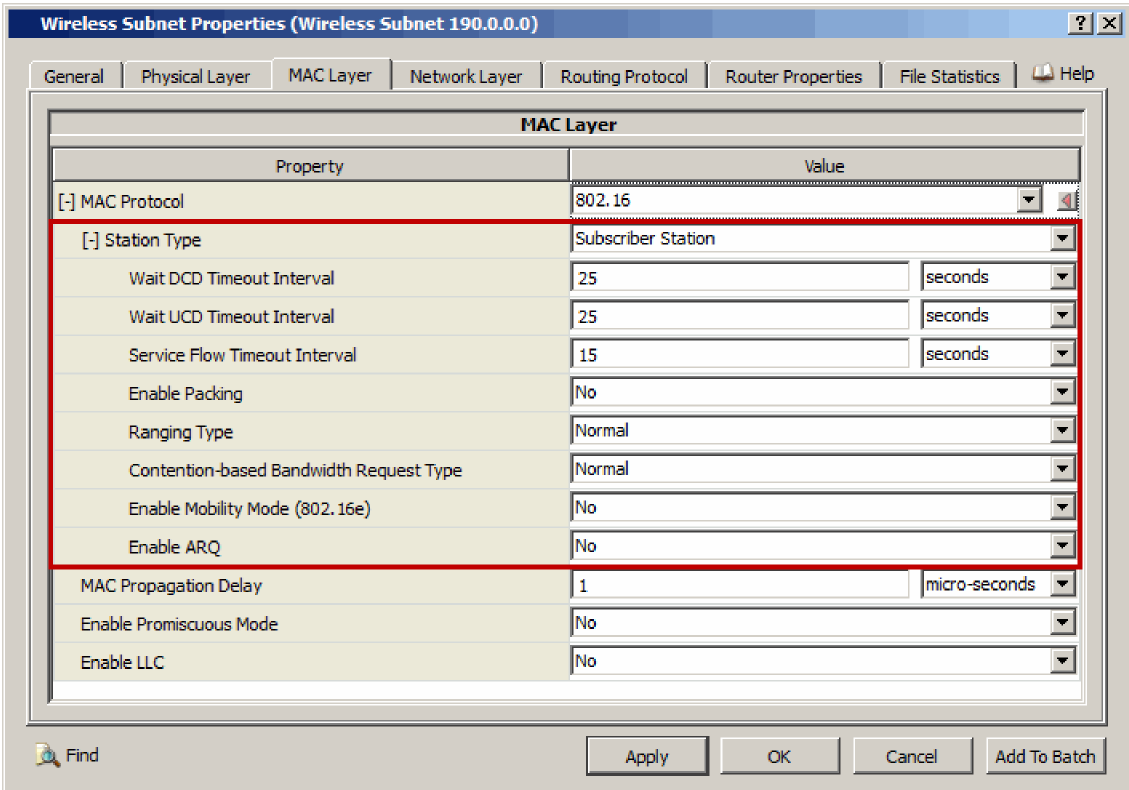


FIGURE 3-4. Setting Subscriber Station Parameters

TABLE 3-5. Command Line Equivalent of Subscriber Station Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Wait DCD Timeout Interval	Subnet, Interface	`MAC-802.16-SS-WAIT-DCD-TIMEOUT-INTERVAL`
Wait UCD Timeout Interval	Subnet, Interface	`MAC-802.16-SS-WAIT-UCD-TIMEOUT-INTERVAL`
Service Flow Timeout Interval	Subnet, Interface	`MAC-802.16-SERVICE-FLOW-TIMEOUT-INTERVAL`
Enable Packing	Subnet, Interface	`MAC-802.16-PACKING-ENABLED`
Ranging Type	Subnet, Interface	`MAC-802.16-RANGING-TYPE`
Contention-based Bandwidth Request Type	Subnet, Interface	`MAC-802.16-CONTENTION-BASED-BWREQ-TYPE`
Enable Mobility Mode (802.16e)	Subnet, Interface	`MAC-802.16-SUPPORT-MOBILITY`
Enable ARQ	Subnet, Interface	`MAC-802.16-ARQ-ENABLED`

Setting Parameters

- To enable packing, set **Enable Packing** to *Yes*; otherwise, set **Enable Packing** to *No.*
- To enable mobility mode, set **Enable Mobility Mode (802.16e)** to *Yes*; otherwise, set **Enable Mobility Mode (802.16e)** to *No.*
- To enable ARQ, set **Enable ARQ** to *Yes*; otherwise, set **Enable ARQ** to *No.*

2. If **Enable Mobility Mode (802.16e)** is set to *Yes,* then set the dependent parameters listed in Table 3-6.

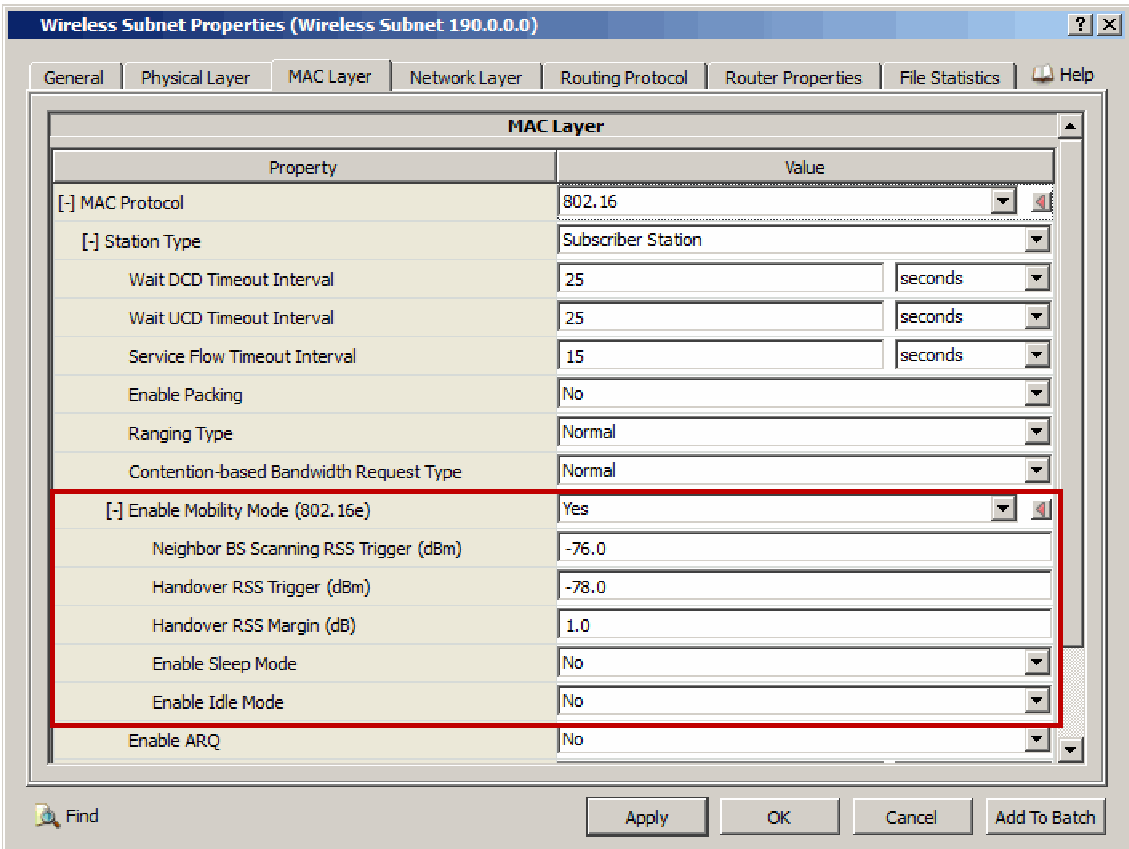


FIGURE 3-5. Setting the Subscriber Station Mobility Mode Parameters

TABLE 3-6. Command Line Equivalent of Subscriber Station Mobility Mode Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Neighbor BS Scanning RSS Trigger	Subnet, Interface	`MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER`
Handover RSS Trigger	Subnet, Interface	`MAC-802.16e-HANDOVER-RSS-TRIGGER`
Handover RSS Margin	Subnet, Interface	`MAC-802.16e-HANDOVER-RSS-MARGIN`

TABLE 3-6. Command Line Equivalent of Subscriber Station Mobility Mode Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Enable Sleep Mode	Subnet, Interface	`MAC-802.16e-SS-SUPPORT-SLEEP-MODE`
Enable Idle Mode	Subnet, Interface	`MAC-802.16e-SS-SUPPORT-IDLE-MODE`

Setting Parameters

- To enable sleep mode, set **Enable Sleep Mode** to *Yes*; otherwise, set **Enable Sleep Mode** to *No*.
- To enable idle mode, set **Enable Idle Mode** to *Yes*; otherwise, set **Enable Idle Mode** to *No*.

3. If **MAC Protocol** *[=802.16]* **> Station Type** *[= Subscriber Station]* **> Enable ARQ** is set to *Yes*, then set the dependent parameters listed in Table 3-11.

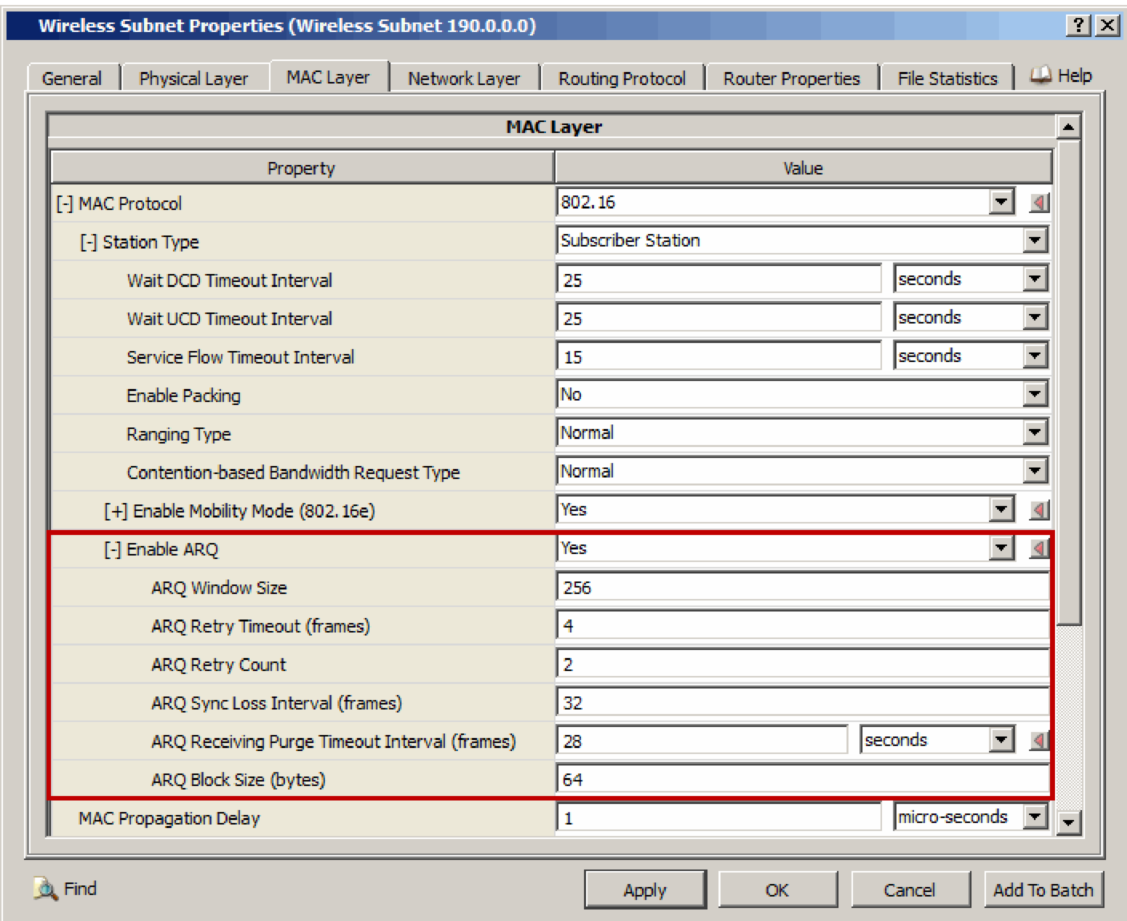


FIGURE 3-6. Setting ARQ Parameters

TABLE 3-7. Command Line Equivalent of ARQ Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
ARQ Window size	Subnet, Interface	`MAC-802.16-ARQ-WINDOW-SIZE`
ARQ Retry Timeout	Subnet, Interface	`MAC-802.16-ARQ-RETRY-TIMEOUT`
ARQ Retry Count	Subnet, Interface	`MAC-802.16-ARQ-RETRY-COUNT`
ARO Sync Loss Interval	Subnet, Interface	`MAC-802.16-ARQ-SYNC-LOSS-INTERVAL`
ARQ Receiving Purge Timeout Interval	Subnet, Interface	`MAC-802.16-ARQ-RX-PURGE-TIMEOUT`
ARQ Block Size	Subnet, Interface	`MAC-802.16-ARQ-BLOCK-SIZE`

Base Station Configuration

To configure base station parameters, perform the following steps:

1. Set **MAC Protocol** *[=802.16]* **> Station Type** to *Base Station* and set the dependent parameters listed in Table 3-8.

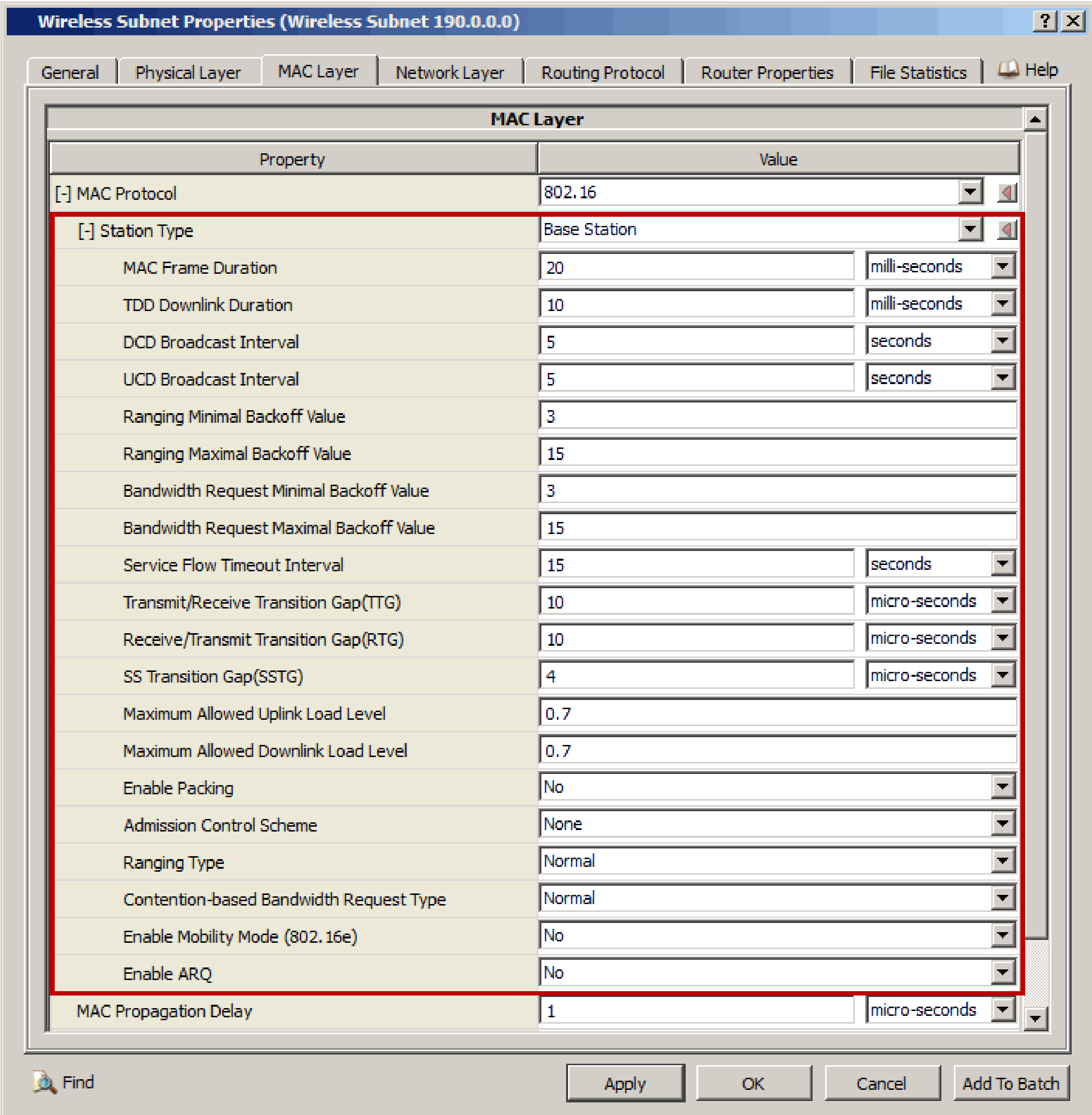


FIGURE 3-7. Setting Base Station Parameters

TABLE 3-8. Command Line Equivalent of Base Station Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
MAC Frame Duration	Subnet, Interface	`MAC-802.16-BS-FRAME-DURATION`
TDD Downlink Duration	Subnet, Interface	`MAC-802.16-BS-TDD-DL-DURATION`
DCD Broadcast Interval	Subnet, Interface	`MAC-802.16-BS-DCD-BROADCAST-INTERVAL`
UCD Broadcast Interval	Subnet, Interface	`MAC-802.16-BS-UCD-BROADCAST-INTERVAL`
Ranging Minimal Backoff Value	Subnet, Interface	`MAC-802.16-BS-RANGING-BACKOFF-MIN`
Ranging Maximal Backoff Value	Subnet, Interface	`MAC-802.16-BS-RANGING-BACKOFF-MAX`
Bandwidth Request Minimal Backoff Value	Subnet, Interface	`MAC-802.16-BS-BANDWIDTH-REQUEST-BACKOFF-MIN`
Bandwidth Request Maximal Backoff Value	Subnet, Interface	`MAC-802.16-BS-BANDWIDTH-REQUEST-BACKOFF-MAX`
Service Flow Timeout Interval	Subnet, Interface	`MAC-802.16-SERVICE-FLOW-TIMEOUT-INTERVAL`
Transmit/Receive Transition Gap (TTG)	Subnet, Interface	`MAC-802.16-BS-TTG`
Receive /Transmit Transition Gap (RTG)	Subnet, Interface	`MAC-802.16-BS-RTG`
SS Transition Gap (SSTG)	Subnet, Interface	`MAC-802.16-BS-SSTG`
Maximum Allowed Uplink Load Level	Subnet, Interface	`MAC-802.16-MAX-ALLOWED-UPLINK-LOAD-LEVEL`
Maximum Allowed Downlink Load Level	Subnet, Interface	`MAC-802.16-MAX-ALLOWED-DOWNLINK-LOAD-LEVEL`
Enable Packing	Subnet, Interface	`MAC-802.16-PACKING-ENABLED`
Admission Control Scheme	Subnet, Interface	`MAC-802.16-BS-ADMISSION-CONTROL-SCHEME`
Ranging Type	Subnet, Interface	`MAC-802.16-RANGING-TYPE`
Contention-based Bandwidth Request Type	Subnet, Interface	`MAC-802.16-CONTENTION-BASED-BWREQ-TYPE`
Enable Mobility Mode(802.16e)	Subnet, Interface	`MAC-802.16-SUPPORT-MOBILITY`
Enable ARQ	Subnet, Interface	`MAC-802.16-ARQ-ENABLED`

Setting Parameters

- To enable packing, set **Enable Packing** to *Yes*; otherwise, set **Enable Packing** to *No.*
- To enable Mobility Mode, set **Enable Mobility Mode (802.16e)** to *Yes*; otherwise, set **Enable Mobility Mode (802.16e)** to *No.*
- To enable ARQ, set **Enable ARQ** to *Yes*; otherwise, set **Enable ARQ** to *No.*

2. If **Enable Mobility Mode (802.16e)** is set to *Yes*, then set the dependent parameters listed in Table 3-9.

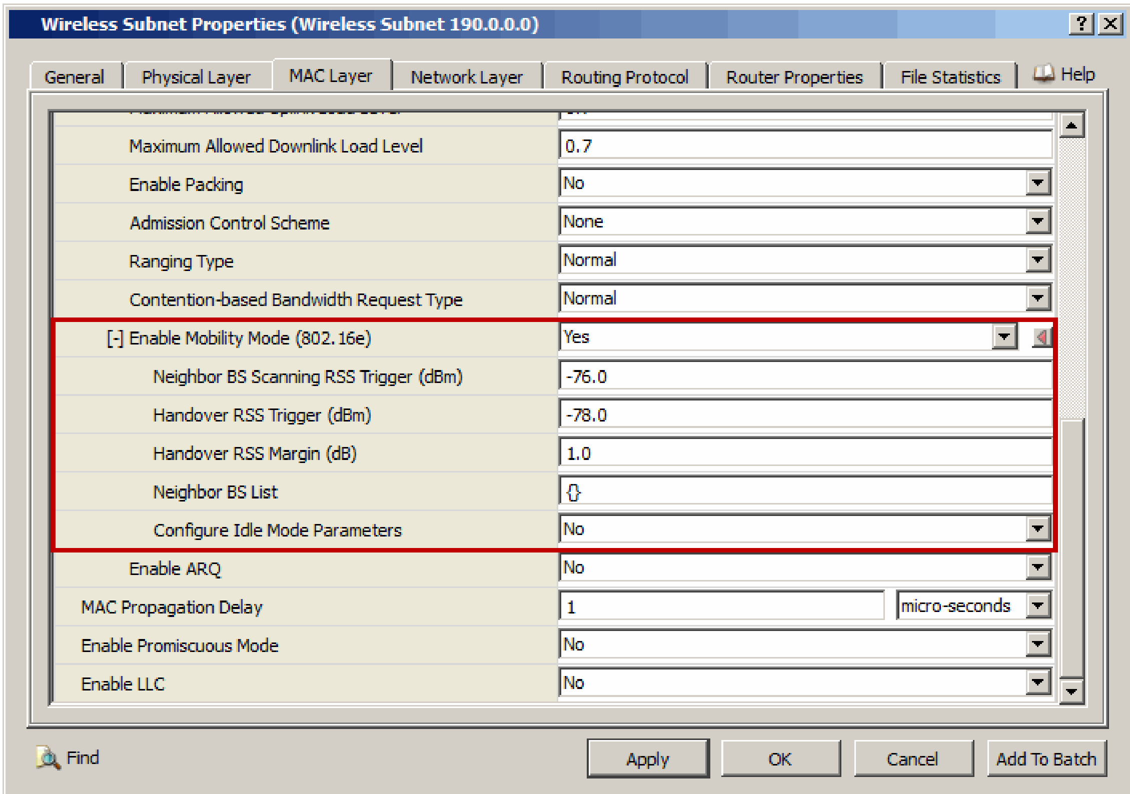


FIGURE 3-8. Configuring Base Station Mobility Mode Parameters

TABLE 3-9. Command Line Equivalent of Base Station Mobility Mode Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Neighbor BS Scanning RSS Trigger	Subnet, Interface	`MAC-802.16e-NEIGHBOR-SCAN-RSS-TRIGGER`
Handover RSS Trigger	Subnet, Interface	`MAC-802.16e-HANDOVER-RSS-TRIGGER`
Handover RSS Margin	Subnet, Interface	`MAC-802.16e-HANDOVER-RSS-MARGIN`
Neighbor BS List	Subnet, Interface	`MAC-802.16-BS-NEIGHBOR`
Configure Idle Mode Parameters	Subnet, Interface	N/A

Setting Parameters

- To enable idle mode, set **Configure Idle Mode Parameters** to *Yes*; otherwise, set **Configure Idle Mode Parameters** to *No*.

3. If **Configure Idle Mode Parameters** is set to *Yes,* then set the dependent parameters listed in Table 3-10.

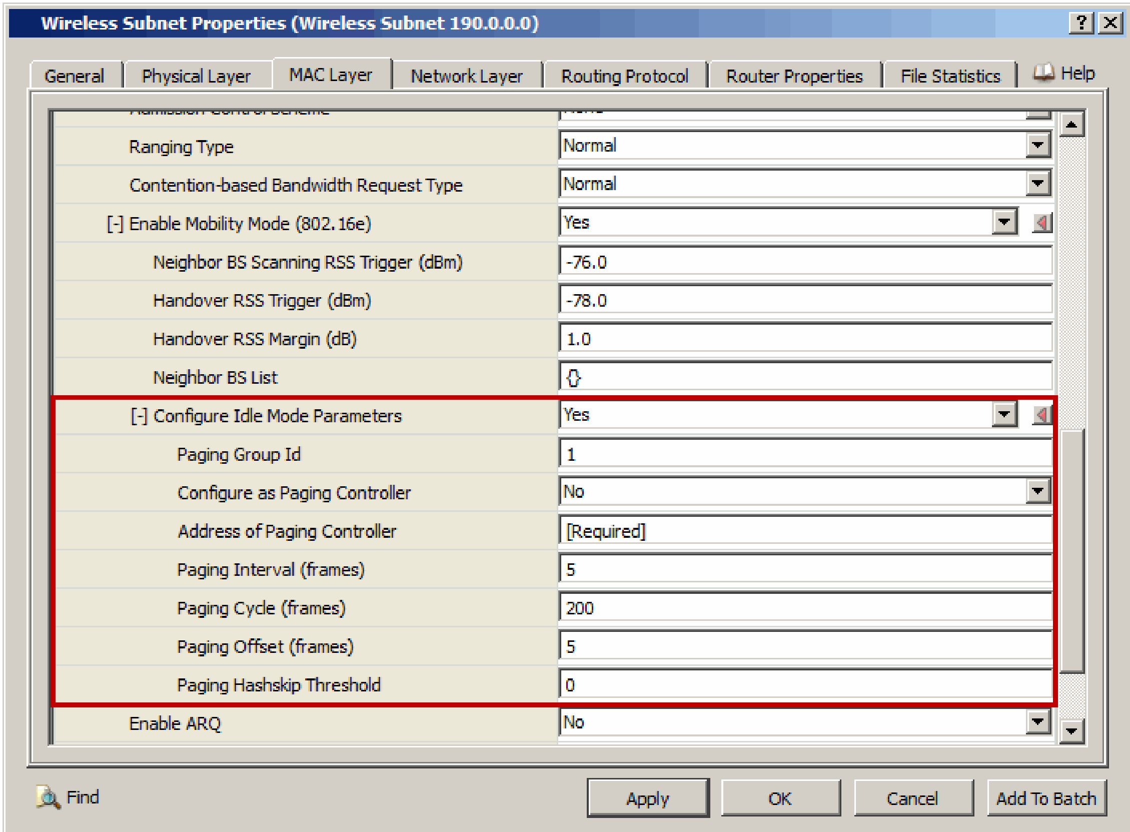


FIGURE 3-9. Setting Base Station Idle Mode Parameters

TABLE 3-10. Command Line Equivalent of Base Station Idle Mode Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
Paging Group Id	Subnet, Interface	`MAC-802.16e-BS-PAGING-GROUP-ID`
Configure as Paging Controller	Subnet, Interface	`MAC-802.16e-BS-IS-PAGING-CONTROLLER`
Address of Paging Controller	Subnet, Interface	`MAC-802.16e-BS-PAGING-CONTROLLER`
Paging Interval	Subnet, Interface	`MAC-802.16e-BS-PAGING-INTERVAL-LENGTH`
Paging Cycle	Subnet, Interface	`MAC-802.16e-BS-PAGING-CYCLE`
Paging Offset	Subnet, Interface	`MAC-802.16e-BS-PAGING-OFFSET`
Paging Hashskip Threshold	Subnet, Interface	`MAC-802.16e-PAGING-HASHSKIP-THRESHOLD`

4. If **MAC Protocol** *[=802.16]* **> Station Type** *[= Base Station]* **> Enable ARQ** is set to *Yes*, then set the dependent parameters listed in Table 3-11.

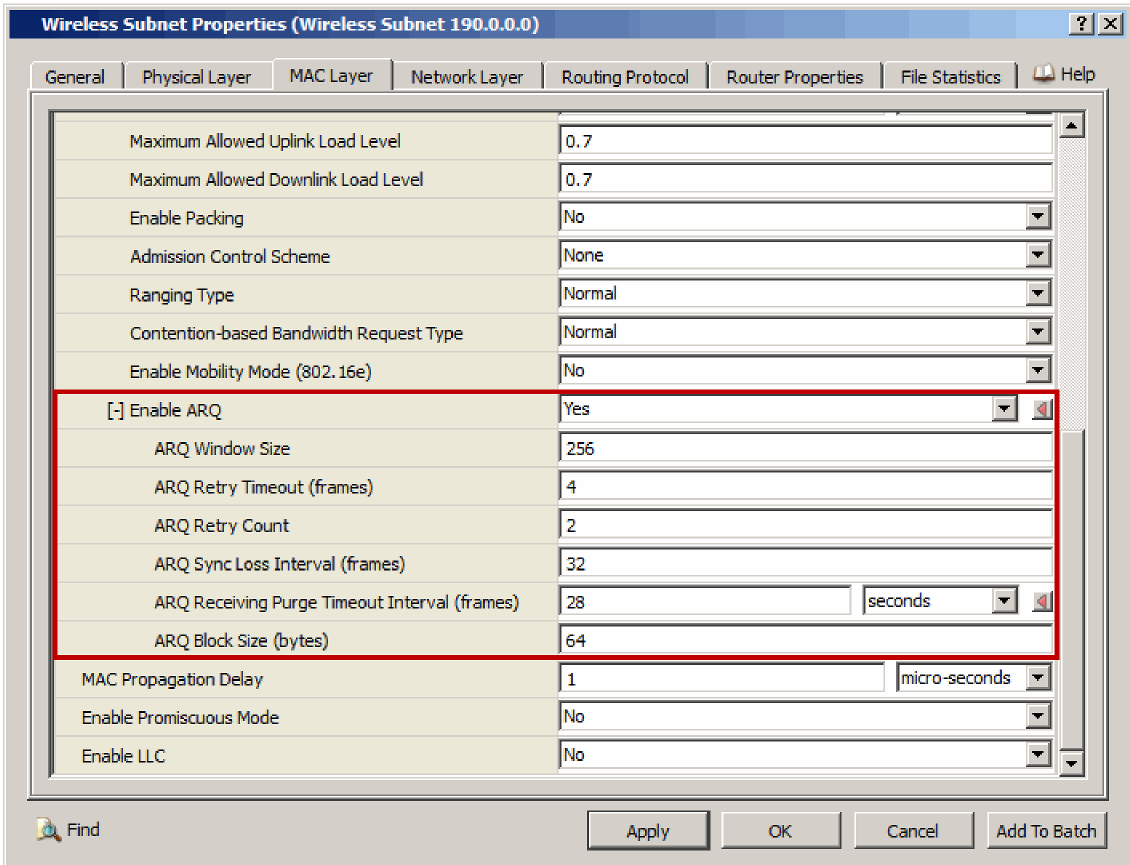


FIGURE 3-10. Setting ARQ Parameters

TABLE 3-11. Command Line Equivalent of ARQ Parameters

GUI Parameter	Scope of GUI Parameter	Command Line Parameter
ARQ Window size	Subnet, Interface	`MAC-802.16-ARQ-WINDOW-SIZE`
ARQ Retry Timeout	Subnet, Interface	`MAC-802.16-ARQ-RETRY-TIMEOUT`
ARQ Retry Count	Subnet, Interface	`MAC-802.16-ARQ-RETRY-COUNT`
ARO Sync Loss Interval	Subnet, Interface	`MAC-802.16-ARQ-SYNC-LOSS-INTERVAL`
ARQ Receiving Purge Timeout Interval	Subnet, Interface	`MAC-802.16-ARQ-RX-PURGE-TIMEOUT`
ARQ Block Size	Subnet, Interface	`MAC-802.16-ARQ-BLOCK-SIZE`

Configuring Statistics Parameters

Statistics for the 802.16 MAC 802.16e MAC models 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 802.16 MAC and 802.16e MAC, check the box labeled **MAC** in the appropriate properties editor.

TABLE 3-12. Command Line Equivalent of Statistics Parameters

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

3.1.6 Statistics

This section describes the file and dynamic statistics of the IEEE 802.16 MAC model.

3.1.6.1 File Statistics

Table 3-13 lists the IEEE 802.16 MAC statistics that are output to the statistics (.stat) file at the end of simulation.

TABLE 3-13. 802.16 MAC Statistics

Statistic	Description
General Statistics	
Station type	Indicates the station type of the node; SS for a subscriber station, and BS for a base station.
Statistics Collected for Subscriber Stations	
Number of data packets from upper layer	Number of data packets from upper layer at a SS.
Number of data packets sent in MAC frames	Number of data packets sent in MAC frames by a SS.
Number of data packets rcvd in MAC frames	Number of data packets received from MAC layer by a SS.
Number of DL-MAP messages rcvd	Number of DL-MAP messages received by a SS.
Number of UL-MAP messages rcvd	Number of UL-MAP messages received by a SS.
Number of DCD messages rcvd	Number of DCD messages received by a SS.
Number of UCD messages rcvd	Number of UCD messages received by a SS.
Number of network entry performed	Number of network entry performed by a SS.
Number of RNG-REQ messages sent	Number of range request messages sent by a SS.
Number of RNG-RSP messages rcvd	Number of range response messages received by a SS.
Number of SBC-REQ messages sent	Number of basic capability request messages sent by a SS.
Number of SBC-RSP messages rcvd	Number of basic capability response messages received by a SS.
Number of PKM-REQ messages sent	Number of public key management request messages sent by a SS.
Number of PKM-RSP messages rcvd	Number of public key management response messages received by a SS.
Number of REG-REQ messages sent	Number of registration request messages sent by a SS.
Number of REG-RSP messages rcvd	Number of registration response messages received by a SS.

TABLE 3-13. 802.16 MAC Statistics (Continued)

Statistic	Description
Number of REP-REQ messages rcvd	Number of report request for signal strength messages received by a SS.
Number of REP-RSP messages sent	Number of report response for signal strength messages sent by a SS.
Number of DSA-REQ messages rcvd	Number of service flow adding request messages received by SS
Number of DSA-RSP messages sent	Number of service flow adding response messages sent by a SS
Number of DSA-ACK messages rcvd	Number of service flow adding acknowledgement messages received by a SS.
Number of DSA-REQ messages sent	Number of service flow adding request messages sent by a SS
Number of DSX-RVD messages rcvd	Number of dynamic service flow management receipt messages received by a SS.
Number of DSA-RSP messages rcvd	Number of service flow adding response messages received by a SS.
Number of DSA-ACK messages sent	Number of service flow adding acknowledgement messages sent by a SS.
Number of DSC-REQ messages rcvd	Number of service flow change request messages received by a SS.
Number of DSC-RSP messages sent	Number of service flow change response messages sent by a SS.
Number of DSC-ACK messages rcvd	Number of service flow change acknowledgement messages received by a SS.
Number of DSC-REQ messages sent	Number of service flow change request messages sent by a SS.
Number of DSC-RSP messages rcvd	Number of service flow change response messages received by a SS.
Number of DSC-ACK messages sent	Number of service flow change acknowledgement messages sent by a SS.
Number of DSD-REQ messages rcvd	Number of service flow deletion request messages received by a SS.
Number of DSD-RSP messages sent	Number of service flow deletion response messages sent by a SS.
Number of DSD-REQ messages sent	Number of service flow deletion request messages sent by a SS.
Number of DSD-RSP messages rcvd	Number of service flow deletion response messages received by a SS.
Number of data packets to classify	Number of data packet from upper layer which need to be classified at CS sublayer by a SS.
Number of data packets classified	Number of packets that were classified at CS sublayer by a SS.
Number of classifiers	Number of classifiers created at the CS sublayer by a SS.
Number of ARQ blocks sent	Number of ARQ blocks sent by a SS.
Number of ARQ blocks discarded	Number of ARQ blocks discarded by a SS.
802.16e Mobility Related Statistics for a SS (only when 802.16e mobility support is enabled)	
Number of neighbor BS scanning performed	Number of neighbor BS scanning performed by a SS.
Number of handovers performed	Number of handovers performed by a SS.
Number of MOB-NBR-ADV messages rcvd	Number of neighbor BS advertisement messages received by a SS.
Number of MOB-SCN-REQ messages sent	Number of neighbor scanning request messages sent by a SS.
Number of MOB-SCN-RSP messages rcvd	Number of neighbor scanning response messages received by a SS.

TABLE 3-13. 802.16 MAC Statistics (Continued)

Statistic	Description
Number of MOB-SCN-REP messages sent	Number of neighbor scanning report messages sent by a SS.
Number of MOB-MSHO-REQ messages sent	Number of MS initiated handover request messages sent by a SS.
Number of MOB-BSHO-REQ messages rcvd	Number of BS initiated handover request messages received by a SS.
Number of MOB-HO-IND messages sent	Number of handover indication messages sent by a SS.
Statistics Collected for Base Stations	
Number of data packets from upper layer	Number of data packets from upper layer at a BS.
Number of data packets dropped due to unknown SS	Number of data packets dropped due to the reason that the destination SS is not registered with the BS.
Number of data packets dropped due to SS moved out of cell	Number of data packets dropped due to the reason that the SS has moved out from the cell of the BS.
Number of data packets dropped due to SS in handover status	Number of data packets dropped due to the reason that the destination SS is in handover status.
Number of data packets sent in MAC frames	Number of data packets sent in MAC frames by a BS.
Number of data packets rcvd in MAC frames	Number of data packets received in MAC frames by a BS.
Number of DL-MAP messages sent	Number of DL-MAP messages sent by a BS.
Number of UL-MAP messages sent	Number of UL-MAP messages sent by a BS.
Number of DCD messages sent	Number of DCD messages sent by a BS.
Number of UCD messages sent	Number of UCD messages sent by a BS.
Number of RNG-REQ messages rcvd	Number of range request messages received by a BS.
Number of RNG-RSP messages sent	Number of range response messages sent by a BS.
Number of SBC-REQ messages rcvd	Number of basic capability request messages received by a BS.
Number of SBC-RSP messages sent	Number of basic capability response messages sent by a SS.
Number of PKM-REQ messages rcvd	Number of public key management request messages received by a BS.
Number of PKM-RSP messages sent	Number of public key management messages sent by a BS.
Number of REG-REQ messages rcvd	Number of registration request messages received by a BS.
Number of REG-RSP messages sent	Number of registration response messages sent by a BS.
Number of DSA-REQ messages rcvd	Number of service flow adding request messages received by a BS.
Number of DSX-RVD messages sent	Number of dynamic service flow management receipt messages sent by a BS.
Number of DSA-RSP messages sent	Number of service flow adding response messages sent by a BS.
Number of DSA-ACK messages rcvd	Number of service flow adding acknowledgement messages received by a BS.
Number of DSA-REQ messages sent	Number of service f low adding request messages sent by a BS
Number of DSA-RSP messages rcvd	Number of service flow adding response messages received by a BS.
Number of DSA-ACK messages sent	Number of service flow adding acknowledgement messages sent by a BS.
Number of DSC-REQ messages rcvd	Number of service flow change request messages received by a BS.
Number of DSC-RSP messages sent	Number of service flow change response messages sent by a BS.

TABLE 3-13. 802.16 MAC Statistics (Continued)

Statistic	Description
Number of DSC-ACK messages rcvd	Number of service flow change acknowledgement messages received by a BS.
Number of DSC-REQ messages sent	Number of service flow change request messages sent by a BS.
Number of DSC-RSP messages rcvd	Number of service flow change response messages received by a BS.
Number of DSC-ACK messages sent	Number of service flow change acknowledgement messages sent by a BS.
Number of DSC-REQ messages rejected	Number of service flow change request messages rejected by a BS due to admission control.
Number of DSD-REQ messages rcvd	Number of service flow deletion request messages received by a BS.
Number of DSD-RSP messages sent	Number of service flow deletion response messages sent by a BS.
Number of DSD-REQ messages sent	Number of service flow deletion request messages sent by a BS.
Number of DSD-RSP messages rcvd	Number of service flow deletion response messages received by a BS.
Number of data packets to classify	Number of data packet from upper layer which need to be classified at CS sublayer by a BS.
Number of data packets classified	Number of packets that were classified at CS sublayer by a BS.
Number of classifiers	Number of classifiers created at the CS sublayer by a BS.
Number of ARQ blocks sent	Number of ARQ blocks sent by a BS.
Number of MOB-TRF-IND messages sent	Number of traffic indication messages sent by a BS.
802.16e Mobility Related Statistics for a BS (only when 802.16e mobility support is enabled)	
Number of MOB-NBR-ADV messages sent	Number of neighbor BS advertisement messages sent by a BS.
Number of MOB-SCN-REQ messages rcvd	Number of neighbor scanning request messages received by a BS.
Number of MOB-SCN-RSP messages sent	Number of neighbor scanning response messages sent by a BS.
Number of MOB-SCN-REP messages rcvd	Number of neighbor scanning report messages received by a BS.
Number of MOB-MSHO-REQ messages rcvd	Number of MS initiated handover request messages received by a BS.
Number of MOB-BSHO-RSP messages sent	Number of BS handover response messages sent by a BS.
Number of MOB-BSHO-REQ messages sent	Number of BS initiated handover request messages sent by a BS.
Number of MOB-HO-IND messages rcvd	Number of handover indication messages received by a BS.
Number of Inter-BS Hello messages sent	Number of neighbor BS hello messages sent over backbone by a BS.
Number of Inter-BS Hello messages rcvd	Number of neighbor BS hello messages received over backbone by a BS.
Number of Inter-BS HO Finish messages sent	Number of HO finished notification received by a BS from MS's current serving BS via the backbone.
Number of Inter-BS HO Finish messages rcvd	Number of HO finished notification sent by a BS to previous serving BS via the backbone.
Number of DREG-CMD messages sent	Number of de-registration messages sent by a BS.
Number of DREG-REQ messages rcvd	Number of de-registration messages received by a BS.
Number of MOB-PAG-ADV messages sent	Number of paging broadcast messages sent.

3.1.6.2 Dynamic Statistics

This section lists the dynamic statistics that are enabled for the IEEE 802.16 MAC model. Refer to Chapter 6 of *EXata User's Guide* for details of viewing dynamic statistics in the GUI during the simulation.

The following dynamic statistics are enabled for a subscriber station:

- Last Measured Downlink CINR (dB)
- Last Measured Downlink RSS (dBm)
- Number of Data Packets Transmitted
- Number of Data Packets Received
- Number of Active Neighbor BSs Discovered

The following dynamic statistics are enabled for a base station:

- Number of Data Packets Transmitted
- Number of Data Packets Received
- Number of Data Packets Dropped due to Handover

3.1.7 Sample Scenario

In this section, we use an example to show how you can configure a scenario with 802.16 MAC.

3.1.7.1 Scenario Description

Assume the scenario contains two subnets. Subnet 1 contains node 1 to node 10 and subnet 2 contains node 11 to node 20. Both subnets run 802.16 MAC with node 1 as the BS of subnet 1 and node 15 as the BS of subnet 2. The two base stations, node 1 and node 15, are connected via a wired point-to-point link, as shown in Figure 3-11.

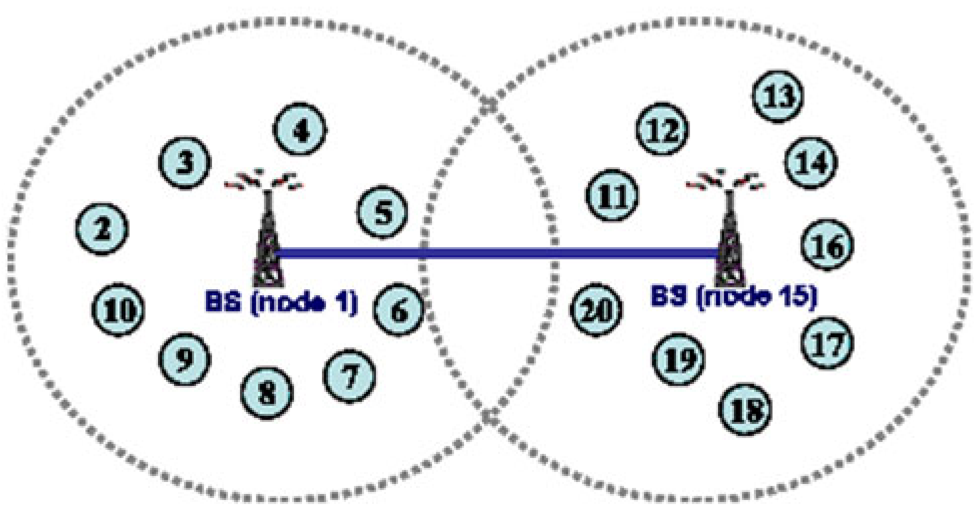


FIGURE 3-11. Topology of Sample Scenario

3.1.7.2 Command Line Configuration

1. Define the two subnets and a point-to-point link between node 1 and node 15.

```
SUBNET N8-0.0 {1 thru 10}
SUBNET N8-1.0 {11 thru 20}
LINK N2-2.0 {1, 15}
```

2. Create two wireless channels.

```
PROPAGATION-CHANNEL-FREQUENCY[0] 10.0e9
PROPAGATION-CHANNEL-FREQUENCY[1] 10.1e9
PROPAGATION-CHANNEL-NAME[0] channel-0
PROPAGATION-CHANNEL-NAME[1] channel-1
```

3. Assign channel 0 to subnet 1 and channel 1 to subnet 2.

```
[N8-0.0] PHY-LISTENABLE-CHANNELS channel-0, channel-1
[N8-0.0] PHY-LISTENING-CHANNELS  channel-0

[N8-1.0] PHY-LISTENABLE-CHANNELS channel-0, channel-1
[N8-1.0] PHY-LISTENING-CHANNELS  channel-1
```

4. Specify 802.16 MAC as the MAC protocol for both subnets.

```
[N8-0.0] MAC-PROTOCOL MAC802.16
[N8-1.0] MAC-PROTOCOL MAC802.16
```

5. Specify node 1 as BS of subnet 1 and node 15 as the BS of subnet 2.

```
[0.0.0.1] MAC-802.16-STATION-TYPE    BS    // node 1
[0.0.1.5] MAC-802.16-STATION-TYPE    BS    // node 15
```

6. Enable mobility for all nodes in the subnet.

```
[N8-0.0] MAC-802.16-MOBILITY-SUPPORT YES
[N8-0.1] MAC-802.16-MOBILITY-SUPPORT YES
```

7. Enable ARQ for all the nodes in the subnet.

```
[N8-0.0.0.0] MAC-802.16-ARQ-ENABLED YES
[N8-0.0.1.0] MAC-802.16-ARQ-ENABLED YES
```

8. Specify 802.16 PHY as the radio type for both subnets.

```
[N8-0.0] PHY-MODEL          PHY802.16
[N8-0.0] PHY-RX-MODEL       PHY802.16
[N8-1.0] PHY-MODEL          PHY802.16
[N8-1.0] PHY-RX-MODEL       PHY802.16
```

3.1.7.3 GUI Configuration

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

1. Create two wireless subnets. Subnet 1 contains nodes 1 to 10 and subnet 2 contains nodes 11 to 20. Connect nodes 1 and 15 using a point-to-point link.
2. Go to **Scenario Properties Editor > Channel Properties**, set the **Number of Channels** to *2*.

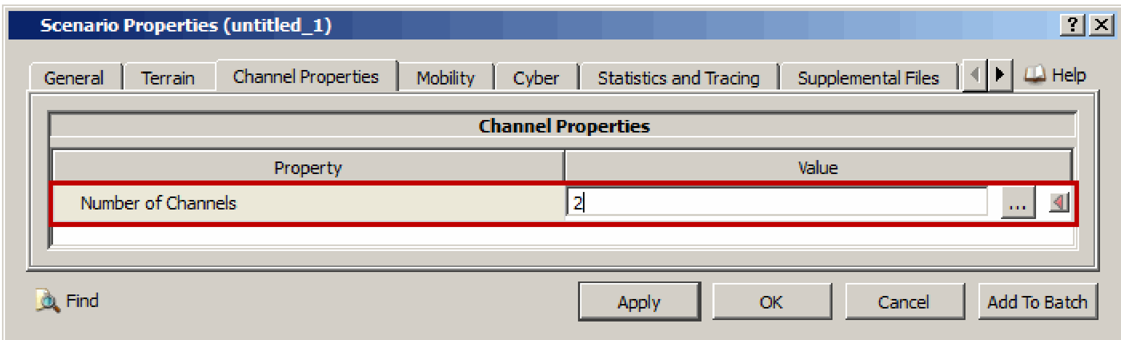


FIGURE 3-12. Setting Number of Channels

3. To configure the properties for the number of channels, do the following:

   a. Click the **Open Array Editor**  button in the **Value** column. This opens the Array Editor (Figure 3-13).

   b. Set the parameters for each channel index.

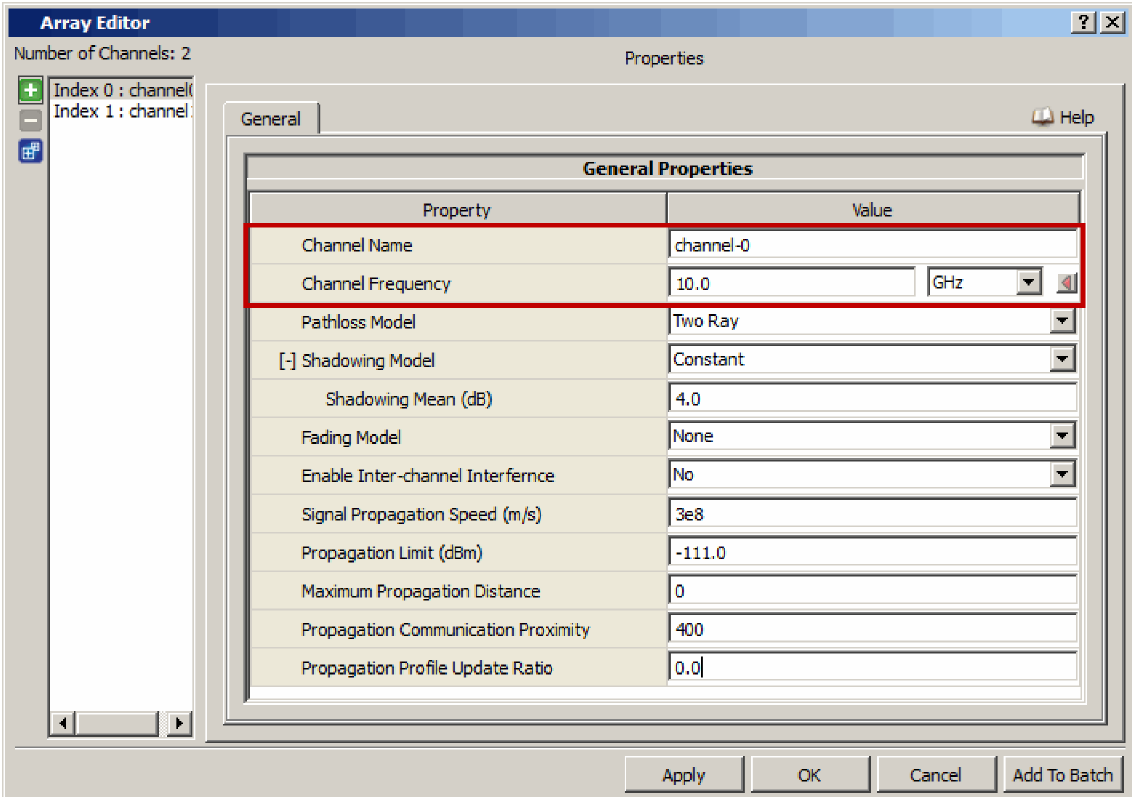


FIGURE 3-13. Setting Channel Parameters

4. Go to **Wireless Subnet Properties Editor > Physical Layer** for subnet 1. Set **Listenable Channels** to *channel-0, channel-1* and **Listening Channels** to *channel-0,* as shown in Figure 3-14.

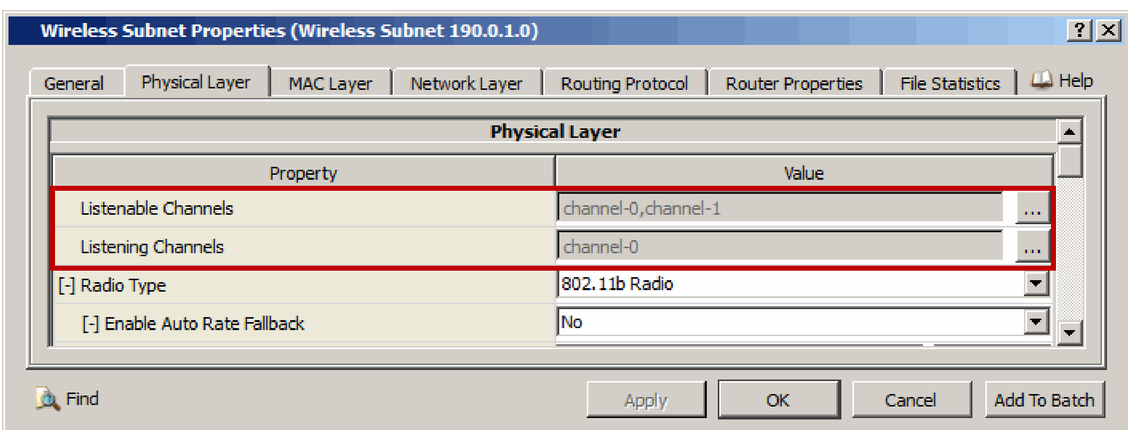


FIGURE 3-14. Setting Listenable and Listening Channels

5. Similarly, for subnet 2 set **Listenable Channels** to *channel-0, channel-1* and **Listening Channels** to *channel-1*.

6. For both subnets, go to **Group Wireless Subnet Properties Editor > Physical Layer** and set **Radio Type** to *802.16 Radio*, as shown in the Figure 3-15.

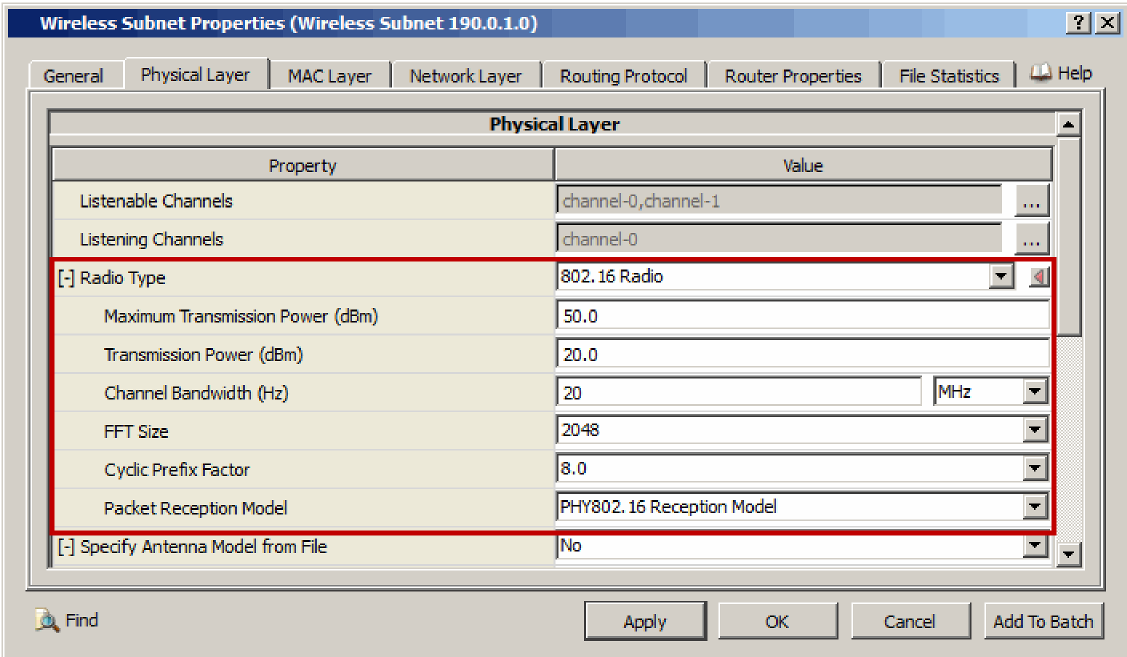


FIGURE 3-15. Setting the Radio Type

7. For both subnets, go to **Group Wireless Subnet Properties Editor > MAC Layer** and set **MAC Protocol** to *802.16*, as shown in Figure 3-16.

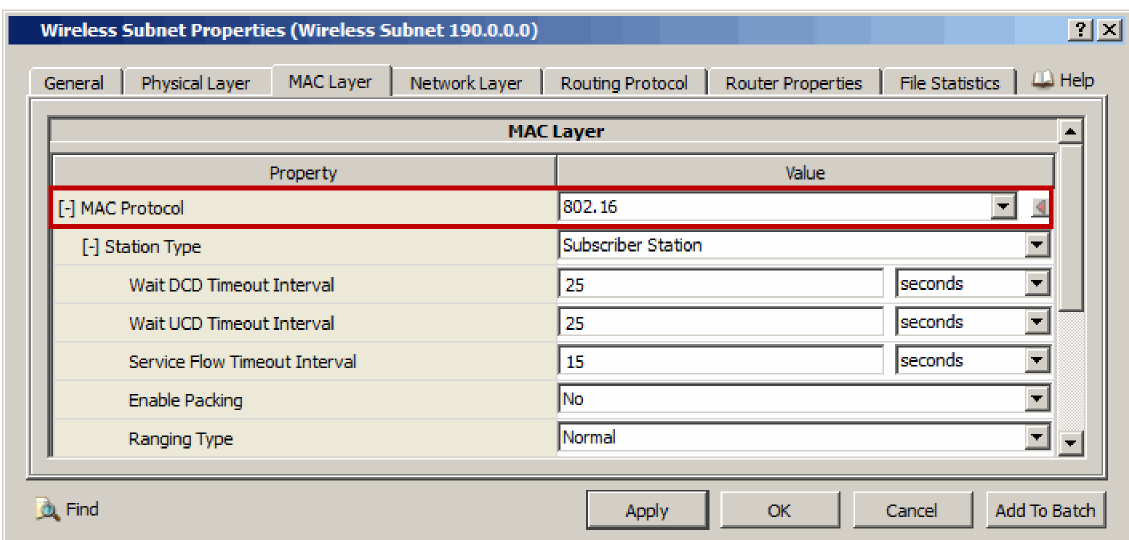


FIGURE 3-16. Setting the MAC Protocol

8. Set ***Enable Mobility Mode (802.16e)*** to *Yes and* set the dependent parameters as shown in Figure 3-8.
9. Set **Enable ARQ** to *Yes* and set the dependent parameters as shown in Figure 3-10**.**
10. For node 1 and node 15, go to **Default Device Properties Editor > Interfaces > MAC Layer**, set **MAC Protocol** *[= 802.16]* **> Station Type** to *Base Station* as shown in Figure 3-17.

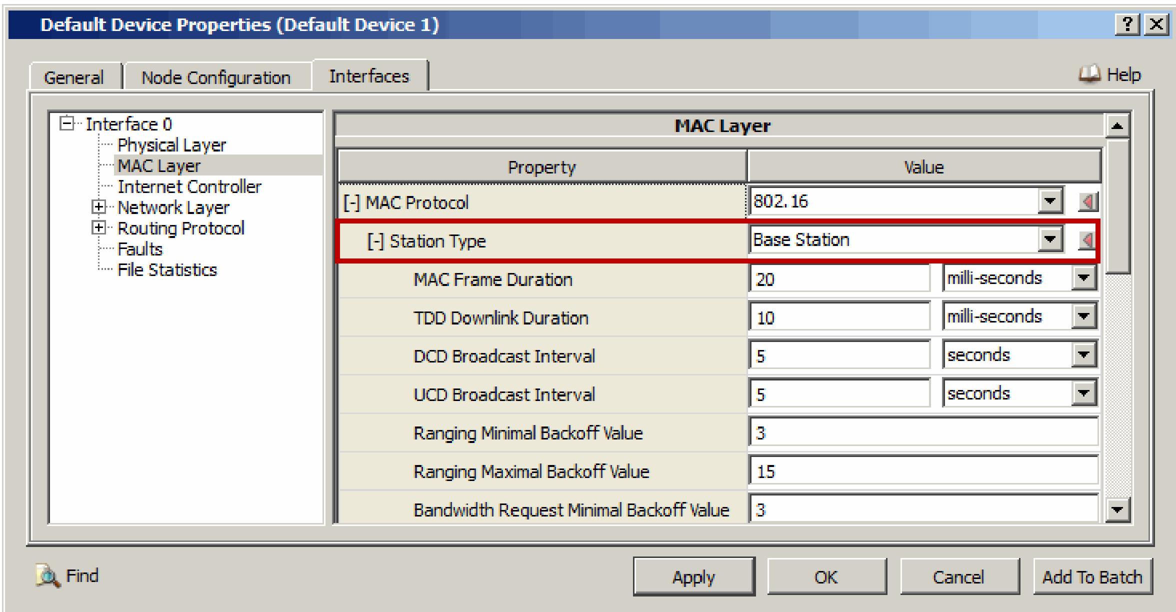


FIGURE 3-17. Setting Base Station Parameters

3.1.8 Scenarios Included in EXata

The EXata distribution includes several verification scenarios for the IEEE 802.16 MAC model. All scenarios are located in the directory EXATA_HOME/scenarios/advanced_wireless/802.16. Table 3-14 lists the sub-directory where each scenario is located.

TABLE 3-14. IEEE 802.16 MAC Scenarios Included in EXata

Scenario	Description
Admission-Control	Shows an example of Admission control scheme procedure for 802.16 network.
ARQ	Show the functionality of ARP for 802.16 network
CDMA	Shows the functionality of CDMA based ranging and bandwidth request process for 802.16 network.
dualIP	Shows the functionality of IEEE 802.16 when ruining with Dual IP.
Fragmentation	Shows an example of Fragmentation functionality for 802.16 network.
Idle-Mode	Shows an example of IDLE-MODE functionality for 802.16 network.
IPv6-routing-protocol	Shows an example of functionality of IEEE 802.16 when running IPv6 routing protocols.
mobility_two_cell	Shows the functionality of basic handover of IEEE 802.16e.
multicast	Shows the functionality of IEEE 802.16 when running with multicast and unicast applications.
multi-cell	Shows an example of the interoperability between 802.16 and wired 802.3 subnet as well as wireless 802.11 hot spots.
multicell-high-mobility	Shows an example of the basic handover functionality of IEEE 802.16e in multicell environment and with high mobility.
multi-rates	Shows an example of the multiple rates capability of 802.16 using different coding and modulation combinations. The rates are properly chosen based on signal strengths. In this sample, the signal strength is mainly decided by the distance between the BS and SS.
packing	Shows an example of the Packing functionality for 802.16 network.
service-types	Shows an example of the four service types, namely UGS, ertPs, rtPS, nrtPS and BE. Five flows are defined with different service types. They will get different quality of service based on their service types
single-cell	Shows an example of the basic functionality of a single cell 802.16 network with IPv4.
single-cell-ipv6	Shows an example of the basic functionality of a single cell 802.16 network with IPv6.
SleepMode	Shows an example of the sleep mode functionality for 802.16 wireless network.
two-cell-backbone	Shows an example of two separated 802.16 subnets operating on different channels. The BSs of the two subnets are connected via a wired point-to-point link.
UrbanEnv	Shows an example of a WiMAX system working in urban environment, i.e., urban terrain and urban propagation.

3.1.9 References

1. IEEE Std 802.16-2004, “Part 16: Air Interface for Fixed Broadband Wireless Access Systems,” IEEE Standard for Local and metropolitan area networks, Oct. 2004.
2. IEEE Std 802.16e-2005, "Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems: Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1," Feb 2006.