Lab 4 Frame Relay Network Performance

Overview

Frame Relay is a connection-oriented, unreliable technology based on virtual circuits. A virtual circuit must be set up between a source and destination before any data may be exchanged. Most Frame Relay service providers support Permanent Virtual Circuits (PVC), which are long-lived connections, as opposed to Switched Virtual Circuits (SVC), which are set up at call time. When a PVC is set up, certain parameters which govern the behavior of the PVC are agreed upon. These include the Committed Information Rate (CIR), committed burst rate (Bc), and the excess burst rate (Be). The CIR is the rate (in bits per second) which the service provider guarantees to the customer. The committed burst rate specifies how quickly that data may be sent. For instance, a customer may contract for a CIR of 64 Kbps, and a Bc of 32 Kbits/100 ms. In this case, the customer may send 64 Kbits per second, but no more than 32 Kbits in any 100 ms period. Frame Relay service providers will accept additional data above the CIR and transmit it if there is excess capacity in the network at that time. The amount of excess data that they will carry is defined by the excess burst rate. Any data frames that are sent in excess of the CIR are marked with the Discard Eligible bit set. These frames are discarded first in the event of congestion.

Objective

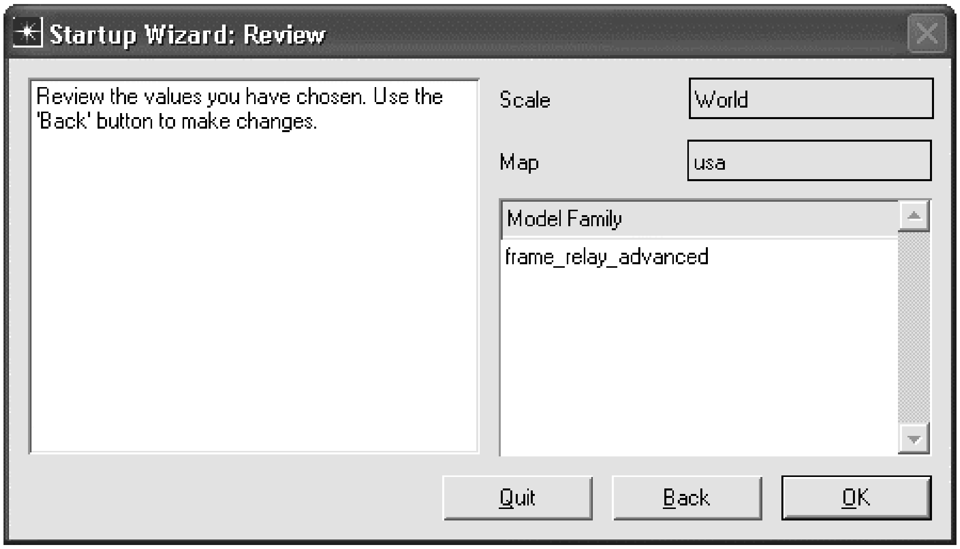
To examine the behavior of a Frame Relay PVC as contract parameters are varied.

Build the Simulation Model

Start up OPNET IT Guru Academic Edition.

First, it would be useful to read the information provided by OPNET regarding Frame Relay configuration.
Select the **File** tab => **Open**. Choose the **Frame_Relay** project and click on **OK**. Read through the Objective, Network Configuration, and Glossary pages.
Select **File** => **Close** when you are done.

Select the **File** tab => **New...**
Choose **Project** and click on **OK**.
Change the **Project Name** to **xx_WAN_Frame_Relay** (where **xx** are your initials). Set the **Scenario Name** to **CIR64** and click on **OK**.
In the **Initial Topology** window, select **Create Empty Scenario** and click on **Next**.
In the **Choose Network Scale** window, select **World** and click on **Next**.
In the **Choose Map** window, choose **usa** and click on **Next**.
In the **Select Technologies** window, scroll down and include the **frame_relay_advanced** model family, and then click on **Next**.
In the **Review** window, click on **OK**.


Startup Wizard: Review

Review the values you have chosen. Use the 'Back' button to make changes.

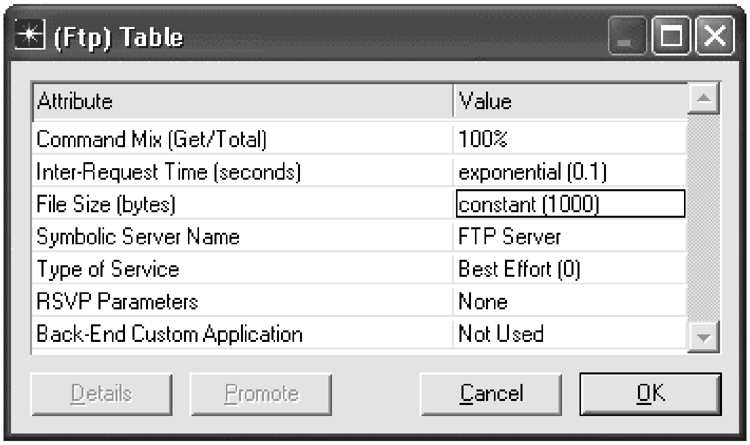
Scale: World

Map: usa

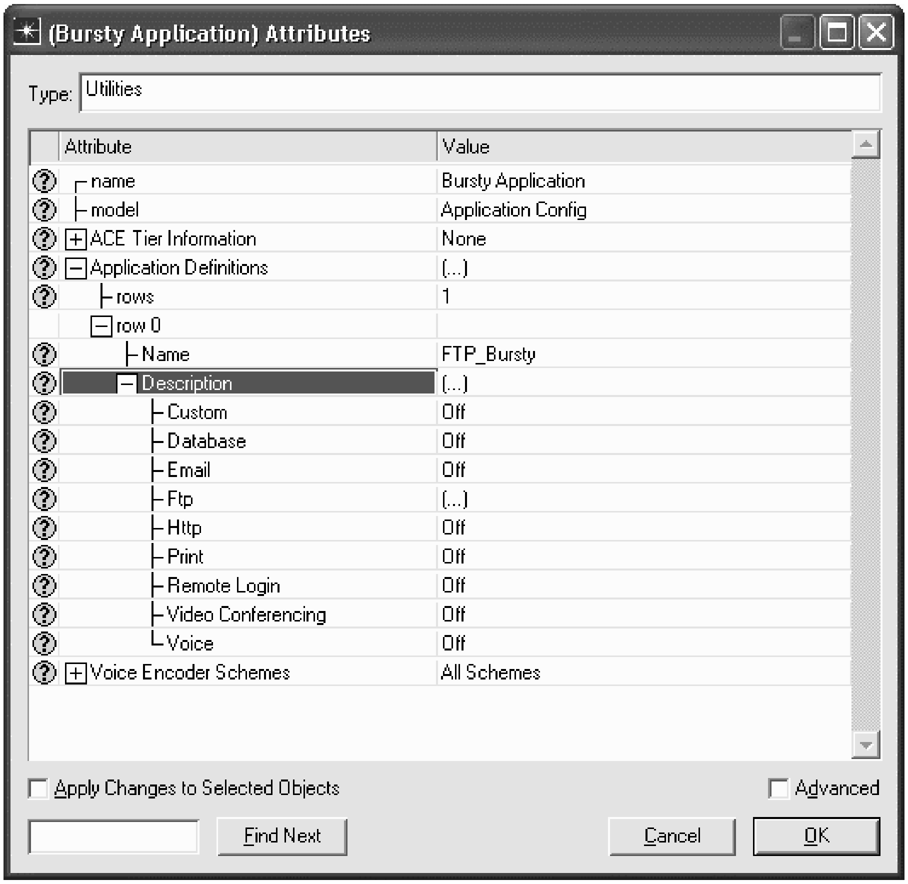
Model Family
frame_relay_advanced

First, we will configure a bursty data application to generate traffic over our frame relay network. The File Transfer Protocol (FTP) will serve our purposes.

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 **Bursty Application**. Expand the **Application Definitions** attribute and set the **rows** attribute to **1**. Expand the **row 0** attribute and set the **Name** attribute to **FTP_Bursty**. Expand the **Description** attribute and edit the value of the **Ftp** attribute. Set the **Inter-Request Time (secs)** attribute to **exponential(0.1)**. Set the **File Size (bytes)** attribute to **constant(1000)**. In both cases, you will need to set the **Special Value** field to **Not Used** in order to modify the attribute values. The application you have now defined will transfer an average of ten 1-KB files every second. The exponential distribution is often used to model waiting times so we can use it here to model the time between file requests. Click on **OK** to close the window.


(Ftp) Table

Attribute	Value
Command Mix (Get/Total)	100%
Inter-Request Time (seconds)	exponential (0.1)
File Size (bytes)	constant (1000)
Symbolic Server Name	FTP Server
Type of Service	Best Effort (0)
RSVP Parameters	None
Back-End Custom Application	Not Used



(Bursty Application) Attributes

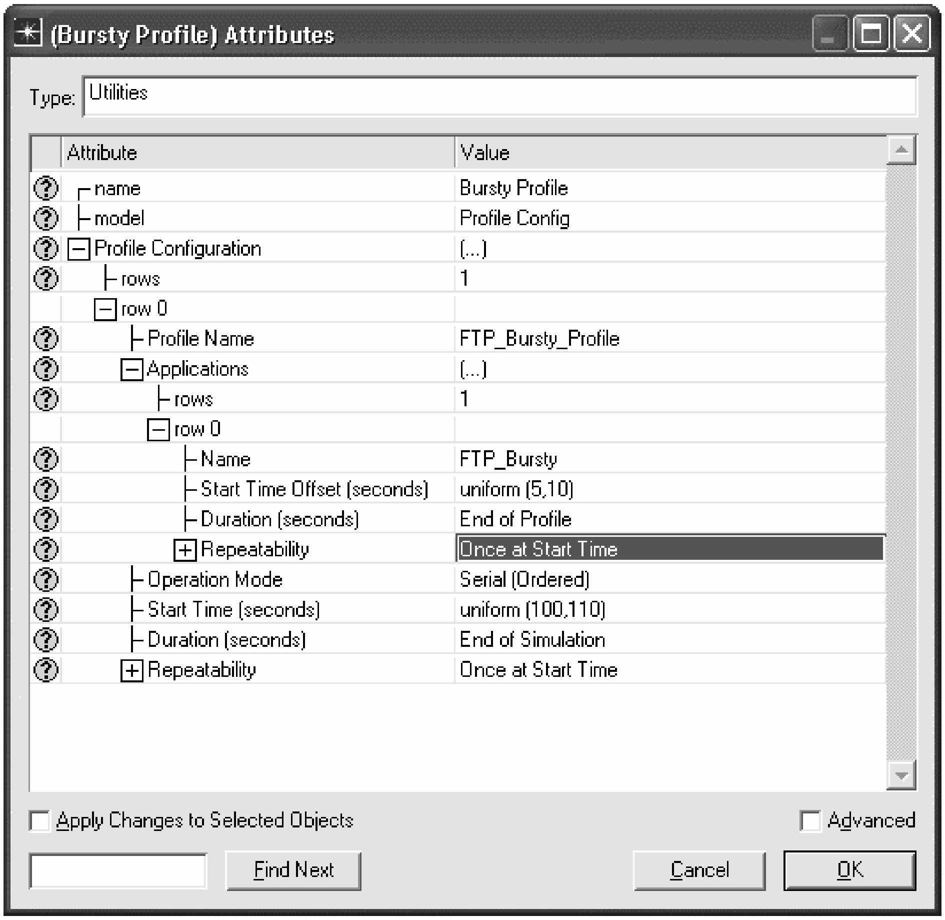
Type: Utilities

Attribute	Value
name	Bursty Application
model	Application Config
⊞ ACE Tier Information	None
⊟ Application Definitions	(...)
rows	1
⊟ row 0	
Name	FTP_Bursty
⊟ Description	(...)
Custom	Off
Database	Off
Email	Off
Ftp	(...)
Http	Off
Print	Off
Remote Login	Off
Video Conferencing	Off
Voice	Off
⊞ Voice Encoder Schemes	All Schemes

□ Apply Changes to Selected Objects

□ Advanced

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 **Bursty Profile**. Expand the **Profile Configuration** attribute and set the **rows** attribute to **1**. Expand the **row 0** attribute and set the **Profile Name** to **FTP_Bursty_Profile**. Expand the **Applications** attribute and set the **rows** attribute to **1**. Expand the **row 0** attribute and set the **Name** to **FTP_Bursty**. Set the **Repeatability** attribute to **Once at Start Time**. Click on **OK** to close the window.



(Bursty Profile) Attributes

Type: Utilities

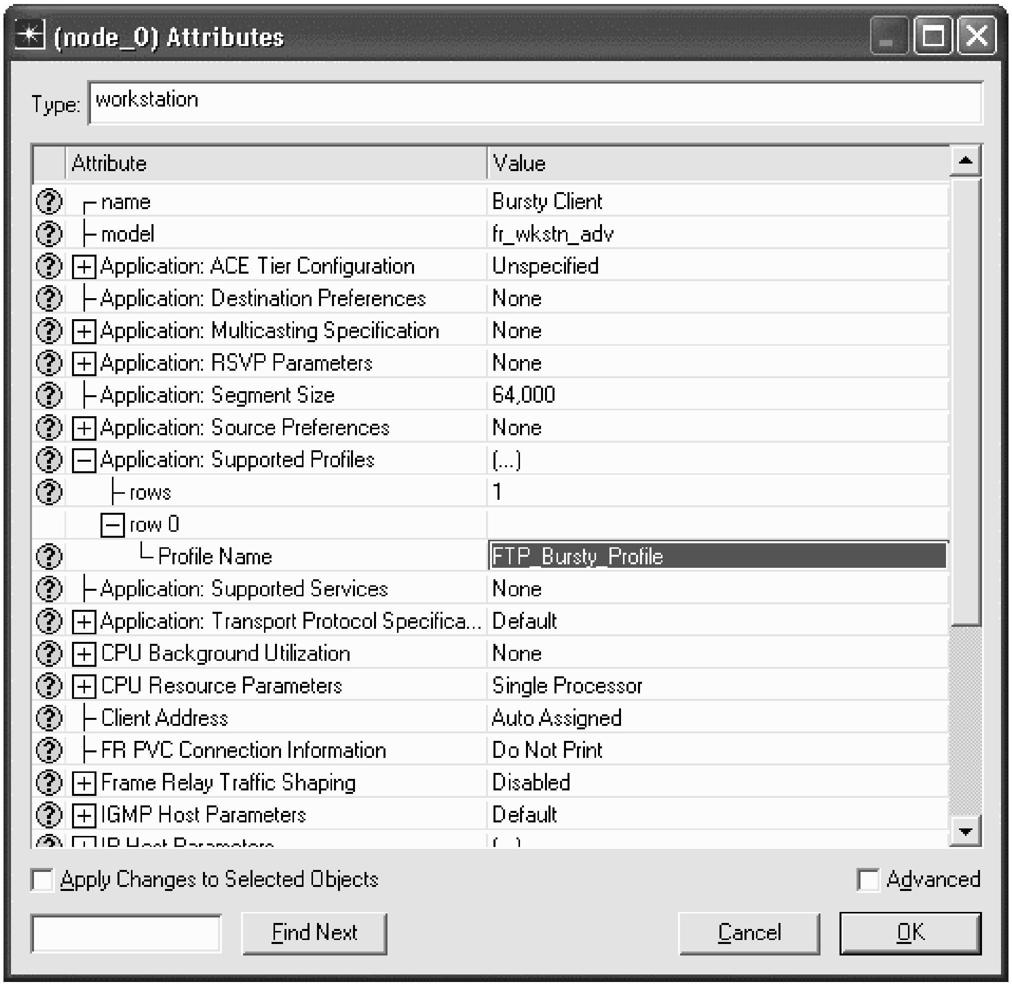
Attribute	Value
name	Bursty Profile
model	Profile Config
Profile Configuration	(...)
rows	1
row 0	
Profile Name	FTP_Bursty_Profile
Applications	(...)
rows	1
row 0	
Name	FTP_Bursty
Start Time Offset (seconds)	uniform (5,10)
Duration (seconds)	End of Profile
Repeatability	Once at Start Time
Operation Mode	Serial (Ordered)
Start Time (seconds)	uniform (100,110)
Duration (seconds)	End of Simulation
Repeatability	Once at Start Time

□ Apply Changes to Selected Objects

□ Advanced

Select an **fr32_cloud** object from the Object Palette and place it in the project workspace. Right click on the cloud and choose **View Node Description**. The cloud represents a WAN that consists of Frame-Relay-capable switches and that supports up to 32 Frame Relay connections.
Right click on the cloud and select **Set Name**. Set the name to **Frame_Relay_Cloud**. Click on **OK** to close the window.

Select an **fr_wkstn_adv** device from the Object Palette and place it in the project workspace. Right click on the station and choose **View Node Description**. Note that the station supports the Frame Relay protocol. We will now set up the client to use the bursty FTP application that we defined.
Right click on the station and choose **Edit Attributes**. Modify the **name** attribute of the device to **Bursty Client**. Edit the **Application: Supported Profiles** attribute. Insert a row and set the **Profile Name** to **FTP_Bursty_Profile**. Click on **OK** to close the window.



(node_0) Attributes

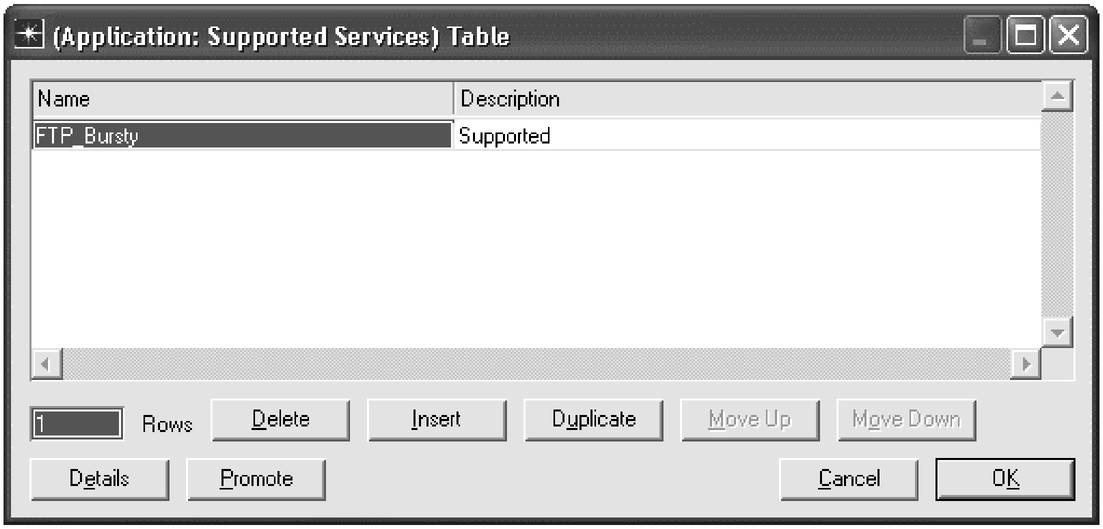
Type: workstation

Attribute	Value
name	Bursty Client
model	fr_wkstn_adv
⊞ Application: ACE Tier Configuration	Unspecified
Application: Destination Preferences	None
⊞ Application: Multicasting Specification	None
⊞ Application: RSVP Parameters	None
Application: Segment Size	64,000
⊞ Application: Source Preferences	None
⊟ Application: Supported Profiles	(...)
rows	1
⊟ row 0	
Profile Name	FTP_Bursty_Profile
Application: Supported Services	None
⊞ Application: Transport Protocol Specifica...	Default
⊞ CPU Background Utilization	None
⊞ CPU Resource Parameters	Single Processor
Client Address	Auto Assigned
FR PVC Connection Information	Do Not Print
⊞ Frame Relay Traffic Shaping	Disabled
⊞ IGMP Host Parameters	Default
⊞ IP Host Parameters	(...)

☐ Apply Changes to Selected Objects ☐ Advanced

Select an **fr_server_adv** device from the Object Palette and place it in the project workspace. Right click on the server and choose **View Node Description**. Note that the server also supports the Frame Relay protocol. We will now set up the server to support the Bursty FTP application that we defined.

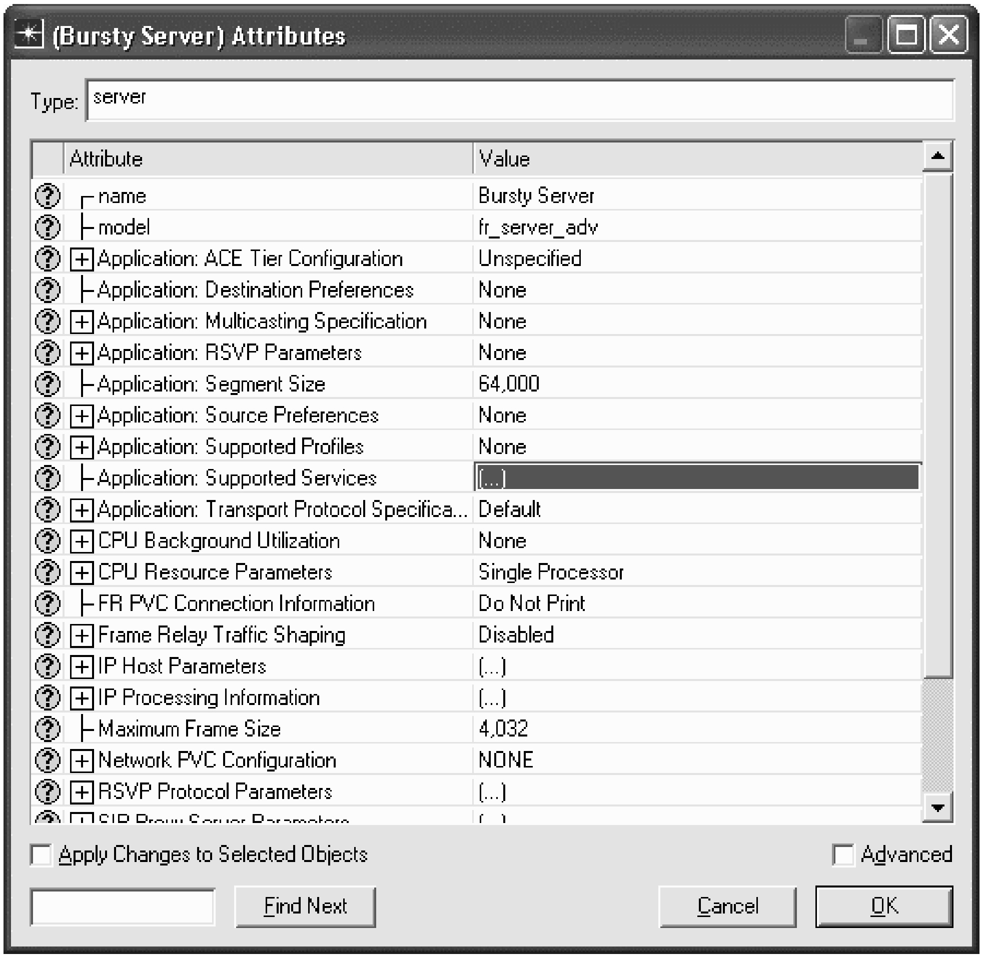
Right click on the device and choose **Edit Attributes**. Modify the **name** attribute of the server to **Bursty Server**. Edit the **Application: Supported Services** attribute. Insert a row and set the **Name** to **FTP_Bursty**. Click on **OK** to close the table window. Click on **OK** to close the window.



(Application: Supported Services) Table

Name	Description
FTP_Bursty	Supported

1 Rows



(Bursty Server) Attributes

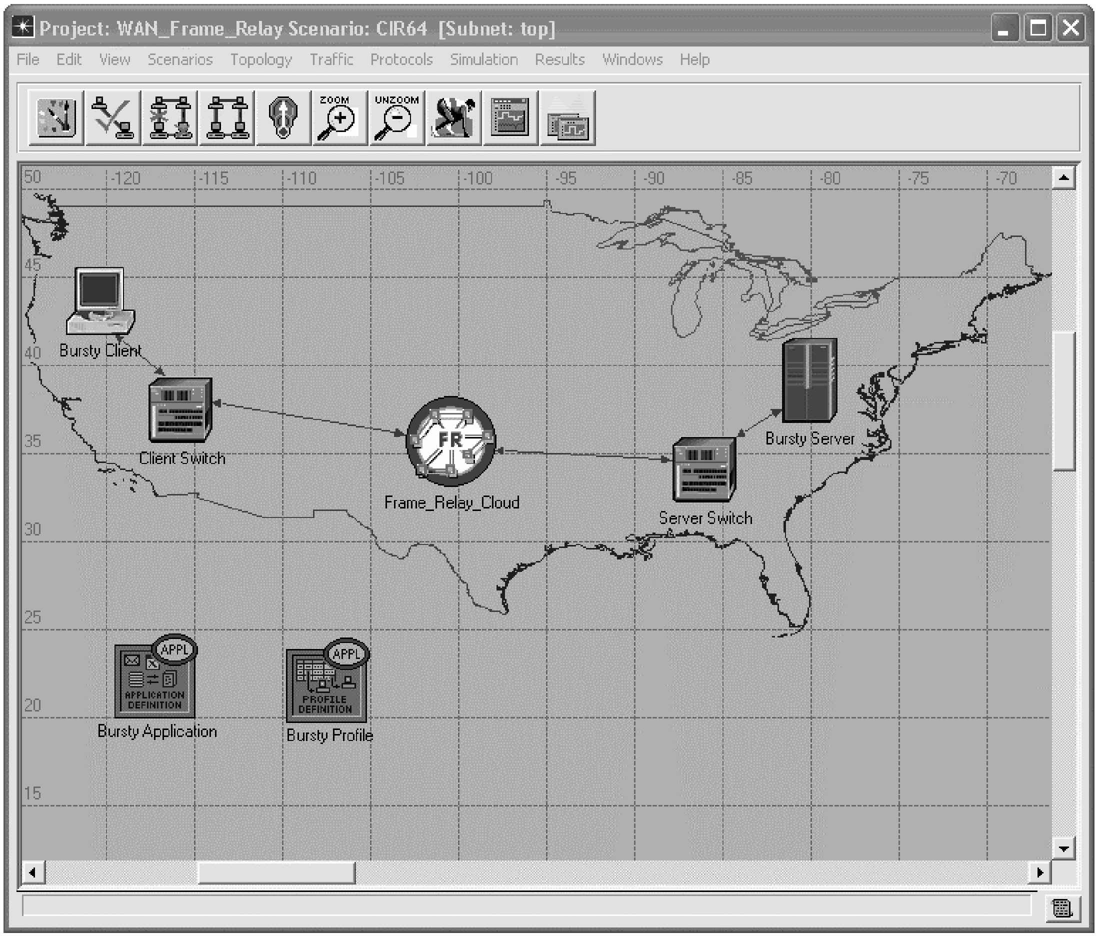
Type: server

Attribute	Value
name	Bursty Server
model	fr_server_adv
⊞ Application: ACE Tier Configuration	Unspecified
Application: Destination Preferences	None
⊞ Application: Multicasting Specification	None
⊞ Application: RSVP Parameters	None
Application: Segment Size	64,000
⊞ Application: Source Preferences	None
⊞ Application: Supported Profiles	None
Application: Supported Services	(...)
⊞ Application: Transport Protocol Specifica...	Default
⊞ CPU Background Utilization	None
⊞ CPU Resource Parameters	Single Processor
FR PVC Connection Information	Do Not Print
⊞ Frame Relay Traffic Shaping	Disabled
⊞ IP Host Parameters	(...)
⊞ IP Processing Information	(...)
Maximum Frame Size	4,032
⊞ Network PVC Configuration	NONE
⊞ RSVP Protocol Parameters	(...)
⊞ SIP Proxy Server Parameters	(...)

☐ Apply Changes to Selected Objects ☐ Advanced

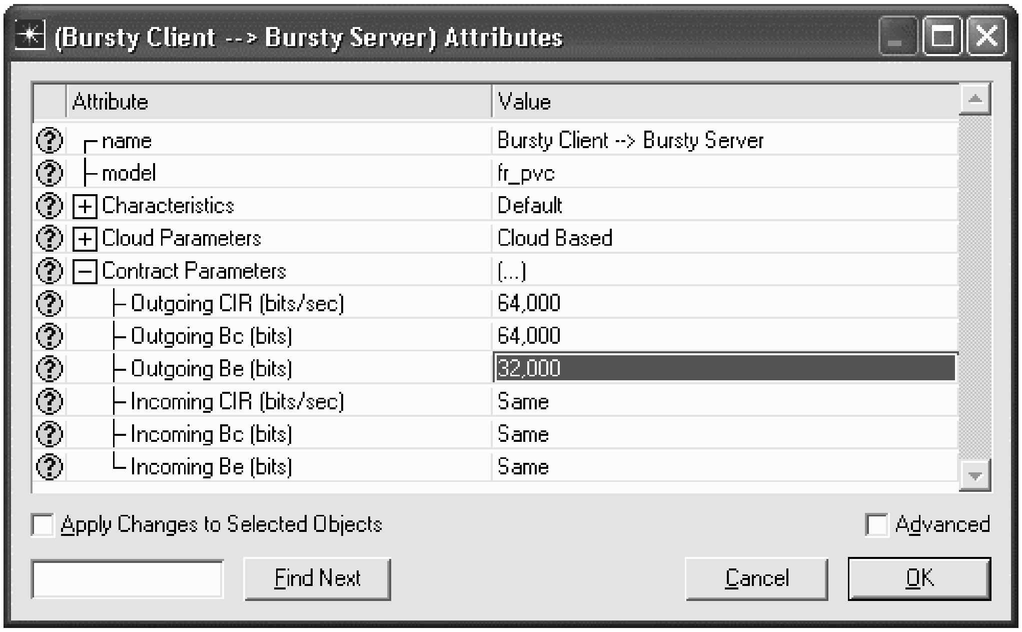
Select two **fr8_switch_adv** objects from the Object Palette. Place one next to the client and one next to the server. Right click on one of the switches and choose **View Node Description**. Note that the switch takes action when it becomes congested. It will discard the frames marked with the Discard Eligible Bit first, but may even discard normal frames. Click on the close window icon to close the window.
Right click on the client's switch and select **Set Name**. Set the name to **Client Switch**. Click on **OK** to close the window.
Right click on the server's switch and select **Set Name**. Set the name to **Server Switch**. Click on **OK** to close the window.

Select three **FR_T1_int** links from the Object Palette, and use them to connect the client to its switch, the server to its switch and the two switches to the Frame Relay cloud. Remember that T1 speed is 1.5 Mbps.



Finally, we can set up a permanent virtual circuit (PVC) between the client and the server so that they can communicate. Select an **FR PVC Config** object from the Object Palette, and place it in the project workspace. Right click on it and select **Set Name**. Set the **Name** to **PVC Config.** The **FR PVC Config** object must be placed in the workspace before any PVCs may be set up. Click on **OK** to close the window.

Select an **fr_pvc** object from the Object Palette and use it to connect the client to the server. When you right click to finish placing the PVC, choose **Abort Demand Definition**.
Right click on the PVC, and expand the **Contract Parameters** attribute. These parameters constitute the agreement between the end systems (client and server) and the Frame Relay service provider. Set the **Outgoing CIR (bits/sec)** attribute to **64000**. Set the **Outgoing Bc (bits)** to **64000**. Set the **Outgoing Be (bits)** to **32000**. The Committed Information Rate (CIR) is the amount of traffic that the service provider has agreed to carry. The committed burst size (Bc) indicates how much data can be sent in a given interval. In this case, the interval is one second, so the CIR = Bc. The excess burst size (Be) is the amount of traffic that the service provider may accept in addition to the committed rate, if network conditions allow. Excess data may be discarded if the service provider's network becomes congested. Click on **OK** to close the window.

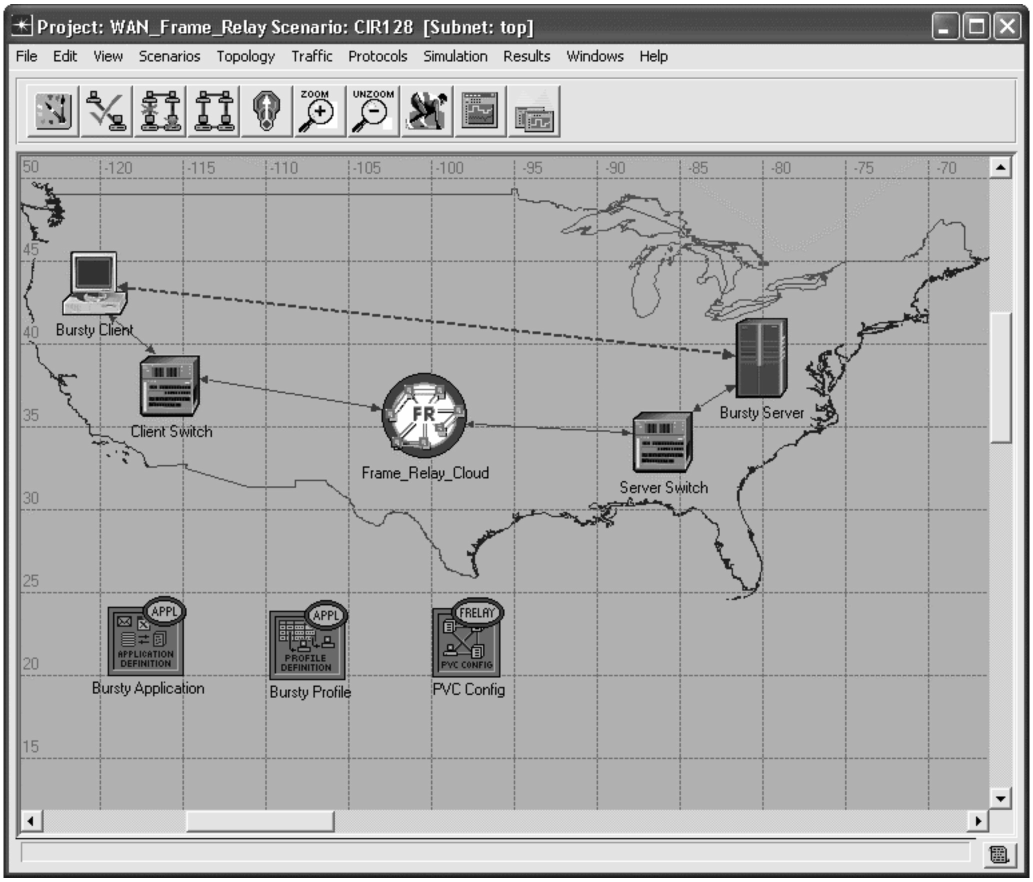


(Bursty Client --> Bursty Server) Attributes

Attribute	Value
name	Bursty Client --> Bursty Server
model	fr_pvc
⊞ Characteristics	Default
⊞ Cloud Parameters	Cloud Based
⊟ Contract Parameters	(...)
Outgoing CIR (bits/sec)	64,000
Outgoing Bc (bits)	64,000
Outgoing Be (bits)	32,000
Incoming CIR (bits/sec)	Same
Incoming Bc (bits)	Same
Incoming Be (bits)	Same

☐ Apply Changes to Selected Objects ☐ Advanced

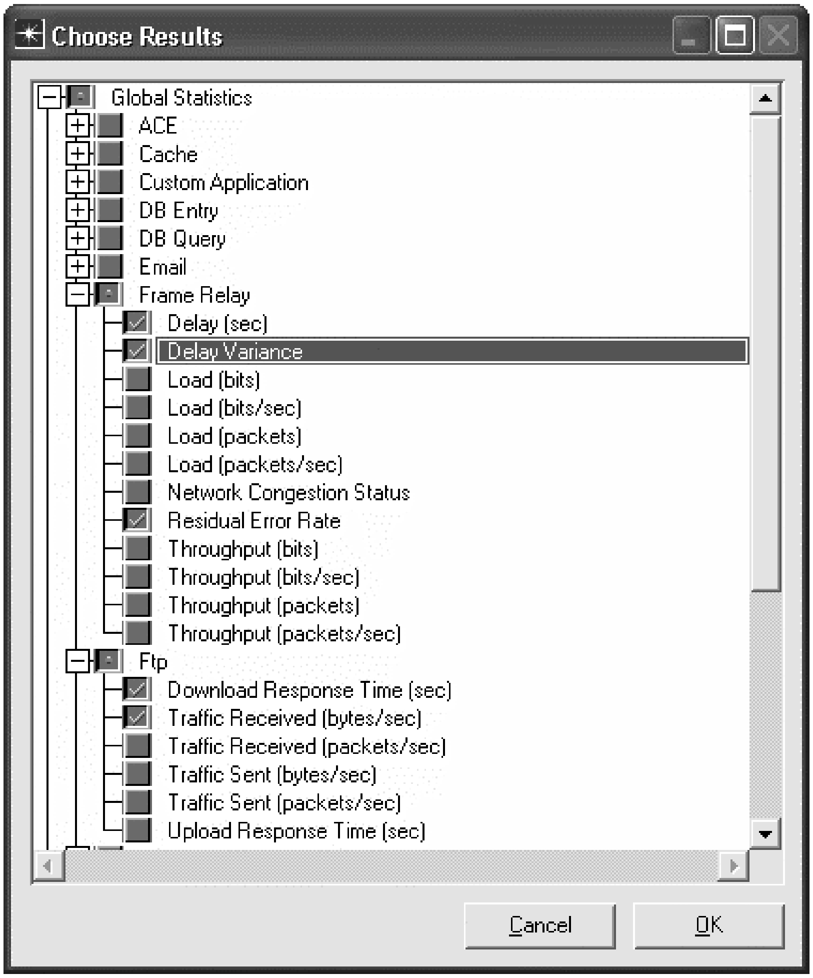
Find Next Cancel OK



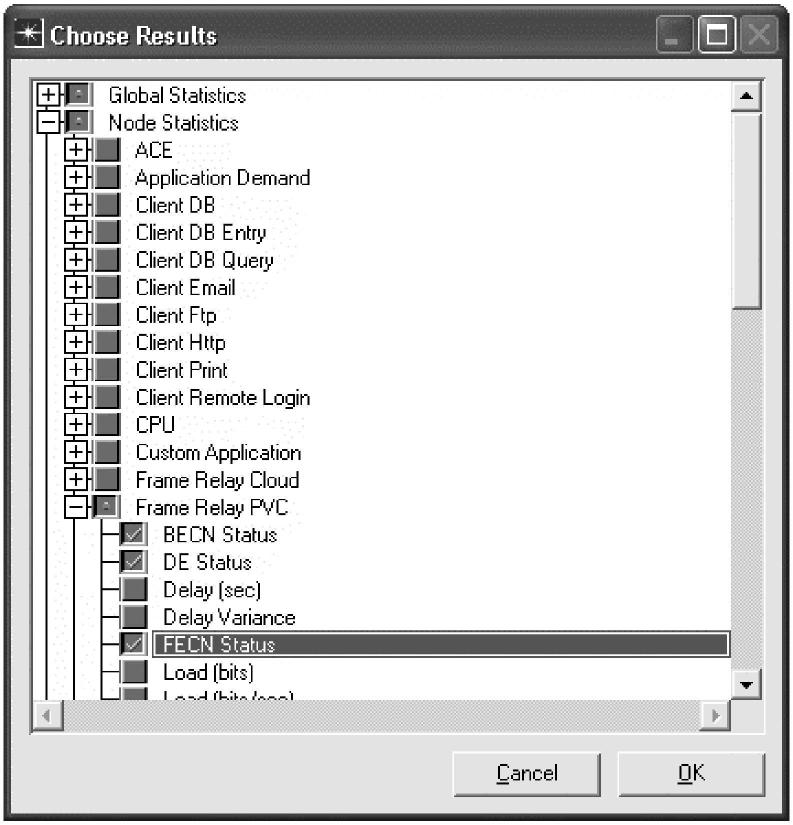
Configure and Run the Simulation

Select the **Simulation** tab => **Choose Individual Statistics…**
Expand the **Global Statistics** item and the **Frame Relay** item, and select the **Delay (sec)**, **Delay Variance**, and **Residual Error Rate** statistics.
Expand the **FTP** item, and select the **Download Response Time (sec)** and **Traffic Received (bytes/sec)** statistics.

Expand the **Node Statistics** item and the **Frame Relay PVC** item, and select the **BECN Status**, **DE Status**, and **FECN Status** statistics.
Click on **OK** to close the window.



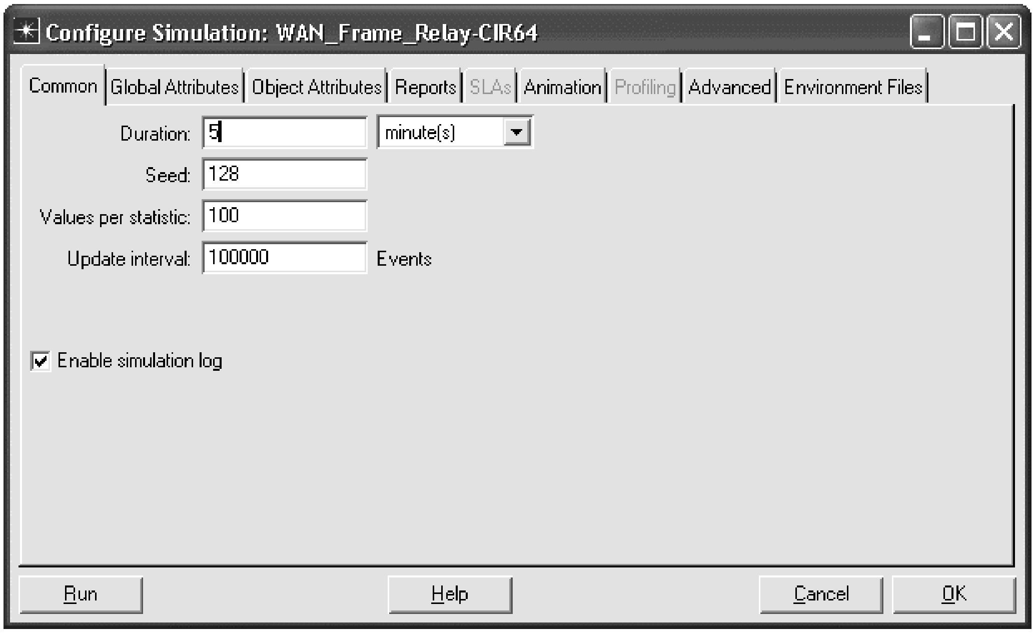
- Global Statistics
  - ACE
  - Cache
  - Custom Application
  - DB Entry
  - DB Query
  - Email
  - Frame Relay
    - ☑ Delay (sec)
    - ☑ Delay Variance
    - □ Load (bits)
    - □ Load (bits/sec)
    - □ Load (packets)
    - □ Load (packets/sec)
    - □ Network Congestion Status
    - ☑ Residual Error Rate
    - □ Throughput (bits)
    - □ Throughput (bits/sec)
    - □ Throughput (packets)
    - □ Throughput (packets/sec)
  - Ftp
    - ☑ Download Response Time (sec)
    - ☑ Traffic Received (bytes/sec)
    - □ Traffic Received (packets/sec)
    - □ Traffic Sent (bytes/sec)
    - □ Traffic Sent (packets/sec)
    - □ Upload Response Time (sec)



Choose Results

- Global Statistics
- Node Statistics
  - ACE
  - Application Demand
  - Client DB
  - Client DB Entry
  - Client DB Query
  - Client Email
  - Client Ftp
  - Client Http
  - Client Print
  - Client Remote Login
  - CPU
  - Custom Application
  - Frame Relay Cloud
  - Frame Relay PVC
    - ☑ BECN Status
    - ☑ DE Status
    - □ Delay (sec)
    - □ Delay Variance
    - ☑ FECN Status
    - □ Load (bits)

Select **Simulation** => **Configure Discrete Event Simulation…**
Under the **Common** tab, set the **Duration** to **5** and the unit to **minute(s)**.
Click on **OK** to close the window.



Configure Simulation: WAN_Frame_Relay-CIR64

Duration: 5 minute(s)
Seed: 128
Values per statistic: 100
Update interval: 100000 Events

☑ Enable simulation log

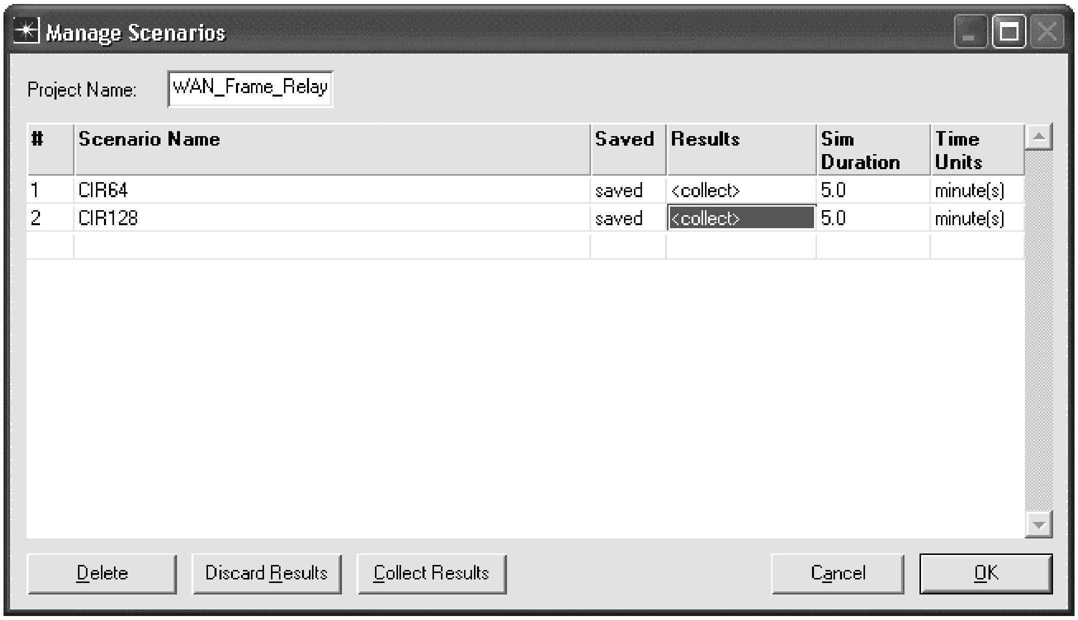
Duplicate the Scenario

We are now going to duplicate the scenario and configure the PVC to support a higher data rate. This will allow us to compare the performance across the two PVC rates. Choose **Scenarios** => **Duplicate Scenario**, and name the new scenario **CIR128**.

Right click on the PVC, and expand the **Contract Parameters** attribute. Set the **Outgoing CIR (bits/sec)** attribute to **128000**. Set the **Outgoing Bc (bits)** to **128000**. Leave the **Outgoing Be (bits)** unchanged at **32000**. Click on **OK** to close the window.

Run the Simulation

Select the **Scenarios** tab => **Manage Scenarios…**
Edit the **Results** field in both rows and set the value 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 window.



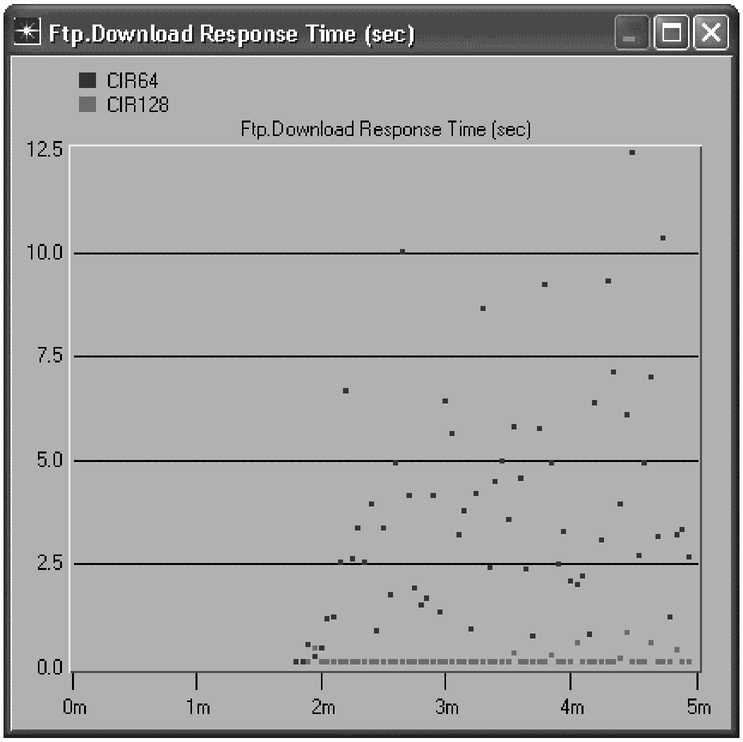
Project Name: WAN_Frame_Relay

#	Scenario Name	Saved	Results	Sim Duration	Time Units
1	CIR64	saved	<collect>	5.0	minute(s)
2	CIR128	saved	<collect>	5.0	minute(s)

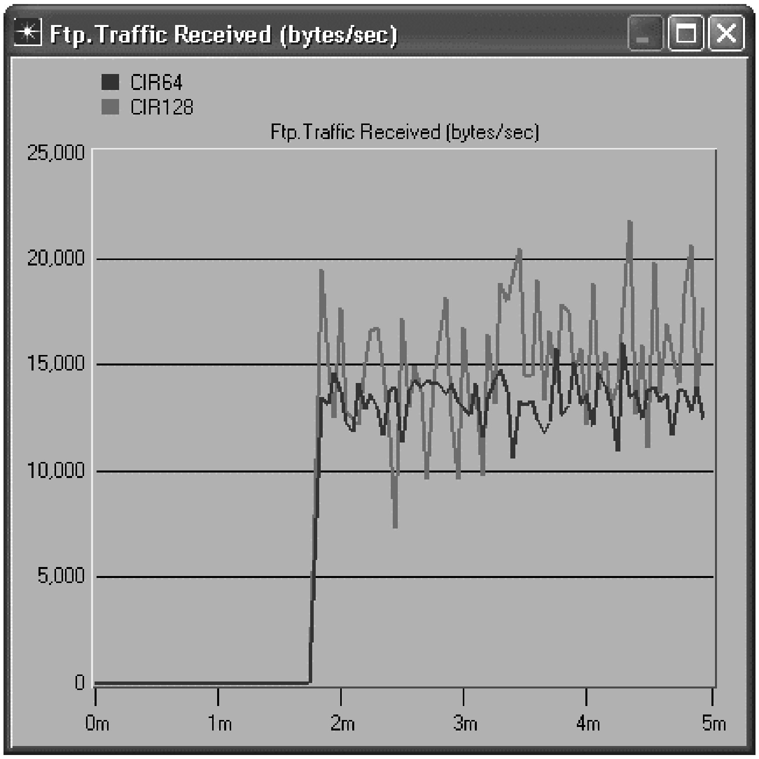
Inspect and Analyze Results

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

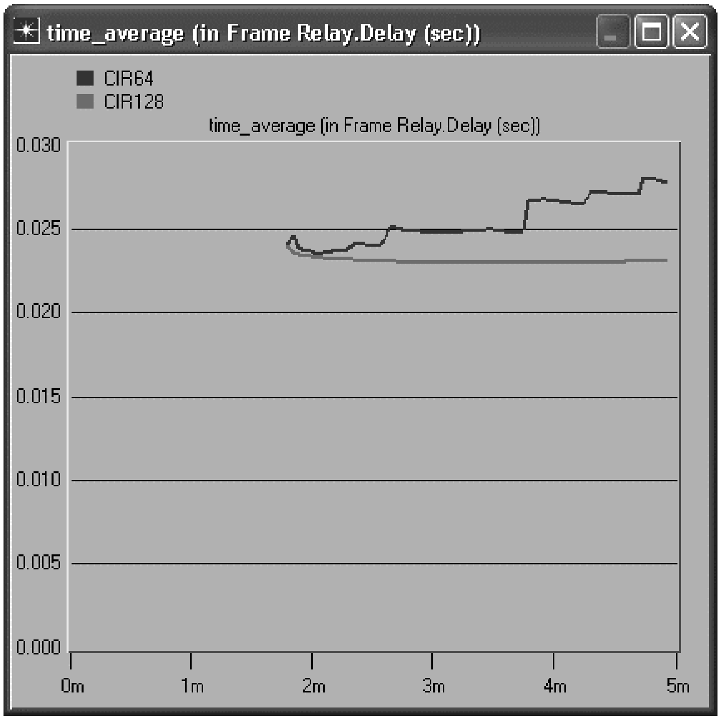
Select and expand the **Global Statistics** item and the **Ftp** item, and select the **Download Response Time (sec)** statistic. Use **As Is** mode to view this statistic. Click on **Show** to see a more detailed graph. The statistic shows how long each download took, and there will be one point for each file downloaded. You can see that the downloads took much less time in the CIR128 case and that the variation in download times was much less. This is to be expected since there was more capacity available to the application in the second scenario. Click on the close window icon and choose to **Delete** the panel. Click on the statistic again to disable the preview.


Ftp.Download Response Time (sec)
CIR64
CIR128
Ftp.Download Response Time (sec)
12.5
10.0
7.5
5.0
2.5
0.0
0m
1m
2m
3m
4m
5m

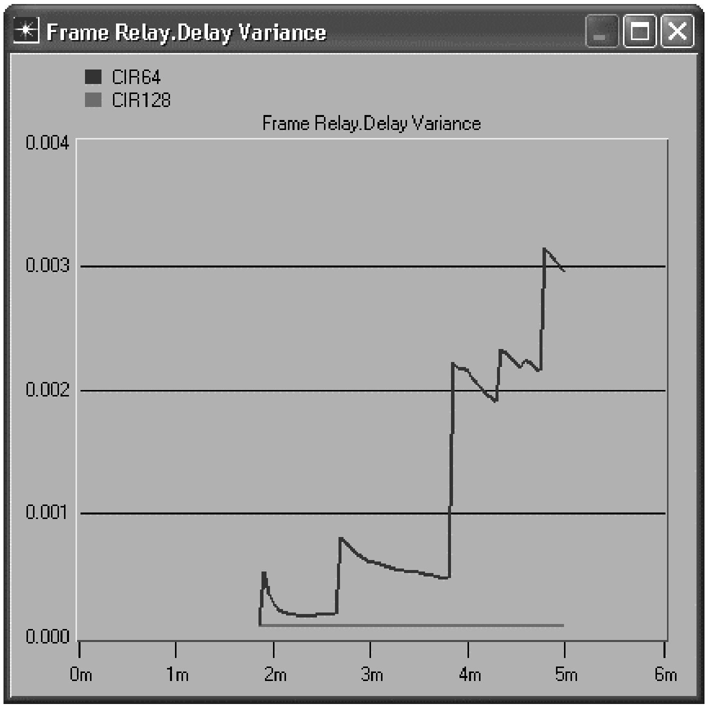
Expand the **Traffic Received (bytes/sec)** statistic and view using **As Is** mode. Click on **Show** to see a more detailed graph. This statistic shows the total amount of FTP traffic received by both the server and client. You can see that more traffic is received in the CIR128 case, and that there is more variation than in the CIR64 case. Click on the close window icon and choose to **Delete** the panel. Click on the statistic again to disable the preview.


Ftp.Traffic Received (bytes/sec)
CIR64
CIR128
Ftp.Traffic Received (bytes/sec)
25,000
20,000
15,000
10,000
5,000
0
0m
1m
2m
3m
4m
5m

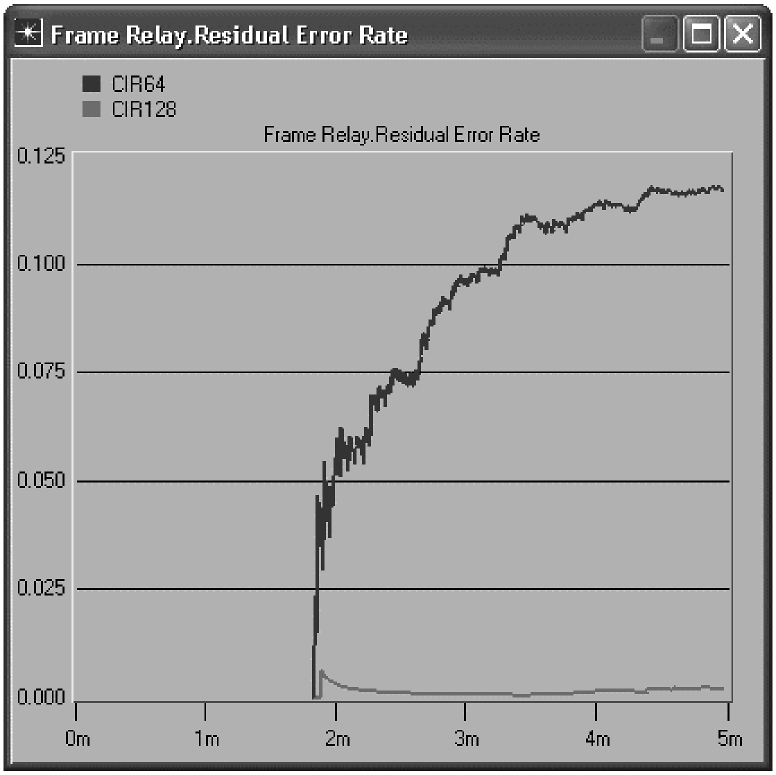
Select and expand the **Global Statistics** item and the **Frame Relay** item, and select the **Delay (sec)** statistic. Use **time_average** mode to view this statistic as this mode will make it easier to see the difference in performance. Click on the **Show** button to see more detail. The statistic shows how long each frame took to be delivered. You can see that the delay is greater in the CIR64 case and that the delay is growing over time. This is due to longer delays within the switches due to full buffers. Click on the close window icon and **Delete** the panel. Click on the statistic again to disable the preview.



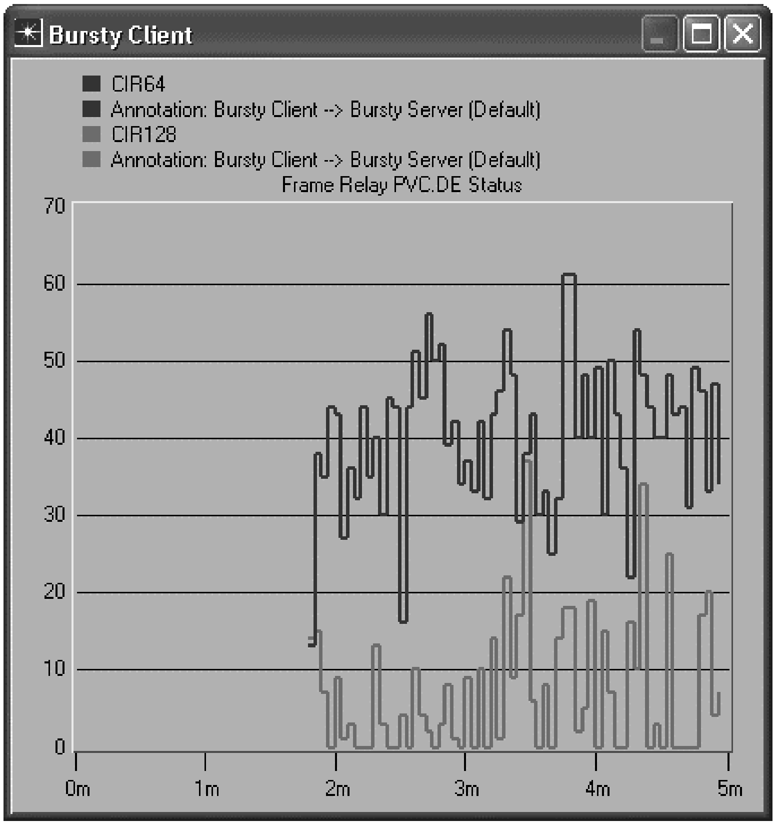
Expand the **Delay Variance (sec)** statistic and view using **As Is** mode. Click on **Show**. This statistic shows the variance in frame delivery delay. The CIR64 case shows much more variability and the variability is growing over time. Click on the close window icon and **Delete** the panel. Click on the statistic again to disable the preview.



Expand the **Residual Error Rate** statistic and view using **As Is** mode. Click on **Show**. This statistic shows the percentage of frames which are discarded due to congestion or corruption. You can see that many more frames are discarded in the CIR64 case and that the percentage is growing as the switch becomes more and more congested. Click on the close window icon and **Delete** the panel. Click on the statistic again to disable the preview.



Select and expand the **Object Statistics** item, the **Bursty Client** item, and the **Frame Relay PVC** item. Select the **DE Status** statistic and view using **As Is** mode. Click on **Show**. This statistic shows the number of frames which were received by the client which had the DE bit set. When many frames are received with the DE bit set, that indicates that the source of the frames was frequently sending faster than the contracted CIR. You can see that far more frames are marked with the DE bit in the CIR64 case. This makes sense since the application produces the same amount of traffic in both scenarios, but the CIR128 scenario provides more capacity for carrying the traffic. Click on the close window icon and **Delete** the panel. Click on the statistic again to disable the preview.



The **BECN Status** or **FECN Status** statistics show how many frames were received with the BECN or FECN bits set. These bits are set by the switch when it is congested. If you view these statistics, you will see that no frames were received with the bits set. The offered traffic is not sufficient yet to cause congestion at the switches.

Save your model and close all windows.

Questions

1. How much traffic is being generated by the Bursty Server? You can calculate this data rate using the **Inter-Request Time** and **File Size** parameters you set when configuring the bursty application.

2. Given the traffic level calculated in Question 1, explain how this traffic can be carried given the speed of the links used to connect the devices, and the contract parameters of the PVC connecting the client and server.

3. Duplicate the CIR64 scenario, and replace the T1 link between the client and its switch with an **FR_DS0_int** link. Remember that DS0 speed is 64 Kbps. Rerun the simulation and inspect the **BECN Status** and **FECN Status** statistics for both the **Bursty Client** and **Bursty Server**. How do they compare to the CIR64 scenario results? Explain your results. Explain the usage of the BECN and FECN bits in the Frame Relay header. Also inspect the **Residual Error Rate** statistic. How does it compare to the CIR64 case?

4. Frame Relay service providers often offer Frame Relay PVC contracts called *zero CIR*. In these cases, *all* packets are marked discard eligible. Zero CIR service is usually less expensive, but provides fewer guarantees. Duplicate the CIR64 scenario, and edit the PVC attributes. Set all the **Contract Parameters** to zero. Rerun the simulation and compare your results to the CIR64 results. What differences did you find? What would be the effect on the Traffic Received at the Bursty Client if you added another client with a CIR of 64 Kbps to the zero CIR case? Explain your answer.

5. In Question 3, some frames are discarded due to congestion at the switch. The congestion can be relieved if the traffic source transmits frames less frequently. Frame Relay systems provide traffic shaping algorithms to restrain the traffic source from sending too quickly. Duplicate the DS0 scenario from Question 3, and edit the

Bursty Server attributes. Expand the **Frame Relay Traffic Shaping** attribute, and set the **Status** to **Enabled**. Click on the question mark to the left of each of the traffic shaping attributes to determine their function. Calculate values for these attributes that will result in an uncongested network; in other words, restrict the data rate to less than the speed of the DS0 line (64 Kbps). Write down the function of each attribute, the value you calculated, and an explanation of the calculations. Run the simulation and gather statistics to show that you achieved the goal of reducing congestion (and corresponding frame discards).