Lab 6 Quality of Service: Impact of Traffic Shaping

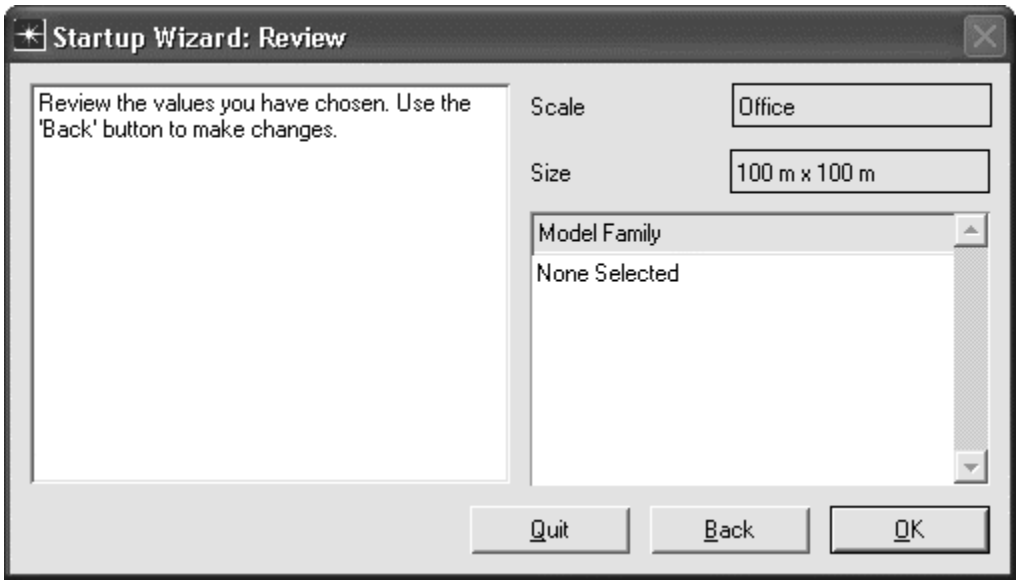
Overview
The shape of the traffic that is offered to a network can have a large effect on the resulting delay and variation in delay that the traffic experiences. Smooth, regular traffic patterns are generally easier for routers to handle than bursty, irregular patterns. When a large burst of traffic arrives, a router may not have sufficient capacity to immediately forward the packets, and it must place the packets in a queue. The packets will wait there until capacity is available. In the meantime, the packets experience increased delay. If the size of the queue varies over time (due again to irregular traffic patterns), incoming packets will experience different amounts of queuing delay. In general, for any application, it is desirable to reduce delay. Applications based on voice and video, however, cannot tolerate a large amount of delay variation either.

Traffic-shaping schemes, such as leaky bucket or token bucket, are designed to smooth out the traffic patterns at the source. The hope is that smoother patterns will see less delay and less variation in delay.

Objective
To examine the effects of traffic shaping on router performance. We will examine buffer usage, queuing delay, and queuing delay variation when generating constant bit rate (CBR) traffic, and two varieties of bursty traffic.

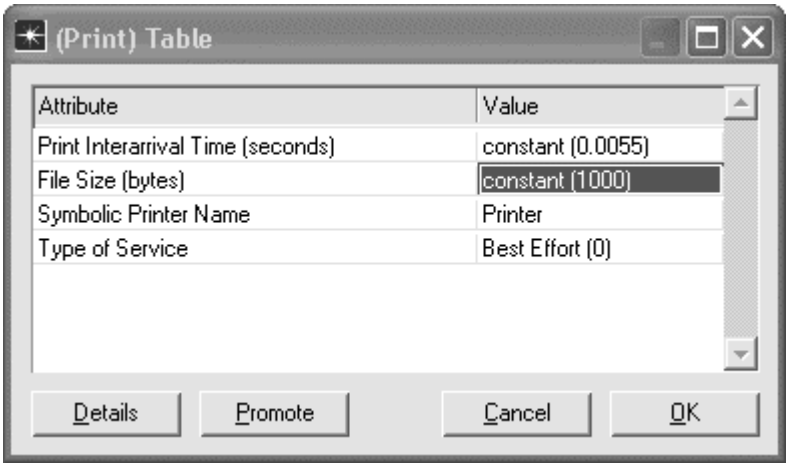
Build the Simulation Model

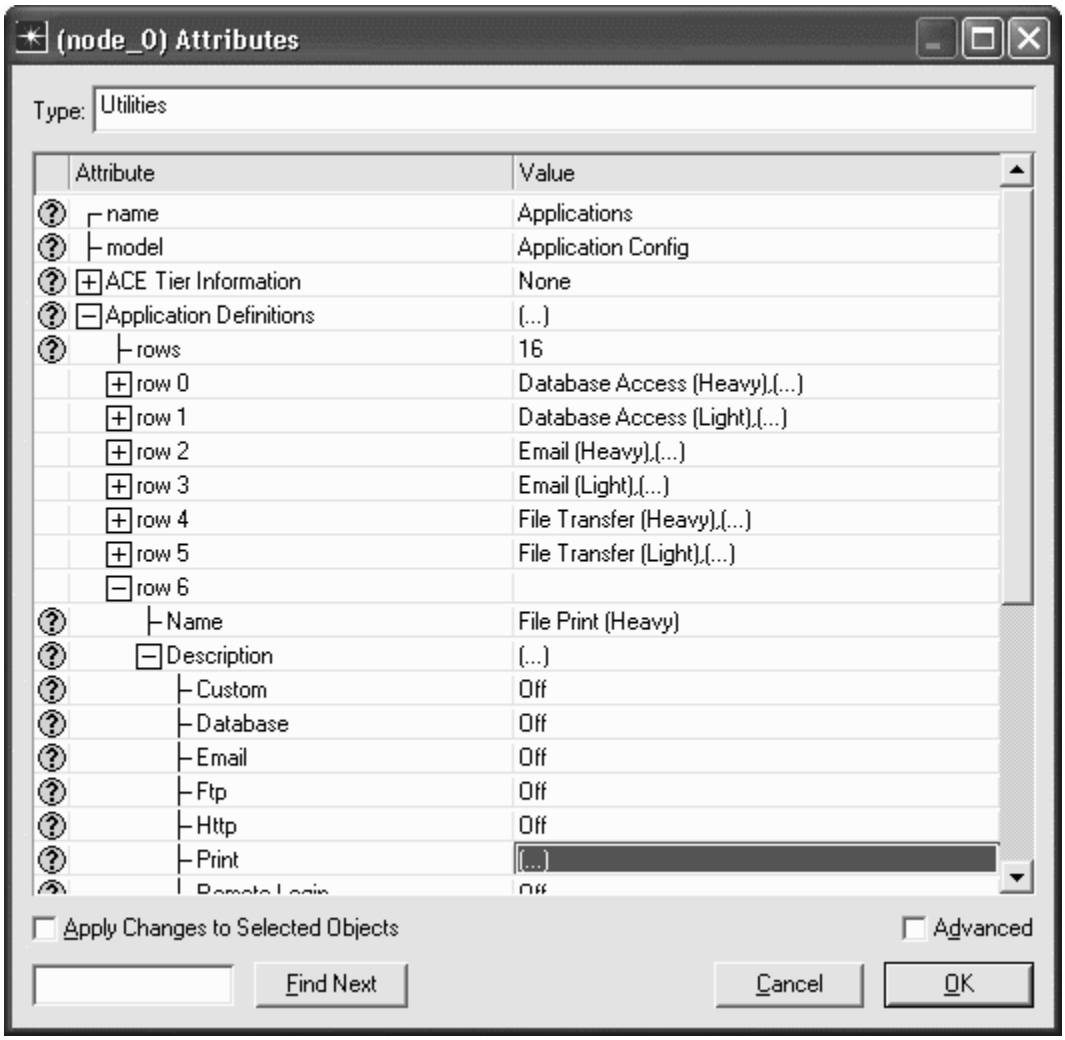
Start up OPNET IT Guru Academic Edition.
Select the **File** tab => **New...**
Choose **Project** and click on **OK**.
Change the **Project Name** to **xx_QoS_Shaping** (where **xx** are your initials). Set the **Scenario Name** to **CBR** and click on **OK**.
In the **Initial Topology** window, select **Create Empty Scenario** and click on **Next**.
In the **Choose Network Scale** window, select **Office** and click on **Next**.
In the **Specify Size** window, click on **Next**.
In the **Select Technologies** window, click on **Next**.
In the **Review** window, click on **OK**.



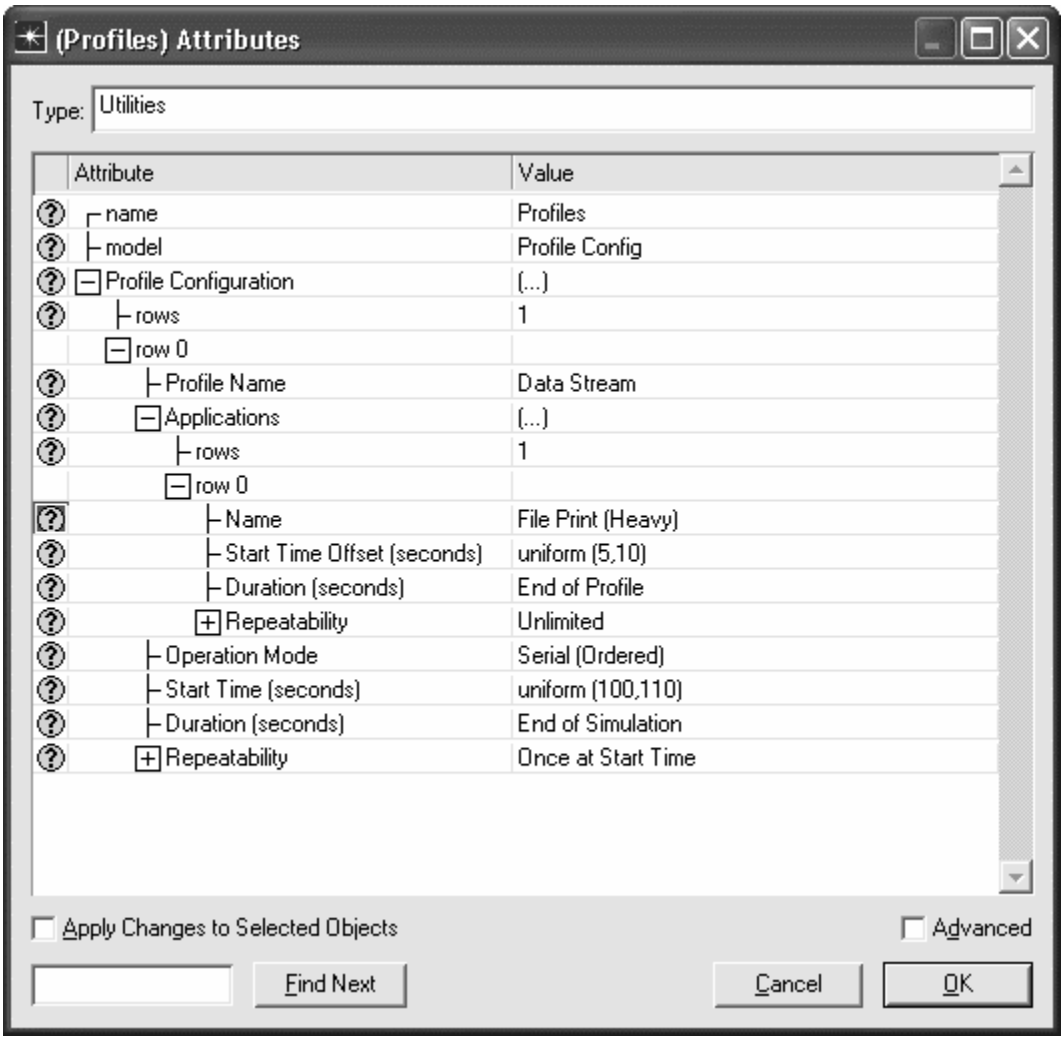
First, we will modify the existing **File Print (Heavy)** application to generate traffic at a constant bit rate. The File Print application is based on a simple model and is easy to modify.

Select an **Application Config** object from the Object Palette and place it in the project workspace. Right click on the object and choose **Edit Attributes**. Set the **name** attribute to **Applications**.
Edit the **Application Definitions** attribute and set the value to **Default**. Now expand the **Application Definitions** item, the **row 6** item (which corresponds to the **File Print (Heavy)** application) and the **Description** item. Edit the **Print** attribute. Set the **Print Interarrival Time (seconds)** attribute to **constant(0.0055)**. Set the **File Size (bytes)** attribute to **constant(1000)**. The application you have now defined will transfer one 1000 byte file every 0.0055 second (5.5 milliseconds) without variation. Click on **OK** to close the window.





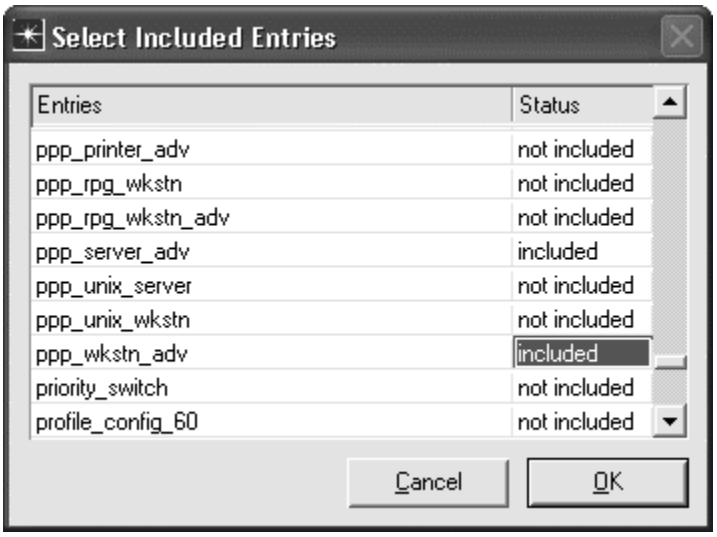
Select a **Profile Config** object from the Object Palette and place it in the project workspace. Right click on the object and choose **Edit Attributes**. Set the **name** attribute to **Profiles**.
Expand the **Profile Configuration** attribute and set the **rows** attribute to **1**. Expand the **row 0** attribute and set the **Profile Name** to **Data Stream**. Expand the **Applications** attribute and set the **rows** attribute to **1**. Expand the **row 0** attribute and set the **Name** to **File Print (Heavy)**. Click on **OK** to close the window.



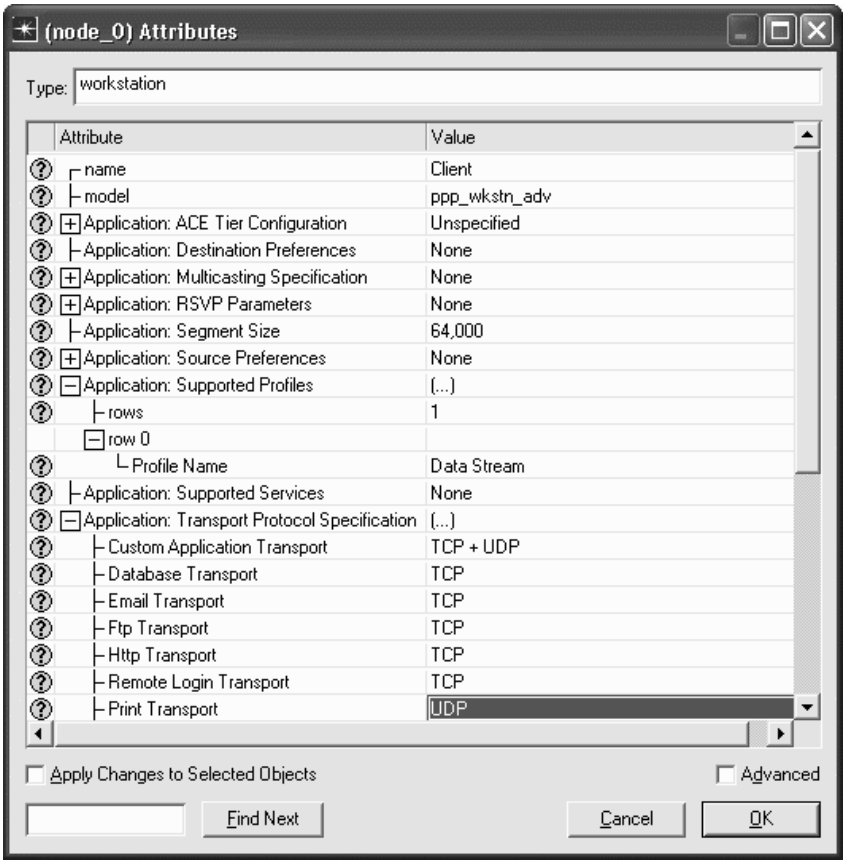
Select a **QoS Attribute Config** object from the Object Palette and place it in the project workspace. Right click on the object, choose **Set Name**, and set the **Name** to QoS. Click on **OK** to close the window. The QoS object is necessary as we will be configuring a router to do quality of service monitoring.

Now we will build a client-server system based on the file printing application and profile that we just created.

Click on **Configure Palette** in the Object Palette. Click on **Node Models**. Scroll down and choose to include the **ppp_server_adv** and **ppp_wkstn_adv** models. Click on **OK** twice, and choose to save your model to finish configuring the palette.

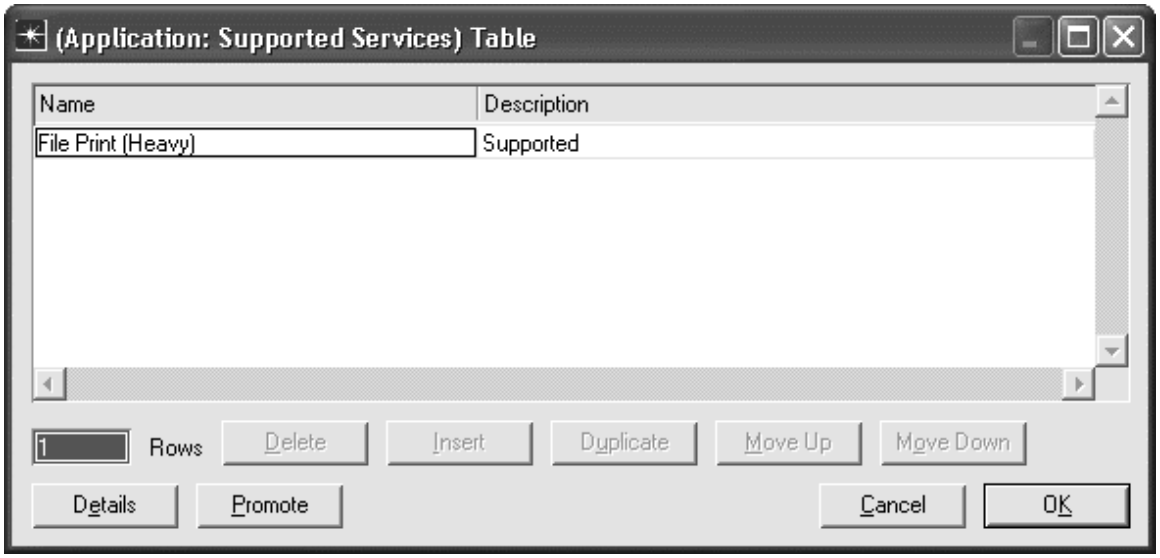


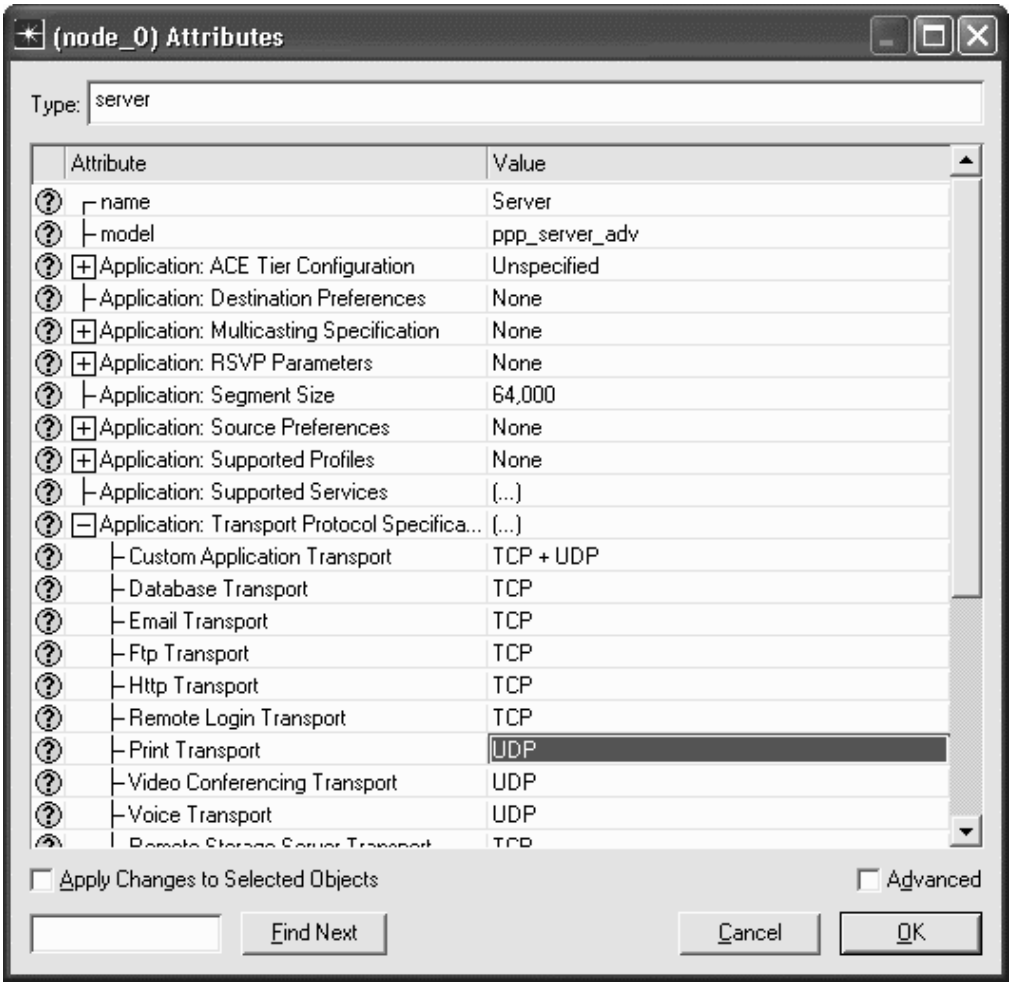
Select a **ppp_wkstn_adv** device from the Object Palette and place it in the project workspace. Right click on the workstation and choose **Edit Attributes**. Modify the **name** attribute of the device to **Client**. Edit the **Application: Supported Profiles** attribute. Set the **rows** attribute to **1**, expand the **row 0** attribute, and set the **Profile Name** to **Data Stream**. Expand the **Application: Transport Protocol Specification** attribute, and set the **Print Transport** attribute to **UDP**. Click on **OK** to close the window. By specifying that UDP be used rather than TCP, we eliminate the TCP connection setup and teardown overhead that would affect our results.



Select a **ppp_server_adv** device from the Object Palette and place in the project workspace. Right click on the device and choose **Edit Attributes**. Modify the **name** attribute of the server to **Server**.

Edit the **Application: Supported Services** attribute. Set the **rows** attribute to **1** and expand the **row 0** attribute. Set the **Name** to **File Print (Heavy)**. Click on **OK** to close the window. Expand the **Application: Transport Protocol Specification** attribute, and set the **Print Transport** attribute to **UDP**. Click on **OK** to close the window.

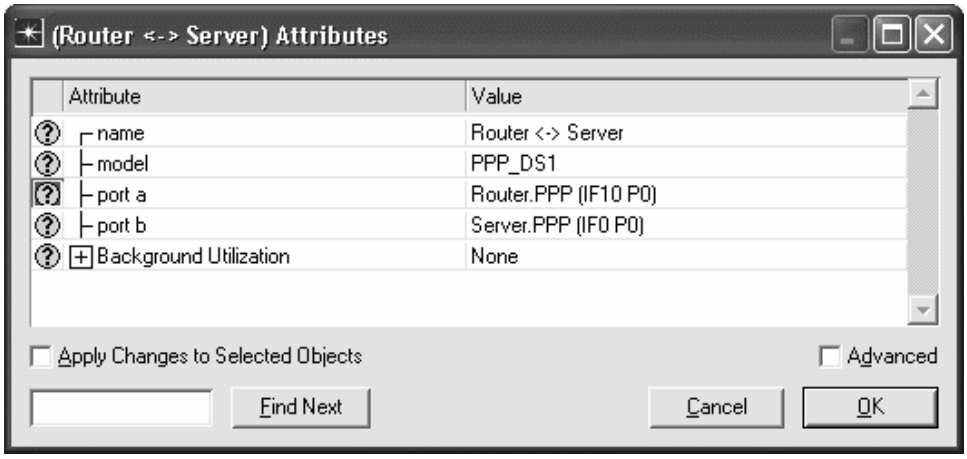




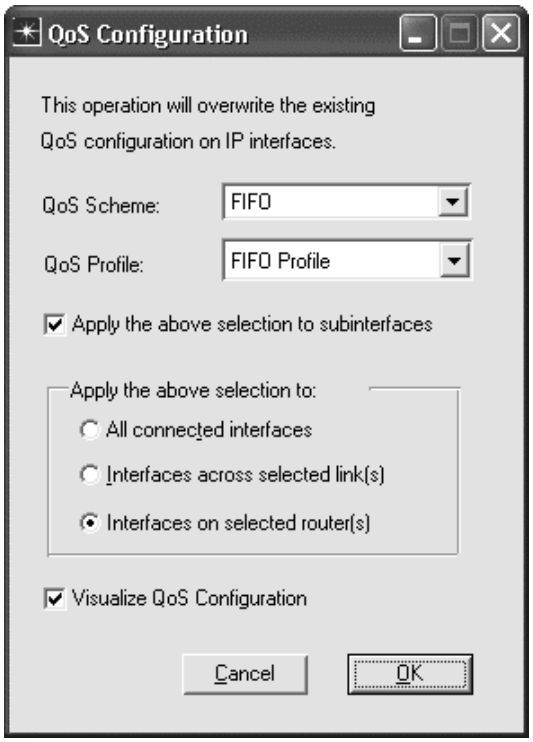
Select an **ethernet4_slip8_gtwy** device from the Object Palette and place it in the project workspace. Right click on the router and choose **Set Name**. Set the **Name** to **Router** and click on **OK** to close the window.

Select a **PPP_DS1** link from the Object Palette and use it to connect the server to the router. Select a **PPP_DS3** link from the Object Palette and use it to connect the client to the router. The inequality in data rates will help us to see the effects of different traffic-shaping schemes.

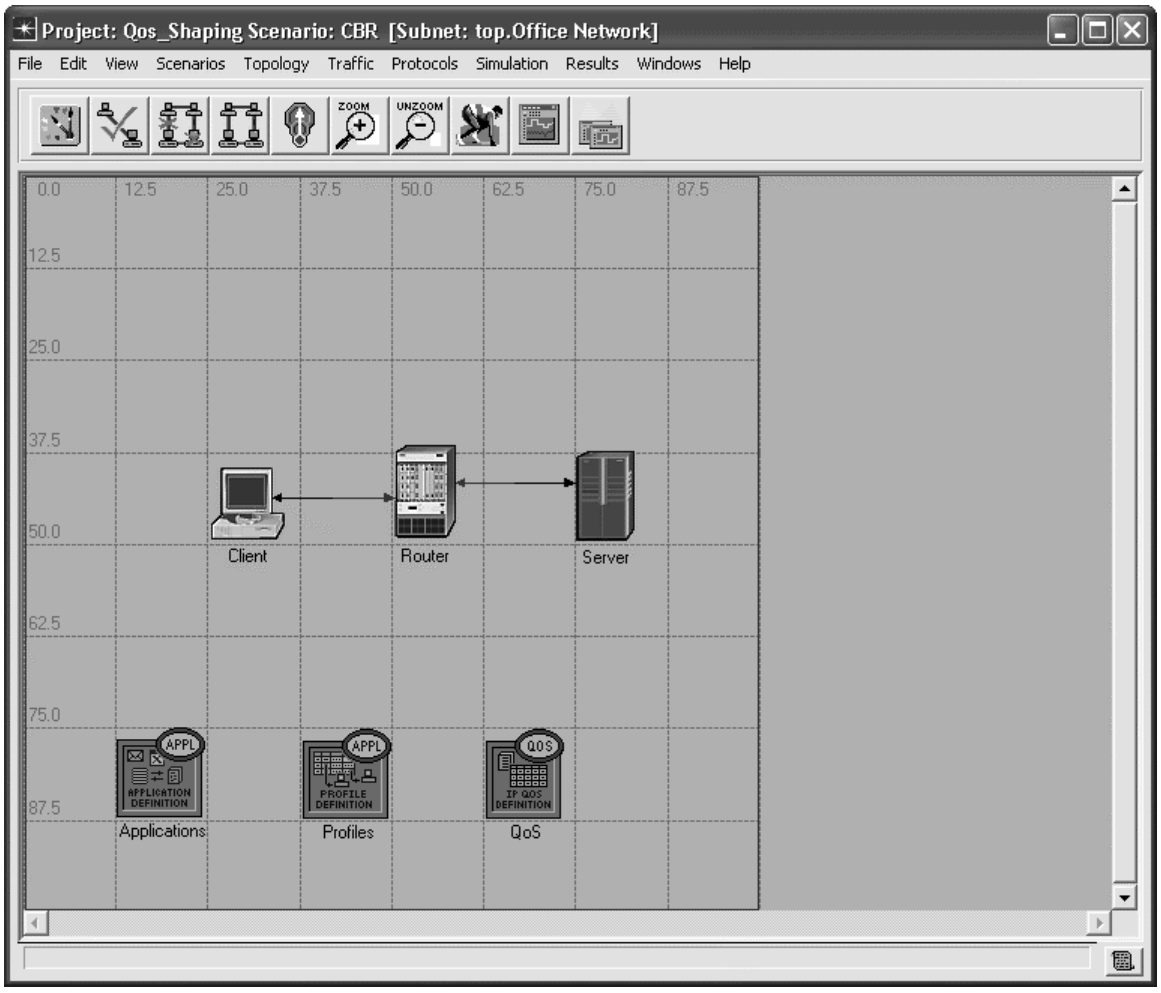
Right click on the PPP link which connects the Router and the Server, and choose **Edit Attributes**. Inspect the **port a** and **port b** attributes to see which interface is being used on the Router (IF10 in our example). Your configuration may differ from the one shown depending on how you placed your PPP link. You will need this interface information when viewing results. Click on **OK** to close the window.



Left click on the router to select it, and then select the **Protocols** tab => **IP** => **QoS** => **Configure QoS…** Note that the default QoS scheme is FIFO (First-In First-Out). Click on the radio button marked **Interfaces on selected routers**, and click on **OK** to finish configuring quality of service on the router.

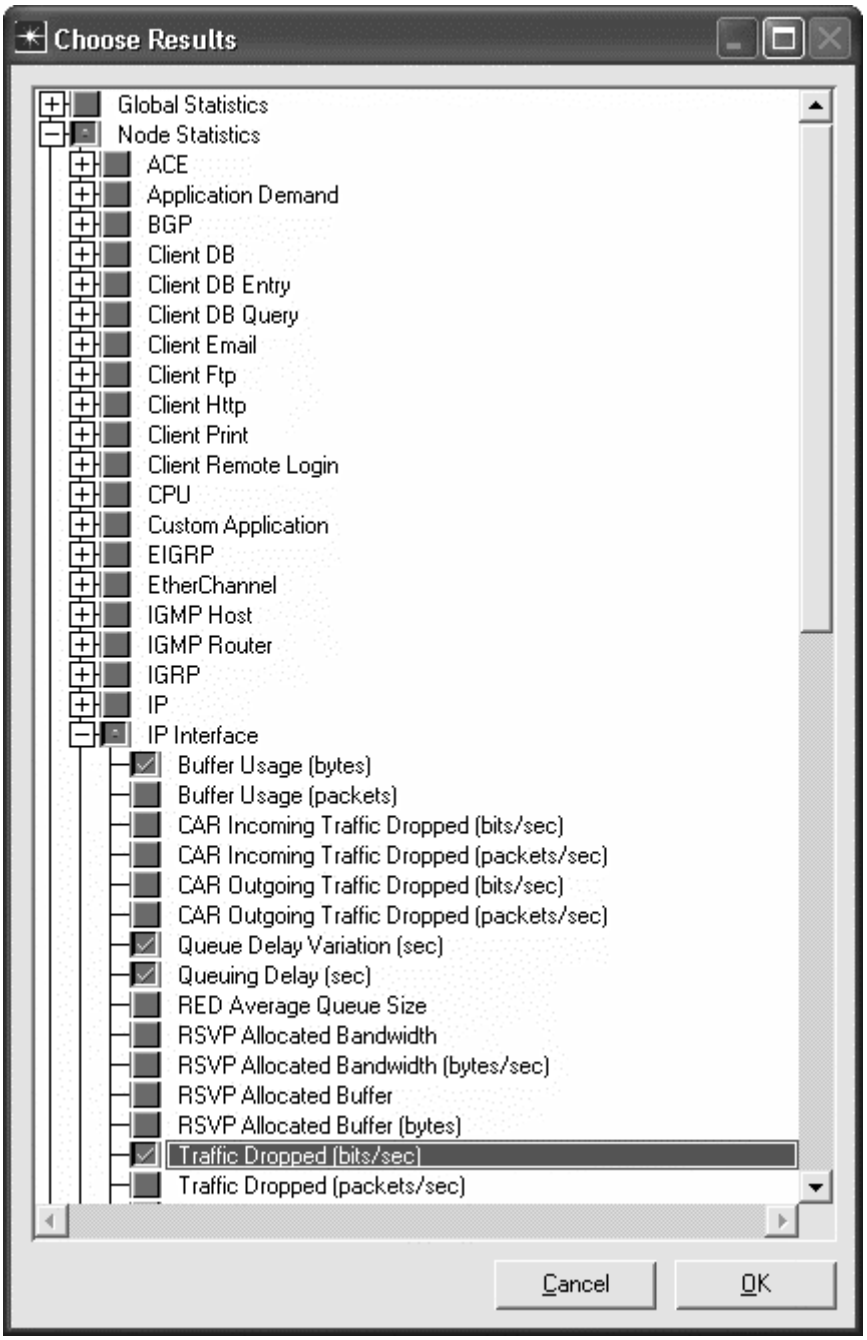


Our model is now complete.

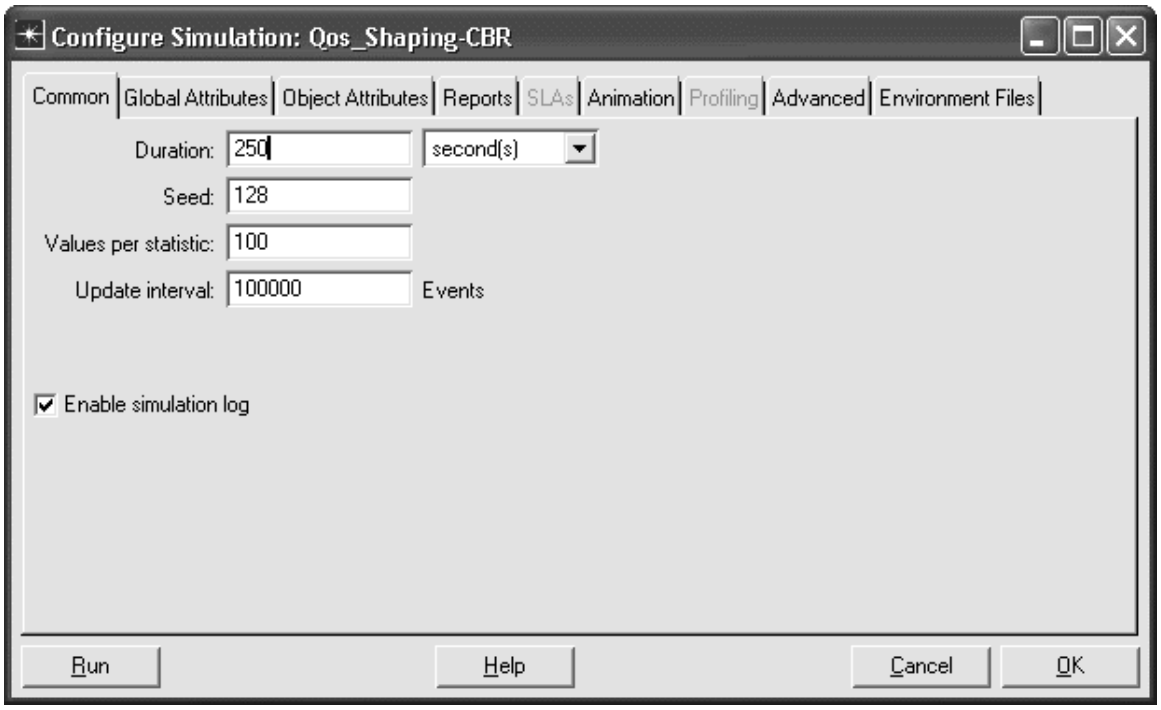


Configure the Simulation

Select the **Simulation** tab => **Choose Individual Statistics..**. Expand the **Node Statistics** item and the **IP Interface** item, and select the **Buffer Usage (bytes)**, the **Queue Delay Variation (sec)**, the **Queuing Delay (sec)**, and the **Traffic Dropped (bits/sec)** statistics. Click on **OK** to close window.



Select **Simulation => Configure Discrete Event Simulation…**
Under the **Common** tab, set the **Duration** to **250**, and the unit to **second(s)**.
Click on **OK** to close the window.

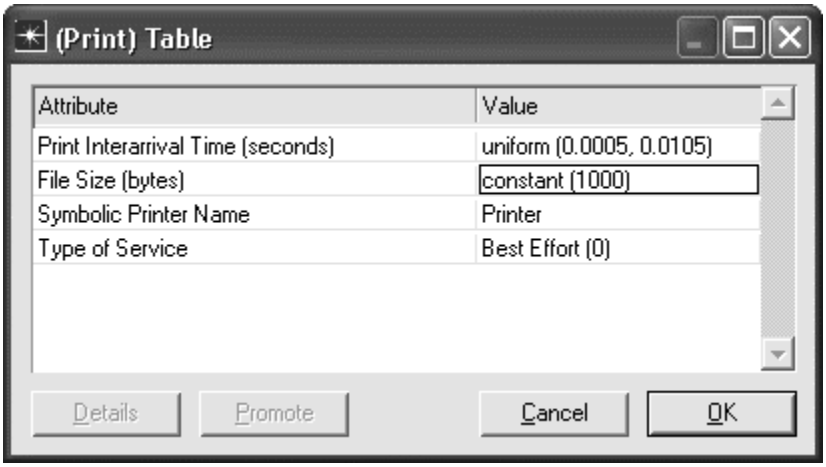


Duplicate the Scenario

We are now going to duplicate the scenario and change the characteristics of the data stream. We will create one scenario where the stream interarrivals are based on a uniform distribution, which provides somewhat variable interarrival times, and another based on the exponential distribution, which provides extremely variable interarrival times. In all three cases, however, the average amount of traffic generated per second will be the same. This will allow us to compare the effects on the router of traffic which is shaped differently.

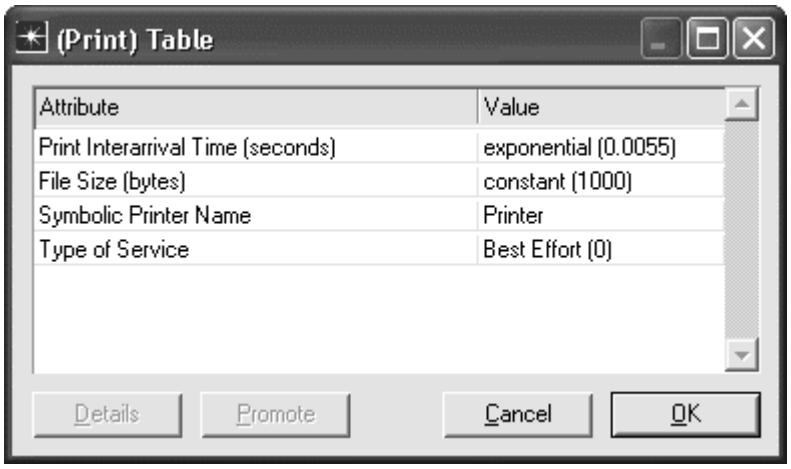
Choose **Scenarios => Duplicate Scenario**, and name the new scenario **Uniform**. Click on **OK** to create the scenario.

Right click on the Applications node and choose **Edit Attributes**. Expand the **Application Definitions**, **row 6** (which corresponds to **File Print (Heavy)**), and **Description** attributes. Edit the **Print Interarrival Time (seconds)** attribute and set the value to **uniform(0.0005,0.0105)**. Click on **OK** twice to close the windows. Packets will now be generated at random intervals ranging from 0.5 to 10.5 milliseconds.



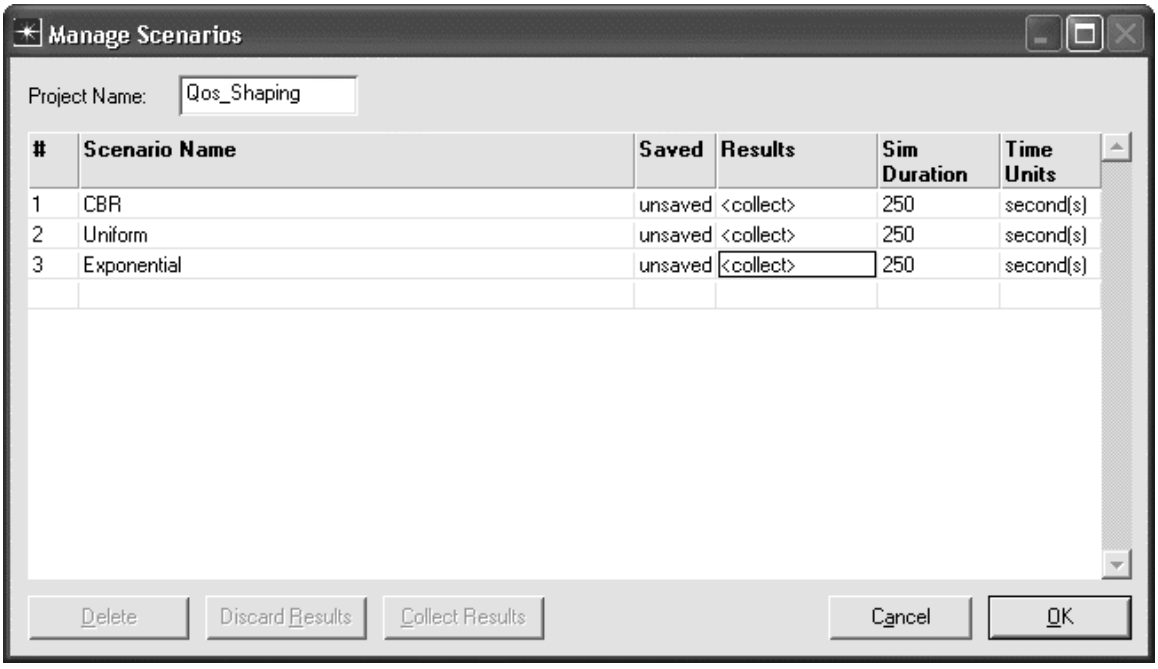
Choose **Scenarios => Duplicate Scenario**, and name the new scenario **Exponential**. Click on **OK** to create the scenario.

Right click on the Applications node and choose to **Edit Attributes**. Expand the **Application Definitions**, **row 6** (corresponding to **File Print (Heavy)**), and **Description** attributes. Edit the **Print Interarrival Time (seconds)** attribute and set the value to **exp(0.00055)**. Click on **OK** twice to close the windows. Packets will now be generated at random intervals with a mean of 5.5 milliseconds.



Run the Simulation

Select the **Scenarios** tab => **Manage Scenarios…**
Edit the **Results** field in all three rows and set the value to **<collect>** or **<recollect>**.
Click on **OK** to run the scenarios (one after the other).
When the simulation has completed, click on **Close** to close the window.

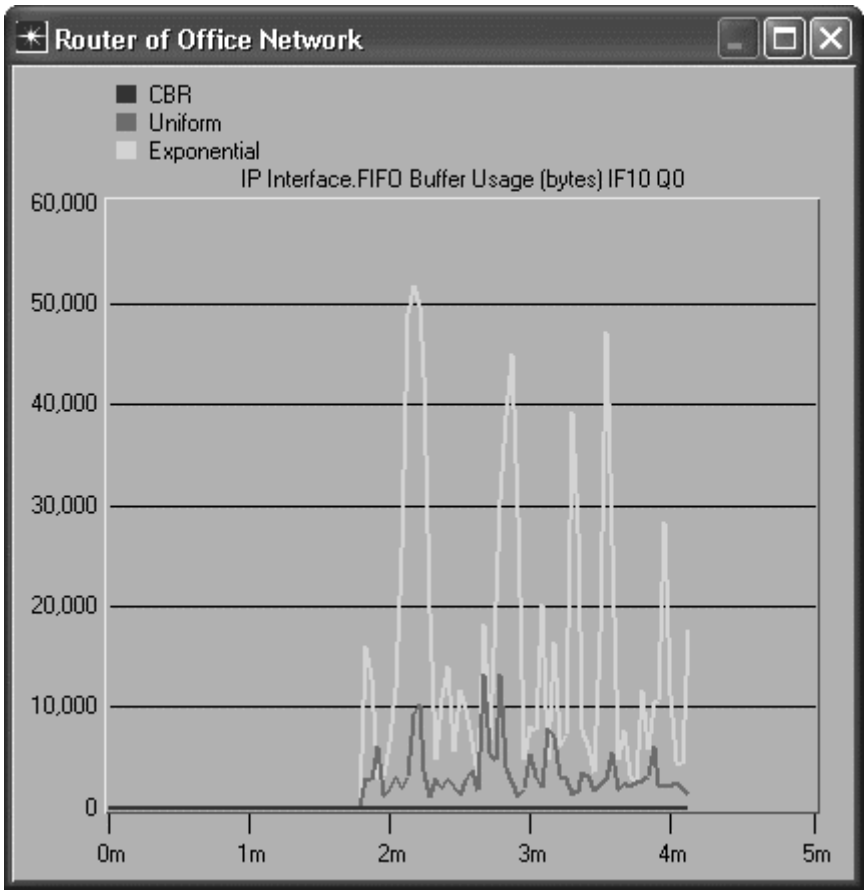


Inspect and Analyze Results

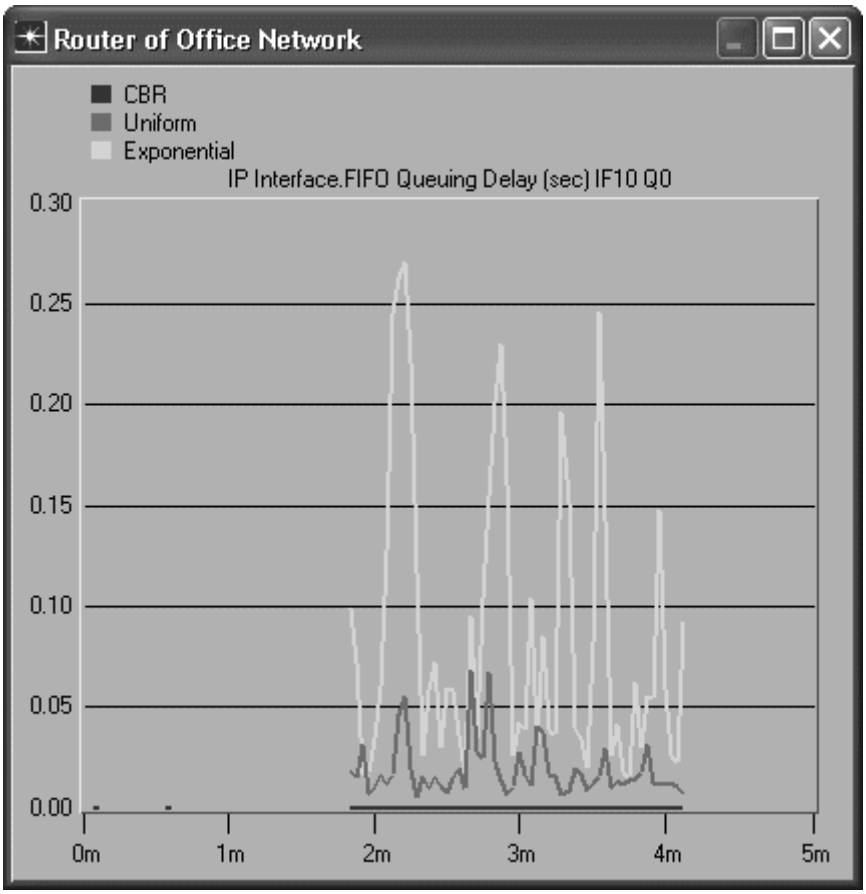
Select the **Results** tab => **Compare Results…**

Select and expand the **Object Statistics** item, the **Office Network** item, the **Router** item, and the **IP Interface** item. Select the **FIFO Buffer Usage (bytes) IF10 Q0** statistic. Note that interface 10 (IF10) is the interface

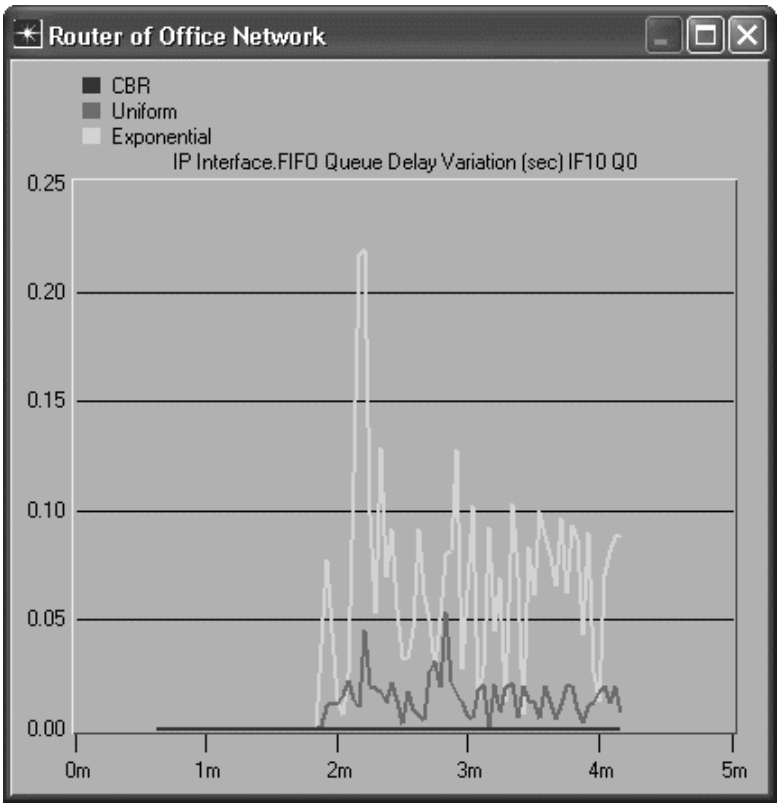
on the Router that connects it to the Server. If, during configuration setup, you found that a different interface was used in your model, replace IF10 with that interface for the rest of the results analysis steps. Use the **As Is** mode to view all statistics. Click on **Show** to see a detailed version of the graph. This statistic shows how full the router's buffers were during the simulation. The buffers can fill up if a large burst of traffic is received at once. You can see that the router can handle the traffic easily if the packets are received at constant intervals. The buffer does not fill at all. When packets are received more irregularly, in the uniform distribution case, buffer usage begins to grow. When packets are received very irregularly, buffer usage is high. Click on the close window icon and choose to **Delete** the panel. Click on the statistic again to disable the preview.



Select the **FIFO Queuing Delay (sec) IF10 Q0** statistic. Click on **Show** to see a detailed version of the graph. This statistic shows how long packets had to wait in the queue before being sent. As a router's buffers fill up, incoming packets must wait longer to be sent. Since the buffers were always empty in the CBR case, there is no queuing delay. The uniform case and exponential case see longer delays due to the high buffer usage in those cases. Click on the close window icon and choose to **Delete** the panel. Click on the statistic again to disable the preview.



Select the **FIFO Queue Delay Variation (sec) IF10 Q0** statistic. Click on **Show** to see a detailed version of the graph. This statistic shows the variation in how long packets had to wait in the queue before being sent. When the size of the router's queue changes over time, the delay that each incoming packet sees will be different. The buffers were always empty in the CBR case, so the variation in queuing delay is zero. The uniform case and exponential case had buffers that filled and emptied often, causing a significant in variation delay. Click on the close window icon and choose to **Delete** the panel. Click on the statistic again to disable the preview.



You may also inspect the **FIFO Traffic Dropped (bits/sec) IF10 Q0** statistic to see that no packets were dropped due to full buffers in any of the three scenarios.

Save your model and close all windows.

Questions

1. Look up the formula for the mean of the three distributions used in this lab (constant, uniform, exponential). Find the mean for each. Using the average packet interarrival time and packet size, calculate the load which the client is generating (in bits per second).

2. Choose to collect **Node Statistics**, **Client Print**, **Traffic Sent (bytes/sec)** and rerun the three scenarios. Did the measured traffic sent match up with the numbers you calculated in Question 1? Why or why not?

3. Look up the formula for the variance of the three distributions used in this lab (constant, uniform, exponential). Find the variance of each. How does the variance of the packet interarrival time affect the buffer usage, queuing delay, and queuing delay variation?

4. Duplicate each scenario, and copy and paste the client to create two clients. Connect the new client to the router. Edit the **File Print (Heavy)** application and double the interarrival times. By doing this, each client will generate half the amount of traffic as shown in the lab exercise, but since there are two clients, the same total amount of traffic will be generated. Rerun the three scenarios, and compare the results (buffer usage, queuing delay, and queuing delay variation) with your original results. Were the results different? If so, why?

5. Duplicate the Uniform scenario, and modify the interarrival time of the **File Print (Heavy)** application. In the lab exercise, the uniform interval is 10 milliseconds wide. Make the interval 20 milliseconds wide and rerun the simulation. Make sure that the mean of the interval is still the same. How does the wider interval affect the results? Repeat for intervals which are 40, 80, 160, and 320 milliseconds wide. Graph your results for the five intervals and explain the behavior you see.