INSTITUTO POLITÉCNICO DE TOMAR

ESCOLA SUPERIOR DE TECNOLOGIA DE TOMAR

ENGENHARIA INFORMÁTICA

REDES DE DADOS II

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Lab 3 – Implement Multi-Area OSPFv2 Topology

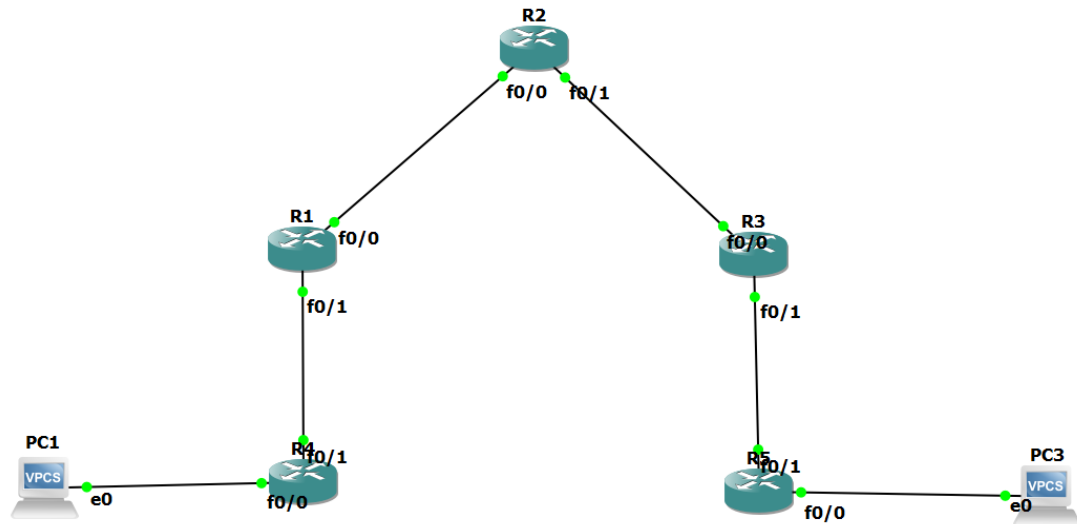Rodrigo Bento 21890

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Parte 1: Build the Network and Configure Basic Device Settings and Interface Addressing

Step 1: Cable the network as shown in the topology.

Step 2: Configure basic settings.

a. **Disable DNS lookup.**

   R1(config)#no ip domain-lookup

b. **Configure device names as shown in the topology.**

   R1(config)#hostname R1
   R2(config)#hostname R2
   R3(config)#hostname R3

c. **Configure password encryption.**

   R1(config)#service password-encryption

d. **Assign class as the privileged EXEC password.**

   R1(config)#enable password class

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e. **Assign cisco as the console and vty passwords.**

R1(config)#line console 0

R1(config-line)#password cisco

R1(config-line)#exit

R1(config)#line vty 0 4

R1(config-line)#password cisco

R1(config-line)#exit

f. **Configure a MOTD banner to warn users that unauthorized access is prohibited.**

R1(config)#banner motd "Unauthorized access is prohibited"

g. **Configure logging synchronous for the console line.**

R1(config)#line console 0

R1(config-line)#login

R1(config-line)#exit

h. **Configure the IP addresses listed in the Addressing Table for all interfaces.**

Comandos para uma interface do R1 (processo semelhante, com endereços diferentes para as restantes interfaces e routers):

R1#conf t

R1(config)#int f0/0

R1(config-if)#ip add 172.16.0.2 255.255.255.252

R1(config-if)#no shut

R1(config-if)#exit

Router1:

```
interface FastEthernet0/0
 ip address 172.16.0.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.10.0.1 255.255.255.252
 duplex auto
 speed auto
!
```

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Router2:

```
interface Loopback0
 ip address 209.165.200.225 255.255.255.224
!
interface FastEthernet0/0
 ip address 172.16.0.1 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 172.16.1.1 255.255.255.252
 duplex auto
 speed auto
!
```

Router3:

```
interface FastEthernet0/0
 ip address 172.16.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.10.4.1 255.255.255.252
 duplex auto
 speed auto
!
```

Router4:

```
interface FastEthernet0/0
 ip address 10.10.1.1 255.255.255.0
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.10.0.2 255.255.255.252
 duplex auto
 speed auto
!
```

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Router5:

```
interface FastEthernet0/0
 ip address 10.10.5.1 255.255.255.0
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.10.4.2 255.255.255.252
 duplex auto
 speed auto
!
```

Parte 2: Configure Multiarea OSPFv2

Step 1: Configure OSPF on all routers and L3 switches.
   a. **Configure OSPF on all routing devices according to the network diagram.
   Changing the reference bandwidth to a higher value allows for a differentiation of
   cost between higher-speed interfaces.**

```
Router1(config)#router ospf 1
Router1(config-router)#router-i
Router1(config-router)#router-id 1.1.1.1
Router1(config-router)#network 172.16.0.0 0.0.0.3 area 0
Router1(config-router)#network 10.10.0.0  0.0.0.3 area 1
Router1(config-router)#auto-cost reference-
Router1(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
Router1(config-router)#
```

```
Router2(config)#router ospf 1
Router2(config-router)#router-id 2.2.2.1
Router2(config-router)#network 172.16.0.0 0.0.0.3 area 0
*Mar  1 00:43:19.207: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/0
from LOADING to FULL, Loading Done
Router2(config-router)#network 172.16.1.0  0.0.0.3 area 0
Router2(config-router)#auto-cost refere
Router2(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
Router2(config-router)#
```

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```
Router3(config)#router ospf 1
Router3(config-router)#router-id 3.3.3.1
Router3(config-router)#network 172.16.1.0 0.0.0.3 area 0
Router3(config-router)#network
*Mar  1 00:20:32.531: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.1 on FastEthernet0/0
from LOADING to FULL, Loading Done
Router3(config-router)#network 10.10.4.0 0.0.0.3 area 2
Router3(config-router)#auto-cos
Router3(config-router)#auto-cost ref
Router3(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
       Please ensure reference bandwidth is consistent across all routers.
Router3(config-router)#
```

```
Router4(config)#router ospf 1
Router4(config-router)#router-id 1.1.1.2
Router4(config-router)#network 10.10.1.0 0.0.0.255 area 1
Router4(config-router)#network 10.10.0.0 0.0.0.3 area 1
Router4(config-router)#auto-cost ref
Router4(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
       Please ensure reference bandwidth is consistent across all routers.
Router4(config-router)#
*Mar  1 00:23:30.175: %OSPF-5-ADJCHG: Process 1, Nbr 1.1.1.1 on FastEthernet0/1
from LOADING to FULL, Loading Done
Router4(config-router)#
```

```
Router5(config)#router ospf 1
Router5(config-router)#router-id 3.3.3.2
Router5(config-router)#network 10.10.4.0 0.0.0.3 area 2
Router5(config-router)#network 10.10.4.0 0.0.0.3 area 2
*Mar  1 00:51:54.763: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.1 on FastEthernet0/1
from LOADING to FULL, Loading Done
Router5(config-router)#network 10.10.5.0 0.0.0.255 area 2
Router5(config-router)#auto-cost ref
Router5(config-router)#auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
       Please ensure reference bandwidth is consistent across all routers.
Router5(config-router)#
```

O comando auto-cost reference-bandwidth 1000 serve para declarar que as ligações são feitas para 1Gbps.

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b. Verify the OSPF configuration on all routing devices using the show ip protocols command.

```
Router1#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 1.1.1.1
  It is an area border router
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.0.0 0.0.0.3 area 1
    172.16.0.0 0.0.0.3 area 0
 Reference bandwidth unit is 1000 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.1              110       00:01:45
    1.1.1.2              110       00:09:40
    2.2.2.1              110       00:15:47
  Distance: (default is 110)

Router1#
```

```
Router2#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 2.2.2.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    172.16.0.0 0.0.0.3 area 0
    172.16.1.0 0.0.0.3 area 0
 Reference bandwidth unit is 1000 mbps
  Routing Information Sources:
    Gateway         Distance      Last Update
    1.1.1.1              110       00:10:03
    3.3.3.1              110       00:02:09
  Distance: (default is 110)

Router2#
```

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```
Router3#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 3.3.3.1
  It is an area border router
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.4.0 0.0.0.3 area 2
    172.16.1.0 0.0.0.3 area 0
 Reference bandwidth unit is 1000 mbps
  Routing Information Sources:
    Gateway          Distance      Last Update
    1.1.1.1              110        00:02:28
    3.3.3.2              110        00:02:28
  Distance: (default is 110)

Router3#
```

```
Router4#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 1.1.1.2
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.0.0 0.0.0.3 area 1
    10.10.1.0 0.0.0.255 area 1
 Reference bandwidth unit is 1000 mbps
  Routing Information Sources:
    Gateway          Distance      Last Update
    1.1.1.1              110        00:02:45
  Distance: (default is 110)

Router4#
```

```
Router5#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 3.3.3.2
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.4.0 0.0.0.3 area 2
    10.10.5.0 0.0.0.255 area 2
 Reference bandwidth unit is 1000 mbps
  Routing Information Sources:
    Gateway          Distance      Last Update
    3.3.3.1              110        00:03:14
  Distance: (default is 110)

Router5#
```

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c. Verify the OSPF interfaces using the show ip ospf interface brief command on each routing device

```
Router1#show ip ospf int br
Interface    PID   Area        IP Address/Mask    Cost   State Nbrs F/C
Fa0/0        1     0           172.16.0.2/30      100    DR    1/1
Fa0/1        1     1           10.10.0.1/30       100    DR    1/1
Router1#
```

```
Router2#show ip ospf int br
Interface    PID   Area        IP Address/Mask    Cost   State Nbrs F/C
Fa0/1        1     0           172.16.1.1/30      100    DR    1/1
Fa0/0        1     0           172.16.0.1/30      100    BDR   1/1
Router2#
```

```
Router3#show ip ospf int br
Interface    PID   Area        IP Address/Mask    Cost   State Nbrs F/C
Fa0/0        1     0           172.16.1.2/30      100    BDR   1/1
Fa0/1        1     2           10.10.4.1/30       100    DR    1/1
Router3#
```

```
Router4#show ip ospf int br
Interface    PID   Area        IP Address/Mask    Cost   State Nbrs F/C
Fa0/1        1     1           10.10.0.2/30       100    BDR   1/1
Fa0/0        1     1           10.10.1.1/24       100    DR    0/0
Router4#
```

```
Router5#show ip ospf int br
Interface    PID   Area        IP Address/Mask    Cost   State Nbrs F/C
Fa0/0        1     2           10.10.5.1/24       100    DR    0/0
Fa0/1        1     2           10.10.4.2/30       100    BDR   1/1
Router5#
```

d. Verify which OSPF neighbors R1 has established an adjacency with using the show ip ospf neighbor command.

```
Router1#show ip ospf neighbor

Neighbor ID     Pri   State      Dead Time   Address       Interface
2.2.2.1           1   FULL/BDR   00:00:30    172.16.0.1    FastEthernet0/0
1.1.1.2           1   FULL/BDR   00:00:39    10.10.0.2     FastEthernet0/1
Router1#
```

```
Router2#show ip ospf neighbor

Neighbor ID     Pri   State      Dead Time   Address       Interface
3.3.3.1           1   FULL/BDR   00:00:30    172.16.1.2    FastEthernet0/1
1.1.1.1           1   FULL/DR    00:00:36    172.16.0.2    FastEthernet0/0
Router2#
```

```
Router3#show ip ospf neighbor

Neighbor ID     Pri   State      Dead Time   Address       Interface
2.2.2.1           1   FULL/DR    00:00:38    172.16.1.1    FastEthernet0/0
3.3.3.2           1   FULL/BDR   00:00:33    10.10.4.2     FastEthernet0/1
Router3#
```

```
Router4#show ip ospf neighbor

Neighbor ID     Pri   State      Dead Time   Address       Interface
1.1.1.1           1   FULL/DR    00:00:38    10.10.0.1     FastEthernet0/1
Router4#
```

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```
Router5#show ip ospf neighbor

Neighbor ID     Pri   State         Dead Time   Address       Interface
3.3.3.1           1   FULL/DR       00:00:38    10.10.4.1     FastEthernet0/1
Router5#
```

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e. **Use the show ip ospf neighbor detail command to get additional information about neighbor adjacencies.**

```
Router1#show ip ospf neighbor detail
 Neighbor 2.2.2.1, interface address 172.16.0.1
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 172.16.0.2 BDR is 172.16.0.1
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:38
    Neighbor is up for 00:31:46
    Index 1/1, 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 1.1.1.2, interface address 10.10.0.2
    In the area 1 via interface FastEthernet0/1
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.10.0.1 BDR is 10.10.0.2
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:37
    Neighbor is up for 00:22:24
    Index 1/2, 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
Router1#
```

```
Router2#show ip ospf neighbor detail
 Neighbor 3.3.3.1, interface address 172.16.1.2
    In the area 0 via interface FastEthernet0/1
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 172.16.1.1 BDR is 172.16.1.2
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:32
    Neighbor is up for 00:29:27
    Index 2/2, 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 1.1.1.1, interface address 172.16.0.2
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 172.16.0.2 BDR is 172.16.0.1
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:38
    Neighbor is up for 00:32:12
    Index 1/1, 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
Router2#
```

```
Router3#show ip ospf neighbor detail
 Neighbor 2.2.2.1, interface address 172.16.1.1
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 172.16.1.1 BDR is 172.16.1.2
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:32
    Neighbor is up for 00:29:54
    Index 1/1, 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 3.3.3.2, interface address 10.10.4.2
    In the area 2 via interface FastEthernet0/1
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.10.4.1 BDR is 10.10.4.2
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:37
    Neighbor is up for 00:15:52
    Index 1/2, 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
Router3#
```

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```
Router4#show ip ospf neighbor detail
 Neighbor 1.1.1.1, interface address 10.10.0.1
    In the area 1 via interface FastEthernet0/1
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.10.0.1 BDR is 10.10.0.2
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:32
    Neighbor is up for 00:23:37
    Index 1/1, 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
Router4#
```

```
Router5#show ip ospf neighbor detail
 Neighbor 3.3.3.1, interface address 10.10.4.1
    In the area 2 via interface FastEthernet0/1
    Neighbor priority is 1, State is FULL, 6 state changes
    DR is 10.10.4.1 BDR is 10.10.4.2
    Options is 0x12 in Hello (E-bit L-bit )
    Options is 0x52 in DBD (E-bit L-bit O-bit)
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:37
    Neighbor is up for 00:16:30
    Index 1/1, 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
Router5#
```

   f.   **Verify the OSPF routes in the routing table using the show ip route ospf command.**

```
Router1#show ip route ospf
      172.16.0.0/30 is subnetted, 2 subnets
O        172.16.1.0 [110/200] via 172.16.0.1, 00:30:34, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O        10.10.1.0/24 [110/200] via 10.10.0.2, 00:24:27, FastEthernet0/1
O IA     10.10.4.0/30 [110/300] via 172.16.0.1, 00:24:27, FastEthernet0/0
O IA     10.10.5.0/24 [110/400] via 172.16.0.1, 00:16:33, FastEthernet0/0
Router1#
```

```
Router2#show ip route ospf
      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O IA     10.10.0.0/30 [110/200] via 172.16.0.2, 00:31:03, FastEthernet0/0
O IA     10.10.1.0/24 [110/300] via 172.16.0.2, 00:24:56, FastEthernet0/0
O IA     10.10.4.0/30 [110/200] via 172.16.1.2, 00:31:03, FastEthernet0/1
O IA     10.10.5.0/24 [110/300] via 172.16.1.2, 00:17:01, FastEthernet0/1
Router2#
```

```
Router3# show ip route ospf
      172.16.0.0/30 is subnetted, 2 subnets
O        172.16.0.0 [110/200] via 172.16.1.1, 00:31:19, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O IA     10.10.0.0/30 [110/300] via 172.16.1.1, 00:17:17, FastEthernet0/0
O IA     10.10.1.0/24 [110/400] via 172.16.1.1, 00:17:17, FastEthernet0/0
O        10.10.5.0/24 [110/200] via 10.10.4.2, 00:17:17, FastEthernet0/1
Router3#
```

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```
Router4# show ip route ospf
     172.16.0.0/30 is subnetted, 2 subnets
O IA    172.16.0.0 [110/200] via 10.10.0.1, 00:25:26, FastEthernet0/1
O IA    172.16.1.0 [110/300] via 10.10.0.1, 00:25:26, FastEthernet0/1
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O IA    10.10.4.0/30 [110/400] via 10.10.0.1, 00:25:26, FastEthernet0/1
O IA    10.10.5.0/24 [110/500] via 10.10.0.1, 00:17:35, FastEthernet0/1
Router4#
```

```
Router5#show ip route ospf
     172.16.0.0/30 is subnetted, 2 subnets
O IA    172.16.0.0 [110/300] via 10.10.4.1, 00:17:53, FastEthernet0/1
O IA    172.16.1.0 [110/200] via 10.10.4.1, 00:17:53, FastEthernet0/1
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O IA    10.10.0.0/30 [110/400] via 10.10.4.1, 00:17:53, FastEthernet0/1
O IA    10.10.1.0/24 [110/500] via 10.10.4.1, 00:17:53, FastEthernet0/1
Router5#
```

g. **Get detailed information on how R1 learned about the OSPF entry using the show ip route ospf 10.10.1.0 command.**

Aprendeu por OSPF do router 4, na interface f0/1, com a gateway de 10.10.0.2, tal como mostra a foto

```
Router1#show ip route ospf
     172.16.0.0/30 is subnetted, 2 subnets
O        172.16.1.0 [110/200] via 172.16.0.1, 00:32:38, FastEthernet0/0
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O        10.10.1.0/24 [110/200] via 10.10.0.2, 00:26:31, FastEthernet0/1
O IA    10.10.4.0/30 [110/300] via 172.16.0.1, 00:26:31, FastEthernet0/0
O IA    10.10.5.0/24 [110/400] via 172.16.0.1, 00:18:37, FastEthernet0/0
Router1#
```

Step 2: Verify end-to-end connectivity.
a. **From PC1, verify end-to-end connectivity by pinging PC3**

```
PC1> ping 10.10.5.10
84 bytes from 10.10.5.10 icmp_seq=1 ttl=59 time=100.368 ms
84 bytes from 10.10.5.10 icmp_seq=2 ttl=59 time=97.668 ms
84 bytes from 10.10.5.10 icmp_seq=3 ttl=59 time=98.226 ms
84 bytes from 10.10.5.10 icmp_seq=4 ttl=59 time=98.798 ms
84 bytes from 10.10.5.10 icmp_seq=5 ttl=59 time=105.654 ms

PC1>
```

b. **Verify the route taken by doing a traceroute to PC3 from PC1.**

```
PC3> trace 10.10.1.10
trace to 10.10.1.10, 8 hops max, press Ctrl+C to stop
1   10.10.5.1    8.951 ms   9.929 ms   9.087 ms
2   10.10.4.1    31.546 ms  31.485 ms  30.609 ms
3   172.16.1.1   42.229 ms  42.189 ms  41.350 ms
4   172.16.0.2   52.940 ms  63.692 ms  52.906 ms
5   10.10.0.2    74.417 ms  74.470 ms  73.490 ms
6   *10.10.1.10   85.056 ms (ICMP type:3, code:3, Destination port unreachable)

PC3>
```

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Parte 3: Explore Link State Announcements

Step 1: Verify OSPF and Exploring LSAs on D1
   a. **D1 learned about these networks from LSAs. A router maintains a LSDB for each area it has interfaces in. Because D1 is an internal OSPF router, it will only have entries for Area 1. To display the contents of the LSDB of D1, use the show ip ospf database command.**

```
Router4#show ip ospf database

            OSPF Router with ID (1.1.1.2) (Process ID 1)

            Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         930         0x80000004 0x002F6A 1
1.1.1.2         1.1.1.2         886         0x80000004 0x00F914 2

            Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.10.0.1       1.1.1.1         930         0x80000002 0x00CA4F

            Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.10.4.0       1.1.1.1         1173        0x80000003 0x00F004
10.10.5.0       1.1.1.1         426         0x80000003 0x00E3A8
172.16.0.0      1.1.1.1         1680        0x80000004 0x00B95E
172.16.1.0      1.1.1.1         1420        0x80000003 0x009C17
Router4#
```

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b. Additional information about the Router Link States type 1 LSA can be gathered using the show ip ospf database router command.

```
Router4#show ip ospf database router

            OSPF Router with ID (1.1.1.2) (Process ID 1)

                Router Link States (Area 1)

  Routing Bit Set on this LSA
  LS age: 978
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.1
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000004
  Checksum: 0x2F6A
  Length: 36
  Area Border Router
  Number of Links: 1

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.10.0.1
     (Link Data) Router Interface address: 10.10.0.1
      Number of TOS metrics: 0
       TOS 0 Metrics: 100


  LS age: 938
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.2
  Advertising Router: 1.1.1.2
  LS Seq Number: 80000004
  Checksum: 0xF914
  Length: 48
  Number of Links: 2

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.10.0.1
     (Link Data) Router Interface address: 10.10.0.2
      Number of TOS metrics: 0
       TOS 0 Metrics: 100

    Link connected to: a Stub Network
     (Link ID) Network/subnet number: 10.10.1.0
     (Link Data) Network Mask: 255.255.255.0
      Number of TOS metrics: 0
       TOS 0 Metrics: 100


Router4# 
```

c. To learn more about type 2 network LSAs, use show ip ospf database network command.

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```
Router4# show ip ospf database network

            OSPF Router with ID (1.1.1.2) (Process ID 1)

               Net Link States (Area 1)

  Routing Bit Set on this LSA
  LS age: 1181
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 10.10.0.1 (address of Designated Router)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000002
  Checksum: 0xCA4F
  Length: 32
  Network Mask: /30
        Attached Router: 1.1.1.1
        Attached Router: 1.1.1.2

Router4#
```

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d. To learn more about type 3 summary LSAs, use show ip ospf database summary command.

```
Router4#show ip ospf database summary

            OSPF Router with ID (1.1.1.2) (Process ID 1)

                Summary Net Link States (Area 1)

  Routing Bit Set on this LSA
  LS age: 1459
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.4.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000003
  Checksum: 0xF004
  Length: 28
  Network Mask: /30
        TOS: 0  Metric: 300

  Routing Bit Set on this LSA
  LS age: 712
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.5.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000003
  Checksum: 0xE3A8
  Length: 28
  Network Mask: /24
        TOS: 0  Metric: 400

  Routing Bit Set on this LSA
  LS age: 1967
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 172.16.0.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000004
  Checksum: 0xB95E
  Length: 28
  Network Mask: /30
        TOS: 0  Metric: 100

  Routing Bit Set on this LSA
  LS age: 1708
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 172.16.1.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000003
  Checksum: 0x9C17
```

```
  Length: 28
  Network Mask: /30
        TOS: 0  Metric: 200

Router4#
```

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e. To learn more about type 4 summary LSAs, use show ip ospf database asbr-summary command.

```
Router4#show ip ospf database asbr-summary

           OSPF Router with ID (1.1.1.2) (Process ID 1)
Router4#
```

f. Finally, to learn more about type 5 AS external link LSAs, use show ip ospf database external command.

```
Router4#show ip ospf database external

           OSPF Router with ID (1.1.1.2) (Process ID 1)
Router4#
```

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Step 2: Verify OSPF and exploring LSAs on an ABR R1
- show ip ospf database router

```
Router1#show ip ospf database router

            OSPF Router with ID (1.1.1.1) (Process ID 1)

                Router Link States (Area 0)

  LS age: 1879
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.1
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000005
  Checksum: 0x2D18
  Length: 36
  Area Border Router
  Number of Links: 1

    Link connected to: a Transit Network
      (Link ID) Designated Router address: 172.16.0.2
      (Link Data) Router Interface address: 172.16.0.2
       Number of TOS metrics: 0
        TOS 0 Metrics: 100


  LS age: 1898
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 2.2.2.1
  Advertising Router: 2.2.2.1
  LS Seq Number: 80000006
  Checksum: 0x5FEF
  Length: 48
  Number of Links: 2

    Link connected to: a Transit Network
      (Link ID) Designated Router address: 172.16.1.1
      (Link Data) Router Interface address: 172.16.1.1
       Number of TOS metrics: 0
        TOS 0 Metrics: 100

    Link connected to: a Transit Network
      (Link ID) Designated Router address: 172.16.0.2
      (Link Data) Router Interface address: 172.16.0.1
       Number of TOS metrics: 0
        TOS 0 Metrics: 100


  Routing Bit Set on this LSA
  LS age: 1732
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 3.3.3.1
  Advertising Router: 3.3.3.1
  LS Seq Number: 80000004
  Checksum: 0xC276
  Length: 36
  Area Border Router
  Number of Links: 1

    Link connected to: a Transit Network
      (Link ID) Designated Router address: 172.16.1.1
      (Link Data) Router Interface address: 172.16.1.2
       Number of TOS metrics: 0
```

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```
        TOS 0 Metrics: 100


              Router Link States (Area 1)

  LS age: 1393
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.1
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000004
  Checksum: 0x2F6A
  Length: 36
  Area Border Router
  Number of Links: 1

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.10.0.1
     (Link Data) Router Interface address: 10.10.0.1
      Number of TOS metrics: 0
        TOS 0 Metrics: 100


  LS age: 1352
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.2
  Advertising Router: 1.1.1.2
  LS Seq Number: 80000004
  Checksum: 0xF914
  Length: 48
  Number of Links: 2

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.10.0.1
     (Link Data) Router Interface address: 10.10.0.2
      Number of TOS metrics: 0
        TOS 0 Metrics: 100

    Link connected to: a Stub Network
     (Link ID) Network/subnet number: 10.10.1.0
     (Link Data) Network Mask: 255.255.255.0
      Number of TOS metrics: 0
        TOS 0 Metrics: 100

Router1#
```

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- show ip ospf database network

```
Router1#show ip ospf database network

            OSPF Router with ID (1.1.1.1) (Process ID 1)

                Net Link States (Area 0)

  Routing Bit Set on this LSA
  LS age: 1971
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 172.16.0.2 (address of Designated Router)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000002
  Checksum: 0x4C22
  Length: 32
  Network Mask: /30
        Attached Router: 1.1.1.1
        Attached Router: 2.2.2.1

  Routing Bit Set on this LSA
  LS age: 1990
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 172.16.1.1 (address of Designated Router)
  Advertising Router: 2.2.2.1
  LS Seq Number: 80000002
  Checksum: 0x6FF5
  Length: 32
  Network Mask: /30
        Attached Router: 2.2.2.1
        Attached Router: 3.3.3.1


                Net Link States (Area 1)

  Routing Bit Set on this LSA
  LS age: 1483
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 10.10.0.1 (address of Designated Router)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000002
  Checksum: 0xCA4F
  Length: 32
  Network Mask: /30
        Attached Router: 1.1.1.1
        Attached Router: 1.1.1.2

Router1#
```

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- show ip ospf database summary

```
Router1#show ip ospf database summary

            OSPF Router with ID (1.1.1.1) (Process ID 1)

                Summary Net Link States (Area 0)

  LS age: 263
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.0.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000004
  Checksum: 0x447C
  Length: 28
  Network Mask: /30
        TOS: 0  Metric: 100

  LS age: 1507
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.1.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000002
  Checksum: 0x3B1F
  Length: 28
  Network Mask: /24
        TOS: 0  Metric: 200

  Routing Bit Set on this LSA
  LS age: 1849
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.4.0 (summary Network Number)
  Advertising Router: 3.3.3.1
  LS Seq Number: 80000003
  Checksum: 0xE9CD
  Length: 28
  Network Mask: /30
        TOS: 0  Metric: 100

  Routing Bit Set on this LSA
  LS age: 1077
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.5.0 (summary Network Number)
  Advertising Router: 3.3.3.1
  LS Seq Number: 80000003
  Checksum: 0xDC72
  Length: 28
  Network Mask: /24
        TOS: 0  Metric: 200


                Summary Net Link States (Area 1)

  LS age: 1753
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.4.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000003
  Checksum: 0xF004
  Length: 28
```

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```
         Network Mask: /30
              TOS: 0  Metric: 300

     LS age: 1007
     Options: (No TOS-capability, DC, Upward)
     LS Type: Summary Links(Network)
     Link State ID: 10.10.5.0 (summary Network Number)
     Advertising Router: 1.1.1.1
     LS Seq Number: 80000003
     Checksum: 0xE3A8
     Length: 28
     Network Mask: /24
              TOS: 0  Metric: 400

     LS age: 269
     Options: (No TOS-capability, DC, Upward)
     LS Type: Summary Links(Network)
     Link State ID: 172.16.0.0 (summary Network Number)
     Advertising Router: 1.1.1.1
     LS Seq Number: 80000005
     Checksum: 0xB75F
     Length: 28
     Network Mask: /30
              TOS: 0  Metric: 100

     LS age: 27
     Options: (No TOS-capability, DC, Upward)
     LS Type: Summary Links(Network)
     Link State ID: 172.16.1.0 (summary Network Number)
     Advertising Router: 1.1.1.1
     LS Seq Number: 80000004
     Checksum: 0x9A18
     Length: 28
     Network Mask: /30
              TOS: 0  Metric: 200

Router1#
```

- show ip ospf database asbr-summary

```
Router1#show ip ospf database asbr-summary

          OSPF Router with ID (1.1.1.1) (Process ID 1)
Router1#
```

- show ip ospf database external

```
Router1#show ip ospf database external

          OSPF Router with ID (1.1.1.1) (Process ID 1)
Router1#
```

Step 3: Verify OSPF and exploring LSAs on the ASBR R2.

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show ip ospf database router

```
Router2#show ip ospf database router

            OSPF Router with ID (2.2.2.1) (Process ID 1)

              Router Link States (Area 0)

 Routing Bit Set on this LSA
 LS age: 125
 Options: (No TOS-capability, DC)
 LS Type: Router Links
 Link State ID: 1.1.1.1
 Advertising Router: 1.1.1.1
 LS Seq Number: 80000006
 Checksum: 0x2B19
 Length: 36
 Area Border Router
 Number of Links: 1

   Link connected to: a Transit Network
     (Link ID) Designated Router address: 172.16.0.2
     (Link Data) Router Interface address: 172.16.0.2
      Number of TOS metrics: 0
       TOS 0 Metrics: 100


 LS age: 81
 Options: (No TOS-capability, DC)
 LS Type: Router Links
 Link State ID: 2.2.2.1
 Advertising Router: 2.2.2.1
 LS Seq Number: 80000007
 Checksum: 0x5DF0
 Length: 48
 Number of Links: 2

   Link connected to: a Transit Network
     (Link ID) Designated Router address: 172.16.1.1
     (Link Data) Router Interface address: 172.16.1.1
      Number of TOS metrics: 0
       TOS 0 Metrics: 100

   Link connected to: a Transit Network
     (Link ID) Designated Router address: 172.16.0.2
     (Link Data) Router Interface address: 172.16.0.1
      Number of TOS metrics: 0
       TOS 0 Metrics: 100


 Routing Bit Set on this LSA
 LS age: 1952
 Options: (No TOS-capability, DC)
 LS Type: Router Links
 Link State ID: 3.3.3.1
 Advertising Router: 3.3.3.1
 LS Seq Number: 80000004
 Checksum: 0xC276
 Length: 36
 Area Border Router
 Number of Links: 1

   Link connected to: a Transit Network
     (Link ID) Designated Router address: 172.16.1.1
     (Link Data) Router Interface address: 172.16.1.2
      Number of TOS metrics: 0
       TOS 0 Metrics: 100

Router2#
```

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- show ip ospf database network

```
Router2#show ip ospf database network

            OSPF Router with ID (2.2.2.1) (Process ID 1)

                Net Link States (Area 0)

  Routing Bit Set on this LSA
  LS age: 204
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 172.16.0.2 (address of Designated Router)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000003
  Checksum: 0x4A23
  Length: 32
  Network Mask: /30
        Attached Router: 1.1.1.1
        Attached Router: 2.2.2.1

  Routing Bit Set on this LSA
  LS age: 159
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 172.16.1.1 (address of Designated Router)
  Advertising Router: 2.2.2.1
  LS Seq Number: 80000003
  Checksum: 0x6DF6
  Length: 32
  Network Mask: /30
        Attached Router: 2.2.2.1
        Attached Router: 3.3.3.1

Router2#
```

- show ip ospf database network

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- show ip ospf database summary

```
Router2#show ip ospf database summary

            OSPF Router with ID (2.2.2.1) (Process ID 1)

                Summary Net Link States (Area 0)

  Routing Bit Set on this LSA
  LS age: 465
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.0.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000004
  Checksum: 0x447C
  Length: 28
  Network Mask: /30
        TOS: 0  Metric: 100

  Routing Bit Set on this LSA
  LS age: 1709
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.1.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000002
  Checksum: 0x3B1F
  Length: 28
  Network Mask: /24
        TOS: 0  Metric: 200

  Routing Bit Set on this LSA
  LS age: 9
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.4.0 (summary Network Number)
  Advertising Router: 3.3.3.1
  LS Seq Number: 80000004
  Checksum: 0xE7CE
  Length: 28
  Network Mask: /30
        TOS: 0  Metric: 100

  Routing Bit Set on this LSA
  LS age: 1276
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.5.0 (summary Network Number)
  Advertising Router: 3.3.3.1
  LS Seq Number: 80000003
  Checksum: 0xDC72
  Length: 28
  Network Mask: /24
        TOS: 0  Metric: 200

Router2#
```

- show ip ospf database asbr-summary

```
Router2#show ip ospf database asbr-summary

            OSPF Router with ID (2.2.2.1) (Process ID 1)
Router2#
```

- show ip ospf database external

```
Router2#show ip ospf database external

            OSPF Router with ID (2.2.2.1) (Process ID 1)
Router2#
```

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Parte 4: Link State Database optimizations

Step 1: Configure Área 1 as a stub area.

```
Router1(config)#router ospf 1
Router1(config-router)#area 1 stub
Router1(config-router)#exit

Router4(config)#router ospf 1
Router4(config-router)#area 1 stub
Router4(config-router)#exit
```

Step 2: Verify the link state database differences on R1 and D1

```
Router1#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

     172.16.0.0/30 is subnetted, 2 subnets
C       172.16.0.0 is directly connected, FastEthernet0/0
O       172.16.1.0 [110/200] via 172.16.0.1, 00:38:12, FastEthernet0/0
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.10.0.0/30 is directly connected, FastEthernet0/1
O       10.10.1.0/24 [110/200] via 10.10.0.2, 00:36:57, FastEthernet0/1
O IA    10.10.4.0/30 [110/300] via 172.16.0.1, 00:36:57, FastEthernet0/0
Router1#
```

```
Router4#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 10.10.0.1 to network 0.0.0.0

     172.16.0.0/30 is subnetted, 2 subnets
O IA    172.16.0.0 [110/200] via 10.10.0.1, 00:30:32, FastEthernet0/1
O IA    172.16.1.0 [110/300] via 10.10.0.1, 00:30:32, FastEthernet0/1
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.10.0.0/30 is directly connected, FastEthernet0/1
C       10.10.1.0/24 is directly connected, FastEthernet0/0
O IA    10.10.4.0/30 [110/400] via 10.10.0.1, 00:30:32, FastEthernet0/1
O*IA 0.0.0.0/0 [110/101] via 10.10.0.1, 00:30:32, FastEthernet0/1
Router4#
```

Step 3: Configure Area 2 as a totally stub area.
```
Router3(config)#router ospf 1
Router3(config-router)#area 2 st
Router3(config-router)#area 2 stub no
Router3(config-router)#area 2 stub no-summary
```

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Step 4: Verify the link state database differences on R3 and D2.

```
Router3#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

     172.16.0.0/30 is subnetted, 2 subnets
O       172.16.0.0 [110/200] via 172.16.1.1, 00:17:28, FastEthernet0/0
C       172.16.1.0 is directly connected, FastEthernet0/0
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
O IA    10.10.0.0/30 [110/300] via 172.16.1.1, 00:17:23, FastEthernet0/0
O IA    10.10.1.0/24 [110/400] via 172.16.1.1, 00:17:23, FastEthernet0/0
C       10.10.4.0/30 is directly connected, FastEthernet0/1
Router3#
```

```
Router5#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, 2 subnets, 2 masks
C       10.10.4.0/30 is directly connected, FastEthernet0/1
C       10.10.5.0/24 is directly connected, FastEthernet0/0
Router5#
```

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