Laboratory
1

Ethernet

A Direct Link Network with Media Access Control

Objective

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 with a frame to send transmits with probability 1 whenever a busy line goes idle.

In this lab you will set up an Ethernet with 14 nodes connected via 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.

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.

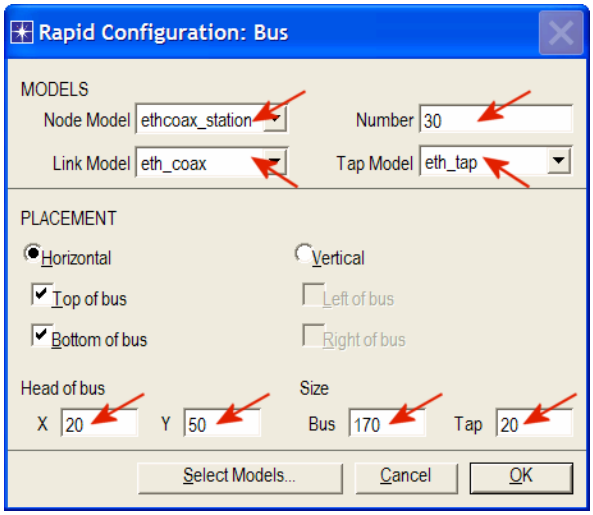
Create the Network

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**.
3. In the *Rapid Configuration* dialog box, set the following eight values 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 via taps.

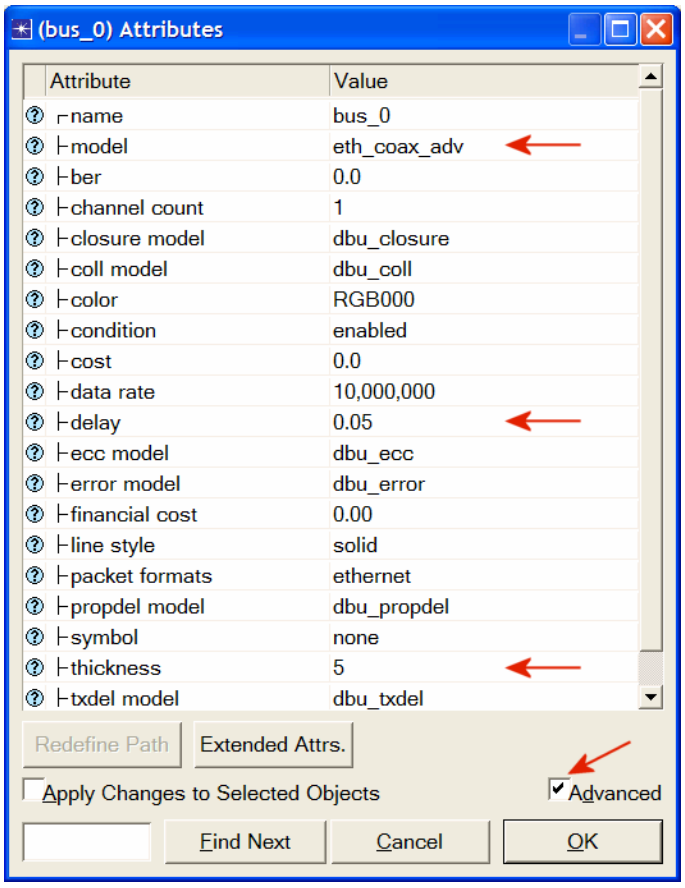


4. To configure the coaxial bus, right-click on the horizontal link ⇒ Select **Advanced Edit Attributes** from the menu:

   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 sec/m).
   c. Assign **5** to the **thickness** attribute.
   d. Click **OK**.

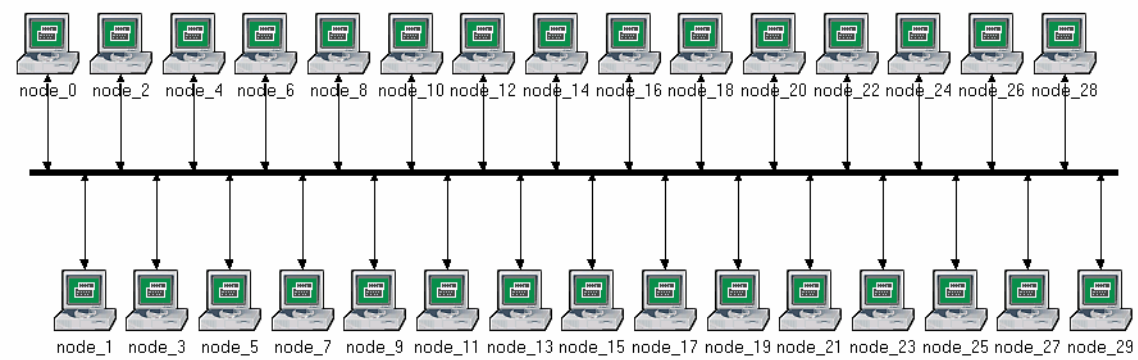
A higher delay is used here as an alternative to generating higher traffic which would require much longer simulation time.

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



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

6. Make sure to save your project.



Configure the Network Nodes

To configure the traffic generated by the nodes:

1. Right-click on any of the 30 nodes ⇒ **Select Similar Nodes**. Now all nodes in the network are selected.

2. Right-click on any of the 30 nodes ⇒ **Edit Attributes.**

3. Check the **Apply Changes to Selected Objects** check box. This is important 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.)

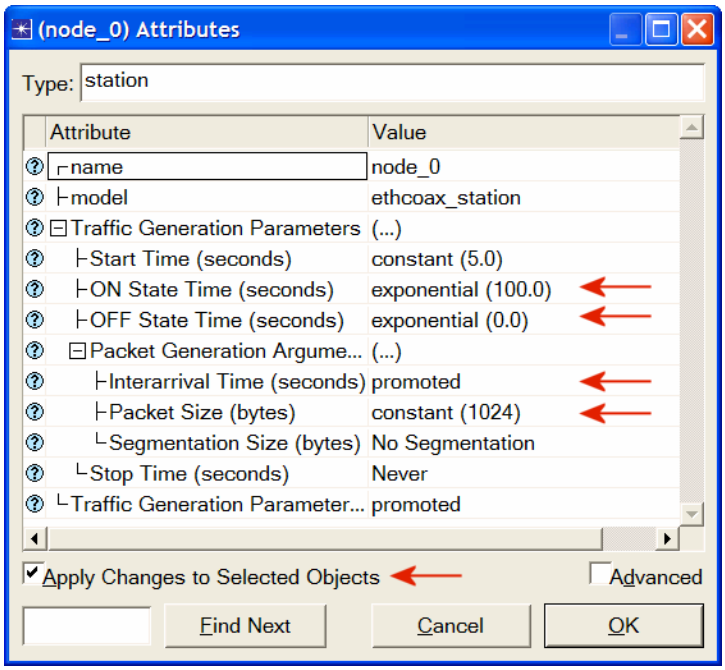
The argument of the **exponential** distribution is the mean of the interval between successive events. In the exponential distribution the probability of occurrence of the next event by a given time is not at all dependent upon the time of occurrence of the last event or the elapsed time since that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

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.

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



6. Click **OK** to return back to the *Project Editor*.

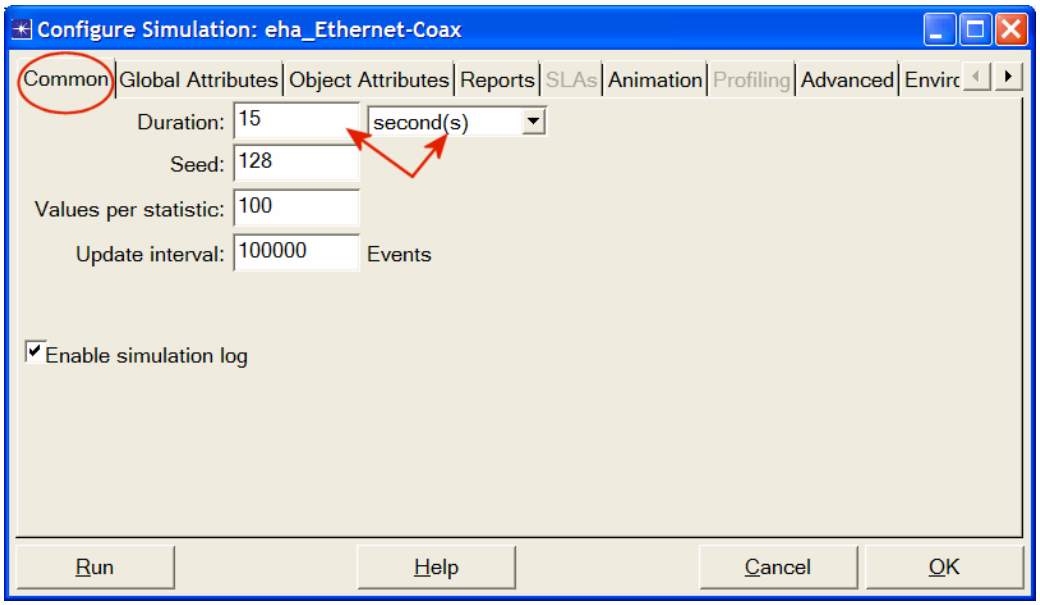
7. Make sure to save your project.

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: 

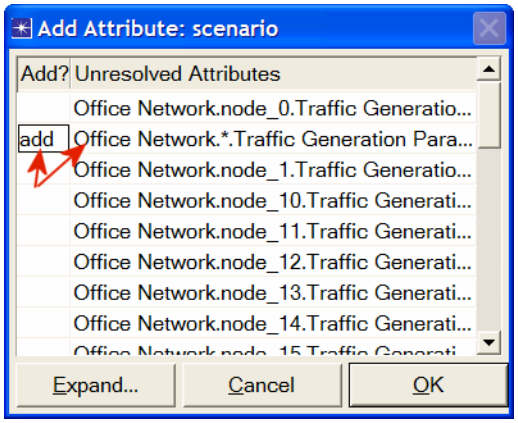
2. Make sure that the **Common** tab is chosen ⇒ Assign **15** seconds to the **Duration.**



3. Click on the **Object Attributes** tab.

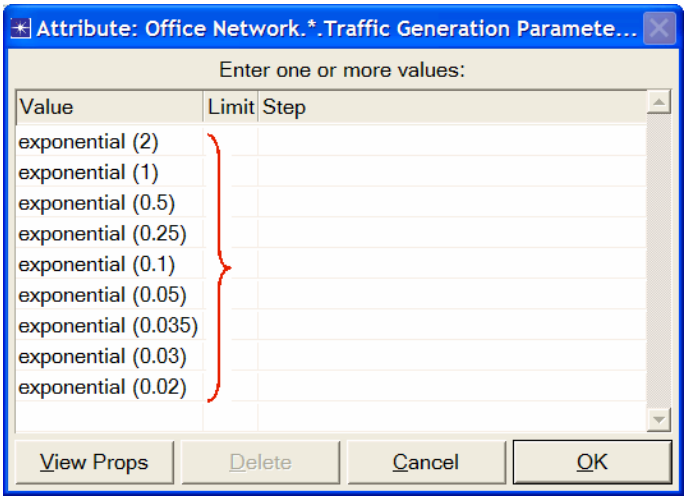
4. Click on the **Add** button. The *Add Attribute* dialog box should appear filled with the promoted attributes of all nodes in the network (if you do not see the attributes in the list, close the whole project and reopen it). You need to add the **Interarrival Time** attribute for all nodes. To do that:

   a. Click on the first attribute in the list (**Office Network.node_0.Traffic Generation** ….) ⇒ Click the **Wildcard** button ⇒ Click on **node_0** and choose the asterisk (*****) from the drop-down menu ⇒ Click **OK**.
   b. A new attribute is now generated containing the asterisk (the second one in the list), and you need to add it by clicking on the corresponding cell under the **Add?** column.
   c. The *Add Attribute* dialog box should look like the following. Click **OK**.

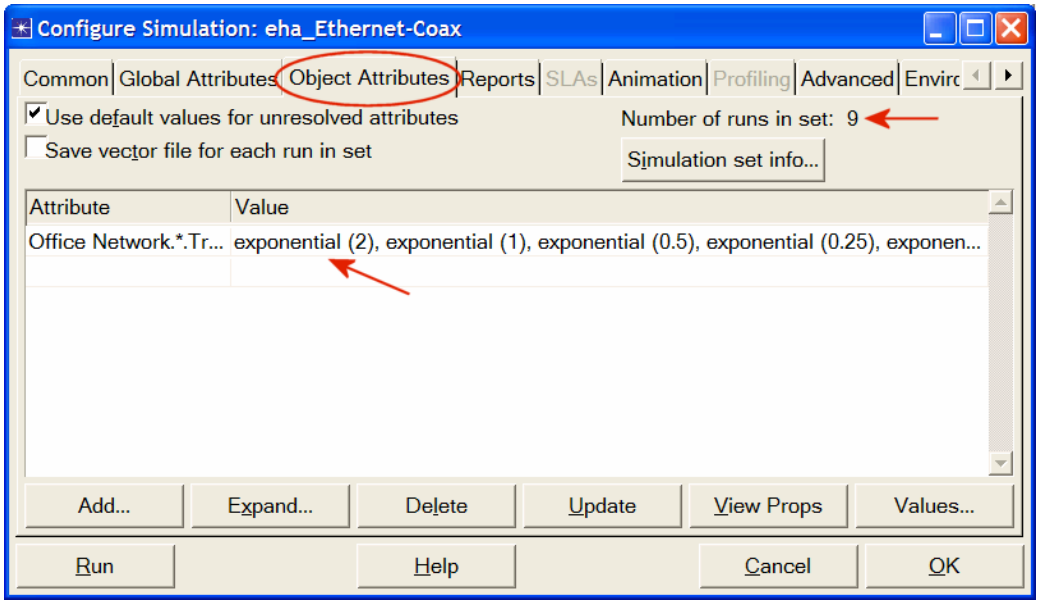


5. Now you should see the **Office Network.*.Traffic Generation Parameter …** in the list of simulation object attributes. Click on that attribute to select it ⇒ Click the **Values** button of the dialog box.

6. Add the following nine values. (*Note:* To add the first value, double-click on the first cell in the **Value** column ⇒ Type "exponential (2)" into the textbox and hit enter. Repeat this for all nine values.)

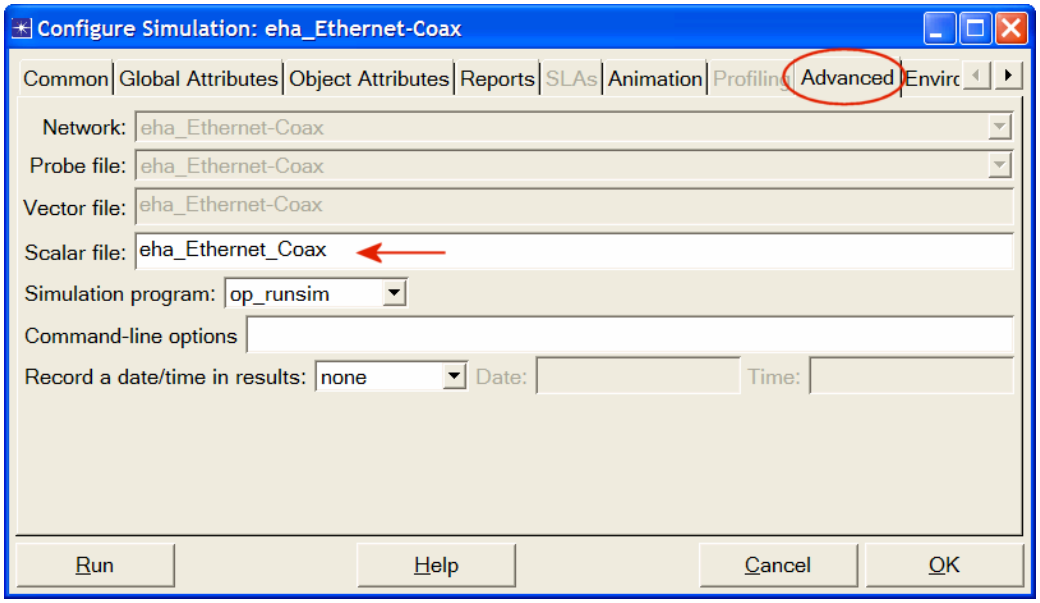


7. Click **OK**. Now look at the upper-right corner of the *Simulation Configuration* dialog box and make sure that the *Number of runs in set* is **9**.



8. 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.

9. Assign **<your initials>_Ethernet_Coax** to the *Scalar file* text field.



10. 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:

    a. Select **Choose Statistics (Advanced)** from the *Simulation* menu.

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

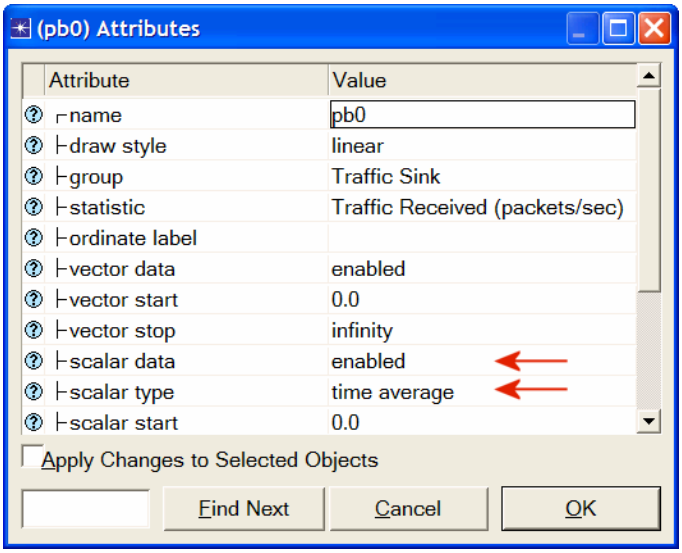
    b. The **Traffic Sent** and **Traffic Received** probes should appear under the **Global Statistic Probes**.

    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 and then close that window.

    f. Now you are back to the *Project Editor*. Make sure to save your project.



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 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 nine simulation runs complete, 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** ⇒ Select **(.os): Output Scalars** ⇒ Select the scalar file to be deleted; in this lab it is **<your initials>_Ethernet_Coax_Scalar** ⇒ Confirm the deletion by clicking **OK** ⇒ Click **Close.**

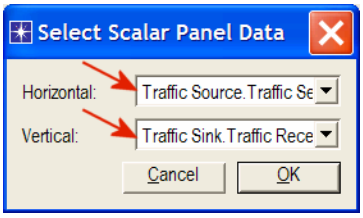
View the Results

To view and analyze the results:

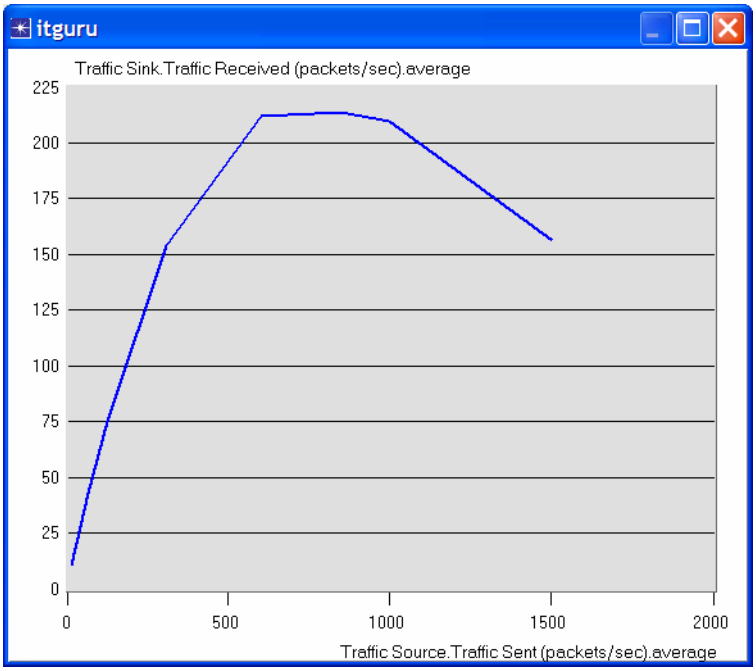
1. Select **View Results (Advanced)** from the **Results** menu. Now the **Analysis Configuration** tool is open.

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**.

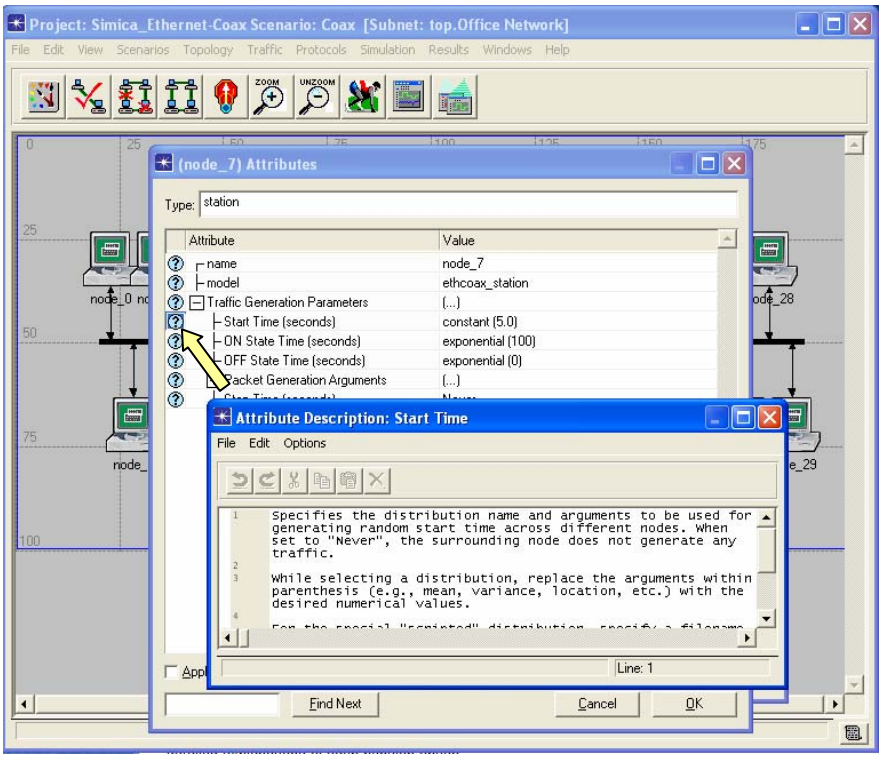


4. The resulting graph should resemble the one below:



Further Reading

To familiarize yourself with the significance, physical interpretation and the actual use of various parameters mentioned in this laboratory, use the built-in ITGuru help feature. For example, to learn more about (node) **Attributes → Traffic Generation Parameters → Start Time** parameter, click on the respective question mark icon, as shown in the figure below:



Exercise

After you have successfully executed the steps outlined on pages 1 to 10, you are expected to do the following three exercises: E.1 to E.3. Your deliverable for this laboratory should be a 4-5 page typed report in which you will provide concise answers to all questions from E.1 to E.3 and include all required screenshots of obtained simulation results/graphs.

Exercise E.1 Load-Throughput Graph

Explain the graph shown in page 10, which shows the relationship between the sent packets (load) and received packets (throughput). Why does the throughput drop when the load is either very low or very high?

Exercise E.2 Performance (Collision Count and Throughput) Under Different Loads

Exercise E.2.a)

Modify the profile of your project **<your initials>_Ethernet**, by performing the following steps:

1. Click on the **Configure/Run Simulation** button  . From the *Object Attribute* menu/tab delete the multiple value attribute (the only shown in the list).

2. Right-click on any of the 30 nodes. Choose **Select Similar Nodes**. Now all nodes in the network are selected.

3. Right-click on any of the 30 nodes. Choose **Edit Attributes**.
   - Check the **Apply Changes to Selected Objects** check box. This is important to avoid reconfiguring each node individually.
   - Expand the **Traffic Generation Parameters** hierarchy.
   - Expand the **Packet Generation Arguments** hierarchy.
     a. Set the *Interarrival Time* attribute to **exponential(0.1)**.
     b. Click OK twice.

4. Right-click on **node_0**. Choose **Choose Individual Statistics**.
   - Expand the **Ethcoax** hierarchy.
     a. Click the check box next to *Collision Count*.
   - Expand the **Traffic Source** hierarchy.
     a. Click the check box next to *Traffic Sent (packets/sec)*.
     b. Click OK.

5. Right-click anywhere in the project workspace, but not on one of the nodes or links. Choose **Choose Individual Statistics**.
   - Expand the **Global Statistics / Traffic Sink** hierarchy.
     a. Click the check box next to *Traffic Received (packets/sec)*.
   - Expand the **Global Statistics / Traffic Source** hierarchy.
     a. Click the check box next to *Traffic Sent (packets/sec)*.
     b. Click OK.

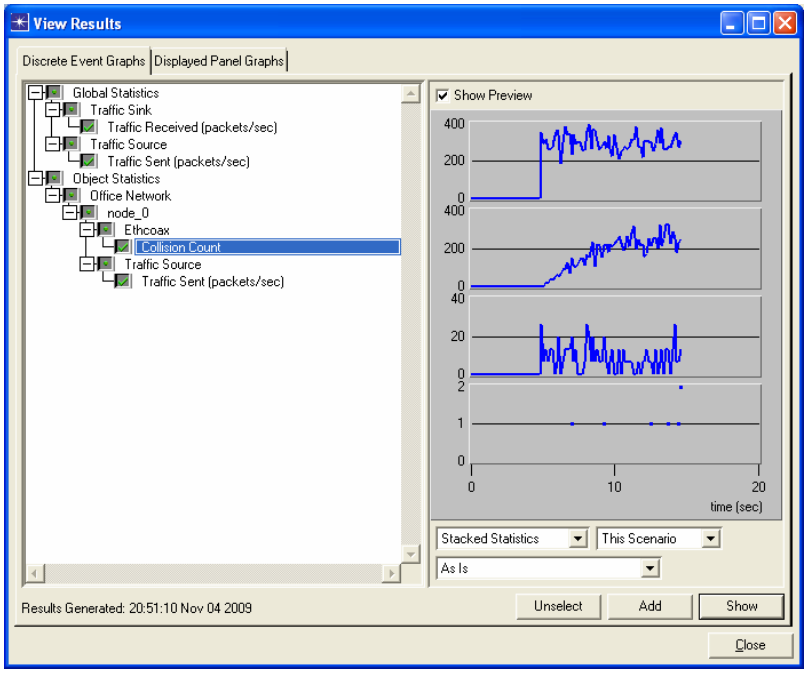
6. **Save your project!**

Run the simulation by clicking on **Configure/Run Simulation** button  , and then clicking **Run**.

View the collected results by doing the following:

1. Select **View Results** from **Results** Menu.
   - Expand the **Global Statistics / Traffic Source** hierarchy.
     a. Click the check box next to *Traffic Sent (packets/sec)*.
   - Expand the **Global Statistics / Traffic Sink** hierarchy.
     a. Click the check box next to *Traffic Received (packets/sec)*.
   - Expand the **Object Statistics / Office Network / node_0 / Traffic Source** hierarchy.
     a. Click the check box next to *Traffic Sent (packets/sec)*.
   - Expand the **Object Statistics / Office Network / node_0 / Ethcoax** hierarchy.
     a. Click the check box next to *Collision Count*.

The resultant window and graphs should resemble the one(s) below.



Make a screenshot of your own respective)results, and include them in the final report!

Exercise E.2.b)

Repeat the steps from Exercise E.2.a), but in Step 3 set the *Interarrival Time* attribute to **exponential(0.05)**.
Make a screenshot of obtained results, and include them in the final report!

Exercise E.2.c)

Repeat the steps from Exercise E.2.a), but in Step 3 set the *Interarrival Time* attribute to **exponential(0.025)**.
Make a screenshot of obtained results, and include them in the final report!

Exercise E.2.d)

Compare **node_0**'s *Collision Counts* from the previous three exercises (E.2.a), E.2.b), E.2.c)). What do you observe, and how do you explain the difference in the obtained graphs?

Exercise E.3 Performance under Smaller Packet Size

Exercise E.3.a)

Modify the profile of your project **<your initials>_Ethernet**, by performing the following steps:

1. Right-click on any of the 30 nodes. Choose **Select Similar Nodes**. Now all nodes in the network are selected.

2. Right-click on any of the 30 nodes. Choose **Edit Attributes**.
   - Check the **Apply Changes to Selected Objects** check box. This is important to avoid reconfiguring each node individually.
   - Expand the **Traffic Generation Parameters** hierarchy.
   - Expand the **Packet Generation Arguments** hierarchy.
     a. Set the *Packet Size* attribute to **constant(512)**.
     b. Set the *Interarrival Time* attribute to **exponential(0.05)**.
     c. Click OK twice.

3. Right-click on **node_0**. Choose **Choose Individual Statistics**.
   - Expand the **Ethcoax** hierarchy.
     a. Click the check box next to *Collision Count*.
   - Expand the **Traffic Source** hierarchy.
     c. Click the check box next to *Traffic Sent (packets/sec)*.
     d. Click OK.

4. Right-click anywhere in the project workspace, but not on one of the nodes or links. Choose **Choose Individual Statistics**.
   - Expand the **Global Statistics / Traffic Sink** hierarchy.
     a. Click the check box next to *Traffic Received (packets/sec)*.
   - Expand the **Global Statistics / Traffic Source** hierarchy.
     c. Click the check box next to *Traffic Sent (packets/sec)*.
     d. Click OK.

5. **Save your project!**

Run the simulation by clicking on **Configure/Run Simulation** button  , and then clicking **Run**. Access the collected results by following the procedure from exercise E.2. **Make a screenshot of obtained results, and include them in the final report!**

Exercise E.3.b)

Compare the graphs obtained in exercise E.3.a) with those from exercise E.2.b). (In the two exercises, the packet interarrival times are the same, the packet sizes are different.) What do you observe, and how do you explain the difference in the obtained graphs?