CSE 4512 [Computer Networks Lab]

Lab # 07

1. Objectives:

- Describe the concept of OSPF and related terminologies
- Explain advantages of OSPF over RIP
- Configure OSPF in a network topology following given specifications

2. Theory:

In the previous lab you learnt the concept of dynamic routing, Routing Information Protocol (RIP) and how to configure RIP in a network. In this lab, you'll learn about OSPF which is one of the most commonly used dynamic routing protocols and you'll also see how to configure OSPF in a simple network topology.

Open Shortest Path First (OSPF) Routing Protocol:

As you know already, OSPF uses Link State Routing (LSR) algorithm. In OSPF, each router sends its link information to the directly connected routers, known as neighbors, which in turn sends the info to other neighbors. After that each router runs the Shortest Path Algorithm on the received information to determine the optimal route to different networks. The running of the algorithm is one of the reason why OSPF is a CPU-intensive protocol as whenever there's a change the algorithm is run. Still OSPF is better than RIP due to its fast convergence and better load-balancing. Remember that, RIP sends the whole routing table to its neighbors whereas OSPF only sends the link information with various optimizations in place. You can learn more about OSPF and RIP here.

There's a plethora of terminologies and concepts related to OSPF that one needs to know for full understanding of the protocol. Some most common ones are listed here. But for our purpose, we'll just cover the ones necessary for our lab.

- **Area**: OSPF networks are divided into **areas** which are a logical collection of routers, links having the *same area identification*. A router within an area must maintain a topological database *for the area to which it belongs*. The router does not have detailed information about network topology outside of its area, which thereby reduces the size of its database. There's a special area called the **backbone area** (*area 0*) to which all other areas must be connected. Different areas can communicate with each other through area 0.
- **Area Border Router (ABR)**: A router with interfaces in two areas is called an ABR. This router is the boundary between two areas.
- **Autonomous System (AS):** OSPF operates within a single Autonomous System which is a collection of areas. AS is basically a group of networks running under a single administrative control. It controls how far the routing information should be propagated and facilitates filtering of information for sharing with other AS.
- **Designated Router (DR):** A router is elected as the Designated Router (DR) and another as Backup Designated Router (BDR) on a multi-access network (like LAN) in OSPF. DR and BDR

serve as the *central point* for exchanging OSPF routing information. Each non-DR or non-BDR router will exchange routing information *only* with the DR and BDR, instead of exchanging updates with every router on the network segment. DR will then distribute topology information to every other router inside the same area, which greatly reduces OSPF traffic. For more, you can read on here.

- **Router ID**: Each router running the OSPF protocol is assigned a router ID to **uniquely identify that router within an AS**. This is a 32 bit number and can be set *manually* by using the `router-id` command. If router ID is not set manually then the highest IP address of the router's *loopback address* will be the router ID. If there's no loopback address then the highest *active IP address* on any of the router's interface will be the router ID. Remember to restart the router to reflect the new router-id assignment. The `reload` command will restart the router. Also, the `clear ip ospf process` command will work for new router-id assignment.
- **Cost**: The cost in OSPF is calculated as **Reference Bandwidth / Interface Bandwidth**. The default value of reference bandwidth is *100 Mbps* but it can be set manually. The command to manually set the reference bandwidth is `auto-cost reference-bandwidth <value>`. Note that, `value` here is in units of *Mbps*. So, `value`=100 would mean 100 Mbps. You can change the interface bandwidth with the `bandwidth <value>` command. But, here the `value` is in units of *kbps*.
- **Wildcard Mask:** The command to configure which networks to advertise is `network <ip_address> <wildcard_mask> area <area_id>`. Unlike RIP, the `network` command in OSPF supports classless routing and that support is achieved by the `wildcard_mask`. This mask is like an inverted subnet_mask but with different interpretation. The **0** bits in the mask indicate the corresponding bit positions that *must match* the same bit positions in the IP address. The **1** bits indicate the corresponding bit positions *don't need to match* the same bit positions in the IP address. Its best understood by an example. Suppose, there's a `10.0.1.0` directly connected subnet to our router that we want to advertise in the OSPF routing process. The command to include that subnet in the advertisement would be:

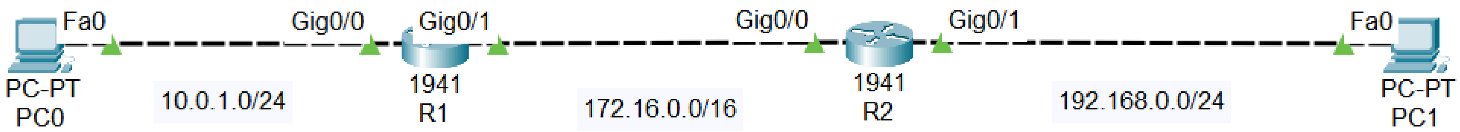
  ```
  network 10.0.1.0 0.0.0.255 area 0
  ```

  According to the wildcard_mask used in the above command, first 24 bits of the addresses must match and rest 8 bits don't need to match. So, any interface having IP address in the format **`10.0.1.X`** will match in this case. A more detailed explanation of wildcard_mask with more examples can be found here.
- **Process ID**: When enabling OSPF in a router, you need to mention a process ID. All OSPF functions will then be performed under that process. OSPF configuration mode is entered using the command `router ospf <process_id>`. You can have more than one OSPF processes in a single router. The process IDs will be different for different processes. Each OSPF process has its separate database, topology table etc. More on process ID can be read from here.

Now lets mention some key concepts in OSPF. OSPF enabled routers send *hello* packets to each other in certain intervals known as the *hello interval*. This is required to establish neighbor relationship and to let other router know the availability of the router. For example, if the *hello interval* is 5 seconds, then each router will send *hello* packets to the neighboring router in every 5 seconds. There's another interval known as the *dead interval* which is usually `4 times` of the hello interval. If a router doesn't receive *hello* packets from its neighbors then after this *dead interval* amount of time that neighbor will be declared *non-operational* and the routing table will be updated accordingly.

In OSPF, some interfaces are configured as passive-interfaces. Passive interfaces don't send hello packets. This is usually done for the local-LAN facing interfaces. Note that, the network connected with the passive interface will still be advertised as OSPF has been enabled in that interface. Check out this to learn more about passive interfaces.

3. Configure OSPF:



I. **Configure R1 Interfaces**

```
R1(config)# int g0/0
R1(config-if)# ip address 10.0.1.1 255.255.255.0
R1(config-if)# no shutdown
R1(config-if)# exit

R1(config)# int g0/1
R1(config-if)# ip address 172.16.0.1 255.255.0.0
R1(config-if)# no shutdown
R1(config-if)# exit

R1# copy running-config startup-config
```

II. **Configure R2 Interfaces**

```
R2(config)# int g0/1
R2(config-if)# ip address 192.168.0.1 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# exit

R2(config)# int g0/0
R2(config-if)# ip address 172.16.0.2 255.255.0.0
R2(config-if)# no shutdown
R2(config-if)# exit

R2# copy running-config startup-config
```

III. Configure PC0

```
IP: 10.0.1.10
Mask: 255.255.255.0
Gateway: 10.0.1.1
```

IV. Configure PC1

```
IP: 192.168.0.10
Mask: 255.255.255.0
Gateway: 192.168.0.1
```

V. **Configure OSPF in R1**

```
R1(config)# router ospf 1
R1(config-router)# network 10.0.1.0 0.0.0.255 area 0
R1(config-router)# network 172.16.0.0 0.0.255.255 area 0
```

VI. **Configure OSPF in R2**

```
R2(config)# router ospf 1
R2(config-router)# network 192.168.0.0 0.0.0.255 area 0
R2(config-router)# network 172.16.0.0 0.0.255.255 area 0
```

VII. **Verify**

```
R1# show ip ospf neighbor
R2# show ip ospf neighbor

Ping PC1 from PC0
```

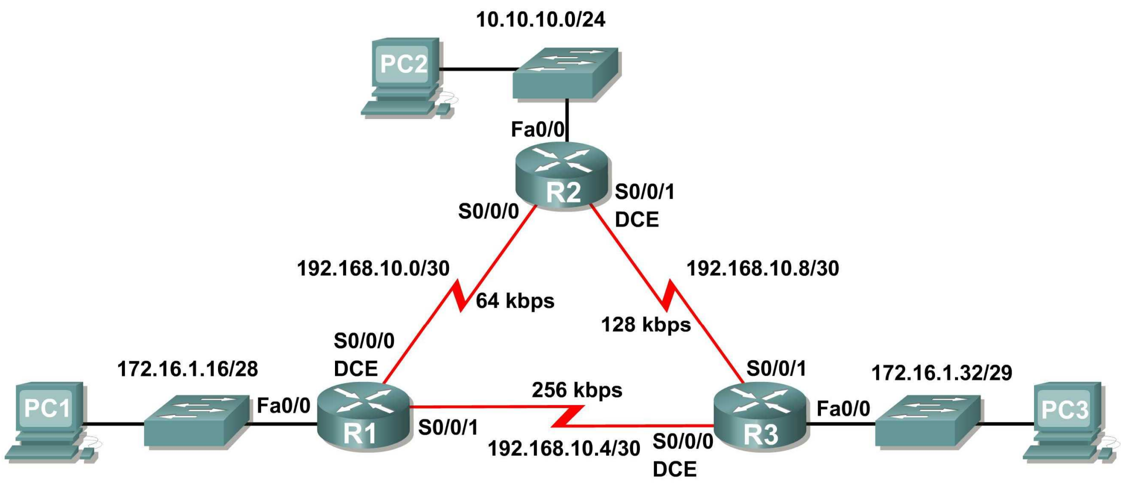
4. Tasks:

I. Implement the given network topology with the provided address specifications as described in the pdf ***Task-1_OSPF***. Answer the questions accordingly. You're ***not*** provided a .pka file for this task. Make sure you've properly read on the *theory section of this handout* to understand the concepts mentioned in ***Task-1_OSPF***. Otherwise, you'll face difficulties and might not get everything that's introduced there.

II. You will answer the given questions in this task and implement very small portion of OSPF. The task description for this task is provided in the pdf ***Task-2_verify-single-area-ospfv2***. You're provided a .pka file for this task. As with task 1, make sure you've read on the theory section properly. Our suggestion would be to attempt task 2 after you've completed task 1 as many of the concepts of OSPF is explained and shown in task 1.

Lab: Basic OSPF Configuration Lab

Topology Diagram



Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	Fa0/0	172.16.1.17	255.255.255.240	N/A
	S0/0/0	192.168.10.1	255.255.255.252	N/A
	S0/0/1	192.168.10.5	255.255.255.252	N/A
R2	Fa0/0	10.10.10.1	255.255.255.0	N/A
	S0/0/0	192.168.10.2	255.255.255.252	N/A
	S0/0/1	192.168.10.9	255.255.255.252	N/A
R3	Fa0/0	172.16.1.33	255.255.255.248	N/A
	S0/0/0	192.168.10.6	255.255.255.252	N/A
	S0/0/1	192.168.10.10	255.255.255.252	N/A
PC1	NIC	172.16.1.20	255.255.255.240	172.16.1.17
PC2	NIC	10.10.10.10	255.255.255.0	10.10.10.1
PC3	NIC	172.16.1.35	255.255.255.248	172.16.1.33

Step 1: Configure the routers

On the routers, enter global configuration mode and configure the hostname as shown on the chart. Then configure the console, virtual terminal lines password (both “cisco”) and privileged EXEC password (“class”):

Step 2: Disable DNS lookup

```
Router(config)#no ip domain-lookup
```

Step 3: Configure the interfaces on R1, R2, and R3

Configure the interfaces on the R1, R2, and R3 routers with the IP addresses from the table under the Topology Diagram.

Step 4: Verify IP addressing and interfaces

Use the **`show ip interface brief`** command to verify that the IP addressing is correct and that the interfaces are active.

Step 5: Configure Ethernet interfaces of PC1, PC2, and PC3

Configure the Ethernet interfaces of PC1, PC2, and PC3 with the IP addresses and default gateways from the table under the Topology Diagram.

Task: Configure OSPF on the R1 Router

Step 1: Use the router ospf command in global configuration mode to enable OSPF on the R1 router. Enter a process ID of 1 for the *`process-ID`* parameter.

```
R1(config)#router ospf 1
R1(config-router)#
```

Step 2: Configure the `network` statement for the LAN network.
Once you are in the Router OSPF configuration sub-mode, configure the LAN network 172.16.1.16/28 to be included in the OSPF updates that are sent out of R1.

The OSPF **`network`** command uses a combination of *`network-address`* and *`wildcard-mask`* similar to that which can be used by EIGRP. Unlike EIGRP, the wildcard mask in OSPF is required.

Use an area ID of 0 for the OSPF *`area-id`* parameter. 0 will be used for the OSPF area ID in all of the **`network`** statements in this topology.

```
R1(config-router)#network 172.16.1.16 0.0.0.15 area 0
R1(config-router)#
```

Step 3: Configure the router to advertise the 192.168.10.0/30 network attached to the Serial0/0/0 interface.

```
R1(config-router)# network 192.168.10.0 0.0.0.3 area 0
R1(config-router)#
```

Step 4: Configure the router to advertise the 192.168.10.4/30 network attached to the Serial0/0/1 interface.


```
R1(config-router)# network 192.168.10.4 0.0.0.3 area 0
R1(config-router)#
```

Step 5: When you are finished with the OSPF configuration for R1, return to privileged EXEC mode.

```
R1(config-router)#end
%SYS-5-CONFIG_I: Configured from console by console
R1#
```

Task: Configure OSPF on the R2 and R3 Routers

Step 1: Enable OSPF routing on the R2 router using the router ospf command.
Use a process ID of 1.

```
R2(config)#router ospf 1
R2(config-router)#
```

Step 2: Configure the router to advertise the LAN network 10.10.10.0/24 in the OSPF updates.

```
R2(config-router)#network 10.10.10.0 0.0.0.255 area 0
R2(config-router)#
```

Step 3: Configure the router to advertise the 192.168.10.0/30 network attached to the Serial0/0/0 interface.

```
R2(config-router)#network 192.168.10.0 0.0.0.3 area 0
R2(config-router)#
00:07:27: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.10.5 on Serial0/0/0
from EXCHANGE to FULL, Exchange Done
```

Notice that when the network for the serial link from R1 to R2 is added to the OSPF configuration, the router sends a notification message to the console stating that a neighbor relationship with another OSPF router has been established.

Step 4: Configure the router to advertise the 192.168.10.8/30 network attached to the Serial0/0/1 interface.
When you are finished, return to privileged EXEC mode.

```
R2(config-router)#network 192.168.10.8 0.0.0.3 area 0
R2(config-router)#end
%SYS-5-CONFIG_I: Configured from console by console
R2#
```

Step 5: Configure OSPF on the R3 router using the `router ospf` and `network` commands.
Use a process ID of 1. Configure the router to advertise the three directly connected networks. When you are finished, return to privileged EXEC mode.

```
R3(config)#router ospf 1
```



```
R3(config-router)#network 172.16.1.32 0.0.0.7 area 0
R3(config-router)#network 192.168.10.4 0.0.0.3 area 0
R3(config-router)#
00:17:46: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.10.5 on Serial0/0/0
from LOADING to FULL, Loading Done
R3(config-router)#network 192.168.10.8 0.0.0.3 area 0
R3(config-router)#
00:18:01: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.10.9 on Serial0/0/1
from EXCHANGE to FULL, Exchange Done
R3(config-router)#end
%SYS-5-CONFIG_I: Configured from console by console
R3#
```

Notice that when the networks for the serial links from R3 to R1 and R3 to R2 are added to the OSPF configuration, the router sends a notification message to the console stating that a neighbor relationship with another OSPF router has been established.

Task: Configure OSPF Router IDs

The OSPF router ID is used to uniquely identify the router in the OSPF routing domain. A router ID is an IP address. Cisco routers derive the Router ID in one of three ways and with the following precedence:

1. IP address configured with the OSPF **`router-id`** command.
2. Highest IP address of any of the router's loopback addresses.
3. Highest active IP address on any of the router's physical interfaces.

Step 1: Examine the current router IDs in the topology.

Since no router IDs or loopback interfaces have been configured on the three routers, the router ID for each router is determined by the highest IP address of any active interface.

What is the router ID for R1? ____________________
What is the router ID for R2? ____________________
What is the router ID for R3? ____________________

The router ID can also be seen in the output of the **show ip protocols**, **show ip ospf**, and **show ip ospf interfaces** commands.

```
R3#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.10
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4

<output omitted>


R3#show ip ospf
 Routing Process "ospf 1" with ID 192.168.10.10
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs

<output omitted>

R3#show ip ospf interface
FastEthernet0/0 is up, line protocol is up
  Internet address is 172.16.1.33/29, Area 0
  Process ID 1, Router ID 192.168.10.10, Network Type BROADCAST, Cost:
1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.10.10, Interface address 172.16.1.33
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:00
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)

<output omitted>

R3#
```

Step 2: Use loopback addresses to change the router IDs of the routers in the topology.

```
R1(config)#interface loopback 0
R1(config-if)#ip address 10.1.1.1 255.255.255.255

R2(config)#interface loopback 0
R2(config-if)#ip address 10.2.2.2 255.255.255.255

R3(config)#interface loopback 0
R3(config-if)#ip address 10.3.3.3 255.255.255.255
```


Step 3: Reload the routers to force the new Router IDs to be used.

When a new Router ID is configured, it will not be used until the OSPF process is restarted. Make sure that the current configuration is saved to NRAM, and then use the **`reload`** command to restart each of the routers..

When the router is reloaded, what is the router ID for R1? ____________________
When the router is reloaded, what is the router ID for R2? ____________________
When the router is reloaded, what is the router ID for R3? ____________________

Step 4: Use the `show ip ospf neighbors` command to verify that the router IDs have changed.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address
Interface
10.3.3.3          0  FULL/  -        00:00:30    192.168.10.6
Serial0/0/1
10.2.2.2          0   FULL/  -        00:00:33    192.168.10.2
Serial0/0/0
```

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address
Interface
10.3.3.3          0   FULL/  -        00:00:36    192.168.10.10
Serial0/0/1
10.1.1.1          0   FULL/  -        00:00:37    192.168.10.1
Serial0/0/0
```

```
R3#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address
Interface
10.2.2.2          0   FULL/  -        00:00:34    192.168.10.9
Serial0/0/1
10.1.1.1          0   FULL/  -        00:00:38    192.168.10.5
Serial0/0/0
```

Step 5: Use the `router-id` command to change the router ID on the R1 router.

Note: Some IOS versions do not support the **`router-id`** command. If this command is not available, continue to the next Task.

```
R1(config)#router ospf 1
R1(config-router)#router-id 10.4.4.4
Reload or use "clear ip ospf process" command, for this to take effect
```

If this command is used on an OSPF router process which is already active (has neighbors), the new router-ID is used at the next reload or at a manual OSPF process restart. To manually restart the OSPF process, use the **`clear ip ospf process`** command.


```
R1#(config-router)#end
R1# clear ip ospf process
Reset ALL OSPF processes? [no]:yes
R1#
```

Step 6: Use the show ip ospf neighbor command on router R2 to verify that the router ID of R1 has been changed.

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address
Interface
10.3.3.3          0   FULL/  -        00:00:36    192.168.10.10
Serial0/0/1
10.4.4.4          0   FULL/  -        00:00:37    192.168.10.1
Serial0/0/0
```

Step 7: Remove the configured router ID with the no form of the router-id command.

```
R1(config)#router ospf 1
R1(config-router)#router-id 10.4.4.4
Reload or use “clear ip ospf process” command, for this to take effect
```

Step 8: Restart the OSPF process using the clear ip ospf process command.

Restarting the OSPF process forces the router to use the IP address configured on the Loopback 0 interface as the Router ID.

```
R1(config-router)#end
R1# clear ip ospf process
Reset ALL OSPF processes? [no]:yes
R1#
```

Task: Verify OSPF Operation

Step 1: On the R1 router, Use the show ip ospf neighbor command to view the information about the OSPF neighbor routers R2 and R3. You should be able to see the neighbor ID and IP address of each adjacent router, and the interface that R1 uses to reach that OSPF neighbor.

```
R1#show ip ospf neighbor
Neighbor ID     Pri   State           Dead Time   Address
Interface
10.2.2.2          0   FULL/-          00:00:32    192.168.10.2
Serial0/0/0
10.3.3.3          0   FULL/-          00:00:32    192.168.10.6
Serial0/0/1
R1#
```

Step 2: On the R1 router, use the show ip protocols command to view information about the routing protocol operation.

Notice that the information that was configured in the previous Tasks, such as protocol, process ID, neighbor ID, and networks, is shown in the output. The IP addresses of the adjacent neighbors are also shown.


```
R1#show ip protocols

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    172.16.1.16 0.0.0.15 area 0
    192.168.10.0 0.0.0.3 area 0
    192.168.10.4 0.0.0.3 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.2.2.2         110      00:11:43
    10.3.3.3         110      00:11:43
  Distance: (default is 110)

R1#
```

Notice that the output specifies the process ID used by OSPF. Remember, the process ID must be the same on all routers for OSPF to establish neighbor adjacencies and share routing information.

Task: Examine OSPF Routes in the Routing Tables

View the routing table on the R1 router. OSPF routes are denoted in the routing table with an “O”.

```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, 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

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.1.1.1/32 is directly connected, Loopback0
O       10.10.10.0/24 [110/65] via 192.168.10.2, 00:01:02, Serial0/0/0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.1.16/28 is directly connected, FastEthernet0/0
O       172.16.1.32/29 [110/65] via 192.168.10.6, 00:01:12, Serial0/0/1
     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0/0
C       192.168.10.4 is directly connected, Serial0/0/1
O       192.168.10.8 [110/128] via 192.168.10.6, 00:01:12, Serial0/0/1
                     [110/128] via 192.168.10.2, 00:01:02, Serial0/0/0
R1#
```


Notice that unlike RIPv2 and EIGRP, OSPF does not automatically summarize at major network boundaries.

Task: Configure OSPF Cost

Step 1: Use the show `ip route` command on the R1 router to view the OSPF cost to reach the 10.10.10.0/24 network.

```
R1#show ip route

<output omitted>

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.1.1.1/32 is directly connected, Loopback0
O       10.10.10.0/24 [110/65] via 192.168.10.2, 00:16:56, Serial0/0/0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.1.16/28 is directly connected, FastEthernet0/0
O       172.16.1.32/29 [110/65] via 192.168.10.6, 00:17:06, Serial0/0/1
     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0/0
C       192.168.10.4 is directly connected, Serial0/0/1
O       192.168.10.8 [110/128] via 192.168.10.6, 00:17:06, Serial0/0/1
                     [110/128] via 192.168.10.2, 00:16:56, Serial0/0/0
R1#
```

Step 2: Use the show `interfaces serial0/0/0` command on the R1 router to view the bandwidth of the Serial 0/0/0 interface.

```
R1#show interfaces serial0/0/0
Serial0/0/0 is up, line protocol is up (connected)
  Hardware is HD64570
  Internet address is 192.168.10.1/30
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec, rely 255/255, load
1/255
  Encapsulation HDLC, loopback not set, keepalive set (10 sec)
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0 (size/max/drops); Total output drops: 0
```

<output omitted>

On most serial links, the bandwidth metric will default to 1544 Kbits. If this is not the actual bandwidth of the serial link, the bandwidth will need to be changed so that the OSPF cost can be calculated correctly.

Step 3: Use the bandwidth command to change the bandwidth of the serial interfaces of the R1 and R2 routers to the actual bandwidth, 64 kbps.

R1 router:
```
R1(config)#interface serial0/0/0
R1(config-if)#bandwidth 64
R1(config-if)#interface serial0/0/1
R1(config-if)#bandwidth 64
```


R2 router:
```
R2(config)#interface serial0/0/0
R2(config-if)#bandwidth 64
R2(config)#interface serial0/0/1
R2(config-if)#bandwidth 64
```

Step 4: Use the show `ip ospf interface` command on the R1 router to verify the cost of the serial links.

The cost of each of the Serial links is now 1562, the result of the calculation: 10^8/64,000 bps.

```
R1#show ip ospf interface

<output omitted>

Serial0/0/0 is up, line protocol is up
  Internet address is 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT-TO-POINT, Cost:
1562
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 10.2.2.2
  Suppress hello for 0 neighbor(s)
Serial0/0/1 is up, line protocol is up
  Internet address is 192.168.10.5/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT-TO-POINT, Cost:
1562
  Transmit Delay is 1 sec, State POINT-TO-POINT,

<output omitted>
```

Step 5: Use the `ip ospf cost` command to configure the OSPF cost on the R3 router.

An alternative method to using the **`bandwidth`** command is to use the **`ip ospf cost`** command, which allows you to directly configure the cost. Use the **`ip ospf cost`** command to change the bandwidth of the serial interfaces of the R3 router to 1562.

```
R3(config)#interface serial0/0/0
R3(config-if)#ip ospf cost 1562
R3(config-if)#interface serial0/0/1
R3(config-if)#ip ospf cost 1562
```

Step 6: Use the show `ip ospf interface` command on the R3 router to verify that the cost of the link the cost of each of the Serial links is now 1562.

```
R3#show ip ospf interface

<output omitted>
```



```
Serial0/0/1 is up, line protocol is up
  Internet address is 192.168.10.10/30, Area 0
  Process ID 1, Router ID 10.3.3.3, Network Type POINT-TO-POINT, Cost:
1562
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 10.2.2.2
  Suppress hello for 0 neighbor(s)
Serial0/0/0 is up, line protocol is up
  Internet address is 192.168.10.6/30, Area 0
  Process ID 1, Router ID 10.3.3.3, Network Type POINT-TO-POINT, Cost:
1562
  Transmit Delay is 1 sec, State POINT-TO-POINT,

<output omitted>
```

Task: Redistribute an OSPF Default Route

Step 1: Configure a loopback address on the R1 router to simulate a link to an ISP.

```
R1(config)#interface loopback1

%LINK-5-CHANGED: Interface Loopback1, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback1, changed
state to up

R1(config-if)#ip address 172.30.1.1 255.255.255.252
```

Step 2: Configure a static default route on the R1 router.

Use the loopback address that ha been configured to simulate a link to an ISP as the exit interface.

```
R1(config)#ip route 0.0.0.0 0.0.0.0 loopback1
R1(config)#
```

Step 3: Use the `default-information originate` command to include the static route in the OSPF updates that are sent from the R1 router.

```
R1(config)#router ospf 1
R1(config-router)#default-information originate
R1(config-router)#
```


Step 4: View the routing table on the R2 router to verify that the static default route is being redistributed via OSPF.

```
R2#show ip route

<output omitted>

Gateway of last resort is 192.168.10.1 to network 0.0.0.0

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.2.2.2/32 is directly connected, Loopback0
C       10.10.10.0/24 is directly connected, FastEthernet0/0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.16/28 [110/1563] via 192.168.10.1, 00:29:28,
Serial0/0/0
O       172.16.1.32/29 [110/1563] via 192.168.10.10, 00:29:28,
Serial0/0/1
     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0/0
O       192.168.10.4 [110/3124] via 192.168.10.10, 00:25:56,
Serial0/0/1
                     [110/3124] via 192.168.10.1, 00:25:56, Serial0/0/0
C       192.168.10.8 is directly connected, Serial0/0/1
O*E2 0.0.0.0/0 [110/1] via 192.168.10.1, 00:01:11, Serial0/0/0
R2#
```

Task: Configure Additional OSPF Features

Step 1: Use the `auto-cost reference-bandwidth` command to adjust the reference bandwidth value.

Increase the reference bandwidth to 10000 to simulate 10GigE speeds. Configure this command on all routers in the OSPF routing domain.

```
R1(config-router)#auto-cost reference-bandwidth 10000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all
routers.

R2(config-router)#auto-cost reference-bandwidth 10000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all
routers.


R3(config-router)#auto-cost reference-bandwidth 10000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all
routers.
```

Step 2: Examine the routing table on the R1 router to verify the change in the OSPF cost metric.

Notice that the values are much larger cost values for OSPF routes.

```
R1#show ip route

<output omitted>
```



```
Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.1.1.1/32 is directly connected, Loopback0
O       10.10.10.0/24 [110/65635] via 192.168.10.2, 00:01:01,
Serial0/0/0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.1.16/28 is directly connected, FastEthernet0/0
O       172.16.1.32/29 [110/65635] via 192.168.10.6, 00:00:51,
Serial0/0/1
     172.30.0.0/30 is subnetted, 1 subnets
C       172.30.1.0 is directly connected, Loopback1
     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0/0
C       192.168.10.4 is directly connected, Serial0/0/1
O       192.168.10.8 [110/67097] via 192.168.10.2, 00:01:01,
Serial0/0/0
S*   0.0.0.0/0 is directly connected, Loopback1
R1#
```

Step 3: Use the show `ip ospf neighbor` command on R1 to view the Dead Time counter.
The Dead Time counter is counting down from the default interval of 40 seconds.

```
R1#show ip ospf neighbor
Neighbor ID     Pri   State           Dead Time   Address
Interface
10.2.2.2          0   FULL/-          00:00:34    192.168.10.2
Serial0/0/0
10.3.3.3          0   FULL/-          00:00:34    192.168.10.6
Serial0/0/1
```

Step 4: Configure the OSPF Hello and Dead intervals.
The OSPF Hello and Dead intervals can be modified manually using the **`ip ospf hello-interval`** and **`ip ospf dead-interval`** interface commands. Use these commands to change the hello interval to 5 seconds and the dead interval to 20 seconds on the Serial 0/0/0 interface of the R1 router.

```
R1(config)#interface serial0/0/0
R1(config-if)#ip ospf hello-interval 5
R1(config-if)#ip ospf dead-interval 20
R1(config-if)#
01:09:04: %OSPF-5-ADJCHG: Process 1, Nbr 10.2.2.2 on Serial0/0/0 from
FULL to DOWN, Neighbor Down: Dead timer expired
01:09:04: %OSPF-5-ADJCHG: Process 1, Nbr 10.2.2.2 on Serial0/0/0 from
FULL to Down: Interface down or detached
```

After 20 seconds the Dead Timer on R1 expires. R1 and R2 loose adjacency because the Dead Timer and Hello Timers must be configured identically on each side of the serial link between R1 and R2.

Step 5: Modify the Dead Timer and Hello Timer intervals.
Modify the Dead Timer and Hello Timer intervals on the Serial 0/0/0 interface in the R2 router to match the intervals configured on the Serial 0/0/0 interface of the R1 router.


```
R2(config)#interface serial0/0/0
R2(config-if)#ip ospf hello-interval 5
R2(config-if)#ip ospf dead-interval 20
R2(config-if)#
01:12:10: %OSPF-5-ADJCHG: Process 1, Nbr 10.1.1.1 on Serial0/0/0 from
EXCHANGE to FULL, Exchange Done
```

Notice that the IOS displays a message when adjacency has been established with a state of Full.

Step 5: Use the show `ip ospf interface serial0/0/0` command to verify that the Hello Timer and Dead Timer intervals have been modified.

```
R2#show ip ospf interface serial0/0/0
Serial0/0/0 is up, line protocol is up
  Internet address is 192.168.10.2/30, Area 0
  Process ID 1, Router ID 10.2.2.2, Network Type POINT-TO-POINT, Cost:
1562
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 5, Dead 20, Wait 20, Retransmit 5
    Hello due in 00:00:00
  Index 3/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.1.1
  Suppress hello for 0 neighbor(s)
R2#
```

Step 6: Use the show `ip ospf neighbor` command on R1 to verify that the neighbor adjacency with R2 has been restored.

Notice that the Dead Time for Serial 0/0/0 is now much lower since it is counting down from 20 seconds instead of the default 40 seconds. Serial 0/0/1 is still operating with default timers.

```
R1#show ip ospf neighbor
Neighbor ID     Pri   State           Dead Time   Address
Interface
10.2.2.2          0   FULL/-          00:00:19    192.168.10.2
Serial0/0/0
10.3.3.3          0   FULL/-          00:00:34    192.168.10.6
Serial0/0/1
R1#
```

Task: Clean Up

Erase the configurations and disconnect attached cabling

Packet Tracer - Verify Single-Area OSPFv2

Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	G0/0	172.16.1.1	255.255.255.0	N/A
	G0/1	64.100.54.6	255.255.255.252	
	S0/0/0	172.16.3.1	255.255.255.252	
	S0/0/1	192.168.10.5	255.255.255.252	
R2	G0/0	172.16.2.1	255.255.255.0	N/A
	S0/0/0	172.16.3.2	255.255.255.252	
	S0/0/1	192.168.10.9	255.255.255.252	
R3	G0/0	192.168.1.1	255.255.255.0	N/A
	G0/1	192.168.11.1	255.255.255.0	
	S0/0/0	192.168.10.6	255.255.255.252	
	S0/0/1	192.168.10.10	255.255.255.252	
R4	G0/0/0	192.168.1.2	255.255.255.0	N/A
	G0/0/1	192.168.11.1	255.255.255.0	
ISP Router	NIC	64.100.54.5	255.255.255.252	N/A
PC1	NIC	172.16.1.2	255.255.255.0	172.16.1.1
PC2	NIC	172.16.2.2	255.255.255.0	172.16.2.1
PC3	NIC	192.168.1.2	255.255.255.0	192.168.1.1
Laptop	NIC	DHCP	DHCP	DHCP

Objectives

In this lab, you will use the CLI commands to verify the operation of an existing OSPFv2 network. In Part 2, you will add a new LAN to the configuration and verify connectivity.

- Identify and verify the status of OSPF neighbors.
- Determine how the routes are being learned in the network.
- Explain how the neighbor state is determined.
- Examine the settings for the OSPF process ID.
- Add a new LAN into an existing OSPF network and verify connectivity.

Background / Scenario

You are the network administrator for a branch office of a larger organization. Your branch is adding a new wireless network into an existing branch office LAN. The existing network is configured to exchange routes using OSPFv2 in a single-area configuration. Your task is to verify the operation of the existing OSPFv2 network, before adding in the new LAN. When you are sure that the current OSPFv2 LAN is operating correctly, you will connect the new LAN and verify that OSPF routes are being propagated for the new LAN. As branch office network administrator, you have full access to the IOS on routers R3 and R4. You only have read access to the enterprise LAN routers R1 and R2, using the username **BranchAdmin**, and the password **Branch1234**.

Instructions

Part 1: Verify the existing OSPFv2 network operation.

The following commands will help you find the information needed to answer the questions:

```
show ip interface brief
show ip route
show ip route ospf
show ip ospf neighbor
show ip protocols
show ip ospf
show ip ospf interface
```

Step 1: Verify OSPFv2 operation.

Wait until STP has converged on the network. You can click the Packet Tracer Fast Forward Time button to speed up the process. Continue only when all link lights are green.

a. Log into router **R1** using the username **BranchAdmin** and the password **Branch1234**. Execute the **show ip route** command.

```
R1# show ip route
--- output omitted ----

Gateway of last resort is 172.16.3.2 to network 0.0.0.0

     172.16.0.0/16 is variably subnetted, 5 subnets, 3 masks
C       172.16.1.0/24 is directly connected, GigabitEthernet0/0
L       172.16.1.1/32 is directly connected, GigabitEthernet0/0
O       172.16.2.0/24 [110/65] via 172.16.3.2, 00:02:18, Serial0/0/0
C       172.16.3.0/30 is directly connected, Serial0/0/0
L       172.16.3.1/32 is directly connected, Serial0/0/0
O    192.168.1.0/24 [110/65] via 192.168.10.6, 00:02:18, Serial0/0/1
     192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C       192.168.10.4/30 is directly connected, Serial0/0/1
L       192.168.10.5/32 is directly connected, Serial0/0/1
O       192.168.10.8/30 [110/128] via 172.16.3.2, 00:02:18, Serial0/0/0
                        [110/128] via 192.168.10.6, 00:02:18, Serial0/0/1
O*E2 0.0.0.0/0 [110/1] via 172.16.3.2, 00:02:18, Serial0/0/0
```

How did router **R1** receive the default route?

From which router did **R1** receive the default route?

How can you filter the output of **show ip route** to show only the routes learned through OSPF?

b. Execute the **show ip ospf neighbor** command on **R1**.

   Which routers have formed adjacencies with router **R1**?

   What are the router IDs and state of the routers shown in the command output?

   Are all of the adjacent routers shown in the output?

c. Using the command prompt on **PC1**, ping the address of the **ISP Router** shown in the Address Table. Is it successful? If not, do a **clear ospf process** command on the routers and repeat the ping command.

Step 2: Verify OSPFv2 operation on R2.

a. Log into router **R2** using the username **BranchAdmin** and the password **Branch1234**. Execute the **show ip route** command. Verify that routes to all the networks in the topology are shown in the routing table.

   How did router R2 learn the default route to the ISP?

b. Enter the **show ip ospf interface g0/0** on router **R2**.

   What type of OSPF network is attached to this interface?

   Are OSPF hello packets being sent out this interface? Explain.

c. Using the command prompt on **PC2**, ping the S0/0/1 address on router **R3**.

   Is it successful?

Step 3: Verify OSPFv2 operation on R3.

a. Execute the **show ip protocols** command on router R3.

   Router R3 is routing for which networks?

b. Execute the **show ip ospf neighbor detail** command on router **R3**.

   What is the neighbor priority shown for the OSPF neighbor routers? This value is the default.

c. Using the command prompt on **PC3**, ping the address of the **ISP Router** shown in the Address Table.

Is it successful?

Part 2: Add the new Branch Office LAN to the OSPFv2 network.

You will now add the pre-configured Branch Office LAN to the OSPFv2 network.

Step 1: Verify the OSPFv2 configuration on router R4.

Execute a **show run | begin router ospf** command on router **R4**. Verify that the network statements are present for the networks that are configured on the router.

Which interface is configured to not send OSPF update packets?

Step 2: Connect the Branch Office router R4 to the OSPFv2 network.

a. Using the correct Ethernet cable, connect the G0/0/0 interface on router **R4** to the G0/1 interface on switch **S3**. Use the **show ip ospf neighbor** command to verify that router **R4** is now adjacent with router **R3.**

   What state is displayed for router **R3**?

b. Using the **show ip ospf neighbor** command on **R3**, determine the state of router **R4**. There may be a delay while OSPF converges.

   Why is the state of router R4 different than the state of R1 and R2?

c. Using the command prompt on Laptop, ping the address of PC2.

   Is it successful?