LAB 1

CSMA

A Direct Link Network with Media Access Control

OBJECTIVES

This lab is designed to demonstrate the operation of the Ethernet network. The simulation in this lab will help you examine the performance of the Ethernet network under different scenarios.

OVERVIEW

The Ethernet is a working example of the more general carrier sense multiple access with collision detect (CSMA/CD) local area network technology. The Ethernet is a multiple-access network, meaning that a set of nodes sends and receives frames over a shared link. The "carrier sense" in CSMA/CD means that all the nodes can distinguish between an idle and a busy link. The "collision detect" means that a node listens as it transmits and can, therefore, detect when a frame it is transmitting has interfered (collided) with a frame transmitted by another node. The Ethernet is said to be a 1-persistent protocol because an adaptor transmits its ready frame with probability 1 whenever a busy line goes idle.

In this lab, you will set up an Ethernet with 30 nodes connected through a coaxial link in a bus topology. The coaxial link is operating at a data rate of 10 Mbps. You will study how the throughput of the network is affected by the network load as well as the size of the packets.

PRE-LAB ACTIVITIES

Read Section 2.6 from *Computer Networks: A Systems Approach, 5th Edition.*

Go to www.net-seal.net and play the following animation:
- Hub

PROCEDURE

Create a New Project

To create a new project for the Ethernet network:

1. Start **OPNET IT Guru Academic Edition** → Choose **New** from the **File** menu.
2. Select **Project** → Click **OK** → Name the project **<your initials>_Ethernet**, and the scenario **Coax** → Click **OK**.

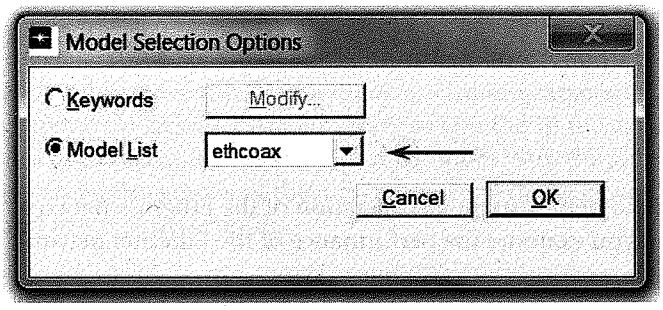
Local area networks (LANs) are designed to span distances of up to a few thousand meters.

3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty Scenario** is selected → Click **Next** → Choose **Office** from the *Network Scale* list → Click **Next** → Assign **200** to **X Span** and keep **Y Span** as **100** → Click **Next** twice → Click **OK**.
4. Close the *Object Palette* dialog box.

Create the Network

To create our coaxial Ethernet network:

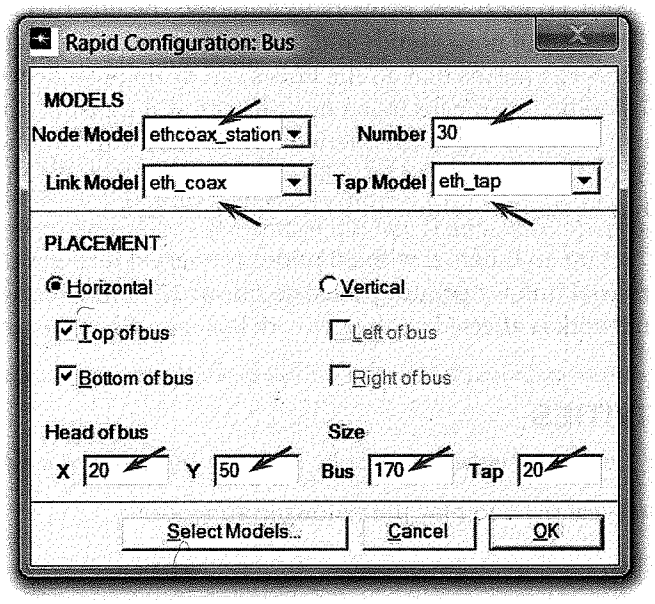
1. To create the network configuration, select **Topology** → **Rapid Configuration**. From the drop-down menu choose **Bus** and click **OK**.
2. Click the **Select Models** button in the *Rapid Configuration* dialog box. From the *Model List* drop-down menu choose **ethcoax** and click **OK**.



The **eth_tap** is an Ethernet bus tap that connects a node with the bus.

The **eth_coax** is an Ethernet bus that can connect nodes with bus receivers and transmitters through taps.

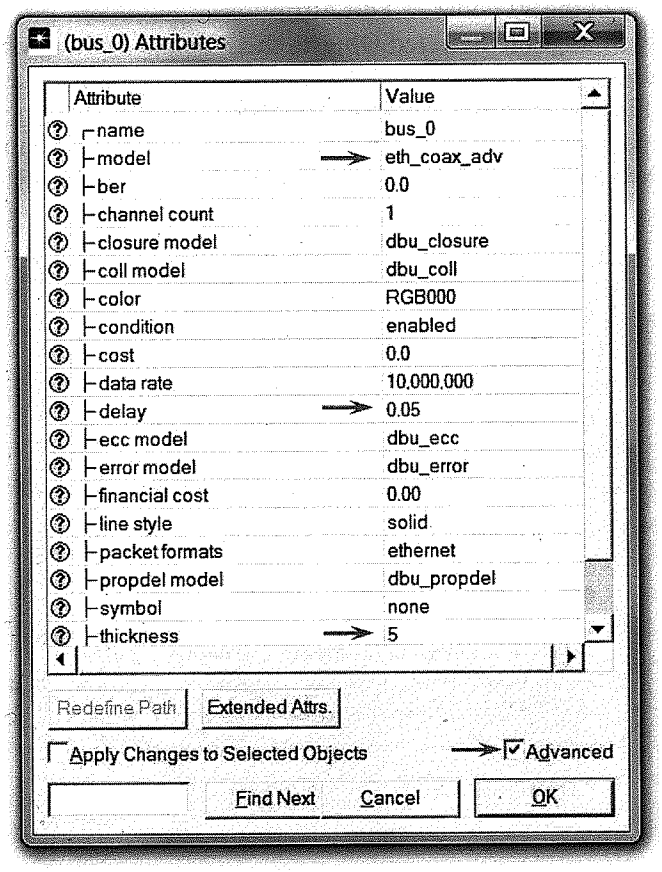
3. In the *Rapid Configuration* dialog box, set the following eight values, and click **OK**.



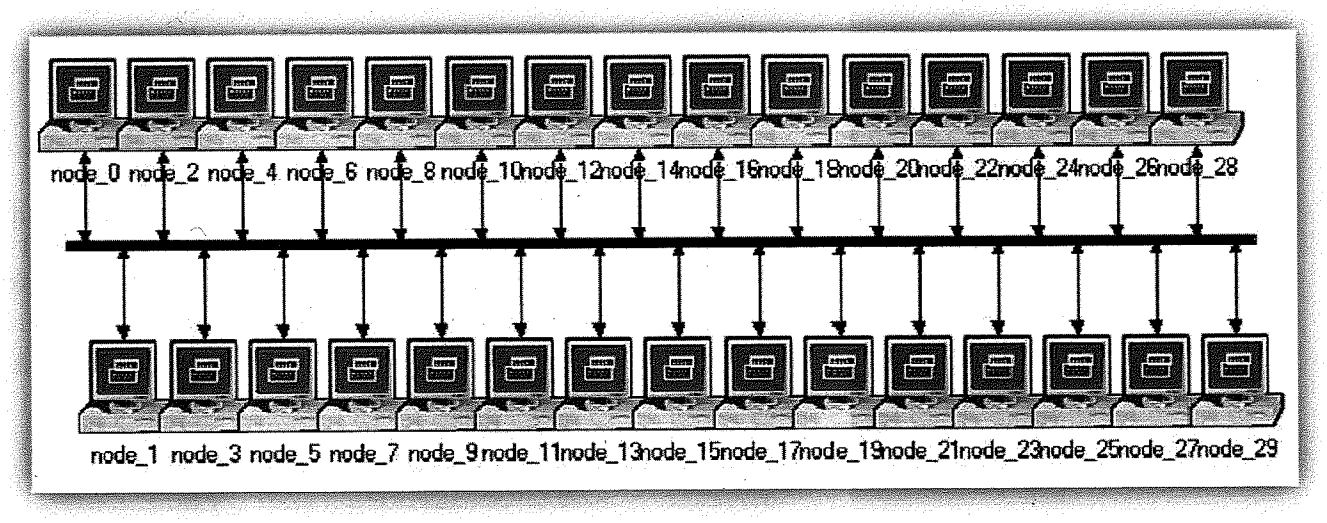
A **higher delay** is used here as an alternative to generating higher traffic, which would require much longer simulation time.

Thickness specifies the thickness of the line used to "draw" the bus link.

4. To configure the coaxial bus, right-click on the horizontal link → Select **Advanced Edit Attributes** from the menu:
   a. Click on the value of the **model** attribute → Select **Edit** from the drop-down menu → Choose the **eth_coax_adv** model.
   b. Assign the value **0.05** to the **delay** attribute (propagation delay in seconds per meter).
   c. Assign **5** to the **thickness** attribute.
   d. Click **OK**.



5. Now you have created the network. It should look like the following illustration.



Configure the Network Nodes

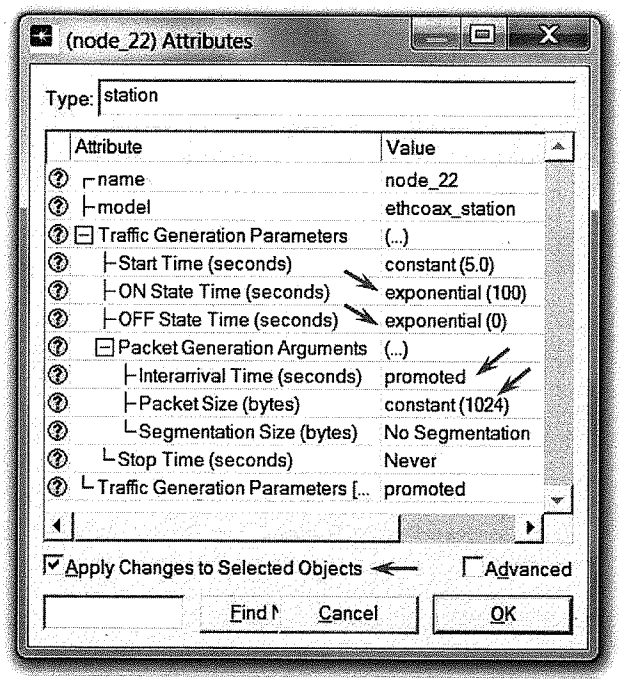
To configure the traffic generated by the nodes:

1. Right-click on any of the 30 nodes → **Select Similar Nodes** to select all 30 nodes in the network.

The argument of the **exponential** distribution is the mean of the interval between successive events. In the exponential distribution, the probability of occurrence of the next event by a given time is not at all dependent on the time of occurrence of the last event or the elapsed time since that event.

The **interarrival time** is the time between successive packet generations in the "ON" state.

2. Right-click on any of the 30 nodes → **Edit Attributes**.
3. Check the **Apply Changes to Selected Objects** check box to avoid reconfiguring each node individually.
4. Expand the **Traffic Generation Parameters** hierarchy:
   a. Change the value of the **ON State Time** to **exponential(100)** → Change the value of the **OFF State Time** to **exponential(0)**. (*Note:* Packets are generated only in the "ON" state.)

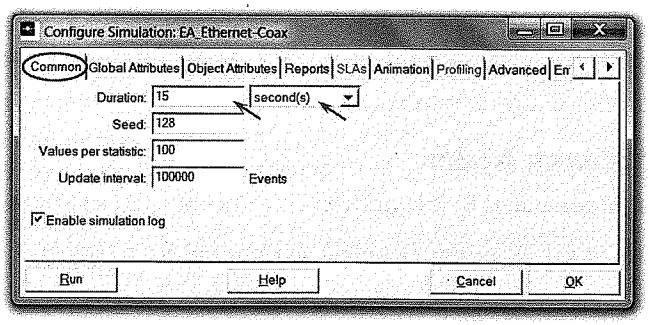


5. Expand the **Packet Generation Arguments** hierarchy:
   a. Change the value of the **Packet Size** attribute to **constant(1024)**.
   b. Right-click on the **Interarrival Time** attribute and choose **Promote Attribute to Higher Level**. This allows us to assign multiple values to the **Interarrival Time** attribute and hence to test the network performance under different loads.
6. Click **OK** to return to the *Project Editor*, and **Save** your project.

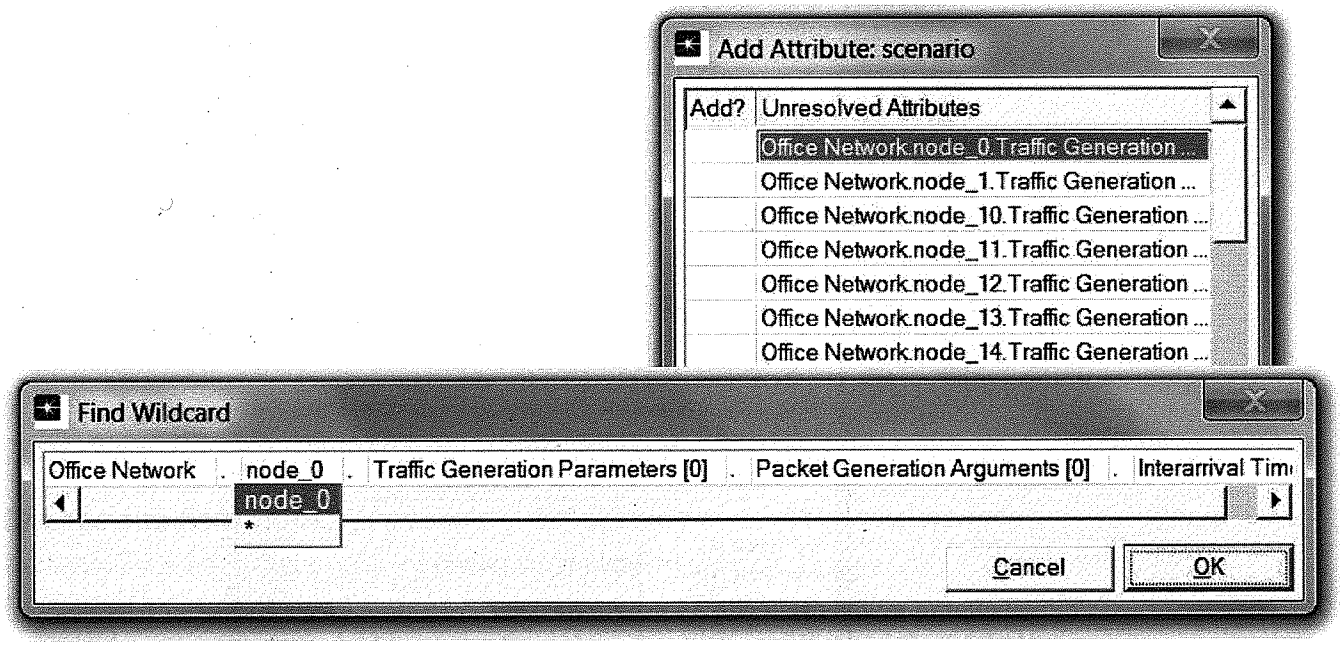
Configure the Simulation

To examine the network performance under different loads, you need to run the simulation several times by changing the load into the network. There is an easy way to do that. Recall that we promoted the **Interarrival Time** attribute for package generation. Here, we will assign different values to that attribute:

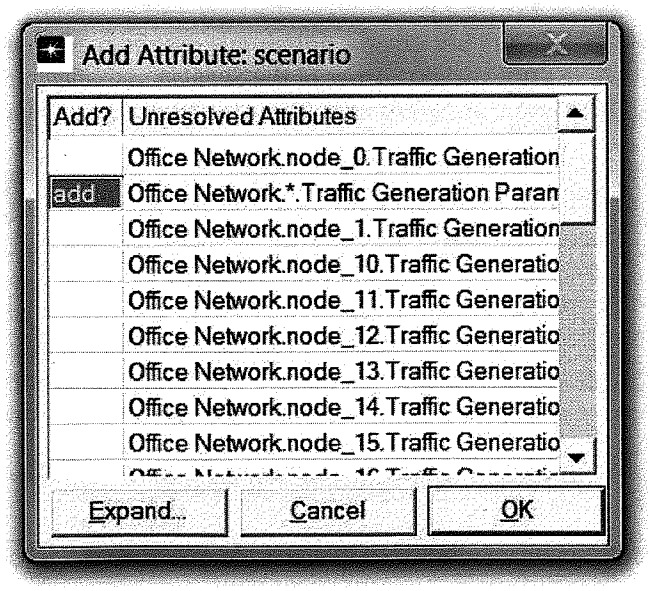
1. Click on the **Configure/Run Simulation** button: → Make sure that the **Common** tab is chosen → Assign **15** s to the **Duration**.



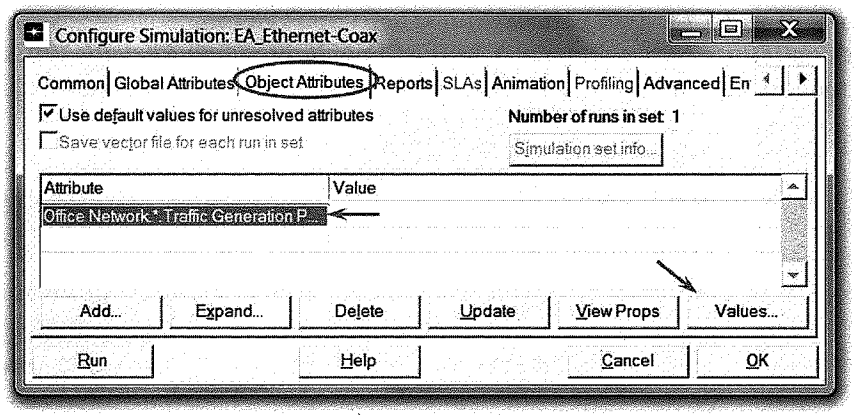
2. Click on the **Object Attributes** tab.
3. Click the **Add** button. The *Add Attribute* dialog box should appear filled with the promoted attributes of all nodes in the network (if you do not see the attributes in the list, close the whole project and reopen it). Add the **Interarrival Time** attribute for all nodes as follows:
   a. Click on (**Office Network.node_0.Traffic Generation ....**) → Click the **Wildcard** button → Click on **node_0** and choose (*) from the drop-down menu → Click **OK**.



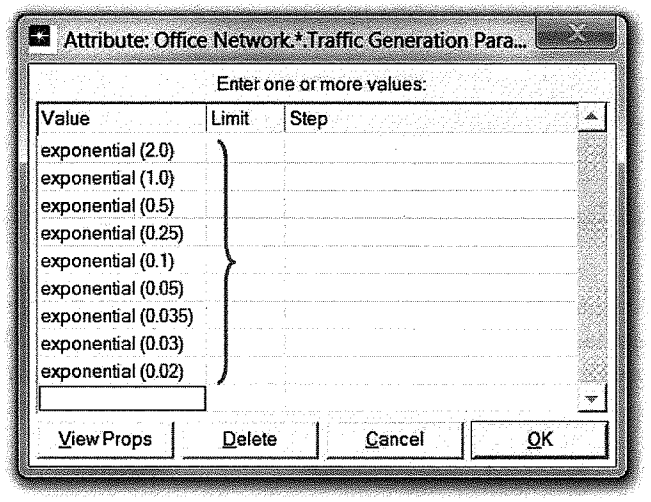
   b. A new attribute is now generated containing the asterisk (the second one in the list). Click on the empty cell to the left of this attribute to add it as shown → Click **OK**.



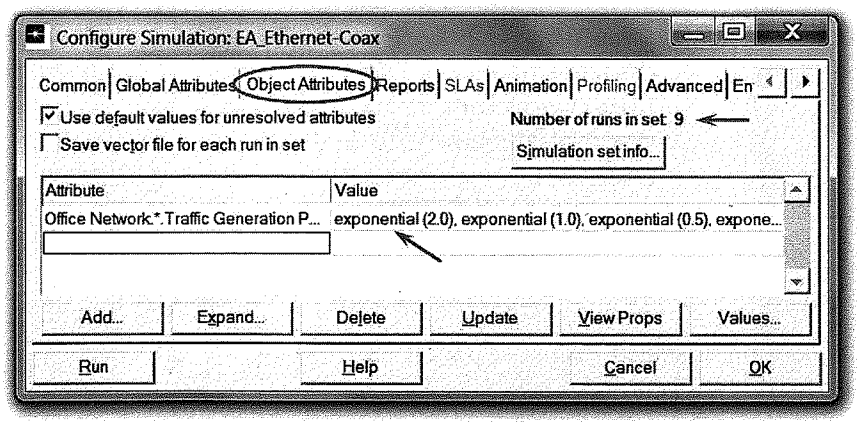
4. Now you should see the **Office Network.*.Traffic Generation Parameter ...** in the list of simulation object attributes. Click on that attribute to select it → Click the **Values** button of the dialog box as shown.



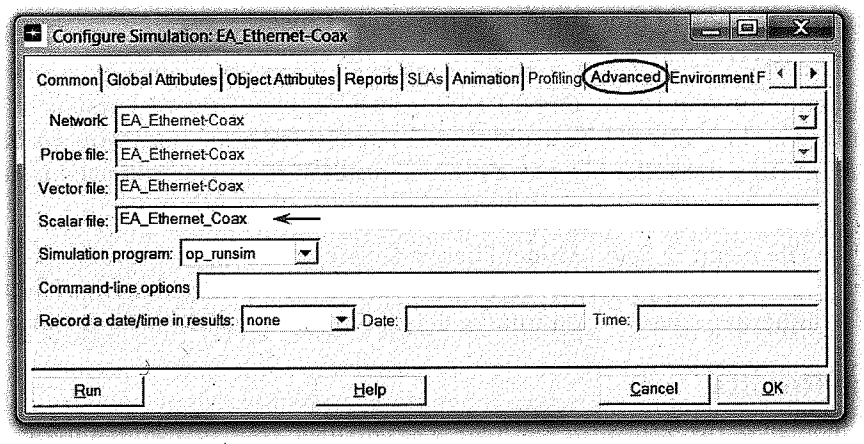
5. Add the nine shown values. (*Note:* To add the first value, double-click on the first cell under the **Value** column → Type "exponential (2)" into the textbox and press **Enter**. Repeat this process for all nine values.)



6. Click **OK**. Now look at the upper-right corner of the *Simulation Configuration* dialog box and make sure that the *Number of runs in set* is 9.



7. For each simulation of the nine runs, we need the simulator to save a "scalar" value that represents the "average" load in the network and to save another scalar value that represents the average throughput of the network. To save these scalars we need to configure the simulator to save them in a file. Click on the **Advanced** tab in the *Configure Simulation* dialog box.
8. Assign **<your initials>_Ethernet_Coax** to the *Scalar file* text field.
9. Click **OK** and then save your project.

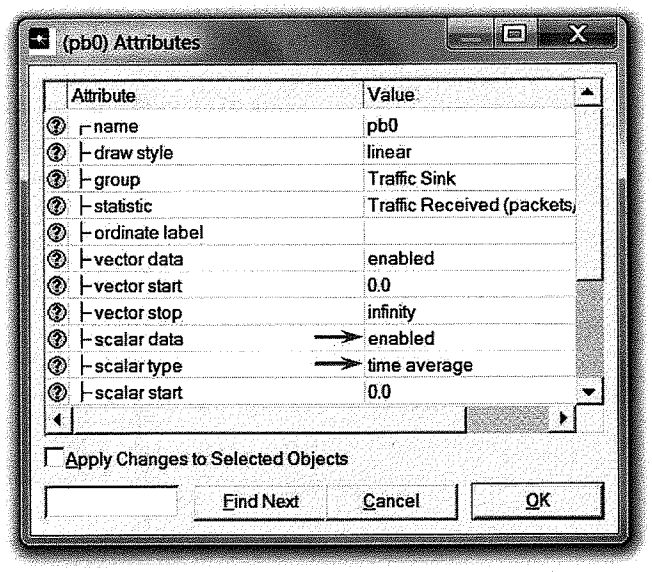


Choose the Statistics

To choose the statistics to be collected during the simulation:

1. Right-click anywhere in the project workspace (but not on one of the nodes or links) and select **Choose Individual Statistics** from the pop-up menu → Expand the **Global Statistics** hierarchy.
   a. Expand the **Traffic Sink** hierarchy → Click the check box next to **Traffic Received (packets/sec)** (make sure you select the statistic with units of packets/sec).
   b. Expand the **Traffic Source** hierarchy → Click the check box next to **Traffic Sent (packets/sec)**.
   c. Click **OK**.
2. Now to collect the average of the above statistics as a scalar value by the end of each simulation run, do the following:
   a. Select **Choose Statistics (Advanced)** from the *Simulation* menu.
   b. The **Traffic Sent** and **Traffic Received** probes should appear under the **Global Statistic Probes**.
   c. Right-click on **Traffic Received** probe → **Edit Attributes**. Set the **scalar data** attribute to **enabled** → Set the **scalar type** attribute to **time average** → Compare to the following figure and click **OK**.
   d. Repeat the previous step with the **Traffic Sent** probe.
   e. Select **Save** from the **File** menu in the *Probe Model* window.
   f. Select **Close** from the **File** menu in the *Probe Model* window.
3. Now you are back to the *Project Editor*. Make sure to save your project.

A **probe** represents a request by the user to collect a particular piece of data about a simulation.



Run the Simulation

To run the simulation:

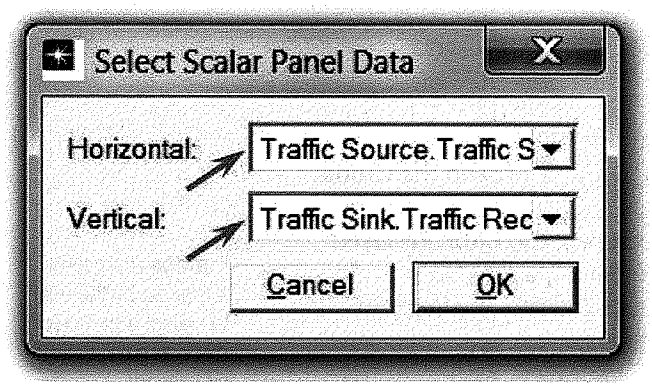
1. Click on the **Configure/Run Simulation** button: → Make sure that **15 second(s)** (not hours) is assigned to the **Duration** → Click **Run**. Depending on the speed of your processor, this process may take several minutes to complete.
2. Now the simulator is completing nine runs, one for each traffic generation interarrival time (representing the load into the network). Notice that each successive run takes longer to complete because the traffic intensity is increasing.
3. After the completion of nine simulation runs, click **Close**.
4. **Save** your project.

When you rerun the simulation, OPNET IT Guru will "append" the new results to the results already in the scalar file. To avoid that, delete the scalar file *before* you start a new run. (*Note:* Deleting the scalar file *after* a run will result in losing the collected results from that run.)

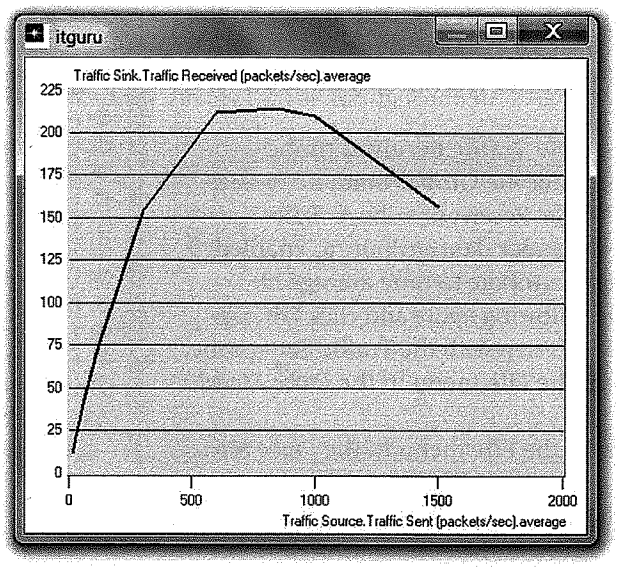
- Go to the **File** menu → Select **Model Files** → **Delete Model Files** → **other model files** → Select **(.os): Output Scalars** → Select the scalar file to be deleted; in this lab it is **<your initials>_Ethernet_Coax** → Confirm the deletion by clicking **OK** → Click **Close**.

View the Results

To view and analyze the results:



1. Select **View Results (Advanced)** from the **Results** menu. Now the **Analysis Configuration** tool is open.
2. Recall that we saved the average results in a scalar file. To load this file, select **Load Output Scalar File** from the **File** menu → Select **<your initials>_Ethernet-Coax** from the pop-up menu.
3. Select **Create Scalar Panel** from the **Panels** menu → Assign **Traffic Source.Traffic Sent (packets/sec). average** to **Horizontal** → Assign **Traffic Sink. Traffic Received (packets/sec).average** to **Vertical** → Click **OK**.
4. The resulting graph should resemble the one below:



FURTHER READING

IEEE 802.3 Ethernet Working Group: www.ieee802.org/3/

EXERCISES

1. Explain the graph we received in the simulation that shows the relationship between the received (throughput) and sent (load) packets. Why does the throughput drop when the load is either very low or very high?
2. Create three duplicates of the simulation scenario implemented in this lab. Name these scenarios **Coax_Q2a**, **Coax_Q2b**, and **Coax_Q2c**. Set the **Interarrival Time** attribute of the *Packet Generation Arguments* for all nodes in the new scenarios as follows:
   - **Coax_Q2a** scenario: exponential(0.1)
   - **Coax_Q2b** scenario: exponential(0.05)
   - **Coax_Q2c** scenario: exponential(0.025)

   In all these new scenarios, open the *Configure Simulation* dialog box, and from the *Object Attributes*, delete the multiple-value attribute (the only attribute shown in the list). Choose the following statistic for node 0: **Ethcoax → Collision Count**. Make sure that the following global statistic is chosen: **Global Statistics → Traffic Sink → Traffic Received (packet/sec)**. (Refer to the "Choose the Statistics" section in the lab.)
   Run the simulation for all three new scenarios. Get two graphs: one to compare node 0's collision counts in these three scenarios and the other graph to compare the received traffic from the three scenarios. Explain the graphs and comment on the results. (*Note:* To compare results you need to select **Compare Results** from the **Results** menu after the simulation run is done.)
3. To study the effect of the number of stations on Ethernet segment performance, create a duplicate of the **Coax_Q2c** scenario, which you created in Exercise 2. Name the new scenario **Coax_Q3**. In the new scenario, remove the odd-numbered nodes, a total of 15 nodes (node 1, node 3, ..., and node 29). Run the simulation for the new scenario. Create a graph that compares node 0's collision counts in scenarios **Coax_Q2c** and **Coax_Q3**. Explain the graph and comment on the results.
4. In the simulation, a packet size of 1024 bytes is used. (*Note:* Each Ethernet packet can contain up to 1500 bytes of data.) To study the effect of the packet size on the throughput of the created Ethernet network, create a duplicate of the **Coax_Q2c** scenario, which you created in Exercise 2. Name the new scenario **Coax_Q4**. In the new scenario, use a packet size of 512 bytes (for all nodes). For both **Coax_Q2c** and **Coax_Q4** scenarios, choose the following global statistic: **Global Statistics → Traffic Sink → Traffic Received (bits/sec)**. Rerun the simulation of **Coax_Q2c** and **Coax_Q4** scenarios. Create the following graphs and explain them:
   a. A graph that compares the throughput as packets per second in **Coax_Q2c** and **Coax_Q4** scenarios
   b. A graph that compares the throughput as bits per second in **Coax_Q2c** and **Coax_Q4** scenarios

LAB REPORT

Prepare a report that follows the guidelines explained in the Introduction Lab. The report should include the answers to the preceding exercises as well as the graphs you generated from the simulation scenarios. Discuss the results you obtained and compare these results with your expectations. Mention any anomalies or unexplained behaviors.