TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

LAB 7: Configuration of Dynamic Routing using OSPF

(Computer Networks)

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Lab 7: Configuration of Dynamic Routing using OSPF

Objective:

- To be familiar with OSPF and its configuration

Requirements:

- Computer with Cisco Packet Tracer installed.

Exercises:

1. What is OSPF? How does it differ from RIP? Explain OSPF configurations with examples.

=> OSPF(Open Shortest Path First) is a dynamic routing protocol among a family of IP Routing protocols. It is a link-state routing protocol, so it gathers comprehensive information about the network topology and calculates the shortest path to each node. In contrast, RIP(Routing Information Protocol) is a distance vector routing protocol, where each router only knows about its immediate neighbors and not the entire network topology. It propagates link-state advertisements rather than routing table updates and because of it, OSPF networks converge more quickly than RIP networks. RIP uses cost as its metric, that is based on bandwidth, while RIP uses hop count as its metric, with 15 maximum hops. That makes RIP suitable for small networks, and OSPF for large networks.

Configuration of OSPF:

OSPF is enabled on a router by using the router ospf PROCESS-ID global configuration command. The process ID should be within the 16-bit number range i.e. from 1 to 65535.

We need to also define on which interfaces OSPF will run and what networks will be advertised, which is done by using the network IP_ADDRESS WILDCARD_MASK AREA_ID command from the ospf configuration. The Area ID has to be the same on all neighboring routers in order for routers to become neighbors. Example:

```
conf term
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 1
Router(config-router)#network 24.24.26.0 0.0.1.255 area 1
Router(config-router)#network 24.24.24.0 0.0.1.255 area 1
Router(config-router)#network 24.24.31.224 0.0.0.3 area 1
Router(config-router)#end
```

In this configuration, OSPF is enabled on the Router with process ID 1, and the networks 24.24.26.0/23, 24.24.24.0/23 and 24.24.31.224/30 are advertised within area 1.

2. What is multi-area OSPF? Why is it used? How can the multi-area OSPF be configured? Explain with examples.

=> Multi-area OSPF is an extension of OSPF designed to optimize the processing and memory overhead in large network deployments. In multi-area OSPF, the network is divided into multiple smaller areas. Each router within an area maintains knowledge of the topology only within that area, which improves the stability and speeds up convergence. The backbone area (area 0) interconnects all other areas, and Area Border Routers (ABRs) connect the backbone area with non-backbone areas. Another benefit of a multi area OSPF is that the routing information is broadcasted among members in an area only, and not the entire network topology. Example:

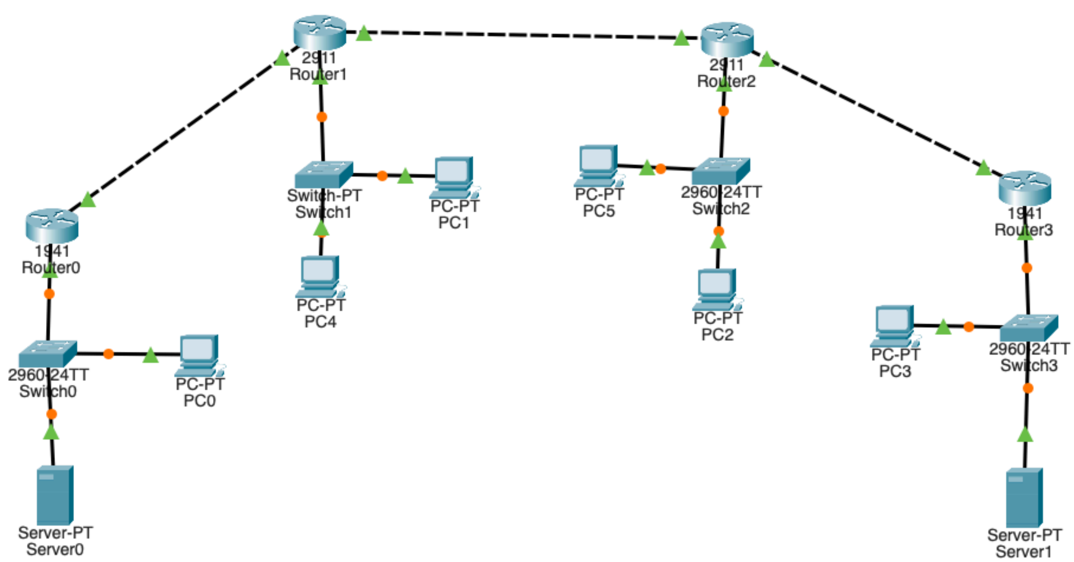
```
Router#conf term
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 1
Router(config-router)# network 24.24.31.224 0.0.0.3 area 1
Router(config-router)# network 24.24.30.128 0.0.0.127 area 1
Router(config-router)# network 24.24.31.228 0.0.0.3 area 0
Router(config-router)# network 24.24.31.128 0.0.0.63 area 0
Router(config-router)#end
```

In this configuration, OSPF is enabled on the Router with process ID 1. The network 24.24.31.224/30 is in area 1, and 24.24.31.228/30 is in area 0.

3. How can dynamic routing address the changing topology of the network? Explain with reference to the observation of your lab exercise.

=> Dynamic routing protocols automatically update the routing information in the routing table whenever a change occurs in the network topology. This is done via communication between routers regarding the latest status of the network topology. For example, in activity B, breaking a link between two routers results in the change of the routing table of all the routers denoting the change in the topology.

Activity A: VLSM Subnetting was done as follows.



Network	Net-Id	Broadcast Address	Subnet Mask
LAN1 (55)	200.100.100.0	200.100.100.63	255.255.255.192
LAN4 (45)	200.100.100.64	200.100.100.127	255.255.255.192
LAN2 (25)	200.100.100.128	200.100.100.159	255.255.255.224
LAN3 (10)	200.100.100.160	200.100.100.175	255.255.255.240
NET5 (2)	200.100.100.176	200.100.100.179	255.255.255.252
NET6 (2)	200.100.100.180	200.100.100.183	255.255.255.252
NET7 (2)	200.100.100.184	200.100.100.187	255.255.255.252

1. The remaining(unused) IP address range was 200.100.100.188 to 200.100.100.255.

2. The networks were configured, and all the routers, PCs and servers were configured with their required addresses as given.

3. OSPF was enabled in all the routers with these commands, with all networks in area 0. Example,

Router 0 ospf config:
#network 200.100.100.0 0.0.0.63 area 0
#network 200.100.100.176 0.0.0.3 area 0

Router 1 ospf config:
#network 200.100.100.176 0.0.0.3 area 0
#network 200.100.100.180 0.0.0.3 area 0
#network 200.100.100.128 0.0.0.31 area 0

4. All the ping commands from a PC of any LAN to the PC of any other LAN were successful.

5. The tracert command from PC0 to PC3 showed the hops made along the way. The hops happened as expected, the packet traveled from one router to the next one till it reached the expected destination.

```
C:\>tracert 200.100.100.66

Tracing route to 200.100.100.66 over a maximum of 30 hops:

  1   0 ms      0 ms      0 ms      200.100.100.1
  2   0 ms      0 ms      1 ms      200.100.100.178
  3   0 ms      0 ms      0 ms      200.100.100.182
  4   0 ms      0 ms      0 ms      200.100.100.186
  5   0 ms      0 ms      0 ms      200.100.100.66

Trace complete.
```

6. As OSPF was used, the routing table was set up automatically.

```
Router#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     200.100.100.0/24 is variably subnetted, 10 subnets, 5 masks
O       200.100.100.0/26 [110/2] via 200.100.100.177, 00:00:14, GigabitEthernet0/0
O       200.100.100.64/26 [110/3] via 200.100.100.182, 00:08:27, GigabitEthernet0/2
C       200.100.100.128/27 is directly connected, GigabitEthernet0/1
L       200.100.100.129/32 is directly connected, GigabitEthernet0/1
O       200.100.100.160/28 [110/2] via 200.100.100.182, 00:09:21, GigabitEthernet0/2
C       200.100.100.176/30 is directly connected, GigabitEthernet0/0
L       200.100.100.178/32 is directly connected, GigabitEthernet0/0
C       200.100.100.180/30 is directly connected, GigabitEthernet0/2
L       200.100.100.181/32 is directly connected, GigabitEthernet0/2
O       200.100.100.184/30 [110/2] via 200.100.100.182, 00:10:16, GigabitEthernet0/2
```

Activity B: Router4 was added to the network and its interfaces were configured with appropriate IP addresses and OSPF was enabled in it.

1. Since the route via the new router is the shortest, instead of going through the old route, the packets travel through the newly connected route.

```
C:\>tracert 200.100.100.66

Tracing route to 200.100.100.66 over a maximum of 30 hops:

  1   0 ms      0 ms      0 ms      200.100.100.1
  2   *         0 ms      0 ms      200.100.100.4
  3   *         0 ms      0 ms      200.100.100.66

Trace complete.
```

2. The show ip route command showed the ospf connected networks automatically. The routing table for Router0 shows a new pathway to 200.100.100.184 via 200.100.100.4 (which is the newly added router).

Router#show ip route

```
Gateway of last resort is not set

     200.100.100.0/24 is variably subnetted, 9 subnets, 5 masks
C       200.100.100.0/26 is directly connected, GigabitEthernet0/0
L       200.100.100.1/32 is directly connected, GigabitEthernet0/0
O       200.100.100.64/26 [110/2] via 200.100.100.4, 00:01:08, GigabitEthernet0/0
O       200.100.100.128/27 [110/2] via 200.100.100.178, 00:15:02, GigabitEthernet0/1
O       200.100.100.160/28 [110/3] via 200.100.100.178, 00:15:02, GigabitEthernet0/1
C       200.100.100.176/30 is directly connected, GigabitEthernet0/1
L       200.100.100.177/32 is directly connected, GigabitEthernet0/1
O       200.100.100.180/30 [110/2] via 200.100.100.178, 00:15:02, GigabitEthernet0/1
O       200.100.100.184/30 [110/3] via 200.100.100.4, 00:01:08, GigabitEthernet0/0
                           [110/3] via 200.100.100.178, 00:01:08, GigabitEthernet0/1

Router#
```

The visibility of local links (L, links to each device in the network) are visible sometimes, and sometimes not. It depends on the choice of the router made, and is visible in the ip route table here.

3. Since the link was broken, only a single path was now available, to which OSPF quickly adapted to. Thus the packets traveled to the destination via 200.100.100.1.

```
C:\>tracert 200.100.100.66

Tracing route to 200.100.100.66 over a maximum of 30 hops:

  1   0 ms      0 ms      0 ms      200.100.100.1
  2   *         0 ms      0 ms      200.100.100.178
  3   0 ms      0 ms      0 ms      200.100.100.182
  4   0 ms      0 ms      0 ms      200.100.100.186
  5   0 ms      0 ms      0 ms      200.100.100.66

Trace complete.
```

4. The routing table updated after the topology was changed. And thus tracert too has changed the same way. Pinging PC1 from PC0 worked as expected.

Router#show ip route

```
Gateway of last resort is not set

     200.100.100.0/24 is variably subnetted, 8 subnets, 5 masks
O       200.100.100.0/26 [110/5] via 200.100.100.65, 00:04:44, GigabitEthernet0/1
C       200.100.100.64/26 is directly connected, GigabitEthernet0/1
L       200.100.100.68/32 is directly connected, GigabitEthernet0/1
O       200.100.100.128/27 [110/4] via 200.100.100.65, 00:05:15, GigabitEthernet0/1
O       200.100.100.160/28 [110/3] via 200.100.100.65, 00:54:49, GigabitEthernet0/1
O       200.100.100.176/30 [110/4] via 200.100.100.65, 00:05:15, GigabitEthernet0/1
O       200.100.100.180/30 [110/3] via 200.100.100.65, 00:05:15, GigabitEthernet0/1
O       200.100.100.184/30 [110/2] via 200.100.100.65, 00:54:49, GigabitEthernet0/1
```

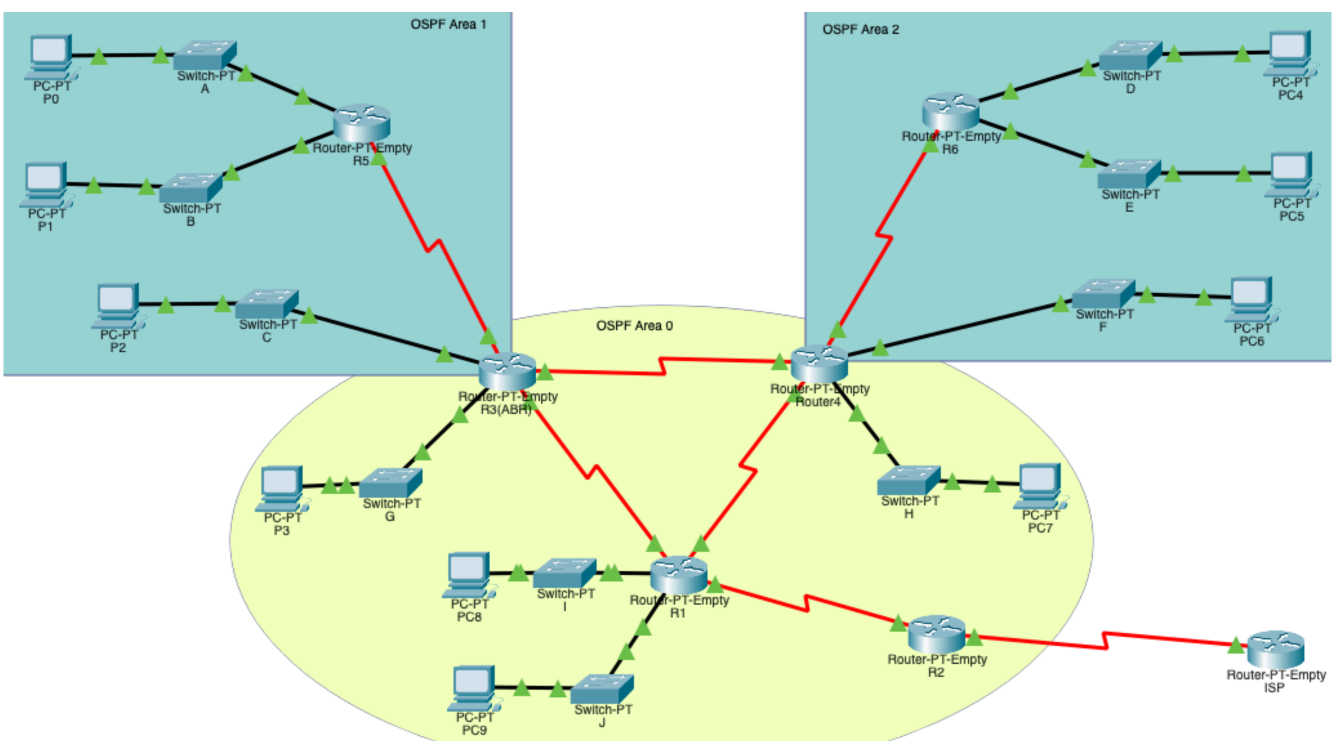
```
C:\>tracert 200.100.100.130

Tracing route to 200.100.100.130 over a maximum of 30 hops:

  1   0 ms      0 ms      0 ms      200.100.100.1
  2   0 ms      4 ms      0 ms      200.100.100.178
  3   0 ms      0 ms      0 ms      200.100.100.130

Trace complete.
```

6. Routes to 200.100.100.178 /30 was broken as that network no longer exists, rest of the pathways all lead out of the subnet 200.100.100.0 /26 via 200.100.100.4 i.e.Router4.

8. RIP only accounts for hop count while OSPF accounts for other factors like the bandwidth of the network connection, further elaborated in the exercise section.

Activity C:

1. As the IP address of 24.24.24.0/21 was given to us, we configured the network as required, along with all the address configurations for routers, PCs and switches.



Network	Net-Id	Uncommon Bits	Broadcast Address	Subnet Mask	Wildcard Mask
B (500)	24.24.24.0	00*.**** ****	24.24.25.255	255.255.254.0	0.0.1.255
A (400)	24.24.26.0	01*.**** ****	24.24.27.255	255.255.254.0	0.0.1.255
F (200)	24.24.28.0	100.**** ****	24.24.28.255	255.255.255.0	0.0.0.255
J (120)	24.24.29.0	101.0*** ****	24.24.29.127	255.255.255.128	0.0.0.127
I (110)	24.24.29.128	101.1*** ****	24.24.29.255	255.255.255.128	0.0.0.127
D (100)	24.24.30.0	110.0*** ****	24.24.30.127	255.255.255.128	0.0.0.127
C (90)	24.24.30.128	110.1*** ****	24.24.30.255	255.255.255.128	0.0.0.127
E (80)	24.24.31.0	111.0*** ****	24.24.31.127	255.255.255.128	0.0.0.127
G (40)	24.24.31.128	111.10** ****	24.24.31.191	255.255.255.192	0.0.0.63
H (20)	24.24.31.192	111.110* ****	24.24.31.223	255.255.255.224	0.0.0.31
R53 (2)	24.24.31.224	111.1110 00**	24.24.31.227	255.255.255.252	0.0.0.3
R31 (2)	24.24.31.228	111.1110 01**	24.24.31.231	255.255.255.252	0.0.0.3
R34 (2)	24.24.31.232	111.1110 10**	24.24.31.235	255.255.255.252	0.0.0.3
R41 (2)	24.24.31.236	111.1110 11**	24.24.31.239	255.255.255.252	0.0.0.3
R12 (2)	24.24.31.240	111.1111 00**	24.24.31.243	255.255.255.252	0.0.0.3
R64 (2)	24.24.31.244	111.1111 01**	24.24.31.247	255.255.255.252	0.0.0.3
R2I (2)	24.24.31.248	111.1111 10**	24.24.31.251	255.255.255.252	0.0.0.3

2. In practice, the R2I is actually defined by the ISP and not us, but here we have done its IP address configuration. The unused IP address range was 24.24.31.252 to 24.24.31.255.

3. Since no dynamic routing has been done, the command show ip route only showed the connected (C) links at the respective routers. Like in router 1, we could see the networks I, J and the serially connected links to Router2, Router3 and Router4.
For router1,

```
Gateway of last resort is not set

     24.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C       24.24.29.0/25 is directly connected, GigabitEthernet4/0
C       24.24.29.128/25 is directly connected, GigabitEthernet3/0
C       24.24.31.236/30 is directly connected, Serial1/0
C       24.24.31.240/30 is directly connected, Serial2/0
C       24.24.31.228/30 is directly connected, Serial0/0

Router#
```

4. Done, **show run** for the router5 was as shown below:

```
router ospf 1
 log-adjacency-changes
 network 24.24.26.0 0.0.1.255 area 1
 network 24.24.24.0 0.0.1.255 area 1
 network 24.24.31.224 0.0.0.3 area 1
```

On router3,

```
router ospf 1
 log-adjacency-changes
 network 24.24.30.128 0.0.0.127 area 1
 network 24.24.31.224 0.0.0.3 area 1
 network 24.24.31.128 0.0.0.63 area 0
 network 24.24.31.232 0.0.0.3 area 0
 network 24.24.31.228 0.0.0.3 area 0
```

5. C signifies that the connections were direct while IA signifies the connections were made via OSPF within an area. All networks were routed via current router, along with path cost and administrative cost.

Router5# show ip route

```
Gateway of last resort is not set

     24.0.0.0/8 is variably subnetted, 17 subnets, 6 masks
C       24.24.24.0/23 is directly connected, GigabitEthernet2/0
C       24.24.26.0/23 is directly connected, GigabitEthernet1/0
O IA    24.24.28.0/24 [110/129] via 24.24.31.226, 00:09:39, Serial0/0
O IA    24.24.29.0/25 [110/129] via 24.24.31.226, 00:17:05, Serial0/0
O IA    24.24.29.128/25 [110/129] via 24.24.31.226, 00:17:05, Serial0/0
O IA    24.24.30.0/25 [110/193] via 24.24.31.226, 00:09:39, Serial0/0
O       24.24.30.128/25 [110/65] via 24.24.31.226, 00:30:53, Serial0/0
O IA    24.24.31.0/25 [110/193] via 24.24.31.226, 00:09:39, Serial0/0
O IA    24.24.31.128/26 [110/65] via 24.24.31.226, 00:30:53, Serial0/0
O IA    24.24.31.192/27 [110/129] via 24.24.31.226, 00:09:39, Serial0/0
C       24.24.31.224/30 is directly connected, Serial0/0
O IA    24.24.31.228/30 [110/128] via 24.24.31.226, 00:21:25, Serial0/0
O IA    24.24.31.232/30 [110/128] via 24.24.31.226, 00:22:49, Serial0/0
O IA    24.24.31.236/30 [110/192] via 24.24.31.226, 00:18:09, Serial0/0
O IA    24.24.31.240/30 [110/192] via 24.24.31.226, 00:16:38, Serial0/0
O IA    24.24.31.244/30 [110/192] via 24.24.31.226, 00:09:39, Serial0/0
O IA    24.24.31.248/30 [110/256] via 24.24.31.226, 00:15:23, Serial0/0

Router#
```

6. All PCs can ping each other.

7. Pinging a PC in network J from network A resulted in an expected output, the packet is first handed off to the default gateway which is then sent to the destination following OSPF's pathing.

```
C:\>tracert 24.24.29.2

Tracing route to 24.24.29.2 over a maximum of 30 hops:

  1   0 ms      0 ms      0 ms      24.24.26.1
  2   10 ms     11 ms     11 ms     24.24.31.226
  3   0 ms      13 ms     1 ms      24.24.31.230
  4   *         13 ms     15 ms     24.24.29.2

Trace complete.
```

8. Since we only dynamically handled the IPs present in the network using OSPF and no default route was set, any IP that the router doesn't recognize will get held off until they're dropped. In this case, after reaching the default gateway, the packet was dropped after the TTL limit for the packet was reached.

```
C:\>tracert 1.1.1.1

Tracing route to 1.1.1.1 over a maximum of 30 hops:

  1   0 ms      0 ms      0 ms      24.24.26.1
  2   0 ms      *         0 ms      24.24.26.1
  3   *         0 ms      *         Request timed out.
  4   0 ms      *         0 ms      24.24.26.1
  5   *         0 ms      *         Request timed out.
  6   0 ms      *         0 ms      24.24.26.1
  7   *         0 ms      *         Request timed out.
  8   0 ms      *         0 ms      24.24.26.1
```

9. The default route was configured in each router to forward any Internet traffic towards ISP Router. We also configured a static route in the ISP router to forward the packets destined for our network.

10. A static route (S*) is observed, which appeared after configuring the default route using static routing. In router5,

```
     24.0.0.0/8 is variably subnetted, 17 subnets, 6 masks
C       24.24.24.0/23 is directly connected, GigabitEthernet2/0
C       24.24.26.0/23 is directly connected, GigabitEthernet1/0
O IA    24.24.28.0/24 [110/129] via 24.24.31.226, 00:08:31, Serial0/0
O IA    24.24.29.0/25 [110/129] via 24.24.31.226, 00:08:31, Serial0/0
O IA    24.24.29.128/25 [110/129] via 24.24.31.226, 00:08:31, Serial0/0
O IA    24.24.30.0/25 [110/193] via 24.24.31.226, 00:08:31, Serial0/0
O       24.24.30.128/25 [110/65] via 24.24.31.226, 00:08:46, Serial0/0
O IA    24.24.31.0/25 [110/193] via 24.24.31.226, 00:08:31, Serial0/0
O IA    24.24.31.128/26 [110/65] via 24.24.31.226, 00:08:46, Serial0/0
O IA    24.24.31.192/27 [110/129] via 24.24.31.226, 00:08:31, Serial0/0
C       24.24.31.224/30 is directly connected, Serial0/0
O IA    24.24.31.228/30 [110/128] via 24.24.31.226, 00:08:46, Serial0/0
O IA    24.24.31.232/30 [110/128] via 24.24.31.226, 00:08:46, Serial0/0
O IA    24.24.31.236/30 [110/192] via 24.24.31.226, 00:08:31, Serial0/0
O IA    24.24.31.240/30 [110/192] via 24.24.31.226, 00:08:31, Serial0/0
O IA    24.24.31.244/30 [110/192] via 24.24.31.226, 00:08:31, Serial0/0
O IA    24.24.31.248/30 [110/256] via 24.24.31.226, 00:08:31, Serial0/0
S*   0.0.0.0/0 is directly connected, Serial0/0

Router#
```

11. Due to default routing, the packet reaches the ISP router after which the packet is dropped after the TTL limit is reached.

```
C:\>tracert 1.1.1.1

Tracing route to 1.1.1.1 over a maximum of 30 hops:

  1   4 ms      4 ms      4 ms      24.24.26.1
  2   6 ms      6 ms      6 ms      24.24.31.226
  3   8 ms      8 ms      8 ms      24.24.31.230
  4   10 ms     10 ms     10 ms     24.24.31.242
  5   12 ms     12 ms     12 ms     24.24.31.250
  6   12 ms     *         12 ms     24.24.31.250
  7   *         12 ms     *         Request timed out.
  8   12 ms     *         12 ms     24.24.31.250
  9   *         12 ms     *         Request timed out.
  10  12 ms     *         12 ms     24.24.31.250
```

12. As we removed the link between router R1 and R3, the routing table of routers in area 0 changed the routes according to the network. The route was updated as the intermediate path was removed. The log showed how the neighbor was detached.

```
Router#
%LINK-3-UPDOWN: Interface Serial1/0, changed state to down

%LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0, changed state to down

00:51:33: %OSPF-5-ADJCHG: Process 1, Nbr 24.24.31.245 on Serial1/0 from FULL to DOWN,
Neighbor Down: Interface down or detached
```

In the routing table, paths were updated automatically. After removing the link between router3 and router4, In router3, the path to network I, was updated from:
24.24.29.0/25 [110/65] via 24.24.31.230, 00:07:35, Serial2/0
to:
24.24.29.0/25 [110/129] via 24.24.31.234,00:02:39, Serial1/0

The output of tracert from the computer of network A to 1.1.1.1 followed the default path till Router3, and then the packet was dropped because the default path was broken.

Discussion

OSPF's link-state nature allows it to have a comprehensive understanding of the network topology, leading to faster convergence and more efficient routing decisions and also more scalability for larger and complex networks compared to RIP. RIP's hop count limitation and slower convergence make it less suitable for larger networks.

Activity A focused on configuring a basic OSPF setup within a single area. This involved assigning IP addresses, enabling OSPF on routers, and verifying connectivity with ping and traceroute tests. These steps highlighted how OSPF maintains up-to-date routing tables and dynamically adapts to network changes, ensuring efficient data packet routing.

Activity B illustrated OSPF's capability to adapt to changing topologies. It showed how OSPF quickly updated routing information, allowing for seamless integration of new devices and maintaining optimal routing paths.

Activity C taught about the OSPF configuration in a complex VLSM network with multiple areas. It also simulated a network failure by removing a link between routers. Observing the quick updates in the routing tables and the rerouting of traffic demonstrated OSPF's ability to handle network failures efficiently. This reinforces the importance of OSPF in ensuring minimal network downtime and maintaining robust network performance.

Conclusion

This lab exercise effectively demonstrated the advantages of the Open Shortest Path First (OSPF) routing protocol. Through configuring and testing OSPF in different scenarios, we observed its superior scalability, faster convergence, and efficient dynamic routing compared to the Routing Information Protocol (RIP). The lab activities highlighted OSPF's ability to adapt quickly to network changes, maintain optimal routing paths, and ensure network stability and connectivity. This hands-on experience reinforced the theoretical understanding of OSPF and its importance in managing complex network topologies.