



Wireless Networks

Labs for Protocol Design

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1.0 Introduction and Objectives of The Exercises

Nowadays network applications – especially in the area of wireless networks – are becoming more and more complex which makes the design and the testing almost impossible without appropriate software. There are many different programs available to aid the user in simulating previously designed scenarios. This work covers the implementation of a number of scenarios using the software QualNet by Scalable Networks in version 7.3. QualNet Developer is network evaluation software that Predicts wireless, wired and mixed-platform network and networking device performance. Designed to take full advantage of the multi-threading capabilities of multi-core 64-bit processors, it supports simulation of thousands of network nodes.

QualNet offers unmatched platform portability and interface flexibility. QualNet runs on sequential and parallel UNIX, Windows, Mac OS X and Linux operating systems, and is also designed to link seamlessly with modelling/simulation applications and live networks. This software comes with various libraries, one of which can be purchased separately as per the requirement.

Components of QualNet Developer

- **QualNet Scenario Designer** is a model setup tool that allows users to set up geographical distribution, physical connections, and the functional parameters of the network nodes. Using intuitive click and drag operations, the user can also define network layer protocols and traffic characteristics down to each node.
- **QualNet Animator** offers in-depth visualization and analysis. As simulations are running, users can watch traffic flow through the network and view dynamic graphs of critical performance metrics. Users can also assign jobs to run in batch mode on a faster server and view the animated data later.
- **QualNet 3D Visualizer** is a QT-based tool for rich animations of network simulations. Users set up QualNet scenarios in QualNet Scenario Designer and then send the simulation to the 3D Visualizer for animation.

- **QualNet Analyser** is a statistical graphing tool that displays hundreds of metrics. Users can choose to see pre-designed reports or customize graphs with their own statistics. Real-time statistics are also an option, where users can view metrics as they are generated while a simulation is running. Multi experiment reports are also available. All graphs are exportable to spreadsheets.
- **QualNet Packet Tracer** is a packet-level visualization tool for viewing the contents of a packet as it goes up and down the network stack. This is a valuable debugging tool.

Opening QualNet in windows (preferable)

You can also launch QualNet Developer GUI from Start > All Programs > QualNet 7.3 Developer > QualNet GUI (see Figure 1).



Figure 1: QualNet Icon

Opening QualNet in DOS

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

For any basic simulation project you will need all of the following files:

- * .config : the main scenario file.
- * .nodes : the node file.
- * .app: the application file.

This lab file consists of a number of hands-on labs practice to be completed for this semester. The “**labs to do**” below will prepare you to do the assignments,

The assignment will be handed on the 19/2/2015; the due date will be 30/04/2015.

Visit my YouTube channel: **Mabrouka Abuhmida** for more details on the labs and the assignment. Use the hashtag **#QualNel_QA** on Twitter.

Labs to Do

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Lab: Starting QualNet

QualNet GUI Components

The QualNet GUI has four components: Architect, Analyzer, Packet Tracer, and File Editor (see the Components Toolbar below in Figure 2).

- Architect is used for creating scenarios (in Design mode) and running simulations (in Visualize mode).
- Analyser is used for analysing simulation results.
- Packet Tracer is used for analysing packet traces obtained by running simulations.
- File Editor is used for editing text files.

When you start the QualNet GUI, by default it opens new empty scenario in the Design mode of Architect. Figure1 shows the window is displayed when the QualNet GUI starts.

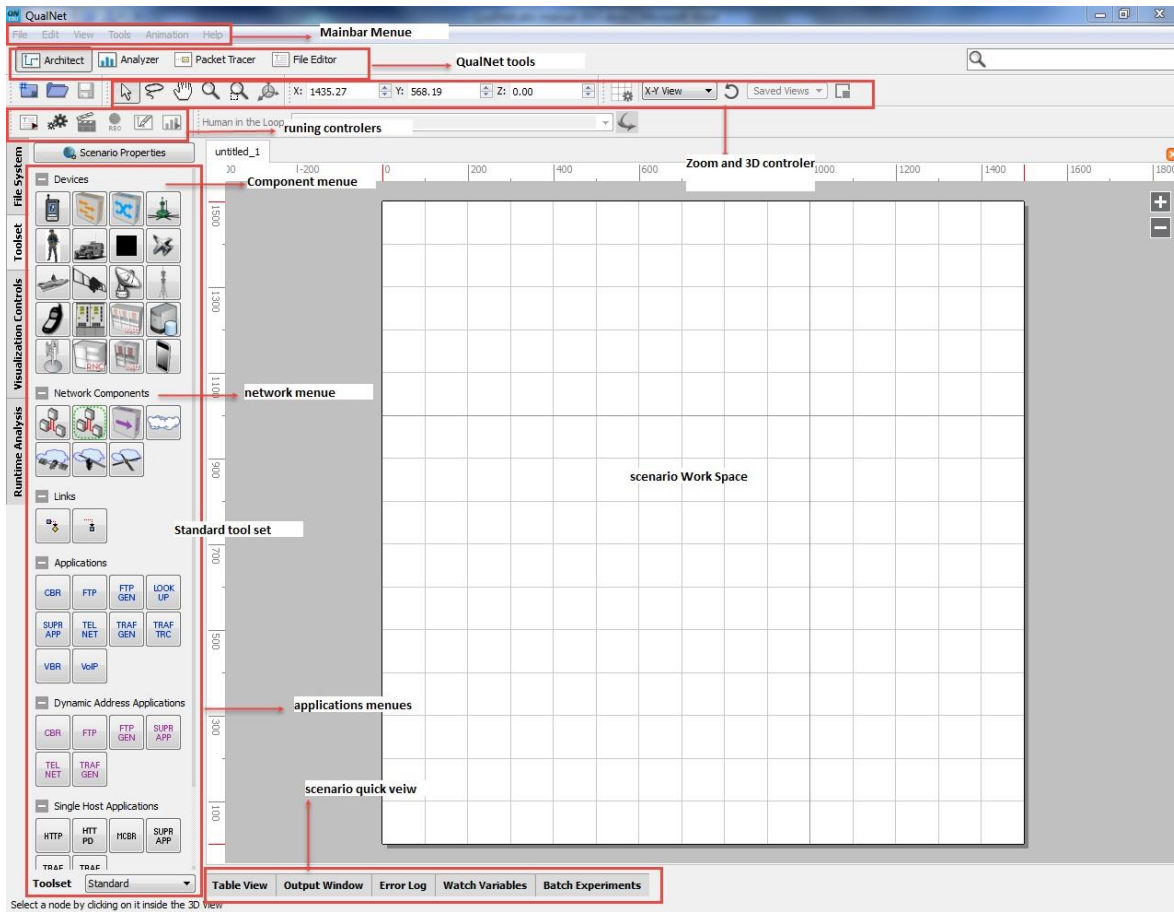


Figure 2: workspace, Menu Bar and Tool Bars

Creating Scenarios:

This section 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.

When you open QualNet it opens new empty scenario (file), another way is to use the short cut (Ctrl+N) or to go to the file menu from the main bar and choose new.

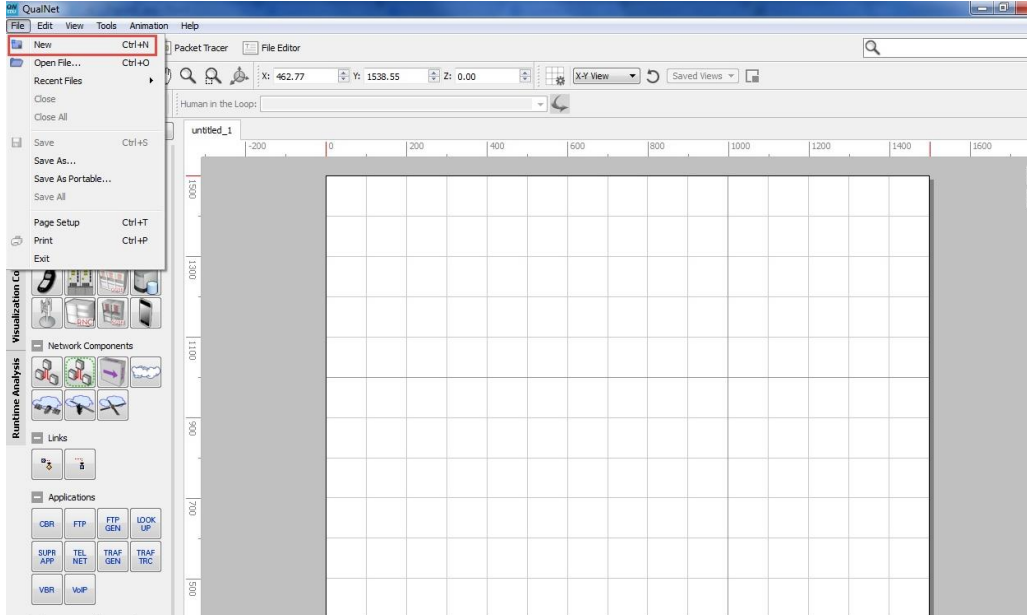


Figure 3: New file menu

To name your scenario Type “Example”, replacing <default name> in the Name field at the top Click Finish (See Figure 4).

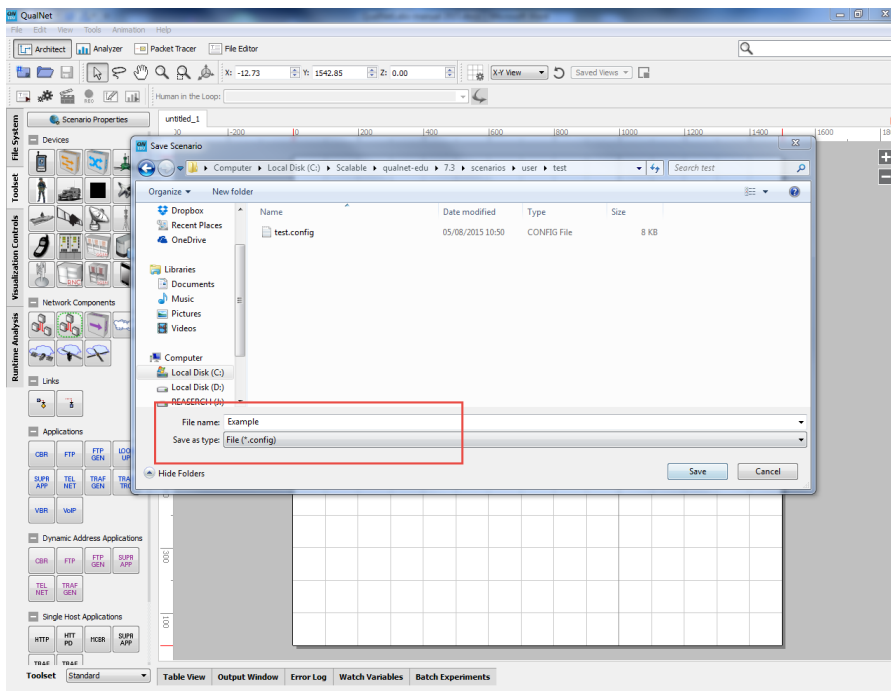


Figure 4: Naming a New Scenario.

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.

In the Scenario-File-Systems window, click on the Inspector tab, click on the 'Arrow' icon next to sub-folder 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.

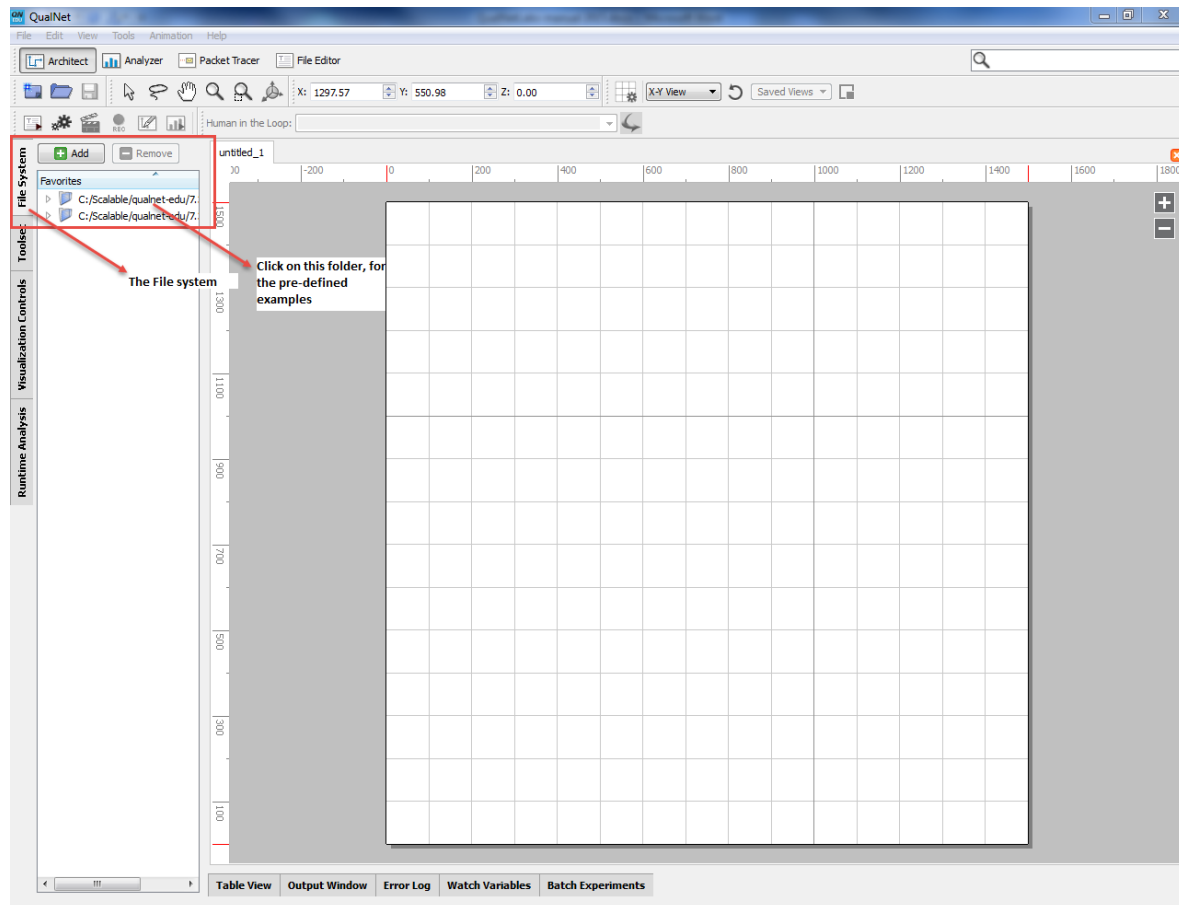


Figure 5: Scenario File Systems

The File Systems 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 6 shows the folder of the Example you've just created.

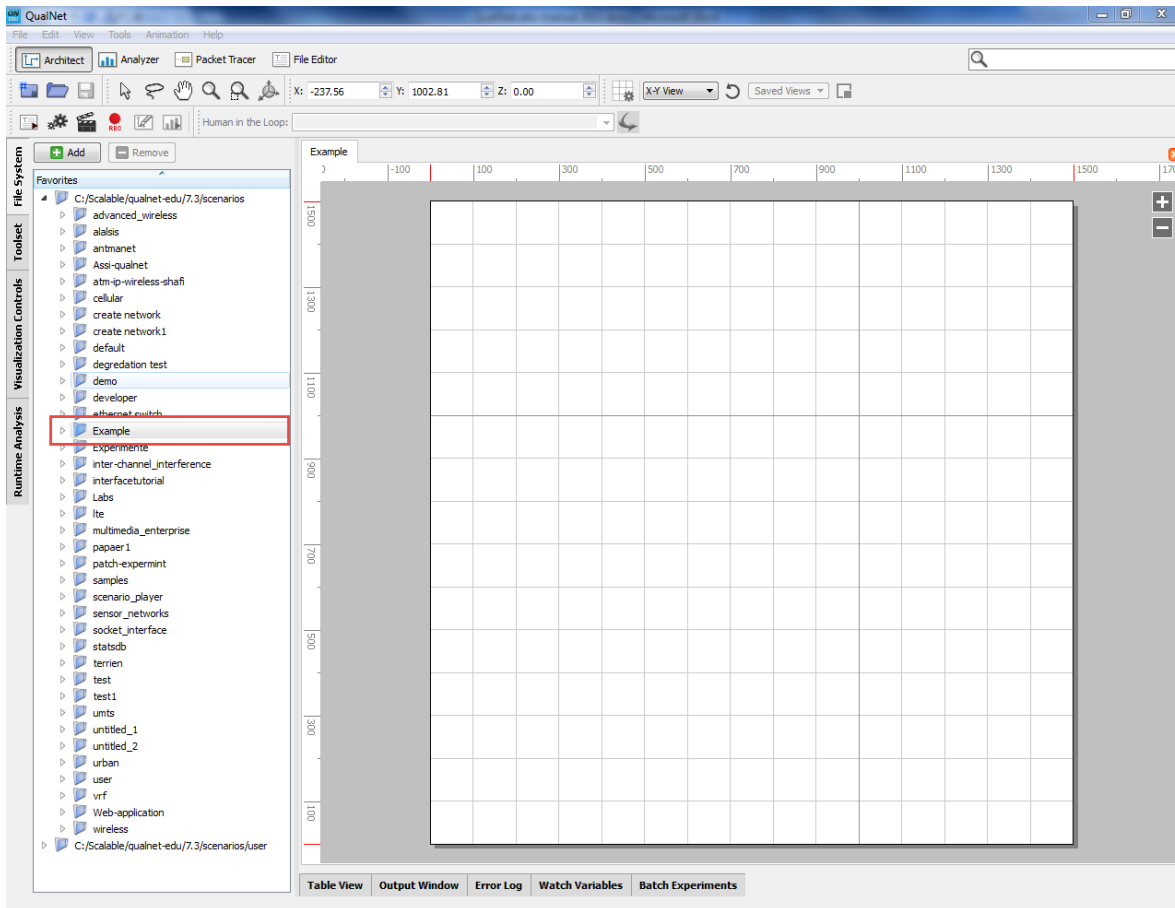


Figure 6: Scenario File Systems example.

Adding Nodes:

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 7.

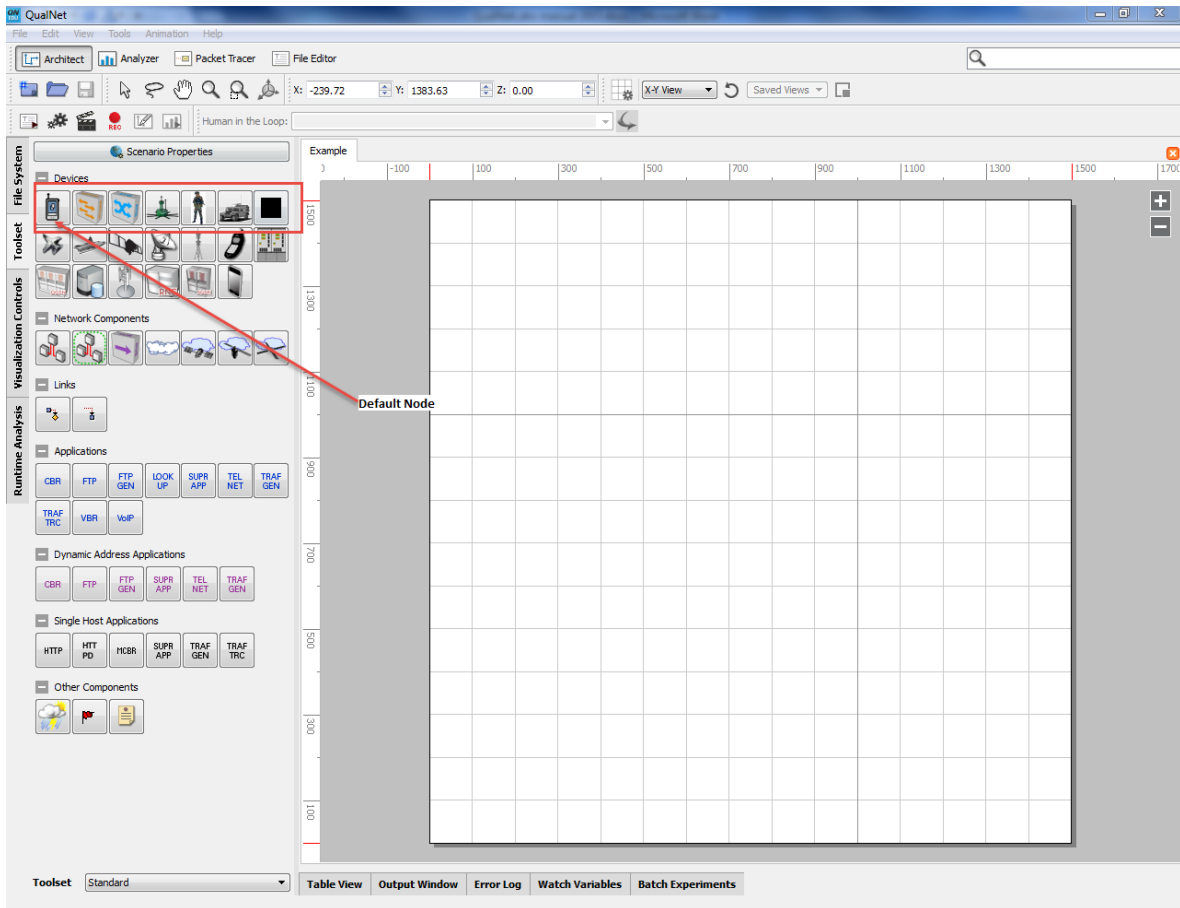


Figure 7: Default Node.

Click on the canvas to create and place nodes as shown in Figure 8. If needed, you can click on  button to move nodes. Once you are finished placing or moving the nodes, click on the  button to go into select mode.

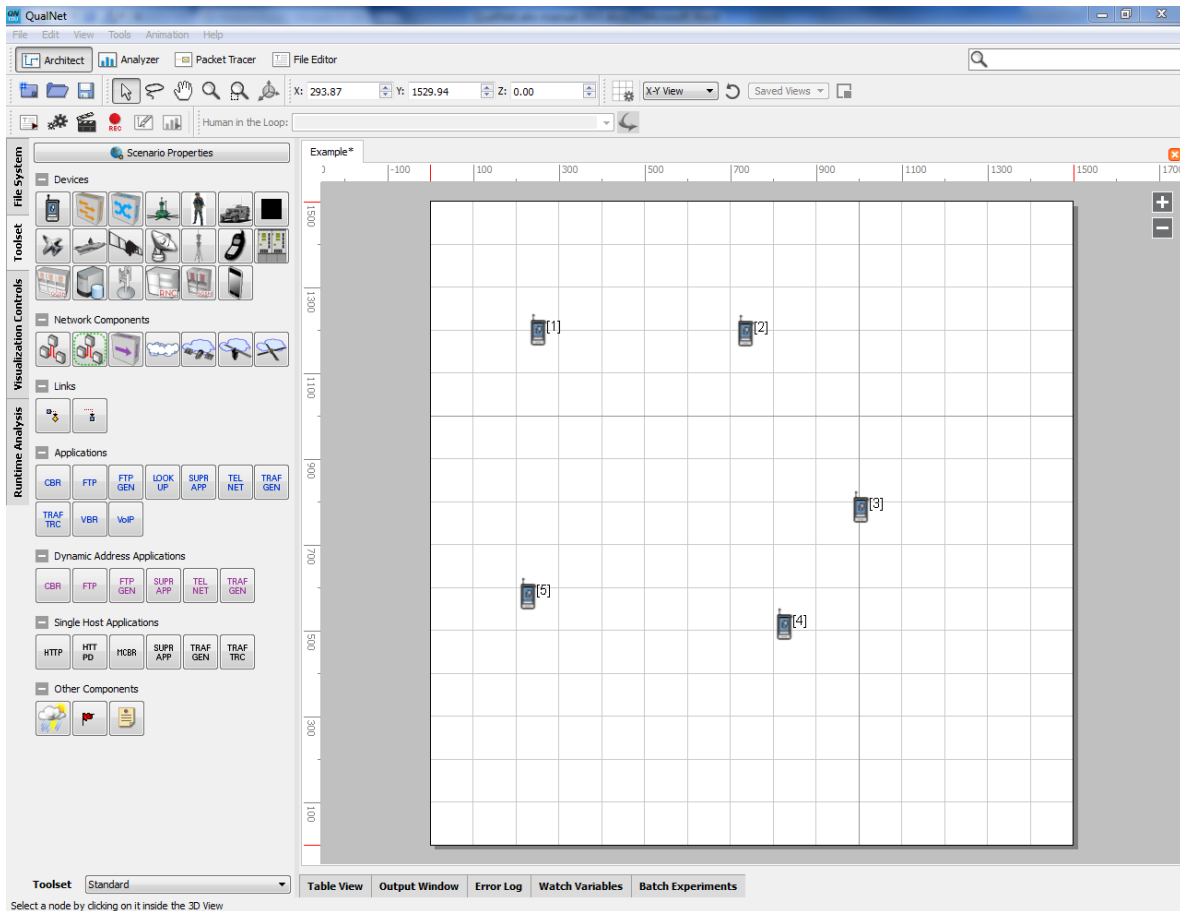


Figure 8: Placement of Nodes

Adding Links:

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 9.

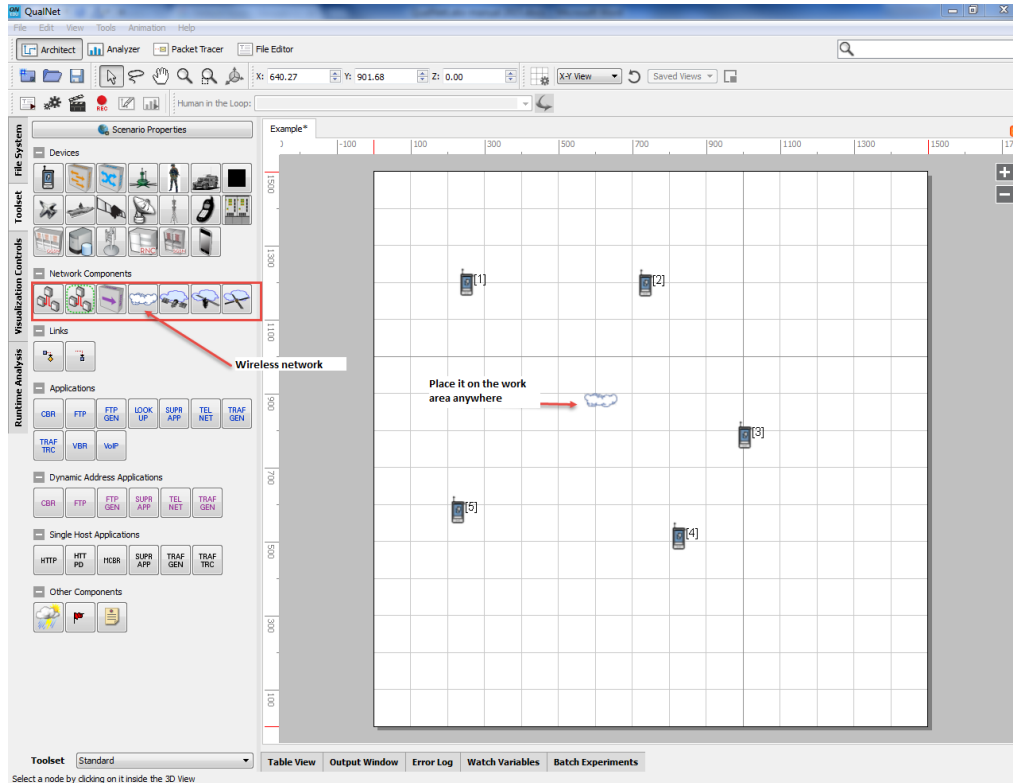


Figure 9: Adding a Wireless Subnet.

To start building the wireless subnet: right Click on the node from the drop down list, go to “Line Selected node to” choose your network as in Figure 10 . Blue dashed lines will appear to indicate a wireless link.

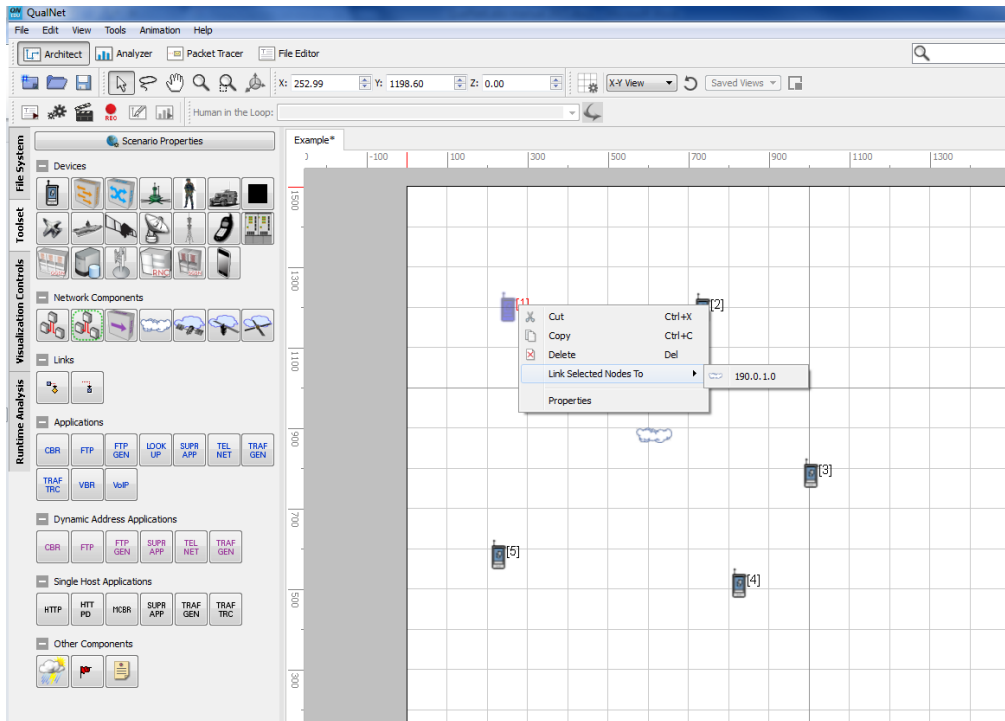


Figure 10: Link node to the wireless network.

Repeat the process to connect the other nodes to the subnet. See Figure 10

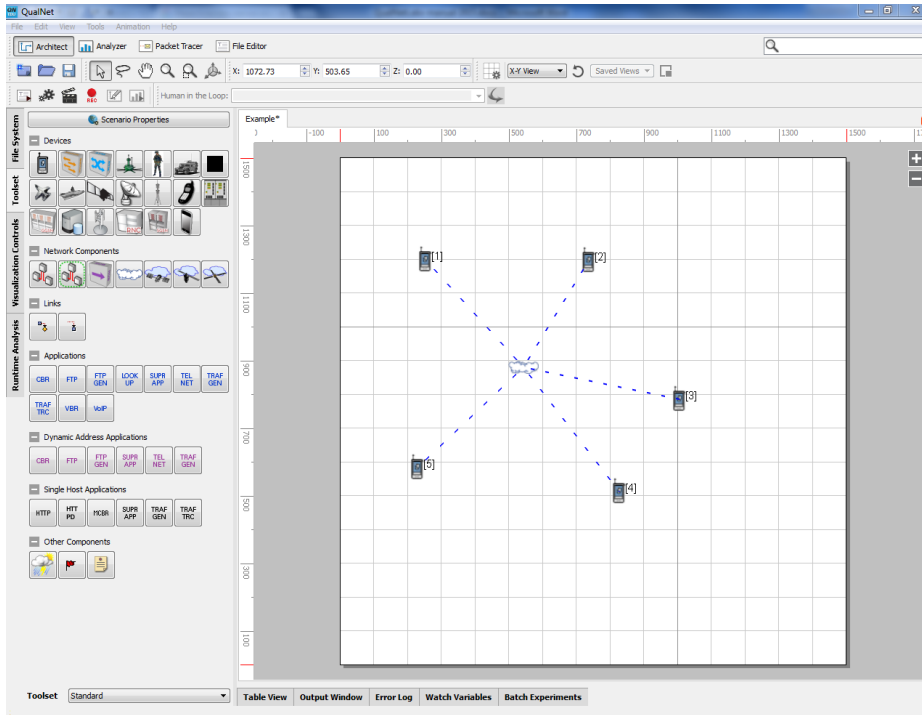


Figure 11: wireless connection.

Adding Applications:

From the application toolbar on the left do the following:

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.config - scenario configuration file for QualNet Developer GUI. (See Figure 12).

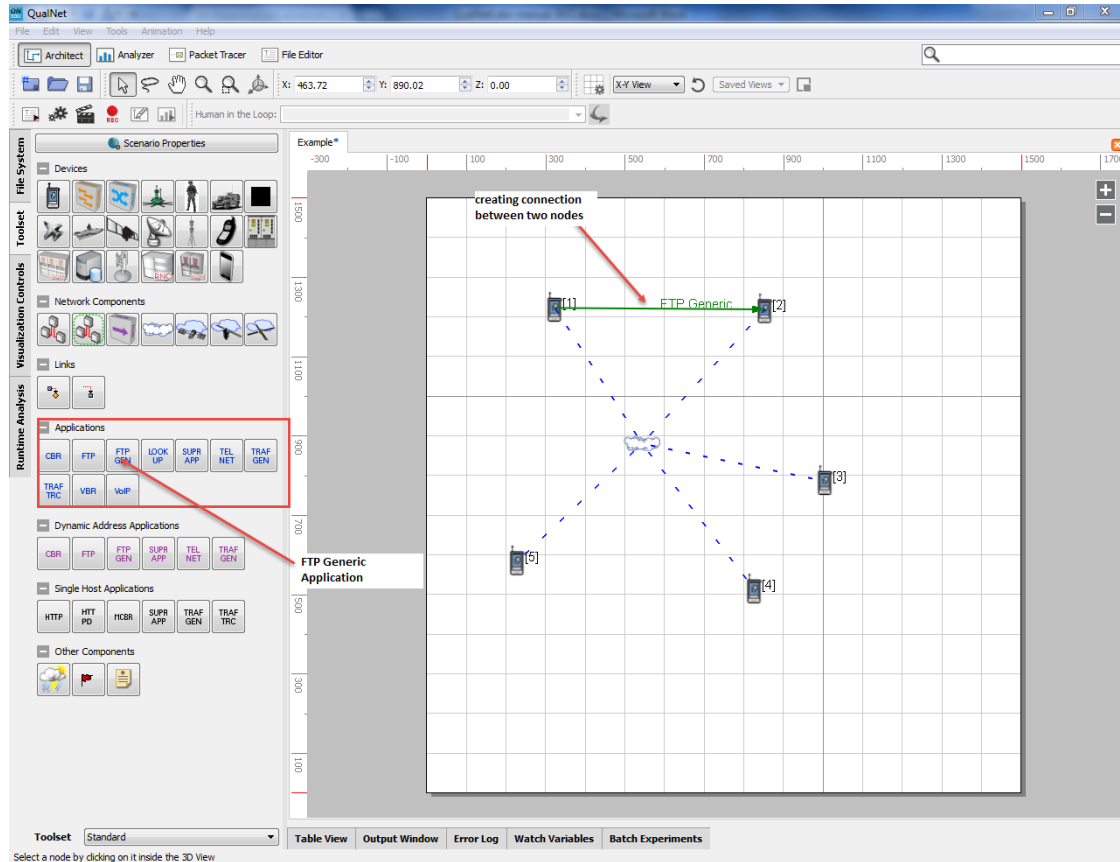


Figure 12: Adding Application Layer Traffic

Running Scenarios

Note:

The 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 13 and Figure 12).

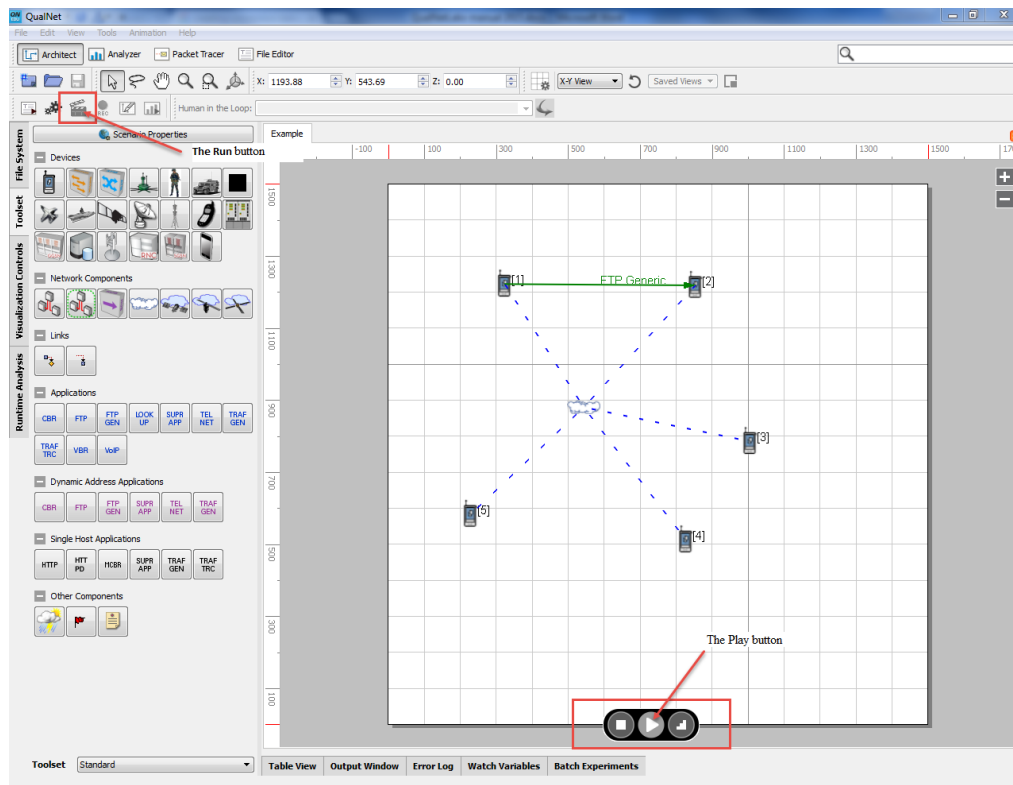


Figure 13: Running a Scenario in Animator

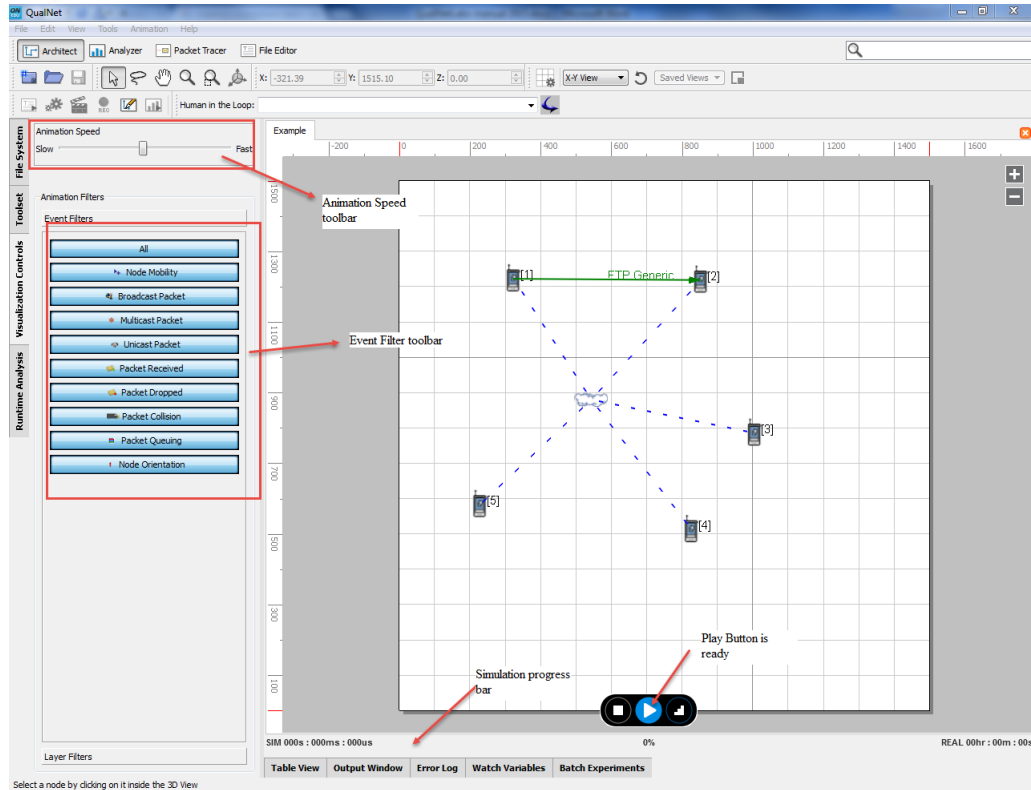


Figure 14: Output Window

- 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.
- 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.

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 File Systems > Example directory, and double-click on Example<date stamp>.stat (See Figure 15)
2. You can click on any of the statistics tabs: Physical, MAC, Network, Transport or Application to analyse them (See Figure 16).

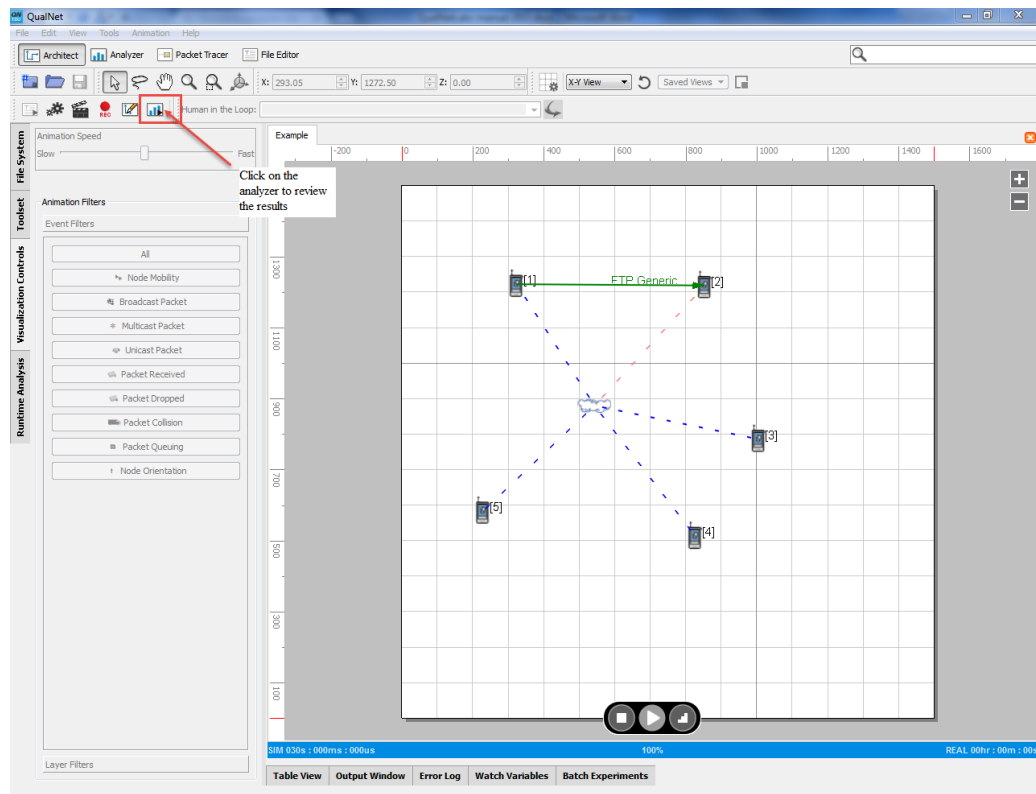


Figure 15: Analyzer.

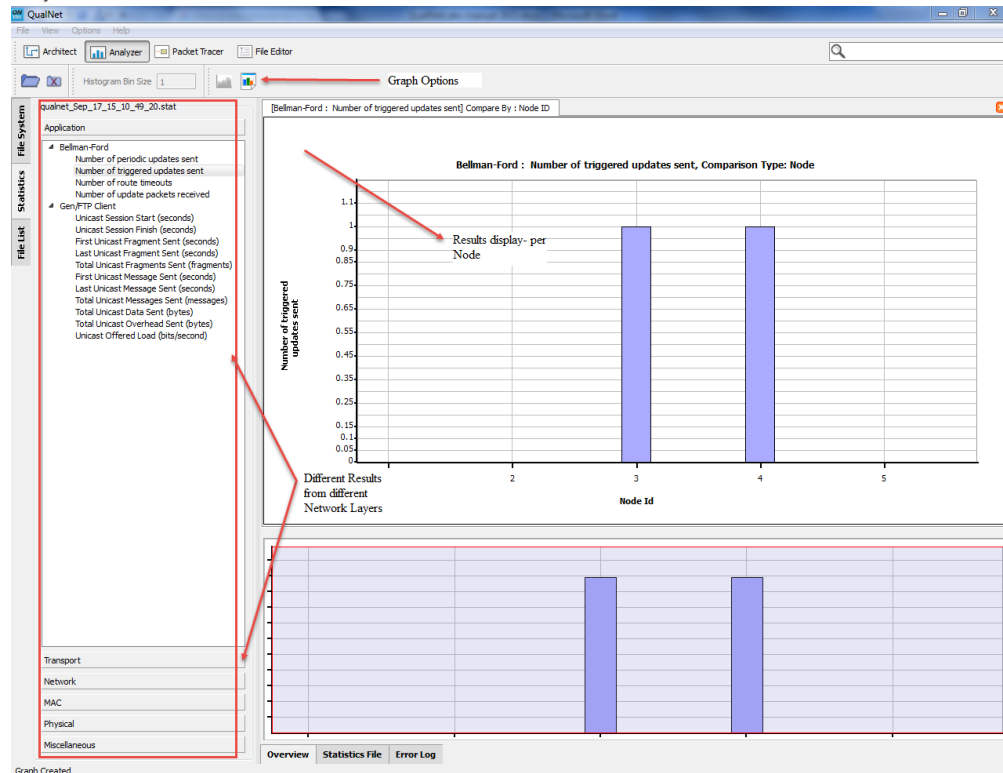


Figure 16: Analyzer Statistics.

Tracing Packets:

Note:

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 File Systems window.

Make sure that your scenario is loaded (Example.config).

1. Click on the Scenario properties button as in Figure 17.
2. Go to the tab statistics tracing; choose Packet tracing from the left side bar; Click Yes for Packet Tracing Enabled. (See Figure 18).

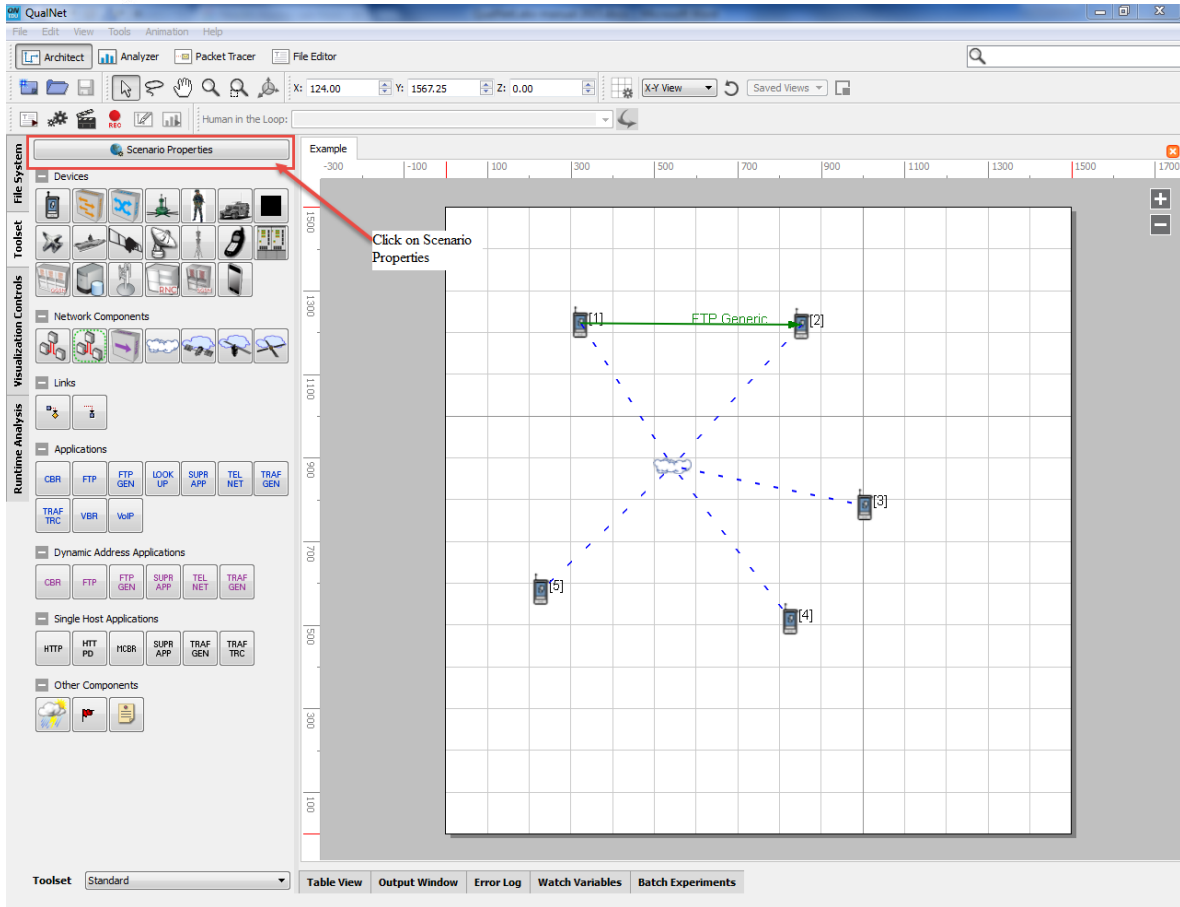


Figure 17: Scenario Properties

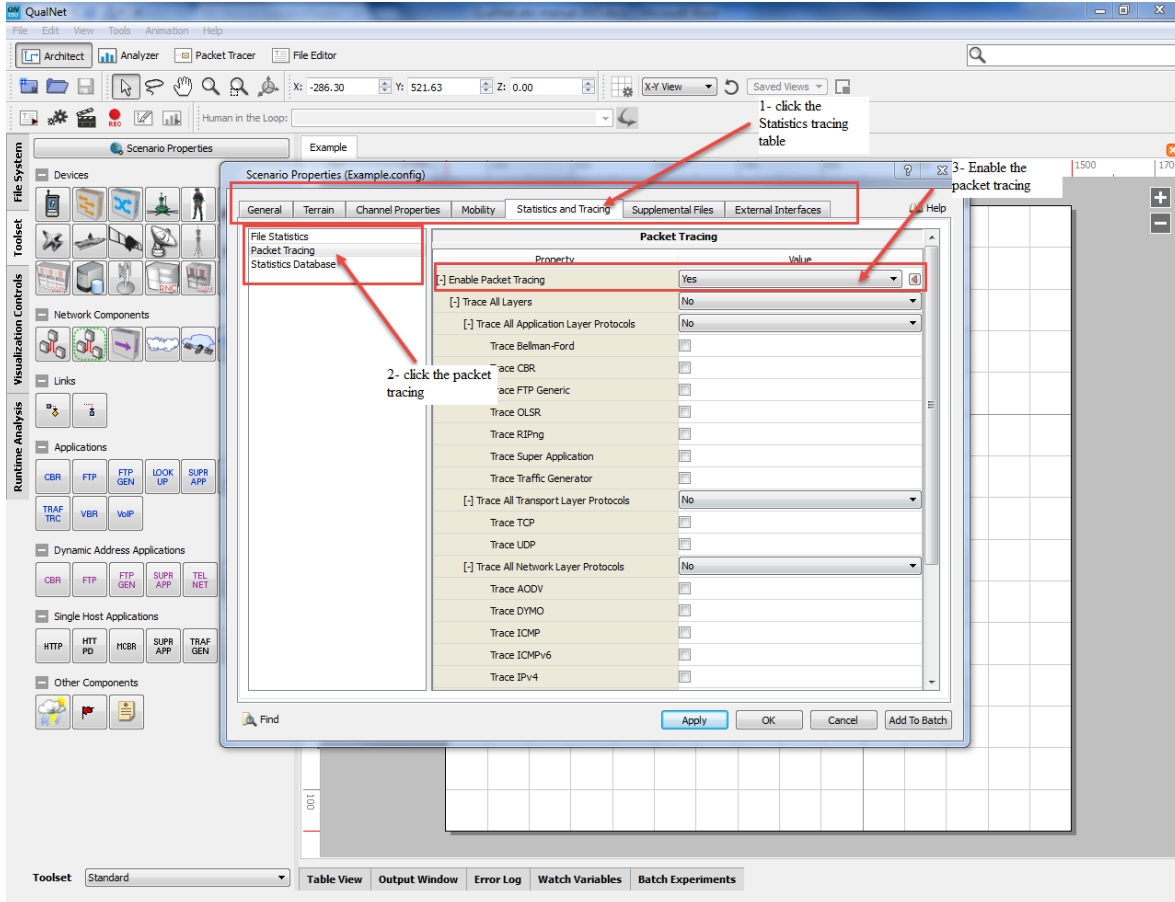


Figure 18: Enable the packet tracing.

3. Press the Run button to load the simulation.
4. Press the Play button to start the simulation.
5. Once the simulation finishes, click on the Packet Tracer tab. (see Figure 19)
6. Load Example. Trace by browsing file system to the \Example directory. The trace file will be called QualNet< timestamp>.trace.
7. Double-click on it to open it in Packet Tracer.

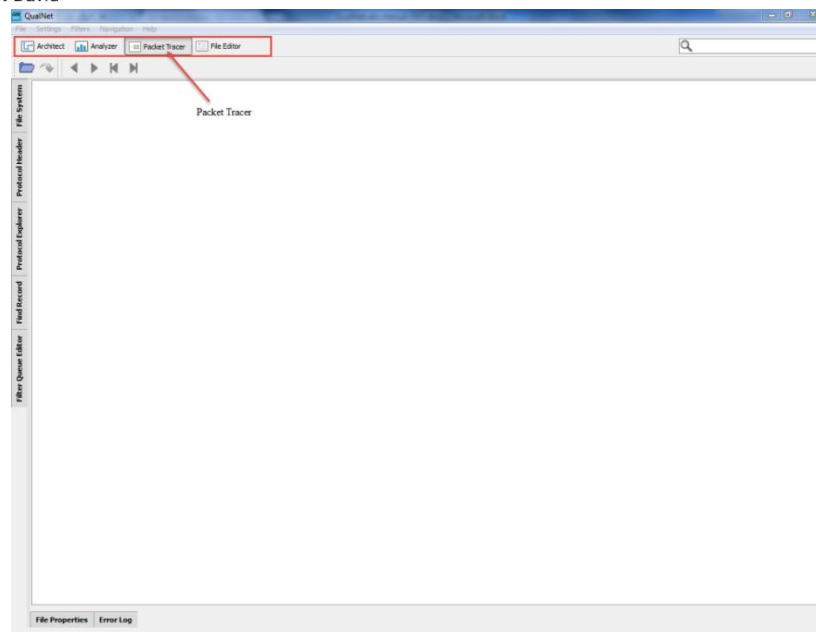


Figure 19: Packet Tracer tab

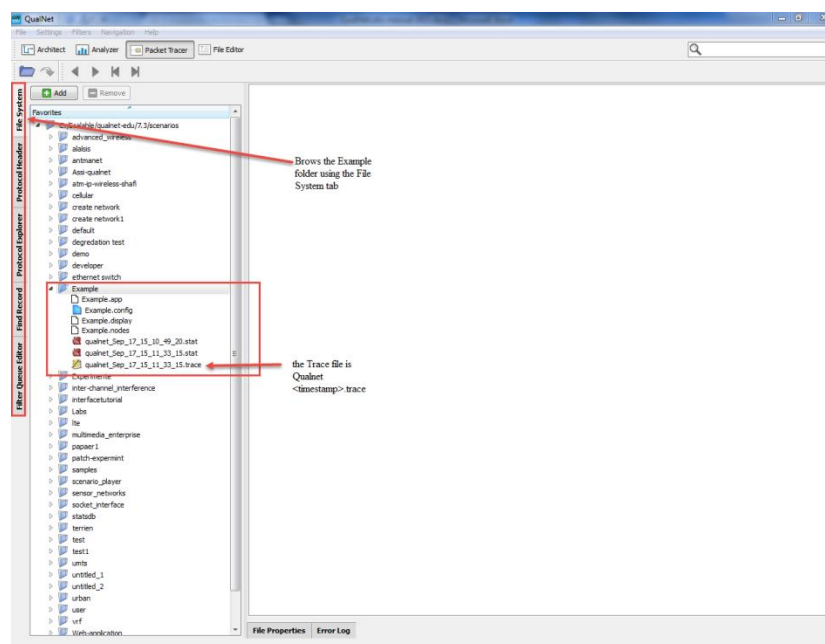


Figure 20: Qualnet.trace

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.

END OF LAB

Lab- Application Layer

Objective

The purpose of this exercise is to develop an appreciation for the client-server network application architecture in modern network applications. Moreover, it helps to gain further experience with QualNet GUI and to start using command line based QualNet.

Overview

First, you will configure and run Web applications over a wireless network of 30 nodes under QualNet GUI. Then, you will use command-line based QualNet to simulate above network applications again with provided configuration files.

Part 1: Using GUI based QualNet

Start QualNet and create new empty file

1. Create a new scenario named Web-Application under the directory '
2. Place 30 nodes automatically in the network.
 - From the **tools** pull down menu, select **Place Nodes**

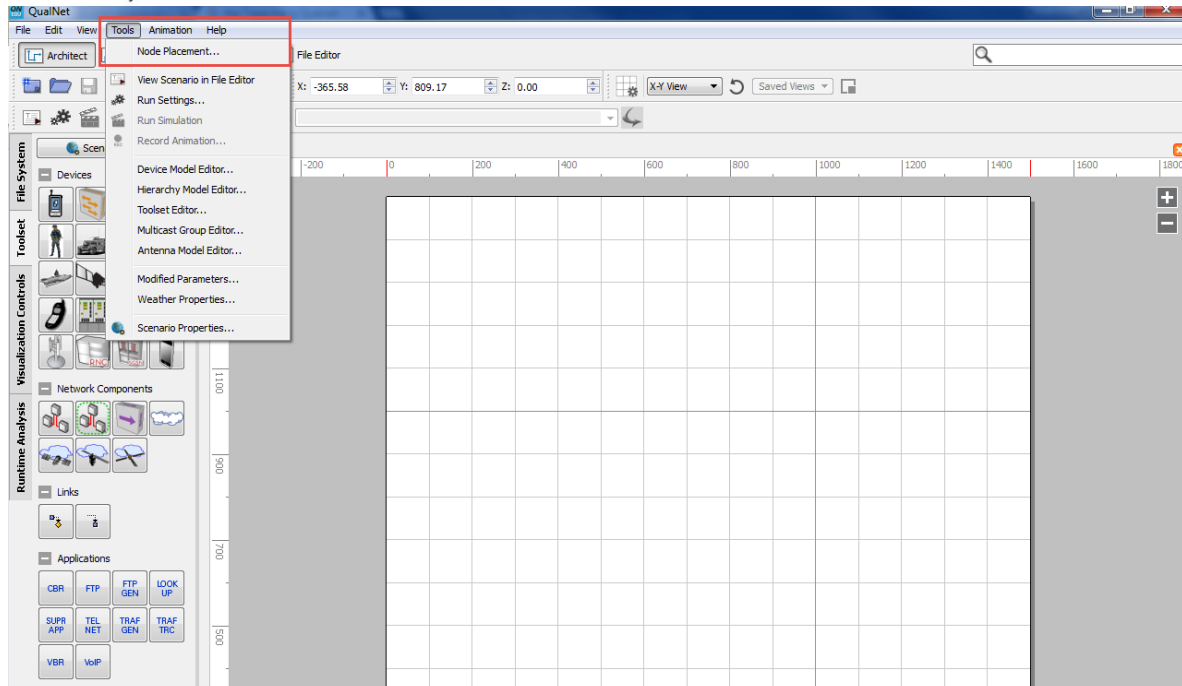


Figure 21: Place Nodes Menu

Within the Automatic Node Placement Wizard, input '30' as Number of Nodes, see in Figure 22.

From the drop menu “Tools” choose “Placement Model”, choose 'Uniform' as **Placement Strategy**. And choose the **Seed** to be 1.

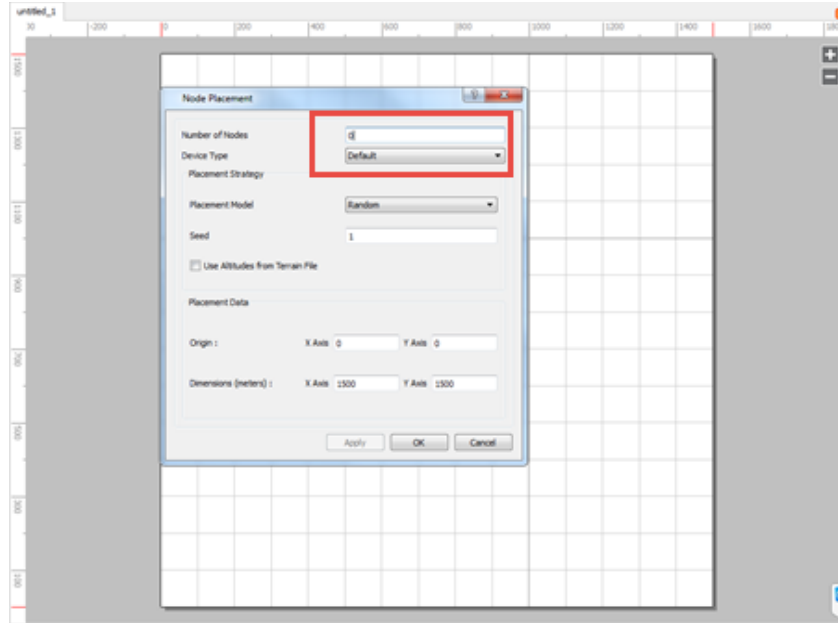


Figure 22: Auto-Place Nodes

Click **OK** and the resulting canvas should look like the following Figure.

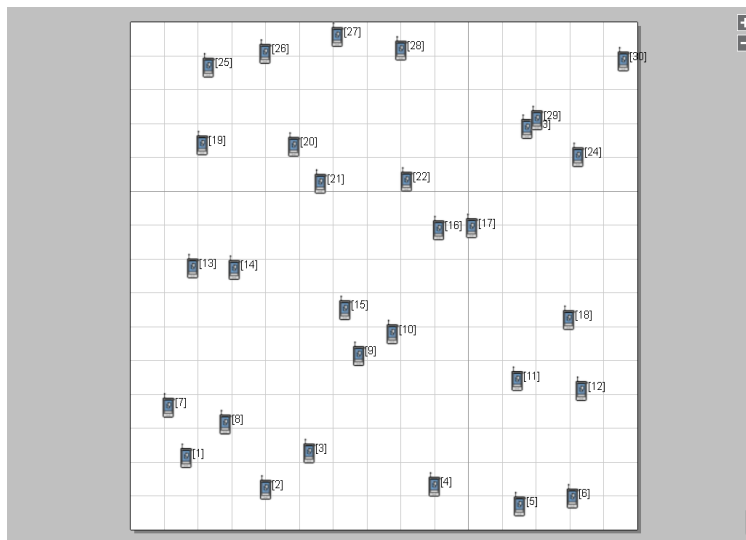


Figure 23: workspace.

3. Add a Web application with node 1 as the HTTP client and nodes 2, 5 and 11 as HTTP servers.

Go to the left hand side toolset in the Single Host Application menu as in the Figure 24.

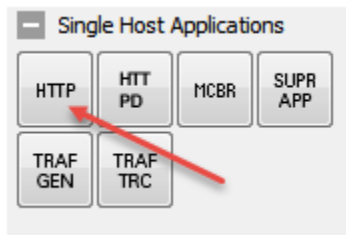


Figure 24: single host application

- Click **Htt**p and click node 1 there will be a **HTTP** sign shown it on the canvas as Figure 25 shows.

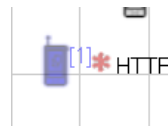


Figure 25: Http Client

- Right click the http sign, **client1 Single Host Applications** to modify **HTTP** properties. Set **Start Time** as '10S', **Threshold Time** as '120S', and **List of Servers** as '2 5 11'. This means the HTTP client on node 1 chooses among HTTP servers {2, 5, 11} when requesting web pages. It begins browsing after 10 seconds of simulation time, and will "think"

(remain idle) for at most 2 minutes at a time. The HHTP application properties are shown in Figure 26.

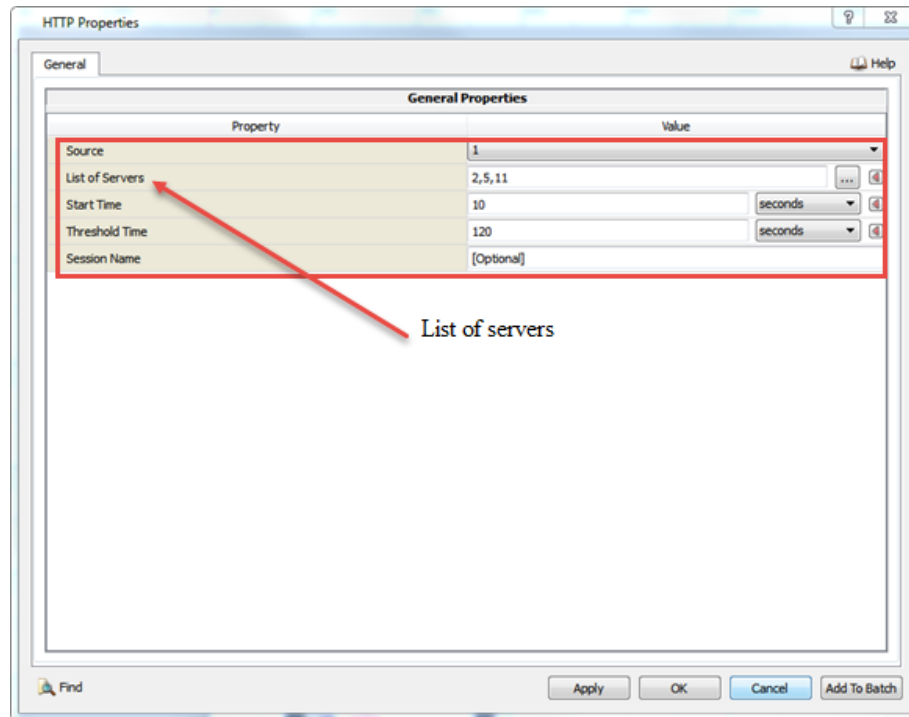


Figure 26: Http Properties

After executing the late task, the 2,5,11 nodes will show a HTTPD sign on the canvas as Figure 27.



Figure 27: HTTPD Nodes

4. Set simulation time to 15 minutes by modifying corresponding property (See Figure 28).

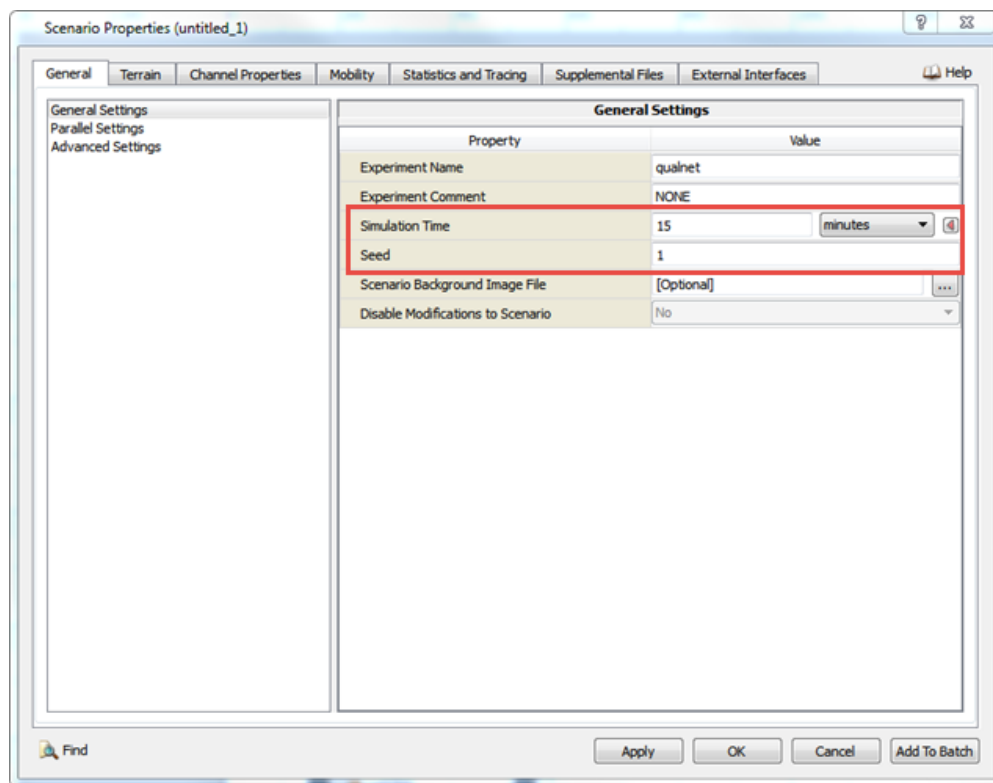


Figure 28: Scenario Properties

5. In the bottom of your screen you will find set of tables known as the “ Table View tabs”, Click on the network tab from the “table view” to examine the network which

connects all nodes in one network in this case the network address should be the default value (169.0.0.0).

- Right click on the network address from the “table view/ network tab” select properties and configure ‘AODV’ as **Routing Protocol** (See Figure 29).

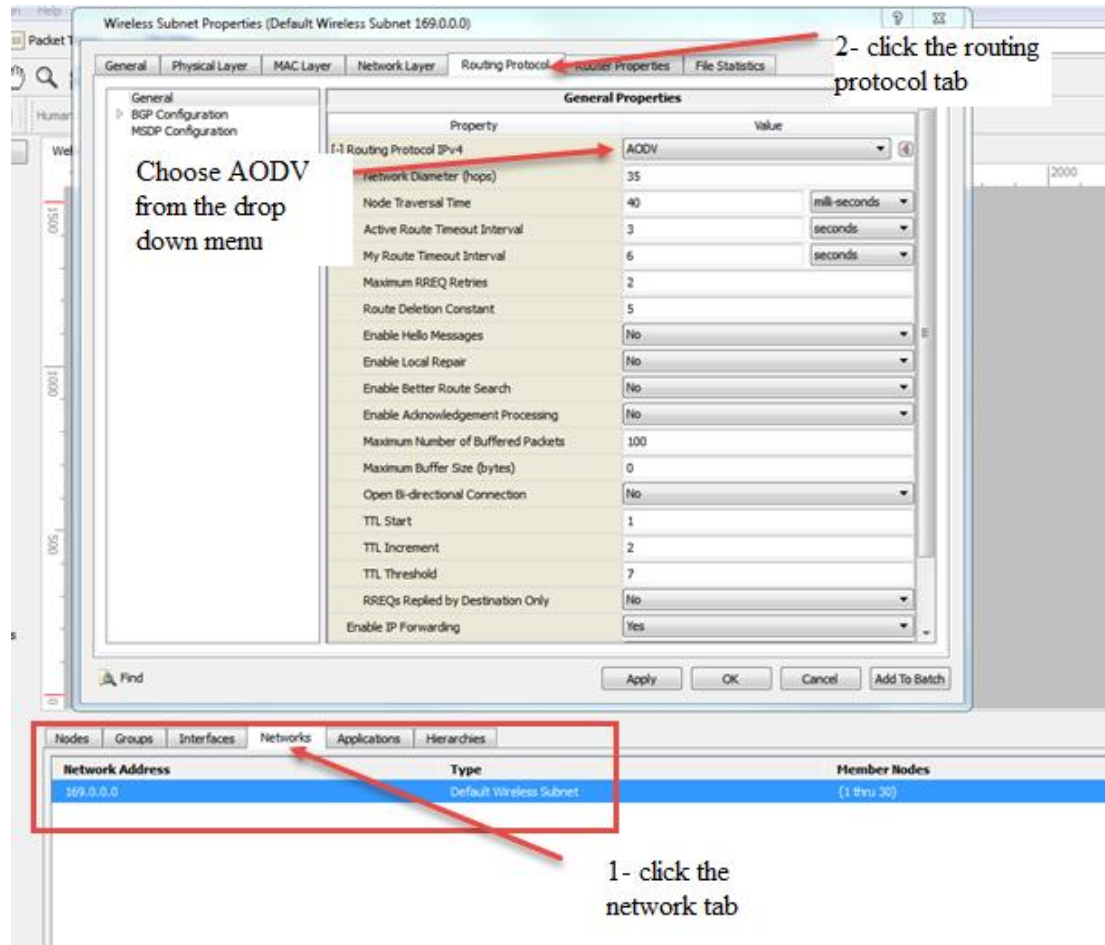


Figure 29: Selecting the Routing Protocol

- Run scenario in the **Animator** (refer related part in lab-Starting QualNet for details).
- Review **Application** statistics in the **Analyzer** (refer related part in lab1Starting QualNet for details).

9. Go back to the **Scenario Architect** to add another Web application in node “15” set it as HTTP client and nodes 2, 5 and 8 as HTTP servers, take similar steps to what you have done in to step 3.
10. Run the modified scenario.
11. Check **Application** statistics in the **Analyzer** again.

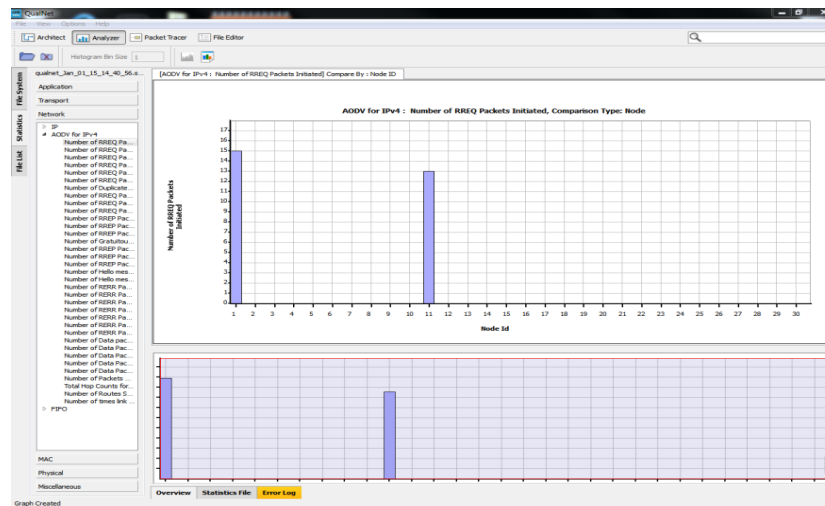


Figure 30: Results

Part 2: Using command line based QualNet

1. Download the configuration files (exp2a.config, exp2a.app, exp2b.config, exp2b.app). Browse and try understanding the main idea of each file, especially the app files (for detailed description, refer corresponding default files with the same suffix under the directory '[QUALNET_HOME]/scenarios/default/'). Place the four downloaded files in the directory '[QUALNET_HOME]/bin/'.
2. **Experiment 2a:** Under above directory, type '**QualNet exp2a.config**' to run QualNet command line with the application file exp2a.app, which defines the same

Web application with one HTTP client and three HTTP servers, as in step 3 of Part

a. The statistics file this experiment produces is exp2a.stat.

3. **Experiment 2b:** Similarly, type '**QualNet exp2b.config**' in command line to run QualNet with the application file exp2b.app, which simulates the same HTTP traffic with two HTTP clients and four HTTP servers, as in step 8 of Part 1. The statistics file this experiment produces is exp2b.stat.

Questions

1. What transport layer protocol is used to support the Web application, TCP or UDP?
2. What HTTP stands for?

END OF LAB

Lab: Transport Layer- Internet transport layer protocols - TCP and UDP

Objective

This exercise is to simulate the data transfer services of the two Internet transport layer protocols - TCP and UDP, and the end-to-end congestion control mechanisms used by an early version of TCP - TCP Tahoe.

Overview

In this exercise, you will simulate both FTP/TCP and CBR/UDP traffic at the same time over a simple wired network of five nodes shown in the following.

You will create the following customized configuration files for above networks: **transport-lab.config** for specifying global parameters like experiment name, time, links, nodes, etc.), **transport-lab.nodes** (for node placement), **transport-lab.app** (for application specification).

1. Start QualNet and open new scenario (new from the file menu) and save it “transport-lab” in the proper directory.

- From the “Scenario Properties” “Set SIMULATION-TIME to “10 Minutes” refer to the start QualNet lab.
- Set TERRAIN-DIMENSIONS to '(600, 400); (see Figure 31)

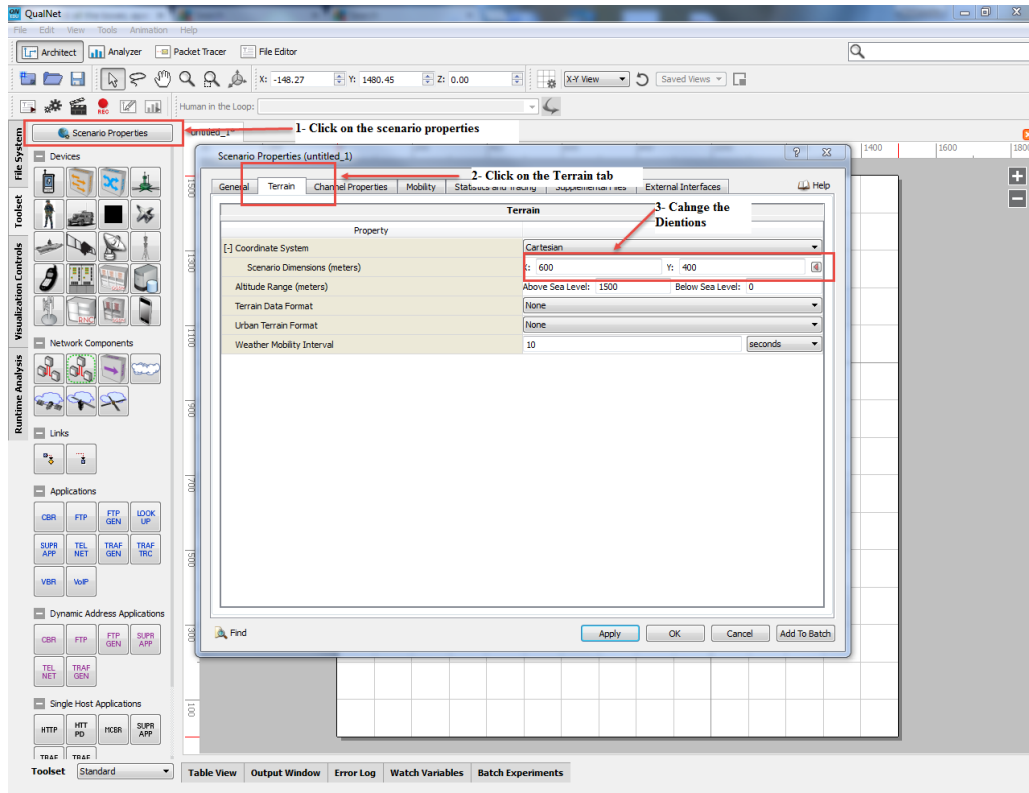


Figure 31: Terrain properties.

Note that Figure 32 is the actual network you need to design. You will require file placement you need to download from your moodle.

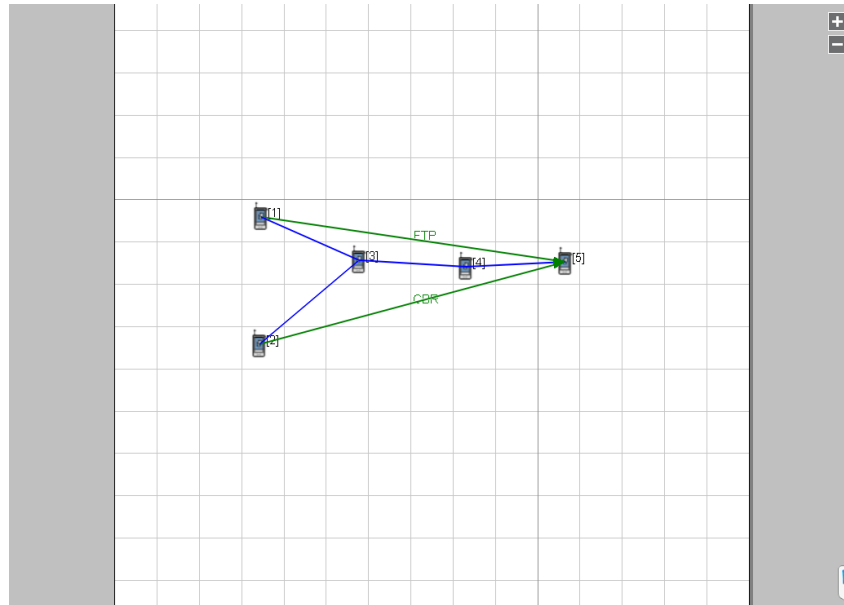


Figure 32: Network Topology.

4. To place the nodes go to place nodes from the tools menu; choose **File as the placement strategy**; Choose the file “Lab” (location is where you downloaded it from moodle). (See Figure 33) file format as follows:

```
<nodeID> <simulation-time> <position>
```



```
# "exp3.nodes", for simulation lab 3.  
# for the network simulations.  
# by Mabrouka Abuhmida.  
  
1 0 (100, 275, 0)  
2 0 (100, 150, 0)  
3 0 (200, 200, 0)  
4 0 (400, 200, 0)  
5 0 (500, 200, 0)
```

Figure 33: node file placement

Connect all the nodes using the wired point-to-point (from the standard Tool bar on the left hand side under “Links”) links according to above topology; modify the p2p link as the following settings. “See Figure 34 and Figure 35”

1. Set LINK-BANDWIDTH to '65536';
2. Set LINK-PROPAGATION-DELAY to '5MS';
3. Set LINK-MAC-PROTOCOL to 'ABSTRACT';
4. Specify a wired routing protocol, say, 'BELLMANFORD'.

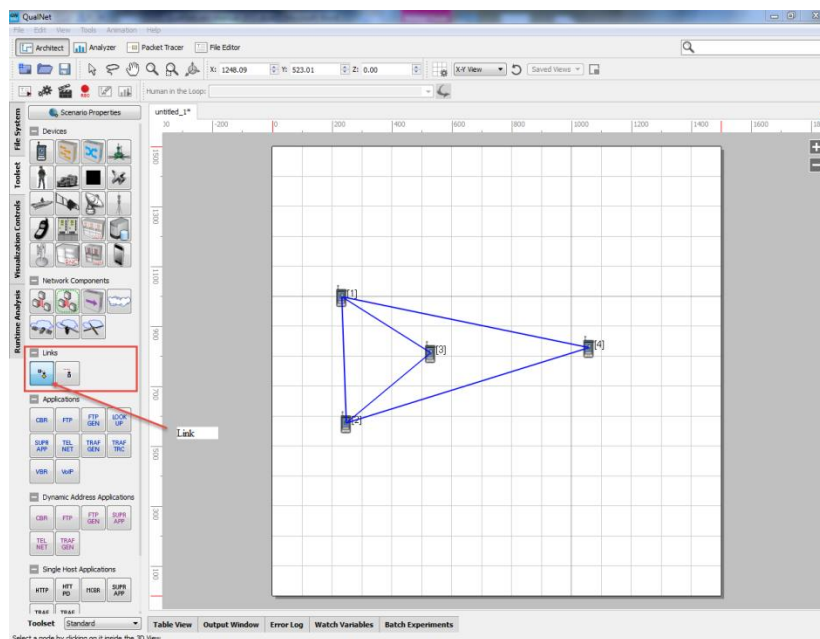


Figure 34: Link

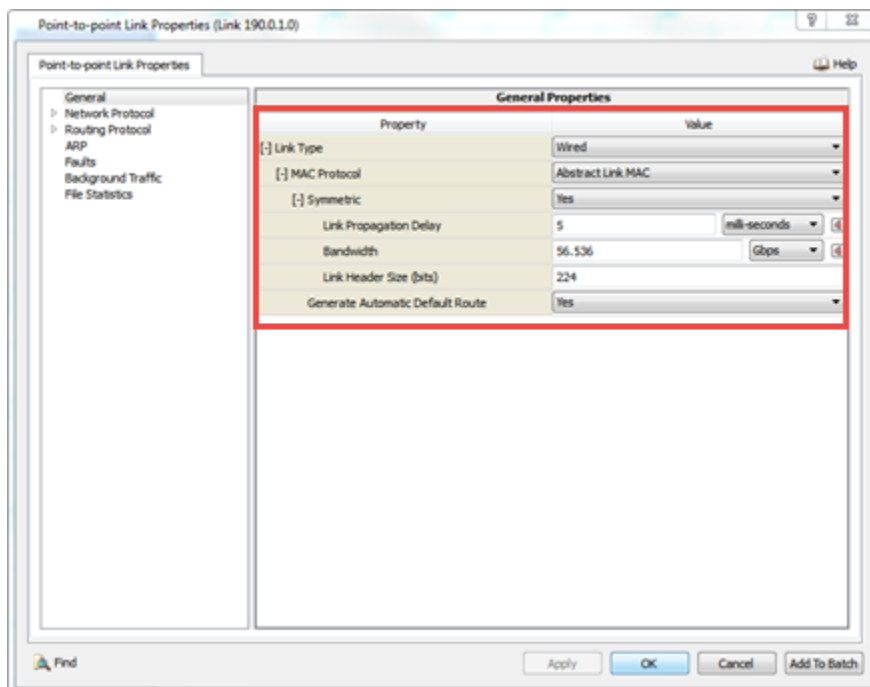


Figure 35: Link properties.

5. In all nodes Set TCP implementation to 'TAHOE', Set TCP-RECEIVE

BUFFER to '65535'; **TCP** Tahoe includes the following features:

- Slow Start
- Congestion Avoidance
- Fast Retransmit

Set TCP-RECEIVE-BUFFER to '65535'; (See Figure 36)

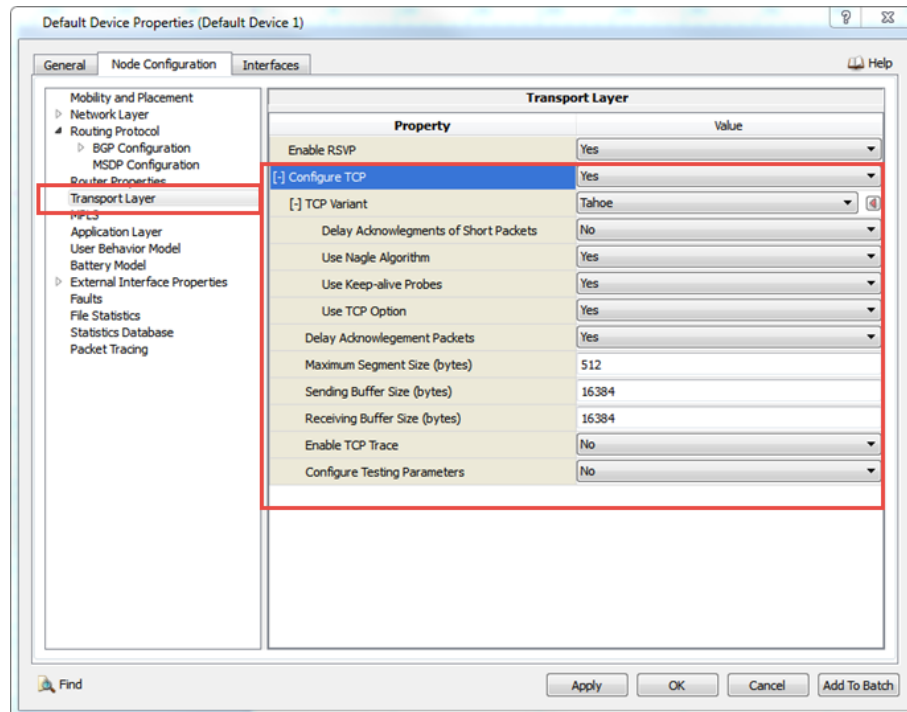


Figure 36: TCP Node Configuration.

6. **TCP traffic:** Create a FTP/GENERIC connection from node 1 to node 5 that from the start of the simulations; choose FTP/GENERIC from the dynamic application set the end time to 590 seconds. (See Figure 37).

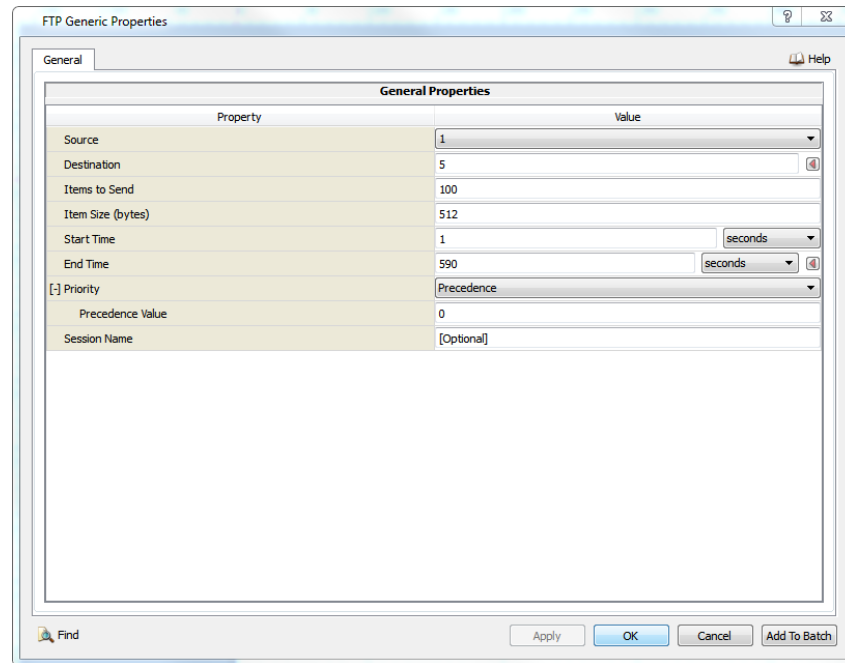


Figure 37: FTP properties

7. **UDP traffic:** Create CBR traffic from node 2 to node 5 that continuously transmits 512-byte application layer data items at the start of the simulation up to 590 seconds into the simulation. (See Figure 38).

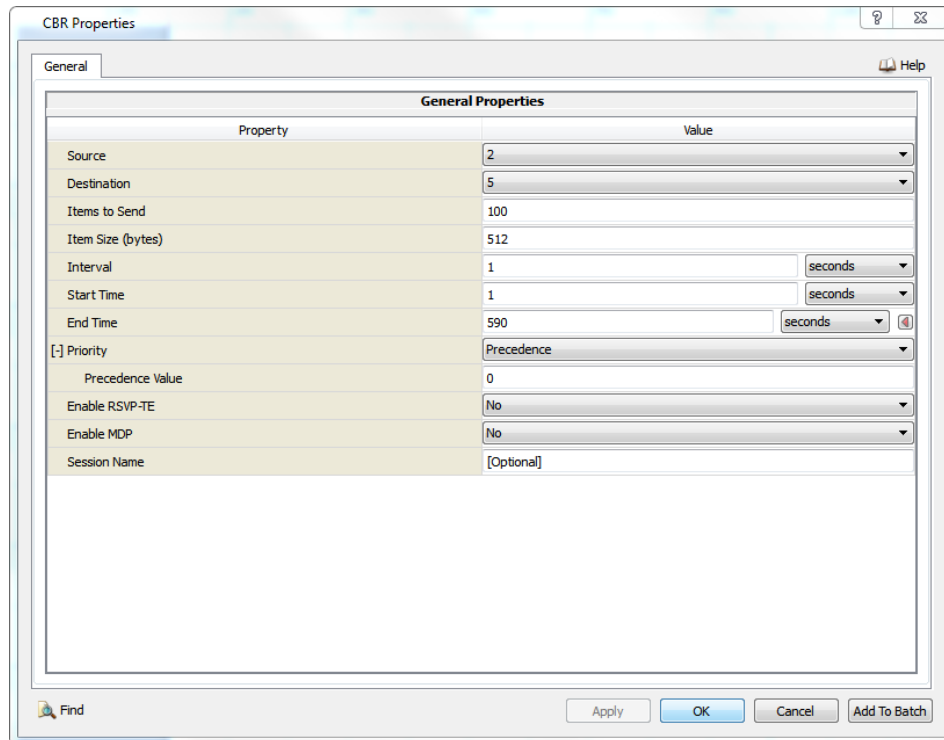


Figure 38: CBR Properties.

8. Choosing the statistics; turn off all statistics except for application, TCP, and UDP. (See Figure 39)
 - a. Go to the scenario properties.
 - b. Choose the statistics and tracing tab.
 - c. On the file statistics; untick all the boxes, apart from the TCP and UDP.

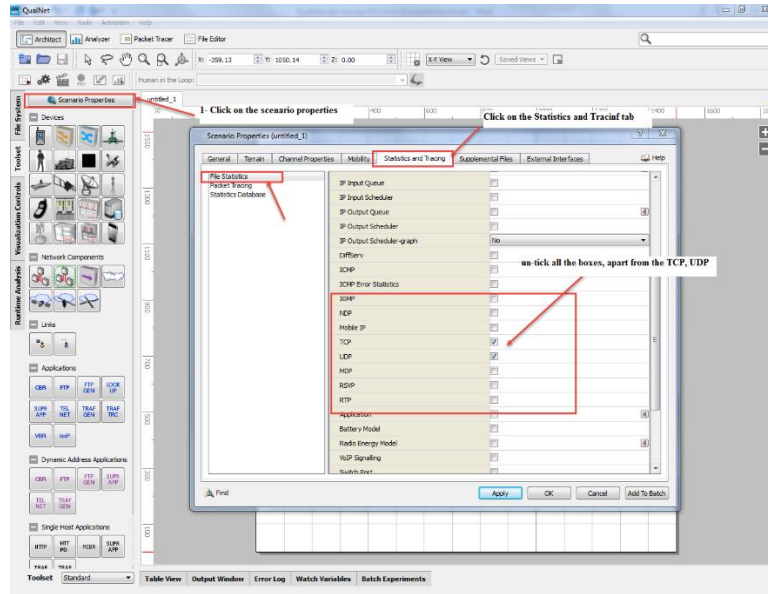


Figure 39: choosing the statistics.

9. To trace the CBR, FTP, TCB enabling Tracing packets from the scenario properties (refer to the get starting QualNet), (see Figure 40).

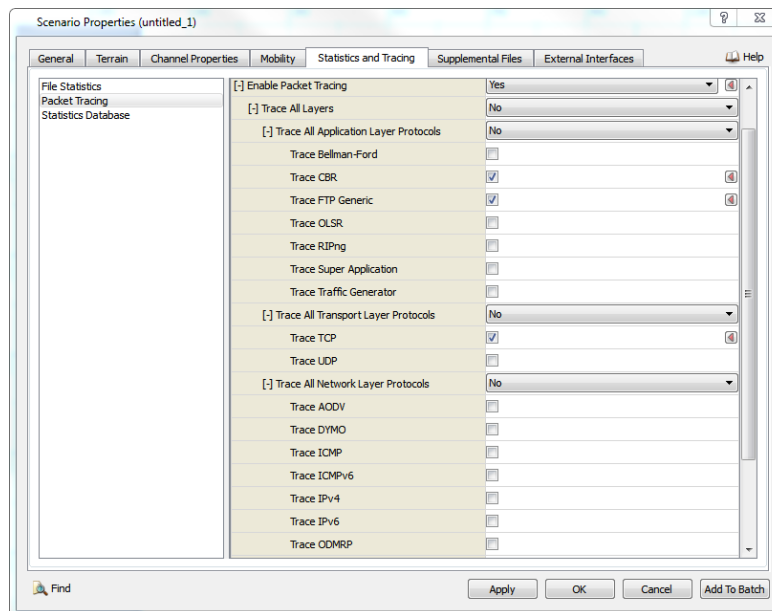


Figure 40: Trace Packets.

10. To trace the TCP and UDP select the option (See Figure 41).

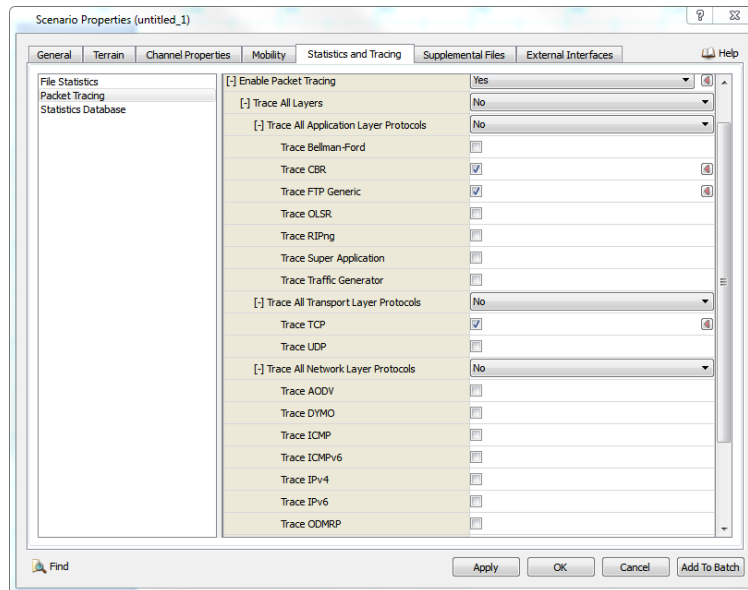


Figure 41: Tracing Packets

After running the scenario by clicking on the  view the results as in Figure 42 and choose the corresponding.

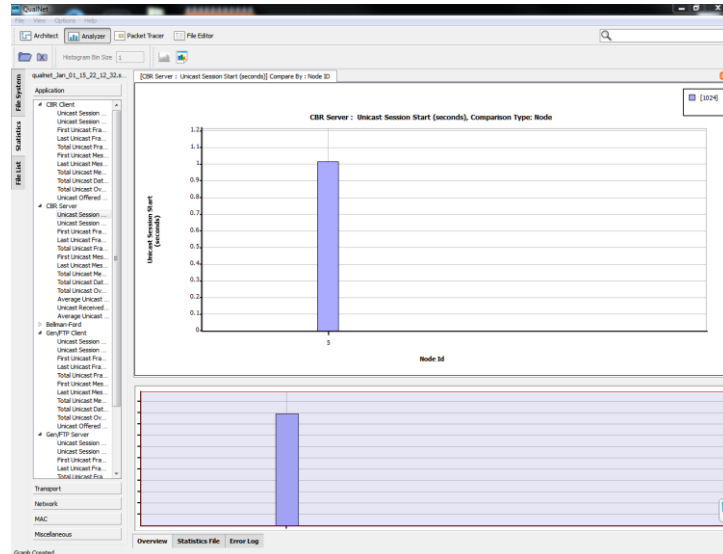


Figure 42: Results

Questions

1. What are the TCP variants supported by QualNet 4.0? Describe the differences among these TCP variants.
2. Examine the FTP/TCP statistics in the file exp3.stat:
 - For node 1 (the TCP sender), what is the '**Total Bytes Sent**' from the FTP application? How about the '**Data Packets Sent**', '**Data Packets in Sequence**', and '**Data Packets Retransmitted**' by TCP? What are the relationships among them?
 - For node 5 (the TCP receiver), what is the '**Total Bytes Received**' by the FTP application? What is the delivery ratio (i.e., #received / #sent) for this FTP application?
3. Examine the CBR/UDP statistics in the file Transport-lab.stat:

- For node 2 (the UDP sender), what is the '**Total Packets Sent**' from the CBR application?
- For node 5 (the UDP receiver), what is the '**Total Packets Received**' by the CBR application? What is the delivery ratio (i.e., #received / #sent) for this CBR application? Compared to TCP, how reliable is UDP's data transfer service?

END OF LAB

Lab-Multi Channel Wireless network

Objective

To show how to configure multiple wireless channels and specify channels for individual subnets using listening and listenable channel masks.

Overview

In this exercise, you will simulate CBR multi-channel wireless network. .

Create network as shown in the following Figure 43: Network Topology

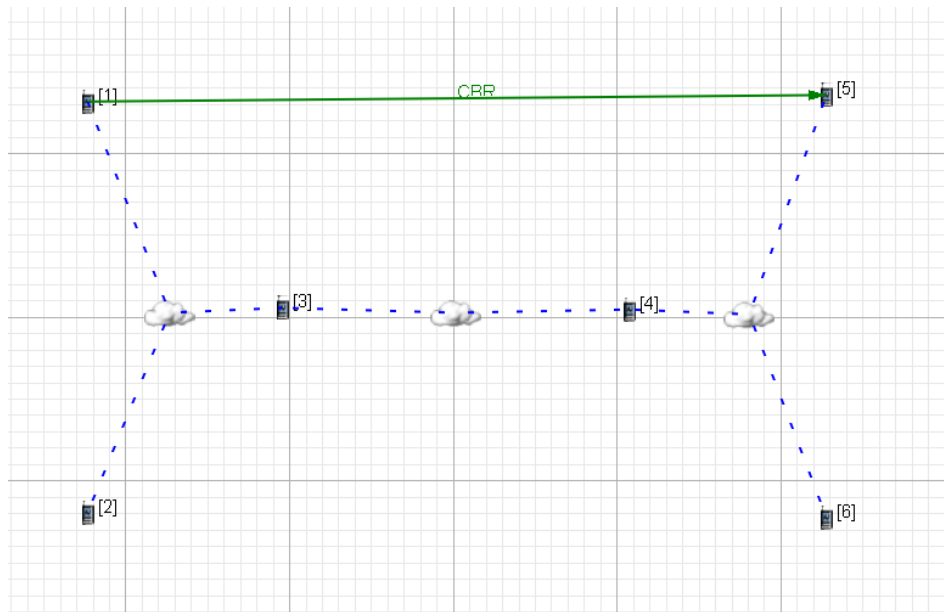


Figure 43: Network Topology

From the “Scenario Properties” go to the “Channel Properties” add four channels as in the following Figure 44: Channel Properties.

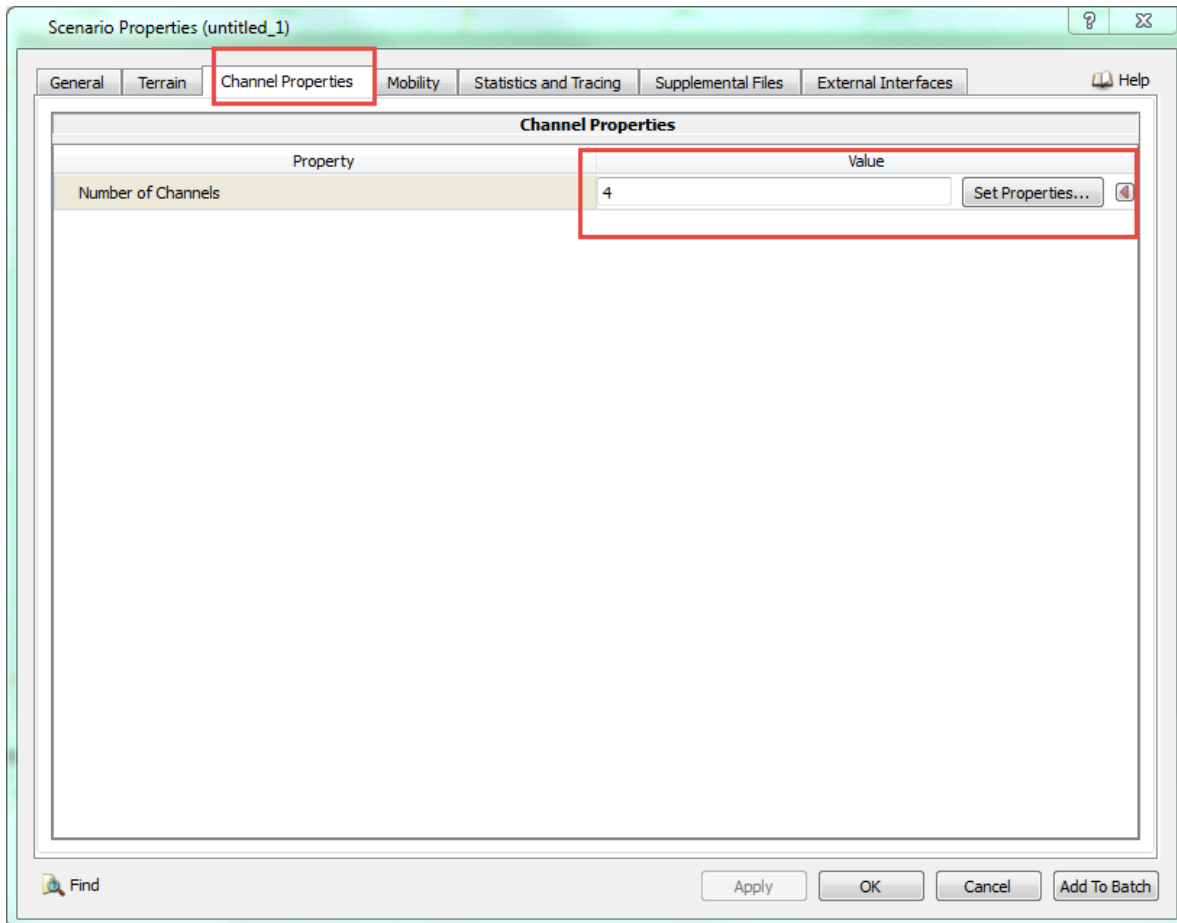


Figure 44: Channel Properties.

Right Click on each wireless network or “could” go-to properties then click on the “physical Layer” tab and change the “Listenable Channel” and “Listening Channels” as follows (see Figure 45: Wireless physical Layer.)

- Node 1, 2, 3 are in one subnet using wireless “channel 1” and “channel 0”

- Node 4, 5, 6 are in one subnet using wireless “channel 2” and “channel 0” Node 3 and 4 are in the third subnet using wireless “channel 3” and “channel 0”

The following figure is an example of what you should see in the second wireless cloud’s “physical layer”

The physical layer notice the channel properties click on there and add channel as follows

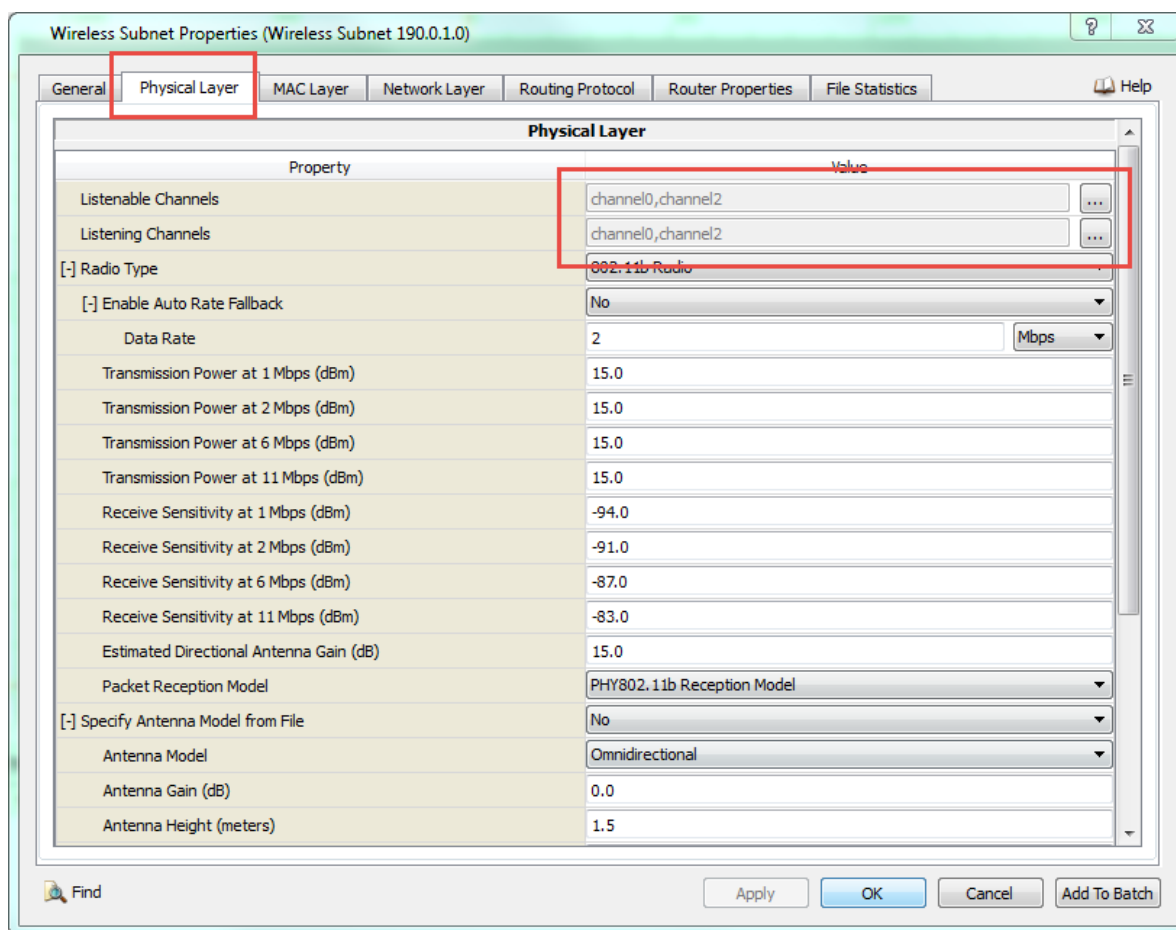


Figure 45: Wireless physical Layer.

Configure “Bellman Ford” as the routing protocol of all the wireless networks from the Cloud’s properties on the routing protocol tab as in the following Figure.

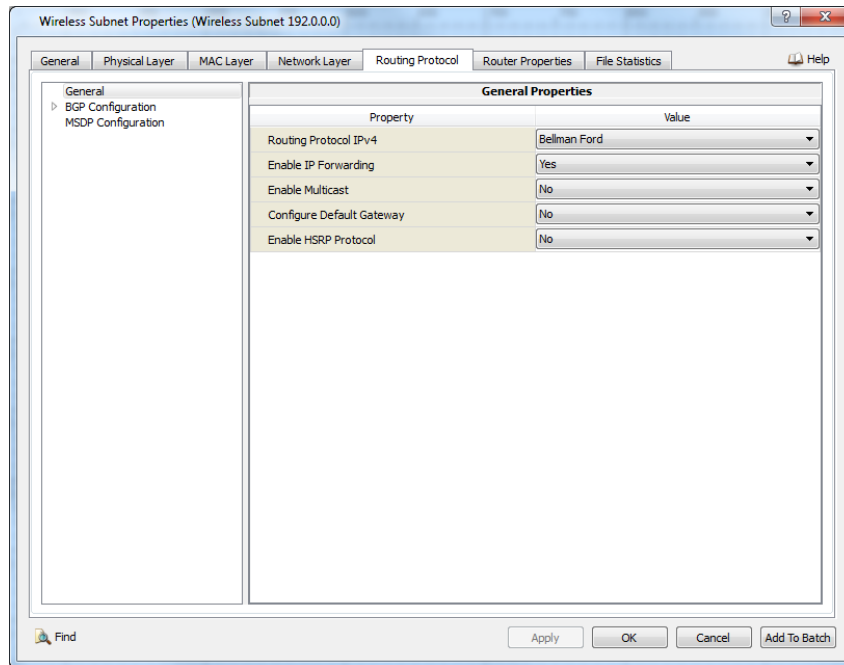


Figure 46: wireless routing protocol

Now I need you to right click on node (4, 5) and click on the “Interfaces” tab, you should see something similar to the following Figure.

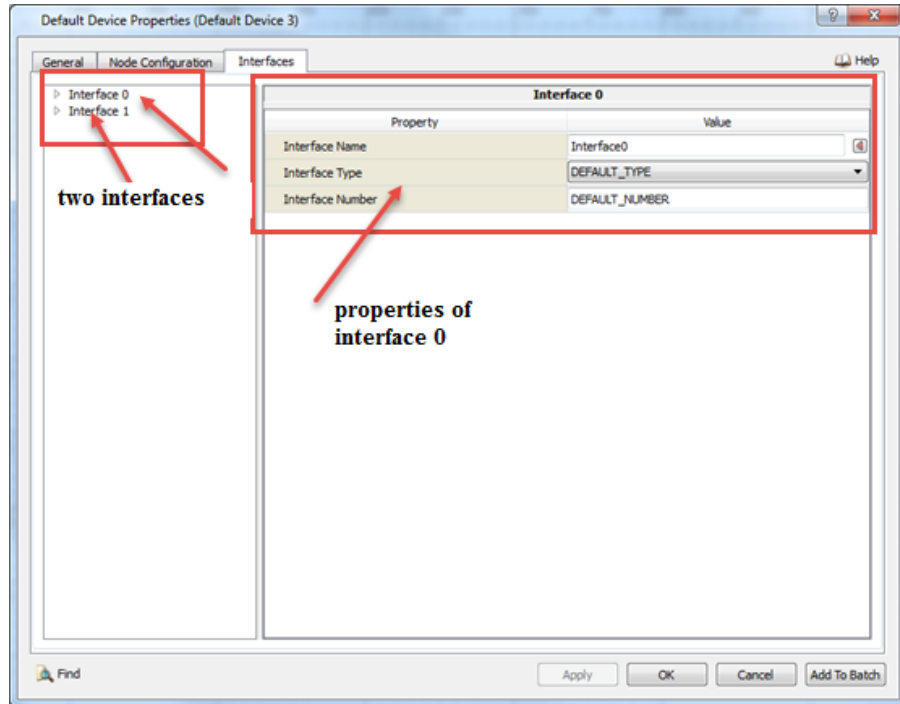


Figure 47: node Multi Interface.

APPLICATIONS figuration as follows:

- CBR 1 ,5 ,50 ,512 ,1S ,1S ,25S PRECEDENCE 0

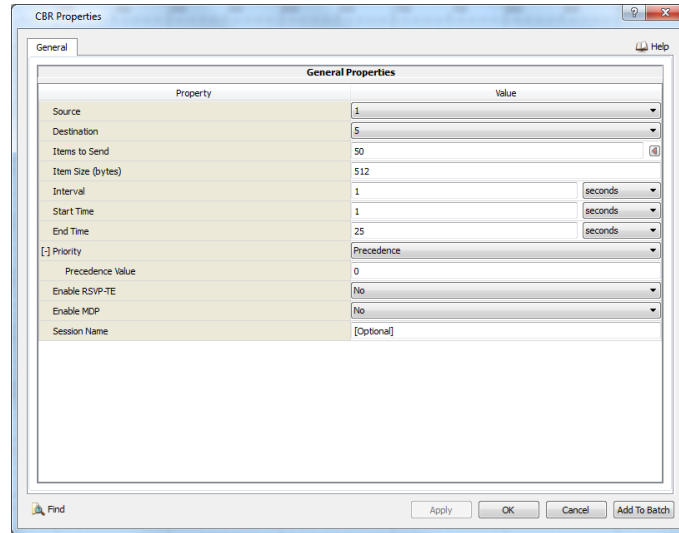


Figure 48: Application Properties

Run the scenario and observe the results.

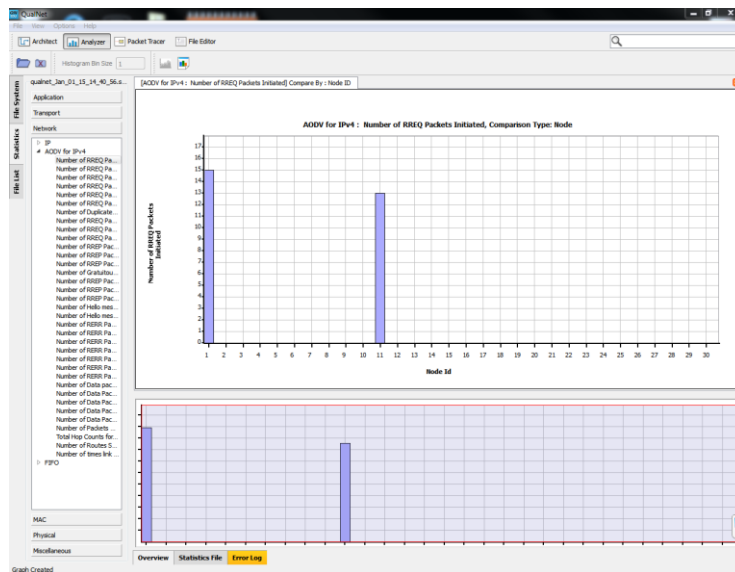


Figure 49: Sample Results

End Lab

Lab: create Network.

Part 1: Setting Up a Network - Basics

The first task is to create a new network scenario. To do this, go to the File Menu ->New.

Save it in your local folder: File Menu ->Save. Choose the local directory where you want to save the scenario. Enter a name for the new scenario (for example, “Example1”). Click Save. A grid should appear in the right hand window (see Fig 1). This is where we will deploy the nodes and create network connections. The left hand window has four panels: File System, Toolset, Visualization Control and Runtime Analysis (Toolset panel open).

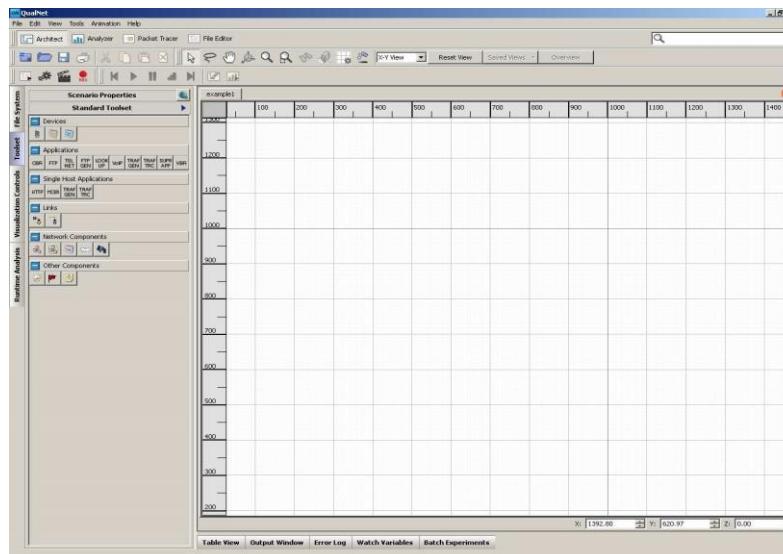


Figure 50: A new scenario has just been created

To setup our first network, we will proceed by a simple example of a 15 node wireless network that accesses the channel using the CSMA/CA scheme defined by the 802.11 protocol. The first step in creating a network is to deploy the nodes. This is done in the

right hand window, the so-called Canvas Area. Nodes can be deployed manually according to an arbitrary topology by selecting **Toolset -> Device -> Default** (just a generic node), then clicking anywhere on the canvas area. In ad-hoc networking scenarios it is often assumed that the nodes are deployed randomly on the terrain and we will assume random deployment in this example. To randomly deploy the nodes we go to the **Tool menu -> Node Placement**. The Automatic Node Placement Wizard will open (see Figure 51).

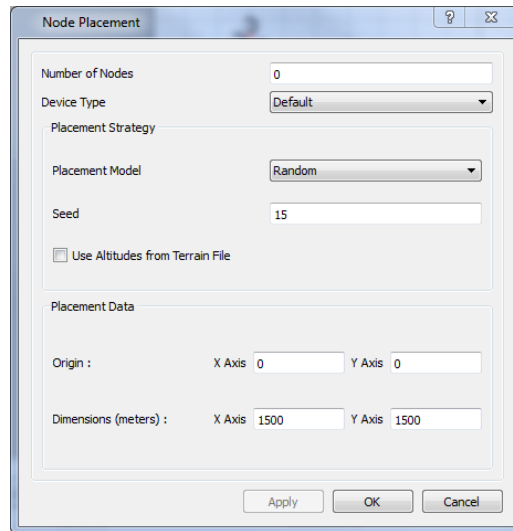


Figure 51: Node placement

We then enter the desired number of nodes we would like in our network. Node Placement Strategy:

- **Random.** It then asks for a seed value for the random number generator (leave it blank). Click OK.

The Placement Wizard will close and the nodes will be deployed randomly on the grid in the Scenario Designer window (see Figure 52). Location of a node may be changed by left

clicking the mouse on the arrow button then left clicking it on the node and dragging it to the desired location.

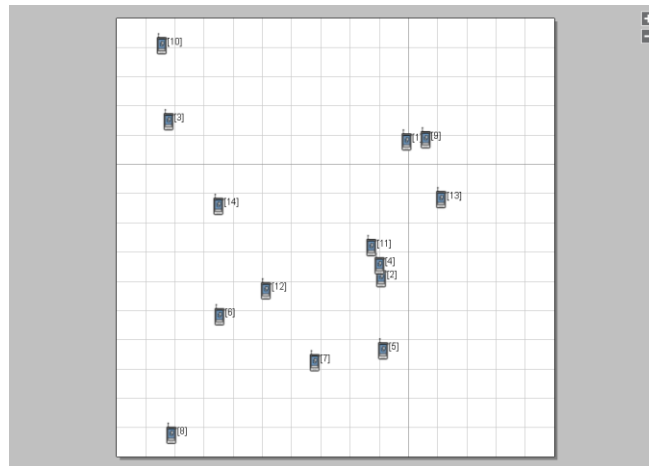


Figure 52: Random node deployment

We now want to add these nodes to a wireless network. The first step is to select the nodes we wish to add to the wireless network. To do this we can use the selection tools (arrow or lasso in the View Toolbar). Select all of the nodes by using either of the selection tools and left clicking and dragging the mouse around the nodes. To connect these nodes to a wireless network, select **Toolset > Network Components -> Wireless Network**. Now click anywhere on the area you selected earlier. A cloud should appear on the canvas area representing this wireless network and the nodes should be joined to this cloud with blue lines representing the newly formed wireless connections (see Figure 53).

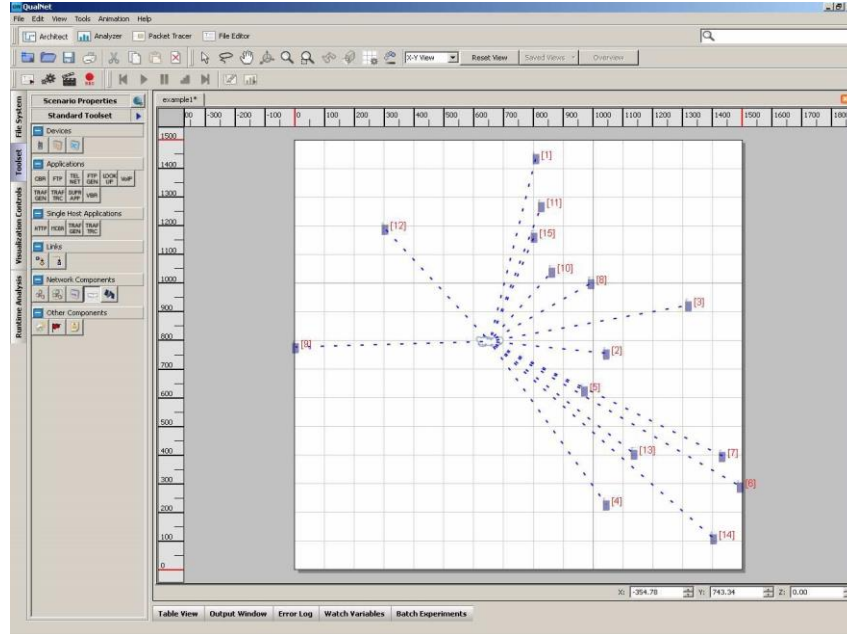


Figure 53: The Nodes Connected to the Wireless Network

Part 2 A: Creation of Application Layer Connections

After setting up the network, the next step is creation of application layer connections between the nodes. At any time, there may be several connections active simultaneously in the network. Each connection will have a source and a destination node. The source node generates traffic and transmits to a destination node. Let us create a connection between nodes 3 (source) and 4 (destination),

Selection of the source node: Left click the mouse over the arrow selection tool and then left click it over the device symbol for node 3, the color of number 3 should turn to red.

Next select a traffic source, the available pre-defined applications such as CBR (Constant Bit Rate), VBR (Variable Bit Rate), FTP Generic, VOIP, and Traffic-Gen

are listed in the left window under the heading -Applications. **We note that Traffic-Gen generates UDP traffic while FTP**

Generic generates TCP traffic. Let us select the Traffic Generator button  by left clicking the mouse over it.

Creation of the connection: Now left click the mouse over node 3, hold, and drag it to node 4. When the mouse is released over node 4, a green arrow pointing from node 3 to node 4 will appear. This creates a basic Traffic Generation application between the nodes 3 and 4 as source and destination respectively.

The next step is to choose the parameter values of this connection:

Let us create a Poisson process of data packets at the source and make the packet length exponentially distributed. To do this, click Table View on the bottom of the right window, and select the Application tab. You should see the connection Traffic-Gen 3->4 listed. Double click the connection. A window of Traffic Generator Properties will show up (Figure 54).

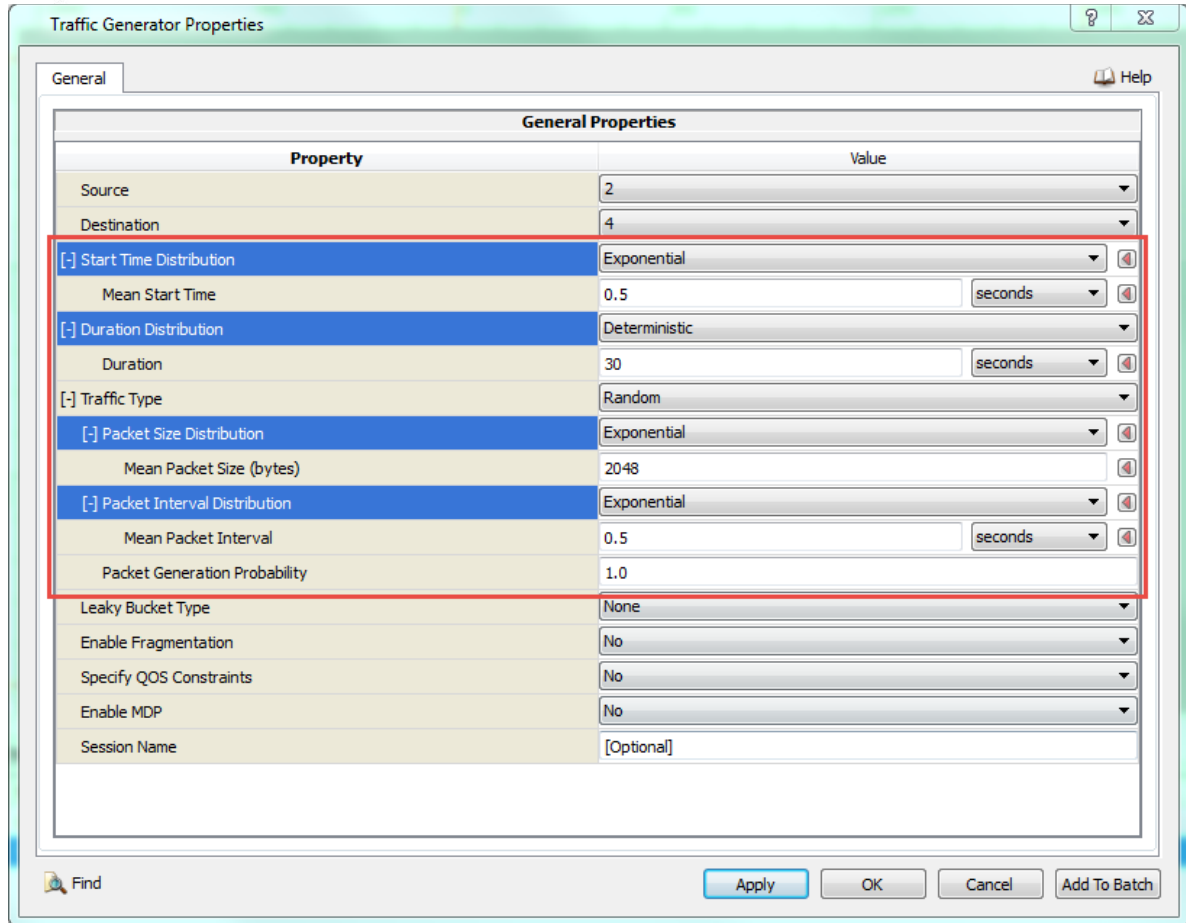
Click on the Packet Size, Recall, we want the packet lengths to be exponentially distributed with mean packet length 2048 bytes. The default size is deterministically set to 512 bytes. Change the Data Size from Deterministic to Exponential. Then change the Mean Size to 2048 bytes. To make the source generate traffic according to a Poisson process, click on Interval from the Traffic Type menu for this connection.

By default traffic is generated deterministically every 1 second. Change the

distribution of the interval between successive packets to Exponential and change the Mean Interval to 0.5 seconds (recall that the inter-arrival times for a Poisson process are exponentially distributed). As well, set the Start Time of the connection to Exponential with mean 0.5 seconds, and the Duration to Deterministic with fixed duration of 30 seconds.

These above steps have been summarized below see Figure 54: Traffic Generator Properties.

- Click on **Start Time Distribution**: Change the distribution to **Exponential** with mean **0.5** seconds.
- Click on **Duration Distribution** to **Deterministic** with fixed duration of **30** seconds.
- Click on **Packet Size Distribution**: Change the **Data Size** from **Deterministic** to **Exponential**. Then change the Mean Size to **2048** bytes.
- Click on **Packet Interval Distribution**: Change the distribution of the interval between successive packets to **Exponential** and change the Mean Interval to **0.5** seconds.



Traffic Generator Properties

General

General Properties

Property	Value
Source	2
Destination	4
[.] Start Time Distribution	Exponential
Mean Start Time	0.5 seconds
[.] Duration Distribution	Deterministic
Duration	30 seconds
[.] Traffic Type	Random
[.] Packet Size Distribution	Exponential
Mean Packet Size (bytes)	2048
[.] Packet Interval Distribution	Exponential
Mean Packet Interval	0.5 seconds
Packet Generation Probability	1.0
Leaky Bucket Type	None
Enable Fragmentation	No
Specify QOS Constraints	No
Enable MDP	No
Session Name	[Optional]

Find Apply OK Cancel Add To Batch

Figure 54: Traffic Generator Properties

Create multiple “Traffic Gen” connection as shown in Figure 55.

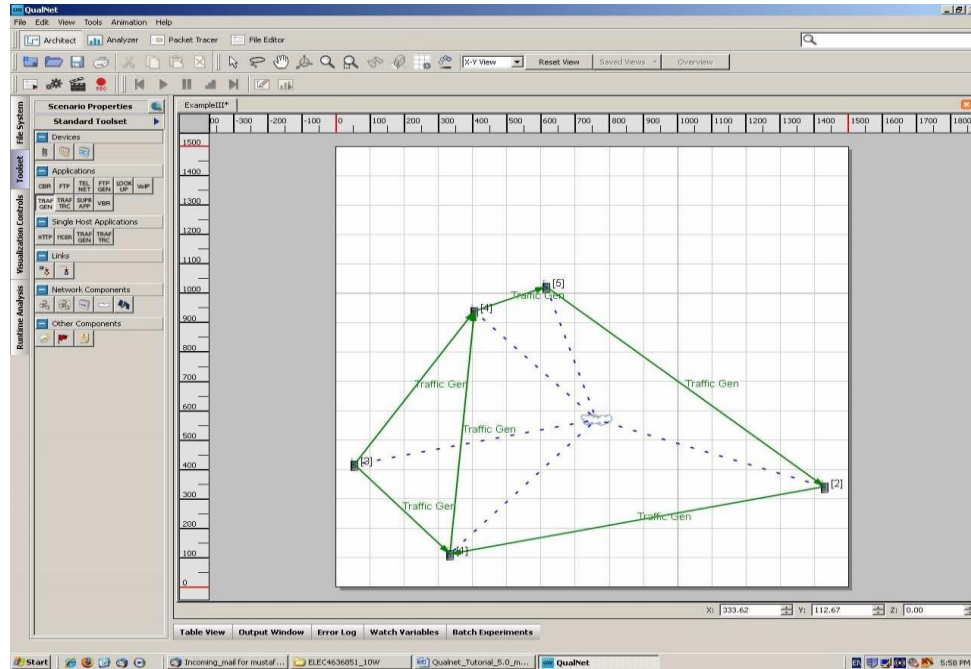


Figure 55: A Wireless Networks with Multiple Connections

Part 2 B: MAC Protocol

The default settings of the MAC protocol can be viewed by clicking on **Table View** in the bottom panel below the canvas. Click the network tab and double click **Wireless Subnet** (see Fig. 7). MAC protocol determines how the nodes access to the physical channel to transmit their packets. We note that the default MAC protocol is 802.11 standard. This standard has two modes of operations known as Distributed Coordination Function (DCF) and Point Coordination Function (PCF). The DCF is more popular in practice and based on the random access mechanism. Briefly, DCF function as follows, (see section 6.10.3 in the textbook for the description of this MAC protocol), DCF uses the CSMA protocol, thus a node, with a packet to transmit, first has to sense the channel. If the channel is busy the node backs off for a random amount of time.

We note that the channel may be idle at the source but not at the destination node. If the source node senses the channel idle, it transmits a short request to send (RTS) packet. If the channel is also idle at the destination node and it receives the RTS packet then replies with clear to send (CTS) packet. After that the source transmits the data packet and destination node replies with an ACK packet if the packet is received error free which completes the transmission of the packet. If the source node does not receive the CTS packet or an ACK following the transmission of the data packet then it backs off for a random amount of time. A source node may retransmit an unsuccessful packet up to a transmission limit, when that limit is passed then the packet is discarded (for values of these limits see Figure 56).

The routing protocol is Bellman-Ford (a Distance Vector routing algorithm). The default settings of the OSI layers can be modified here according to the requirements of the

network. As well, the default settings of an individual node can be viewed by clicking the Nodes tab and double clicking each node. The nodes update their routing tables regularly by exchanging routing packets. We note that in a single wireless sub network all the nodes are one hop away from each other, thus there is no routing, but nevertheless nodes will send routing packets regularly. It is worthwhile to spend a few minutes navigating through the menus to learn where to go in order to view or modify parameters in our network scenario. We can right-click the nodes or wireless network in the canvas area.

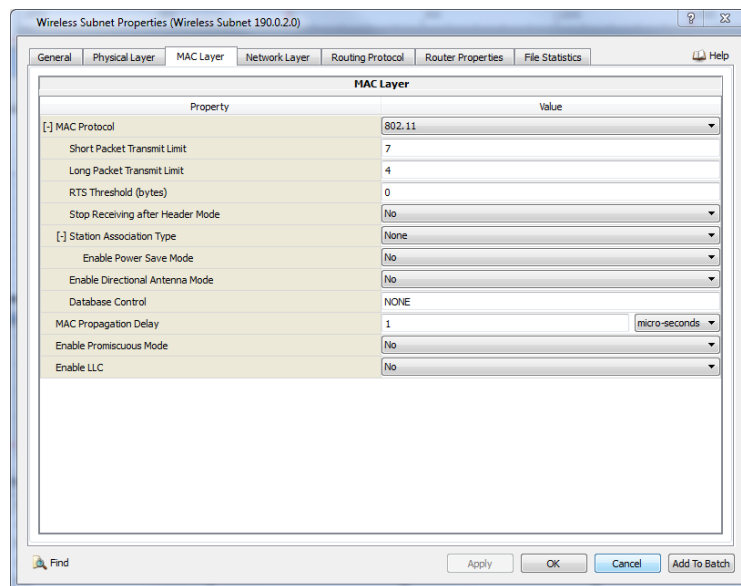


Figure 56: Properties of the MAC Protocol

Part 2 C. Wireless channel with Fading

We may include fading in the wireless channel by choosing the **Scenario Properties** button on the left side of the window and then selecting the **Channel Properties** tab in the new window. (See Figure 57) In the **Channel Properties** window go to the row which says Fading Model [0] and click on where it says “None”. From the drop out menu choose

Fading. Then go to the row which says **Specify Gaussian Component File**, click where it says **No** and change it to **Yes**. After this step is taken, a new menu item is open with the name Gaussian Component File, then fill that tab with the following entry,

C:/snt/qualnet/7.3/scenarios/default/default.fading

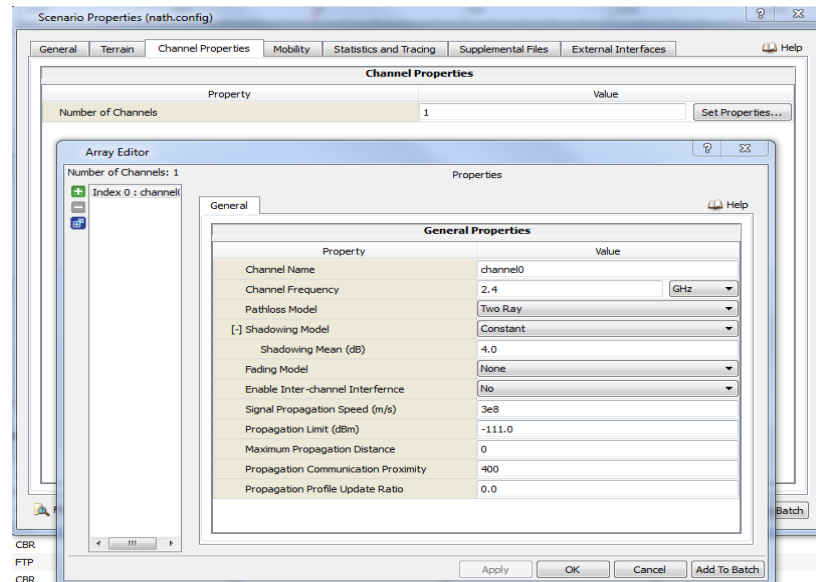


Figure 57: Incorporation of fading to the simulation

Part 3: Running Simulation

The next step is to run simulation of our network. One useful feature of the QualNet Developer package is the ability to trace packets. To enable packet tracing, go to **Scenario Properties** in the left hand window, select **Statistics and Tracing** tab, click Packet Tracing in the left window, select **Enabled Packet Tracing**, click where it says No and change it to Yes. See Figure 58.

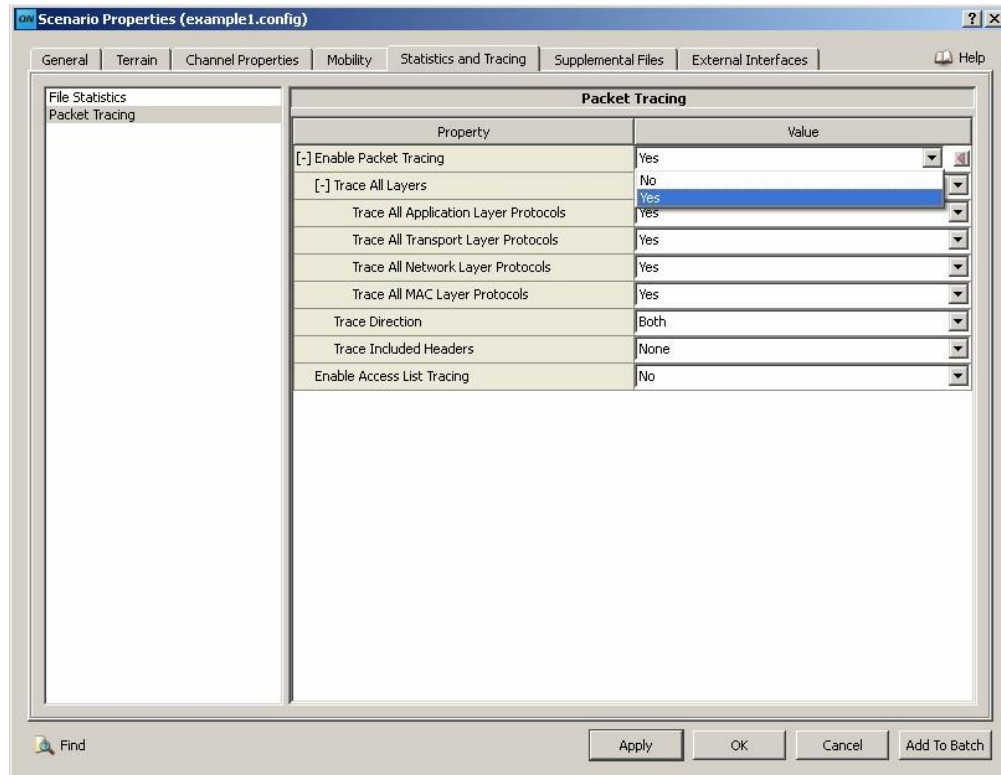


Figure 58: Enabling packet tracing.

On the Run Toolbar, there are a set of icons related to simulation which include an Open Current Scenario in File Editor, a Run Settings, a Run Simulation and Record Animation Trace. To initialize the scenario, click on the Run Simulation icon . The mode of the Architect will be changed from **Design Mode** to **Visualize Mode**. To switch back to Design Mode, click Switch to Design Mode icon . The **Visualization Controls** panel opens in the left window. You should see the coordinates of the nodes and the current simulation time (which is 0.0000 seconds) in the output window. Before running the simulation, we note that the Developer package will by default animate various aspects of the simulation such as packet receptions, packet drops and collisions, and unicast and

multicast transmissions. Others aspects such as packet queue animation can be enabled by clicking on the button in the Animation Filters which should appear in the left hand window. Enable the radio range animation. Simulation will tend to run very fast so if we wish to see the animation it will help to slow down the speed of the animation. This is done by sliding the speed bar to about half way in the Animator window. See Figure 59.

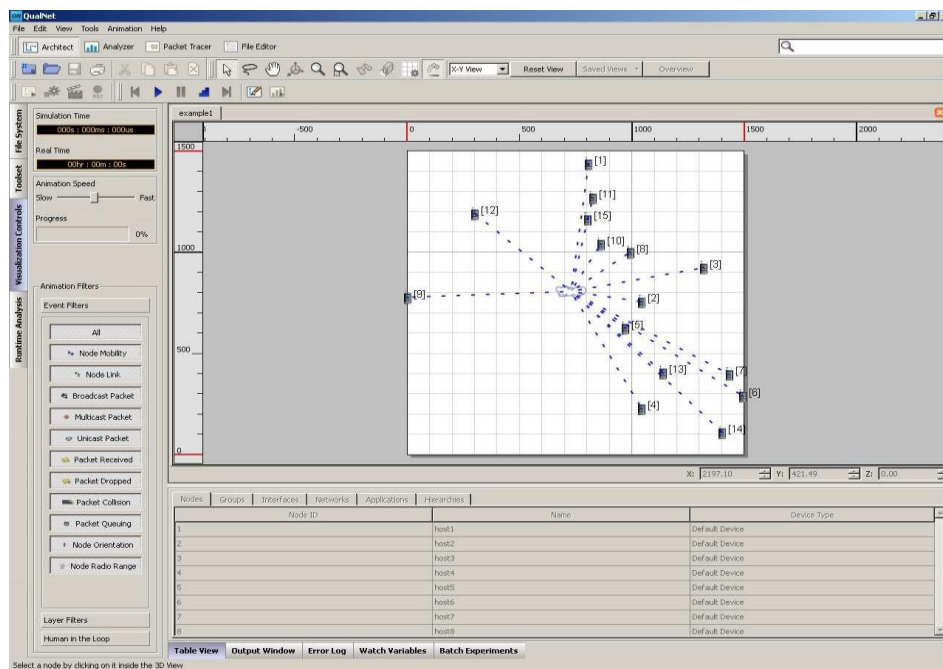


Figure 59: Initialization and animation settings for simulation.

The total simulation time can be changed by switching back to the Design Mode, click the **Scenario Properties** button on the left window, and select the **General** tab. The

Simulation Time is set to 30 seconds by default. We will leave this at its default value for now. We run the simulator by clicking the Play button  on the menu bar. You should see the simulation animations as the simulator runs (Figure 60).

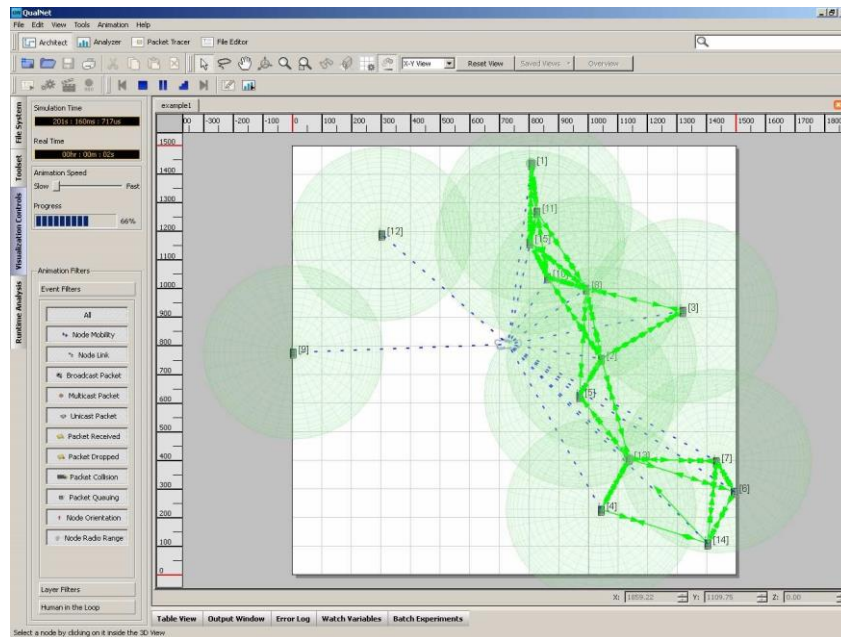


Figure 60: Simulation animations during a run.

You can enable or disable the different animations while the simulation runs. Wait until the simulation completes.

Part4. Routing of the traffic between sub networks

We need to have a router for to be able to route the traffic from one wireless sub network to another. The router will have two network interfaces each one being member of a one sub network. We can create a router as an ordinary node which belongs to both sub networks. Thus the router node is selected among the nodes belonging to that sub network when each

sub network is created (see Figure 61).

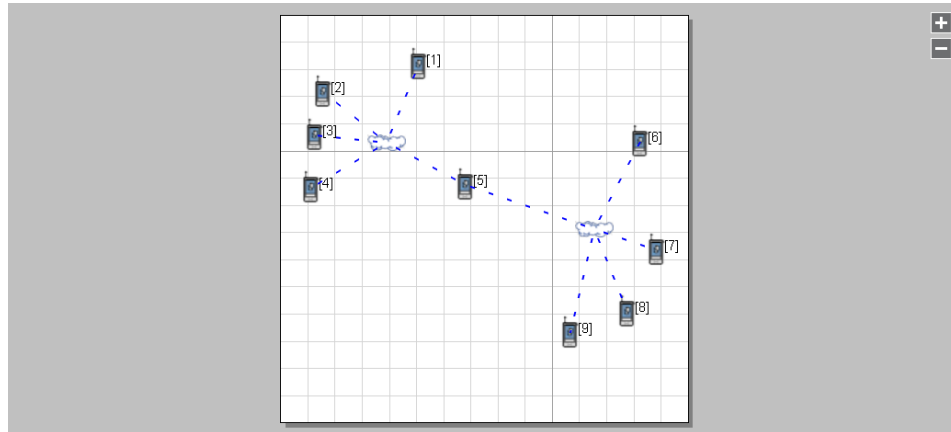


Figure 61: the two sub networks communicate through the router node

Next we will configure node 2 as a router. For this click on the Table view, then on the Node button, then double click on the row for node 2 and click on the Node Configuration button in the window that opens. Then click on the router properties on the left hand window which displays Figure 62.

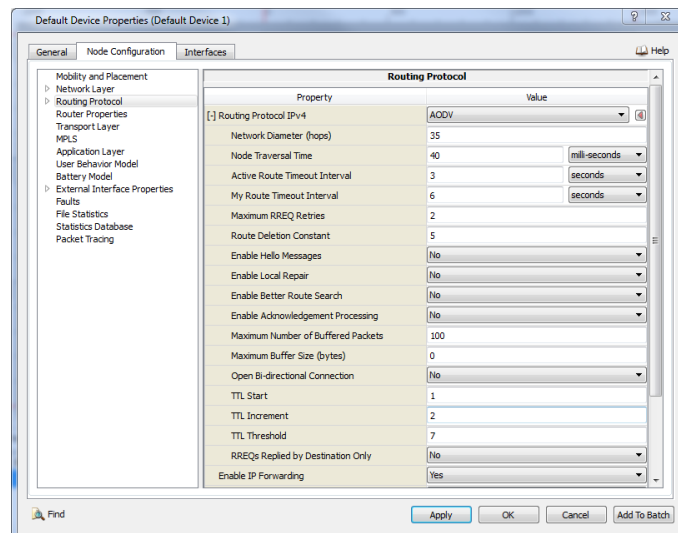


Figure 62: Node configuration window

In the **Node Configuration** window in the row for **Type of Router** click on the arrow for the value **User Specified** and from the opening menu choose **Predefined**. Then in the row for **Router Type** choose the value **Generic**. Finally choosing **Apply** button at the bottom of the window configures node 2 as a router (see Figure 63)

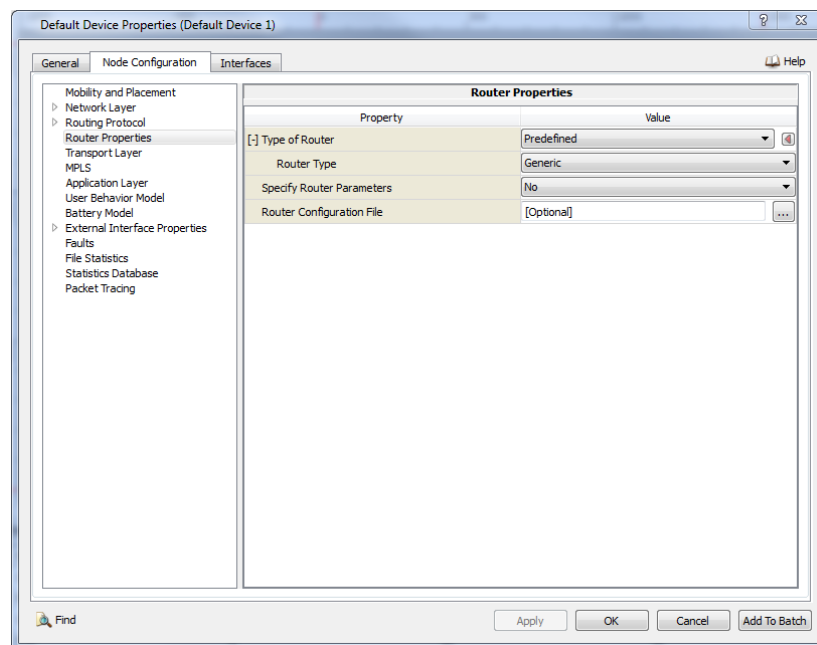


Figure 63: Node 2 Configured as a Router

Part5. Simulation Statistics

After the simulation has been completed, we can view the data collected during the simulation. To view the statistics of the simulation, click on the **Analyze Statistics** icon



in the Components toolbar.

1- Statistics File

If you click on the **Statistics File** button at the bottom of the window, you will see large amount of per node simulation data. Among the collected statistics we see,

The packets generated by the source nodes and received by the destination nodes are listed as unicast packets. In a connection not all the generated packets may be successfully delivered to the destination. As explained, in Part 2b. A packet will be discarded by the source as a result of reaching the number of retransmissions' limit. Transmissions may not be successful because of destination node not sending a CTS packet or as a result of the bit errors in the received packet. We note that the bit errors will depend on the distance between source and destination nodes, fading and shadowing. The strength of the received signal which will decrease as the distance between the source and destination nodes increases. As a result of packet discarding, the throughput of the source and destination nodes in a connection may not be same.

- If the distance between two nodes is higher than the node's transmission range, then, these nodes are not aware of each other. They cannot communicate with each other and they will not know each other's IP addresses. Therefore, if two such nodes will exchange data traffic with each other, the packets will be generated by the Application layer of the source node but they will not be passed to the transport and then to the network layers because the IP address of the destination node is unknown.

- In addition to unicast traffic packets, as may be seen there are other packets being transmitted in the network, RTS, CTS, ACK and Broadcasting packets for routing. For each successfully received unicast packet there will be a corresponding ACK path. The number of RTS and CTS packets will correspond to the total number of transmissions of a packet until it is successfully transmitted.

2- Graph Analyzer Window

If you click on the **Overview** button at the bottom of the window, then we can navigate through the Physical, MAC, Network, Transport, and Application layers shown on left hand window. We can access to each layer data by clicking on the button for that layer at the bottom of left hand window. This results in opening of a menu for that layer in the left hand window. Then clicking on any of the menu items displays a submenu. Clicking on any submenu item displays a bar chart for the data collected for that item during the simulation.

In Figure 64 we are ready to view the data collected in the application layer.

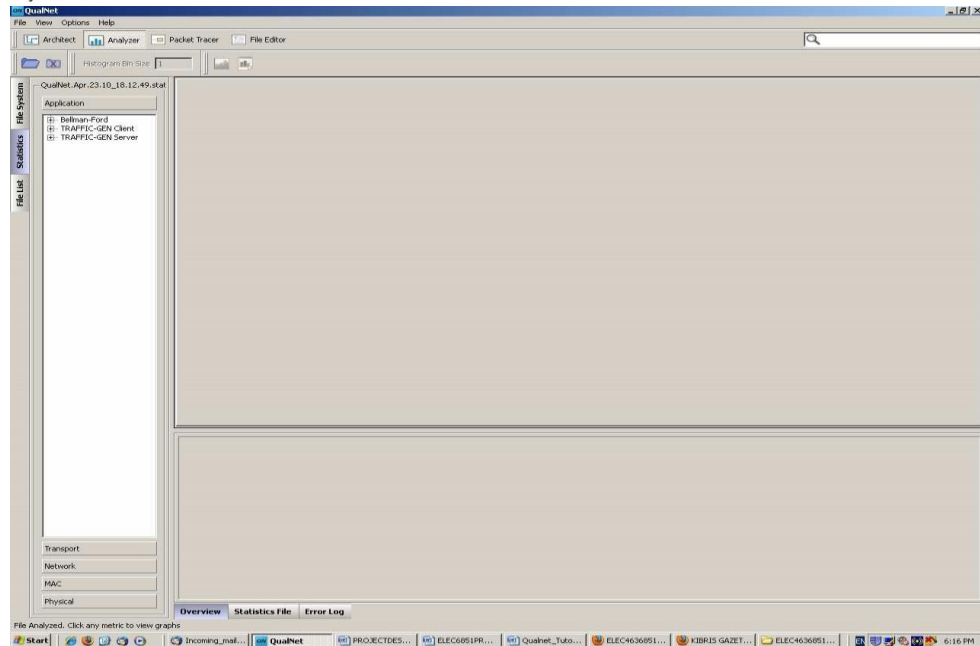


Figure 64: viewing the data collected during the simulation

In Figure 64, when we click on the Traffic-Gen Client button on the left hand window, then from the drop out menu we click on the data units sent. These results in Figure 65 which shows the bar charts for the total number of packets generated at the application layer of each node.

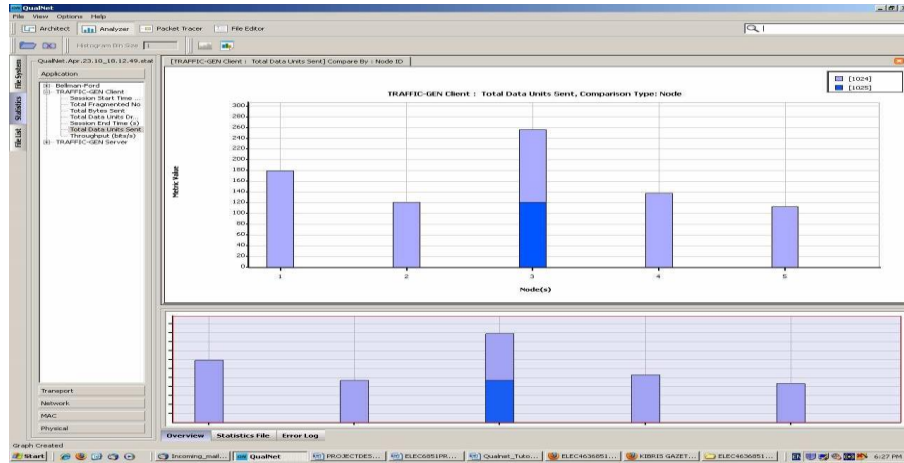


Figure 65: Traffic generated at the application layer of each node

End Lab

Lab: Wired network- Ethernet Switches

Objective

Illustrate implementing Layer 3 Switch Ports in QualNet.

Overview

Here are four Ethernet Switches that form a fully meshed wired network backbone. Each switch has a default device acting as a layer 3 switch port linked with a 1000 Gbps to the switch. The default device facilitates assigning a subnet IP address to the network spoked from the switch as EXata / QualNet Ethernet Switches do not support layer 3 switching definitions. Six nodes are paired using lookup for two way data exchange, RIP is the routing protocol.

Part 1: Using GUI based QualNet

1. Create a new scenario named Wired network ' figure1 is the topology you need to copy. **Note that the Error! Reference source not found. represents the actual topology**

Start QualNet and create new scenario (file) from the File menu.

From the side toolbar; devices menu, select the switches and default devices and place it as in **Error! Reference source not found..**

Figure 66: Network Topology.

Make note of every switch interface (See Figure 67).

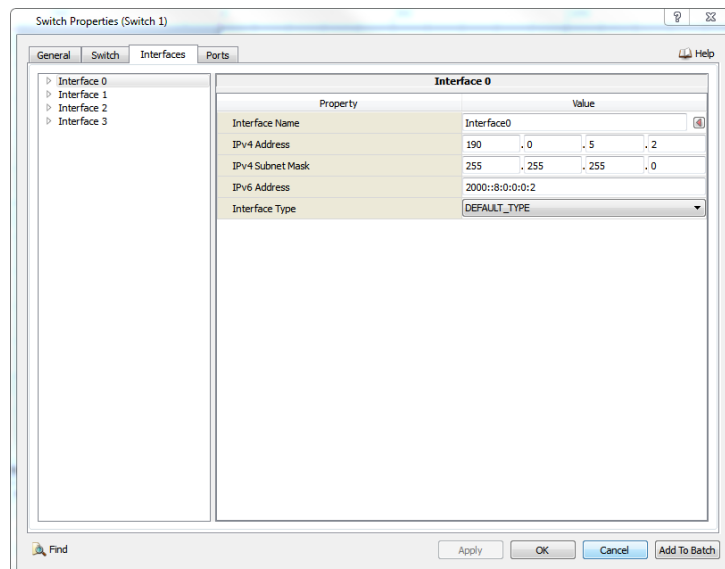


Figure 67: Switch Interfaces.

From the default node properties change names as it is on the topology (See Figure 68).

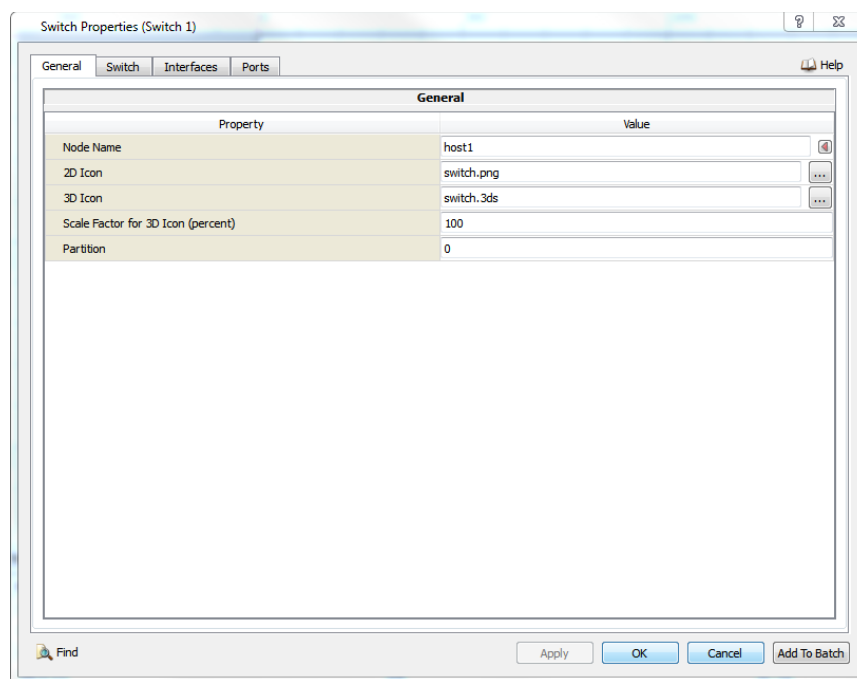


Figure 68: Switches Properties.

Link all the nodes as shown in figure 1 leave it as default except for the nodes between the switches change the bandwidth to 1000 GBps as in Figure 69

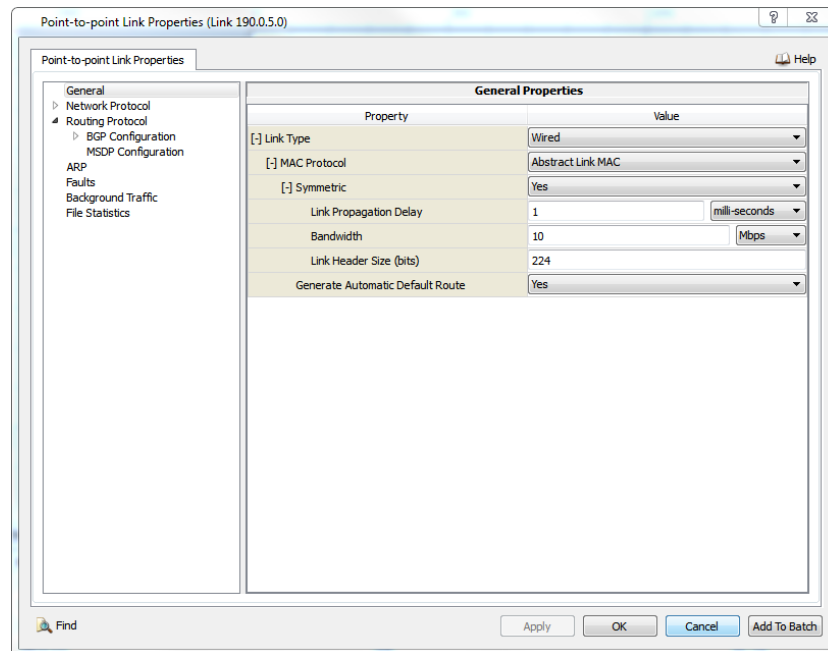


Figure 69: link properties.

From the application tools set choose lookup application as in Figure 70

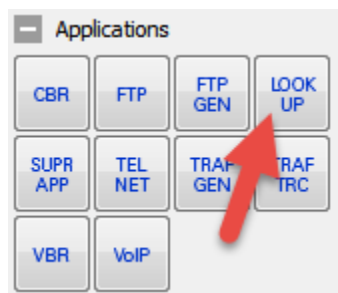
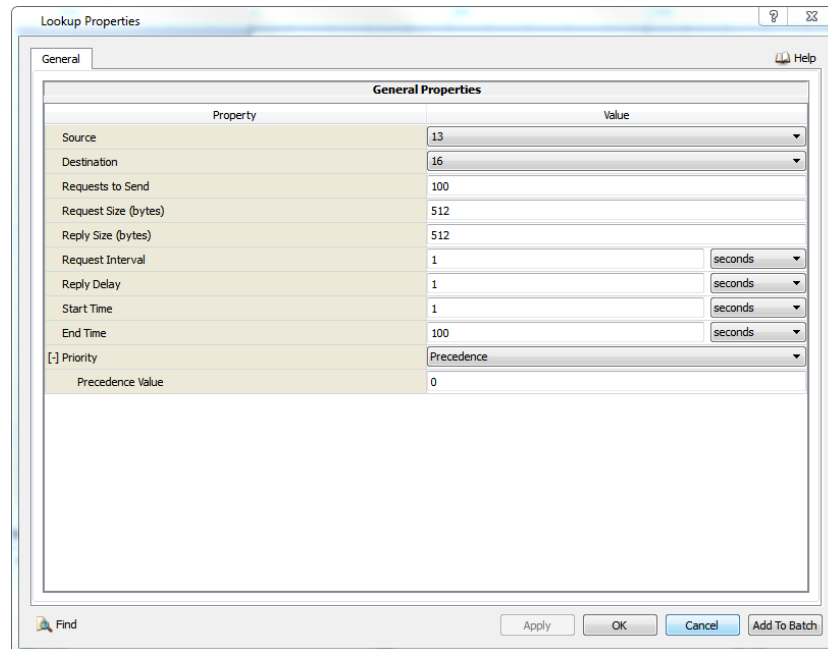


Figure 70 Application toolset

Add the Lookup application between (5—7), (3—6) (4—8) see Figure 72, use default properties as in Figure 71.



Property	Value
Source	13
Destination	16
Requests to Send	100
Request Size (bytes)	512
Reply Size (bytes)	512
Request Interval	1 seconds
Reply Delay	1 seconds
Start Time	1 seconds
End Time	100 seconds
[.] Priority	Precedence
Precedence Value	0

Figure 71: application properties.

Nodes Groups Interfaces Networks Applications Hierarchies				
Type	Source ID	Destination ID	Start Time	End Time
Lookup	12	14	1S	100S
Lookup	13	16	1S	100S
Lookup	11	15	1S	100S

Figure 72: application links.

Now check the networks from the sub networks table and make note of it as in Figure 73.

Nodes Groups Interfaces Networks Applications Hierarchies		
Network Address	Type	Member Nodes
190.0.5.0	Link	{3, 2}
190.0.3.0	Link	{12, 5}
190.0.3.0	Link	{5, 13}
190.0.3.0	Link	{5, 11}
190.0.3.0	Link	{7, 5}
190.0.3.0	Link	{5, 8}
190.0.2.0	Link	{9, 6}
190.0.2.0	Link	{6, 10}
190.0.2.0	Link	{6, 14}
190.0.2.0	Link	{6, 13}

Table View Output Window Error Log Watch Variables Batch Experiments

Figure 73: sub networks.

Set simulation time to 30 minutes by modifying corresponding property as shown in Figure 74.

Scenario Properties (untitled_1)

General Terrain Channel Properties Mobility Statistics and Tracing Supplemental Files External Interfaces Help

General Settings
Parallel Settings
Advanced Settings

Property	Value
Experiment Name	qualnet
Experiment Comment	NONE
Simulation Time	30 minutes
Seed	1
Scenario Background Image File	[Optional]
Disable Modifications to Scenario	No

Find Apply OK Cancel Add To Batch

Figure 74: scenario properties

Select all subnets and modify the routing protocol to be “RIP”.

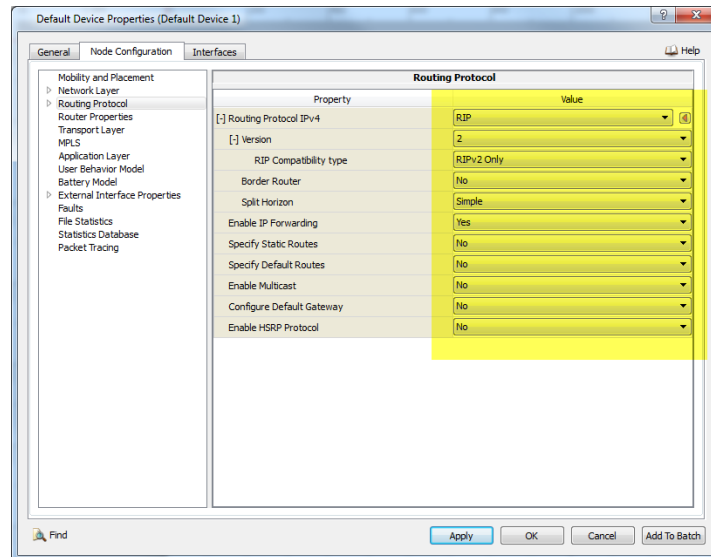


Figure 75: selecting the routing protocol

Run scenario in the **Animator** (refer related part in lab1Starting QualNet for details).

Review **Application** statistics in the **Analyzer** (refer related part in second lab - Starting QualNet for details)

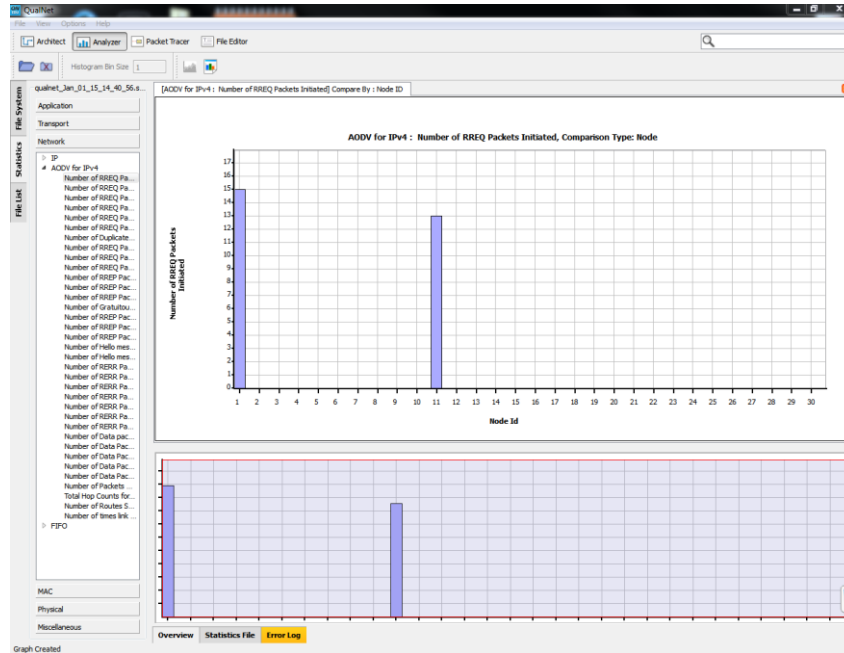


Figure 76: results

END OF LAB

Extra Lab: Implementing new routing protocol in QualNet.

Objective

The objectives of this exercise are to both help understand the Distance-Vector routing algorithm and learn how to implement a custom protocol in the QualNet simulator.

Overview

First, you will study and implement a simple Distance-Vector routing protocol, based on the provided protocol framework. Next, you will integrate the implemented routing protocol into QualNet. There is a tutorial on how to add a new custom routing protocol into QualNet which describes the entire process in a step-by-step manner.

Part 1: A simple Distance-Vector (DV) routing protocol

In Part 1, you will implement a simple routing protocol based on the Distance-Vector algorithm. The protocol is named as Simple Routing Information Protocol (SRIP), which has two major functionalities:

1. Maintaining the routing table according to the DV algorithm.

2. Forwarding data packets as they arrive by consulting the routing table.

Your job is to implement the SRIP algorithm. The necessary framework (including two files: `routing_srip.h` and `routing_srip.cpp`) is provided as a compressed tar file downloadable from Moodle. The only file that you need to modify is `routing_srip.cpp`, where you will modify three out of four functions described below. Please go through both files as you read the following.

1. `SripInit()` -- This function is called upon starting the simulation initially. For SRIP, you should initialize the routing table in this function (i.e., set all distances to INFINITY and all next hops to INVALID_ADDRESS). Please do not forget to initialize the entry for the host node itself so that the distance is 0 and the next hop is its own address. Please examine the provided `routing_srip.h` and `routing_srip.cpp` code for details on the data structure of the routing table.
2. `SripHandleProtocolEvent()`: This function is called whenever a "Route Update Broadcast" message (a.k.a., route update packet) needs to be sent to the neighbours. It is already provided and you do not need to make any change. This function responds to the "Route Broadcast Timer" message. When the timer expires, this function is called. The function constructs a "Route Update" packet, which includes all the valid entries of the routing table, and broadcasts it.
3. `SripHandleProtocolPacket()`: This function is called whenever a protocol packet (which is a "Route Update" packet in SRIP) arrives. You need to modify this

function to update the routing table according to the DV algorithm and the information received in the Route Update packet.

4. SripRouterFunction() : This function is called whenever the IP layer receives a data packet from either its own transport layer or another node, and tries to determine the next hop to which the IP packet should be forwarded. The function consults the routing table to identify the entry for the destination of the received packet. If a valid next hop and distance value are found for the destination node, the packet is sent to the MAC layer using the function NetworkIpSendPacketToMacLayer().

Part 2: Adding a custom routing protocol into QualNet

In Part 1, you've learned to implement the major functions for SRIP. In Part 2, you will integrate the implemented protocol into QualNet.

Please download from Moodle a compressed tar file, which includes the complete SRIP source, configuration files and a tutorial & README explaining in details the entire process of adding a routing protocol to QualNet. Integrate SRIP protocol into QualNet accordingly. Then re-compile and run QualNet with the provided SRIP configuration files srip.config and srip.app.

Questions

1. In which layer is SRIP implemented? How about Internet's RIP?
2. What five major functions are needed in order to implement a network layer routing protocol in QualNet?

3. List all types of protocol event(s)/timer(s) and packet(s) in SRIP?
4. Submit in the generated statistics file (srip.stat) after running QualNet with the provided SRIP configuration files (srip.config and srip.app), and answer the following:
 - What is the SRIP "Route Update" interval used in above run?
 - How many "Route Update" broadcasts are sent out at each node?

The End,

Good Luck every Body.