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

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:

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:

$$\text{Cost} = \frac{\text{Reference bandwidth}}{\text{Link bandwidth}}$$

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**

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.

**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).

**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.

**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.
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.


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.)

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.

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).
● 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 RouterE. 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.