QualNet®
Building Smarter Networks

QualNet 4.5
Product Tour

March 2008

Scalable Network Technologies, Inc.

6701 Center Drive West, Suite 520
Los Angeles, CA 90045

Phone: 310-338-3318
Fax: 310-338-7213

http://www.scalable-networks.com
http://www.qualnet.com

Scalable Network Technologies, Inc.
6701 Center Drive West, Suite 520
Los Angeles, CA 90045
Phone: 310-338-3318
Fax: 310-338-7213
http://www.scalable-networks.com
http://www.qualnet.com

Table of Contents

Preface

How this Guide is Organized

This guide contains the following information:

- Chapter 1 provides an overview of the QualNet 4.5 products, including it's key benefits.
- Chapter 2 is about starting QualNet 4.5 and introduces it's layout.
- Chapter 3 discusses how to create scenarios, add nodes to scenarios, add links to the nodes, and finally how to add applications.
- Chapter 4 describes how to run QualNet 4.5 scenarios.
- Chapter 5 has information on analyzing statistics in QualNet 4.5.
- Chapter 6 talks about tracing packets.
- Chapter 7 discusses advanced network modeling, including semi-automated node placement, connecting multiple nodes, batch execution, and analyzing multiple statistics files.
- Chapter 8 presents some demonstration scenarios that are included in QualNet 4.5.

QualNet Document List

The following list shows the QualNet documentation set and offers a brief description of each document.

QualNet 4.5 API Reference Guide	This reference guide describes the function and parameters of QualNet APIs.
QualNet 4.5 Distributed Reference Guide	This guide gives instructions for running QualNet on a distributed architecture.

QualNet 4.5 Installation Guide	This guide provides detailed steps for installing QualNet 4.5 on UNIX/Linux/MAC and Windows platforms.
QualNet 4.5 Product Tour	This document is designed to quickly cover the basic features of QualNet 4.5 for experienced network modelers. It includes exercises and example scenarios.
QualNet 4.5 Programmer's Guide	This is a guide to the QualNet programming interface and functions, allowing users to develop and customize protocol models.
QualNet 4.5 User's Guide	This guide is a detailed look at the QualNet 4.5 environment and works in combination with the new *QualNet Model Libraries* set of documents to provide extensive information on QualNet protocols for the 4.5 release.
QualNet 4.5 Model Libraries	This set of documents contains detailed reference information on all of the models used in QualNet 4.5.The set of documents includes the following protocol libraries. See *QualNet 4.5 Model Library Index* for an alphabetical list of all our models and a reference to which library they can be found in. Advanced Wireless ALE/ASAPS Advanced Propagation Cellular Developer Information Assurance/Network Security Military Radios Multimedia and Enterprise Network Emulation Interface Satellite Sensor Networks Standard Interfaces TIREM Advanced Propagation Urban Propagation Advanced Propagation Wireless

Document Conventions

QualNet documents use the following conventions:

Book Title	The title of a book. On the web and on the Instant Information CD, it may be a hot link to the book itself.
`Command Input`	A command name or qualified command phrase, daemon, file, or option name.
`Command Output`	Text displayed by the computer.
Note:	Information of special interest.
`[]{}`	In syntax definitions, square brackets indicate items that are optional and braces indicate items that are required.
`Code Segment`	Segment of code from QualNet source files used for illustration.

`Added Code`	Example of code that the user should add to existing QualNet functions and declarations to add a custom model to QualNet. A vertical margin in the left column indicates new lines of code that need to be added.
Ellipses (`...`)	Ellipses are used to indicate lines of code from QualNet source files that have been omitted from an example for the sake of brevity.

More Information

This section describes how to contact us for more information on QualNet products and documentation. It provides links to helpful QualNet sites and information on getting in touch with QualNet.

- For more information on QualNet products, please contact QualNet Sales at sales@scalable-networks.com or visit the Scalable Network Technologies website (www.scalable-networks.com) and click on Products.
- For help on QualNet products, please contact QualNet Support at support@scalable-networks.com or visit the Scalable Network Technologies website (www.scalable-networks.com) and click on Training and Support.
- For help on QualNet documentation, please contact QualNet Support at support@scalable-networks.com or visit the Scalable Network Technologies website (www.scalable-networks.com) and click on Documentation.

CHAPTER 1

Introduction

Welcome to QualNet Developer! QualNet is a fast, scalable and hi-fidelity network modeling software. It enables very efficient and cost-effective development of new network technologies. By building virtual networks in a lab environment, you can test, optimize, and integrate next generation network technologies at a fraction of the cost of deploying physical testbeds.

The QualNet Product Tour is designed to give users a fast overview of the basic features of QualNet. It is intended for users with a basic understanding of computer networking. It uses the QualNet Graphical User Interface (GUI) for an integrated network simulation experience for network design, execution and animation, and analysis. Start using the Product Tour once QualNet has been installed.

QualNet is network modeling software that predicts performance of networking protocols and networks through simulation and emulation. Using emulation and simulation allows you to reproduce the unfavorable conditions of networks in a controllable and repeatable lab setting.

Key Benefits of QualNet

QualNet provides the following key benefits:

- Speed. QualNet can support real-time and faster than real-time simulation speed, which enables software-in-the-loop, network emulation, hardware-in-the-loop, and human-in-the-loop exercises.
- Scalability. QualNet supports thousands of nodes. It can also take advantage of parallel computing architectures to support more network nodes and faster modeling. Speed and scalability are not mutually exclusive with QualNet.
- Model Fidelity. QualNet offers highly detailed models for all aspects of networking. This ensures accurate modeling results and enables detailed analysis of protocol and network performance.
- Portability. QualNet runs on a vast array of platforms, including Linux, Solaris, Windows XP, and Mac OS X operating systems, distributed and cluster parallel architectures, and both 32- and 64-bit computing.
- Extensibility. QualNet connects to other hardware & software applications, such as OTB, real networks, and STK, greatly enhancing the value of the network model.

This tour begins with a high-level look at QualNet basics, including: how to start QualNet, how to create a network modeling scenario and analyze the statistics collected during the simulation - and then steps thru some of the advanced network modeling features in QualNet.

CHAPTER 2

Starting QualNet

Opening QualNet

This section shows you how to open QualNet in Windows, DOS, Linux, Solaris, and Mac OS X. Throughout the Product Tour QUALNET_HOME is used to refer to the directory where QualNet is installed on your computer.

Open in Microsoft Windows®

Double-click on the QualNet Developer GUI icon on your Windows desktop:

You can also launch QuaLNet Developer GUI from **Start > All Programs > QualNet 4.5 Developer > QualNet GUI**.

Open in DOS

1. Change the directory to %QUALNET_HOME%\gui\netbeans\bin.
2. Type runidew.exe and press the Enter button.

Open in Linux / Solaris/ Mac OS X®

1. Open a terminal or command-line window.
2. Type cd $QUALNET_HOME/gui/bin and press the Enter button.
3. Type runide.sh and press the Enter button

Figure 1 shows the screen that appears when QualNet successfully opens:

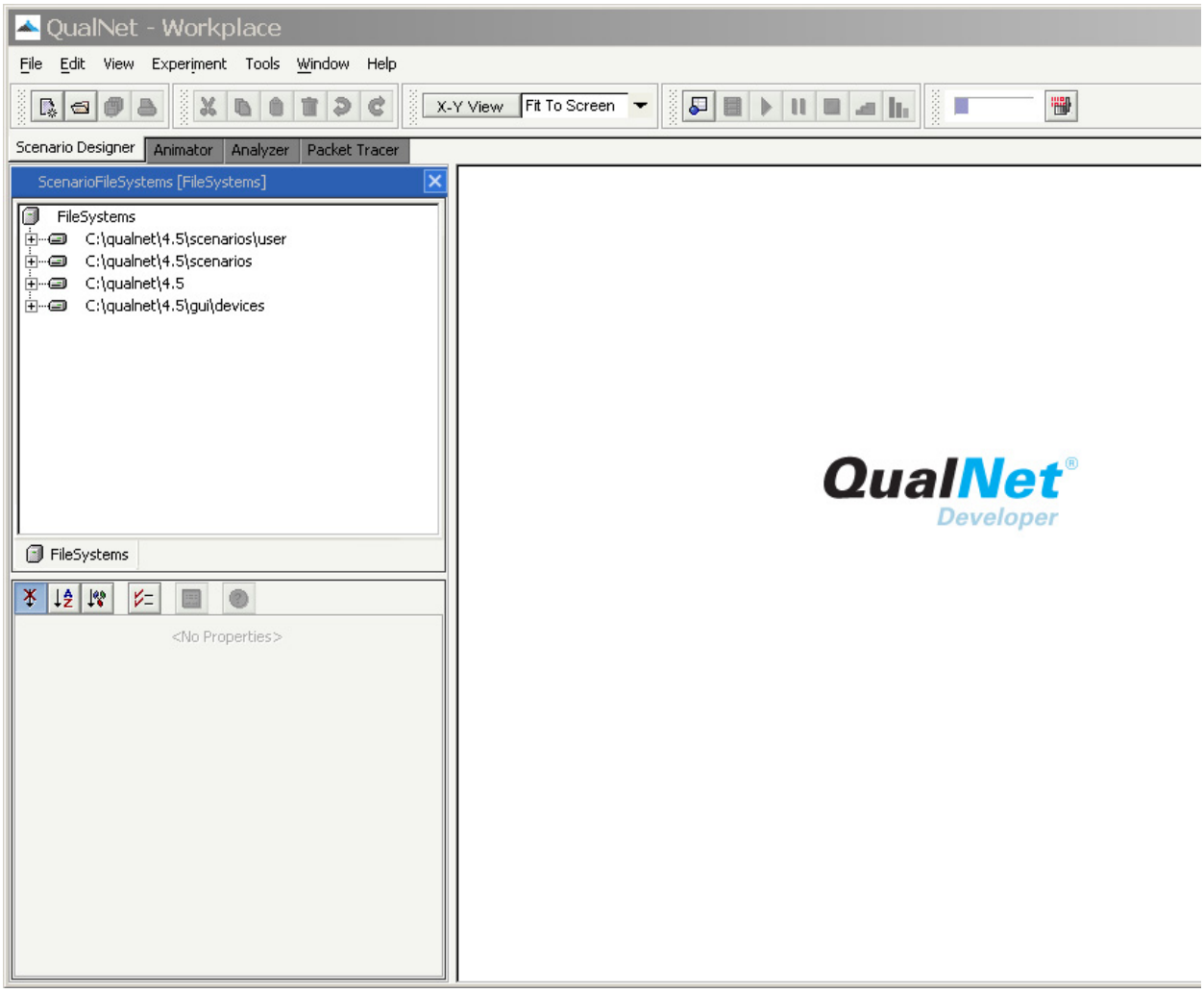

FIGURE 1. QualNet Opening Window

The rest of the Product Tour assumes that Microsoft Windows XP is the operating system and QualNet is installed in C:\qualnet\4.5. Users on other operating systems should change this to the directory where QualNet is installed on their computer.

QualNet GUI Layout

QualNet's user interface has four tools to provide a complete suite for modeling and analyzing communication networks. These tools can be accessed from the tabs at the top of the window. The four tools in QualNet's user interface are:

- Scenario Designer - Scenario Designer enables users to create and modify networking scenarios. It includes a comprehensive set of network components, and links and applications for modeling

networks. Users can configure all the elements of a scenario: terrain, mobility, radio type and parameters, and mac, network, transport and application layer protocols.

- Animator - Once a scenario is created, Animator allows you to run your simulation and provides various options to 'animate' various network events. It also allows you to control the speed of the simulation to clearly observe and analyze the scenario. You can also use animation filters to control the amount of information displayed.
- Analyzer - Analyzer enables graphical analyses of the statistics collected during the simulation. Using per-node and per-protocol model statistics users can better understand the implications of using particular protocols, parameter values and network architecture.
- Packet Tracer - Once a simulation scenario has been run or executed, tracing provides per-packet analyses of the simulation. Packet Tracer displays information about packet headers and fields in an organized way.

The tabs for these tools are located in the upper left area of the screen. The names and the information contained in the workspace windows change to match the functions of the current operation.

QualNet Simulator

The Animator uses the QualNet simulator as its processing engine to run a scenario. QualNet simulator is an advanced discrete-event simulator that enables fast, scalable, and hi-fidelity modeling of networks.

The QualNet simulator can also be run from command-line. This enables advanced protocol designers and network modelers/planners to use other command-line tools like shell scripts and remote execution to quickly modify and execute the scenarios with different parameter and model values. The command-line mode also runs a lot faster since the graphical events do not have to be animated, but produces the same results as the Animator since both use the same simulation engine. Analyzer and Packet Tracer can still be used for detailed analyses of the simulation results after the simulator has run. Figure 2 shows the most commonly used toolbars and menus in QualNet GUI.

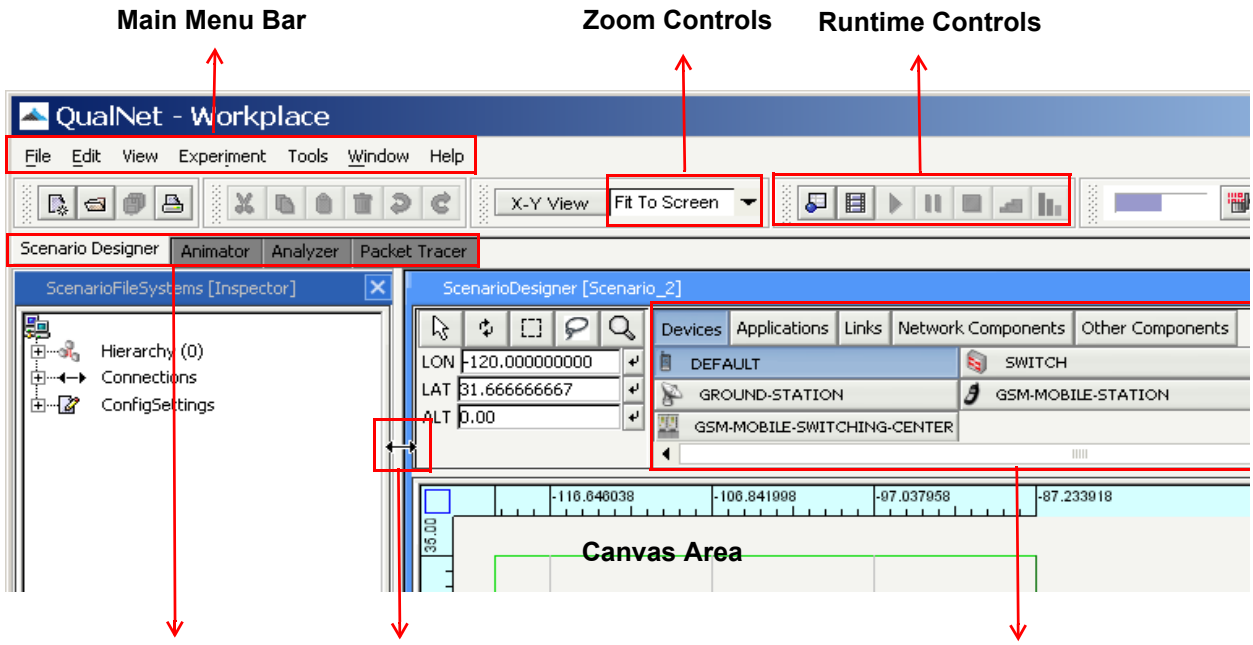

FIGURE 2. Menu Bar and Tool Bars

CHAPTER 3

Creating Scenarios

Chapter 3 shows how to create a new scenario using Scenario Designer. We create an example scenario using the default values configured in QualNet. By default, nodes are configured as IEEE 802.11 (WiFi) wireless nodes. In later sections we run the scenario, analyze the statistics, and modify the scenario.

Creating a New Scenario

Follow these steps to create a new scenario and see Figure 3:

1. Start by clicking on the **File New** menu option, or pressing the  button in the upper left hand corner of the screen.
2. In the **New Wizard** select **Templates > Scenario > Scenario.scn**.

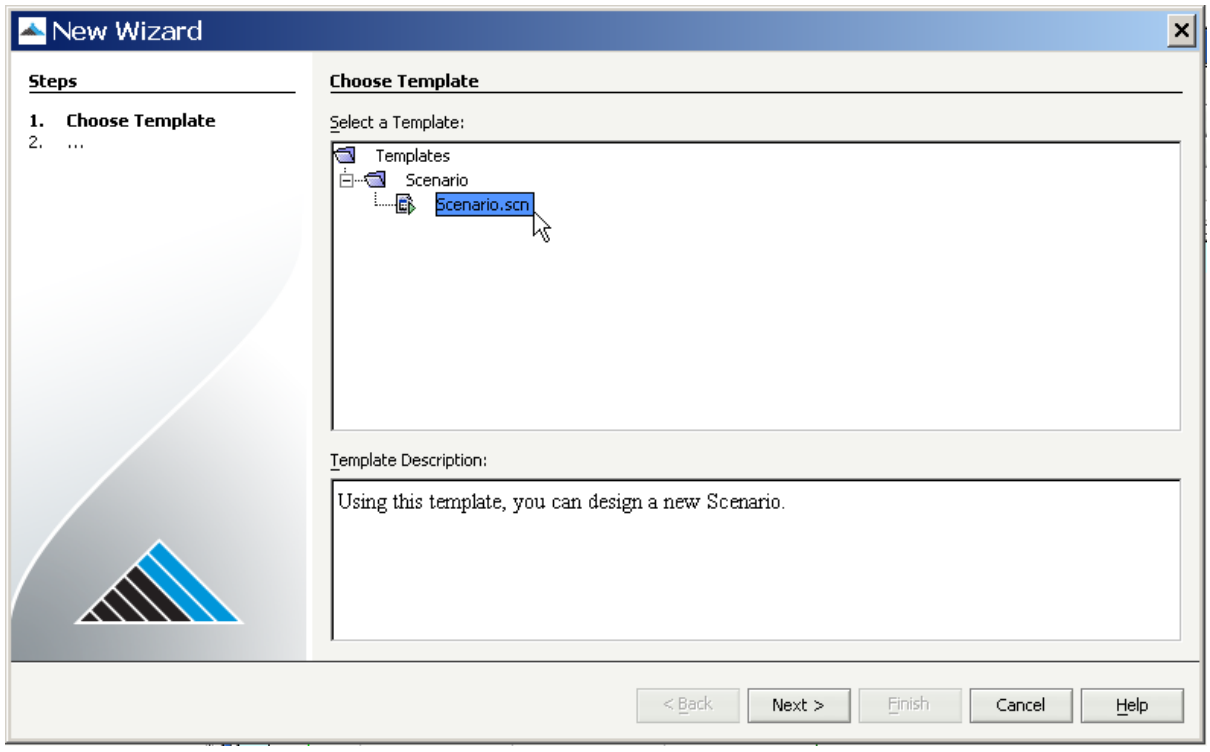

FIGURE 3. **New Scenario Creation**

3. Click **Next** to continue.
4. Ensure that C:\qualnet\4.5\scenario\user is selected as the directory. This is where user created scenarios should be saved. Other pre-created scenarios bundled with QualNet are available in the C:\qualnet\4.5\scenarios directory.
5. Type **Example** to name your scenario, replacing **<default name>** in the **Name** field at the top.
6. Click **Finish**. See Figure 4.

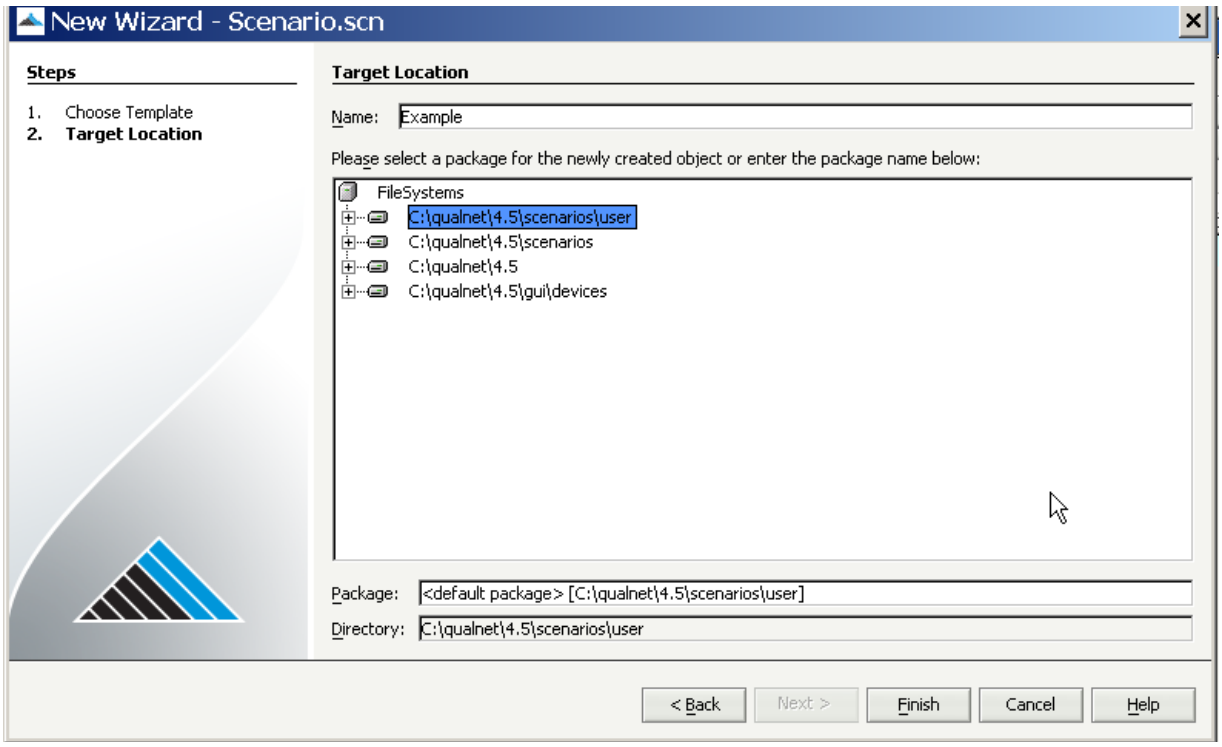

FIGURE 4. Naming a New Scenario

A blank canvas appears on the right side of the screen with the name of the scenario, **Example** on the title bar of the window.

Figure 5 will help you configure the following steps.

7. In the **ScenarioFileSystems** window, click on the **Inspector** tab, click on the '+' icon next to **ConfigSettings** to expand the list of globally configurable properties.

   The **Hierarchy** property allows you to set per-node properties. The **Connections** property allows you to modify the properties of links and applications. We will explore these later in the Product Tour.
8. Expand **General** property and click on **General** sub-property.
9. In the property sheet **ScenarioFileSystems**, click on **QualNet** (opposite **Experiment Name**) and change it to **Example**. This will ensure that statistics collected during the simulation are stored in a file named **Example<run#>.stat** in the **Example** directory.
10. Click on the **FileSystems** tab in the left window to reveal the folders and files.

11. Click on **+** icon next to the **Example** folder to see the files created for the scenario.

    The **FileSystems** window on the left shows the creation and placement of the new **Example** scenario folder and files in the scenario. New files related to this scenario are automatically created and stored in this directory. Files will also be automatically created or updated in this directory every time you execute the scenario.

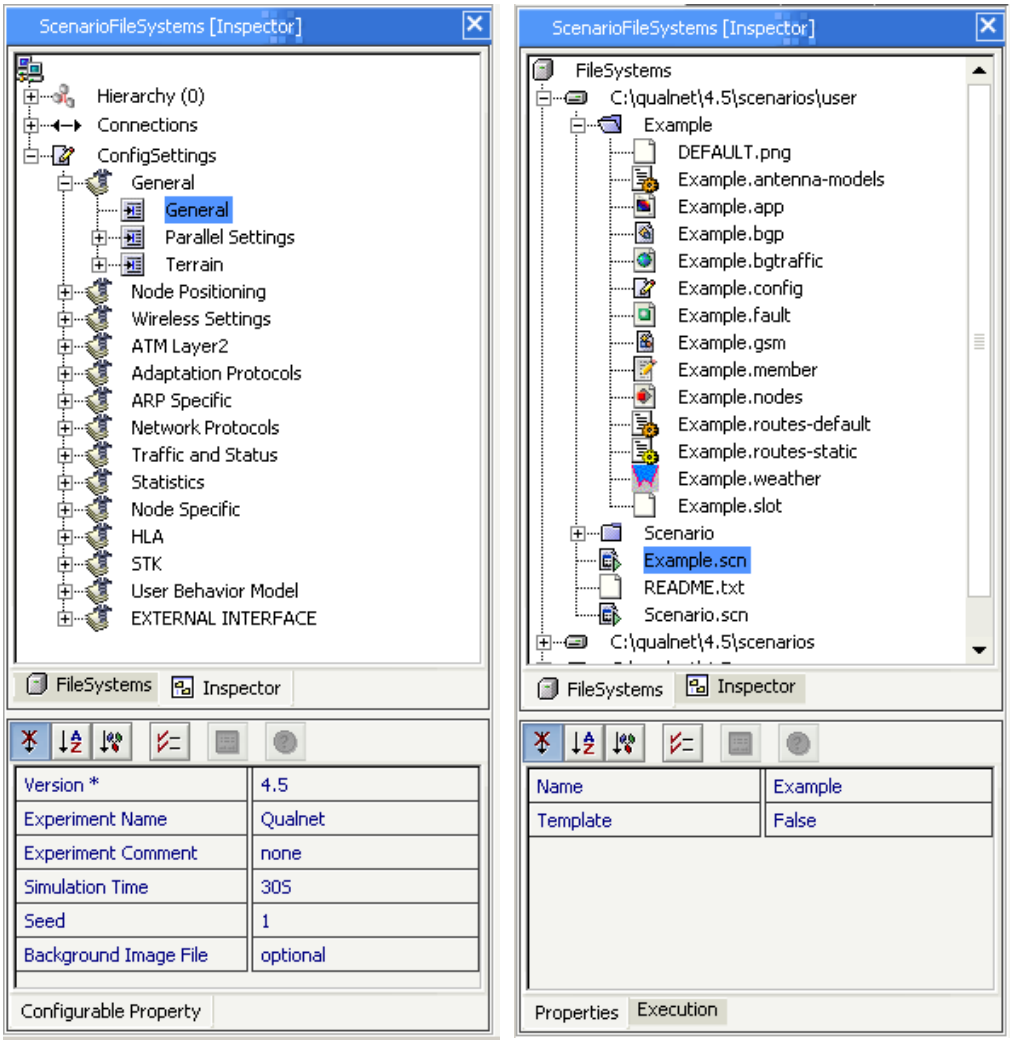

FIGURE 5. Inspector and FileSystems Windows of the Example Scenario

Adding Nodes

1. To add nodes to the scenario canvas, click on the **Devices** tab in the Components Tool Bar at the top. The **DEFAULT** node type is pre-selected. See Figure 6.

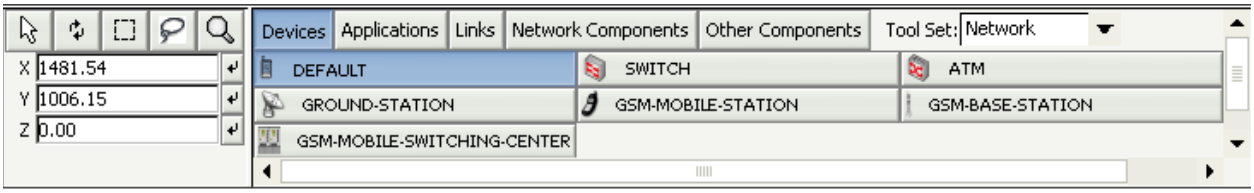

FIGURE 6. Selecting a Node Type

2. Click on the canvas to create and place nodes as shown in Figure 7.
3. If needed, you can click on  button to move nodes.
4. Once you are finished placing or moving the nodes, click on the  button to go into select mode.

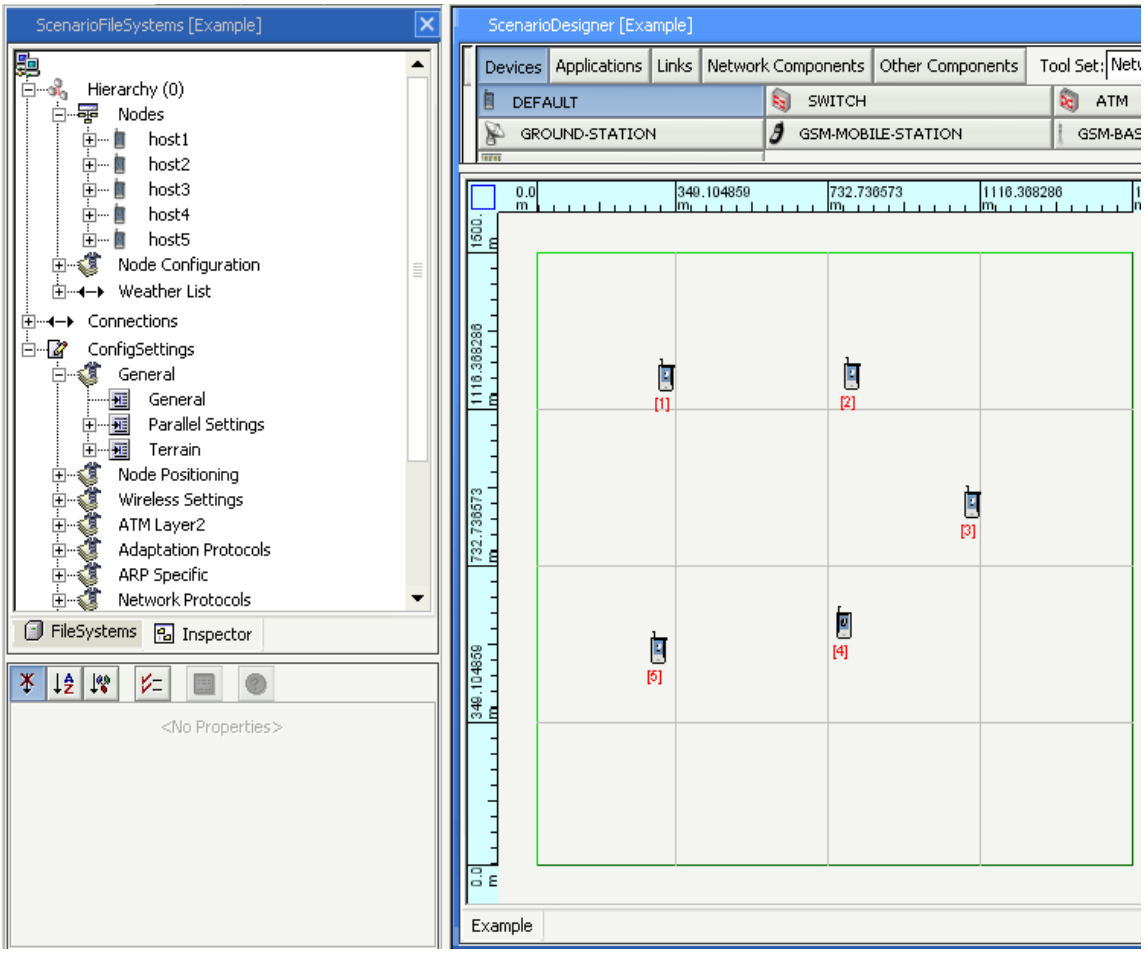

FIGURE 7. Placement of Nodes

Adding Links

1. Add a wireless subnet by clicking on the **Network Components > Wireless Network** button and clicking between the nodes to place it. A cloud icon appears, representing a wireless subnet. See Figure 8.

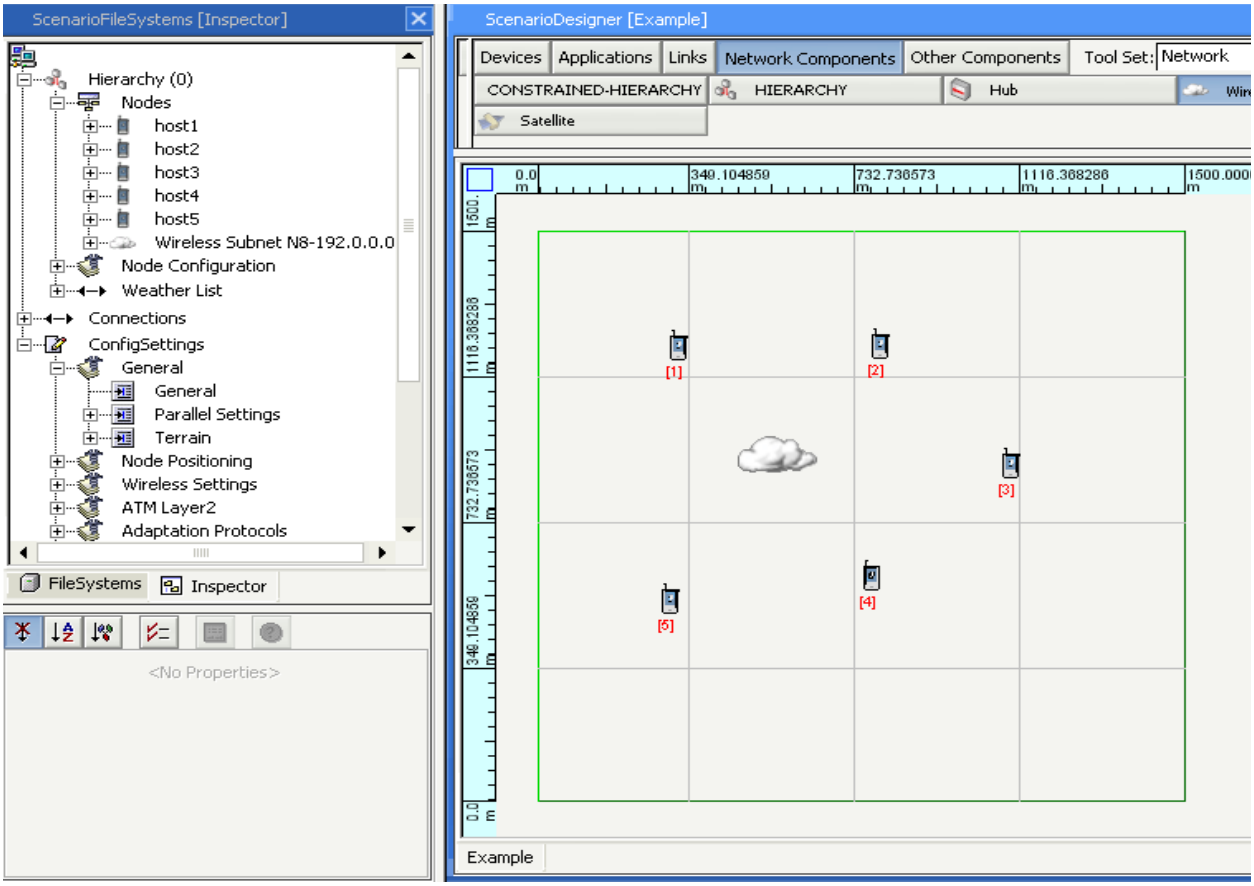

FIGURE 8. Adding a Wireless Subnet

2. Click on the **Links** tab > **Link** button to start building the wireless subnet.
3. Connect node 1 to the subnet cloud by clicking on it and dragging the mouse to the cloud icon. Green dashed lines will appear to indicate a wireless link.

   Repeat the process to connect the other nodes to the subnet. See Figure 9.

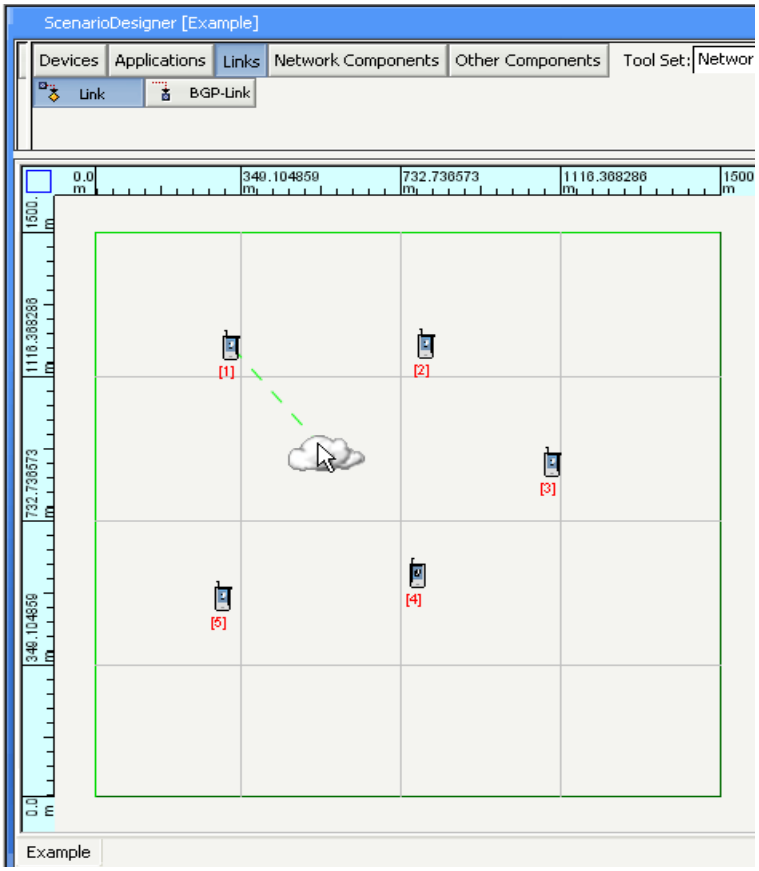

FIGURE 9. Adding Wireless Links

Adding Applications

1. Click on the Applications tab FTP/GENERIC button.
2. Click on node 1 to select it as the source and drag the mouse to node 2 to select it as the destination for FTP traffic.
3. Click on the  button in the left top of the screen to save the scenario.

   Scenario Designer will save the settings into **Example.scn** - scenario configuration file for QualNet Developer GUI. See Figure 10.

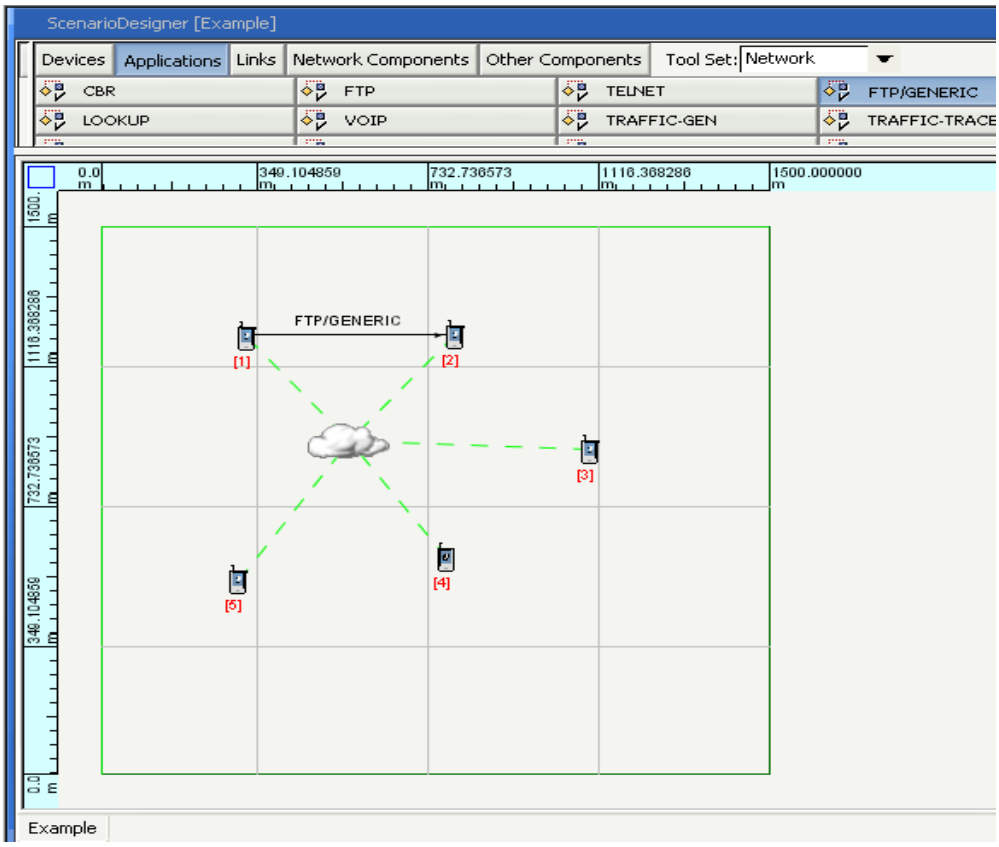

FIGURE 10. Adding Application Layer Traffic

CHAPTER 4

Running Scenarios

Animator allows you to run a network scenario and provides various options to 'animate' various network events like: radio transmissions, packet receptions, mobility and queues.

Running the *Example* Scenario

Use the following steps to run the Example scenario you just created in Scenario Designer:

1. Click on the **Run** button at the top of the window to load the scenario into Animator. This initializes all the nodes with their configured protocols.
2. Drag the **Speed** slider half-way left to slow down the speed of simulation. This allows you to clearly observe the network events. See Figure 11 and Figure 12.

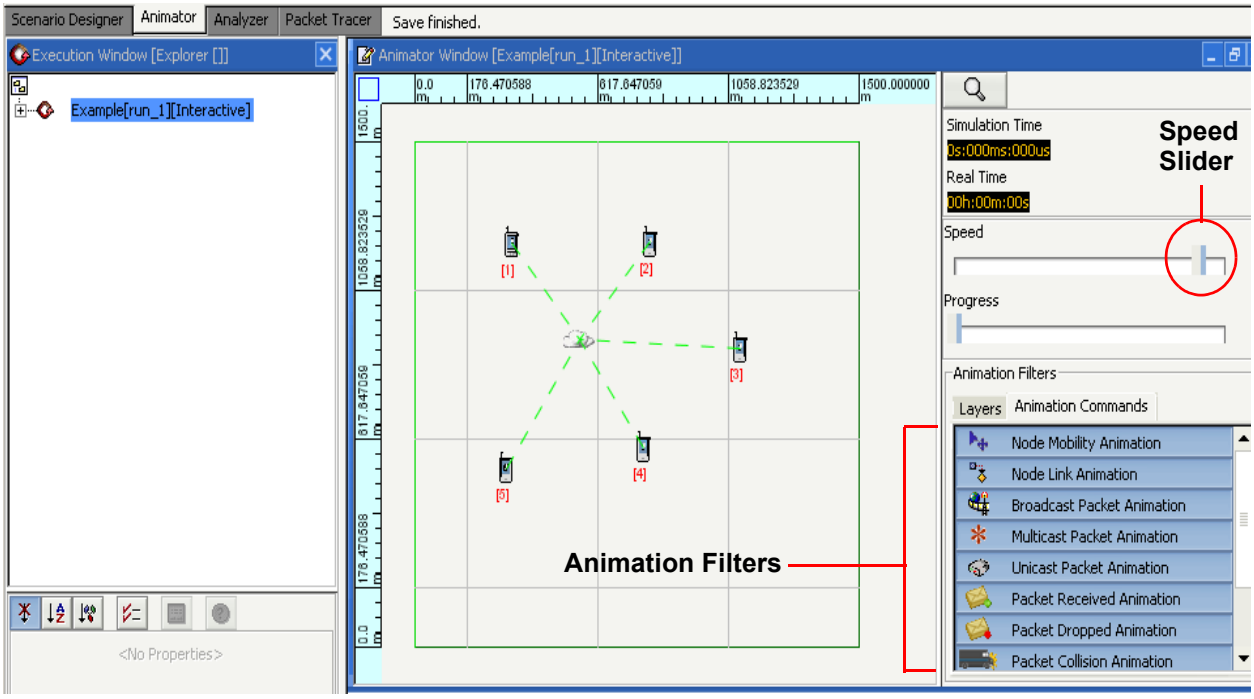

FIGURE 11. Running a Scenario in Animator

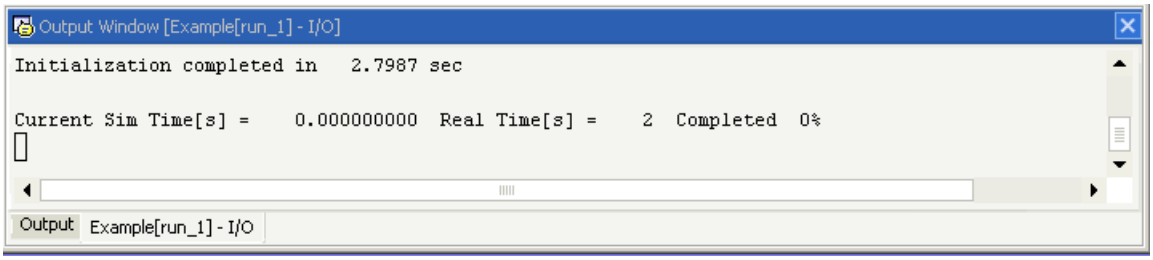

FIGURE 12. Output Window

3. Click on the **Play** button  to start Animator. The blue circles show radio transmissions; the size of the circles show the approximate range of radio transmissions. The green arrows show packet receptions. The display of such animation can be controlled by Animation Filters in the right bottom side of the window.

4. If you want to run the simulation again, click on the **Scenario Designer** tab, click on the  button to re-load the scenario in Animator, and then click on the  button.

CHAPTER 5 Analyzing Statistics

QualNet allows you to collect statistics at every protocol layer. By default, QualNet collects statistics for the physical, mac, transport, network and application layers. You can enable/disable statistics collection on a per-layer or per-protocol basis. Once Animator finishes running the simulation, the Analyzer button becomes active. To analyze the statistics collected for the Example scenario follow the steps below:

1. Click on the  button to load statistics in Analyzer, or Expand **FileSystems > Example** directory, and double-click on **Example<date stamp>.stat**.
2. You can click on any of the statistics tabs: Physical, MAC, Network, Transport or Application to analyze them. See Figure 13.

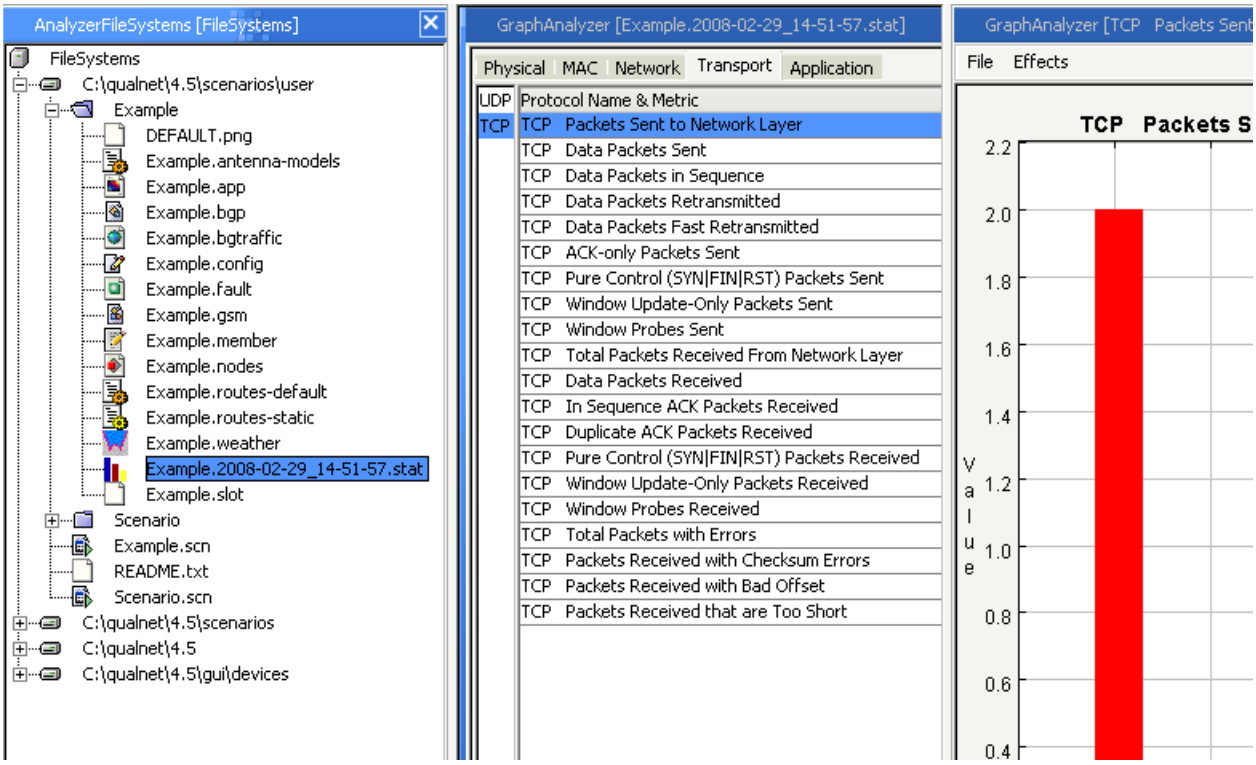

FIGURE 13. Analyzer - TCP Statistics

This figure shows TCP Packets Sent to Network Layer (from the transport layer) by each of the nodes. As expected, nodes 1 and 2 have the only packets since they were involved in the FTP traffic.

CHAPTER 6

Tracing Packets

Packet Tracer is a QualNet tool that lets you view packet-specific information. It displays information about packet headers and fields in an organized way. The header-specific information is shown in a tree format, while the packet-specific information is shown in a table format. The Packet Tracer tool is accessed by the **Packet Tracer** tab. Trace files created by QualNet can be accessed through the **FileSystems** window.

Setting Up Packet Tracer

1. Load the Example scenario (**Example.scn**) using the **ScenarioFileSystems > FileSystems** window from the C:\qualnet\4.5\scenarios\user directory.
2. Expand **ConfigSettings > Traffic and Status > Tracing > Packet Tracing Enabled?** in the **Inspector** window.
3. Click **Yes** for **Packet Tracing Enabled?** in the Properties window shown in Figure 14.

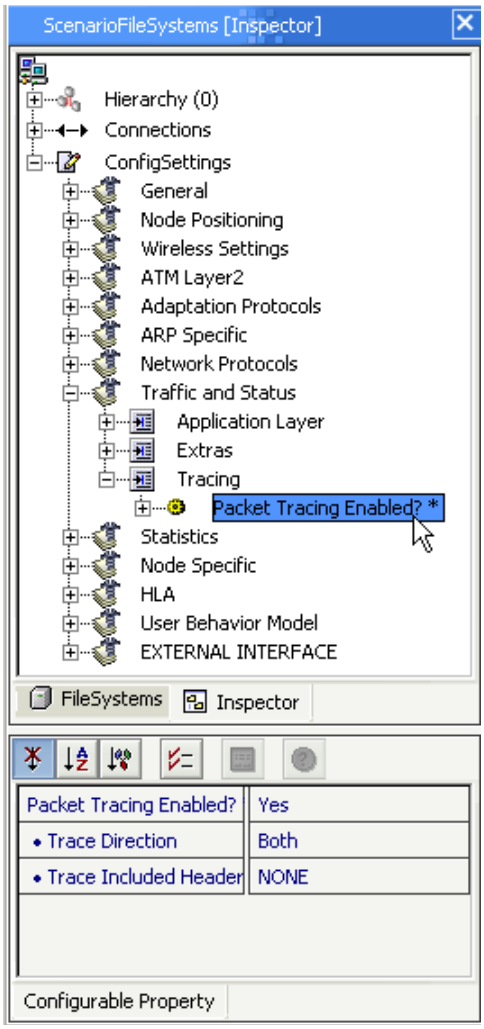

FIGURE 14. Enable Packet Tracing

4. Press the **Run** button to load the simulation.
5. Press the **Play** button to start the simulation.
6. Once the simulation finishes, click on the **Packet Tracer** tab.
7. Load **Example.trace** by browsing to C:\qualnet\4.5\scenarios\user\Example directory. If you did not rename the scenario's Experiment Name property in step 9 of Chapter 3, the trace file will be called Qualnet.trace.
8. Double-click on it to open it in Packet Tracer.

Clicking on one of the rows of data provides details for that packet. Figure 15 shows details of a TCP packet. For the Example scenario, Packet Tracer has collected traces for IP, TCP and UDP protocols.

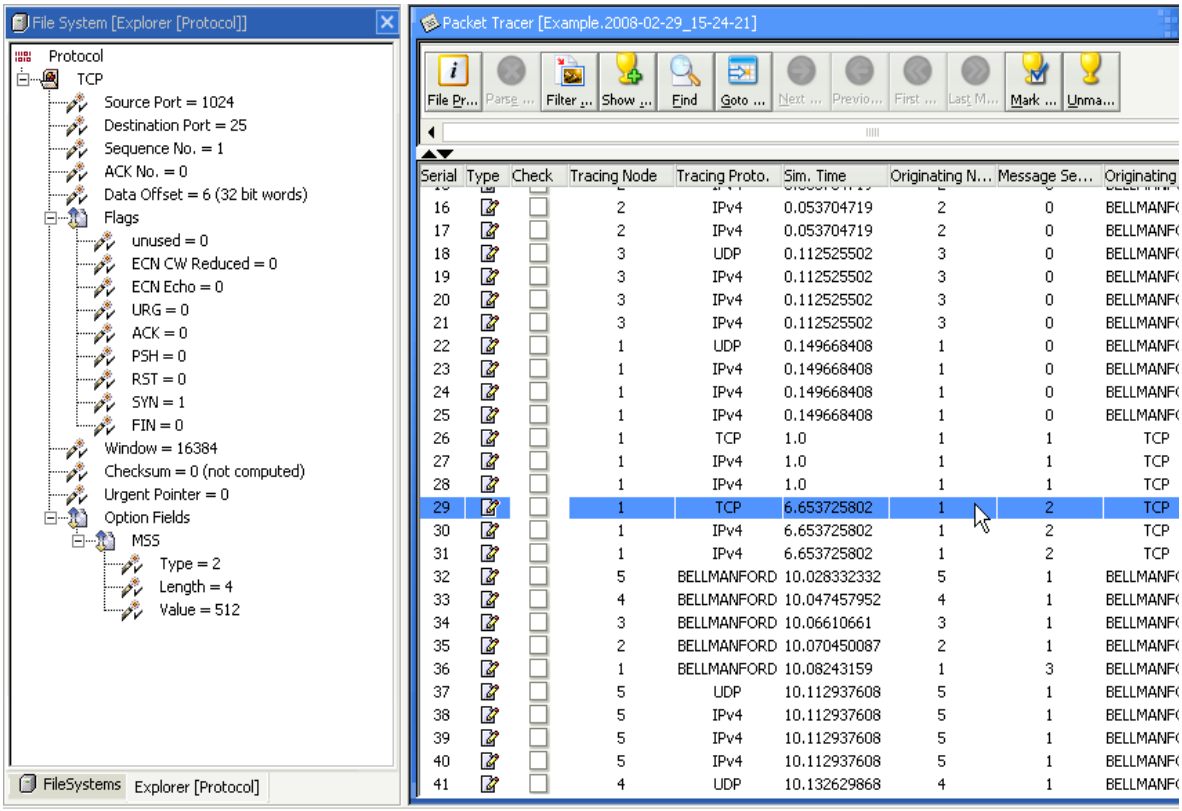

FIGURE 15. Packet Tracing

9. You can also use the various Packet Filter features via the buttons at the top, including:
   a. Filtering by protocol.
   b. Text search for a protocol or packet.
   c. Sorting packets by origin, destination, protocol, simulation time, packet sequence number, protocol state.

CHAPTER 7

Advanced Network Modeling

So far in the Product Tour you have created a simple scenario, executed it, analyzed the statistics and traced the packets. Now let's use the advanced features of QualNet to create more sophisticated scenarios.

Semi-automated Node Placement

1. Create a new scenario file as described in "Creating a New Scenario", in Chapter 3 of this book. Name the new scenario **Example2**. Be sure to modify the **Experiment Name** to be **Example2**. See step 9 of Creating a New Scenario for more details.
2. Save the scenario by clicking on  the button.
3. In the main menu bar select **Experiment > Place Nodes**. The Automatic Node Placement Wizard now guides you through the parameters so that nodes are placed automatically, instead of manually.

   Note: If Experiment Place Nodes is grayed out in the main menu bar, click on the canvas to refresh the program.

4. Type 36 in the Number Of Nodes field. See Figure 16.

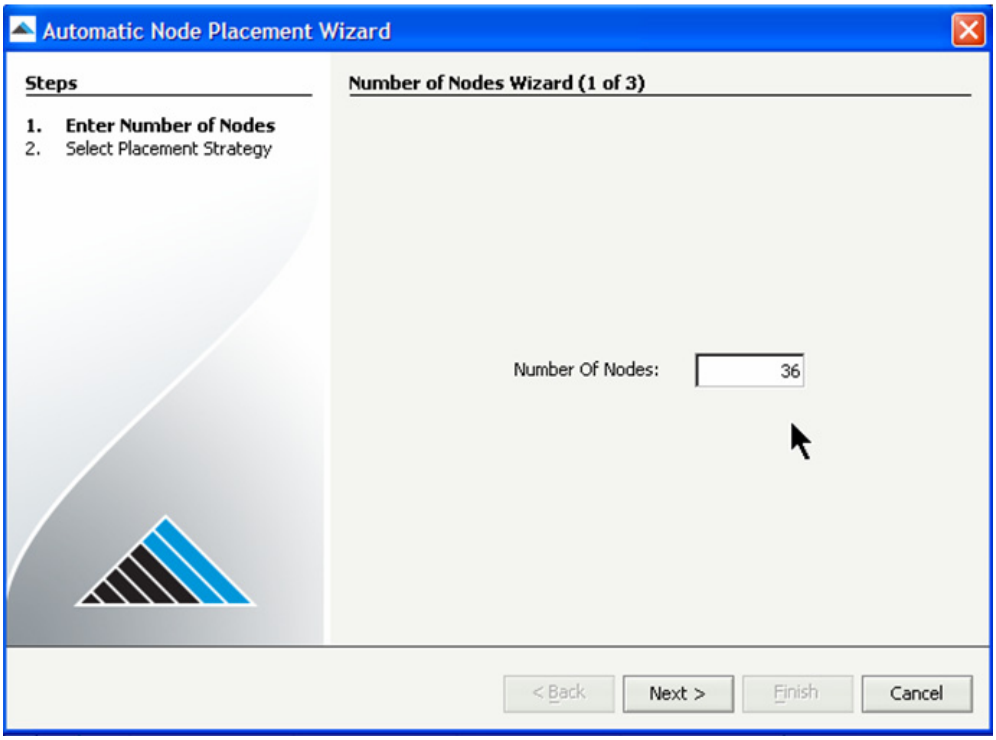

FIGURE 16. Automatic Node Placement

5. Click **Next** and select **Grid** as the node **Placement Strategy** from the drop down list that also has options for **Uniform** and **Random** node placement.
6. Click **Next** and type **300** in the **Grid Unit** field. This is the distance between two nodes, in meters.
7. Click **Finish**.

You will see 36 nodes automatically populate the canvas in a grid pattern.

Connecting Multiple Nodes

Now let's set the properties of a group of nodes instead of setting them individually.

1. Click on the Select Region button  .
2. Click on the right-bottom corner side of node 26 and drag the mouse to the left-top corner as shown below. All four nodes (25, 26, 31 & 32) are now selected.

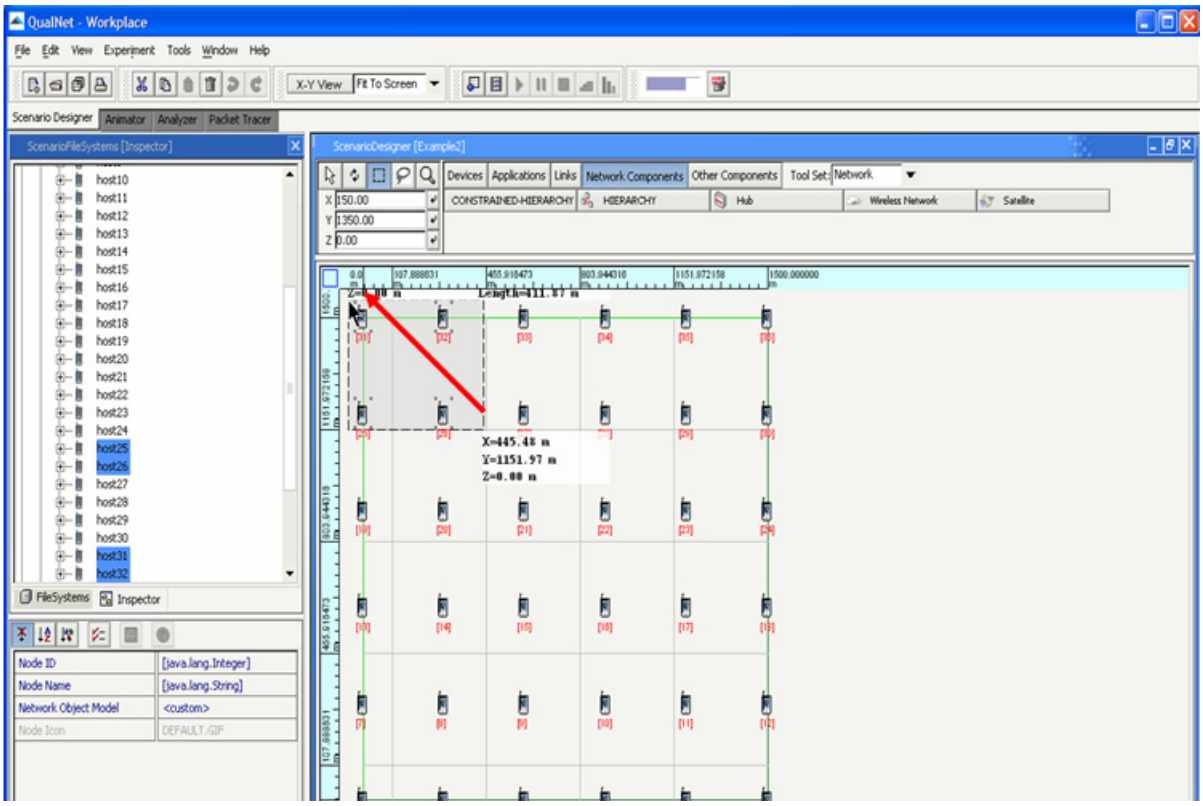

FIGURE 17. Selecting a Group of Nodes

3. In the **Network Components** tool bar click on **Hub** and then click in the center of the selected region. All the nodes in the selected region will automatically be connected to this hub.

The hub represents an IEEE 802.3 wired subnet. You can check for this by clicking on **ScenarioFileSystems > Hierarchy > Nodes** and then scrolling down to check on the properties of the subnet. See Figure 18.

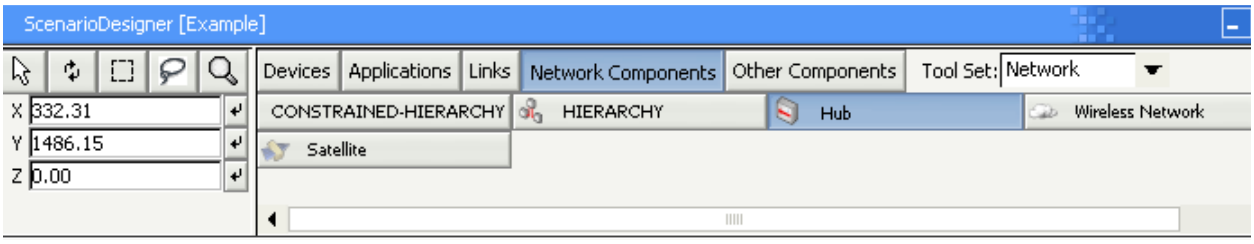

FIGURE 18. Network Components Toolbar

4. Similarly, select an area on the bottom right corner and connect nodes into a wireless subnet.

5. To go into the normal selection mode click on the **Select** button and then select any node from **ScenarioFileSystems > Hierarchy** window.
6. Select **Applications > CBR** (Constant Bit Rate) as the traffic type from the Components Tool Bar.
7. Select node 1 and while holding down the mouse select node 36 to set up a CBR session between the two nodes.
8. Save the scenario by clicking on the **Save** button.

Compared to the method we used to connect the nodes in the Example scenario, this is a much faster way of setting the properties of nodes. You can also use the **Select Irregular Region** button to select a group of nodes in any particular fashion.

Batch Execution

We will now use batch execution to run the same scenario with different mobility models.

1. In the **FileSystems** window right-click on **Example2** scenario and select **Run Batch Experiment**. See Figure 19.

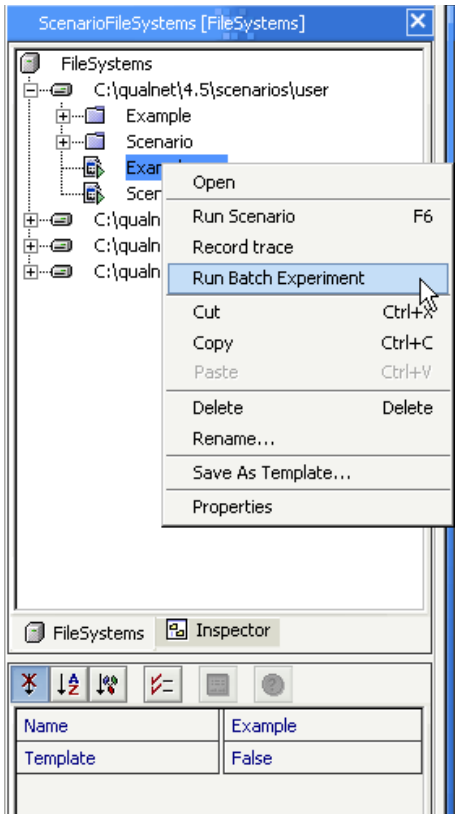

FIGURE 19. Run Batch Experiments

The Batch Experiment Setup Option wizard appears and gives you the option of specifying the number of experiments or a range of values. If you choose to specify the number of experiments, you are prompted to supply the specific variables for each experiment that runs. If you choose the range of

values option, you will select variables and their respective values, and QualNet will run every possible combination.

2. Click **Specify range of values for each variable and run all possible combinations**, which is the second option in the wizard. See Figure 20.

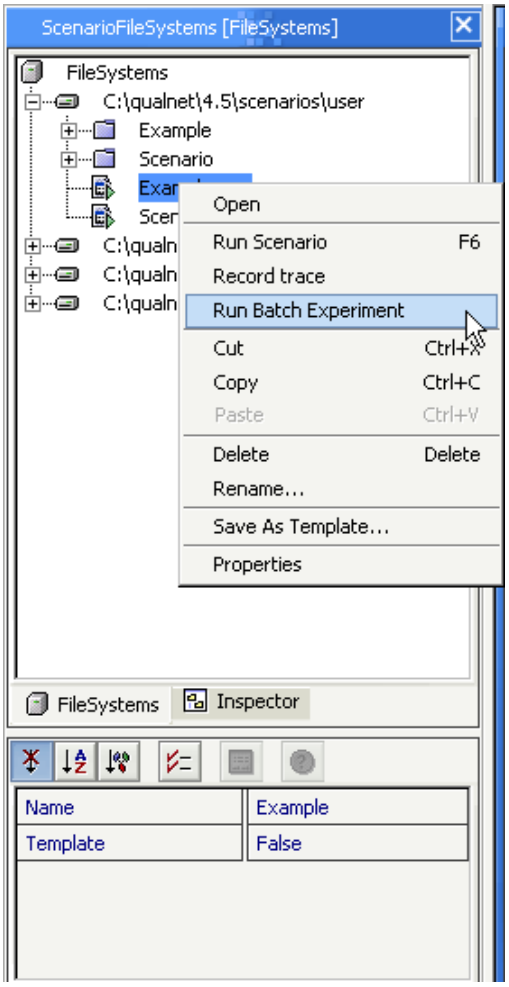

FIGURE 20. Batch Experiment Setup

3. Click **Next** and browse to **ConfigSettings > Node Positioning > Mobility > Mobility Model**.

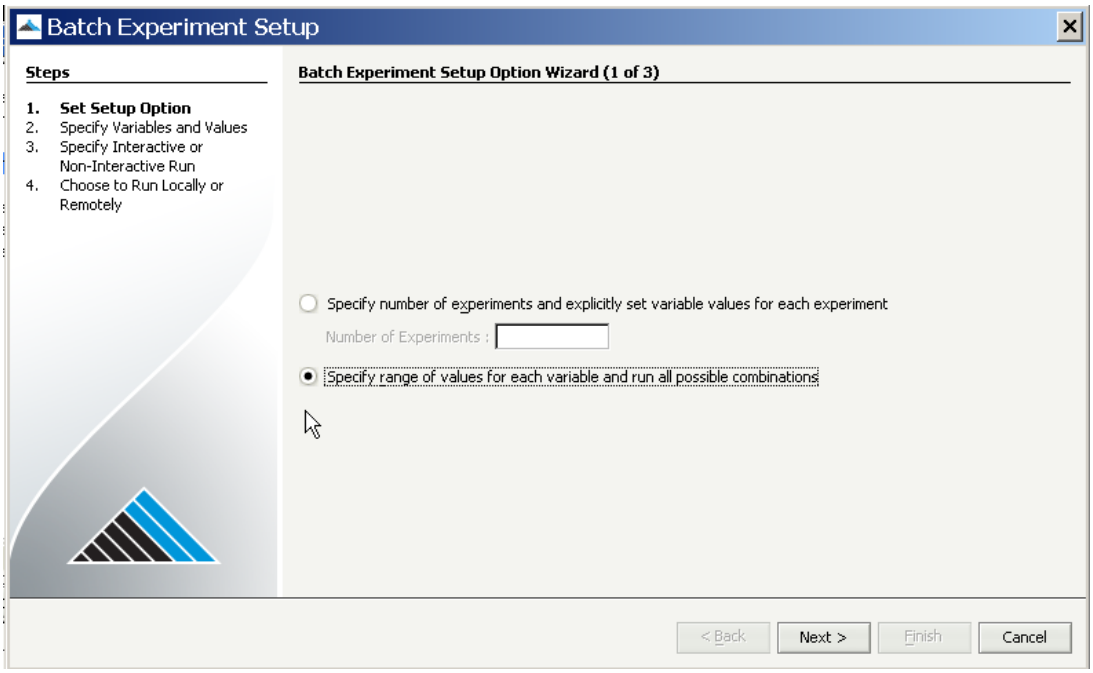

FIGURE 21. Batch Experiment Setup - Mobility Model

4. Press **Add** button to add **Mobility Model** as a variable in the dialog box.
5. Click on **Values** in the dialog box and the value button will appear.
6. Click on this button to set values for mobility model.

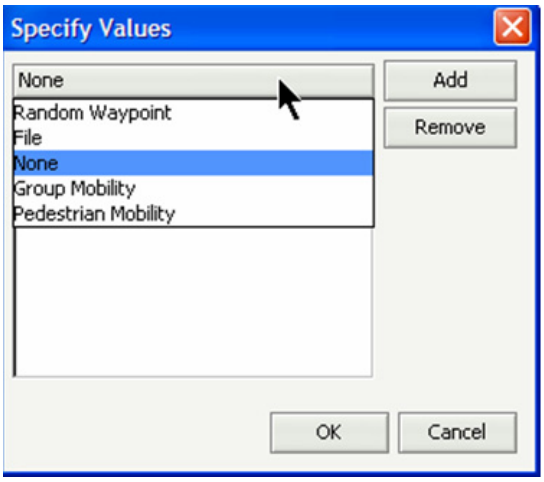

FIGURE 22. Batch Experiment Values

7. Select **None** and click on **Add**. This adds a no mobility model to the batch experiment setup.
8. Select **Random Waypoint** and click on **Add**.
9. Click on **OK** to continue.
10. Select **Run Interactively**. QualNet Animator will load up and you can now run **Example2** scenario with no mobility and then random waypoint mobility.
11. Click on the **Play** button to start Example2 with no mobility
12. Once the first run finishes, click on the **Play** button to start Example2 with random waypoint mobility.

You may want to slow down the speed of animation by using the Speed property in the Animator to clearly observe the effects of mobility and packet routing.

Analyzing Multiple Statistics Files

QualNet Analyzer allows you to compare multiple statistics files side-by-side to analyze the differences. For the Example2 scenario you can now see the impact of wireless mobility on the packet delivery ratio.

1. Click on the **Scenario Designer** tab.
2. Expand the Example2 directory from the **ScenarioFileSystems >** C:\qualnet\4.5\scenarios\user\ directory.
3. Click once on **Example2_Mobility ModelNode.stat** and then holding down the **Ctrl** key click on **Example2_Mobility ModelRandom Waypoint.stat**.
4. Right-click and select Analyze to load both the files into Analyzer for side-by-side comparison. See Figure 23.

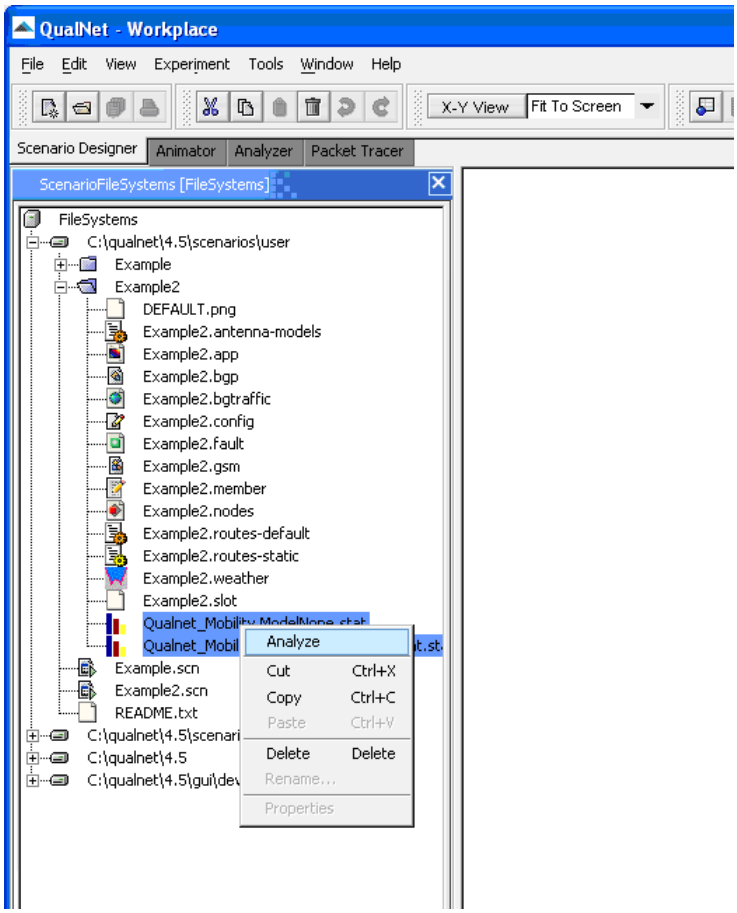

FIGURE 23. Selecting Multiple Statistics Files for Analysis

Figure 24 shows lower throughput for the random waypoint execution (second column) since mobility causes out of range transmissions and routing problems.

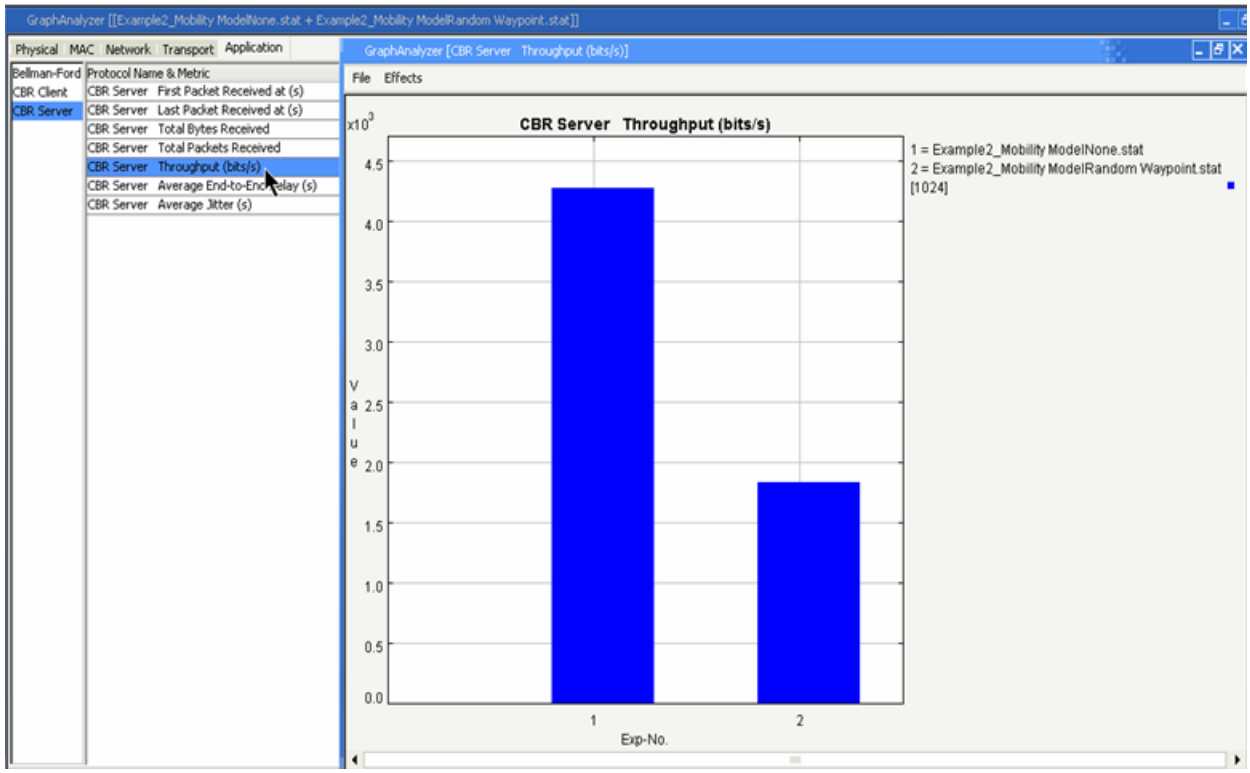

FIGURE 24. Analyzing CBR Throughput for Multiple Statistics Files

CHAPTER 8

Demonstration Scenarios

Opening & Running Existing Scenarios

Chapter 4 explained how to run a scenario that is already loaded in the Scenario Designer. This section describes how to open and run existing scenario files. Scenarios are either user-created or those included with QualNet. The scenarios included in QualNet demonstrate the capabilities of various communications protocols like 802.11 (WiFi), 802.16 (WiMAX), and hybrid networks.

User-created scenarios are typically saved in the QUALNET_HOME\scenarios\user directory.

Scenarios included in QualNet are:

1. Demonstration scenarios located in QUALNET_HOME\gui directory.

   These are scenarios created with the QualNet GUI and have a filename extension of '.scn'. These files can be directly modified in the Scenario Designer and can only be run in QualNet GUI.
2. Library specific scenarios located in QUALNET_HOME\scenarios\<library name> directory

   These scenarios are available only if the particular library has been purchased. Evaluation versions of QualNet include models from a number of libraries like Wireless, Multimedia & Enterprise and Advanced Wireless (WiMAX).

Some of the scenarios in this section use models that all customers may not have purchased. The evaluation version of QualNet includes all the models necessary to run the scenarios discussed here. QualNet customers who did not purchase a model discussed here are invited to test the evaluation version (available for free at our website).

High Speed Mobility Scenario

This scenario includes six mobile nodes two relay station towers and a hierarchy of nodes. The mobile stations use 802.11b radios while they move around a surface path or freeway at high speeds (around 100 kmph). The mobiles (nodes 1 through 6) use the relay stations (nodes 7 and 8) as their network access

points for a variety of applications like Telnet, Video (approximated by a constant bit rate session), and FTP.

Opening Scenarios: High Speed Mobility

1. In Scenario Designer click on the 'FileSystems' tab on the lower left to browse through the computer's file system
2. Expand the QUALNET_HOME\scenarios\gui directory. You will see a list of directories and scenario files (with .scn extensions).
3. Double-click on 'HighSpeedMobility.scn' to load it in Scenario Designer.

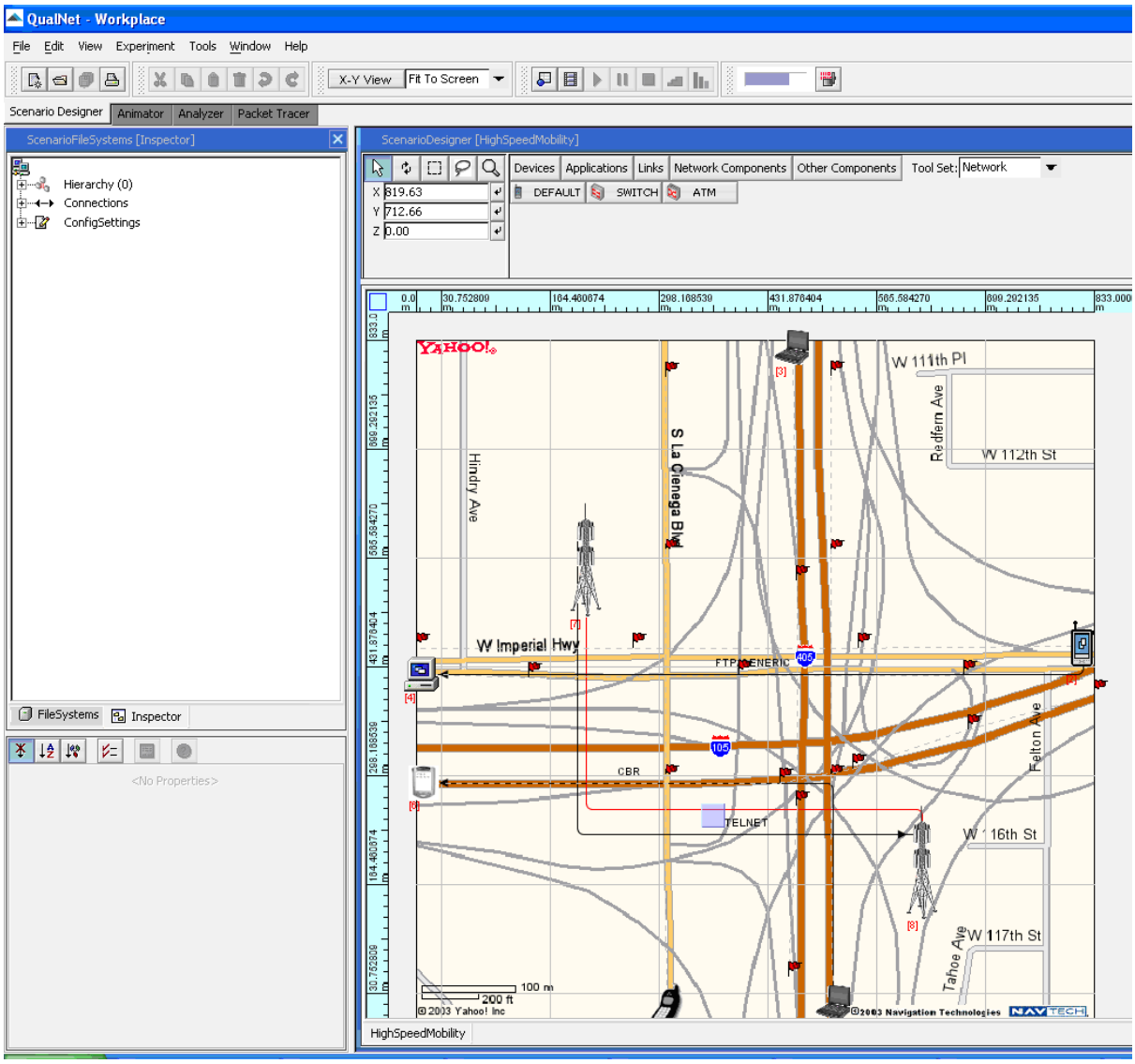

FIGURE 25. Opening the 'HighSpeedMobility.scn' Scenario

The two relay stations are connected by a complex wired network representing the backhaul of a service provider. This complex wired network is represented by a hierarchy that is only visible as a small purple box in the scenario. To see the details of the hierarchy click on its icon  and press 'o' on the keyboard. To close the hierarchy click on 'c'. The red flags in the scenario show the mobility path of the various nodes.

You can now explore the details of this scenario, for example to see the properties of a particular application between two nodes click on the application traffic link between them. To see the configuration of a particular node, click on it and expand its properties in the ScenarioFileSystems window on the left side.

To run this scenario click on the button at the top of the window and once the scenario has executed you can analyze its statistics by clicking on the button.

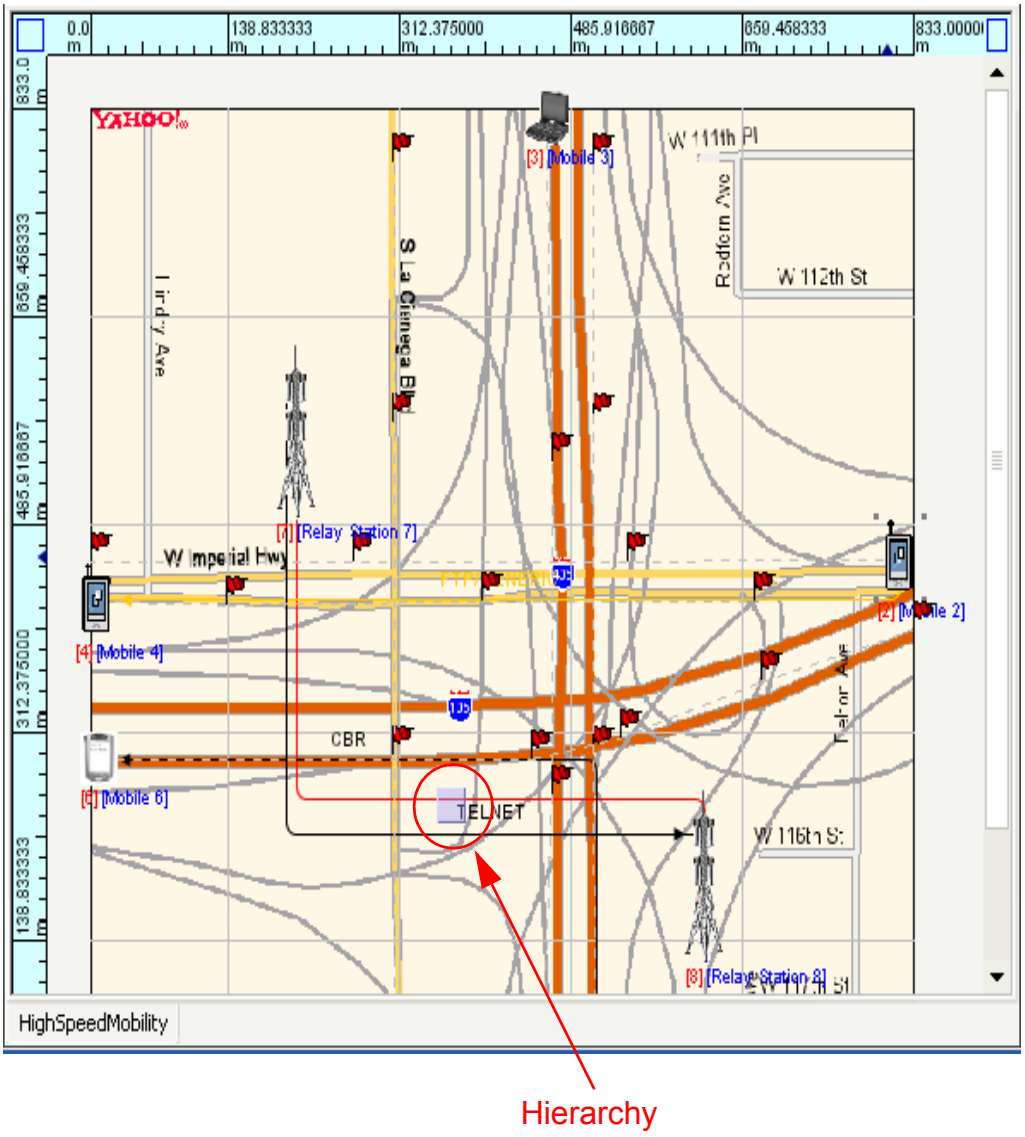

FIGURE 26. High Speed Mobility Scenario Details

WiMAX Scenario

The WiMAX models are part of the Advanced Wireless library. This scenario demonstrates the handover functionality of the IEEE 802.16e standard. It uses a large 40 x 30 km terrain with four base stations that provide coverage along a freeway path. A mobile station moves along the freeway path and maintains a

400 kbps video connection (approximated by a CBR traffic session sending 512 byte packets every 0.01 seconds) during this period. Note: 512 x 8 x 100 = 409.6 kbs.

Opening Scenarios: WiMAX Scenario

1. In Scenario Designer click on the 'FileSystems' tab on the lower left to browse through the computer's file system
2. Expand the QUALNET_HOME\scenarios\advanced_wireless directory. You will see a list of directories and scenario files (with .scn extensions).
3. Double-click on 'WiMAXHomeToOffice.scn' to load it in Scenario Designer.
4. To run this scenario click on the  button at the top of the window.

The red flags indicate the path of mobile station node 5 (named 'SS 5' in the scenario). Once the simulation is running, green arrows show the packet receptions and the mobile node will undergo handover when it passes from the coverage area of base station 1 to base station 2. It will experience similar handovers when passing into the coverage area of the other base stations. The blue circles showing radio transmissions will generally inundate the scenario because WiMAX base stations have a lot of periodic broadcast messages. To turn off these transmissions you can click on the "Broadcast Packet Animation" button on the right side of the Animator window as shown in the figure below.

Once the simulation has been executed we can check on some of the simulation results in Analyzer by clicking on the  button:

1. To check application layer throughput: click on Applications ' CBR ' CBR Server ' CBR Server Throughput (bits/s). You can see the throughput of about 400 kbps.
2. To check on the number of handovers: click on MAC ' 802.16e ' 802.16e Number of handovers performed.

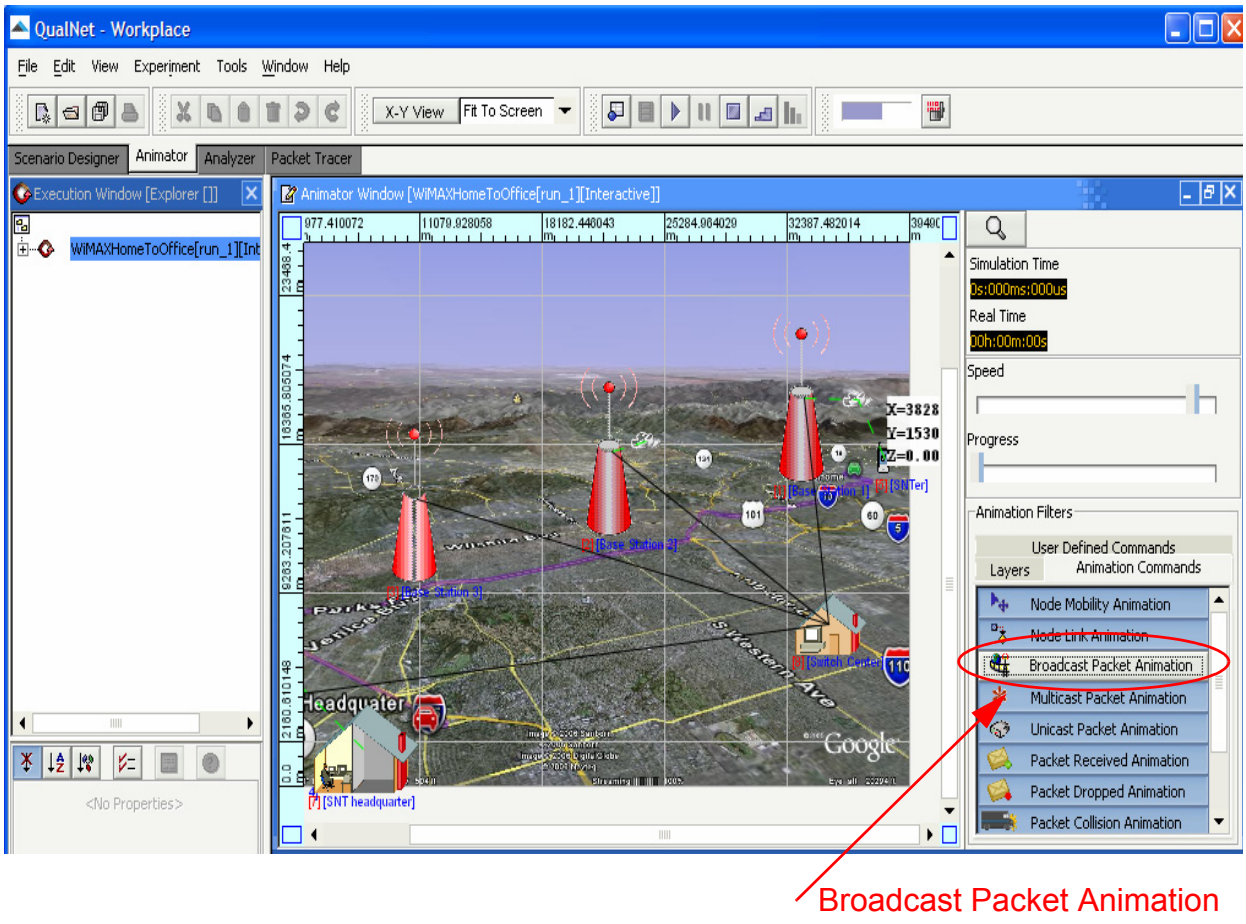

FIGURE 27. WiMAX Scenario with Handover

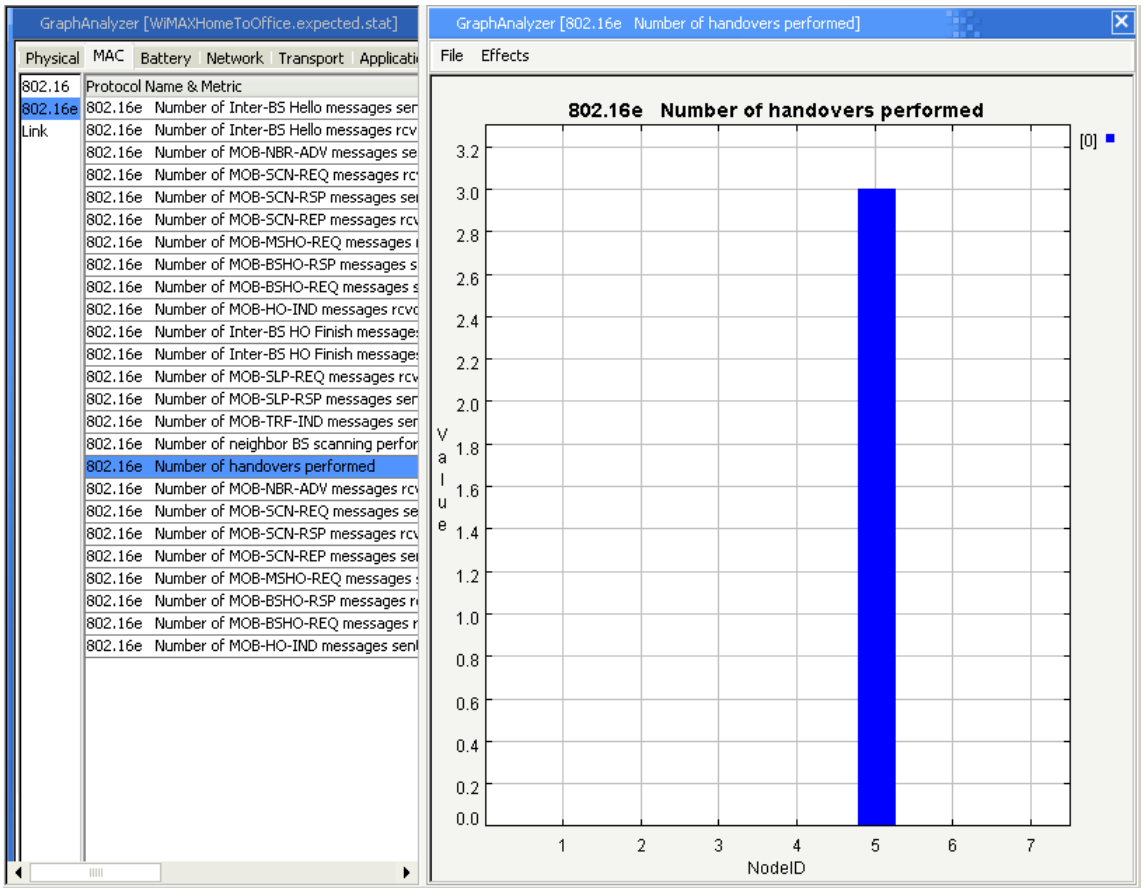

FIGURE 28. WiMAX Handover Statistics Showing Mobile Node 5 with 3 Handovers

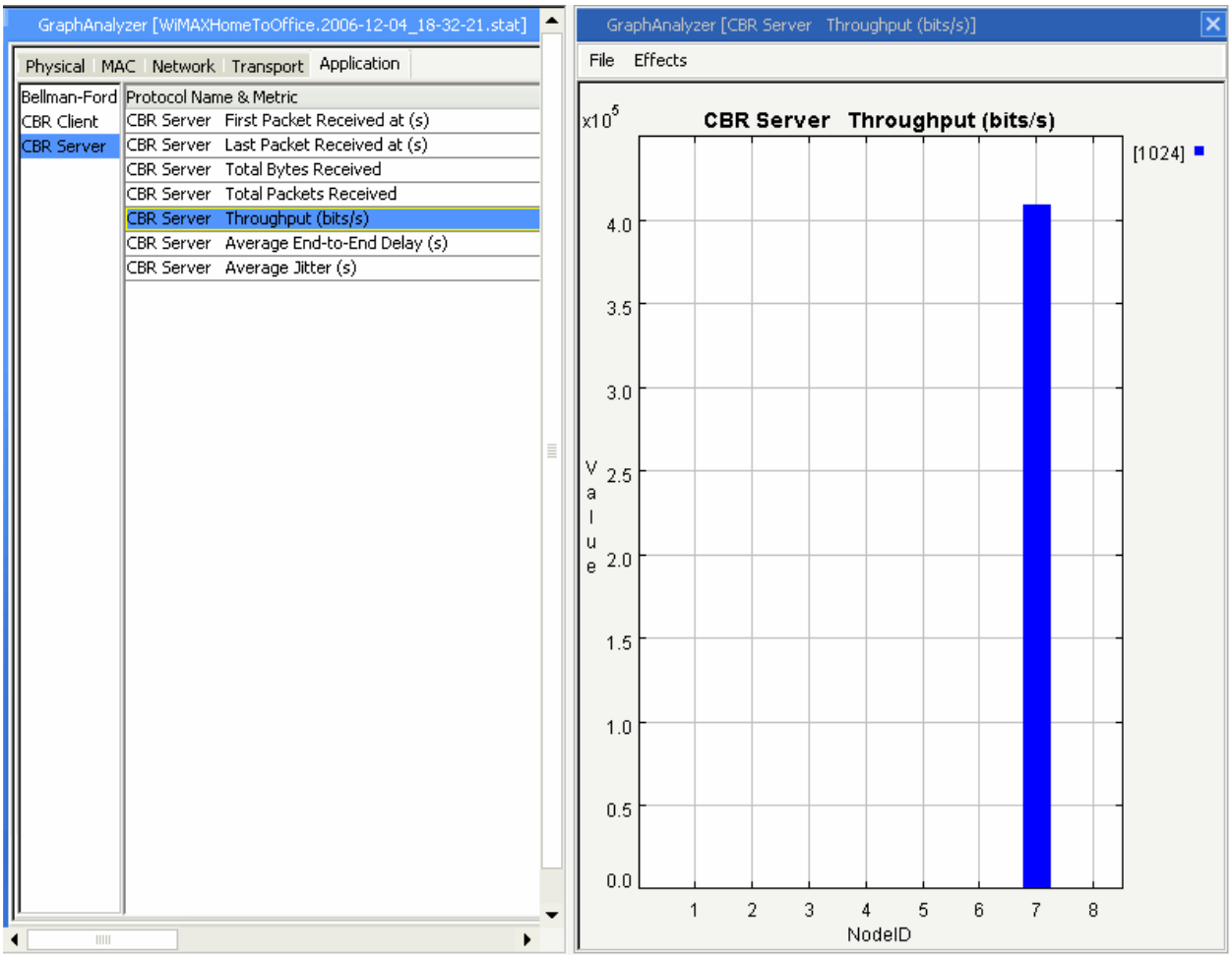

FIGURE 29. WiMAX CBR Statistics

Other scenarios to try:

1. Hybrid/Mixed Networks

   Location: QUALNET_HOME\scenarios\gui\MixedNetwork.scn

   Description: This scenario demonstrates a simple mixed network of wireless (802.11) and wired (802.3) nodes.

2. TCP Congestion Control

   Location: QUALNET_HOME\scenarios\gui\bottleneck-TCP

   Description: This scenario shows how a bottleneck (the link between nodes 3 and 4) triggers congestion control in TCP.

3. Terrain Effects

   Location: QUALNET_HOME\scenarios\gui\dtedtest.scn

Description: Shows how terrain effects affect wireless communications. It uses a ITM (Irregular Terrain Format) pathloss model and DTED terrain format file to simulate terrain effects.

The demonstration scenarios have small run times to allow you to quickly explore the functionality of specific models. To analyze them in detail you should slow down the execution speed (using the 'Speed' slider in Animator) and open the statistics in Analyzer.

Summary

The QualNet Product Tour has provided you with a quick, high-level tour of some of the features available in QualNet. There are additional documents available to QualNet customers who would like to go into further details. A complete list of these documents is provided at the beginning of this document. Some of the topics covered in these documents are:

- Taking advantage of the performance benefits available through the latest dual-core, multi-core and cluster systems
- Creating/designing wireless, wired and hybrid networks in QualNet
- Creating and using groupings/hierarchies of nodes
- Setting channel properties such as frequency, fading, pathloss and shadowing
- Designing new protocols/models in QualNet
- Adding user-defined devices and models to QualNet GUI menus and toolbars
- Creating and using dynamic statistics
- Enabling and disabling statistics on a per-node, per-protocol or per-layer basis

QualNet provides a rich environment for modeling of communication networks by enabling users to design new protocols and model a variety of network architectures. QualNet allows you the full flexibility of creating a model for any layer, device or system, from military radios to WiFi radios and WiMAX base stations. And all of this can be done in a fast, scalable and high-fidelity environment.