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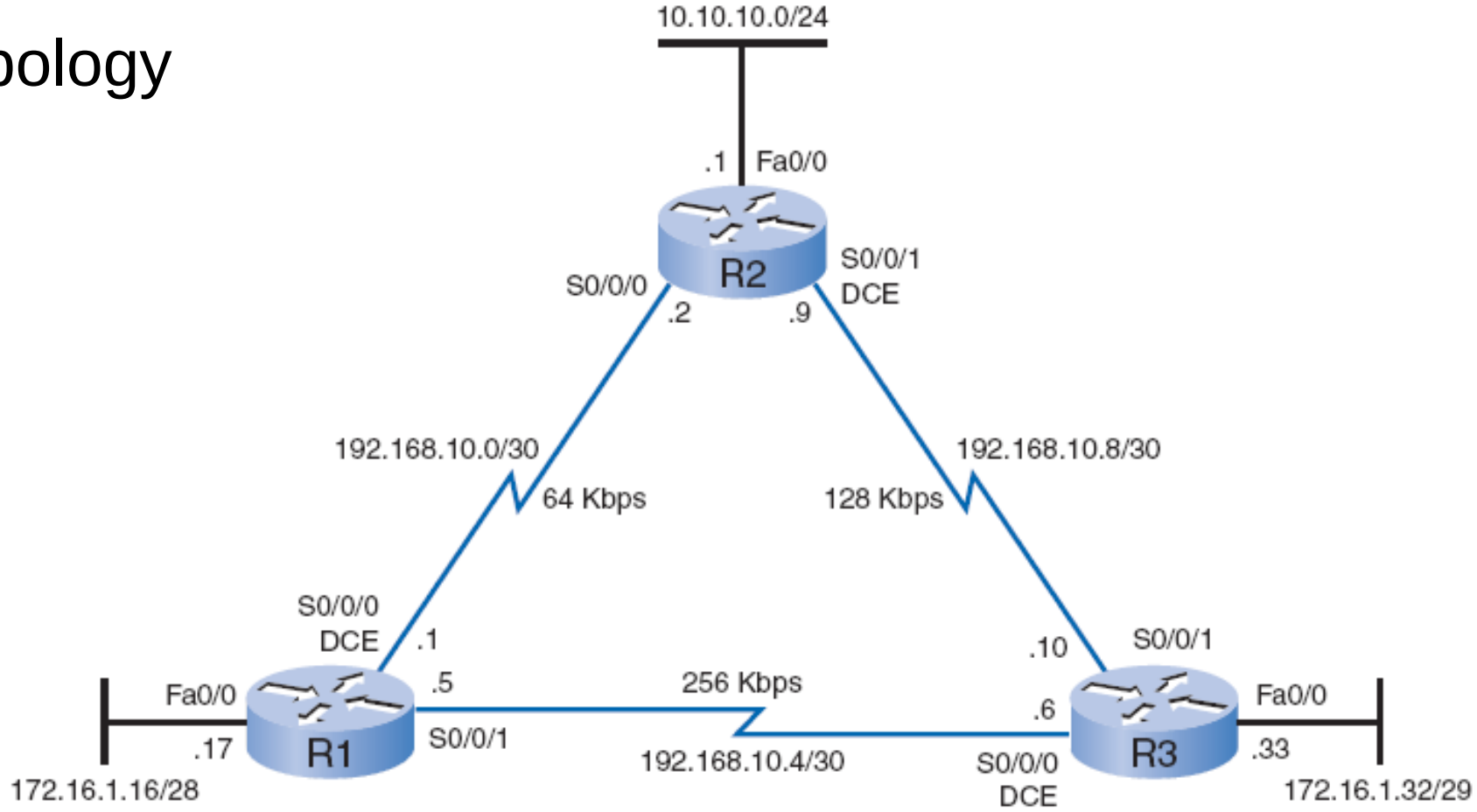
# Single Area OSPF

# Revision

# Module 2

# Topology




- Notice that the addressing scheme is ***discontiguous***.
  - OSPF is a classless routing protocol.
- There are **three serial links of various bandwidths** and that each router has multiple paths to each remote network.

# The network Command

*Process-ID does NOT have to be the same on all routers*

```
R1(config)# router ospf 1
R1(config-router)# network 172.16.1.16 0.0.0.15 area 0
R1(config-router)# network 192.168.10.0 0.0.0.3 area 0
R1(config-router)# network 192.168.10.4 0.0.0.3 area 0
```

*Area-ID must be the same on all routers*

```
R2(config)# router ospf 1
R2(config-router)# network 10.10.10.0 0.0.0.255 area 0
R2(config-router)# network 192.168.10.0 0.0.0.3 area 0
R2(config-router)# network 192.168.10.8 0.0.0.3 area 0
```

*Wildcard mask must be used*

```
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)# network 192.168.10.8 0.0.0.3 area 0
```

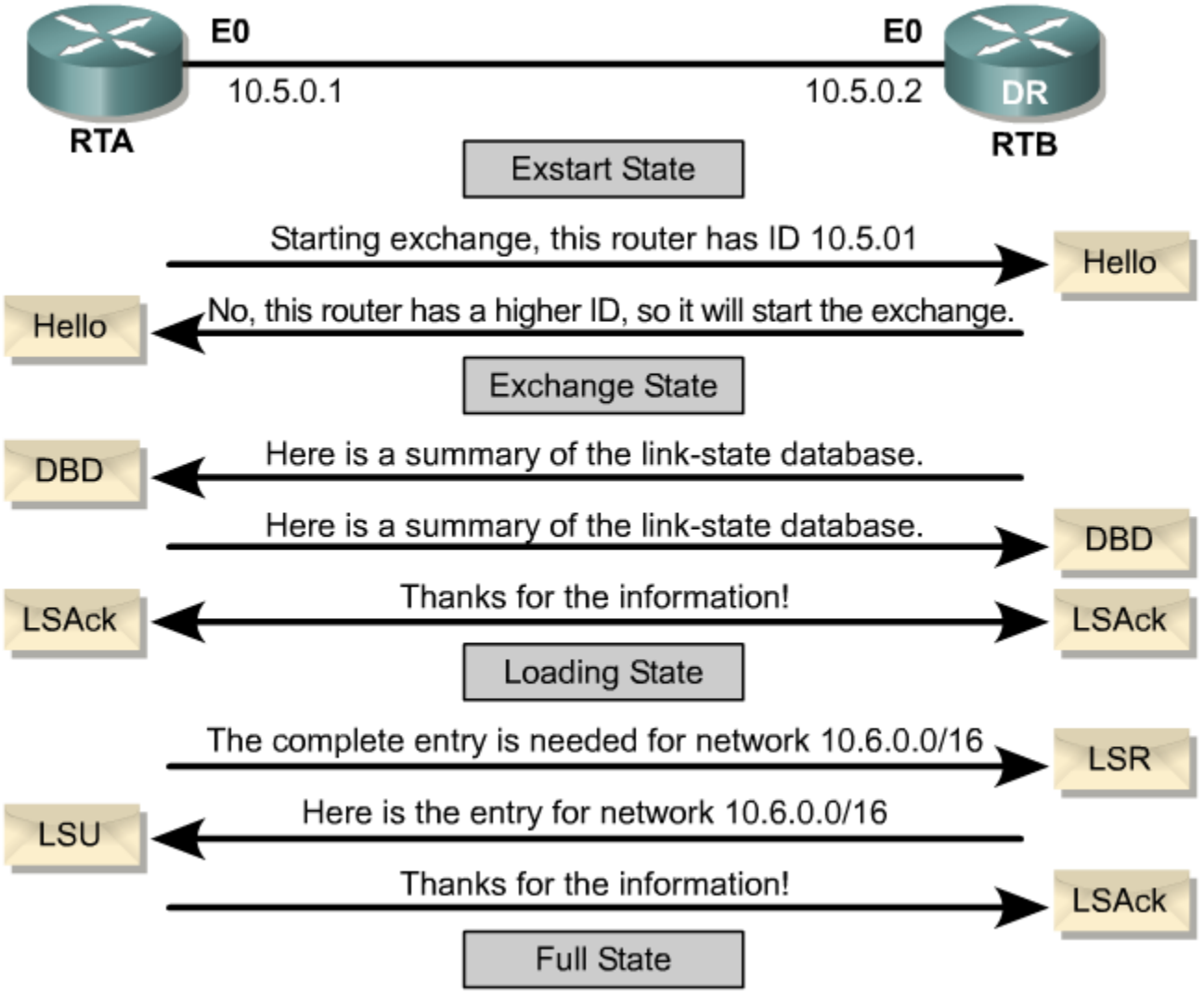
- **`network`** commands for all three routers, enabling OSPF on all interfaces.
- At this point, all routers should be able to ping all networks.

# Steps to OSPF Operation with States

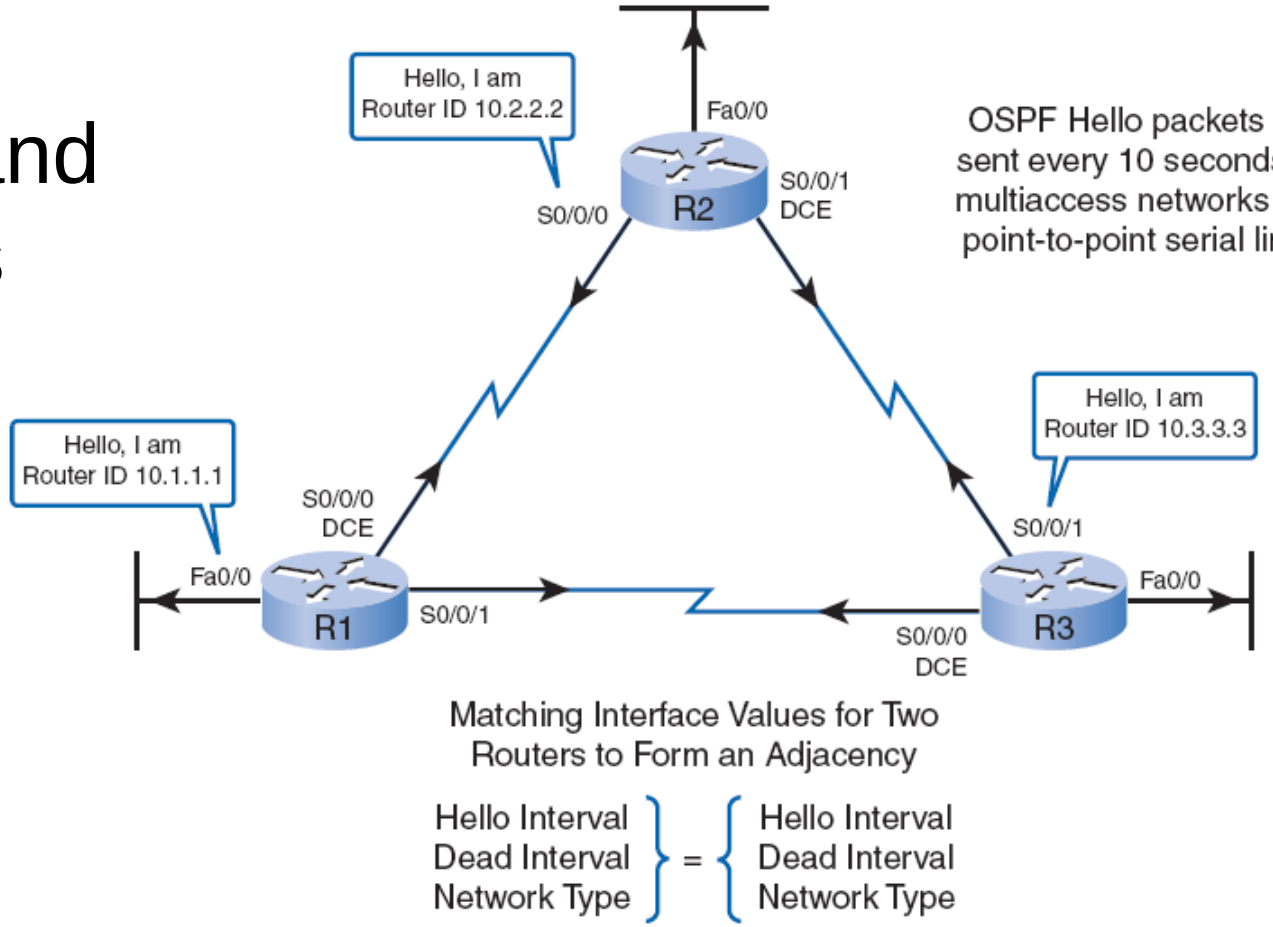
1. **Establishing router adjacencies (Routers are adjacent)**
   - Down State – No Hello received
   - Init State – Hello received, but not with this router's Router ID
     - "Hi, my name is Carlos." "Hi, my name is Maria."
   - Two-way State – Hello received, and with this router's Router ID
     - "Hi, Maria, my name is Carlos." "Hi, Carlos, my name is Maria."
2. **Electing DR and BDR – Multi-access (broadcast) segments only**
   - ExStart State with DR and BDR
   - Two-way State with all other routers
3. **Discovering Routes**
   - ExStart State
   - Exchange State
   - Loading State
   - Full State (Routers are "fully adjacent")
4. Calculating the Routing Table
5. Maintaining the LSDB and Routing Table

# Steps to OSPF Operation with States

## Discovering Routes and Reaching Full State



# Neighbors and Adjacencies

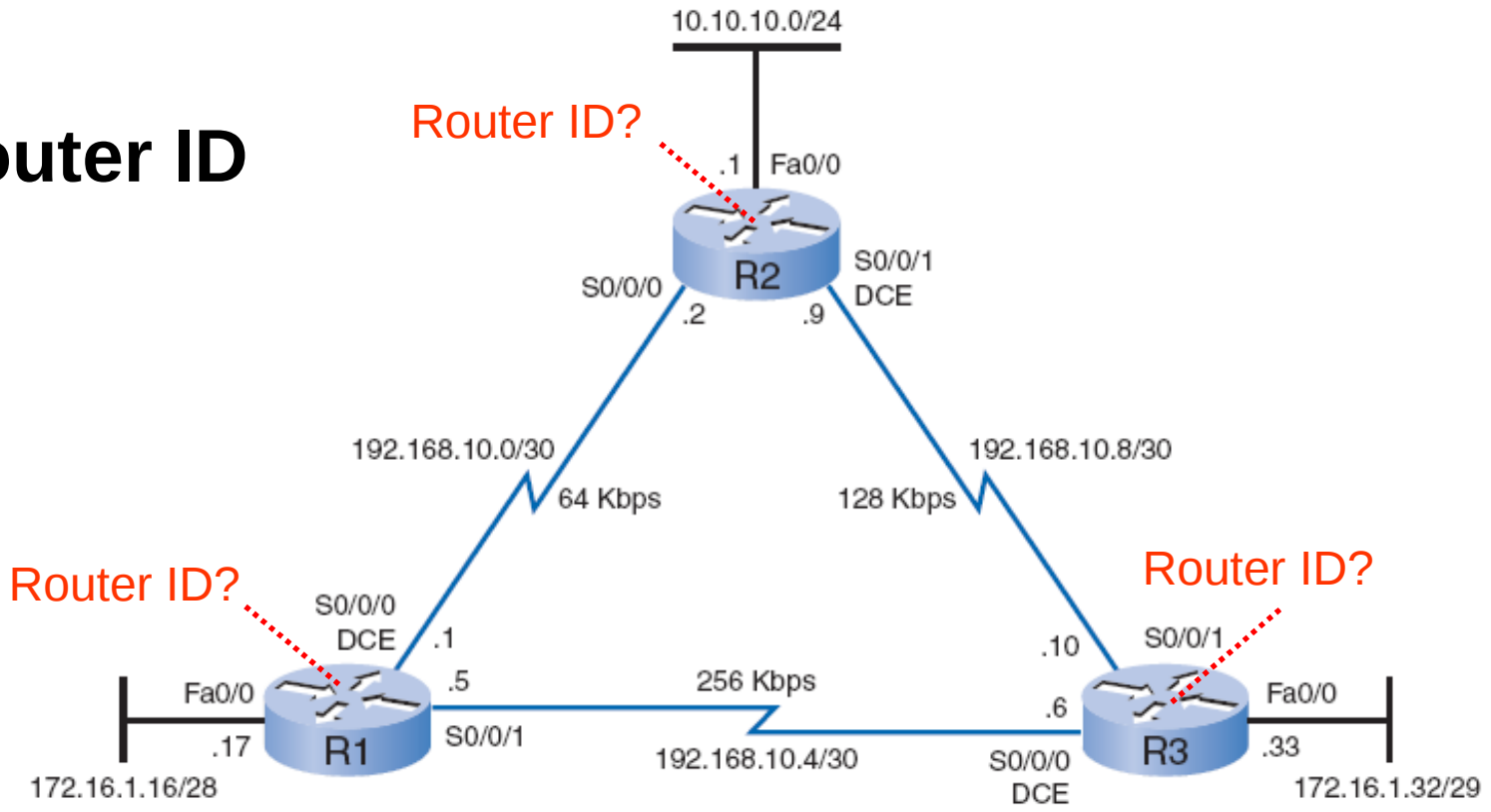



Matching Interface Values for Two Routers to Form an Adjacency

| | | |
|---|---|---|
| Hello Interval | = | Hello Interval |
| Dead Interval | = | Dead Interval |
| Network Type | = | Network Type |

- Before an OSPF router can flood its link states, must discover neighbors.
- Before two routers can form an OSPF neighbor adjacency, they must agree on three values:
  - Hello interval
  - Dead interval
  - Network type
- Both the interfaces must be part of the same network, including having the same subnet mask.

# OSPF Router ID




- **OSPF Router ID** is an IP address used to uniquely identify an OSPF router.
  - Also used in the DR and BDR process.

**1.** Use the IP address configured with the **OSPF `router-id` command**.

**2. Highest IP address** of any of its **loopback interfaces.**

**3. Highest *active* IP address** of any of its physical interfaces.

# Verifying OSPF

```
R1# show ip ospf neighbor

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

- **Neighbor ID:** The router ID of the neighboring router.
- **Pri:** The OSPF priority of the interface. (***later***)
- **State:** The OSPF state of the interface.
  - FULL state means that the router's interface is fully adjacent with its neighbor and they have identical OSPF link-state databases.
  - OSPF states are discussed in ***CCNP***.
- **Dead Time:** The amount of time remaining that the router will wait to receive an OSPF Hello packet from the neighbor before declaring the neighbor down.
  - This value is reset when the interface receives a Hello packet.
- **Address:** The IP address of the neighbor's interface to which this router is directly connected.
- **Interface:** The interface on which this router has formed adjacency with the neighbor.

# Verifying OSPF

```
R1# show ip ospf interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
  <output omitted>
```

- Two routers may not form an OSPF adjacency if:
  - The subnet masks do not match, causing the routers to be on separate networks.
  - OSPF Hello or Dead timers do not match.
  - OSPF network types do not match.
  - There is a missing or incorrect OSPF **network** command.
- Other powerful OSPF troubleshooting commands include the following:
  - **show ip protocols**
  - **show ip ospf**
  - **show ip ospf interface**

# Verifying 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:
    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
  Reference bandwidth unit is 100 mbps
   Routing Information Sources:
     Gateway         Distance      Last Update
     10.2.2.2        110           11:29:29
     10.3.3.3        110           11:29:29
  Distance: (default is 110)
```

*OSPF Process ID*

*OSPF Router ID*

*Networks OSPF is advertising that are originating from this router*

*OSPF Neighbors*

*Administrative Distance*

# Examining the Routing Table

```
R1# show ip route
Codes: <some code output omitted>
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

    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 192.168.10.2, 14:27:57, Serial0/0/0
    172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/65] via 192.168.10.6, 14:27:57, Serial0/0/1
C       172.16.1.16/28 is directly connected, FastEthernet0/0
    10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O       10.10.10.0/24 [110/65] via 192.168.10.2, 14:27:57, Serial0/0/0
C       10.1.1.1/32 is directly connected, Loopback0
```

- The quickest way to verify OSPF convergence is to look at the routing table for each router.
- Loopback interfaces are included.
- Unlike RIPv2 and EIGRP, OSPF does not automatically summarize at major network boundaries.

# Examining the Routing Table

```
R2# show ip route
Codes: <some code output omitted>
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

    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 [110/128] via 192.168.10.1, 14:31:18, Serial0/0/0
C       192.168.10.8 is directly connected, Serial0/0/1
    172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/65] via 192.168.10.10, 14:31:18, Serial0/0/1
O       172.16.1.16/28 [110/65] via 192.168.10.1, 14:31:18, Serial0/0/0
    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
```

# Examining the Routing Table

```
R3# show ip route
Codes: <some code output omitted>
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

    192.168.10.0/30 is subnetted, 3 subnets
O      192.168.10.0 [110/845] via 192.168.10.9, 14:31:52, Serial0/0/1
                    [110/845] via 192.168.10.5, 14:31:52, Serial0/0/0
C      192.168.10.4 is directly connected, Serial0/0
C      192.168.10.8 is directly connected, Serial0/1
    172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C      172.16.1.32/29 is directly connected, FastEthernet0/0
O      172.16.1.16/28 [110/782] via 192.168.10.5, 14:31:52, Serial0/0/0
    10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C      10.3.3.3/32 is directly connected, Loopback0
O      10.10.10.0/24 [110/782] via 192.168.10.9, 14:31:52, Serial0/0/1
```

# OSPF Metric

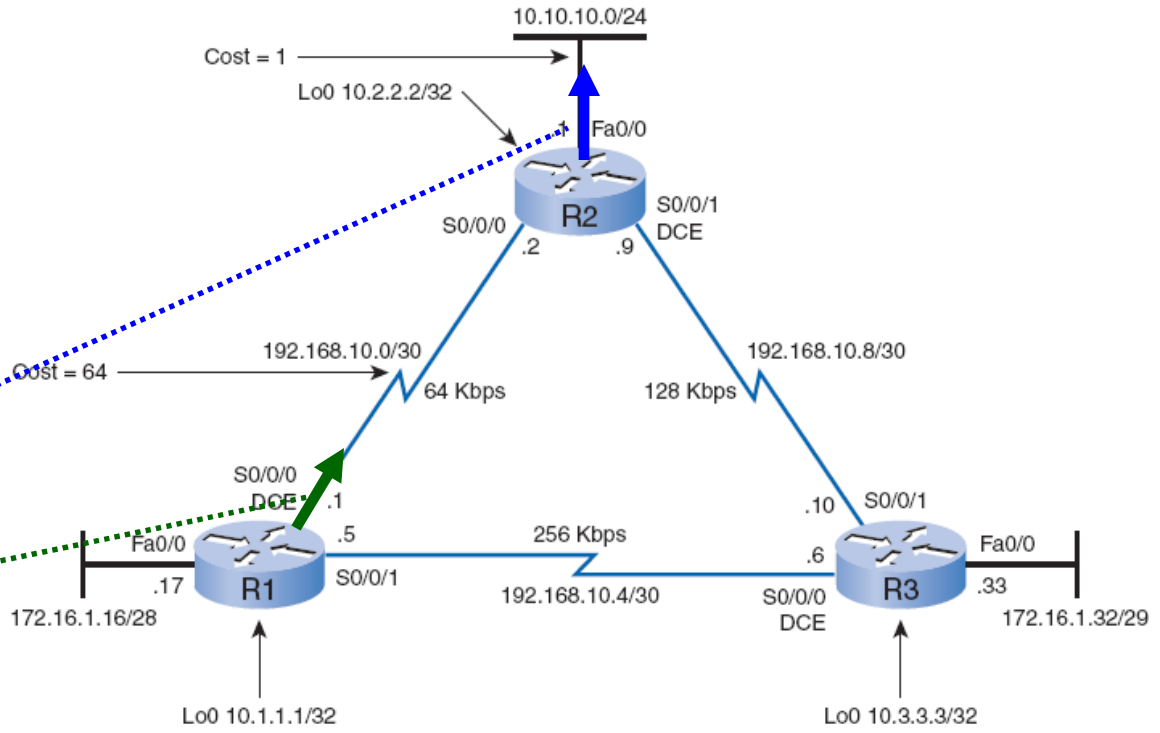
| Interface Type | $10^8$/bps = Cost |
|---|---|
| Fast Ethernet and faster | $10^8$/100,000,000 bps = 1 |
| Ethernet | $10^8$/10,000,000 bps = 10 |
| E1 | $10^8$/2,048,000 bps = 48 |
| T1 | $10^8$/1,544,000 bps = 64 |
| 128 Kbps | $10^8$/128,000 bps = 781 |
| 64 Kbps | $10^8$/64,000 bps = 1562 |
| 56 Kbps | $10^8$/56,000 bps = 1785 |

Cisco IOS Cost for OSPF = $10^8$/bandwidth in bps

- Cisco IOS software uses the cumulative bandwidths of the outgoing interfaces from the router to the destination network as the cost value.
- **$10^8$** is known as the *reference bandwidth*

# OSPF Accumulates Cost

| Interface Type | $10^8$/bps = Cost |
|---|---|
| Fast Ethernet and faster | $10^8$/100,000,000 bps = 1 |
| Ethernet | $10^8$/10,000,000 bps = 10 |
| E1 | $10^8$/2,048,000 bps = 48 |
| T1 | $10^8$/1,544,000 bps = 64 |
| 128 Kbps | $10^8$/128,000 bps = 781 |
| 64 Kbps | $10^8$/64,000 bps = 1562 |
| 56 Kbps | $10^8$/56,000 bps = 1785 |




Serial interfaces bandwidth value defaults to T1 or 1544 Kbps.

```
R1# show ip route

O    10.10.10.0/24 [110/65] via 192.168.10.2, 14:27:57, Serial0/0/0
```

- T1 cost **64** + Fast Ethernet cost **1** = **65**
- The "**Cost = 64**" refers to the default cost of the serial interface, $10^8$/1,544,000 bps = 64, and not to the actual 64-Kbps "speed" of the link.

# Modifying the Cost of the Link

```
Router(config-if)# bandwidth bandwidth-kbps
```

```
R1(config)# inter serial 0/0/0
R1(config-if)# bandwidth 64
R1(config-if)# inter serial 0/0/1
R1(config-if)# bandwidth 256
R1(config-if)# end
R1# show ip ospf interface serial 0/0/0
Serial0/0 is up, line protocol is up
Internet Address 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,
<output omitted>
```

```
100,000,000/64,000 = 1562
```

- The **bandwidth** command is used to modify the bandwidth value used by the Cisco IOS software in calculating the OSPF cost metric.
  - Same as with EIGRP

# The **ip ospf cost** Command

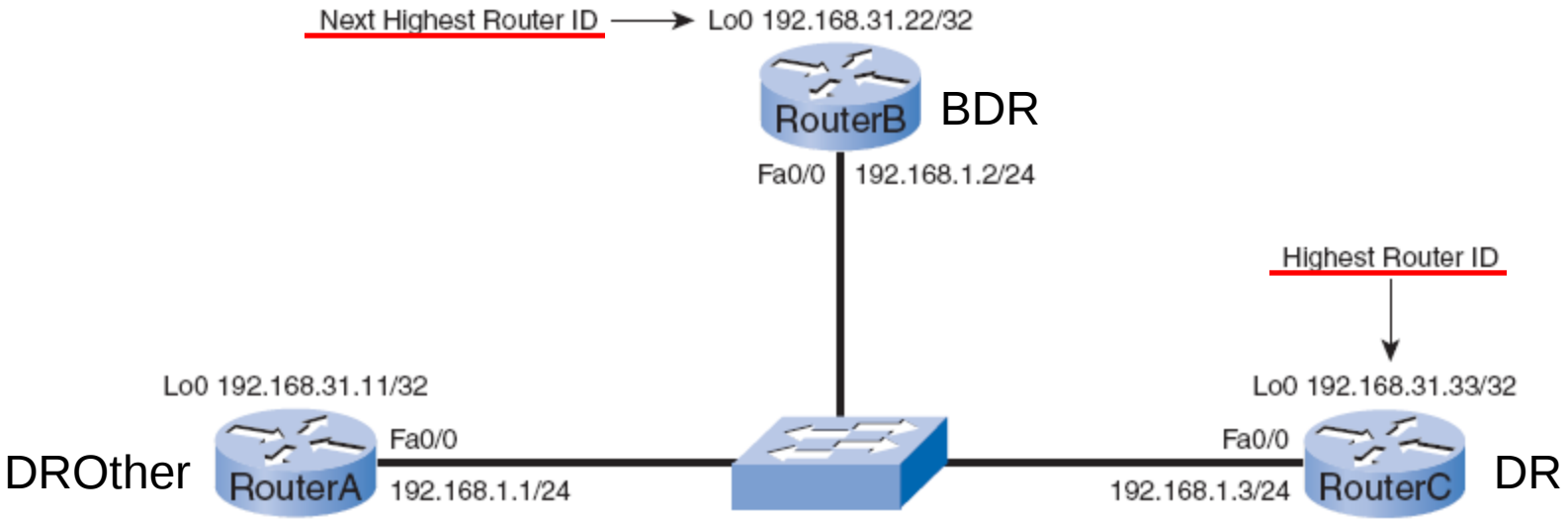
```
R1(config)# inter serial 0/0/0
R1(config-if)# bandwidth 64
R1(config-if)# end
R1# show ip ospf interface serial 0/0/0
Serial0/0 is up, line protocol is up
Internet Address 192.168.10.1/30, Area 0
Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 1562
<output omitted>
```

100,000,000/64,000 = 1562

```
R1(config)# interface serial 0/0/0
R1(config-if)# ip ospf cost 1562
```

- An alternative method to using the **bandwidth** command is to use the **ip ospf cost** command, which allows you to directly specify the cost of an interface.
- This will not change the output of the **show ip ospf interface** command,

# DR/BDR Election




- The following criteria are applied:
  1. **DR**: Router with the highest OSPF interface priority.
  2. **BDR**: Router with the second highest OSPF interface priority.
  3. If OSPF interface priorities are equal, the highest router ID is used to break the tie.
- Default OSPF interface priority is **1**.
- Current configuration, the **OSPF router ID** is used to elect the DR and BDR.

```
RouterA# show ip ospf neighbor
Neighbor ID     Pri State           Dead Time   Address     Interface
192.168.31.33   1   FULL/DR         00:00:39    192.168.1.3 FastEthernet0/0
192.168.31.22   1   FULL/BDR        00:00:36    192.168.1.2 FastEthernet0/0
```

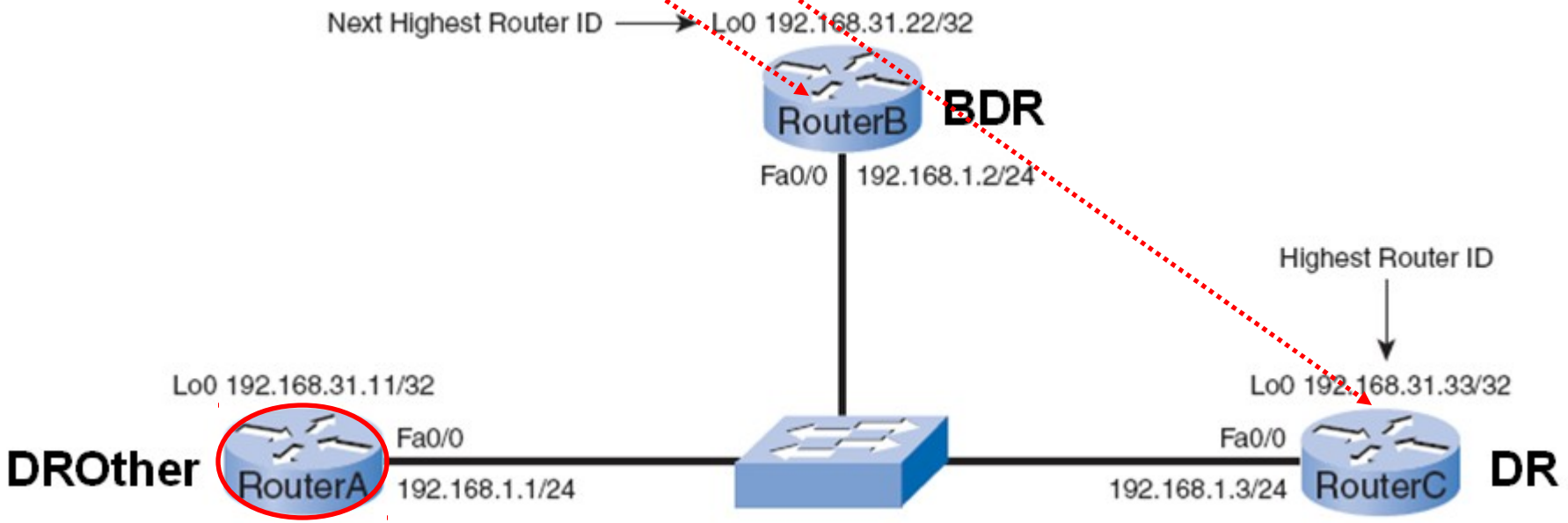
```
RouterB# show ip ospf neighbor
Neighbor ID     Pri State           Dead Time   Address     Interface
192.168.31.33   1   FULL/DR         00:00:34    192.168.1.3 FastEthernet0/0
192.168.31.11   1   FULL/DROTHER    00:00:38    192.168.1.1 FastEthernet0/0
```

```
RouterC# show ip ospf neighbor
Neighbor ID     Pri State           Dead Time   Address     Interface
192.168.31.22   1   FULL/BDR        00:00:35    192.168.1.2 FastEthernet0
192.168.31.11   1   FULL/DROTHER    00:00:32    192.168.1.1 FastEthernet0
```

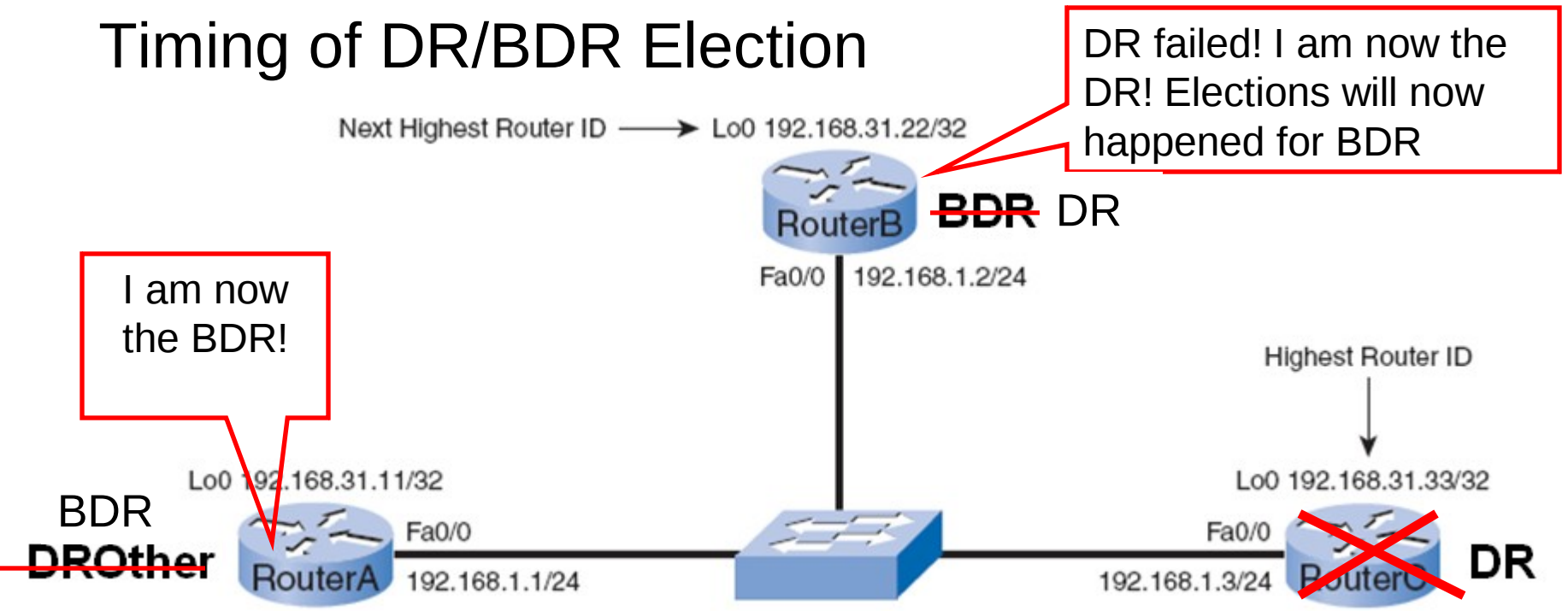
- **DROthers**
  - Only form *full* adjacencies with the DR and BDR
  - Still form a neighbor adjacency with any DROthers (receives Hello packets).
    - Displayed as 2WAY.

# Verifying Router States

```
RouterA# show ip ospf interface fastethernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 192.168.1.1/24, Area 0
  Process ID 1, Router ID 192.168.31.11, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DROTHER, Priority 1
  Designated Router (ID) 192.168.31.33, Interface address 192.168.1.3
  Backup Designated router (ID) 192.168.31.22, Interface address
   192.168.1.2
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
<output omitted>
```

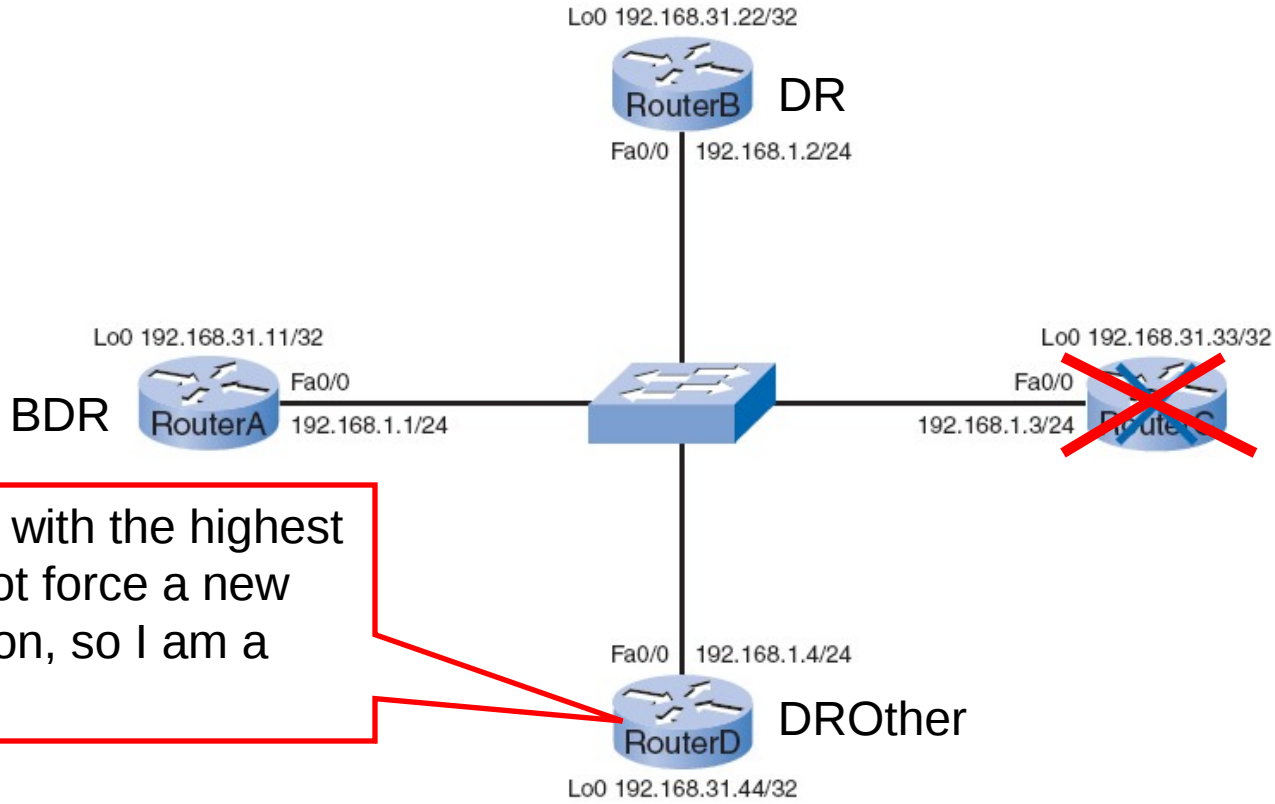


# Timing of DR/BDR Election




- When the DR is elected, it remains the DR until one of the following conditions occurs:
  - The DR fails.
  - The OSPF process on the DR fails.
  - The multiaccess interface on the DR fails.
- If the DR fails, the BDR assumes the role of DR, and an election is held to choose a new BDR.

# Timing of DR/BDR Election




- *If a new router enters the network after the DR and BDR have been elected, it will not become the DR or the BDR even if it has a higher OSPF interface priority or router ID than the current DR or BDR.*

# OSPF Interface Priority

```
Router(config-if)# ip ospf priority {0 - 255}
```

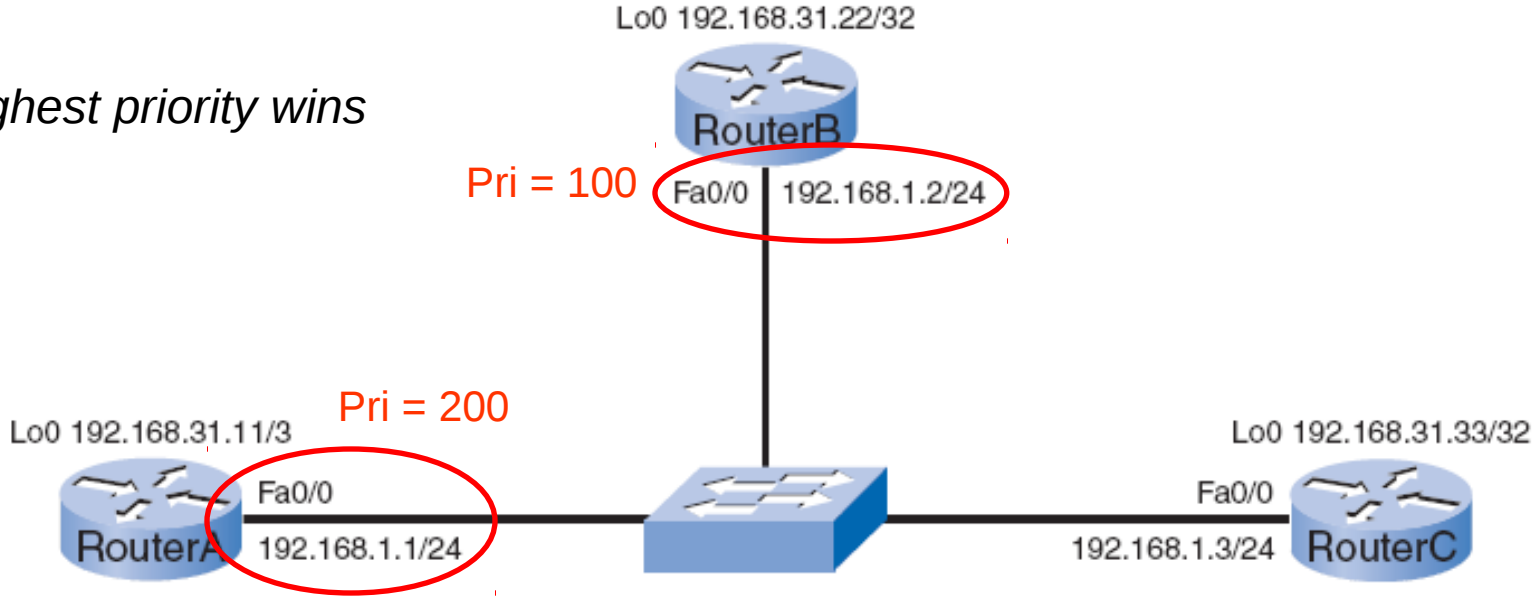
- Important for this router to have sufficient CPU and memory capacity to handle the responsibility.
- Control the election of these routers with the **`ip ospf priority`** interface command.
- Priority (Highest priority wins):
  - **0** = Cannot become DR or BDR
  - **1** = Default
    - Therefore, the router ID determines the DR and BDR.
- Priorities are an interface-specific value, they provide better control of the OSPF multiaccess networks.
- They also allow a router to be the DR in one network and a DROther in another.

# OSPF Interface Priority

```
RouterA# show ip ospf interface fastethernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 192.168.1.1/24, Area 0
  Process ID 1, Router ID 192.168.31.11, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DROTHER, Priority 1
  Designated Router (ID) 192.168.31.33, Interface address 192.168.1.3
  Backup Designated router (ID) 192.168.31.22, Interface address
   192.168.1.2
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
  <output omitted>
```

- The OSPF interface priority can be viewed using the **`show ip ospf interface`** command.

*Highest priority wins*



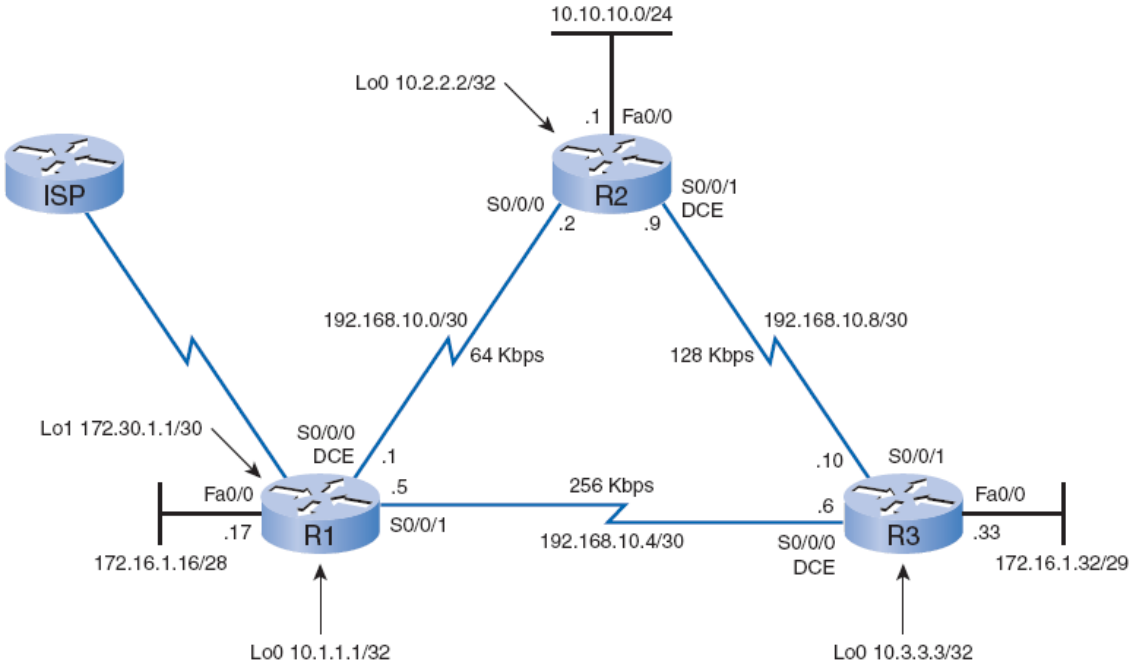

```
RouterA(config)# interface fastethernet 0/0
RouterA(config-if)# ip ospf priority 200
```

```
RouterB(config)# interface fastethernet 0/0
RouterB(config-if)# ip ospf priority 100
```

- After doing a **`shutdown`** and a **`no shutdown`** on the Fast Ethernet 0/0 interfaces of all three routers, we see the result of the change of OSPF interface priorities.

# Redistributing an OSPF Default Route

*The static default route is using the loopback as an exit interface because the ISP router in this topology does not physically exist.*




```
R1(config)# interface loopback 1
R1(config-if)# ip add 172.30.1.1 255.255.255.252
R1(config-if)# exit
R1(config)# ip route 0.0.0.0 0.0.0.0 loopback 1
R1(config)# router ospf 1
R1(config-router)# default-information originate
```

- Like RIP, OSPF requires the use of the **`default-information originate`** command to advertise the 0.0.0.0/0 static default route to the other routers in the area.
- If the **`default-information originate`** command is not used, the default "quad zero" route will not be propagated to other routers in the OSPF area.

# R1's Routing Table

```
R1# show ip route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

   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 [110/1171] via 192.168.10.6, 00:00:58, Serial0/0/1
   172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O     172.16.1.32/29 [110/391] via 192.168.10.6, 00:00:58, Serial0/0/1
C     172.16.1.16/28 is directly connected, FastEthernet0/0
   172.30.0.0/30 is subnetted, 1 subnets
C     172.30.1.0 is directly connected, Loopback1
   10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O     10.10.10.0/24 [110/1172] via 192.168.10.6, 00:00:58, Serial0/0/1
C     10.1.1.1/32 is directly connected, Loopback0
S*  0.0.0.0/0 is directly connected, Loopback1
```

# R2's Routing Table

```
R2# show ip route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

   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 [110/1171] via 192.168.10.6, 00:00:58, Serial0/0/1
   172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O     172.16.1.32/29 [110/391] via 192.168.10.6, 00:00:58, Serial0/0/1
C     172.16.1.16/28 is directly connected, FastEthernet0/0
   172.30.0.0/30 is subnetted, 1 subnets
C     172.30.1.0 is directly connected, Loopback1
   10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O     10.10.10.0/24 [110/1172] via 192.168.10.6, 00:00:58, Serial0/0/1
C     10.1.1.1/32 is directly connected, Loopback0
S*  0.0.0.0/0 is directly connected, Loopback1
```

# R3's Routing Table

```
R3# show ip route

Gateway of last resort is 192.168.10.5 to network 0.0.0.0

     192.168.10.0/30 is subnetted, 3 subnets
O       192.168.10.0 [110/1952] via 192.168.10.5, 00:00:38, S0/0/0
C       192.168.10.4 is directly connected, Serial0/0/0
C       192.168.10.8 is directly connected, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.1.32/29 is directly connected, FastEthernet0/0
O       172.16.1.16/28 [110/391] via 192.168.10.5, 00:00:38, S0/0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.3.3.3/32 is directly connected, Loopback0
O       10.10.10.0/24 [110/782] via 192.168.10.9, 00:00:38, S0/0/1
O*E2 0.0.0.0/0 [110/1] via 192.168.10.5, 00:00:27, Serial0/0/0
```

# External Type 2 Route

```
R3# show ip route

O*E2 0.0.0.0/0 [110/1] via 192.168.10.5, 00:00:27, Serial0/0/0
```

- **E2** denotes that this route is an OSPF External Type 2 route.
- OSPF external routes fall in one of two categories:
  - External Type 1 (E1)
  - External Type 2 (E2)
- OSPF accumulates cost for an **E1 route** as the route is being propagated throughout the OSPF area.
  - This process is identical to cost calculations for normal OSPF internal routes.
- **E2 route** is always the external cost, irrespective of the interior cost to reach that route.
  - In this topology, because the default route has an external cost of 1 on the R1 router, R2 and R3 also show a cost of 1 for the default E2 route.
  - E2 routes at a cost of 1 are the default OSPF configuration.
  - More later