

# Queuing Disciplines

## Order of Packet Transmission and Dropping

### OBJECTIVES

The objective of this lab is to examine the effect of various queuing disciplines on packet delivery and delay for different services.

### OVERVIEW

As part of the resource allocation mechanisms, each router must implement some queuing discipline that governs how packets are buffered while waiting to be transmitted. Various queuing disciplines can be used to control which packets get transmitted (bandwidth allocation) and which packets get dropped (limited buffer space). The queuing discipline also affects the latency experienced by a packet, by determining how long a packet waits to be transmitted. Examples of the common queuing disciplines are first-in/first-out (FIFO) queuing, priority queuing (PQ), and weighted-fair queuing (WFQ).

The idea of FIFO queuing is that the first packet that arrives at a router is the first packet to be transmitted. Given that the amount of buffer space at each router is finite, if a packet arrives and the queue (buffer space) is full, then the router discards (drops) that packet. This is done without regard to which flow the packet belongs to or how important the packet is.

PQ is a simple variation of the basic FIFO queuing. The idea is to mark each packet with a priority; the mark could be carried, for example, in the IP Type of Service (ToS) field. The routers then implement multiple FIFO queues, one for each priority class. Within each priority, packets are still managed in a FIFO manner. This queuing discipline allows high-priority packets to cut to the front of the line.

The idea of the fair queuing (FQ) discipline is to maintain a separate queue for each flow currently being handled by the router. The router then services these queues in a round-robin manner. WFQ allows a weight to be assigned to each flow (queue). This weight effectively controls the percentage allocated to each flow from the link's bandwidth. We could use ToS bits in the IP header to identify that weight.

In this lab, you will set up a network that carries three applications: File Transfer Protocol (FTP), video, and Voice over IP (VoIP). You will study how the choice of the queuing discipline in the routers can affect performance of the applications and utilization of the network resources.

### PRE-LAB ACTIVITIES



Read Section 6.2 from *Computer Networks: A Systems Approach, 5th Edition*.

- 🖥️ Go to [www.net-seal.net](http://www.net-seal.net) and play the following animations:
  - Switch Congestion
  - IP Fragmentation

## PROCEDURE

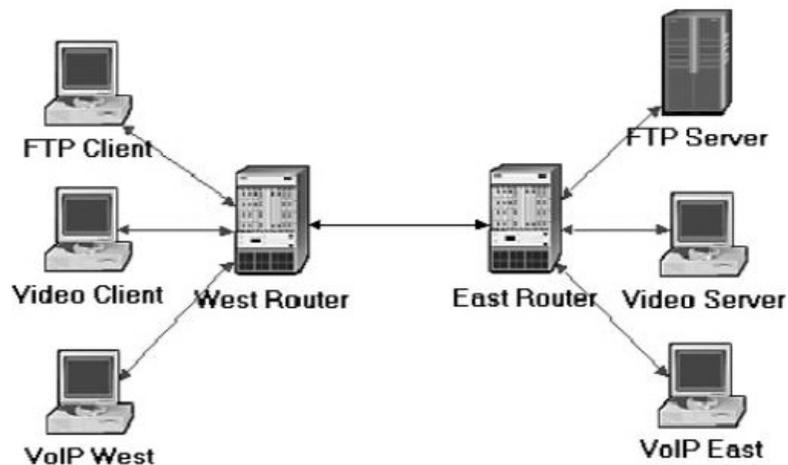
### Create a New Project

1. Start **OPNET IT Guru Academic Edition** → Choose **New** from the **File** menu.
2. Select **Project** and click **OK** → Name the project **<your initials>\_Queues**, and the scenario **FIFO** → Click **OK**.
3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty Scenario** is selected → Click **Next** → Select **Campus** from the *Network Scale* list → Click **Next** three times → Click **OK**.

### Create and Configure the Network

Initialize the network:

The **QoS Attribute Config** node defines attribute configuration details for protocols supported at the IP layer. These specifications can be referenced by the individual nodes using symbolic names. It defines different queuing profiles such as FIFO, WFQ, priority queuing, custom queuing, MDRR, and DWRR.



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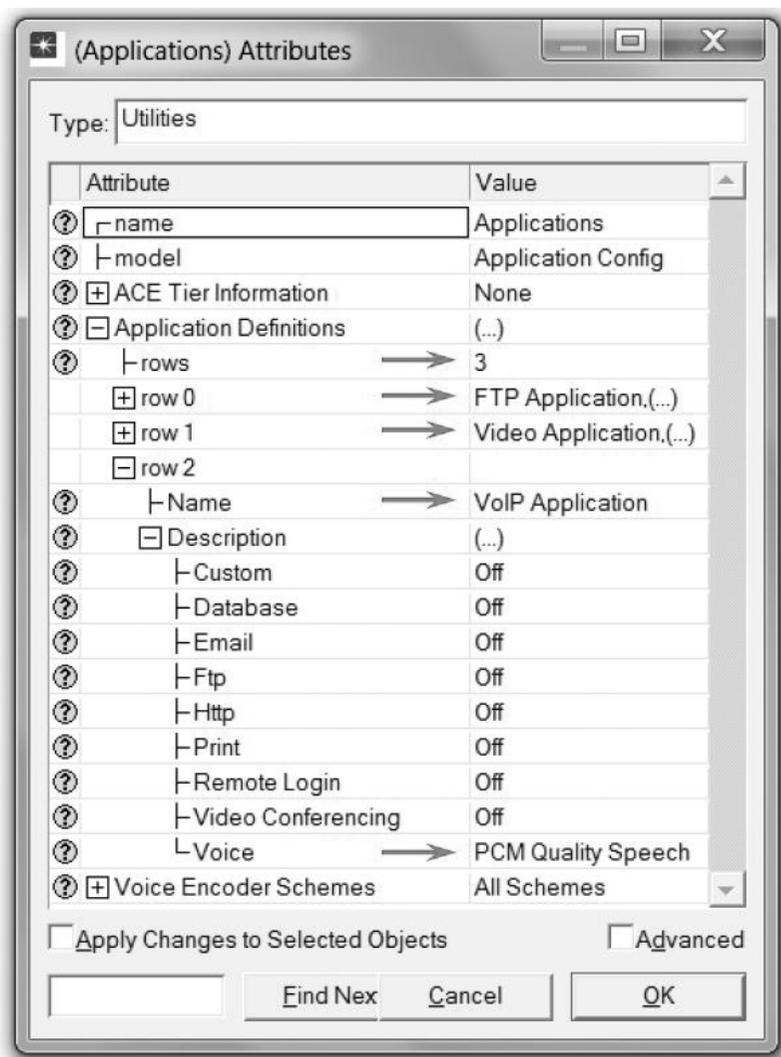
1. The *Object Palette* dialog box should be now on the top of your project space. If it is not there, open it by clicking . Make sure that the **internet\_toolbox** item is selected from the pull-down menu on the object palette.
2. Add to the project workspace the following objects from the palette: **Application Config**, **Profile Config**, **QoS Attribute Config**, **five ethernet\_wkstn**, **one ethernet\_server**, and **two ethernet4\_slip8\_gtwy** routers.
3. Connect both routers together with a bidirectional **PPP\_DS1** link.
4. Connect the workstations and the server to the routers using bidirectional **10Base\_T** links, as shown.
5. Rename the objects you added as shown, and **Save** your project.

Configure the applications:

1. Right-click on the **Applications** node → **Edit Attributes** → Expand the **Application Definitions** hierarchy → **Set rows to 3** → Name the rows: **FTP Application**, **Video Application**, and **VoIP Application**.
  - a. Go to the **FTP Application** row → Expand the **Description** hierarchy → Assign **High Load** to **Ftp** → Click on the **High Load** value and choose **Edit** from the drop-down menu → Assign **Constant(10)** to **Inter-Request Time** → Assign **Constant(1000000)** to **File Size**. Keep the Type of Service (ToS) as Best Effort (0).

**Type of Service (ToS)** is assigned to the IP packets. It represents a session attribute that allows packets to be provided for the appropriate service in the IP queues.

**Best-effort** delivery means that delivery of a packet is attempted but is not guaranteed.

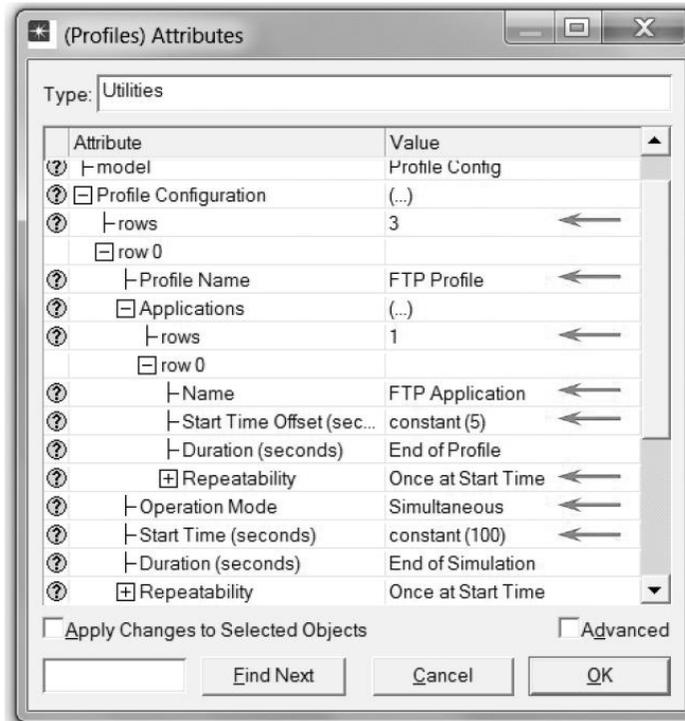


- b. Go to the **Video Application** row → Expand the **Description** hierarchy → Assign **Low Resolution Video** to **Video Conferencing** → Click on the **Low Resolution Video** value and choose **Edit** → Edit the value of the **Type of Service** field (the Configure TOS/DSCP window appears) → From the drop-down menu, assign **Streaming Multimedia (4)** to ToS → Click **OK** twice.
  - c. Go to the **VoIP Application** row → Expand the **Description** hierarchy → Assign **PCM Quality Speech** to **Voice**. If you edit it, you can see that the ToS assigned to it is **Interactive Voice (6)**.
2. Click **OK**, and then **Save** your project.

**PCM** (Pulse Code Modulation) is a procedure used to digitize speech before transmitting it over the network.

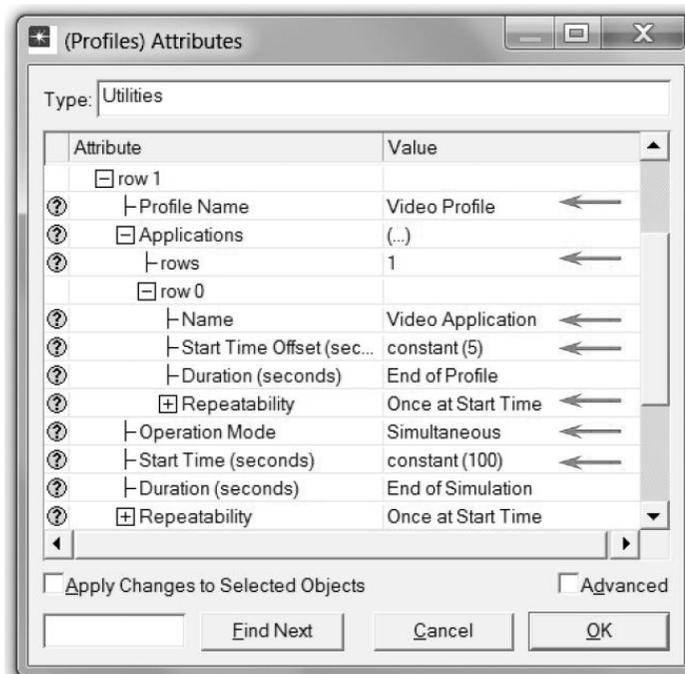
Configure the profiles:

1. Right-click on the **Profiles** node → **Edit Attributes** → Expand the **Profile Configuration** hierarchy → Set **rows** to 3.
2. Name and set the attributes of row 0 as shown:

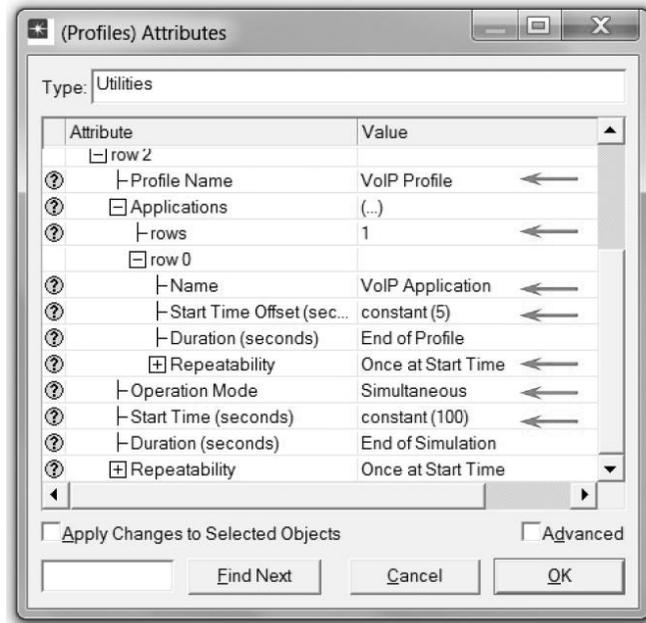


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3. Name and set the attributes of row 1 as shown:



4. Name and set the attributes of row 2 as shown:



5. Click OK, and then Save your project.

Configure the queues:

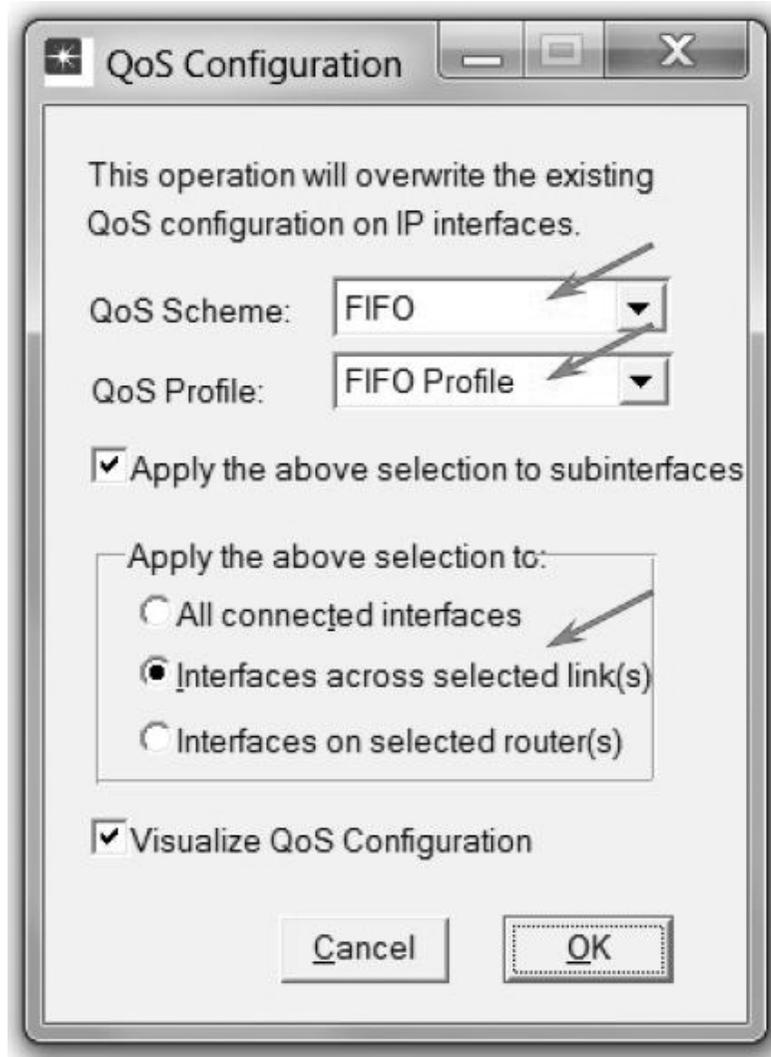
We will keep the default queuing profiles that are defined in our Queues object. It is recommended that you check out the configuration of the FIFO, PQ, and WFQ profiles.

Configure the workstations and servers:

1. Right-click on the FTP Client → Edit Attributes → Expand the Application: Supported Profiles hierarchy → Set rows to 1 → Set Profile Name to FTP Profile → Click OK.
2. Right-click on the Video Client → Edit Attributes → Expand the Application: Supported Profiles hierarchy → Set rows to 1 → Set Profile Name to Video Profile → Click OK.
3. Right-click on the VoIP West → Edit Attributes.
  - a. Expand the Application: Supported Profiles hierarchy → Set rows to 1 → Set Profile Name to VoIP Profile.
  - b. Edit the Application: Supported Services value → Set rows to 1 → Set Service Name to VoIP Application → Click OK twice.
4. Right-click on the VoIP East → Edit Attributes.
  - a. Expand the Application: Supported Profiles hierarchy → Set rows to 1 → Set Profile Name to VoIP Profile.
  - b. Edit the Application: Supported Services value → Set rows to 1 → Set Service Name to VoIP Application → Click OK twice.
5. Right-click on the FTP Server → Edit Attributes → Edit the Application: Supported Services value → Set rows to 1 → Set Service Name to FTP Application → Click OK twice.
6. Right-click on the Video Server → Edit Attributes → Edit the Application: Supported Services value → Set rows to 1 → Set Service Name to Video Application → Click OK twice.
7. Save your project.

Configure the routers:

1. Click on the link connecting the East and West routers to select it → From the **Protocols** menu choose **IP** → **QoS** → **Configure QoS**.
2. Make sure the selected items are as shown in the following *QoS Configuration* dialog box → Click **OK**.



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*Note:* Because the **Visualize QoS Configuration** radio button is checked, the link is colored based on the QoS scheme used (blue for FIFO).

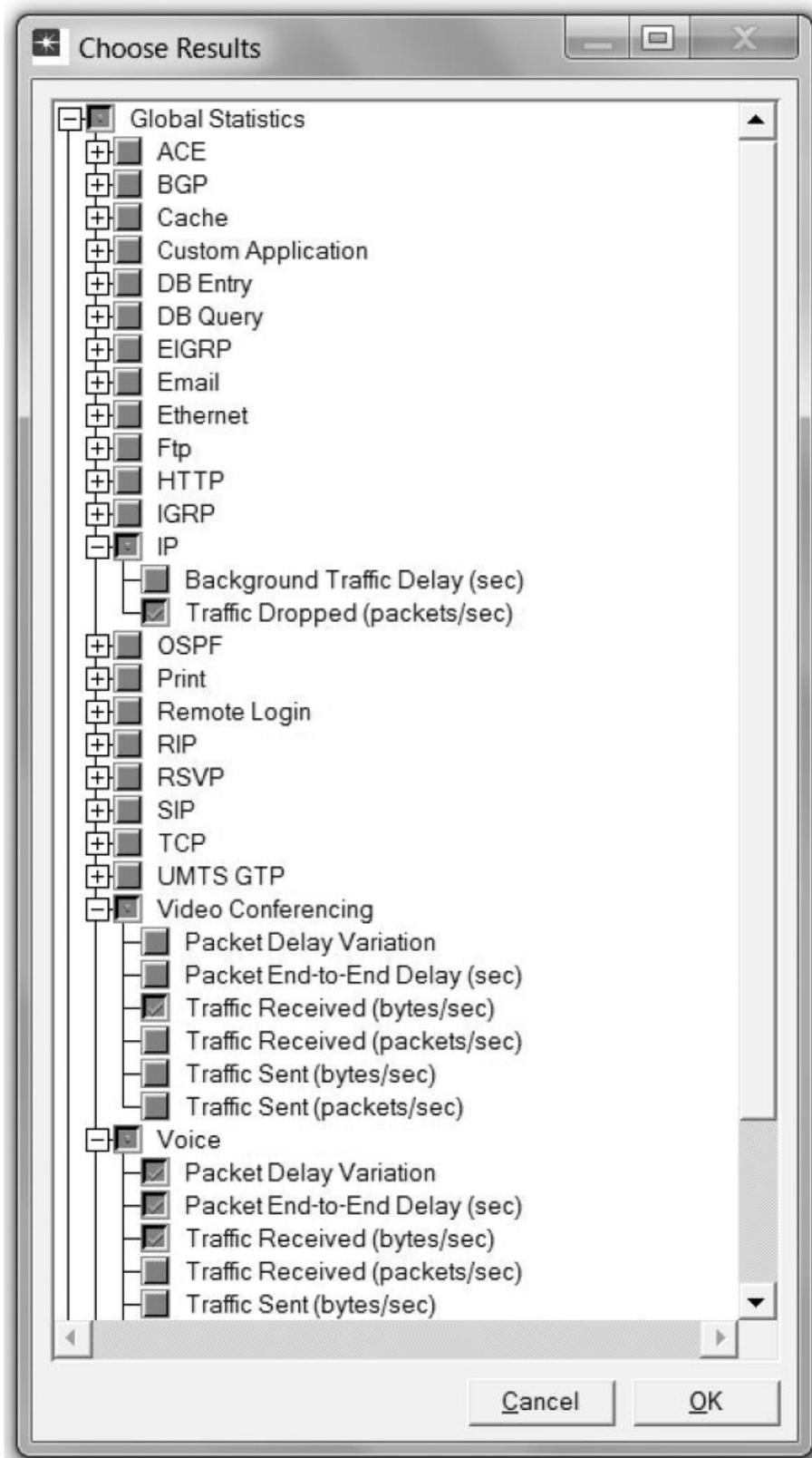
3. Save your project.

### Choose the Statistics

To test the performance of the applications defined in the network, we will collect some of the available statistics as follows:

1. Right-click anywhere in the project workspace, and select **Choose Individual Statistics** from the pop-up menu.

2. In the *Choose Results* dialog box, select the following global statistics:



3. Click OK, and Save your project.

**Traffic Dropped:** The number of IP datagrams dropped by *all* nodes in the network across all IP interfaces. The reasons for dropping an IP datagram can be any one of the following:

Insufficient space in the queue.

Maximum number of hops exceeded by an IP datagram.

On nonrouting nodes, a local router interface was not found to be used as the next hop.

On routing nodes, the route table lookup failed to yield a route to the destination.

### Configure the Simulation

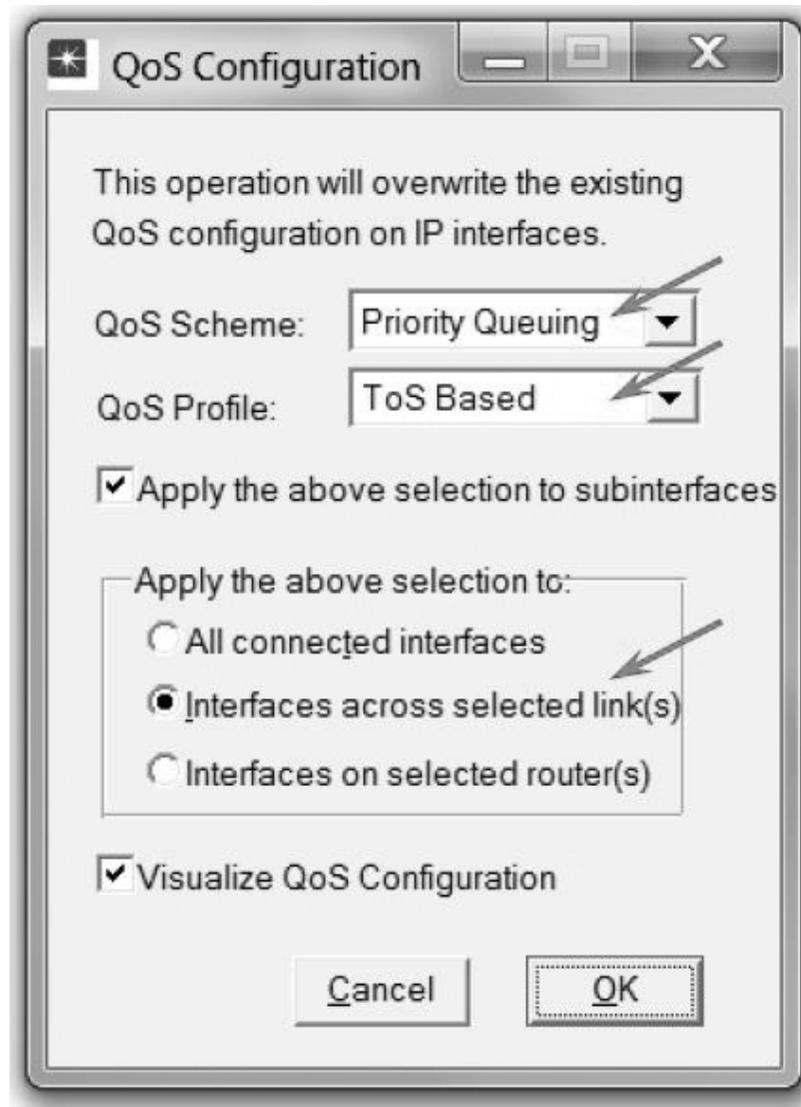
Here we need to configure the duration of the simulation:

1. Click on  and the *Configure Simulation* window should appear.
2. Set the duration to 150 seconds.
3. Click OK.

### Duplicate the Scenario

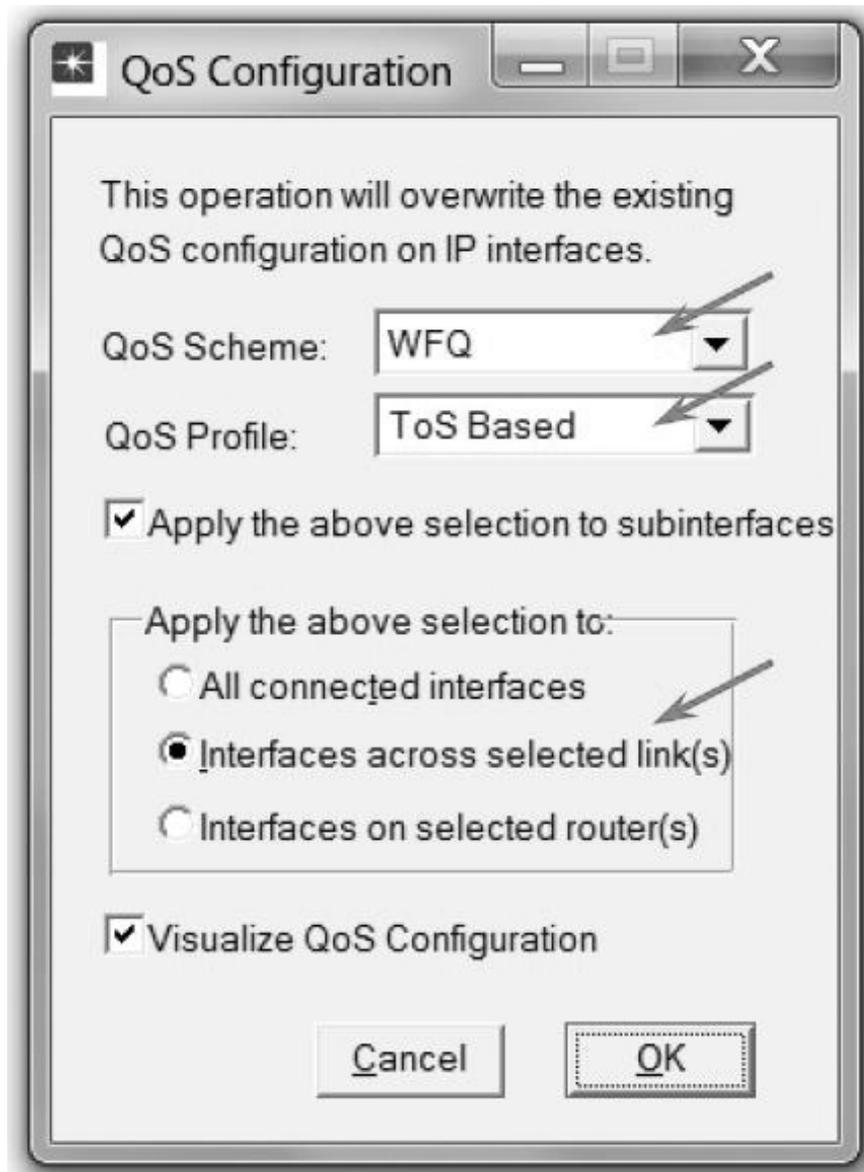
In the network we just created, we used the FIFO queuing discipline in the routers. To analyze the effect of different queuing disciplines, we will create two more scenarios to test the PQ and WFQ disciplines.

1. Select **Duplicate Scenario** from the **Scenarios** menu and give it the name PQ → Click OK.
2. Click on the link connecting the **East** and **West** routers to select it → From the **Protocols** menu choose **IP** → **QoS** → **Configure QoS**.
3. Make sure the selected items are as shown in the following *QoS Configuration* dialog box → Click OK.



*Note:* Because the **Visualize QoS Configuration** radio button is checked, the link is colored based on the QoS scheme used (orange for priority queuing).

4. Save your project.
5. Select **Duplicate Scenario** from the **Scenarios** menu and give it the name **WFQ** → Click **OK**.



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6. Click on the link connecting the **East** and **West** routers to select it → From the **Protocols** menu choose **IP** → **QoS** → **Configure QoS**.
7. Make sure the selected items are as shown in the following *QoS Configuration* dialog box → Click **OK**.

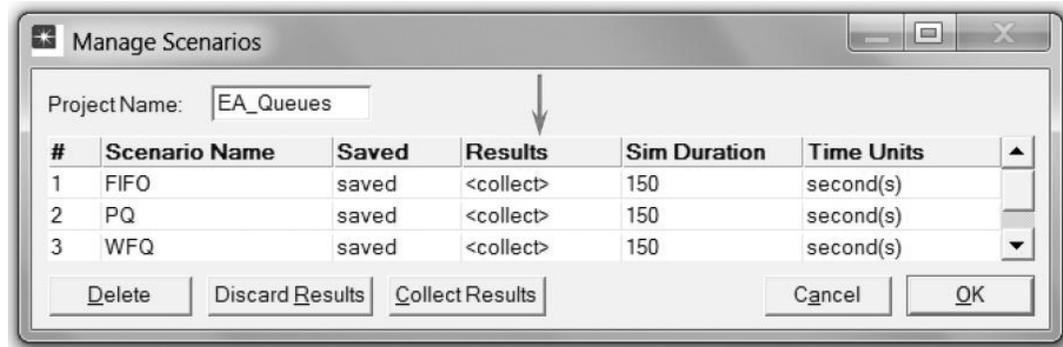
*Note:* Because the **Visualize QoS Configuration** radio button is checked, the link is colored based on the QoS scheme used (green for WFQ).

8. Save your project.

### Run the Simulation

To run the simulation for the three scenarios simultaneously:

1. Go to the **Scenarios** menu → Select **Manage Scenarios**.
2. Change the values under the **Results** column to **<collect>** (or **<recollect>**) for the three scenarios. Compare with the following figure.



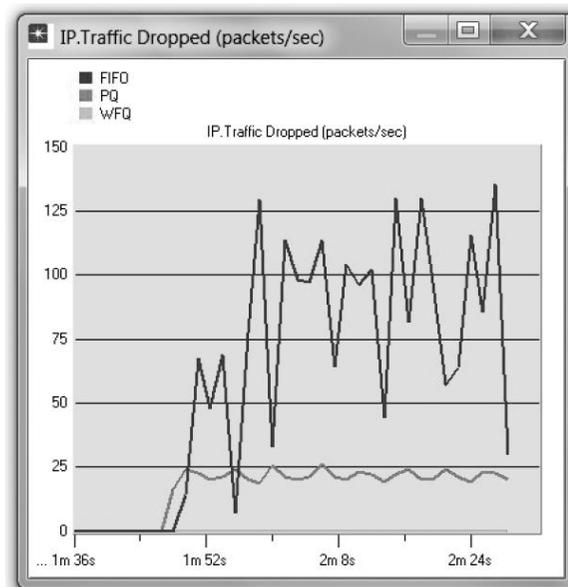
3. Click **OK** to run the three simulations. Depending on the speed of your processor, this task may take several minutes to complete.
4. After the simulation completes the three runs, one for each scenario, click **Close**.
5. **Save** your project.

### View the Results

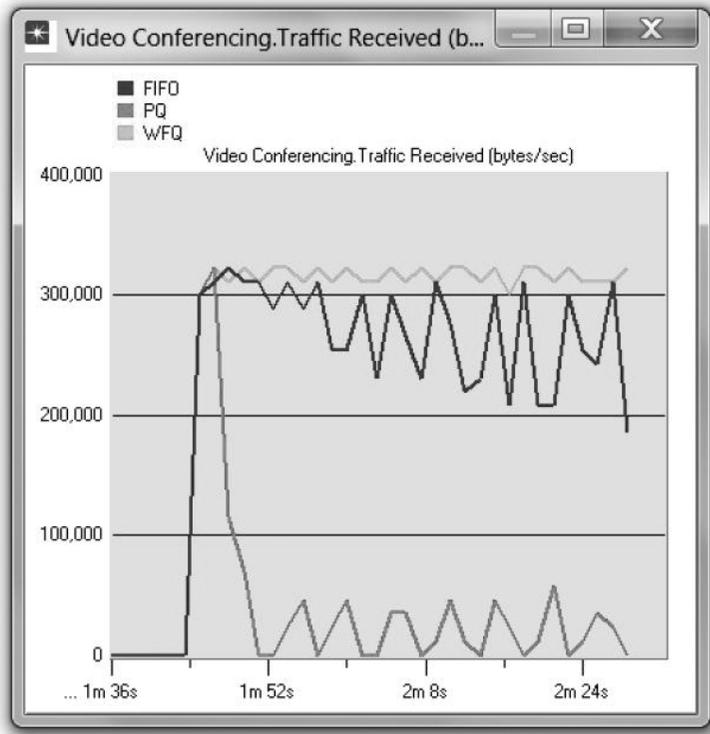
Do the following to view and analyze the results. (*Note: Actual results will vary slightly based on the actual node positioning in the project.*)

1. Select **Compare Results** from the **Results** menu.
2. Select the **IP.Traffic Dropped** statistic and click **Show**. The resulting graph should resemble the one that follows.

*Note:* The following graph is zoomed into the region of interest on the original graph.

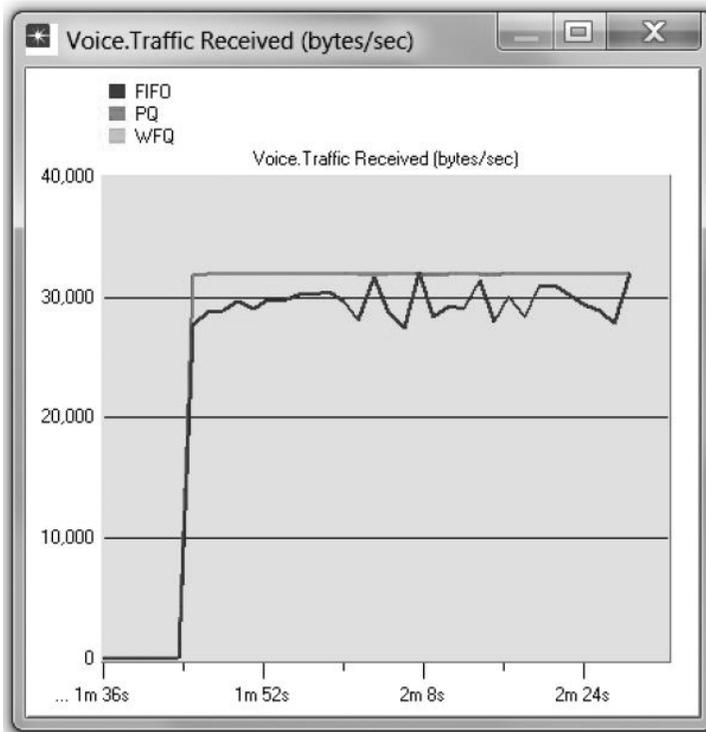


3. Create the graph for Video Conferencing.Traffic Received:

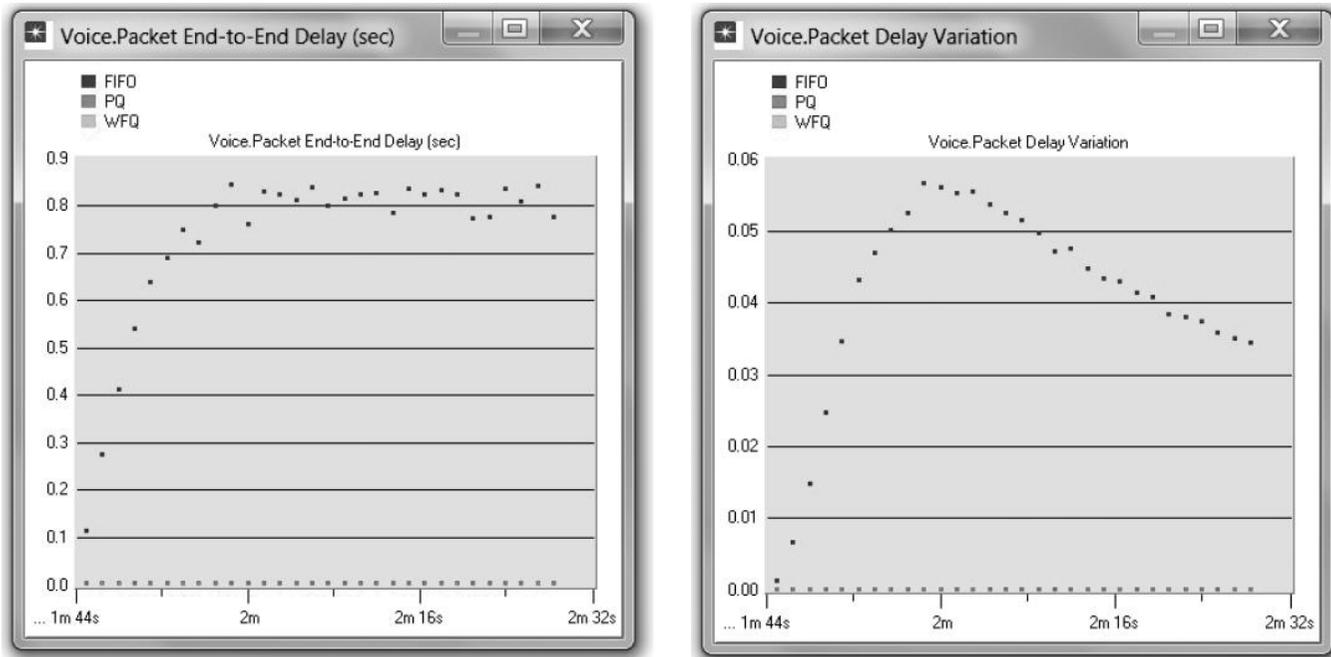


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4. Create the graph for Voice.Traffic Received:



5. Create graphs for **Voice.Packet End-to-End Delay** and **Voice.Packet Delay Variation** as follows. (Note: The trace for **WFQ** is not shown on the following graphs because it is overlapped by the trace of **PQ**.)



## FURTHER READING

The Differentiated Services Field: IETF RFC number 2474 ([www.ietf.org/rfc.html](http://www.ietf.org/rfc.html)).

## EXERCISES

1. Analyze the graphs we obtained and verify the overlap of the **Voice.Packet End-to-End Delay** and **Voice.Packet Delay Variation** graphs. Compare the three queuing disciplines and explain their effect on the performance of the three applications.
2. In the implemented project, edit the **Queues** object and check the profiles assigned to the **FIFO**, **PQ**, and **WFQ** disciplines. For each profile, answer the following questions:
  - a. How many queues are associated with each discipline?
  - b. In this lab, we used **ToS** to identify the priority and weight for the **PQ** and **WFQ** disciplines, respectively. What are the other parameters that can be used to identify the priority and weight?
  - c. In **PQ**, how are queues configured to serve different **ToS** values?
  - d. In **WFQ**, how are queues configured to serve different **ToS** values?
3. For all scenarios, choose the "**queuing delay <-->**" statistic for the link that connects **East Router** and **West Router**. Rerun the simulation and generate the graph that compares that queuing delay for all queuing disciplines (scenarios). Analyze this graph.

*Hint:* The "**queuing delay <-->**" statistic is under the point-to-point hierarchy.

## 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.