RIP: Routing Information Protocol

A Routing Protocol Based on the Distance-Vector Algorithm

OBJECTIVES

The objective of this lab is to configure and analyze the performance of the Routing Information Protocol (RIP) model.

OVERVIEW

A router in the network needs to be able to look at the destination address in the packet and then determine which one of the output ports is the best choice to get the packet to that address. The router makes this decision by consulting a forwarding table. The fundamental problem of routing is: How do routers acquire the information in their forwarding tables?

Routing algorithms are required to build the routing tables and, hence, forwarding tables. The basic problem of routing is to find the lowest-cost path between any two nodes, where the cost of a path equals the sum of the costs of all the edges that make up the path. Routing is achieved in most practical networks by running routing protocols among the nodes. The protocols provide a distributed, dynamic way to solve the problem of finding the lowest-cost path in the presence of link and node failures and changing edge costs.

One of the main classes of routing algorithms is the distance-vector algorithm. Each node constructs a vector containing the distances (costs) to all other nodes and distributes that vector to its immediate neighbors. RIP is the canonical example of a routing protocol built on the distance-vector algorithm. Routers running RIP send their advertisements regularly (e.g., every 30 s). A router also sends an update message whenever a triggered update from another router causes it to change its routing table.

The Internet Control Message Protocol (ICMP) can be utilized to analyze the performance of the created routes. It can be used to model traffic between routers without the need for running applications in an end node.

In this lab, you will set up a network that utilizes RIP as its routing protocol. You will analyze the routing tables generated in the routers, and you will observe how RIP is affected by link failures. You will also utilize the ICMP to create echo reply messages (i.e., ping) to analyze the created routes.

PRE-LAB ACTIVITIES

Read Section 3.3.2 from *Computer Networks: A Systems Approach, 5th Edition*.

Go to www.net-seal.net and play the following animations:
- The Address Resolution Protocol (ARP)
- ARP with Multiple Networks
- Dynamic Host Configuration Protocol (DHCP)
- Routing

PROCEDURE

Create a New Project

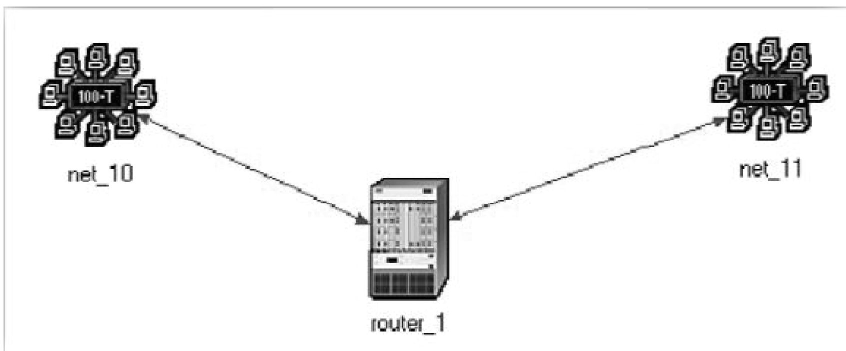
1. Start **OPNET IT Guru Academic Edition** → Choose **New** from the **File** menu.
2. Select **Project** and click **OK** → Name the project **<your initials>_RIP**, and the scenario **No_Failure** → Click **OK**.
3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty 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:

1. The *Object Palette* dialog box should now be on top of your project workspace. If it is not there, open it by clicking . Make sure that the **internet_toolbox** is selected from the pull-down menu on the object palette.
2. Add to the project workspace the following objects from the palette: one **ethernet4_slip8_gtwy** router and two **100BaseT_LAN** objects.
   a. To add an object from a palette, click its icon in the object palette → Move your mouse to the workspace → Click to place the object → Right-click to stop creating objects of that type.
3. Use bidirectional **100BaseT** links to connect the objects you just added as in the following figure. Also, rename the objects as shown (right-click on the node → **Set Name**).
4. Close the *Object Palette* dialog box, and **Save** your project.

The **ethernet4_slip8_gtwy** node model represents an IP-based gateway supporting four Ethernet hub interfaces and eight serial line interfaces. IP packets arriving on any interface are routed to the appropriate output interface based on their destination IP address. The RIP or the OSPF protocols may be used to dynamically create the gateway's routing tables.



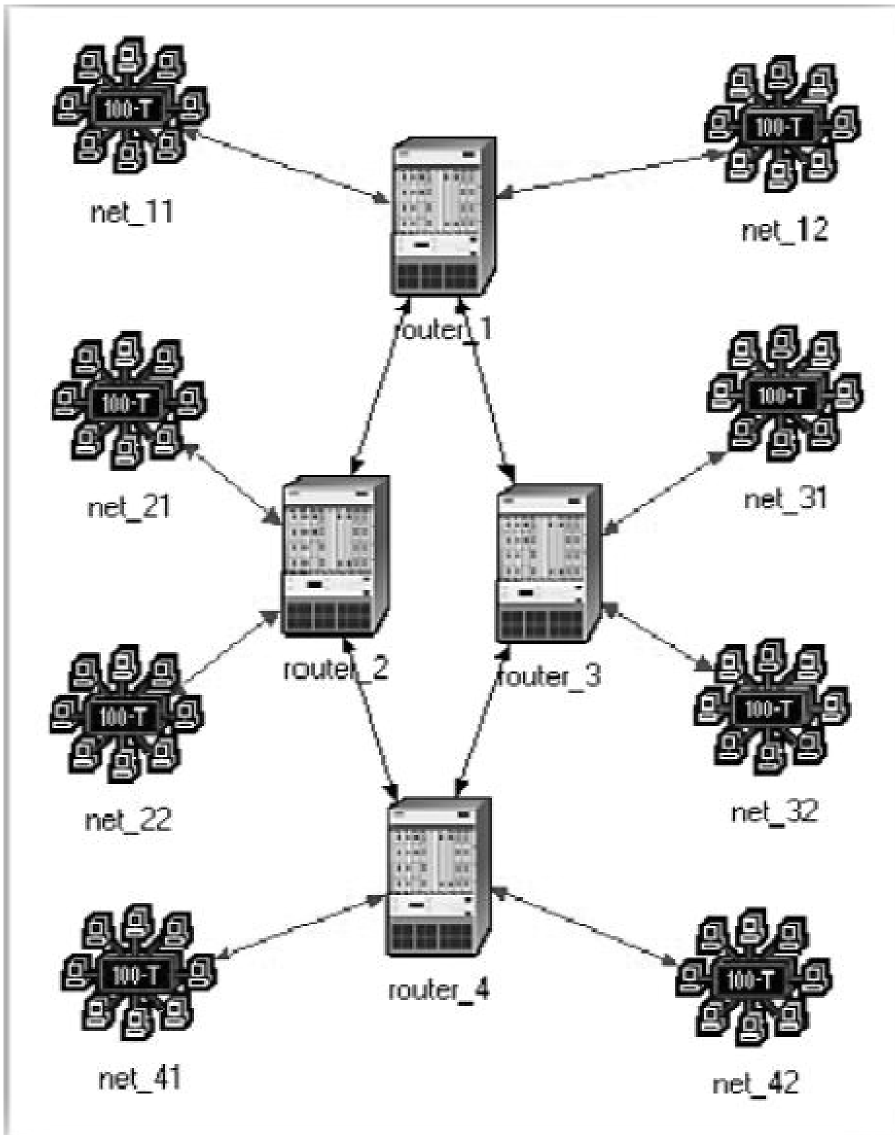
Configure the Router

1. Right-click on **router_1** → **Edit Attributes** → Expand the **IP Routing Parameters** hierarchy and set the following:
   a. **Routing Table Export** = **Once at End of Simulation**. This asks the router to export its routing table at the end of the simulation to the OPNET simulation log.
2. Click **OK**, and then **Save** your project.

Add the Remaining LANs

1. Highlight or select simultaneously (using **Ctrl** + **A**) all five objects that you currently have in the project workspace (one router, two LANs, and two links).
2. Press **Ctrl** + **C** to copy the selected objects, and then press **Ctrl** + **V** three times to paste them to generate three new copies of the objects.
3. Arrange the objects in a way similar to the following figure and rename them as shown.
4. Connect routers as shown using **PPP_DS3** links.

The **PPP_DS3** link has a data rate of 44.736 Mbps.



Choose the Statistics

To test the performance of the RIP, we will collect the following statistics:

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, check the following statistics:
   a. **Global Statistics → RIP → Traffic Sent (bits/sec).**

RIP traffic is the total amount of RIP update traffic (in bits) sent/received per second by all the nodes using RIP as the routing protocol in the IP interfaces in the node.

Total Number of Updates is the number of times the routing table at this node gets updated (e.g., because of a new route addition, an existing route deletion, and/or a next hop update).

Auto Addressed means that all IP interfaces are assigned IP addresses automatically during simulation. The class of address (e.g., A, B, or C) is determined based on the number of hosts in the designed network. Subnet masks assigned to these interfaces are the default subnet masks for that class.

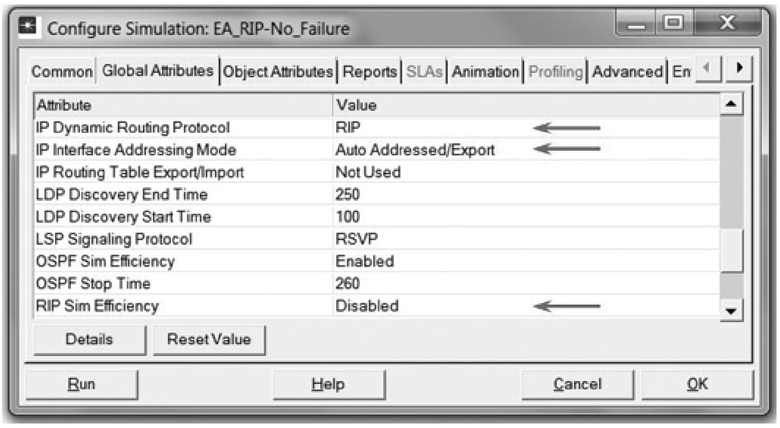
Export causes the autoassigned IP interface to be exported to a file (name of the file is <net_name>-ip_addresses.gdf and gets saved in the primary model directory).

   b. **Global Statistics → RIP → Traffic Received (bits/sec).**
   c. **Nodes Statistics → Route Table → Total Number of Updates.**
3. Click **OK**, and then **Save** your project.

Configure the Simulation

Here we need to configure some of the simulation parameters:

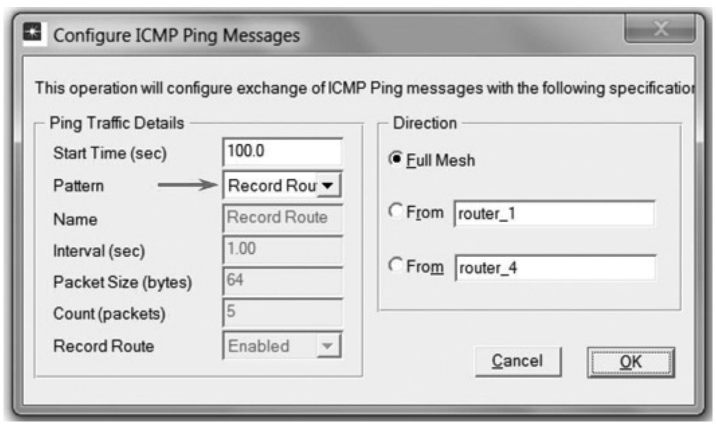
1. Click on and the *Configure Simulation* window should appear.
2. Set the duration to be **10.0 minutes**.
3. Click on the **Global Attributes** tab and change the following attributes:
   a. **IP Dynamic Routing Protocol = RIP**. This sets the RIP protocol to the routing protocol of all routers in the network.
   b. **IP Interface Addressing Mode = Auto Addressed/Export**.
   c. **RIP Sim Efficiency = Disabled**. This makes RIP keep updating the routing table in case there are any changes in the network (as we will see in the second scenario).
4. Click **OK**, and then **Save** the project.



The Ping Scenario

In this scenario, we will utilize the ping model to print the list of traversed nodes while the ICMP request message is sent to the destination and the ICMP response is received from the destination. Traversed routes are logged in the simulation log file.

1. Select **Duplicate Scenario** from the **Scenarios** menu and name it **ICMP_Ping** → Click **OK**.
2. Select both **router_1** and **router_4** simultaneously (click on both of them while holding the **Shift** key) → Select the **Protocols** menu → **IP** → **Demands** → **Configure Ping Traffic on Selected Nodes**.
3. Change the **Pattern** attribute to **Record Route** as shown → Click **OK**.

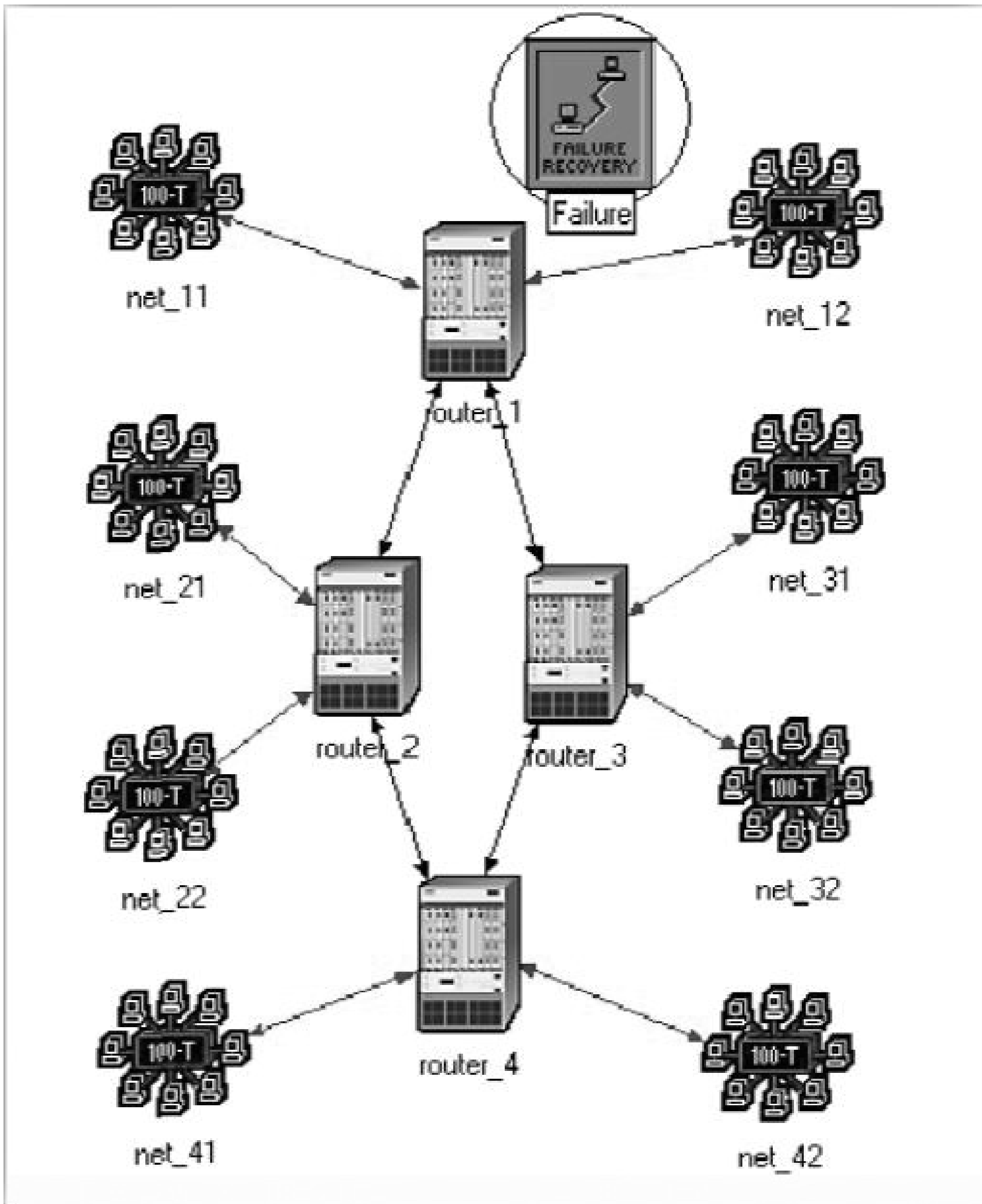


Notice that a Ping Parameter node will be added to the project space. In addition, the ping demand is created between router_1 and router_4 as a dotted line.

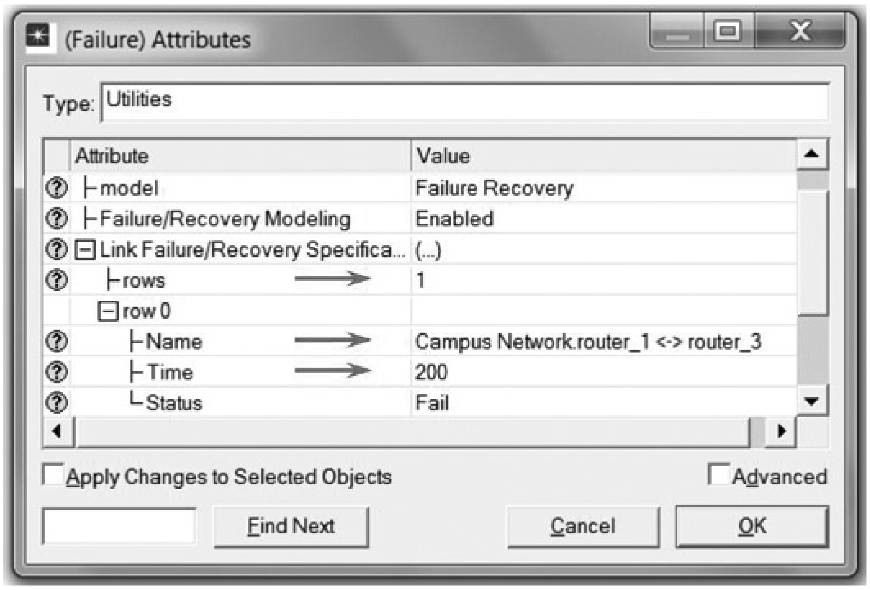
The Failure Scenario

The routers in the network we created will build their routing tables with no need for further updating because we didn't simulate any node or link failures. In this scenario, we will simulate failures so that we can compare the behavior of the routers in both cases.

1. Go to the **No_Failure** scenario by clicking **Ctrl** + **1** → Select **Duplicate Scenario** from the **Scenarios** menu and name it **Failure** → Click **OK**.
2. Open **Object Palette** by clicking . Select the **Utilities** palette from the drop-down menu → Add a **Failure Recovery** object to your workspace and name it **Failure** as shown → Close the *Object Palette* dialog box.



3. Right-click on the **Failure** object → **Edit Attributes** → Expand the **Link Failure/Recovery Specification** hierarchy → Set **rows** to **1** → Set the attributes of the added row, **row 0**, as follows:



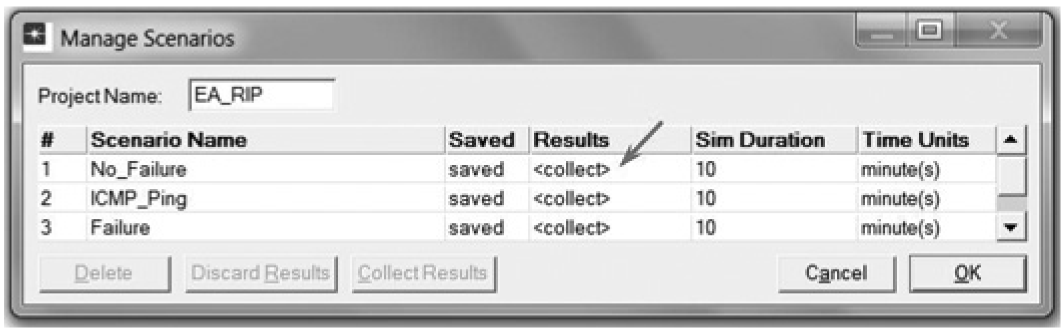
This will "fail" the link between **router_1** and **router_3** 200 s into the simulation.

4. Click **OK**, and then **Save** the project.

Run the Simulation

To run the simulation for both scenarios simultaneously:

1. Go to the **Scenarios** menu → Select **Manage Scenarios**.
2. Change all values under the **Results** column to **<collect>** (or **<recollect>**) as shown.

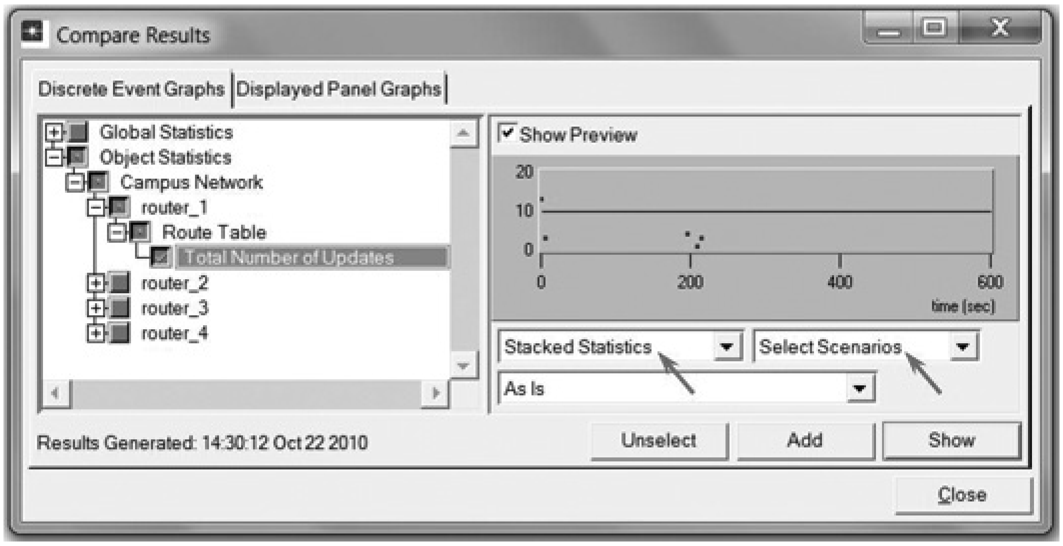


3. Click **OK** to run the three simulations. This task may take several seconds to complete.
4. After the three simulation runs complete, one for each scenario, click **Close**.

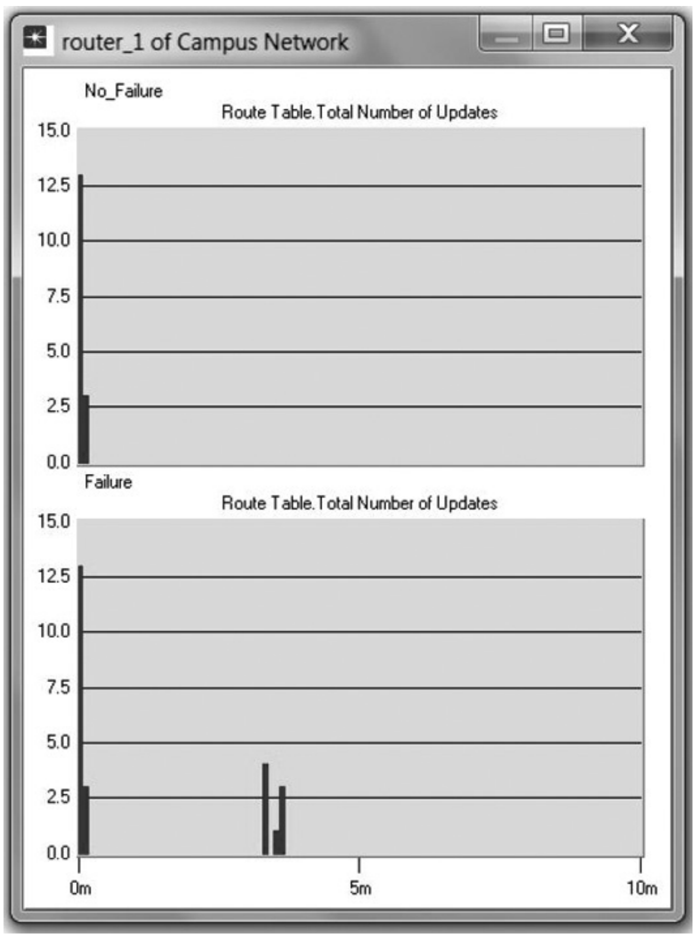
View the Results

Compare the number of updates:

1. Select **Compare Results** from the **Results** menu → From the drop-down menus select **Stacked Statistics** and **Select Scenarios** as shown.



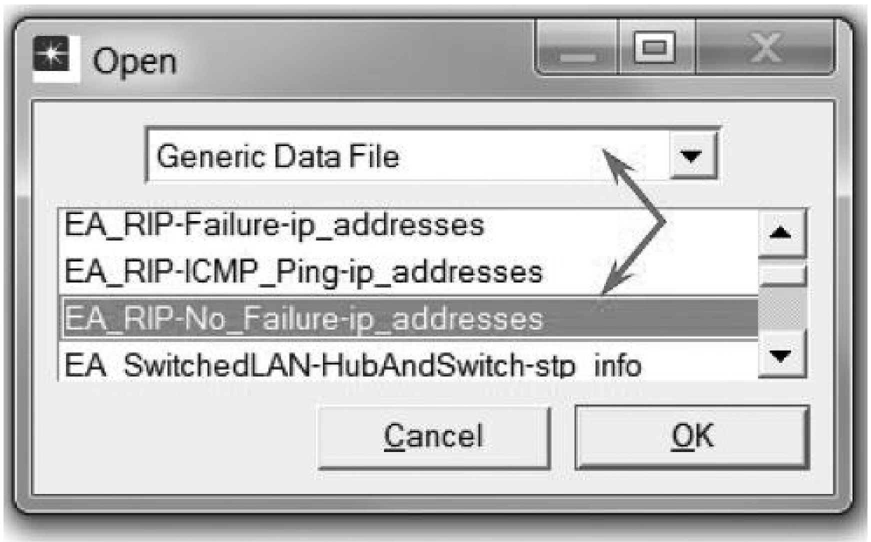
2. Select the **Total Number of Updates** statistic for **router_1** and click **Show** → Select the **NO_Failure** and **Failure** scenarios in the *Select Scenarios* dialog box.
3. You should get two graphs, one for each scenario. Right-click on each graph and select **Draw Style** → **Bar**.
4. The resulting graphs should resemble the following (you can zoom in on the graphs by clicking and dragging a box over the region of interest):



Obtain the IP Addresses of the Interface

Before checking the contents of the routing tables, we need to determine the IP address information for all interfaces in the current network. Recall that these IP addresses are assigned automatically during simulation, and we set the global attribute IP Interface Addressing Mode to export this information to a file.

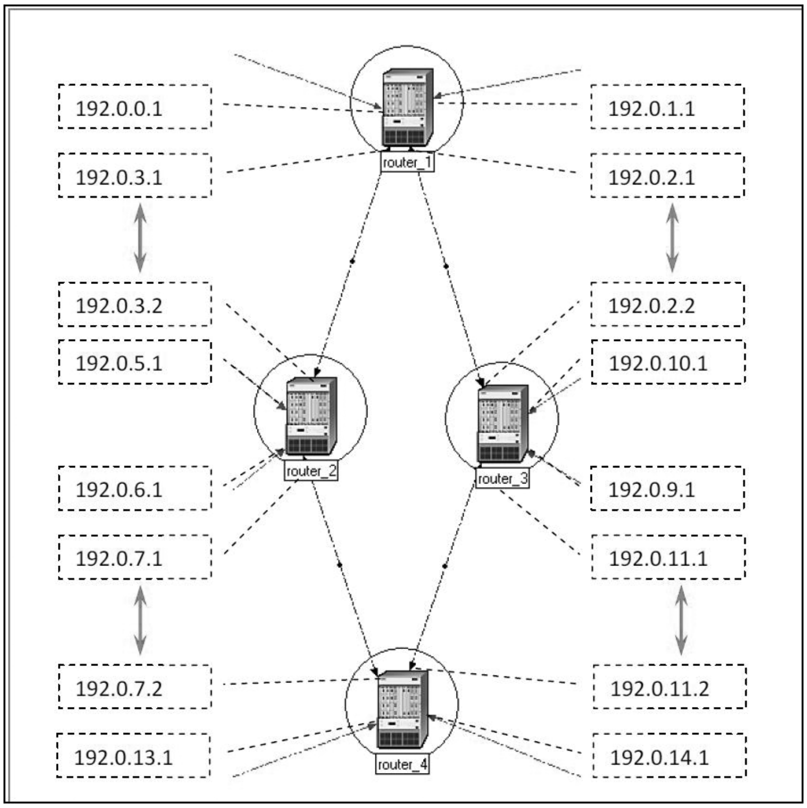
1. From the **File** menu, select **Model Files** → **Refresh Model Directories**. This causes OPNET IT Guru to search the model directories and update its list of files.
2. From the **File** menu, select **Open** → In the top drop-down menu, select **Generic Data File** → Select the **<your initials>_RIP-NO_Failure-ip_addresses** file (the other file created from the Failure scenario should contain the same information) → Click **OK**.



3. The following is a part of the **gdf** file content. It shows the IP addresses assigned to the interfaces of router_1 in our network. For example, the interface of router_1 that is connected to net_11 has the IP address 192.0.0.1. (*Note:* Your result may vary due to different node placement.) The subnet mask associated with that interface indicates that the address of the subnetwork to which the interface is connected is 192.0.0.0 (i.e., the logical AND of the interface IP address and the subnet mask).

```
Node Name: Campus Network.router_1
 Iface Name          Iface Index   IP Address       Subnet Mask      Connected Link
 ----------          -----------   ---------------  ---------------  ----------------
 IF0                 0             192.0.0.1        255.255.255.0    Campus Network.router_1 <-> net_11
 IF1                 1             192.0.1.1        255.255.255.0    Campus Network.router_1 <-> net_12
 IF10                10            192.0.2.1        255.255.255.0    Campus Network.router_1 <-> router_3
 IF11                11            192.0.3.1        255.255.255.0    Campus Network.router_1 <-> router_2
 Loopback            12            192.0.4.1        255.255.255.0    Not connected to any link.
```

4. Print out the layout of the network you implemented in this lab. On this layout and from the information included in the gdf file, write down the IP addresses associated with the interfaces of the four routers as shown in the following diagram. Double-check that the addresses of each subnet agree with the addresses of the interfaces connected to it.



Getting the Ping Report

To check the content of the ping report for router_1:

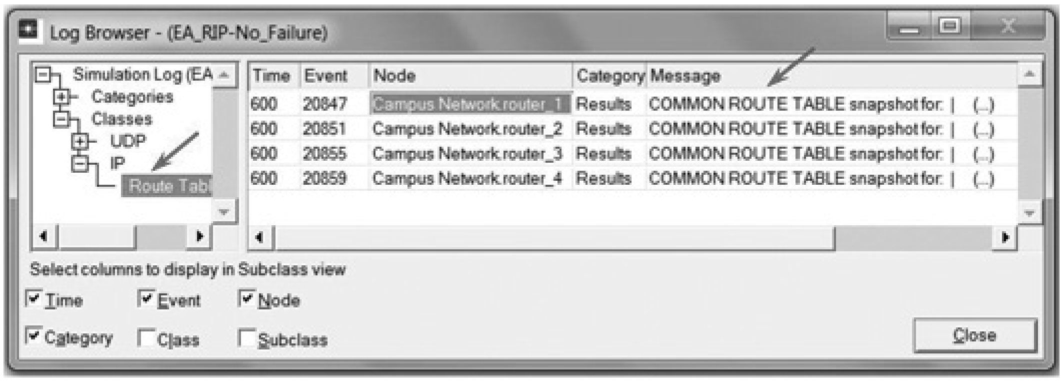
1. Go to the **ICMP_Ping** scenario → Go to the **Results** menu → **Open Simulation Log** → Click on the field **PING REPORT for "Campus Network router_1"** as shown.

```
PING REPORT for "Campus Network.router_1" (192.0.4.1)

DETAILS:
  Received  ICMP echo reply packet for a
  request packet sent to the following node:

    IP Address: 192.0.4.1
    Node Name : Campus Network.router_1

PERFORMANCE:
  Based on the first ICMP echo request packet
  (i.e., a "ping" packet) sent to the above
  node, the following metrics were computed:

    1. Response Time: 0.00025 seconds

    2. List of traversed IP interfaces:

       IP Address        Hop Delay     Node Name
       ----------        ---------     ---------
        192.0.11.2       0.00000      Campus Network.router_4
        192.0.2.2        0.00005      Campus Network.router_3
        192.0.4.1        0.00005      Campus Network.router_1
        192.0.2.1        0.00002      Campus Network.router_1
        192.0.11.1       0.00005      Campus Network.router_3
        192.0.11.2       0.00005      Campus Network.router_4

  Note that the IP addresses shown above represent
  the address of the output interface on which the
  IP datagram was routed from the corresponding
  nodes to the next node enroute to its destination
  and back.
```

Compare the Routing Tables Content

To check the content of the routing tables in router_1 for the NO_Failure and Failure scenarios:

1. Press **Ctrl** + **1** to go to the **NO_Failure** scenario → Go to the **Results** menu → **Open Simulation Log** → Expand the hierarchy on the left as shown in the following figure → Click on the field **COMMON ROUTE TABLE** for **router_1**.



2. Carry out the previous step for the **Failure** scenario. The following are partial contents of router_1's routing table for both scenarios. (*Note:* Your results may vary because of different nodes placement.)

Routing Table of router_1 (NO_Failure scenario)

Router name: Campus Network.router_1
at time: 600.00 seconds

ROUTE TABLE contents:

Dest. Address	Subnet Mask	Next Hop	Interface Name	Metric	Protocol	Insertion Time
192.0.0.0	255.255.255.0	192.0.0.1	IF0	0	Direct	0.000
192.0.1.0	255.255.255.0	192.0.1.1	IF1	0	Direct	0.000
192.0.2.0	255.255.255.0	192.0.2.1	IF10	0	Direct	0.000
192.0.3.0	255.255.255.0	192.0.3.1	IF11	0	Direct	0.000
192.0.4.0	255.255.255.0	192.0.4.1	Loopback	0	Direct	0.000
192.0.5.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.6.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.7.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.8.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.9.0	255.255.255.0	192.0.2.2	IF10	1	RIP	5.000
192.0.10.0	255.255.255.0	192.0.2.2	IF10	1	RIP	5.000
192.0.11.0	255.255.255.0	192.0.2.2	IF10	1	RIP	5.000
192.0.12.0	255.255.255.0	192.0.2.2	IF10	1	RIP	5.000
192.0.13.0	255.255.255.0	192.0.3.2	IF11	2	RIP	7.310
192.0.14.0	255.255.255.0	192.0.3.2	IF11	2	RIP	7.310
192.0.15.0	255.255.255.0	192.0.3.2	IF11	2	RIP	7.310

Loopback interface allows a client and a server on the same host to communicate with each other using TCP/IP.

Routing Table of router_1 (Failure scenario)

Router name: Campus Network.router_1
at time: 600.00 seconds

ROUTE TABLE contents:

Dest. Address	Subnet Mask	Next Hop	Interface Name	Metric	Protocol	Insertion Time
192.0.0.0	255.255.255.0	192.0.0.1	IF0	0	Direct	0.000
192.0.1.0	255.255.255.0	192.0.1.1	IF1	0	Direct	0.000
192.0.2.0	255.255.255.0	192.0.2.1	IF10	0	Direct	0.000
192.0.3.0	255.255.255.0	192.0.3.1	IF11	0	Direct	0.000
192.0.4.0	255.255.255.0	192.0.4.1	Loopback	0	Direct	0.000
192.0.5.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.6.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.7.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.8.0	255.255.255.0	192.0.3.2	IF11	1	RIP	5.000
192.0.13.0	255.255.255.0	192.0.3.2	IF11	2	RIP	7.310
192.0.14.0	255.255.255.0	192.0.3.2	IF11	2	RIP	7.310
192.0.15.0	255.255.255.0	192.0.3.2	IF11	2	RIP	7.310
192.0.11.0	255.255.255.0	192.0.3.2	IF11	2	RIP	215.000
192.0.9.0	255.255.255.0	192.0.3.2	IF11	3	RIP	216.930
192.0.10.0	255.255.255.0	192.0.3.2	IF11	3	RIP	216.930
192.0.12.0	255.255.255.0	192.0.3.2	IF11	3	RIP	216.930

FURTHER READINGS

RIP: IETF RFC number 2453 (www.ietf.org/rfc.html).

ICMP: IETF RFC number 792 (www.ietf.org/rfc.html).

EXERCISES

1. Obtain and analyze the graphs that compare the sent RIP traffic for the **Failure** and **NO_Failure** scenarios. Make sure to change the draw style for the graphs to **Bar**.
2. Describe and explain the effect of the failure of the link connecting **Router1** to **Router2** on the routing tables of **Router1**.
3. Create another scenario as a duplicate of the **Failure** scenario. Name the new scenario **Q3_Recover**. This new scenario has the link connecting **Router1** to **Router2** recover after 400 s. (Make sure to keep the failure that occurs at the 200th second.) Generate and analyze the graph that shows the effect of this recovery on the **Total Number of Updates** in the routing table of **Router1**. Check the contents of **Router1**'s routing table. Compare this table with the corresponding routing tables generated in the **NO_Failure** and **Failure** scenarios.
4. Change the Ping packet size to 5000 bytes. (*Hint:* Edit the attributes of the Ping Parameters node.) Run the simulation to generate a new Ping report. What is the effect of the new size on the ICMP packet response time?

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.