Laboratory

12

# Applications

## Network Application Performance Analysis

## Objective

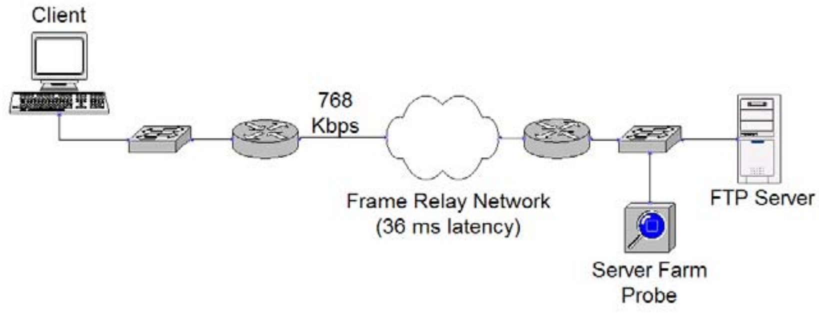
The objective of this lab is to analyze the performance of an Internet application protocol and its relation to the underlying network protocols. In addition, this lab reviews some of the topics covered in previous labs.

## Overview

Network applications are part network protocol (in the sense that they exchange messages with their peers on other machines) and part traditional application program (in the sense that they interact with the users).

OPNET's Application Characterization Environment (ACE) provides powerful visualization and diagnosis capabilities that aid in network application analysis. ACE provides specific information about the root cause of application problems. ACE can also be used to predict application behavior under different scenarios. ACE takes as input a real trace file captured using any protocol analyzer, or using OPNET's capture agents (not included in the Academic Edition).

In this lab you will analyze the performance of an FTP application. You will analyze the probable bottlenecks for the application scenario under investigation. You will also study the sensitivity of the application to different network conditions such as bandwidth and packet loss. The trace was captured on a real network, which is shown in the figure below, and already imported into ACE. The FTP application runs on that network; the client connects to the server over a 768 Kbps Frame Relay circuit with 36 ms of latency. The FTP application downloads a 1 MB file in 37 seconds. Normally, the download time for a file this size should be about 11 seconds.



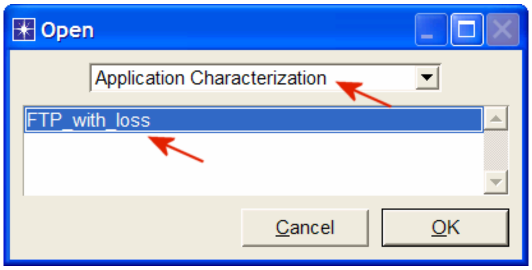
# Procedure

## Open the Application Characterization Environment

1. Start **OPNET IT Guru Academic Edition** ⇒ Choose **Open** from the **File** menu.

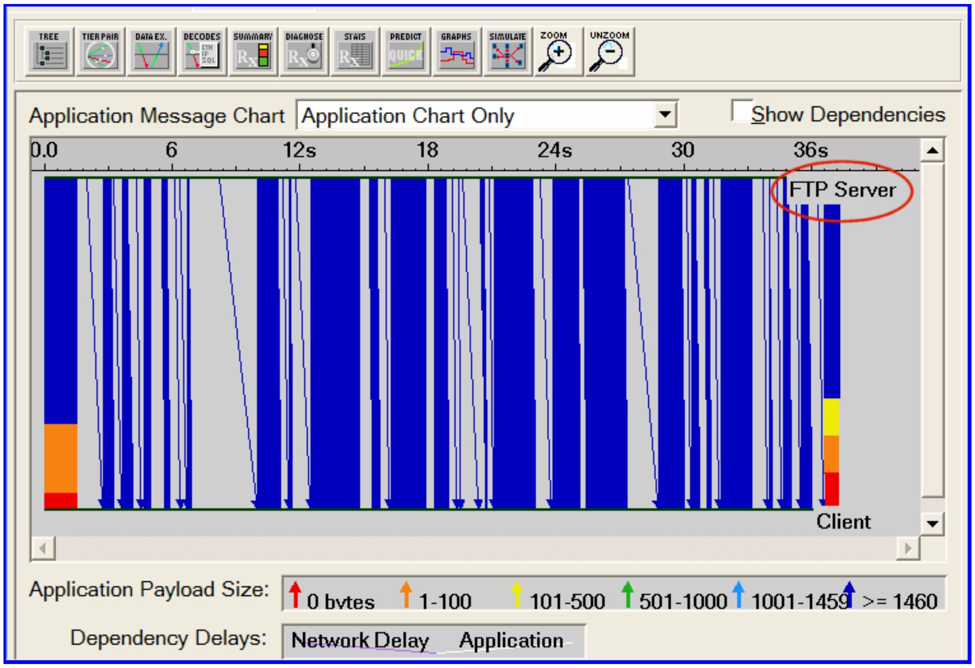
2. Select **Application Characterization** from the pull-down menu.

3. Select **FTP_with_loss** from the list ⇒ Click **OK**.



## Visualize the Application

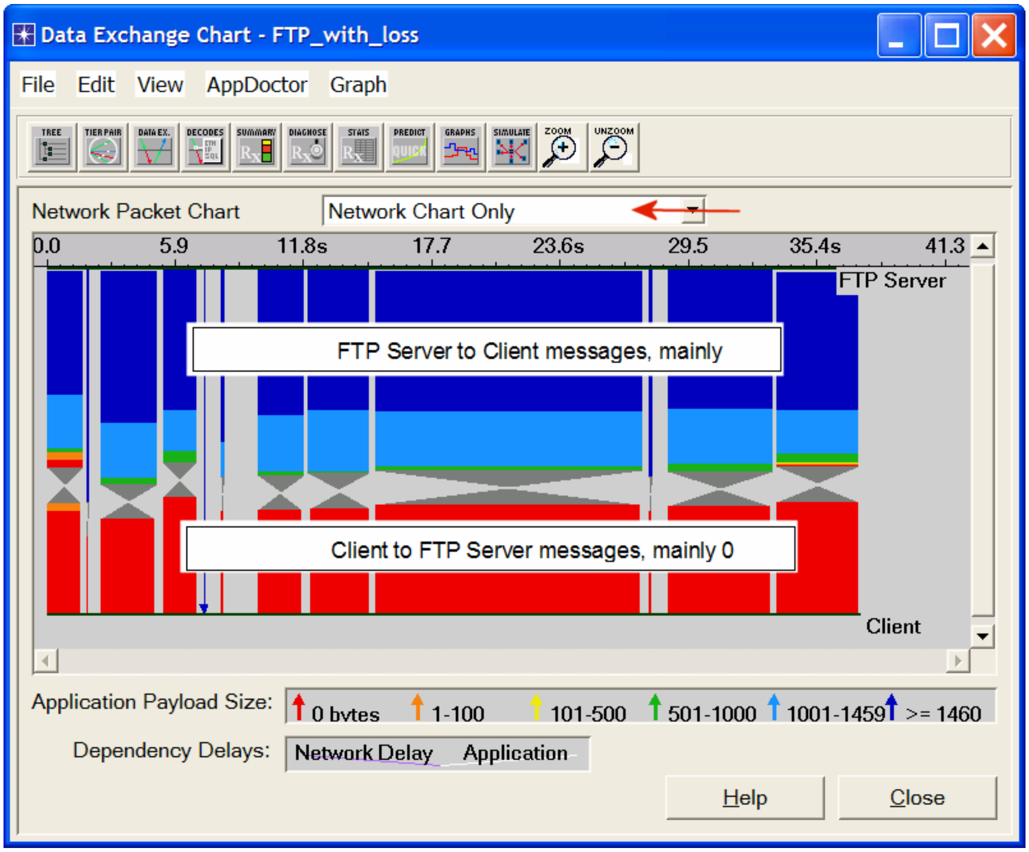
After opening the file, ACE shows the Data Exchange Chart (DEC), depicting the flow of application traffic between tiers. The DEC you see on your screen may or may not show the **FTP Server** tier as the top tier. If it does not, drag the tier label from the bottom to the top, so your screen matches the one shown in the following diagram.



The **Data Exchange Chart** can display the following:
- The **Application Chart,** which shows the flow of application traffic between tiers.
- The **Network Chart,** which shows the flow of network traffic between tiers, including the effects of network protocols on application traffic. Network protocols split packets into segments, add headers, and often include mechanisms to ensure reliable data transfer. These network protocol effects can influence application behavior.

1. Select **Network Chart Only** from the drop-down menu in the middle of the dialog box.

2. Differentiate the messages flowing in different directions by selecting **View** ⇒ **Split Groups**.



Data Exchange Chart - FTP_with_loss

Network Packet Chart: Network Chart Only

FTP Server to Client messages, mainly

Client to FTP Server messages, mainly 0

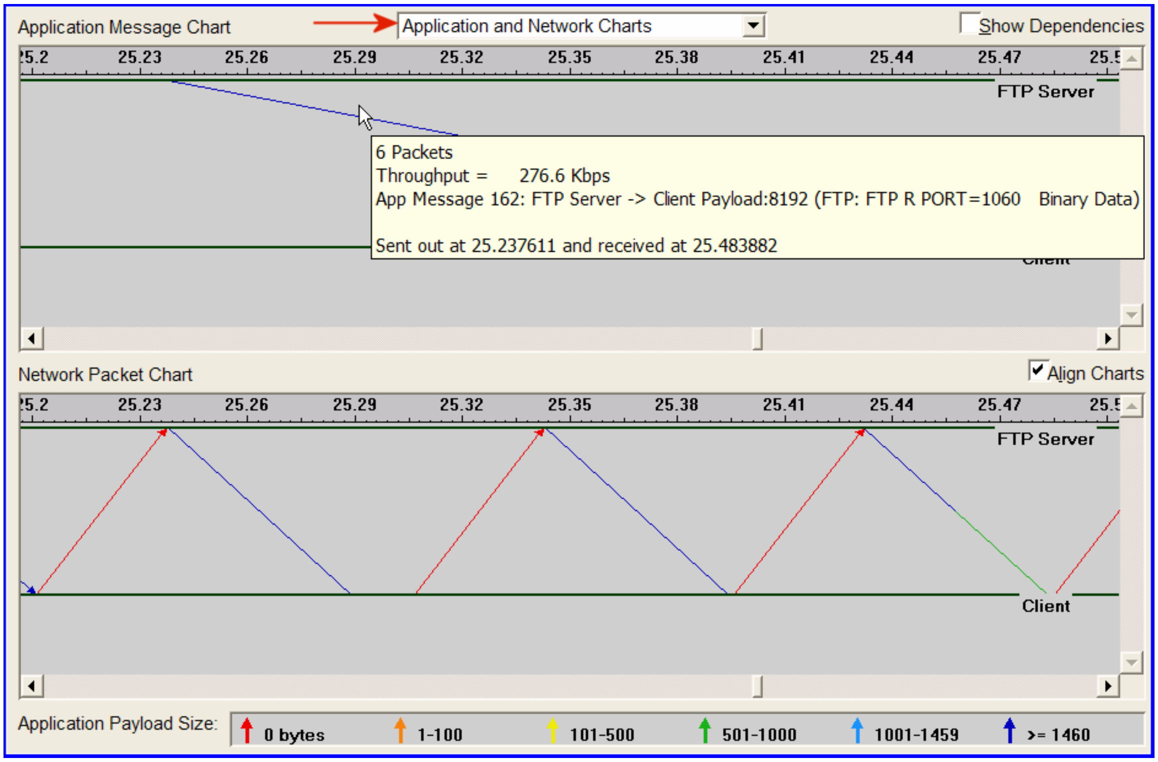
To get a better understanding of this traffic, you will zoom in on the transaction. To understand how the Application Chart and Network Chart views differ, you will view both simultaneously.

3. Select **Application and Network Charts** from the drop-down menu in the middle of the dialog box.

4. To disable the split groups view, select **View** ⇒ **Split Groups**.

5. Select **View** ⇒ **Set Visible Time Range** ⇒ Set **Start Time** to **25.2** and **End Time** to **25.5** ⇒ Click **OK**.

6. The Application Message Chart shows a single message flowing from the FTP Server to the Client. To show the size, rest the cursor on the message to show the tooltip. **Client Payload** is shown as 8192.


Application Message Chart

Application and Network Charts

□ Show Dependencies

6 Packets
Throughput = 276.6 Kbps
App Message 162: FTP Server -> Client Payload:8192 (FTP: FTP R PORT=1060 Binary Data)

Sent out at 25.237611 and received at 25.483882

Network Packet Chart

☑ Align Charts

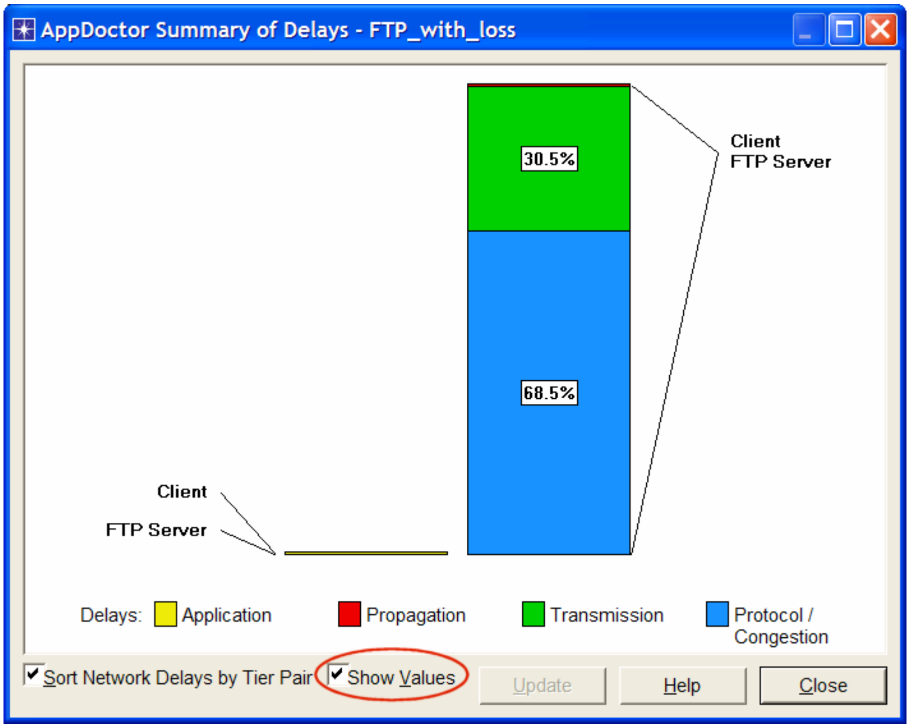
The Network Chart shows that this application message causes many packets to flow over the network. These packets are a mix of large (blue and green) packets from the FTP Server to the Client and small (red) packets from the Client to the FTP Server. As the red color indicates, these packets contain 0 bytes of application data. They are the acknowledgments sent by TCP.

## Analyze with AppDoctor

AppDoctor's *Summary of Delays* provides insight into the root cause of the overall application delay.

1. From the **AppDoctor** menu, select **Summary of Delays** ⇒ Check the **Show Values** checkbox.

Notice that the largest contributing factor to the application response time is protocol/congestion. Only about 30 percent of the file download time is caused by the limited bandwidth of the Frame Relay circuit (768 Kbps). Notice also that application delay (processing inside the node) by both the Client and FTP Server is a very minor contributing factor to the application response time.

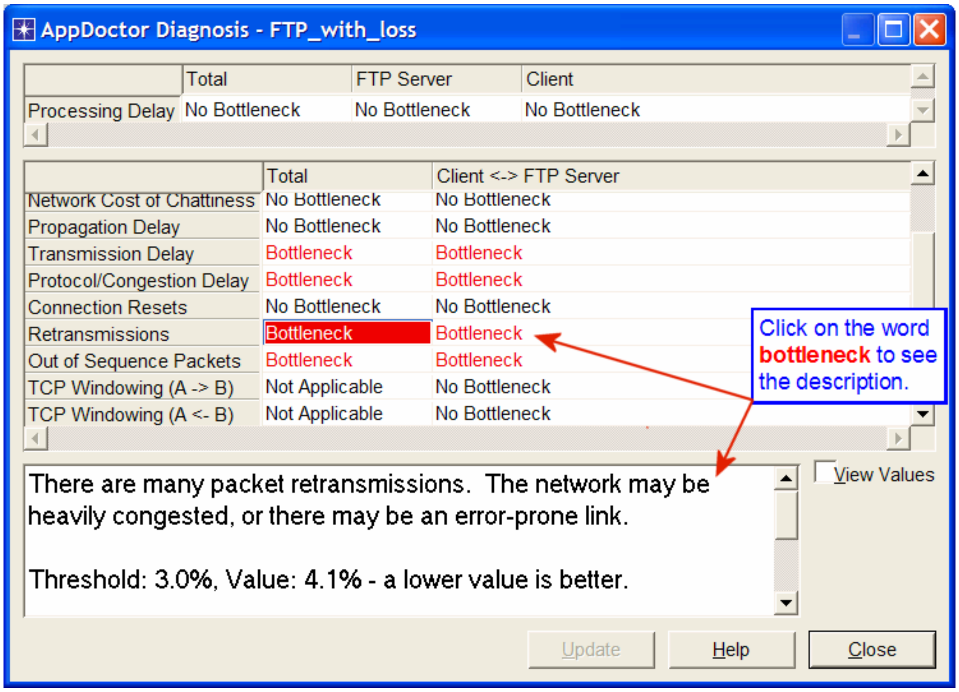

AppDoctor Summary of Delays - FTP_with_loss
30.5%
68.5%
Client
FTP Server
Client
FTP Server
Delays: 🟨 Application 🟥 Propagation 🟩 Transmission 🟦 Protocol / Congestion
Update
Help
Close

☑ Sort Network Delays by Tier Pair ☑ Show Values

2. Close the *Summary of Delays* dialog box.

The **Diagnosis** function of AppDoctor should give further insight into the cause of the protocol/congestion delay.

3. From the **AppDoctor** menu, select **Diagnosis.**



| | Total | FTP Server | Client |
|---|---|---|---|
| Processing Delay | No Bottleneck | No Bottleneck | No Bottleneck |

| | Total | Client <-> FTP Server |
|---|---|---|
| Network Cost of Chattiness | No Bottleneck | No Bottleneck |
| Propagation Delay | No Bottleneck | No Bottleneck |
| Transmission Delay | Bottleneck | Bottleneck |
| Protocol/Congestion Delay | Bottleneck | Bottleneck |
| Connection Resets | No Bottleneck | No Bottleneck |
| Retransmissions | Bottleneck | Bottleneck |
| Out of Sequence Packets | Bottleneck | Bottleneck |
| TCP Windowing (A -> B) | Not Applicable | No Bottleneck |
| TCP Windowing (A <- B) | Not Applicable | No Bottleneck |

Click on the word **bottleneck** to see the description.

There are many packet retransmissions. The network may be heavily congested, or there may be an error-prone link.

Threshold: 3.0%, Value: 4.1% - a lower value is better.

□ View Values

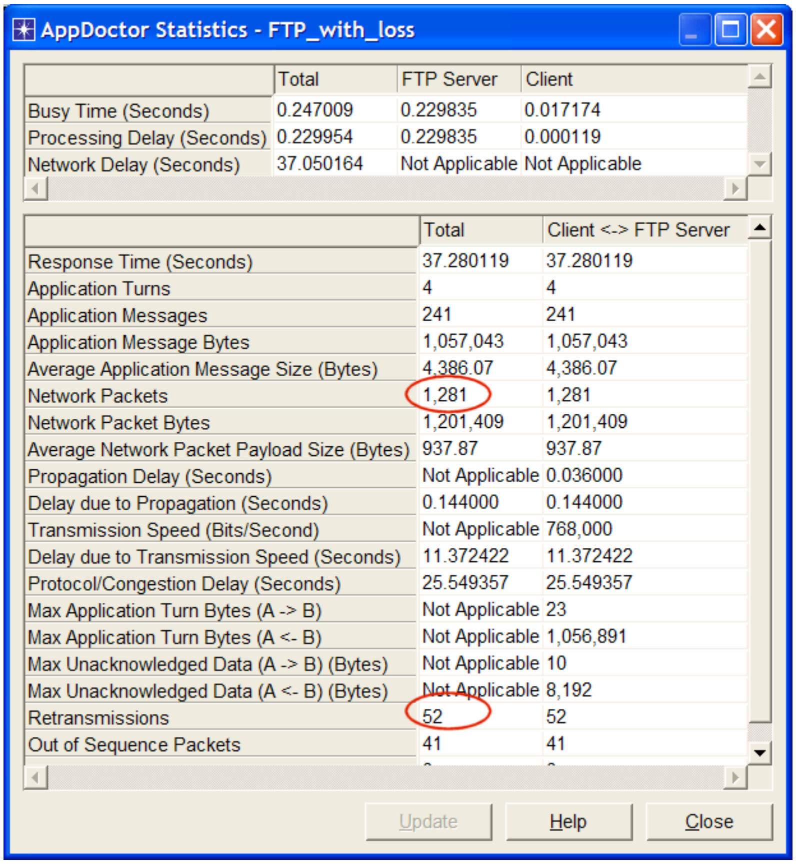
The diagnosis shows four bottlenecks: transmission delay, protocol/congestion delay, retransmissions, and out of sequence packets. One factor that contributes to protocol/congestion delay is retransmissions. So it is no surprise that here, in the more detailed diagnosis, you see retransmissions listed as a bottleneck. The out-of-sequence packets, also listed as a bottleneck, are a side effect of the retransmissions. Correcting that issue will probably also cure the out of sequence packets problem.

4. Close the *Diagnosis* Window.

AppDoctor also provides summary statistics for the application transaction.

5. From the **AppDoctor** menu, select **Statistics.**

Notice that 52 retransmissions occurred during a file transfer composed of 1281 packets, yielding a retransmission rate of 4%.



| | Total | FTP Server | Client |
|---|---|---|---|
| Busy Time (Seconds) | 0.247009 | 0.229835 | 0.017174 |
| Processing Delay (Seconds) | 0.229954 | 0.229835 | 0.000119 |
| Network Delay (Seconds) | 37.050164 | Not Applicable | Not Applicable |

| | Total | Client <-> FTP Server |
|---|---|---|
| Response Time (Seconds) | 37.280119 | 37.280119 |
| Application Turns | 4 | 4 |
| Application Messages | 241 | 241 |
| Application Message Bytes | 1,057,043 | 1,057,043 |
| Average Application Message Size (Bytes) | 4,386.07 | 4,386.07 |
| Network Packets | 1,281 | 1,281 |
| Network Packet Bytes | 1,201,409 | 1,201,409 |
| Average Network Packet Payload Size (Bytes) | 937.87 | 937.87 |
| Propagation Delay (Seconds) | Not Applicable | 0.036000 |
| Delay due to Propagation (Seconds) | 0.144000 | 0.144000 |
| Transmission Speed (Bits/Second) | Not Applicable | 768,000 |
| Delay due to Transmission Speed (Seconds) | 11.372422 | 11.372422 |
| Protocol/Congestion Delay (Seconds) | 25.549357 | 25.549357 |
| Max Application Turn Bytes (A -> B) | Not Applicable | 23 |
| Max Application Turn Bytes (A <- B) | Not Applicable | 1,056,891 |
| Max Unacknowledged Data (A -> B) (Bytes) | Not Applicable | 10 |
| Max Unacknowledged Data (A <- B) (Bytes) | Not Applicable | 8,192 |
| Retransmissions | 52 | 52 |
| Out of Sequence Packets | 41 | 41 |

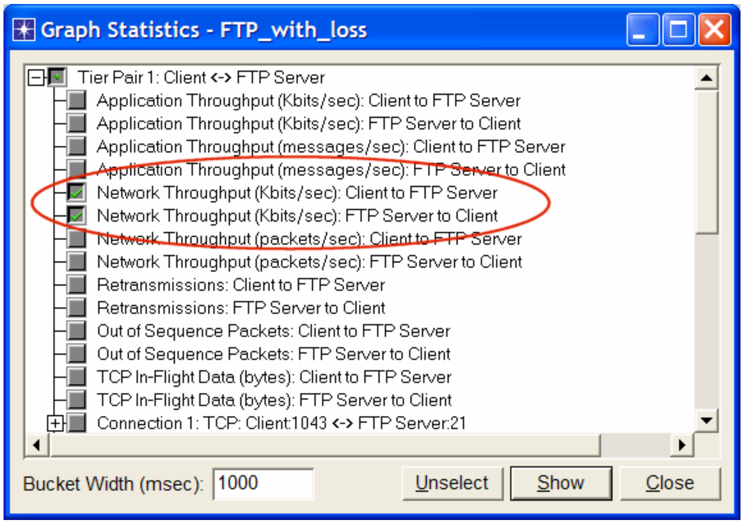
6. Close the *Statistics* window.

## Examine the Statistics

To view the actual network throughput, use the **Graph Statistics** feature.

1. From the Data Exchange Chart, select **Graph Statistics** from the **Graph** menu (or click the button: ).

2. Select the two **Network Throughput** statistics that measure Kbits/sec.

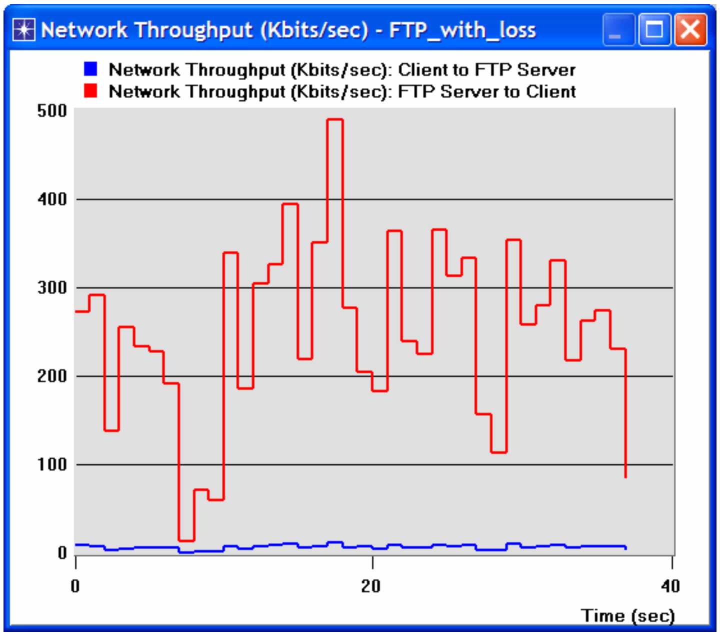


Graph Statistics - FTP_with_loss

- ☑ Tier Pair 1: Client <-> FTP Server
  - □ Application Throughput (Kbits/sec): Client to FTP Server
  - □ Application Throughput (Kbits/sec): FTP Server to Client
  - □ Application Throughput (messages/sec): Client to FTP Server
  - □ Application Throughput (messages/sec): FTP Server to Client
  - ☑ Network Throughput (Kbits/sec): Client to FTP Server
  - ☑ Network Throughput (Kbits/sec): FTP Server to Client
  - □ Network Throughput (packets/sec): Client to FTP Server
  - □ Network Throughput (packets/sec): FTP Server to Client
  - □ Retransmissions: Client to FTP Server
  - □ Retransmissions: FTP Server to Client
  - □ Out of Sequence Packets: Client to FTP Server
  - □ Out of Sequence Packets: FTP Server to Client
  - □ TCP In-Flight Data (bytes): Client to FTP Server
  - □ TCP In-Flight Data (bytes): FTP Server to Client
  - □ Connection 1: TCP: Client:1043 <-> FTP Server:21

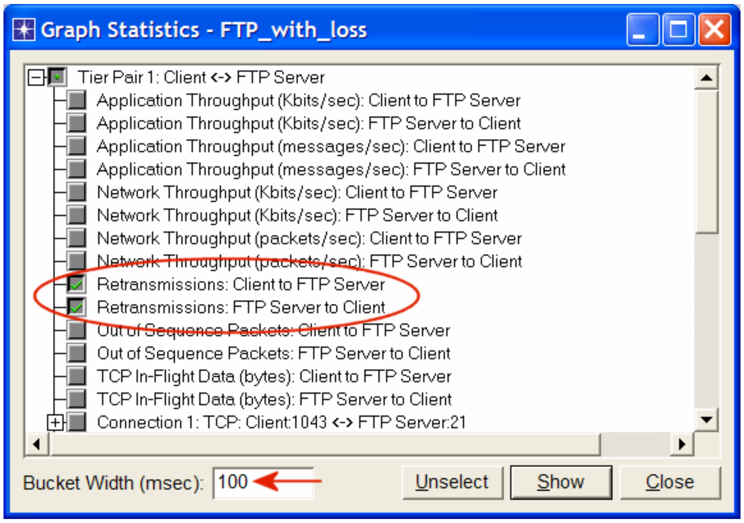
Bucket Width (msec): 1000

3. Click **Show**.



ACE divides the entire task duration into individual **buckets** of time and calculates a mean or total value for each interval. The default bucket width is 1000 msec; you can change this value in the Bucket Width (msec) field of the ACE statistic browser.

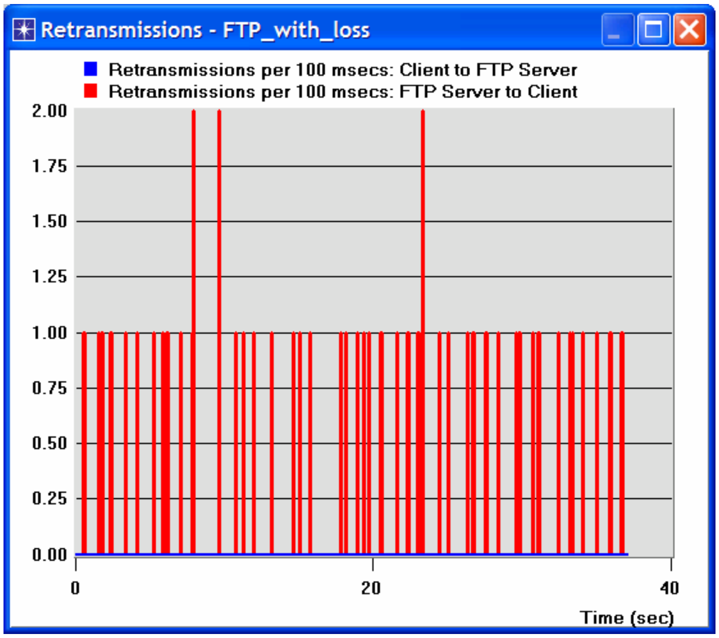
4. Return to the *Graph Statistics* window ⇒ Unselect the throughput statistics and select only the two **Retransmissions** statistics ⇒ Change the **Bucket Width** to **100 ms** ⇒ Click **Show**.



Graph Statistics - FTP_with_loss

- Tier Pair 1: Client <-> FTP Server
  - □ Application Throughput (Kbits/sec): Client to FTP Server
  - □ Application Throughput (Kbits/sec): FTP Server to Client
  - □ Application Throughput (messages/sec): Client to FTP Server
  - □ Application Throughput (messages/sec): FTP Server to Client
  - □ Network Throughput (Kbits/sec): Client to FTP Server
  - □ Network Throughput (Kbits/sec): FTP Server to Client
  - □ Network Throughput (packets/sec): Client to FTP Server
  - □ Network Throughput (packets/sec): FTP Server to Client
  - ☑ Retransmissions: Client to FTP Server
  - ☑ Retransmissions: FTP Server to Client
  - □ Out of Sequence Packets: Client to FTP Server
  - □ Out of Sequence Packets: FTP Server to Client
  - □ TCP In-Flight Data (bytes): Client to FTP Server
  - □ TCP In-Flight Data (bytes): FTP Server to Client
  - □ Connection 1: TCP: Client:1043 <-> FTP Server:21

Bucket Width (msec): 100



## Ideal TCP Window Size

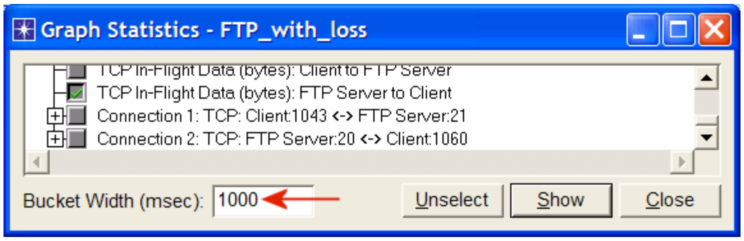
In TCP, rather having a fixed-size sliding window, the receiver advertises a window size to the sender. This is done using the **AdvertisedWindow** field in the TCP header. The sender is then limited to having no more than a value of **AdvertisedWindow** bytes of unacknowledged data at any given time. The receiver selects a suitable value for **AdvertisedWindow** based on the amount of memory allocated to the connection for the purpose of buffering data. This procedure is called *flow control,* and its idea is to keep the sender from overrunning the receiver's buffer.

In addition TCP maintains a new state variable for each connection, called **CongestionWindow,** which is used by the source to limit how much data it is allowed to have in transit at a given time. The congestion window is congestion control's counterpart to flow control's advertised window. It is dynamically sized by TCP in response to the congestion status of the connection.

TCP will send data only if the amount of sent-but-not-yet-acknowledged data is less than the minimum of the congestion window and the advertised window. ACE autocalculates the optimum window size based on the bandwidth-delay product as follows:

The **bandwidth-delay product** of a connection gives the "volume" of the connection—the number of bits it holds. It corresponds to how many bits the sender must transmit before the first bit arrives at the receiver.

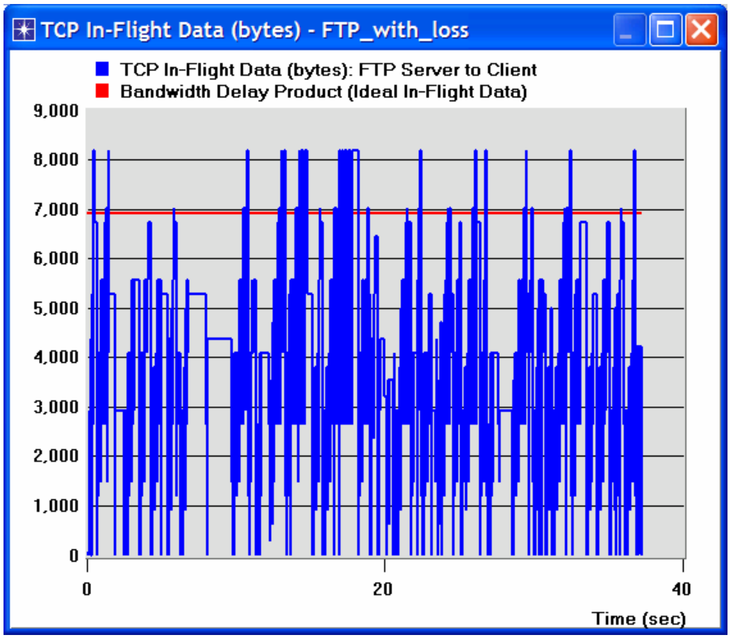
1. Return to the *Graph Statistics* window ⇒ Select the **TCP In-Flight Data (bytes) FTP_Server to Client** statistic ⇒ Assign **1000** to the **Bucket Width (msec)**.



- □ TCP In-Flight Data (bytes): Client to FTP Server
- ☑ TCP In-Flight Data (bytes): FTP Server to Client
- ⊞ □ Connection 1: TCP: Client:1043 <-> FTP Server:21
- ⊞ □ Connection 2: TCP: FTP Server:20 <-> Client:1060

Bucket Width (msec): 1000

2. Click **Show**. From the graph, the ideal window size calculated by ACE is about 7 KB.



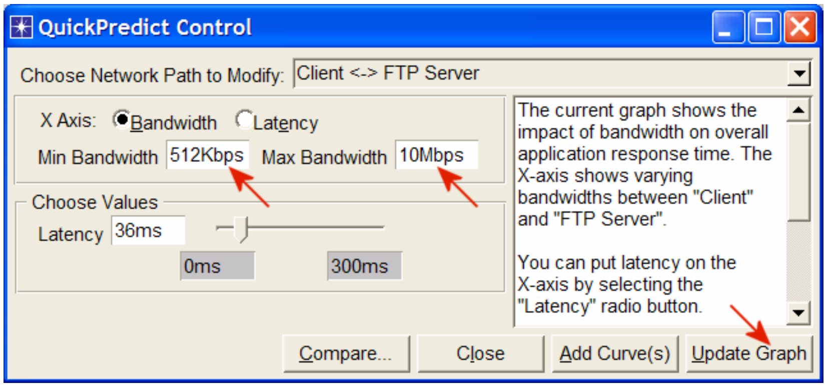
3. You can now close all opened graphs (delete the panel when you are asked to do that) and close the *Graph Statistics* window.

## Impact of Network Bandwidth

ACE QuickPredict enables you to study the sensitivity of an application to network conditions such as bandwidth and latency.

1. Click on the **QuickPredict** button: .

2. In the *QuickPredict Control* dialog box assign **512Kbps** to the **Min Bandwidth** field and **10Mbps** to the **Max Bandwidth** field ⇒ Click the **Update Graph** button.



QuickPredict Control

Choose Network Path to Modify: Client <-> FTP Server

X Axis: ● Bandwidth ○ Latency

Min Bandwidth 512Kbps Max Bandwidth 10Mbps

Choose Values

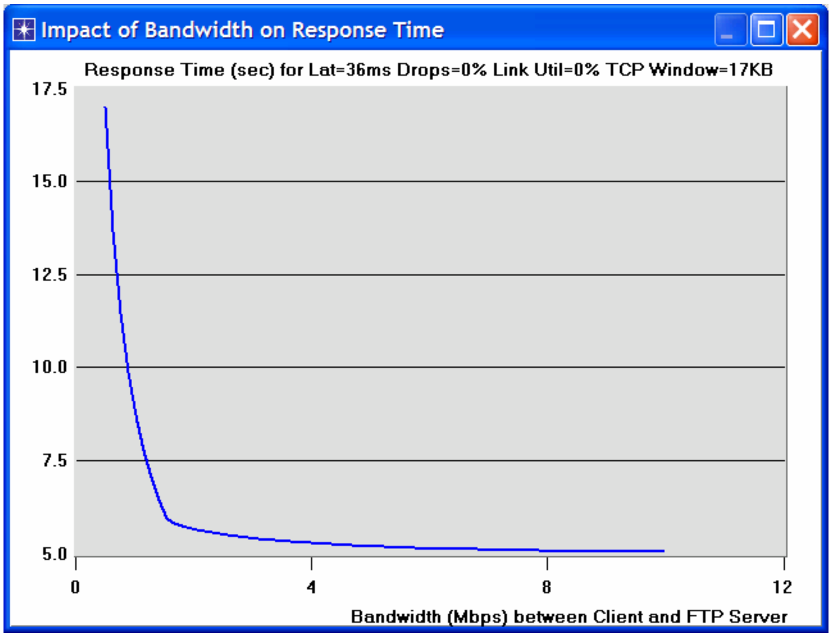
Latency 36ms

0ms 300ms

The current graph shows the impact of bandwidth on overall application response time. The X-axis shows varying bandwidths between "Client" and "FTP Server".

You can put latency on the X-axis by selecting the "Latency" radio button.

3. The resulting graph should resemble the following one:



Impact of Bandwidth on Response Time

4. Close the graph and the *QuickPredict Control* dialog box.

## Deploy an Application

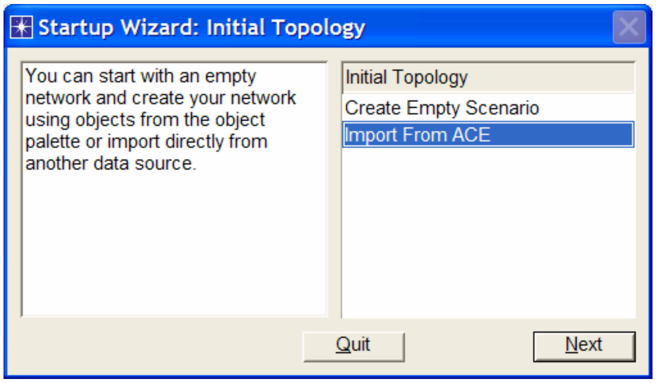
OPNET IT Guru can be used to perform predictive studies of applications that are characterized in ACE. ACE uses the trace files to create application fingerprints that characterize the data exchange between tiers. From these fingerprints, a simulation can show how the application will behave under different conditions. For example the ACE topology wizard can be used to build a network model from the ACE file of this lab, **FTP_with_loss**, to answer the following question: What will the performance of the FTP application be when deployed to 100 simultaneous users over an IP network?

Follow the following steps to answer the above question:

1. From the IT Guru main window, select **File** ⇒ **New** ⇒ Select **Project** from the pull-down menu ⇒ Click **OK**.

2. Name the project <**your initials>_FTP**, and the scenario **ManyUsers** ⇒Click **OK**.

3. In the *Startup Wizard,* select **Import from ACE** ⇒ Click **Next**.



You can start with an empty network and create your network using objects from the object palette or import directly from another data source.

4. The *Configure ACE Application* dialog box appears.

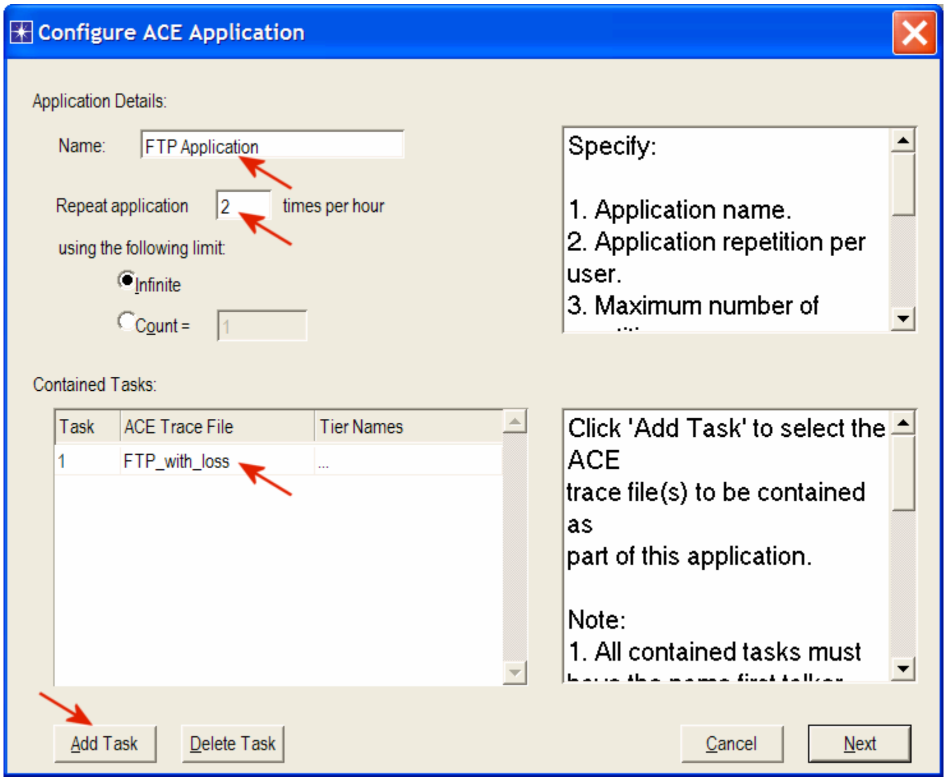
   i. Set the **Name** field to **FTP Application**.

   ii. Set the **Repeat** application field to **2**. This field controls how many times a user executes the application per hour.

   iii. Leave the limit at the default value, **Infinite**.

   iv. Click on **Add Task** ⇒ In the **Contained Tasks** table, click on the word **Specify...** ⇒ Select **FTP_with_loss** from the pull-down menu.

   v. Click **Next**.



Configure ACE Application

Application Details:

Name: FTP Application

Repeat application 2 times per hour

using the following limit:

● Infinite

○ Count = 1

Specify:

1. Application name.
2. Application repetition per user.
3. Maximum number of

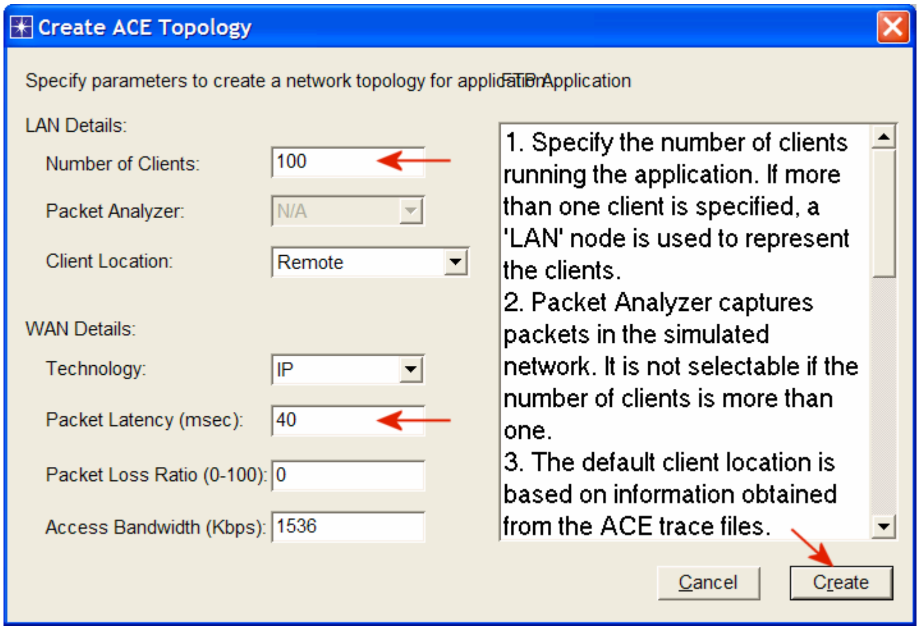
Contained Tasks:

| Task | ACE Trace File | Tier Names |
|---|---|---|
| 1 | FTP_with_loss | ... |

Click 'Add Task' to select the ACE trace file(s) to be contained as part of this application.

Note:
1. All contained tasks must

5. The *Create ACE Topology* dialog box appears. Set **Number of Clients** to 100 and set **Packet Latency** to 40. Leave all other settings at the default values.
6. Click **Create**.



Create ACE Topology

Specify parameters to create a network topology for applicationFTP Application

LAN Details:

Number of Clients: 100

Packet Analyzer: N/A

Client Location: Remote

WAN Details:

Technology: IP

Packet Latency (msec): 40

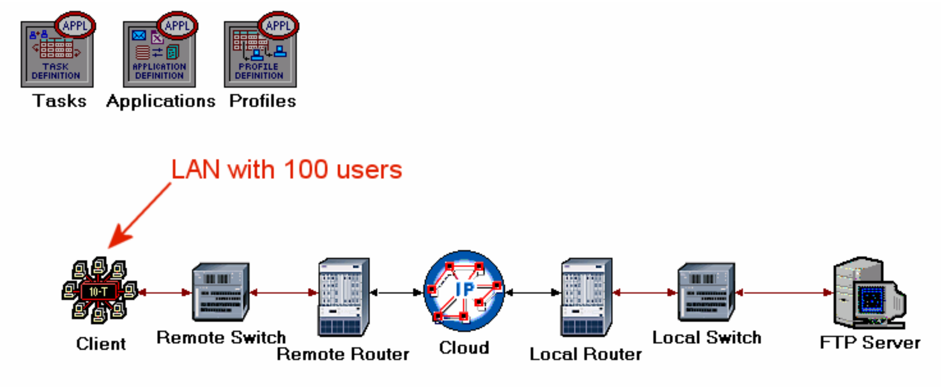
Packet Loss Ratio (0-100): 0

Access Bandwidth (Kbps): 1536

1. Specify the number of clients running the application. If more than one client is specified, a 'LAN' node is used to represent the clients.
2. Packet Analyzer captures packets in the simulated network. It is not selectable if the number of clients is more than one.
3. The default client location is based on information obtained from the ACE trace files.

7. Select **File** ⇒ **Save** ⇒ Click **OK** to save the project.

The ACE Wizard creates a topology similar to the one shown. The **Tasks, Applications,** and **Profiles** objects have all been configured according to the trace files and the entries you made in the ACE Wizard. You can customize them further.



*Run the Simulation and View the Results:*

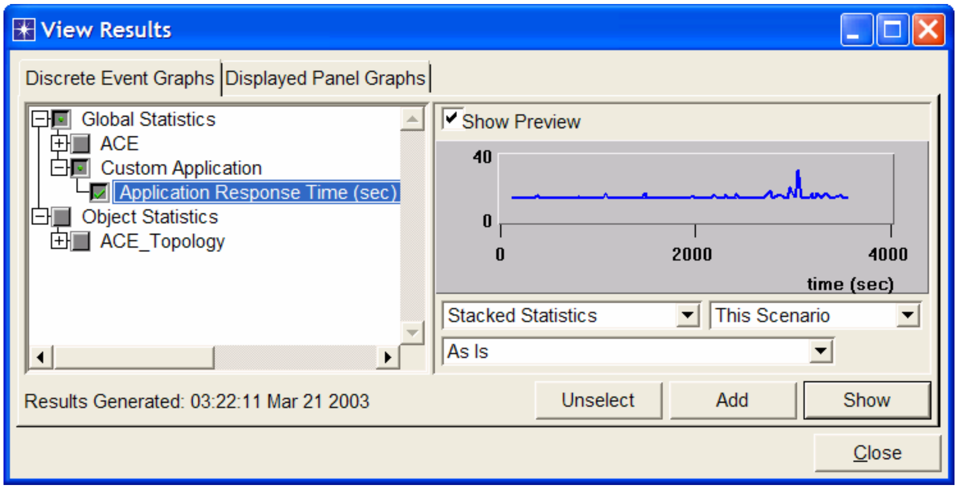
Now that the topology is created, you can run the simulation.

1. Click on the **Configure / Run Simulation** action button .

2. Use the default values. Click **Run**. Depending on the speed of your processor, this may take several minutes to complete.

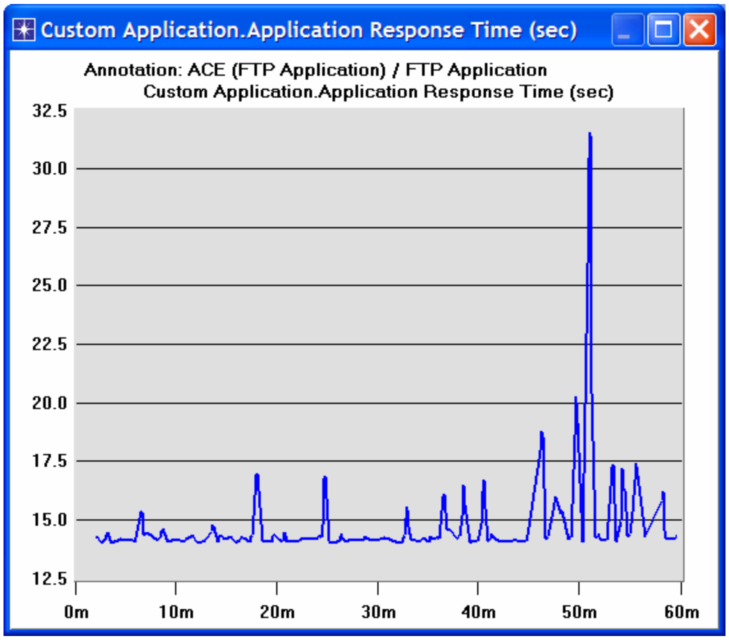
3. Close the dialog box when the simulation completes ⇒ Save your project.

4. Select **View Results** from the **Results** menu ⇒ Expand the **Custom Application** hierarchy ⇒ Select the **Application Response Time (sec)** statistic.



Results Generated: 03:22:11 Mar 21 2003

5. Click **Show**. The resulting graph should resemble the following:



## Further Readings

– File Transfer Protocol (FTP): IETF RFC number 959 (www.ietf.org/rfc.html).

## Questions

**1)** Explain why the Client to FTP Server messages are mainly 0-byte messages?

**2)** From AppDoctor's Summary of Delays, what is the effect of each of the following upgrades on the FTP download time?

   a. Server upgrade
   b. Bandwidth upgrade
   c. Protocol(s) upgrade

**3)** How do retransmissions contribute to protocol/congestion delay? And why are out of sequence packets a side effect of retransmissions?

**4)** Which protocol is responsible for the retransmission, IP, TCP, or FTP? Explain.

**5)** In the **Network Throughput** graph, the throughput from the FTP Server to the Client has an average value of about 300 Kbps and has a spike to about 500 Kbps. But the Frame Relay circuit has an available bandwidth of 768 Kbps. Explain why the throughput is not close to the available bandwidth.

**6)** Explain how the TCP in-flight data is used as an indicator of the TCP window size and how the bandwidth-delay product of the connection is used as an indicator of the ideal window size.

**7)** Comment on the graph we received that shows the relation between the network bandwidth and the FTP application response time. Why does the response time look unaffected by increasing the bandwidth beyond a specific point?

**8)** In the *Deploy an Application* section, a network model with multiple users was created based on the ACE file, **FTP_with_loss**. Duplicate the created scenario to create a new one with the name **Q8_ManyUsers_ExistingTraffic**. In this new scenario add an “existing” traffic of 80% load in the network. Examine how the existing traffic affects the FTP application's response time. *Note:* A simple way to simulate the existing traffic is to apply *background utilization* traffic of 80% to the link between the **Remote Router** and the **IP Cloud**.

## Lab Report

Prepare a report that follows the guidelines explained in Lab 0. The report should include the answers to the above questions 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.