LAB 7

OSPF: Open Shortest Path First

A Routing Protocol Based on the Link-State Algorithm

OBJECTIVES

The objective of this lab is to configure and analyze the performance of the Open Shortest Path First (OSPF) routing protocol.

OVERVIEW

In the RIP lab, we discussed a routing protocol that is the canonical example of a routing protocol built on 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. Link-state routing is the second major class of intradomain routing protocol. The basic idea behind link-state protocols is very simple: Every node knows how to reach its directly connected neighbors, and if we make sure that the totality of this knowledge is disseminated to every node, then every node will have enough knowledge of the network to build a complete map of the network.

Once a given node has a complete map for the topology of the network, it is able to decide the best route to each destination. Calculating those routes is based on a well-known algorithm from graph theory—Dijkstra's shortest-path algorithm.

OSPF introduces another layer of hierarchy into routing by allowing a domain to be partitioned into areas. This means that a router within a domain does not necessarily need to know how to reach every network within that domain; it may be sufficient for it to know how to get to the right area. Thus, there is a reduction in the amount of information that must be transmitted to and stored in each node. In addition, OSPF allows multiple routes to the same destination to be assigned the same cost and causes traffic to be distributed evenly over those routers.

In this lab, you will set up a network that utilizes OSPF as its routing protocol. You will analyze the routing tables generated in the routers and will observe how the resulting routes are affected by assigning areas and enabling load balancing.

PRE-LAB ACTIVITIES

- Read Section 3.3.3 from *Computer Networks: A Systems Approach, 5th Edition*.
- Go to www.net-seal.net and play the following animation:
  - 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>_OSPF**, and the scenario **No_Areas** → Click **OK**.
3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty Scenario** is selected → Click **Next** → Select **Campus** from the *Network Scale* list → Click **Next** three times → Click **OK**.

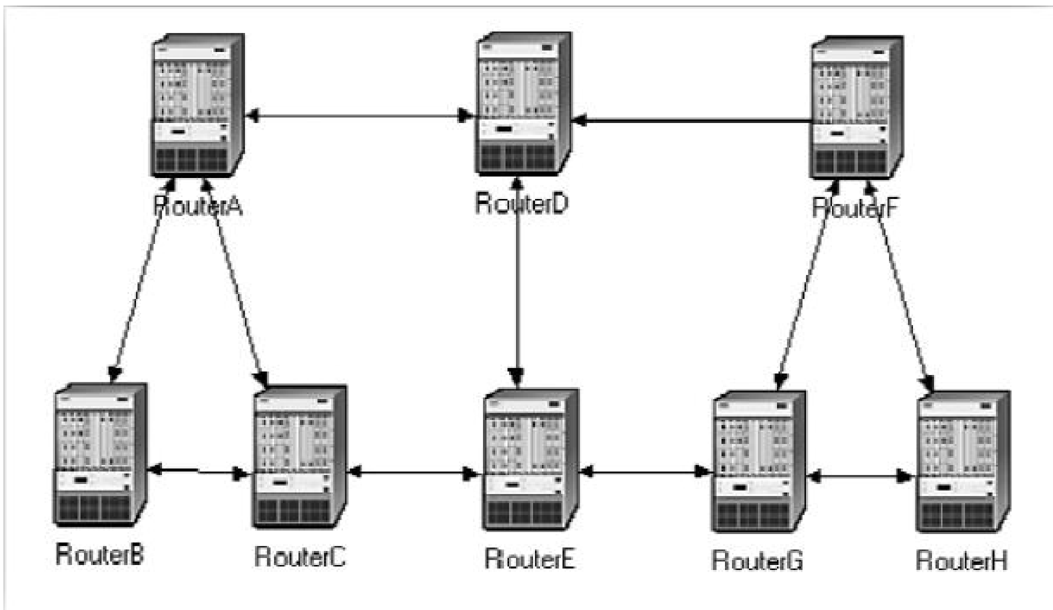
Create and Configure the Network

Initialize the network:

The **slip8_gtwy** node model represents an IP-based gateway supporting up to eight serial line interfaces at a selectable data rate. The RIP or OSPF protocols may be used to automatically and dynamically create the gateway's routing tables and select routes in an adaptive manner.

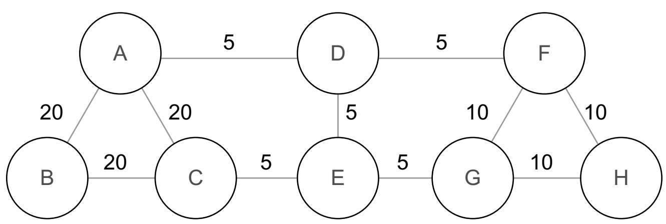
The **PPP_DS3** link has a data rate of 44.736 Mbps.

1. The *Object Palette* dialog box should now be on top of your project workspace. If it is not there, open it by clicking . Select the **routers** item from the pull-down menu on the top of the object palette.
   a. Add to the project workspace eight routers of type **slip8_gtwy**. To add an object from a palette, click its icon in the object palette → Move your mouse to the workspace, and click to place the object → Right-click when you are finished placing the last object.
2. Select the **internet_toolbox** item from the pull-down menu on the top of the object palette. Use the **PPP_DS3** links to connect the routers. Rename the routers as shown → Close the *Object Palette*.



Configure the Link Costs

We need to assign link costs to match the following figure:



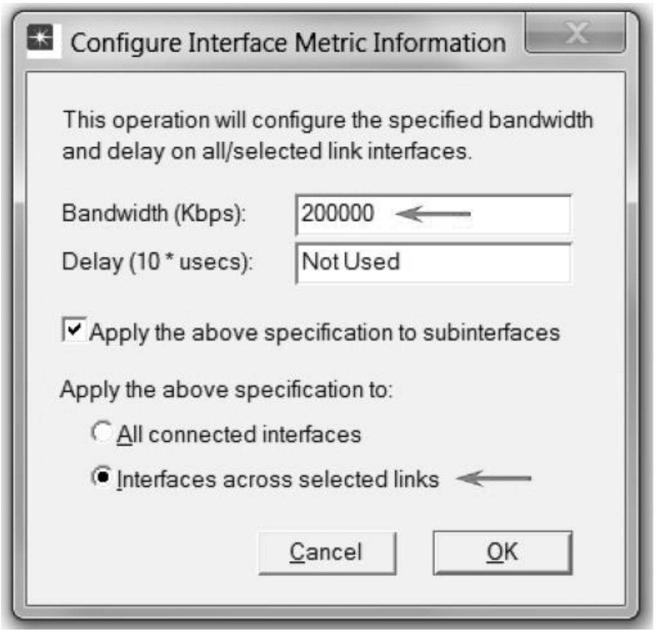
Like many popular commercial routers, OPNET router models support a parameter called a *reference bandwidth* to calculate the actual cost, as follows:

Cost = (Reference bandwidth) / (Link bandwidth)

where the default value of the *reference bandwidth* is 1,000,000 Kbps.

For example, to assign a cost of 5 to a link, assign a bandwidth of 200,000 Kbps to that link. This is not the actual bandwidth of the link in the sense of transmission speed, but merely a parameter used to configure link costs. To assign the costs to the links of our network, do the following:

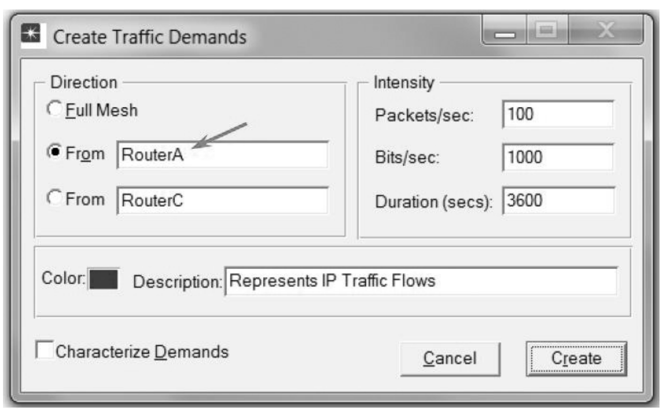
1. Select all links in your network that correspond to the links with a cost of 5 in the preceding graph by shift-clicking on them.
2. Select the **Protocols** menu → **IP** → **Routing** → **Configure Interface Metric Information**.



3. Assign **200000** to the **Bandwidth (Kbps)** field → Check the **Interfaces across selected links** radio button, as shown → Click **OK**.
4. Repeat for all links with a cost of 10 but assign **100000** to the **Bandwidth (Kbps)** field.
5. Repeat for all links with a cost of 20 but assign **50000** to the **Bandwidth (Kbps)** field.
6. **Save** your project.

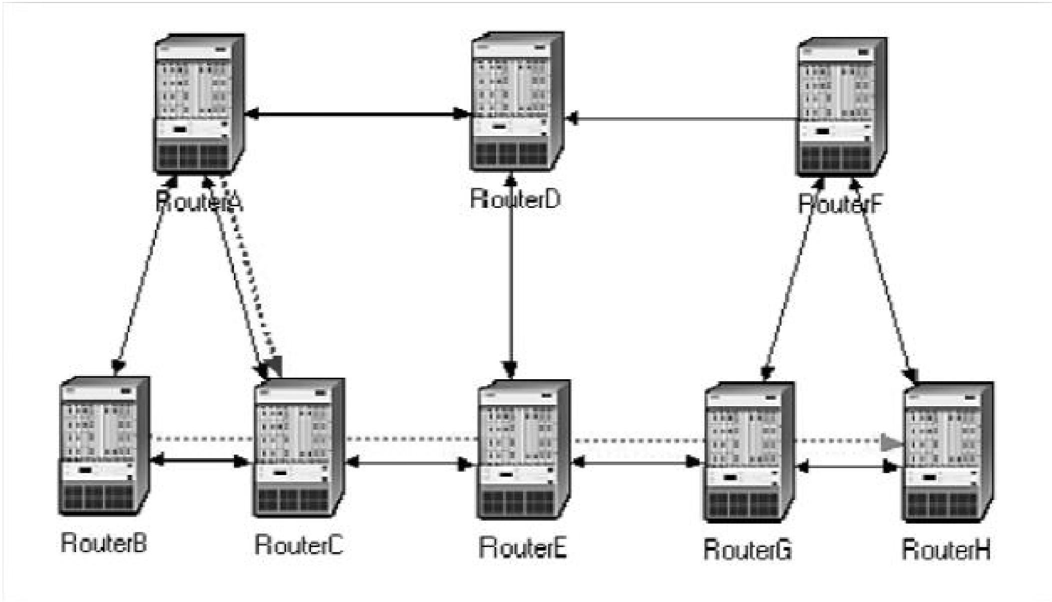
Configure the Traffic Demands

1. Select both **RouterA** and **RouterC** by shift-clicking on them.
   a. Select the **Protocols** menu → **IP** → **Demands** → **Create Traffic Demands** → Check the **From RouterA** radio button as shown → Keep the color as **blue** → Click **Create**. Now you should see a blue dotted line representing the traffic demand between **RouterA** and **RouterC**.



2. Select both **RouterB** and **RouterH** by shift-clicking on them.
   a. Select the **Protocols** menu → **IP** → **Demands** → **Create Traffic Demands** → Check the **From RouterB** radio button → Change the color to **red** → Click **OK** → Click **Create**.

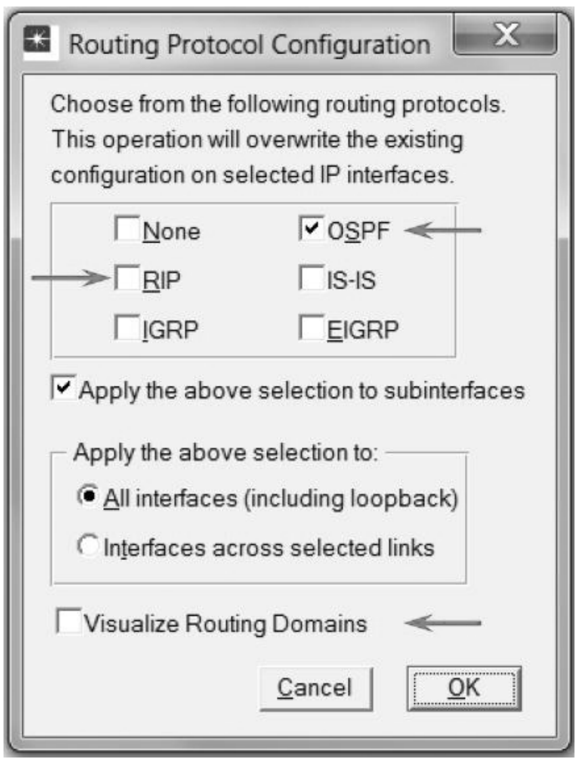
Now you can see the lines representing the traffic demands as shown.



3. To hide these lines: Select the **View** menu → Select **Demand Objects** → Select **Hide All**.

Configure the Routing Protocol and Addresses

1. Select the **Protocols** menu → **IP** → **Routing** → **Configure Routing Protocols**.
2. Check the **OSPF** check box → Uncheck the **RIP** check box → Uncheck the **Visualize Routing Domains** check box, as shown:



3. Click **OK**.
4. Select **RouterA** and **RouterB** only → Select the **Protocols** menu → **IP** → **Routing** → Select **Export Routing Table for Selected Routers** → Click **OK** on the *Status Confirm* dialog box.
5. Select the **Protocols** menu → **IP** → **Addressing** → Select **Auto-Assign IP Addresses**.
6. **Save** your project.

Auto-Assign IP Addresses assigns a unique IP address to connected IP interfaces whose IP address is currently set to auto assigned. It does not change the value of manually set IP addresses.

Configure the Simulation

Here we need to configure some of the simulation parameters:

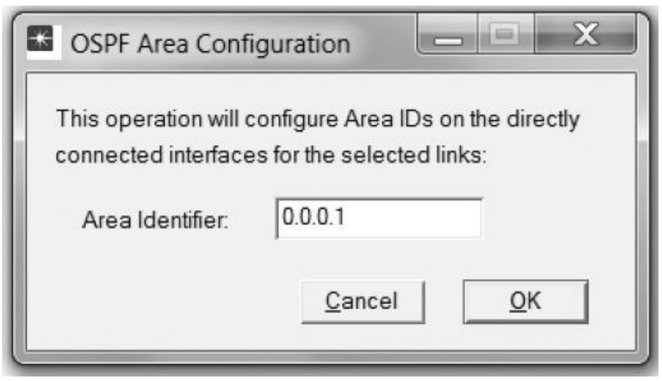
1. Click on  and the *Configure Simulation* window should appear.
2. Set the duration to **10.0 minutes**.
3. Click **OK** and **Save** your project.

Duplicate the Scenario

In the network we just created, all routers belong to one level of hierarchy (i.e., one area). Also, we did not enforce load balancing for any routes. Two new scenarios will be created. The first new scenario will define two new areas in addition to the backbone area. The second one will be configured to balance the load for the traffic demands between **RouterB** and **RouterH**.

THE AREAS SCENARIO

1. Select **Duplicate Scenario** from the **Scenarios** menu, and give it the name **Areas** → Click **OK**.
2. Creating Area 0.0.0.1:
   a. Select the three links that connect **RouterA**, **RouterB**, and **RouterC** by shift-clicking on them → Select the **Protocols** menu → **OSPF** → **Configure Areas** → Assign the value **0.0.0.1** to the **Area Identifier**, as shown → Click **OK**.

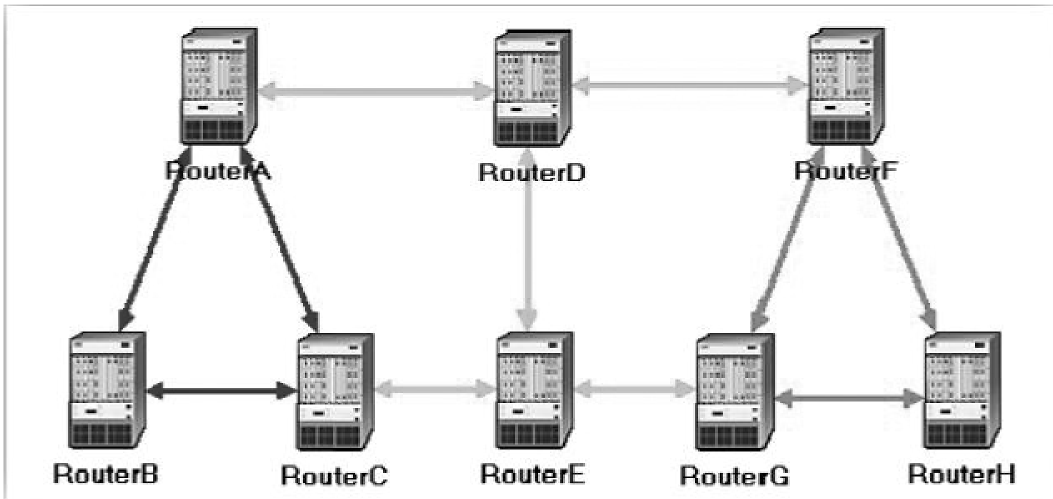


   b. Right-click on **RouterC** → **Edit Attributes** → Expand the **OSPF Parameters** hierarchy → Expand the **Loopback Interfaces** hierarchy → Expand the **row0** hierarchy → Assign **0.0.0.1** to the value of the **Area ID** attribute → Click **OK**.
3. Creating Area 0.0.0.2:
   a. Click somewhere in the project workspace to disable the selected links, and then repeat Step 2a for the three links that connect **RouterF**, **RouterG**, and **RouterH** but assign the value **0.0.0.2** to their **Area Identifier**.
4. To visualize the areas we just created, select the **Protocols** menu → **OSPF** → **Visualize Areas** → Click **OK**. The network should look like the following one with different colors assigned to each area (you may get different colors, though).

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

Note:

- The area you did not configure is the backbone area with **Area Identifier** = 0.0.0.0.
- The figure shows the links with a thickness of 3.



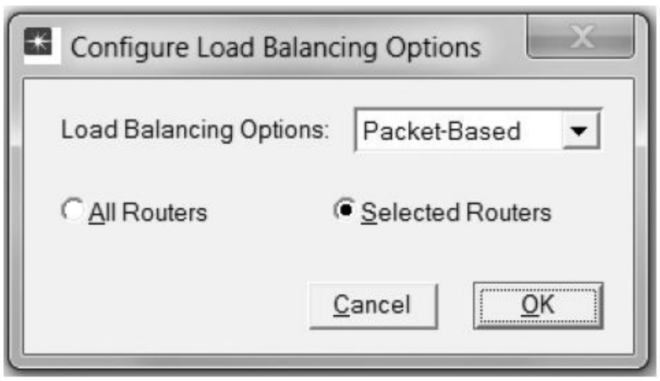
THE BALANCED SCENARIO

1. Under the **Scenarios** menu, **Switch to Scenario** → Select **No_Areas**.
2. Select **Duplicate Scenario** from the **Scenarios** menu and give it the name **Balanced** → Click **OK**.
3. In the new scenario, select both **RouterB** and **RouterH** by shift-clicking on them.
4. Select the **Protocols** menu → **IP** → **Routing** → **Configure Load Balancing Options** → Make sure that the option is **Packet-Based** and the radio button **Selected Routers** is selected as shown → Click **OK**.

OPNET provides two types of IP load balancing:

With **Destination Based**, load balancing is done on a per-destination basis. The route chosen from the source router to the destination network is the same for all packets.

With **Packet Based**, load balancing is done on a per-packet basis. The route chosen from the source router to the destination network is redetermined for every individual packet.

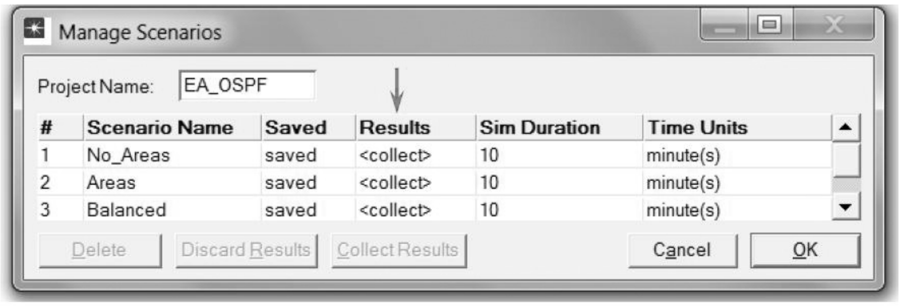


5. **Save** your project.

Run the Simulation

To run the simulation for the three scenarios simultaneously:

1. Go to the **Scenarios** menu → Select **Manage Scenarios**.
2. Click on the row of each scenario, and click the **Collect Results** button. This should change the values under the **Results** column to <**collect**> as shown.

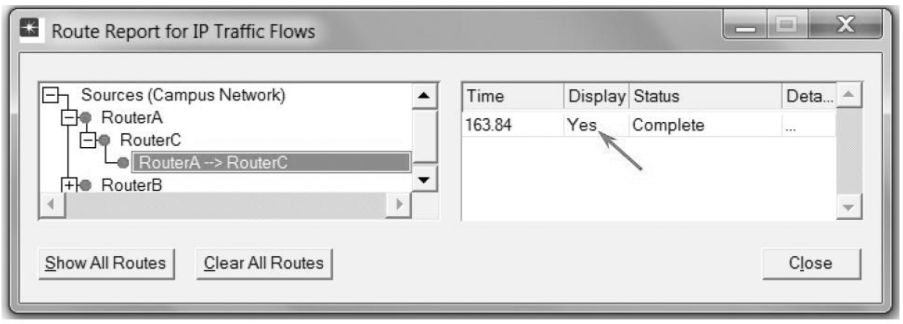


3. Click **OK** to run the three simulations. Depending on the speed of your processor, this task may take several seconds to complete.
4. After the three simulation runs complete, one for each scenario, click **Close**, and then **save** your project.

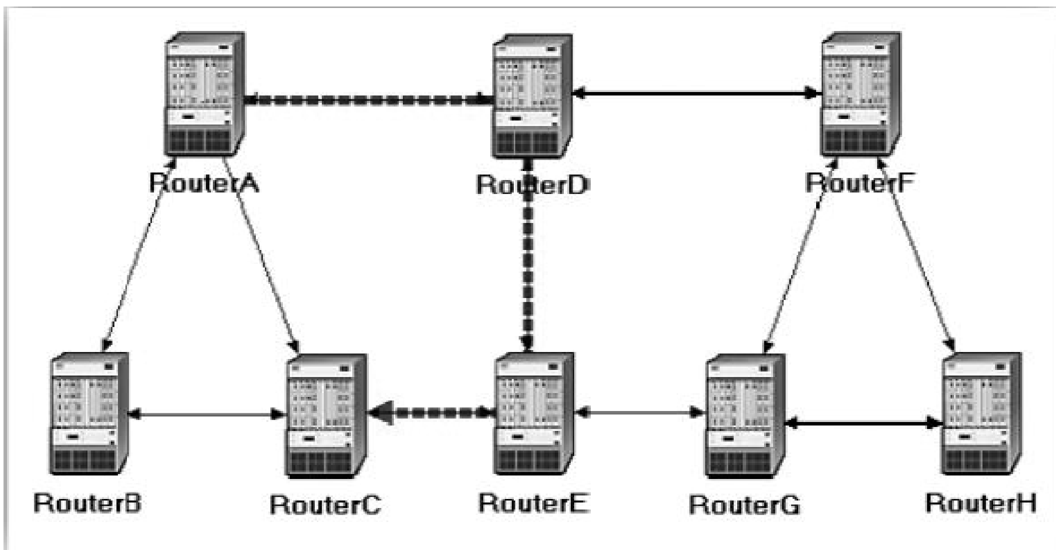
View the Results

THE NO_AREAS SCENARIO

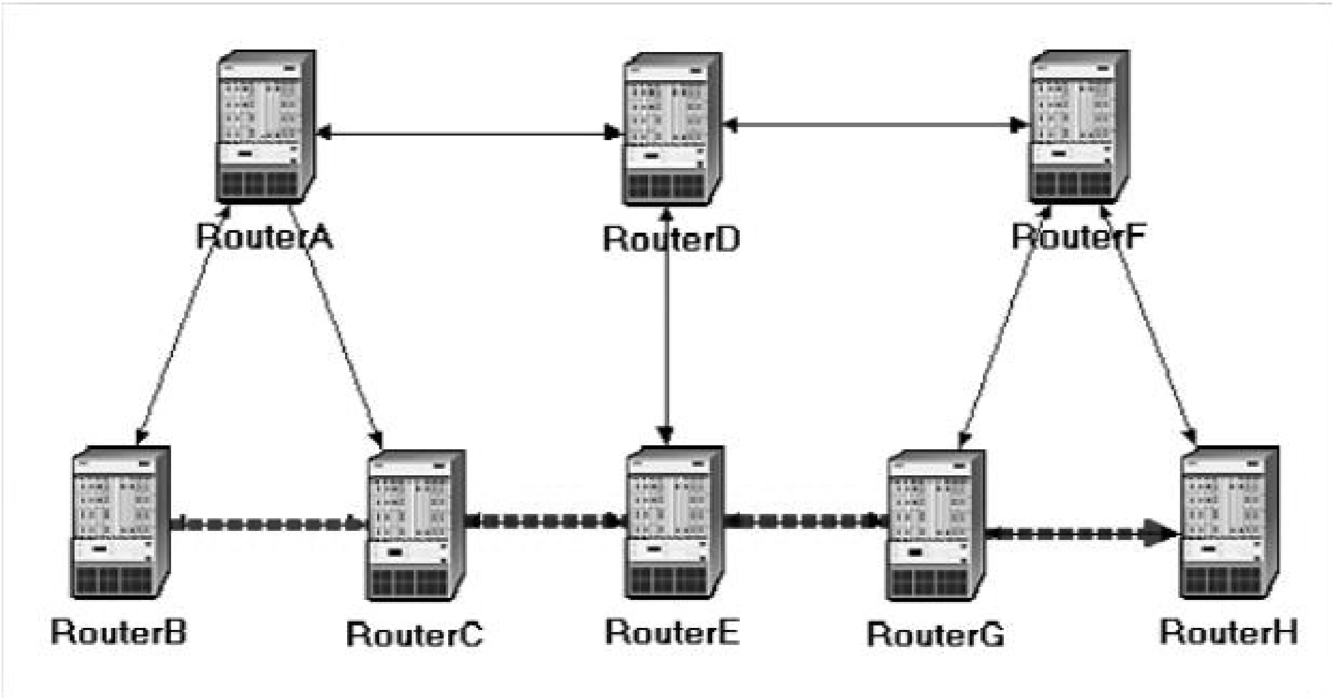
1. Go back to the **No_Areas** scenario.
2. To display the route for the traffic demand between **RouterA** and **RouterC**: Select the **Protocols** menu → **IP** → **Demands** → **Display Routes for Configured Demands** → Expand the hierarchies as shown and select **RouterA** → **RouterC** → Go to the **Display** column and pick **Yes** → Click **Close**.



3. The resulting route will appear on the network as shown:

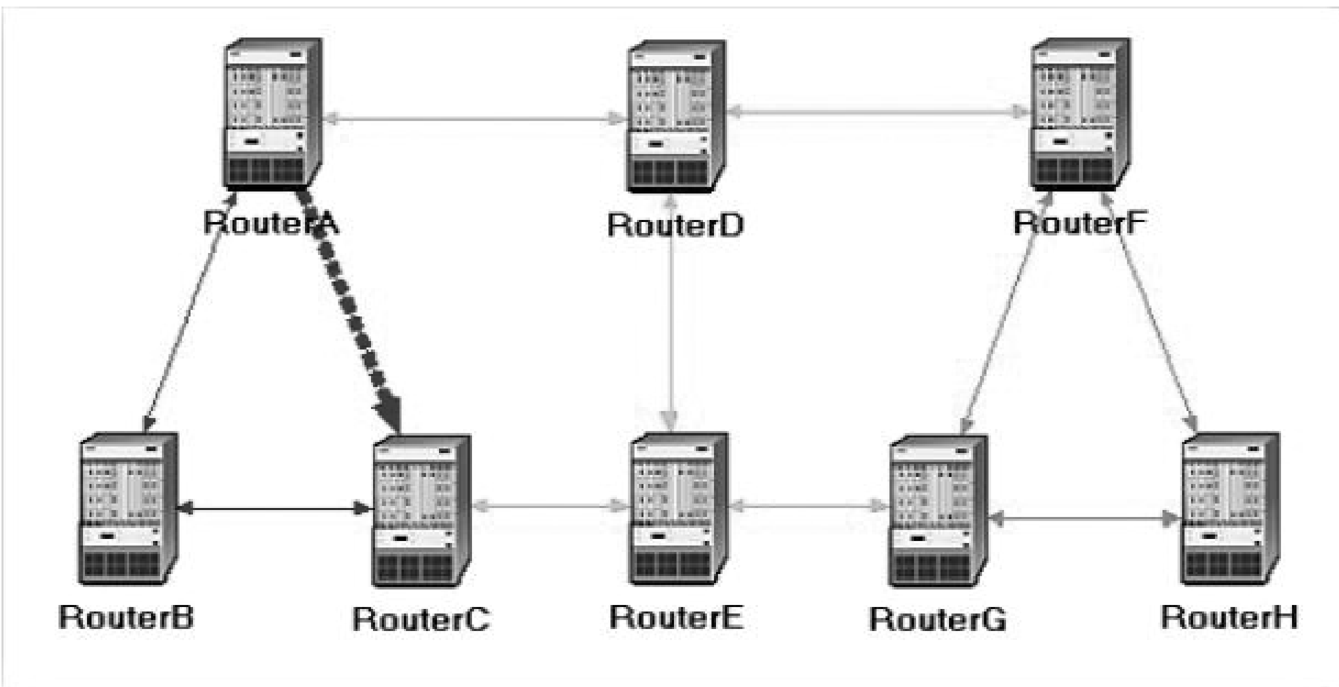


4. Repeat Step 2 to show the route for the traffic demand between **RouterB** and **RouterH**. The route is as shown in the following diagram. (*Note:* Depending on the order in which you created the network topology, the other "equal-cost" path can be used, that is, the *RouterB–RouterA–RouterD–RouterF–RouterH* path).



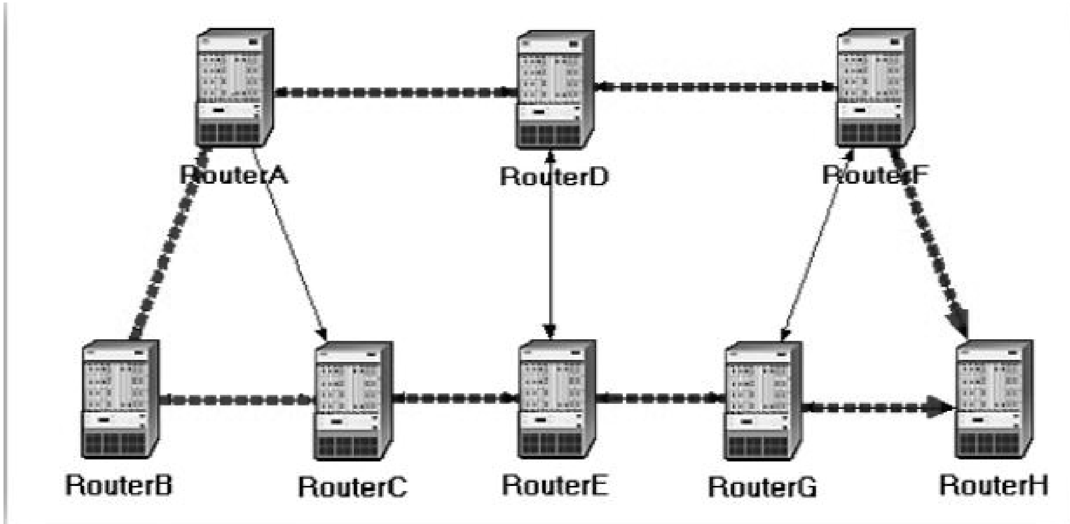
THE AREAS SCENARIO

1. Go to **Areas** scenario.
2. Display the route for the traffic demand between **RouterA** and **RouterC**. The route is as shown here:



THE BALANCED SCENARIO

1. Go to scenario **Balanced**.
2. Display the route for the traffic demand between **RouterB** and **RouterH**. The route is as shown here:



3. **Save** your project.

FURTHER READINGS

OPNET OSPF Model Description: From the **Protocols** menu, select **OSPF → Model Usage Guide**.

OSPF: IETF RFC number 2328 (www.ietf.org/rfc.html).

EXERCISES

1. Explain why, for the same pair of routers, the **Areas** and **Balanced** scenarios result in different routes than those observed in the **No_Areas** scenario.
2. Using the simulation log, examine the generated routing table in **RouterA** for each one of the three scenarios. Explain the values assigned to the *Metric* column of each route.

Hints:

- Refer to the "View Results" section in Lab 6 for information about examining the routing tables. You will need to set the global attribute **IP Interface Addressing Mode** to the value **Auto Addressed/Export** and rerun the simulation.
- To determine the IP address information for all interfaces, you need to open the *Generic Data File* that contains the IP addresses associated with the scenarios.

3. OPNET allows you to examine the link-state database that is used by each router to build the directed graph of the network. Examine this database for **RouterA** in the **No_Areas** scenario. Show how **RouterA** utilizes this database to create a map for the topology of the network, and draw this map. (This is the map that the router will use later to create its routing table.)

Note: A stub network only carries local traffic (i.e., packets to and from local hosts). Even if it has paths to more than one other network, it does not carry traffic for other networks (RFC 1983).

Hints:

- To export the link-state database of a router, **Edit** the attributes of the router, and set the **Link State Database Export** parameter (one of the **OSPF Parameters**, under **Processes**) to **Once at End of Simulation**.

- You will need to set the global attribute **IP Interface Addressing Mode** to the value **Auto Addressed/Export**. This will allow you to check the automatically assigned IP addresses to the interfaces of the network. (Refer to the notes of Exercise 2.)
- After rerunning the simulation, you can check the link-state database by opening the simulation log (from the **Results** menu). The link-state database is available in **Classes** → **OSPF** → **LSDB_Export**.

4. Create another scenario as a duplicate of the **No_Areas** scenario. Name the new scenario **Q4_No_Areas_Failure**. In this new scenario, simulate a failure of the link connecting **RouterD** and **RotuerE**. Have this failure start after 100 s. Rerun the simulation. Show how that link failure affects the content of the link-state database and routing table of **RouterA**. (You will need to disable the global attribute **OSPF Sim Efficiency**. This will allow OSPF to update the routing table if there is any change in the network.)
5. For both **No_Areas** and **Q4_No_Areas_Failure** scenarios, collect the **Traffic Sent (bits/sec)** statistic (one of the **Global Statistics** under **OSPF**). Rerun the simulation for these two scenarios and obtain the graph that compares the OSPF's **Traffic Sent (bits/sec)** in both scenarios. Comment on the obtained graph.

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.