

RSVP: Resource Reservation Protocol

Providing QoS by Reserving Resources in the Network

Objective

The objective of this lab is to study the Resource Reservation Protocol (RSVP) as a part of the Integrated Services approach to providing Quality of Service (QoS) to individual applications or flows.

Overview

For many years, packet-switched networks have offered the promise of supporting multimedia applications, that is, those that combine audio, video, and data. Audio and video applications are examples of *real-time* applications. The best-effort model, in which the network tries to deliver your data but makes no promises and leaves the "cleanup operation" to the edges, is not sufficient for real-time applications. What we need is a new service model—one in which applications that need better assurances can request such service from the network. The network may then respond by providing an assurance that it will do better, or perhaps by saying that it cannot promise anything better at the moment. A network that can provide different levels of service is often said to support QoS.

Two approaches have been developed to provide a range of QoS: Integrated Services and Differentiated Services. The Resource Reservation Protocol follows the Integrated Services approach, whereby QoS is provided to individual applications or flows. The Differentiated Services approach provides QoS to large classes of data or aggregated traffic.

While connection-oriented networks have always needed some sort of setup protocol to establish the necessary virtual circuit state in the routers, connectionless networks like the Internet have had no such protocols. One of the key assumptions underlying RSVP is that it should not detract from the robustness that we find in the Internet. Therefore, RSVP uses the idea of *soft state* in the routers. Soft state—in contrast to the hard state found in connection-oriented networks—does not need to be explicitly deleted when it is no longer needed. Instead, it times out after some fairly short period if it is not periodically refreshed. RSVP adopts the *receiver-oriented* approach—the receivers keep track of their own resource requirements, and they periodically send refresh messages to keep the soft state in place.

In this lab you will set up a network that carries real-time applications and that utilizes RSVP to provide QoS to one of these applications. You will study how RSVP contributes to the performance of the application that makes use of it.

Create a New Project

The idea of the FQ (fair queuing) 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 of the link's bandwidth each flow will get. We could use the ToS (Type of Service) field in the IP header to identify that weight.

- 1. Start **OPNET IT Guru Academic Edition** \Rightarrow Choose **New** from the **File** menu.
- 2. Select the project you created in Lab 9: <your initials>_Queues \Rightarrow Click OK.
- 3. From the File menu, choose Save As \Rightarrow Rename the project to <your initials>_RSVP \Rightarrow Click OK.
- 4. From the Scenarios menu, choose Manage Scenarios \Rightarrow Click on FIFO \Rightarrow Click Delete \Rightarrow Click on PQ \Rightarrow Click Delete.

🛣 Ma	* Manage Scenarios								
Proj	Project Name: eha RSVP								
#	Scenario Name	Saved	Results	Sim Duration	Time Units				
1	FIFO 🔶	saved	out of date	150	second(s)				
2	PQ 🔶	saved	out of date	150	second(s)				
3	WFQ	saved	up to date	150	second(s)				
						-			
	Delete Discard Results Collect Results Cancel OK								

- 5. Click on **WFQ** and rename it to **QoS_RSVP** \Rightarrow Click **OK**.
- Make sure that you have only one scenario in your project named QoS_RSVP. The following figure shows one way to check for the available scenarios in the project.

Image: Project: eha_RSVP Scenario: QoS_RSVP [Subnet: top.Campus Network]											
File	Edit	View	Scenarios	Topology	Traffic	Protocols	s S	imulation	Results	Windows	Help
	I 🔧		New Sce Duplicate Manage	nario e Scenario Scenarios	Ctrl+	Shift+N Shift+D		1			
	E		Previous Next Sce	Scenario enario	Ctrl+ Ctrl+	Up Down					
	Арр	lication	Switch T Scenario	o Scenario Componen	ts		•	QoS_RSV	P Ctrl+1		

7. Save your project.

Configure the Network

Add More VoIP Nodes:

In this project we will set up the two VoIP nodes so that one will always be the *Caller* party and the other will be the *Called* party. In addition, we will add two new VoIP *Caller* and *Called* nodes. These new nodes will utilize RSVP to reserve their required resources through the network.

- Right-click on the VoIP East node ⇒ Edit Attributes ⇒ Rename the node to Voice Called ⇒ Assign None to the Application: Supported <u>Profiles</u> attribute ⇒ Assign Voice Called to the Client Address attribute ⇒ Click OK.
- 2. Right-click on the **VoIP West** node \Rightarrow **Edit Attributes**.
 - i. Rename the node to **Voice Caller**.
 - ii. Assign None to the Application: Supported Services attribute.
 - iii. Edit the value of the Application: Destination Preferences attribute ⇒ Set Rows to 1 ⇒ Assign Voice Destination to the Symbolic Name of the new row ⇒ Edit the Actual Name attribute ⇒ Set Rows to 1 ⇒ Assign Voice Called to the Name attribute of the new row as shown.
 - iv. Click **OK** three times.

👪 (Voice Caller) Attributes				
Type: workstation	Na s	(Application: Destination P	references) Table	
Attribute	Value Voice Caller	Symbolic Name	Actual Name	Å
 Immodel Immodel	ethernet_wkstn Unspecified	Voice Destination	()	
 Application: Destination Preferences Application: Supported Profiles 	() ()	/		
 ◆ ⊢Application: Supported Services ◆ ⊕ Application: Transport Protocol Spe ◆ ⊕ CPU Background Utilization 	None De No 🔀 (Actual N	ame) Table		
 ⊕ CPU Resource Parameters ● ⊢Client Address 	Sil Au Name	Selection Weig	jht	ie M
EIP Host Parameters EIP Processing Information	(Voice Calle	d 10		O <u>K</u>
Apply Changes to Selected Objects				
Eind Next		T.	1	×
	1 Rov	rs Delete Insert		
	D <u>e</u> tails	Promote		

- 3. Click on the Voice Called node to select it ⇒ From the Edit menu, select Copy ⇒ From the Edit menu, select Paste (alternatively, use the standard keyboard shortcuts, Ctrl-C and Ctrl-V).
 - i. Locate the new node somewhere below the **Voice Called** node on the screen \Rightarrow Connect the new node to the **East Router** using a **10BaseT** link.
 - ii. Right-click on the new node \Rightarrow Edit Attributes.
 - iii. Click on the ethernet_wkstn value of the model attribute \Rightarrow Select Edit \Rightarrow Select the ethernet_wkstn_adv model.
 - iv. Rename it to Voice_RSVP Called \Rightarrow Assign Voice_RSVP Called to its Client Address attribute.
 - v. Click OK.
- 4. Copy and paste the **Voice Caller** node.
 - i. Locate the new node somewhere below the Voice Caller node ⇒ Connect the new node to the West Router using a 10BaseT link.
 - ii. Right-click on the new node \Rightarrow Edit Attributes.
 - iii. Click on the ethernet_wkstn value of the model attribute \Rightarrow Select Edit \Rightarrow Select the ethernet_wkstn_adv model.
 - iv. Rename it to Voice_RSVP Caller.
 - v. Edit the Application: Destination Preferences attribute \Rightarrow Open the Actual Name table by clicking in the value field of Actual Name \Rightarrow Assign Voice_RSVP Called to the Name attribute.
 - vi. Click **OK** three times.
- 5. Rename the **Queues** node in the project to **QoS**. Your project should look like the following diagram.
- 6. Save your project.



Define the Data Flow:

Here, we will define the data flow characteristics of the voice traffic in the network. The sender's RSVP module periodically sends RSVP Path messages that uses the data flow characteristics to describe the traffic generated by the sender. When the receiver's RSVP module receives the Path message, the receiver host application checks the characteristics of the requested data flow and decides if resources should be reserved. Once a decision is made to request network resource reservation, the host application sends a request to the local RSVP module to assist in the reservation setup. The receiver's RSVP module then carries the request as Resv messages to all nodes along the reverse data path to the sender.

The flow is defined by its required bandwidth and buffer size. Bandwidth is set to be the *token bucket rate* in the flow specification of the Path and Resv messages. The buffer size represents the amount of the application "bursty" data to be buffered. It specifies the *token bucket size* that will be set in the Path or Resv messages for the session.

- 1. Right-click on the **QoS** node \Rightarrow **Edit Attributes**.
 - i. Expand the **RSVP Flow Specification** hierarchy and its **row 0** hierarchy ⇒ Set **Name** to **RSVP_Flow** ⇒ Assign **50,000** to the **Bandwidth (bytes/sec)** attribute ⇒ Assign **10,000** to the **Buffer Size (bytes)** attribute.
 - ii. Expand the **RSVP Profiles** hierarchy and its row 0 hierarchy \Rightarrow Set **Profile** Name to **RSVP_Profile**.

🞛 (QoS) Attributes 📃 🗖 🔀				
Type: Utilities				
Attribute	Value 🔺			
⑦ ⊢name	QoS			
⑦ ⊢model	QoS Attribute Config			
⑦	Default			
⑦	Standard Schemes			
⑦ ⊞ FIFO Profiles	Standard Schemes			
⑦ ⊞ MWRR / MDRR / DWR	Standard Schemes			
⑦ ⊞ Priority Queuing Profiles	Standard Schemes			
⑦ □ RSVP Flow Specification	()			
⑦ Frows	1			
row 0				
⑦ ⊢Name	RSVP_Flow			
Bandwidth (bytes/se	. 50,000			
Image: Buffer Size (bytes)	10,000			
RSVP Profiles RSVP ProfILe RSVP Pr	()			
⑦ ⊢rows	1			
Profile Name RSVP_Profile				
Threshold (bytes/sec) None				
Apply Changes to Selected Objects				
Eind Next	<u>C</u> ancel <u>O</u> K			

iii. Click **OK** and then save your project.

Configure the Application:

Here we will create a VoIP application that utilizes the RSVP flow specifications we configured.

- 1. Right-click on the **Applications** node \Rightarrow **Edit Attributes** \Rightarrow Expand the **Applications Definitions** hierarchy \Rightarrow Set rows to 4 (to add a fourth row to the **Application Definitions** attribute).
 - i. Name and set the attributes of row 3 as shown:

🔀 (Applications) Attributes	
Type: Utilities	
Attribute	Value
⑦ ⊟ Application Definitions	()
⑦ ⊢rows	4 🔶
⊞row 0	FTP Application,()
⊞row 1	Video Application,()
⊞row 2	VoIP Application,()
🗆 row 3	
⑦ ⊢Name	VoIP_RSVP
⑦	()
⑦ ⊢Custom	Off
⑦ ⊢Database	Off
⑦ ⊢Email	Off
⑦ ⊢Ftp	Off
⑦ ⊢Http	Off
⑦ ⊢Print	Off
⑦ ⊢Remote Login	Off
Ivideo Conferencing	Off
⑦ └Voice	PCM Quality Speech
⑦	All Schemes
Apply Changes to Selected Ol	bjects
Eind Next	<u>C</u> ancel <u>O</u> K

ii. Click on the **PCM Quality Speech** value (shown above) ⇒ Select **Edit** ⇒ Edit the value of the **RSVP Parameters** attribute ⇒ Assign the following values (recall that we defined the **RSVP_Flow** in the QoS node) ⇒ Click **OK** three times.

Ð	(RSVP Parameters) Table	
	Attribute	Value
	RSVP Status	Enabled
(Outbound Flow	RSVP_Flow
\mathbf{r}	hobound Flow	RSVP_Flow
		_
	Details Promote	<u>C</u> ancel <u>O</u> K

Note that the characteristics of the **Outbound Flow** are carried in the Path messages to be sent from sender to receiver, and the characteristics of the **Inbound Flow** parameters are carried in the Resv messages to be sent from the receiver to the sender.

Configure the Profile:

 Right-click on the Profiles node ⇒ Edit Attributes ⇒ Expand the Profile Configuration hierarchy ⇒ Set rows to 4 (to add a fourth row to the Profile Configuration attribute) ⇒ Name and set the attributes of row 3 as shown:

₩	<table-of-contents></table-of-contents>					
Ту	pe: Utilities					
	Attribute	Value				
0	Frows	4 🔶				
	⊞ row 0	FTP Profile,(),Simultaneous,c				
	⊞row 1	Video Profile,(),Simultaneous				
	± row 2	VoIP Profile,(),Simultaneous,				
	⊡ row 3					
?	⊢Profile Name	VoIP_RSVP Profile				
?	Applications	()				
?	Frows	1				
	⊡ row 0					
?	⊢Name	VoIP_RSVP				
?	Start Time Offset (seconds)	constant (5)				
?	Duration (seconds)	End of Profile				
?	⊞ Repeatability	Once at Start Time				
?	←Operation Mode	Simultaneous				
?	⊢Start Time (seconds)	constant (100)				
?	⊢Duration (seconds)	End of Simulation				
?		Once at Start Time				
4						
	Apply Changes to Selected Objects	A <u>d</u> vanced				
	<u>F</u> ind Next	<u>C</u> ancel <u>O</u> K				

2. Click **OK** and then save your project.

Configure the Interfaces:

OPNET IT Guru supports RSVP on a per-interface basis; RSVP can be enabled or disabled for each node's interface.

1. Simultaneously select (shift + left-click) the following three links:



2. From the **Protocols** menu, select **RSVP** \Rightarrow Select **Configure Interface Status** \Rightarrow Make the selections shown below in the configuration dialog box \Rightarrow Click **OK** and then save your project.

🔀 Configure RS 📘 🗖 🔀					
This operation will enable/disable RSVP protocol status across connected interfaces for all/selected links.					
Status: CDisable					
Apply the above selection to:					
<u>C</u> ancel					

The above process enables RSVP on all interfaces along the path between the two Voice parties that need to utilize RSVP.

Configure the Hosts and Routers:

In OPNET IT Guru, the RSVP process runs only in IP-enabled nodes. The advanced versions (*_adv) of those node models must be used, as we did already, to configure RSVP-related parameters. In addition, the RSVP model in OPNET IT Guru requires either WFQ or custom queuing schemes.

- 1. Right-click on the **Voice_RSVP Caller** node \Rightarrow **Edit Attributes.**
 - i. Expand the **Application: Supported Profiles** hierarchy and its **row 0** hierarchy ⇒ Assign **VoIP_RSVP Profile** to the **Profile Name** attribute.
 - ii. Expand the Application: RSVP Parameters hierarchy \Rightarrow Expand its Voice hierarchy \Rightarrow Enable the RSVP Status \Rightarrow Expand the Profile List hierarchy \Rightarrow Assign to the Profile attribute of row 0 the value RSVP_Profile.

Type: workstation						
ļ	Attribute	Value 🔺				
0	⊡Voice	()				
3	-RSVP Status	Enabled 🔶 🚽				
?	⊟Profile List	()				
3	rows	1				
	⊡ row 0					
3	L Profile	RSVP_Profile <				

iii. Expand the IP Host Parameters hierarchy ⇒ Expand its Interface Information hierarchy ⇒ Expand the QoS Information hierarchy ⇒ Assign WFQ to the Queuing Scheme attribute ⇒ Assign ToS Based to the Queuing Profile attribute ⇒ Assign RSVP Enabled to the RSVP Info attribute.

Type: workstation				
Attribute	Value			
⑦ ⊡ IP Host Parameters	()			
Interface Information	()			
⑦ ⊢Name	IFO			
⑦ ⊢Address	Auto Assigned			
⑦ ⊢Subnet Mask	Auto Assigned			
⑦ ⊢MTU (bytes)	Ethernet			
Compression Information	None			
Image: Multicast Mode	Disabled			
②	()			
⑦ ⊢Incoming CAR Profile	None			
Outgoing CAR Profile	None			
Image: Buffer Size (Bytes)	1MBytes			
Processing Rate	Link Speed			
RSVP Info	RSVP Enabled			
② (⊢Queuing Scheme	WFQ			
② Queuing Profile	ToS Based			
	•			

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

BW specifies the percentage of the bandwidth of the connected link that RSVP can reserve on the interface.

Maximum Bandwidth

Per Flow specifies the amount of reservable bandwidth that can be allocated to a single flow.

iv. Expand the RSVP Protocol Parameters hierarchy ⇒ Expand the Interface Information hierarchy. (You should notice that the word *Enabled* is listed in the summary line. When you expand it, you will see that it is the value of RSVP Status. If *Enabled* is not listed, go back to the *Configure the Interfaces* steps.) ⇒ Expand the hierarchy of the row of that interface ⇒ Assign 75% to both the Maximum Reservable BW and Maximum Bandwidth Per Flow attributes as shown:

Attribute	Value .
□ Interface Information	()
Frows	1
⊡ row 0	
Name	
PRSVP Status	Enabled
② (⊢Maximum Reservable BW	75%
Maximum Bandwidth Per Flow	75%
②	None

- v. Click OK.
- 2. Right-click on the **Voice_RSVP Called** node \Rightarrow **Edit Attributes.**
 - i. Edit the Application: Supported Services attribute. The Application: Supported Services Table will popup ⇒ In that table, replace the VoIP Application with VoIP_RSVP and click OK.
 - ii. Expand the Application: RSVP Parameters hierarchy ⇒ Expand its Voice hierarchy ⇒ Enable the RSVP Status ⇒ Expand the Profile List hierarchy ⇒ Edit the value of the Profile attribute of row 0 and write down RSVP_Profile.
 - iii. Expand the **IP Host Parameters** hierarchy \Rightarrow Expand its **Interface Information** hierarchy \Rightarrow Expand the **QoS Information** hierarchy \Rightarrow Assign **WFQ** to the **Queuing Scheme** attribute \Rightarrow Assign **ToS Based** to the **Queuing Profile** attribute \Rightarrow Assign **RSVP Enabled** to the **RSVP Info** attribute.
 - iv. Expand the **RSVP Protocol Parameters** hierarchy ⇒ Expand the **Interface Information** hierarchy. (You should notice that the **RSVP Status** of the interface that is connected to the router is *Enabled*. If not, go back to the *Configure the Interfaces* steps.) ⇒ Expand the hierarchy of the row of that interface ⇒ Assign **75%** to both **Maximum Reservable BW** and **Maximum Bandwidth Per Flow** attributes.
 - v. Click OK.
- 3. Right-click on the **East Router** node \Rightarrow **Edit Attributes**.

- i. Click on the **Ethernet4_slip8_gtwy** value of the **model** attribute ⇒ Select **Edit** ⇒ Select the **Ethernet4_slip8_gtwy_adv** model.
- ii. Expand the RSVP Protocol Parameters hierarchy ⇒ Expand the Interface Information hierarchy. (You should notice that the RSVP Status of two interfaces, which are connected to the West Router and the Voice_RSVP Called node, are *Enabled*. If not, go back to the *Configure the Interfaces* steps.) ⇒ Expand the hierarchies of the rows of these two interfaces ⇒ Assign 75% to both Maximum Reservable BW and Maximum Bandwidth Per Flow attributes.
- iii. Expand the IP Routing Parameters hierarchy ⇒ Expand the Interface Information hierarchy ⇒ Expand the hierarchies of the rows of the same two interfaces you configured in the previous step (step ii) ⇒ Expand the QoS Information hierarchy for both ⇒ Set Queuing Scheme to WFQ and Queuing Profile to ToS Based for both.
- iv. Click OK.
- 4. Right-click on the West Router node \Rightarrow Edit Attributes.
 - i. Click on the Ethernet4_slip8_gtwy value of the model attribute \Rightarrow Select Edit \Rightarrow Select the Ethernet4_slip8_gtwy_adv model.
 - ii. Expand the **RSVP Protocol Parameters** hierarchy ⇒ Expand the **Interface Information** hierarchy. (You should notice that the **RSVP Status** of two interfaces, which are connected to the **East Router** and the **Voice_RSVP Caller** node, are *Enabled*. If not, go back to the *Configure the Interfaces* steps.) ⇒ Expand the hierarchies of the rows of these two interfaces ⇒ Assign **75%** to both **Maximum Reservable BW** and **Maximum Bandwidth Per Flow** attributes.
 - iii. Expand the IP Routing Parameters hierarchy ⇒ Expand the Interface Information hierarchy ⇒ Expand the hierarchies of the rows of the same two interfaces you configured in the previous step (step ii)⇒ Expand the QoS Information hierarchy for both ⇒ Set Queuing Scheme to WFQ and Queuing Profile to ToS Based for both.
 - iv. Click OK.

Choose the Statistics

We will select statistics from three different nodes:

Voice RSVP Caller Statistics:

- 1. Right-click on the Voice_ RSVP Caller node and select Choose Individual Statistics from the pop-up menu.
- 2. Expand the **RSVP** hierarchy and select **Number of Path States**.
- 3. Right-click on the **Number of Path States** statistic ⇒ Select **Change Draw Style** from the pop-up menu ⇒ Choose **bar chart**.
- Right-click on the Number of Path States statistic ⇒ Select Change Collection Mode from the pop-up menu ⇒ Check the Advanced checkbox ⇒ From the Capture mode drop-down menu, select all values, as shown⇒ Click OK.

🗄 Number of Path States	🔣 Number o	of Path States
(Bucket Mode) Sample Frequency:	Capture mode	all values
CEvery seconds	CEvery	seconds
CEvery values	CEvery	values
● <u>I</u> otal of default <u>Values</u>	Image: Contract of the second sec	default 💌 values
	Bucket mode	max value
Advanced <	I ■ <u>R</u> eset	
Cancel OK	Advanced	
	<u>C</u> a	ancel <u>O</u> K

Packet Delay

Variation is the variance among end-to-end delays for voice packets received by this node.

Packet End-to-End

Delay for a voice packet is measured from the time it is created to the time it is received.

- 5. Expand the Voice Calling Party hierarchy and select the following statistics: Packet Delay Variation and Packet End-to-End Delay (sec).
- 6. Click OK.

Voice_RSVP Called Statistics:

- 1. Right-click on the Voice_ RSVP Called node and select Choose Individual Statistics from the pop-up menu.
- 2. Expand the **RSVP** hierarchy and select **Number of Resv States**.
- 3. Right-click on the Number of Resv States statistic \Rightarrow Select Change Draw Style from the pop-up menu \Rightarrow Choose bar chart.

- 4. Right-click on the **Number of Resv States** statistic \Rightarrow Select **Change Collection Mode** from the pop-up menu \Rightarrow Check the **Advanced** checkbox \Rightarrow From the **Capture mode** drop-down menu, select **all values** \Rightarrow Click **OK**.
- 5. Click OK.

Voice Caller Statistics:

- 1. Right-click on the Voice Caller node and select Choose Individual Statistics from the pop-up menu.
- 2. Expand the Voice Calling Party hierarchy and select the following statistics: Packet Delay Variation and Packet End-to-End Delay (sec)
- 3. Click OK.

Configure the Simulation

Here, we need to configure the duration of the simulation:



- 1. Click on and the *Configure Simulation* window should appear.
- 2. Make sure that the duration is set to **150 seconds**.
- 3. Click on the Global Attributes tab and make sure that the following attribute is enabled:
 - a. **RSVP Sim Efficiency = Enabled**. This decreases the simulation time and memory requirements by not sending refresh messages (i.e., Path and Resv refreshes).
- 4. Click **OK** and then save your project.

Run the Simulation

To run the simulation:

- 1. Click on and then click the Run button. Depending on the speed of your processor, this may take several minutes to complete.
- 2. After the simulation completes, click Close.
- 3. Save your project.

View the Results

To view and analyze the results:

- 1. Select View Results from the Results menu.
- As shown in the following figure, choose the Packet End-to-End Delay for both the Voice Caller and Voice_RSVP Caller nodes. Choose Overlaid Statistics and time_average.

🐨 View Results			
Discrete Event Graphs Displayed Panel Graphs			
Campus Network	Show Preview 0.2 0.1		/
Voice_RSVP Caller	0.0	100	- 200 time (sec)
Packet End-to-End Delay (sec) <voli ■ Packet Delay Variation <volp_rsvp ▼<br="">↓</volp_rsvp></voli 	Overlaid Statistics	▼ This So	cenario 💌
Results Generated: 14:43:48 Mar 20 2003	Unselect	Add	Show
			<u>C</u> lose

3. Click **Show** to get the following graph. (*Note:* To zoom in on the graph, click and drag your mouse to draw a rectangle around the area of interest and release the mouse button.)



4. Similarly, you can get the following graph that compares the **Packet Delay Variation** for both the **Voice Caller** and **Voice_RSVP Caller** nodes. (*Note:* Make sure to "unselect" the statistics you chose for the previous graph.)



5. Finally, prepare the graph that displays the number of Path and Resv states by selecting the following statistics. Make sure to select **Stacked Statistics** and **As Is** as shown.



6. Right-click on the resulting graph and choose **Edit Panel Properties** ⇒ Change the assigned values to the **Horizontal Min** and **Horizontal Max** fields as shown (your graph might require a slightly different range):

Ranel Operations	×
Panel Title:	
Panel Coordinates Set Color	
Horizontal Label: time (sec)	
Horizontal Min: 104.999s	
Horizontal Max: 105.072s	
Eull Scale Set All Draw Styles	–
Apply <u>C</u> ancel <u>O</u> K	

7. Click **OK**. The resulting graph should resemble the one below.



Further Readings

- OPNET RSVP Model Description: From the **Protocols** menu, select **RSVP** \Rightarrow **Model Usage Guide**.

Questions

- 1) Analyze the graphs we obtained in this lab. Show the effect of RSVP on the Voice application and explain the obtained numbers of Path and Resv states.
- 2) How does the data rate of the link connecting the East and West routers affect the performance (e.g., Packet End-to-End Delay) of the Voice and Video Conference applications? To answer this question, create a new scenario as a duplicate of the QoS_RSVP scenario. Name the new scenario Q2_HighRate. In the Q2_HighRate scenario replace the current PPP_DS1 link (data rate 1.544 Mbps) with a PPP_DS3 link (data rate 44.736 Mbps).

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.