Laboratory 6

Objective
The purpose of this lab is to demonstrate the behavior of OSPF routing protocol.

Overview
In this lab we will study the OSPF routing protocol. The objective is to construct a network and configure it with all the necessary parameters for OSPF routing. Using this network we will analyze the behavior of the OSPF routing protocol.

Procedure
The Open Shortest Path First (OSPF) protocol is an interior gateway protocol (IGP) used for routing in Internet Protocol (IP) networks. As a link state routing protocol, OSPF is more robust against network topology changes than distance vector protocols such as RIP, IGRP, and EIGRP. OSPF can be used to build large scale networks consisting of hundreds or thousands of routers.

Open Shortest Path First (OSPF) uses the Dijkstra’s algorithm to compute the shortest path to a destination. The algorithm calculates the shortest path to each destination based on the cumulative cost required to reach that destination. The cumulative cost is a function of the cost of the various interfaces needed to be traversed in order to reach that destination.

The cost (or the metric) of an interface in OSPF is an indication of the overhead required to send packets across that interface. The cost of an interface is calculated based on the bandwidth -- it is inversely proportional to the bandwidth of that specific interface (i.e., a higher bandwidth indicates a lower cost). For example, the cost of a T1 interface is much higher than the cost of a 100Mbit Ethernet interface because there is more overhead (e.g., time delays) involved in crossing a T1 interface.

Characteristic features of OSPF
- Link State Based
- Runs directly over IP
- Interior or border gateway protocol
- Multiple paths to each destination. ➔ Load balancing.
- Link-attribute based costing. ➔ Costing is statically assigned.
Create the network

1. Start OPNET and create a new project. File ➔ New… and choose Project.
2. Name the project <initials>_OSPF and the scenario NoAreas. Click OK.
3. Select Create empty scenario and click next.
4. Select Office and click next.
5. Set X Span to 200 and Y Span to 200. Click next.
6. Do not include any technologies and click next.
7. Review the values and click OK.
8. Open the Object palette and change the palette to routers.

9. Click OK.
10. Place ten slip8_gtwy’s in the workspace as in figure 3.
11. Change the object palette to internet_toolbox.

12. Connect all the routers using PPP_DS3 link as in figure 3.
13. Rename all the routers as in *figure 3*. Right click on each router and select Set Name from the pop up menu.

*Figure 3 - Network overview*
Configure router interfaces

We need to designate the interfaces of all routers that use the OSPF protocol. By default, RIP is used on every router interface.

There are three ways to configure router interfaces to use a particular set of routing protocols:

<table>
<thead>
<tr>
<th>Method</th>
<th>Characteristics</th>
<th>When to Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocols ➔ IP ➔ Routing ➔ Configure Routing Protocols… menu operation</td>
<td>• Any number of interfaces can be configured at the same time • Overwrites the IP Routing Parameters ➔ Interface Information ➔ Routing Parameters attribute • Multiple routing protocols can be specified.</td>
<td>In most cases.</td>
</tr>
<tr>
<td>IP Routing Parameters ➔ Interface Information ➔ Routing Protocols</td>
<td>Only one interface can be configured at a time.</td>
<td>When one wants to add a protocol to those already designated on a particular interface.</td>
</tr>
<tr>
<td>IP Dynamic Routing Protocol simulation attribute</td>
<td>• Does not modify router attributes • Overrides the routing protocols configured on the router interfaces for the duration of the simulation • One routing protocol used on all interfaces • When this attribute is set to “Default,” the protocols specified on the router interfaces are used.</td>
<td>You have configured the routing protocols in your network but want to see the effects of running a single protocol throughout the network.</td>
</tr>
</tbody>
</table>

The easiest way to designate routing protocols is the Configure Routing Protocols operation from the Protocols ➔ IP ➔ Routing menu. This operation has the same effect as manually setting the interface routing protocol attributes, but with the added advantage of being able to configure multiple interfaces at the same time. *The previous setting on the interface is overwritten each time this operation is used.*

2. Check the **OSPF** check box. *Figure 4.*
3. Select the **All interfaces** radio button. *Figure 4.*

![Routing Protocol Configuration dialog](image)

*Figure 4 - Configure routing protocols dialog*

4. Save the project.
A **Routing Domain Legend** appears in the bottom left corner on the workspace. All links should have a green O attached to it. This indicates that **OSPF routing protocol** is used over that link. *Figure 5.*

![Routing Domain Legend and Link indication](image)

*Figure 5 - Routing Domain Legend and Link indication*

**Assign addresses to the router interfaces.**

The **Protocols ➔ IP ➔ Addressing ➔ Auto-Assign IP Addresses** operation assigns a unique IP address to the connected IP interfaces whose IP address is currently set to auto-assigned. This operation does not change the value of manually set IP addresses.

1. Use the **Protocols ➔ IP ➔ Addressing ➔ Auto-Assign IP Addresses**.

The message **Assignes 40 IP addresses** appear in the status bar. *Figure 6.*

![Assigned 40 IP addresses](image)

*Figure 6 - Status bar*
Configure routing cost

Cost is specified on a per interface basis and is used as the basis for the shortest path route calculation.

There are two ways of setting this Cost attribute for each interface.

A. **Per-interface:** The interface information table is located by right clicking on a router and selecting the *Edit attributes* option. Figure 7. One can manually specify the cost of an interface by editing the value with the desired cost setting. For example, the default value of *Auto Calculate* can be over-written by any positive integer cost value: When set to *Auto Calculate*, the formula used to calculate the cost is based on the interface speed and another configurable attribute called **Reference Bandwidth:**

\[
\text{Interface Cost} = \frac{\text{Reference Bandwidth}}{\text{Interface Bandwidth}}
\]

*Note: The default value for Reference Bandwidth is 1000 Mbps; therefore, it will cost \(1,000,000,000/100,000,000 = 10\) to traverse a 100Mbps Ethernet interface and it will cost \(1,000,000,000/1,544,000 = 647\) to cross a T1 serial line interface. The default for Interface Bandwidth is computed dynamically using the data rate of the connected interface. It can be over-written by using the Bandwidth setting in the Protocols → IP → Routing → Configure Interface Metric Information table.*

![Figure 7 - Router attributes](image)
B. **Globally for all interfaces:** If wanted to change the interface cost across all interfaces, then, rather than individually setting them on each interface, one can use the model-wide cost configuration option using the following menu option: **Protocols ➔ OSPF ➔ Configure Interface Cost.** This operation will allow for choosing one of the following two cost configuration options:

B1) The **Reference Bandwidth** will be set for all routers. All interfaces will be set with a cost value of **Auto Calculate.**

B2) All interfaces will be set with the specified cost value. The interface/bandwidth settings will be ignored.

![OSPF Interface Cost Configuration dialog](image)

**Figure 8 - OSPF Interface Cost Configuration dialog**

In this lab we use different bandwidths on the links to set different **costs**.

1. Select the links between:
   - **Router A** ➔ **Router B**
   - **Router B** ➔ **Router D**
   - **Router D** ➔ **Router C**
   - **Router C** ➔ **Router A**
   - **Router B** ➔ **Router C**
   by shift clicking on them.

2. Open the Configure Interface Metric Information dialog. **Protocols ➔ IP ➔ Routing ➔ Configure Interface Metric Information.**

3. Set the **Bandwidth** value to **5000 kbps.**

4. Select **Interfaces across selected links** radio button. Click **OK.**

5. Select the links between:
   - **Router B** ➔ **Router E**
   - **Router E** ➔ **Router G**
   - **Router I** ➔ **Router F**
   - **Router F** ➔ **Router D**
   - **Router E** ➔ **Router F**
   by shift clicking on them.

7. Set the Bandwidth value to 20000 kbps.

8. Select Interfaces across selected links radio button. Click OK.

9. Select the links between:
   - Router G ↔ Router H
   - Router H ↔ Router J
   - Router J ↔ Router I
   - Router I ↔ Router G
   - Router G ↔ Router J
   by shift clicking on them.


11. Set the Bandwidth value to 10000 kbps.

12. Select Interfaces across selected links radio button. Click OK.

13. Save the project.

The cost configuration looks as in *figure 9*:

![Figure 9 - Cost overview](image)
Configure the traffic demands
1. Select both Router B and Router D by shift clicking on them.
2. Open the Create traffic demands menu. Protocols ➔ IP ➔ Demands ➔ Create Traffic Demands…
3. Select From Router B radio button.
4. Click Create.
5. Select both Router C and Router J by shift clicking on them.
6. Open the Create traffic demands menu. Protocols ➔ IP ➔ Demands ➔ Create Traffic Demands…
7. Select From Router C radio button.
8. Click Create.

The paths of the traffic demands are now visible. To hide them select View ➔ Demand Objects ➔ Hide All.

Configure Simulation
1. Open the Configure Discrete Event Simulation dialog.
2. Set duration to 10 minutes.
3. Click OK.
4. Save the project.

Duplicate the scenario
In the scenario just created all routers belong to the same level of hierarchy, i.e., one area. No load balancing where enforced for any routers. Two new scenarios will be created to implement areas and load balancing.

Areas scenario
The major addition in OSPF configuration, relative to other protocols, is that the OSPF routing domain can be divided into smaller segments called areas. This reduces memory and computational load on the routers. Each area is numbered and there must always be an area zero, which is the backbone. All other areas attach to the backbone either directly or via virtual links. An area should contain no more than about 50-100 routers for optimum performance. A router that connects to more than one area is called an Area Border Router (ABR).

1. Duplicate the scenario. Scenarios ➔ Duplicate scenario…
2. Name the scenario Areas.

Partition the network into areas. This is a physical partitioning in the sense that an interface can belong to only one area. The distinct interfaces of the same router may still belong to separate areas.
3. Select the links between:
   - Router A ↔ Router B
   - Router B ↔ Router D
   - Router D ↔ Router C
   - Router C ↔ Router A
   - Router B ↔ Router C
   by shift clicking on them.

4. Open the OSPF Area Configuration dialog. Protocols ➔ OSPF ➔ Configure Areas.

5. Set the value 1 to Area Identifier.

6. Click OK.

7. Select the links between:
   - Router B ↔ Router E
   - Router E ↔ Router G
   - Router I ↔ Router F
   - Router F ↔ Router D
   - Router E ↔ Router F
   by shift clicking on them.

8. Open the OSPF Area Configuration dialog. Protocols ➔ OSPF ➔ Configure Areas.

9. Set the value 0 to Area Identifier.

10. Click OK.

11. Select the links between:
    - Router G ↔ Router H
    - Router H ↔ Router J
    - Router J ↔ Router I
    - Router I ↔ Router G
    - Router G ↔ Router J
    by shift clicking on them.

12. Open the OSPF Area Configuration dialog. Protocols ➔ OSPF ➔ Configure Areas.

13. Set the value 2 to Area Identifier.

14. Click OK.

15. Visualize the areas. Protocols ➔ OSPF ➔ Visualize Areas...

16. Click OK in the pop-up dialog.

17. Save the project.

The areas are visualized in different colors.

**Balanced Scenario**

Load balancing is a concept that allows a router to take advantage of multiple best paths (routes) to a given destination. If two routes to the same destination have the same cost, the traffic will be distributed half to each.
1. Go back to the **NoAreas** scenario. Scenarios ➔ Switch To Scenario ➔ **NoAreas**.
2. Duplicate the scenario. Scenarios ➔ Duplicate scenario…
3. Name the scenario **Balanced**.
4. Select both **Router C** and **Router J** by shit clicking on them.
5. Open the **Configure Load Balancing Option** dialog. Protocols ➔ IP ➔ Routing ➔ **Configure Load Balancing Option**.
6. Select **Packet based** in the roll-down menu.
7. Select the **Selected Routers** radio button.
8. Click **OK**.
9. Save the project.

![Configure Load Balancing Option dialog](image)

**Figure 10 - Configure Load Balancing Option dialog**

**Run the simulation**

1. Open the **Manage Scenarios** dialog. Scenarios ➔ Manage Scenarios…
2. Click in the **Results** column on the **NoAreas** row and click the **collect** button.
3. Set the scenarios **Area** and **Balanced** to **collect results**. Repeat the previous step.

<table>
<thead>
<tr>
<th>#</th>
<th>Scenario Name</th>
<th>Saved</th>
<th>Results</th>
<th>Sim Duration</th>
<th>Time Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NoAreas</td>
<td>saved</td>
<td>&lt;collect&gt;</td>
<td>1.0</td>
<td>hou(s)</td>
</tr>
<tr>
<td>2</td>
<td>Areas</td>
<td>saved</td>
<td>&lt;collect&gt;</td>
<td>1.0</td>
<td>hou(s)</td>
</tr>
<tr>
<td>3</td>
<td>Balanced</td>
<td>saved</td>
<td>&lt;collect&gt;</td>
<td>1.0</td>
<td>hou(s)</td>
</tr>
</tbody>
</table>

**Figure 11 - Manage Results dialog**

4. Click **OK** to run the simulation.
5. Click **Close** when the simulation has finished.
View the results

**NoAreas scenario**

1. Switch to the NoAreas scenario. Scenarios ➔ Switch to Scenario ➔ NoAreas.
3. Expand Sources ➔ Router B ➔ Router D.
4. Select **Router B ➔ Router D**.
5. Change the Display attribute to Yes. *Figure 12.*

![Figure 12 - Route Report for IP Traffic Flows dialog](image1)

The traffic flow should look like *figure 13*.

![Figure 13 – NoAreas scenario. Router B ➔ Router D traffic flow](image2)
6. Change the **Display** attribute for **Router B → Router D** to **No**.
7. Expand **Sources → Router C → Router J**.
8. Select **Router C → Router J**.
9. Change the **Display** attribute to **Yes**. *Figure 14.*

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**Figure 14** - Route Report for IP Traffic Flows dialog

The traffic flow should look like *figure 13.*

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**Figure 15** – NoAres scenario. **Router C → Router J** traffic flow
Areas scenario

1. Switch to the Areas scenario. Scenarios ➔ Switch to Scenario ➔ Areas.
3. Expand Sources ➔ Router B ➔ Router D.
4. Select Router B ➔ Router D.
5. Change the Display attribute to Yes.

The traffic flow should look like figure 16.

Figure 16 - Areas scenario. Router B ➔ Router D traffic flow
Balanced scenario

1. Switch to the Balanced scenario. Scenarios ➔ Switch to Scenario ➔ Balanced.
3. Expand Sources ➔ Router C ➔ Router J.
4. Select Router C ➔ Router J.
5. Change the Display attribute to Yes.

The traffic flow should look like figure 17.

![Figure 17 - Balanced scenario. Router C ➔ Router J traffic flow](image)

The lab is completed.