

Lab 1 Shared Ethernet Networks

Overview

In a shared Ethernet network, end systems are typically connected together using a **hub**. The hub retransmits any incoming frames on all outgoing lines creating a single **broadcast domain** for all the devices. Within this domain, the **Carrier Sense Multiple Access with Collision Detection (CSMA/CD)** MAC protocol is used to determine which node may transmit at any given time and to resolve **collisions** if two or more nodes transmit at the same time.

Objective

To determine the throughput of a shared Ethernet network under load.

Build the Simulation Model

Start up OPNET IT Guru Academic Edition.

Select the **File** tab => **New...**

Choose **Project** and click on **OK**.

Change the **Project Name** to **Shared_Ethernet**. Change the **Scenario Name** to **Low_Load**, and click on **OK**.

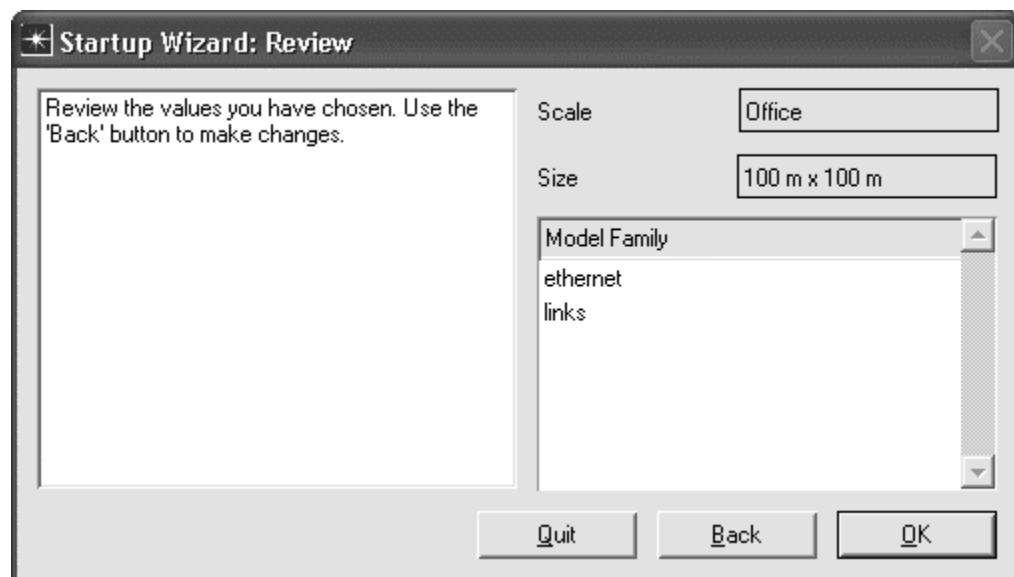
In the **Initial Topology** window, select **Create Empty Scenario** and click on **Next**.

In the **Choose Network Scale** window, select **Office** and click on **Next**.

In the **Specify Size** window, leave the parameters unchanged and click on **Next**.

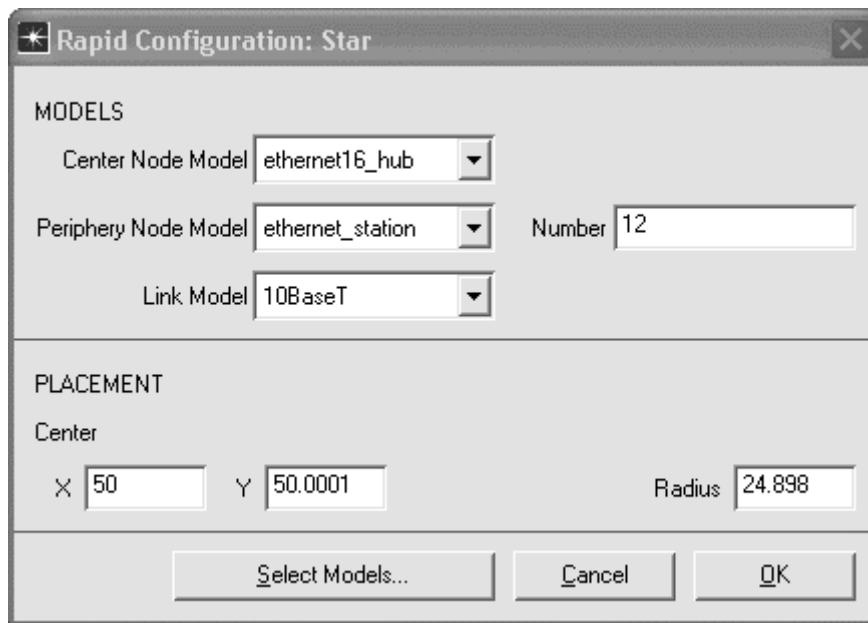
In the **Select Technologies** window, scroll down and include the **ethernet** and **links** model families, and click on **Next**.

In the **Review** window, click on **OK**.



First, we will build a LAN in which the workstations are connected together with an Ethernet hub. An easy way to create a network with a large number of nodes in OPNET is to use the Rapid Configuration tool.

Select the **Topology** tab => **Rapid Configuration**. Set the **Configuration** to **Star** and click on **OK**. Set the **Center Node Model** to **ethernet16_hub**. Set the **Periphery Node Model** to **ethernet_station**. Set the **Link Model** to **10BaseT**. Set the **Number** to **12**, and click on **OK** to create the LAN.



Right click on the hub (the device at the center of the star) and choose **View Node Description**. This device can support up to 16 Ethernet links at 10, 100, or 1000 Mbps. Note that the processing time within the device is considered to be zero, and that the hub retransmits incoming frames on all outgoing lines. Click on the close window icon to close the window. Right click on the hub and select **Set Name**. Set the **Name** to **Hub**. Click on **OK** to close the window.

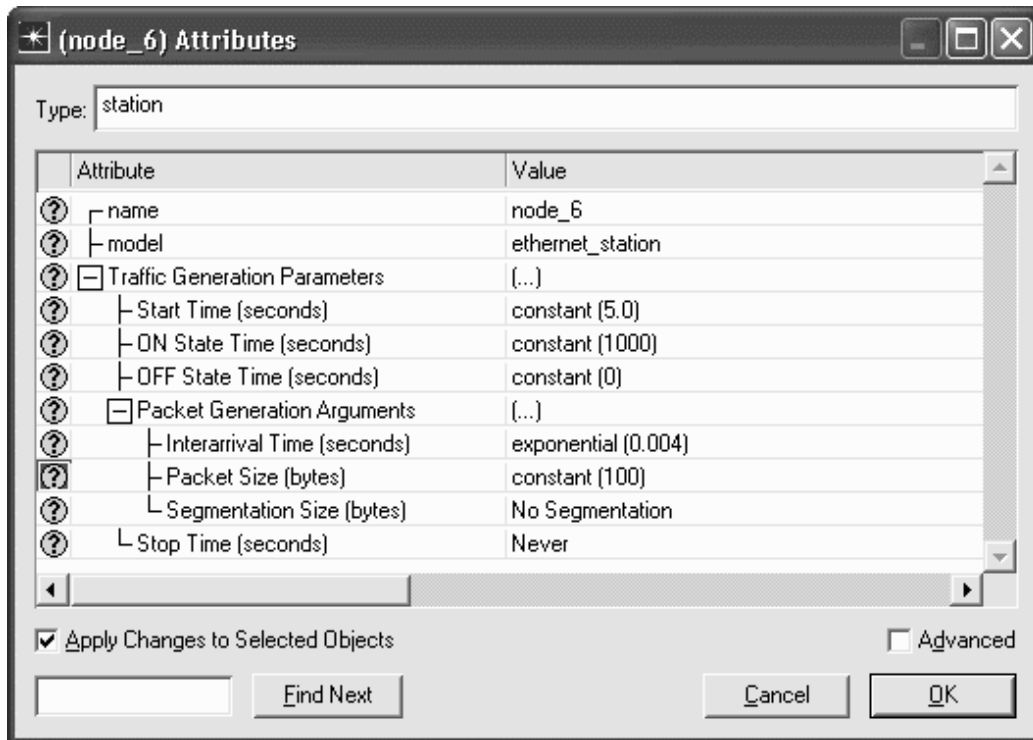
Right click on one of the Ethernet stations and choose **View Node Description**. This device generates and receives Ethernet frames at configurable rates. Note that collision detection and resolution is handled by the hub. Click on the close window icon to close the window.

Now we need to set up the traffic patterns for the Ethernet stations. Right click on any of the stations and choose **Select Similar Nodes**. Next, right click on one of the stations and choose **Edit Attributes**. Put a check in the checkbox next to **Apply Changes to Selected Objects**. Expand the **Traffic Generation Parameters** and **Packet Generation Arguments** attributes. Set the **ON State Time** to **constant(1000)**, and the **OFF State Time** to **constant(0)**. This will ensure that the stations are always sending.

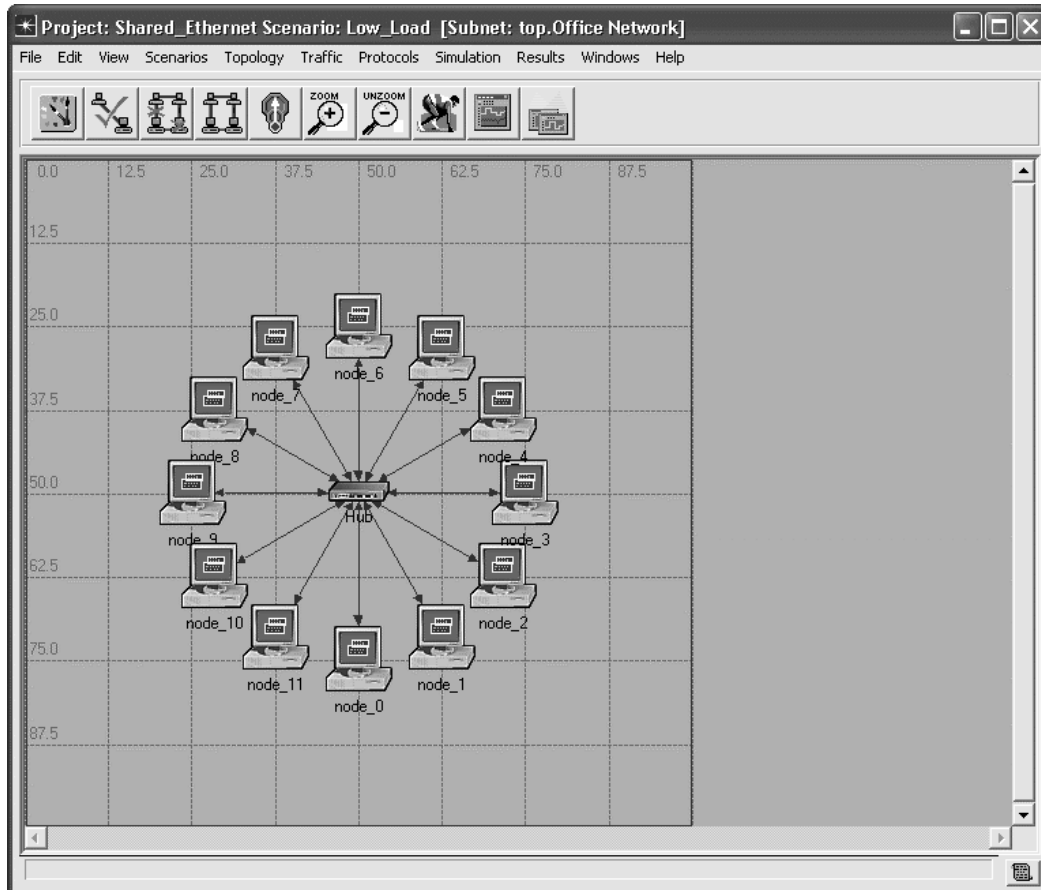
Set the **Interarrival Time (seconds)** to **exponential(0.004)** and the **Packet Size (bytes)** to **constant(100)**. Click on **OK** to apply the changes and close the window. Each station will now generate traffic at an average rate of one 100-byte packet every 4 milliseconds.

You can calculate the average traffic that each node will generate from the interarrival time and the packet size. For instance

$$100 \text{ bytes/packet} * 8 \text{ bits/byte} * 1 \text{ packet}/0.004 \text{ sec} = 200 \text{ Kbps}$$



We are now done building the LAN model.



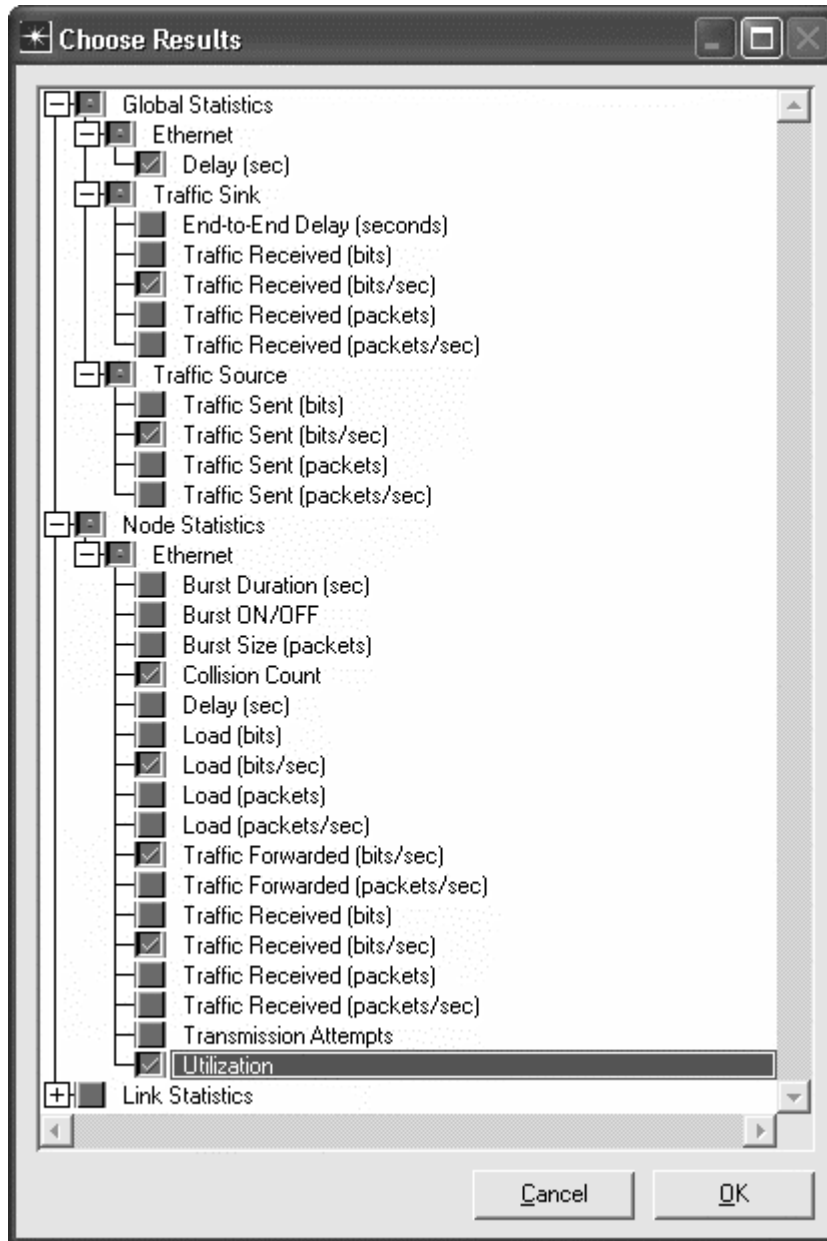
Configure the Simulation

Select the **Simulation** tab => **Choose Individual Statistics...**

Expand the **Global Statistics** item and the **Ethernet** item, and select the **Delay (sec)** statistic. Expand the **Traffic Sink** item and select the **Traffic Received (bits/sec)** statistic. Expand the **Traffic Source** item and select the **Traffic Sent (bits/sec)** statistic.

Expand the **Node Statistics** item and the **Ethernet** item, and select the **Collision Count**, **Load (bits/sec)**, **Traffic Forwarded (bits/sec)**, **Traffic Received (bits/sec)**, and **Utilization** statistics.

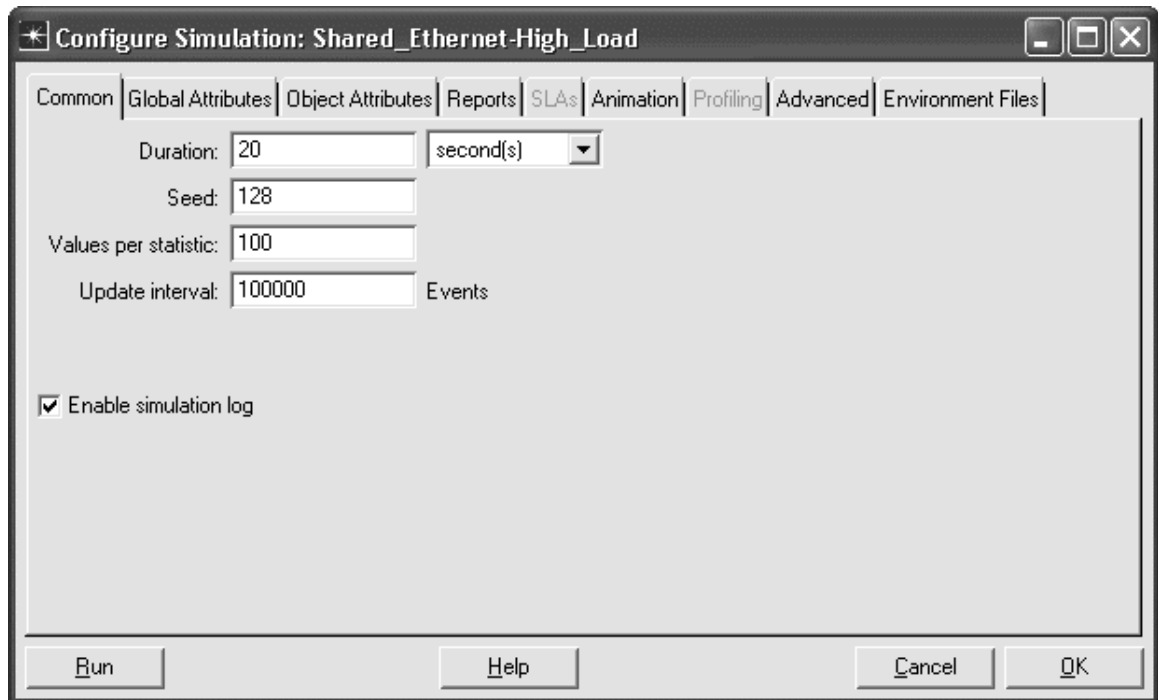
Click on **OK** to close the window.



Select **Simulation** => **Configure Discrete Event Simulation...**

Under the **Common** tab, modify the **Duration** to **20** and the unit to **second(s)**.

Click on **OK** to close the window.



Duplicate the Scenario

Let us build another scenario in which each Ethernet station generates much more traffic. This will allow us to compare the performance of the LAN under different conditions.

Choose **Scenarios => Duplicate Scenario** and name the new scenario **High_Load**. Click on **OK** to create the scenario.

Right click on any of the stations and choose **Select Similar Nodes**. Next, right click on one of the stations and choose **Edit Attributes**. Put a check in the checkbox next to **Apply Changes to Selected Objects**. Expand the **Traffic Generation Parameters** and **Packet Generation Arguments** attributes. Set the **Interarrival Time (seconds)** to **exponential(0.001)**. Click on **OK** to apply the changes and close the window. Note that a shorter interarrival time means that packets will be generated more frequently.

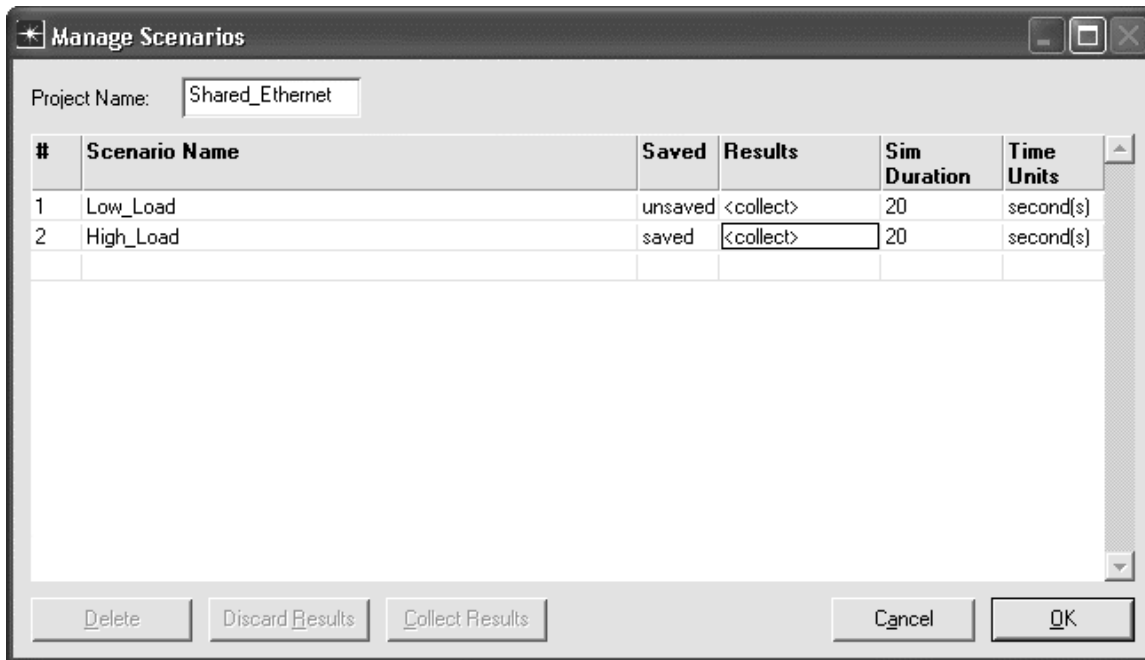
Run the Simulation

Select the **Scenarios** tab => **Manage Scenarios...**

Edit the **Results** field in both rows and set the values to **<collect>** or **<recollect>**.

Click on **OK** to run both scenarios (one after the other).

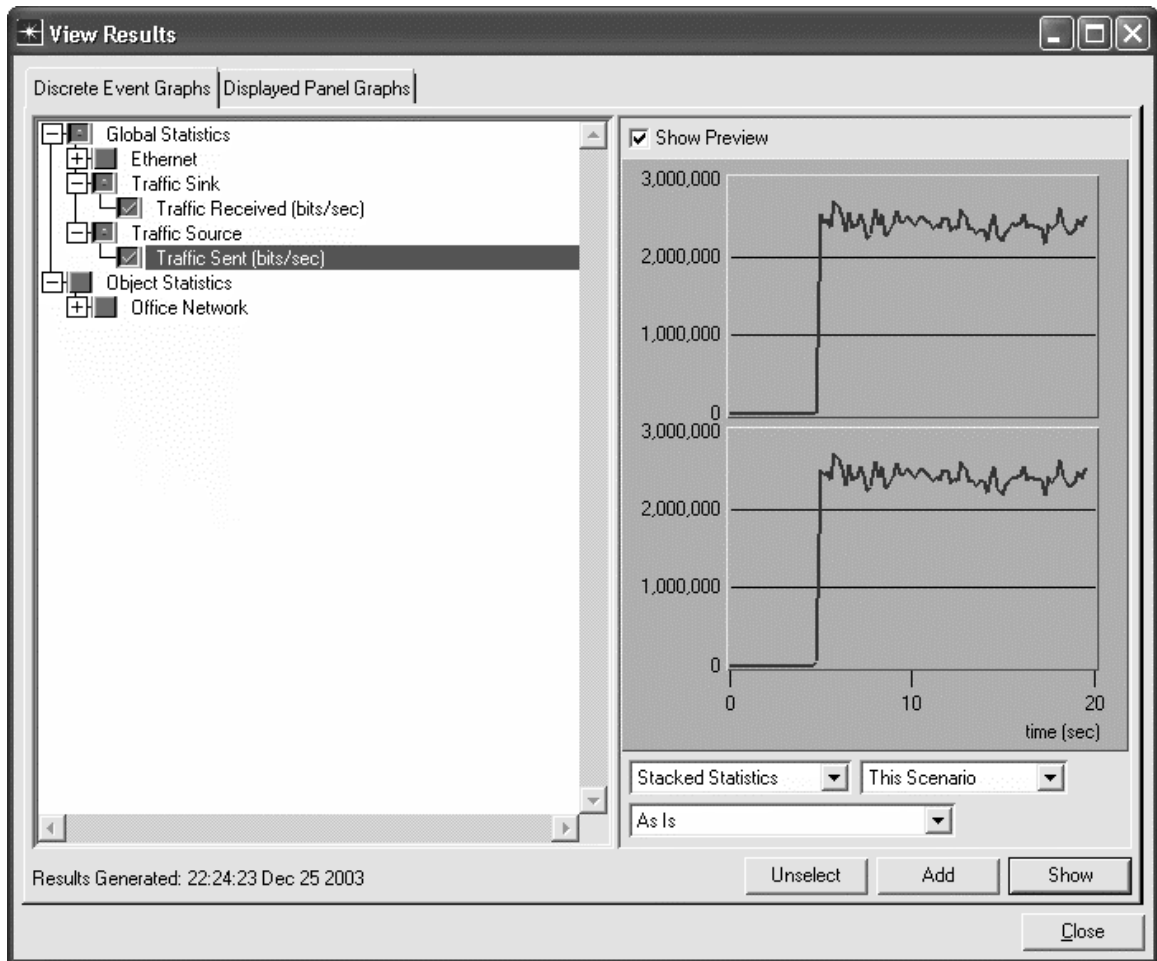
When the simulation has completed, click on **Close** to close the window.



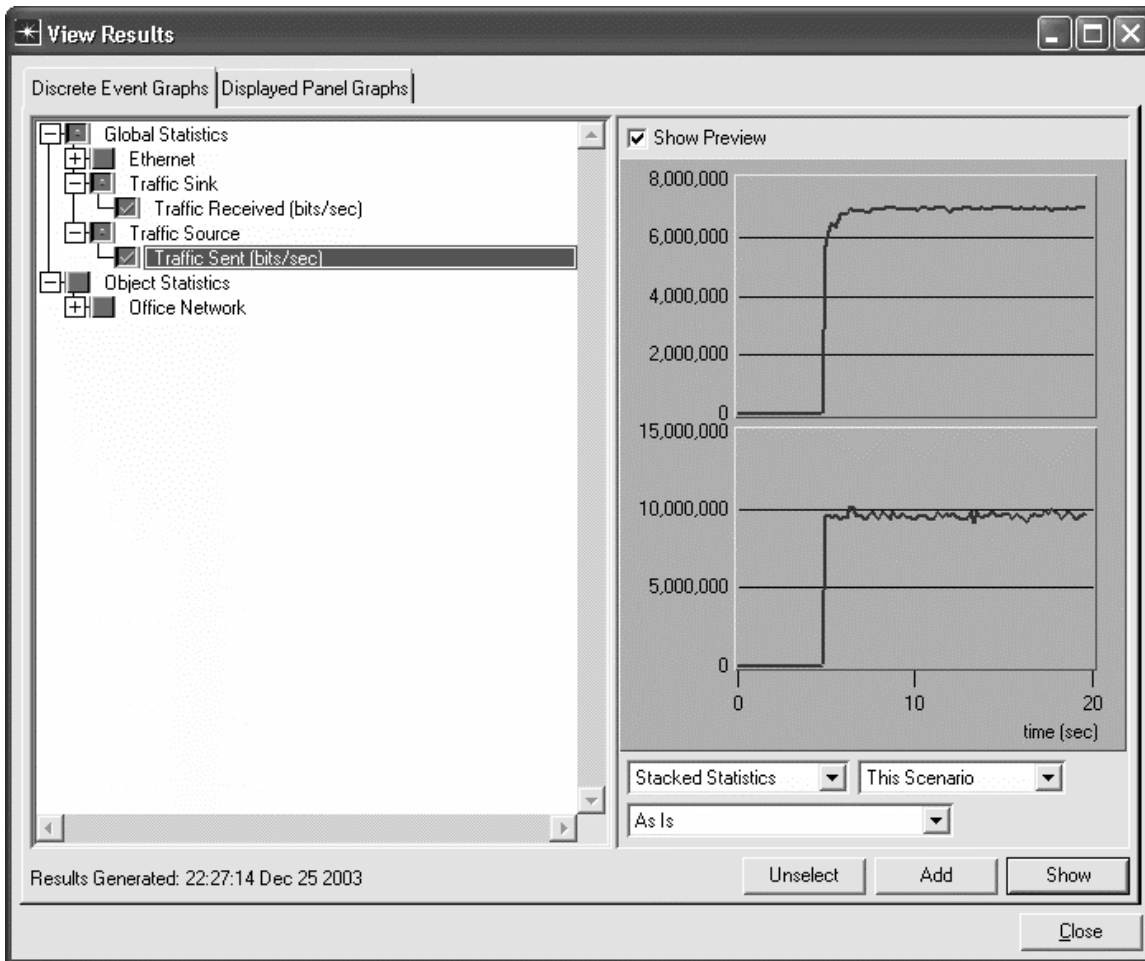
Inspect and Analyze Results

Select the **Scenarios** tab => **Switch to Scenario** and choose the **Low_Load** scenario.
 Select the **Results** tab => **View Results...**

Select and expand the **Global Statistics** item and the **Traffic Source** item. Next, select the **Traffic Sent (bits/sec)** statistic. Also, expand the **Traffic Sink** item and select the **Traffic Received (bits/sec)** statistic. View all statistics in this lab exercise using **As Is** mode. For this level of load, the received bit rate is approximately equal to the sent bit rate. Click on the **Traffic Sent (bits/sec)** and **Traffic Received (bits/sec)** statistics again to disable the preview. Note that you may always click on **Show** for a more detailed graph than the preview provides. Click on **Close** to close the **View Results** window.

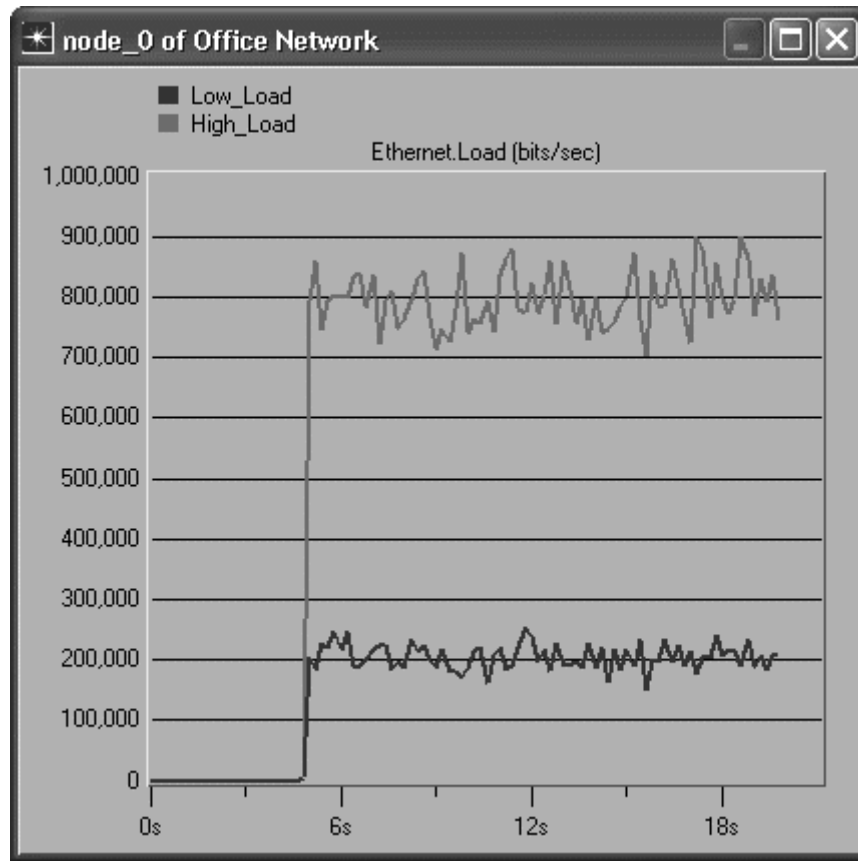


We will now examine the same statistics for the **High_Load** scenario. Repeat the previous steps including switching to the **High_Load** scenario, viewing results, and selecting statistics to view. In this case, you can see that much more traffic was sent than was received. The hub has become overloaded and cannot deliver all the traffic that it receives. Click on **Close** to close the **View Results** window.

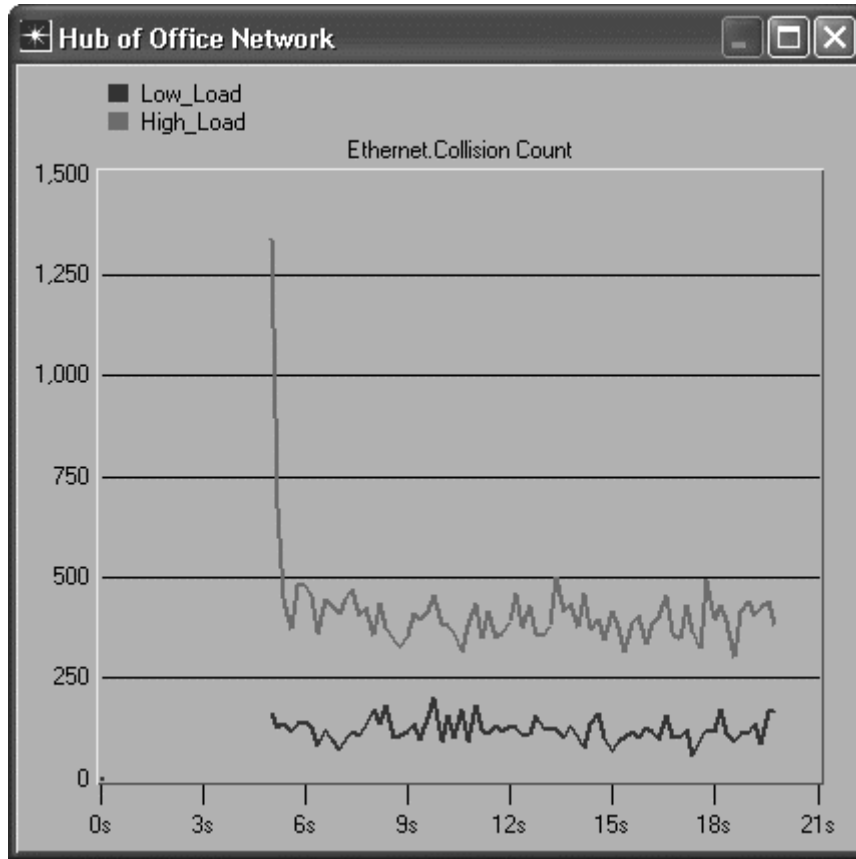


Let us compare results generated by the two scenarios.
 Select the **Results** tab => **Compare Results...**

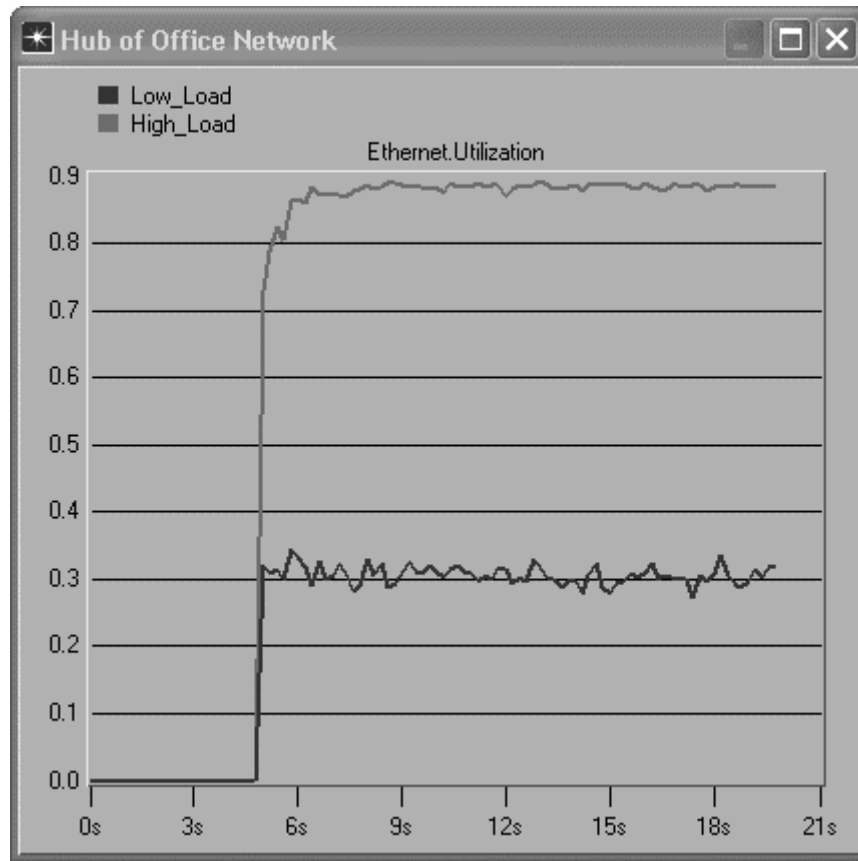
Select and expand the **Object Statistics** item, the **Office Network** item, the **node_0** item, and the **Ethernet** item. Select the **Load (bits/sec)** statistic and view in **As Is** mode. Click on **Show** for a more detailed graph. This statistic shows how much traffic was generated by this device. The measured values should approximately match the calculations we made earlier using the configuration parameters. Again, for the **Low_Load** scenario, $100 \text{ bytes/packet} * 8 \text{ bits/byte} * 1 \text{ packet}/0.004 \text{ sec} = 200 \text{ Kbps}$ load per station. You may do a similar calculation for the **High_Load** scenario. Click on the close window icon and choose to **Delete** the panel to close the window. Click on the **Load (bits/sec)** statistic again to disable the preview.



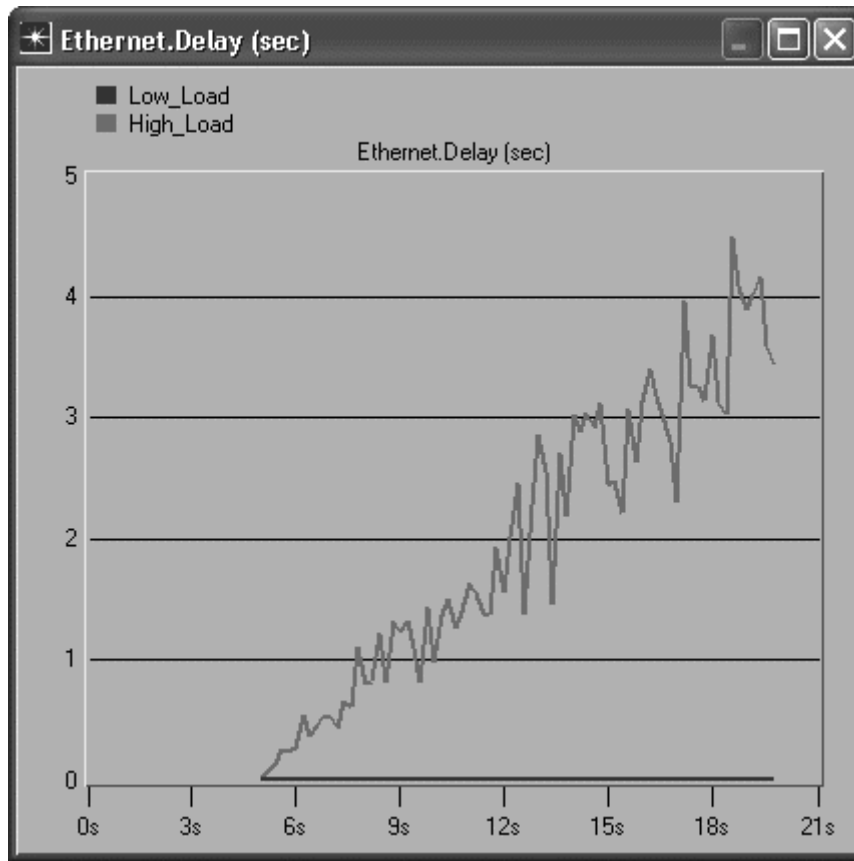
Discrepancies between the send and receive rates can be accounted for by inspecting the **Collision Count** statistic. Expand the **Hub** and the **Ethernet** items. Select the **Collision Count** statistic. Click on **Show** for a more detailed graph. Some of the packets that were sent collided and required retransmissions, reducing the throughput. This is true of both scenarios, but the **High Load** scenario generated far more collisions. Click on the close window icon and **Delete** the panel. Click on the statistic again to disable the preview.



The hub's utilization can be viewed by selecting the **Utilization** statistic. Click on **Show** for a more detailed graph. The utilization essentially describes what percentage of the network's capacity is being used. Since 10BaseT links were used to connect the hub to the Ethernet stations, the capacity is 10 Mbps. You can see that the **High_Load** scenario traffic utilized a great deal more of the hub's capacity than the **Low_Load** scenario traffic. Click on the close window icon and **Delete** the panel. Click on the **Utilization** statistic again to disable the preview.



Lastly, expand the **Global Statistics** item and the **Ethernet** item, and select the **Delay (sec)** statistic. Click on **Show** for a more detailed graph. This statistic shows the delay experienced by all packets which have been successfully delivered. You can see that the delay is fairly consistent in the **Low-Load** scenario, but that the high level of traffic causes growing delays in the **High_Load** scenario. Click on the close window icon and **Delete** the panel. Click on **Close** to close the Compare Results window.



Save your model and close all windows.

Questions

1. Create several duplicate scenarios and modify the interarrival times for all the Ethernet stations to 0.0008, 0.002, 0.003, 0.005, and 0.006, respectively. Rerun the simulation, and record the **Traffic Received (bits/sec)** statistic for each scenario. Using a spreadsheet, plot the values, (together with the results you found in the preceding scenarios using interarrival times of 0.001 and 0.004). Find the interarrival time for which the maximum throughput is achieved. Calculate the offered load that corresponds to this interarrival time. Why does the throughput stop increasing even when the load is increased further?
2. Rerun the simulation using the same interarrival times in Question 1. For each run, record the **utilization** and **Traffic Received (bits/sec)**. Plot the values using a spreadsheet. How are the two statistics related? Why can't the system reach 100% utilization?
3. Some interactive applications require very short delay. Excessive load and resulting collisions can increase delay significantly. Modify the interarrival time and rerun the simulation to determine the **minimum** interarrival time and corresponding per-node load if the delay must be 0.005 second or less.
4. Modify the interarrival time and rerun the simulation to determine how large the interarrival time must be in order for the number of **collisions** per second to become negligible (less than 10 per second). What is the per-node load that corresponds to the interarrival time you found?
5. Under high loads, shared Ethernet LANs tend to perform poorly. Examine the **Delay** statistic for the **High_Load** scenario again. How does the delay experienced by packets change over the run of the simulation? Why does this behavior occur? What will happen to the delay if the load continues at the same level?