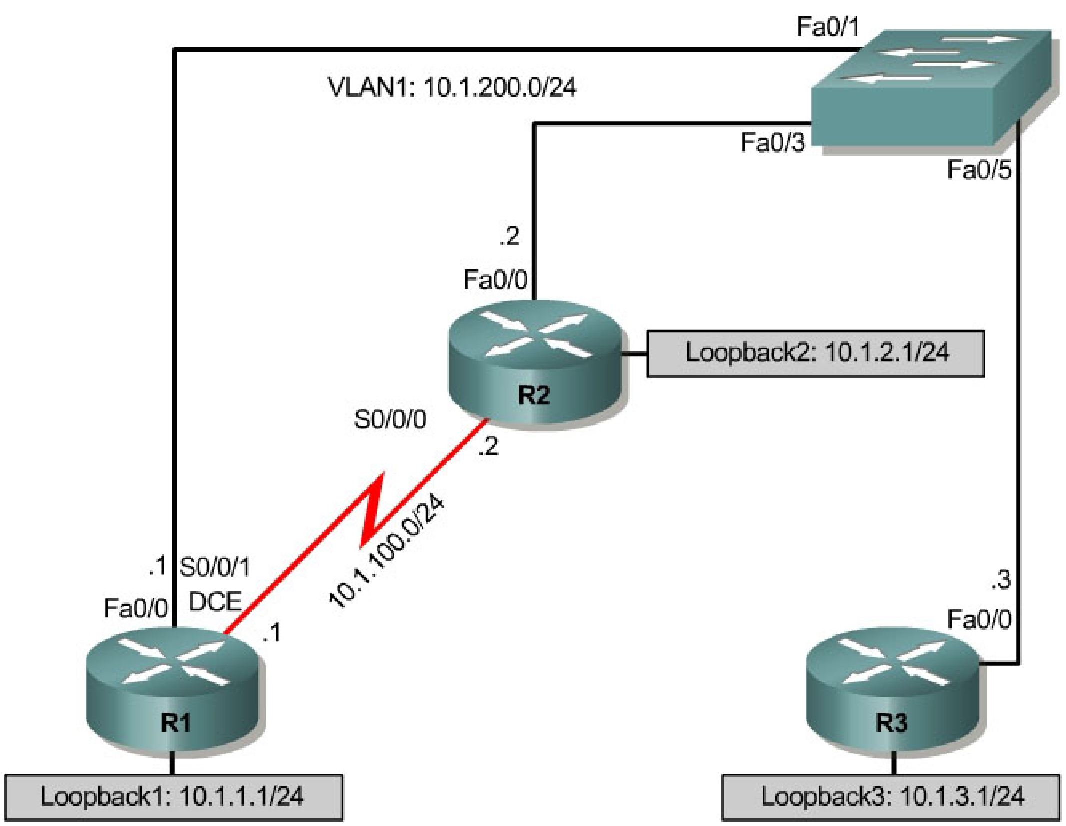
Lab 3-1 Single-Area OSPF Link Costs and Interface Priorities

Learning Objectives

- Configure single-area OSPF on a router
- Advertise loopback interfaces into OSPF
- Verify OSPF adjacencies
- Verify OSPF routing information exchange
- Modify OSPF link costs
- Change interface priorities
- Utilize debugging commands for troubleshooting OSPF

Topology



Scenario

You are responsible for configuring the new network to connect your company's Engineering, Marketing, and Accounting departments, represented by the loopback interfaces on each of the three routers. The physical devices have just been installed and connected by Fast Ethernet and serial cables. Configure OSPF to allow full connectivity between all departments.

You will be using the same physical topology for the labs in this module, so save your configuration for use in the next lab exercise.

Step 1: Addressing

Using the addressing scheme in the diagram, apply IP addresses to the Fast Ethernet interfaces on R1, R2, and R3. Create Loopback1 on R1, Loopback2 on R2, and Loopback3 on R3 and address them according to the diagram.

```
R1# configure terminal
R1(config)# interface Loopback1
R1(config-if)# description Engineering Department
R1(config-if)# ip address 10.1.1.1 255.255.255.0
R1(config-if)# exit
R1(config)# interface FastEthernet0/0
R1(config-if)# ip address 10.1.100.1 255.255.255.0
R1(config-if)# no shutdown

R2# configure terminal
R2(config)# interface Loopback2
R2(config-if)# description Marketing Department
R2(config-if)# ip address 10.1.2.1 255.255.255.0
R2(config-if)# exit
R2(config)# interface FastEthernet0/0
R2(config-if)# ip address 10.1.100.2 255.255.255.0
R2(config-if)# no shutdown

R3# configure terminal
R3(config)# interface Loopback3
R3(config-if)# description Accounting Department
R3(config-if)# ip address 10.1.3.1 255.255.255.0
R3(config-if)# exit
R3(config)# interface FastEthernet0/0
R3(config-if)# ip address 10.1.100.3 255.255.255.0
R3(config-if)# no shutdown
```

Leave the switch in its default (blank) configuration. By default, all switchports are in VLAN1 and are not administratively down.

Also configure the serial interfaces with the IP addresses given in the diagram. Remember to add the **clockrate** command where appropriate.

```
R1(config)# interface Serial 0/0/0
R1(config-if)# ip address 10.1.100.1 255.255.255.0
R1(config-if)# clockrate 64000
R1(config-if)# no shutdown

R2(config)# interface Serial 0/0/0
R2(config-if)# ip address 10.1.100.2 255.255.255.0
R2(config-if)# no shutdown
```

Verify that the line protocols of each interface are up and that you can reliably ping across each link.

Step 2: Adding Physical Interfaces to OSPF

After all your IP addressing is set up and you have local subnet connectivity, you can configure OSPF process 1. To enter the OSPF configuration prompt, use the command **router ospf** *process_number*. The process number is a locally significant number that does not affect how OSPF works. For this lab, use process number 1 on all your routers.

Next, add interfaces with the **network** *address wildcard_mask* **area** *area* command. The address can be any IP address. The mask is an inverse mask, similar to the kind used in an access list. The area is the OSPF area you want to put the interface into. For this lab, we will use area 0, the backbone area, for all interfaces. This command can be very confusing at first. What it means is that any interface with an IP that matches the address and wildcard mask combination in the network statement is added to the OSPF process in that area.

The command **network 10.1.200.1 0.0.0.0 area 0** adds any interface with the IP address of 10.1.200.1 to the OSPF process into area 0. The wildcard mask of 0.0.0.0 means that all 32 bits of the IP address have to be an exact match. A 0 bit in the wildcard mask means the bit in that portion of the interface IP has to match the address. A 1 bit in the wildcard mask means that the bit in the interface IP does not have to match that portion of the IP address.

The command **network 10.1.100.0 0.0.0.255 area 0** means that any interface whose IP address matches 10.1.100.0 for the first 3 octets will match the command and add it to area 0. The last octet is all 1s, because in the wildcard mask it is 255. This means that an interface with an IP of 10.1.100.1, 10.1.100.2, or 10.1.100.250 would match this address and wildcard combination and get added to OSPF.

The wildcard mask does not have to be the inverse of the subnet mask of an interface IP, although it can be helpful. An easy way to calculate a wildcard mask from the subnet mask is to subtract 255 minus the octet value for each octet,. A subnet mask of 255.255.255.252 (/30) becomes 0.0.0.3 to capture all interfaces on that subnet. This is because 255 – 255 = 0, and 255 – 252 = 3.

When configuring OSPF, enter the commands on R1. Then exit to privileged exec mode and type **debug ip ospf adj**. This command lets you watch OSPF neighbors come up and see neighbor relationships.

```
R1(config)# router ospf 1
R1(config-router)# network 10.1.100.0 0.0.0.255 area 0
R1(config-router)# network 10.1.200.1 0.0.0.0 area 0
R1(config-router)# end
R1#
*Oct  2 09:19:16.351: %SYS-5-CONFIG_I: Configured from console by console
R1# debug ip ospf adj
OSPF adjacency events debugging is on
```


Now, add your network statements to the other two routers.

```
R2(config)# router ospf 1
R2(config-router)# network 10.1.100.0 0.0.0.255 area 0
R2(config-router)# network 10.1.200.0 0.0.0.255 area 0

R3(config)# router ospf 1
R3(config-router)# network 10.1.200.0 0.0.0.255 area 0
```

Observe the debug output on R1. When you are done looking at this, you can turn off debugging on R1 with **undebug all**.

What advantage is gained from adding networks with a wildcard mask instead of using classful network addresses?

Step 3: OSPF show Commands

Some **show** commands are very useful for OSPF. The **show ip protocols** command displays basic high-level routing protocol information. The following shows information about OSPF:

```
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:
    10.1.100.0 0.0.0.255 area 0
    10.1.200.1 0.0.0.0 area 0
 Reference bandwidth unit is 100 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.1.2.1             110      00:04:21
  Distance: (default is 110)
```

Another useful command when looking at OSPF is **show ip ospf**:

```
R1# show ip ospf
 Routing Process "ospf 1" with ID 10.1.1.1
 Start time: 00:17:44.612, Time elapsed: 00:10:51.408
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 Supports Link-local Signaling (LLS)
 Supports area transit capability
 Router is not originating router-LSAs with maximum metric
 Initial SPF schedule delay 5000 msecs
 Minimum hold time between two consecutive SPFs 10000 msecs
 Maximum wait time between two consecutive SPFs 10000 msecs
 Incremental-SPF disabled
```



```
 Minimum LSA interval 5 secs
 Minimum LSA arrival 1000 msecs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 Number of areas transit capable is 0
 External flood list length 0
    Area BACKBONE(0)
        Number of interfaces in this area is 2
        Area has no authentication
        SPF algorithm last executed 00:03:21.132 ago
        SPF algorithm executed 5 times
        Area ranges are
        Number of LSA 4. Checksum Sum 0x021A30
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
```

Notice the router ID listed in the show output. The router ID of R1 is 10.1.1.1, even though we have not added this loopback into the OSPF process. The router chooses the router ID using the highest IP on a loopback interface when OSPF is configured. If an additional higher IP address loopback interface is added after OSPF is turned on, it does not become the router ID unless the router is reloaded. If there are no loopback interfaces present on the router, the router takes the highest available IP address on an interface. If there are no IP addresses assigned to interfaces, the OSPF process does not start.

The **show ip ospf neighbor** command displays important neighbor status, including adjacency state, address, router ID, and connected interface:

```
R1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.2.1          1   FULL/DR         00:00:33    10.1.200.2      FastEthernet0/0
10.1.3.1          1   FULL/DROTHER    00:00:32    10.1.200.3      FastEthernet0/0
10.1.2.1          0   FULL/  -        00:00:33    10.1.100.2      Serial0/0/0
```

If you need more detail, use **show ip ospf neighbor detail**, which shows more than just the standard one-line summaries of neighbors. However, in many instances, the regular command gives you all that you need.

Another helpful command is **show ip ospf interface** *interface_type number*. This command shows interface timers and network types. Here is the output for R1 f0/0:

```
R1# show ip ospf interface FastEthernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.1.200.1/24, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State BDR, Priority 1
```



```
  Designated Router (ID) 10.1.2.1, Interface address 10.1.200.2
  Backup Designated router (ID) 10.1.1.1, Interface address 10.1.200.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:09
  Supports Link-local Signaling (LLS)
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 2
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 2, Adjacent neighbor count is 2
    Adjacent with neighbor 10.1.2.1  (Designated Router)
    Adjacent with neighbor 10.1.3.1
  Suppress hello for 0 neighbor(s)
```

Another useful command is **show ip ospf database**, which displays the various LSAs in the OSPF database, organized by area and type.

```
R1# show ip ospf database

            OSPF Router with ID (10.1.1.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.1.1.1        10.1.1.1        123         0x80000005 0x00546C 4
10.1.2.1        10.1.2.1        112         0x80000004 0x006C51 4
10.1.3.1        10.1.3.1        106         0x80000004 0x00F94C 2

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.200.2      10.1.2.1        725         0x80000002 0x00D74F
```

Step 4: Adding Loopback Interfaces to OSPF

All three routers have loopback interfaces, but they are not yet advertised in the routing process. You can verify this with **show ip route** on your three routers.

```
R1# show ip route
Codes: 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
       i - IS-IS, su - IS-IS summary, 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

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.1.0 is directly connected, Loopback1
C       10.1.100.0 is directly connected, Serial0/0/0
C       10.1.200.0 is directly connected, FastEthernet0/0

R2# show ip route
Codes: 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
       i - IS-IS, su - IS-IS summary, 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

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.2.0 is directly connected, Loopback2
C       10.1.100.0 is directly connected, Serial0/0/0
C       10.1.200.0 is directly connected, FastEthernet0/0
```

```
R3# show ip route
Codes: 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
       i - IS-IS, su - IS-IS summary, 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

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.3.0 is directly connected, Loopback3
O       10.1.100.0 [110/65] via 10.1.200.2, 00:06:39, FastEthernet0/0
                   [110/65] via 10.1.200.1, 00:06:39, FastEthernet0/0
C       10.1.200.0 is directly connected, FastEthernet0/0
```

For each of the routers, the only loopback address that comes up is the locally connected one. We can add these into the routing process with the **network** command previously used to add the physical interfaces.

```
R1(config)# router ospf 1
R1(config-router)# network 10.1.1.0 0.0.0.255 area 0

R2(config)# router ospf 1
R2(config-router)# network 10.1.2.0 0.0.0.255 area 0

R3(config)# router ospf 1
R3(config-router)# network 10.1.3.0 0.0.0.255 area 0
```

Verify that these networks have been added to the routing table using the **show ip route** command:

```
R1# show ip route
Codes: 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
       i - IS-IS, su - IS-IS summary, 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, 5 subnets, 2 masks
O       10.1.2.1/32 [110/2] via 10.1.200.2, 00:00:03, FastEthernet0/0
O       10.1.3.1/32 [110/2] via 10.1.200.3, 00:00:03, FastEthernet0/0
C       10.1.1.0/24 is directly connected, Loopback1
C       10.1.100.0/24 is directly connected, Serial0/0/0
C       10.1.200.0/24 is directly connected, FastEthernet0/0
```


Now you can see the loopbacks of the other routers, but their subnet mask is incorrect, because the default network type on loopback interfaces advertises them as /32 (host) routes. To change this, go to the interface configuration mode of each loopback and use the **ip ospf network point-to-point** command. After the routes propagate, you see the correct subnet masks associated with those loopback interfaces.

```
R1(config)# interface loopback1
R1(config-if)# ip ospf network point-to-point

R2(config)# interface loopback2
R2(config-if)# ip ospf network point-to-point

R3(config)# interface loopback3
R3(config-if)# ip ospf network point-to-point

R1# show ip route
Codes: 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
       i - IS-IS, su - IS-IS summary, 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

     10.0.0.0/24 is subnetted, 5 subnets
O       10.1.3.0 [110/2] via 10.1.200.3, 00:00:01, FastEthernet0/0
O       10.1.2.0 [110/2] via 10.1.200.2, 00:00:01, FastEthernet0/0
C       10.1.1.0 is directly connected, Loopback1
C       10.1.100.0 is directly connected, Serial0/0/0
C       10.1.200.0 is directly connected, FastEthernet0/0
```

Step 5: Modifying Link Costs in OSPF

When you use the **show ip route** command on R1, you see that the most direct route to R2’s loopback is through its Ethernet connection. Next to this route is a pair in the form [administrative distance / metric]. The administrative distance is 110, the default administrative distance of OSPF on Cisco routers. The metric depends on the link type. OSPF picks the route with the lowest metric, which is a sum of link costs. You can modify a single link cost by using the interface-level command **ip ospf cost** *cost*. Use this on both ends of the link. In the following commands, the link cost of the Ethernet connection between the three routers is changed to a cost of 50. Notice the change in the metrics in the routing table.

```
R1(config)# interface fastEthernet 0/0
R1(config-if)# ip ospf cost 50

R2(config)# interface fastEthernet 0/0
R2(config-if)# ip ospf cost 50

R3(config)# interface fastEthernet 0/0
R3(config-if)# ip ospf cost 50
```



```
R1# show ip route
Codes: 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
       i - IS-IS, su - IS-IS summary, 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

     10.0.0.0/24 is subnetted, 5 subnets
O       10.1.3.0 [110/51] via 10.1.200.3, 00:01:40, FastEthernet0/0
O       10.1.2.0 [110/51] via 10.1.200.2, 00:01:40, FastEthernet0/0
C       10.1.1.0 is directly connected, Loopback1
C       10.1.100.0 is directly connected, Serial0/0/0
C       10.1.200.0 is directly connected, FastEthernet0/0
```

For reference, here are some default link costs (taken from Cisco.com):

- 56-kbps serial link—Default cost is 1785.
- 64-kbps serial link—Default cost is 1562.
- T1 (1.544-Mbps serial link)—Default cost is 64.
- E1 (2.048-Mbps serial link)—Default cost is 48.
- 4-Mbps Token Ring—Default cost is 25.
- Ethernet—Default cost is 10.
- 16-Mbps Token Ring—Default cost is 6.
- FDDI—Default cost is 1.
- X25—Default cost is 5208.
- Asynchronous—Default cost is 10,000.
- ATM— Default cost is 1.

Step 6: Modifying Interface Priorities

If you use the **show ip ospf neighbor detail** on any of the routers, you see that for the Ethernet network, R3 is the DR (designated router) and R2 is the BDR (backup designated router). This is determined by the interface priority for all routers in that network, which you see in the **show** output. The default priority is 1. If all the priorities are the same (which happens by default), the DR election is then based on router IDs. The highest router ID router becomes the DR, and the second highest becomes the BDR. All other routers become DROthers. If your routers do not have this behavior exactly, it may be because of the order the routers came up in. Routers sometimes do not leave the DR position unless their interface goes down and another router takes over. It is okay if your routers are not exactly like the example. We will change OSPF priorities on R1 and R2 to make R1 the DR and R2 the BDR. To do this, use the interface-level command **ip ospf priority** *number*. After changing this on both interfaces, look at the output of the **show ip ospf neighbor detail** command. You can also see the change with the **show ip ospf neighbor** command, but it requires more interpretation because it comes up with states per neighbor, rather than stating the DR and BDR on a neighbor adjacency network.


```
R1(config)# interface fastEthernet 0/0
R1(config-if)# ip ospf priority 10

R2(config)# interface fastEthernet 0/0
R2(config-if)# ip ospf priority 5

R1# show ip ospf neighbor detail
 Neighbor 10.1.2.1, interface address 10.1.200.2
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 5, State is FULL, 12 state changes
    DR is 10.1.200.1 BDR is 10.1.200.2
    Options is 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:37
    Neighbor is up for 00:01:32
    Index 3/3, retransmission queue length 0, number of retransmission 0
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 0, maximum is 0
    Last retransmission scan time is 0 msec, maximum is 0 msec
 Neighbor 10.1.3.1, interface address 10.1.200.3
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 12 state changes
    DR is 10.1.200.1 BDR is 10.1.200.2
    Options is 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:30
    Neighbor is up for 00:01:12
    Index 1/1, retransmission queue length 0, number of retransmission 3
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 1, maximum is 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
 Neighbor 10.1.2.1, interface address 10.1.100.2
    In the area 0 via interface Serial0/0/0
    Neighbor priority is 0, State is FULL, 12 state changes
    DR is 0.0.0.0 BDR is 0.0.0.0
    Options is 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:35
    Neighbor is up for 00:01:44
    Index 2/2, retransmission queue length 0, number of retransmission 2
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 2, maximum is 2
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

Note: To make a router take over as DR, you may need to use the **clear ip ospf process** command on all your routers after changing the priorities.

What is the purpose of a DR in OSPF?

What is the purpose of a BDR in OSPF?

Challenge: Topology Change

OSPF, like many link-state routing protocols, is reasonably fast when it comes to convergence. To test this, we can have R3 ping R1's loopback with a large number of pings. Mid-ping, we can change the topology. By default, the pings take the path from R3 to R1 over Ethernet, because it has the lowest total path cost. You can check this by performing a traceroute on R3 to the loopback of R1.

```
R3# traceroute 10.1.1.1

Type escape sequence to abort.
Tracing the route to 10.1.1.1

  1 10.1.200.1 0 msec 0 msec *
```

Read the next part carefully before trying out the commands on routers. First, start with having R3 ping R1's loopback with a high repeat number with **ping** *ip* **repeat** *number*. While this ping is going on, perform a **shutdown** on R1's f0/0 interface.

```
R3# ping 10.1.1.1 repeat 10000

R1(config)# interface fastEthernet 0/0
R1(config-if)# shutdown
```

Did you notice that some packets were dropped but then the pings started returning again?

How do you think OSPF would have faired against other routing protocols, such as RIP? What about against EIGRP?

Appendix A: TCL Script Verification

```
R1# tclsh
R1(tcl)#
R1(tcl)#foreach address {
+>(tcl)#10.1.1.1
+>(tcl)#10.1.2.1
+>(tcl)#10.1.3.1
+>(tcl)#10.1.100.1
+>(tcl)#10.1.100.2
+>(tcl)#10.1.200.1
+>(tcl)#10.1.200.2
+>(tcl)#10.1.200.3
+>(tcl)#} {
+>(tcl)#ping $address }
```



```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/57/64 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.100.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms


R2# tclsh
R2(tcl)#
R2(tcl)#foreach address {
+>(tcl)#10.1.1.1
+>(tcl)#10.1.2.1
+>(tcl)#10.1.3.1
+>(tcl)#10.1.100.1
+>(tcl)#10.1.100.2
+>(tcl)#10.1.200.1
+>(tcl)#10.1.200.2
+>(tcl)#10.1.200.3
+>(tcl)#} {
+>(tcl)#ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.100.1, timeout is 2 seconds:
```



```
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.100.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/57/64 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms

R3# tclsh
R3(tcl)#
R3(tcl)#foreach address {
+>(tcl)#10.1.1.1
+>(tcl)#10.1.2.1
+>(tcl)#10.1.3.1
+>(tcl)#10.1.100.1
+>(tcl)#10.1.100.2
+>(tcl)#10.1.200.1
+>(tcl)#10.1.200.2
+>(tcl)#10.1.200.3
+>(tcl)#} {
+>(tcl)#ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.100.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/14/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.200.3, timeout is 2 seconds:
```



```
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
```

Final Configurations

```
R1# show run
!
hostname R1
!
interface Loopback1
 description Engineering Department
 ip address 10.1.1.1 255.255.255.0
 ip ospf network point-to-point
!
interface FastEthernet0/0
 ip address 10.1.200.1 255.255.255.0
 ip ospf cost 50
 ip ospf priority 10
 duplex auto
 speed auto
!
interface Serial0/0/0
 ip address 10.1.100.1 255.255.255.0
 clock rate 64000
!
router ospf 1
 network 10.1.1.0 0.0.0.255 area 0
 network 10.1.100.0 0.0.0.255 area 0
 network 10.1.200.1 0.0.0.0 area 0
!
end

R2# show run
!
hostname R2
!
interface Loopback2
 description Marketing Department
 ip address 10.1.2.1 255.255.255.0
 ip ospf network point-to-point
!
interface FastEthernet0/0
 ip address 10.1.200.2 255.255.255.0
 ip ospf priority 5
!
interface Serial0/0/0
 ip address 10.1.100.2 255.255.255.0
!
router ospf 1
 network 10.1.2.0 0.0.0.255 area 0
 network 10.1.100.0 0.0.0.255 area 0
 network 10.1.200.0 0.0.0.255 area 0
!
end

R3# show run
!
hostname R3
!
interface Loopback3
 description Accounting Department
 ip address 10.1.3.1 255.255.255.0
```



```
 ip ospf network point-to-point
!
interface FastEthernet0/0
 ip address 10.1.200.3 255.255.255.0
!
router ospf 1
 network 10.1.3.0 0.0.0.255 area 0
 network 10.1.200.0 0.0.0.255 area 0
!
end
```

```
tclsh

foreach address {
10.1.1.1
10.1.2.1
10.1.3.1
10.1.100.1
10.1.100.2
10.1.200.1
10.1.200.2
10.1.200.3
} {
ping $address }
```

