The University of Danang
University of Science and Technology

OSPF

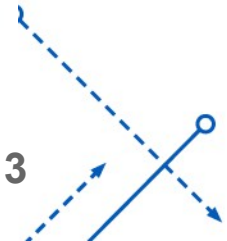
FACULTY OF INFORMATION TECHNOLOGY
PhD. LE TRAN DUC

LINK STATE ROUTING PROTOCOLS

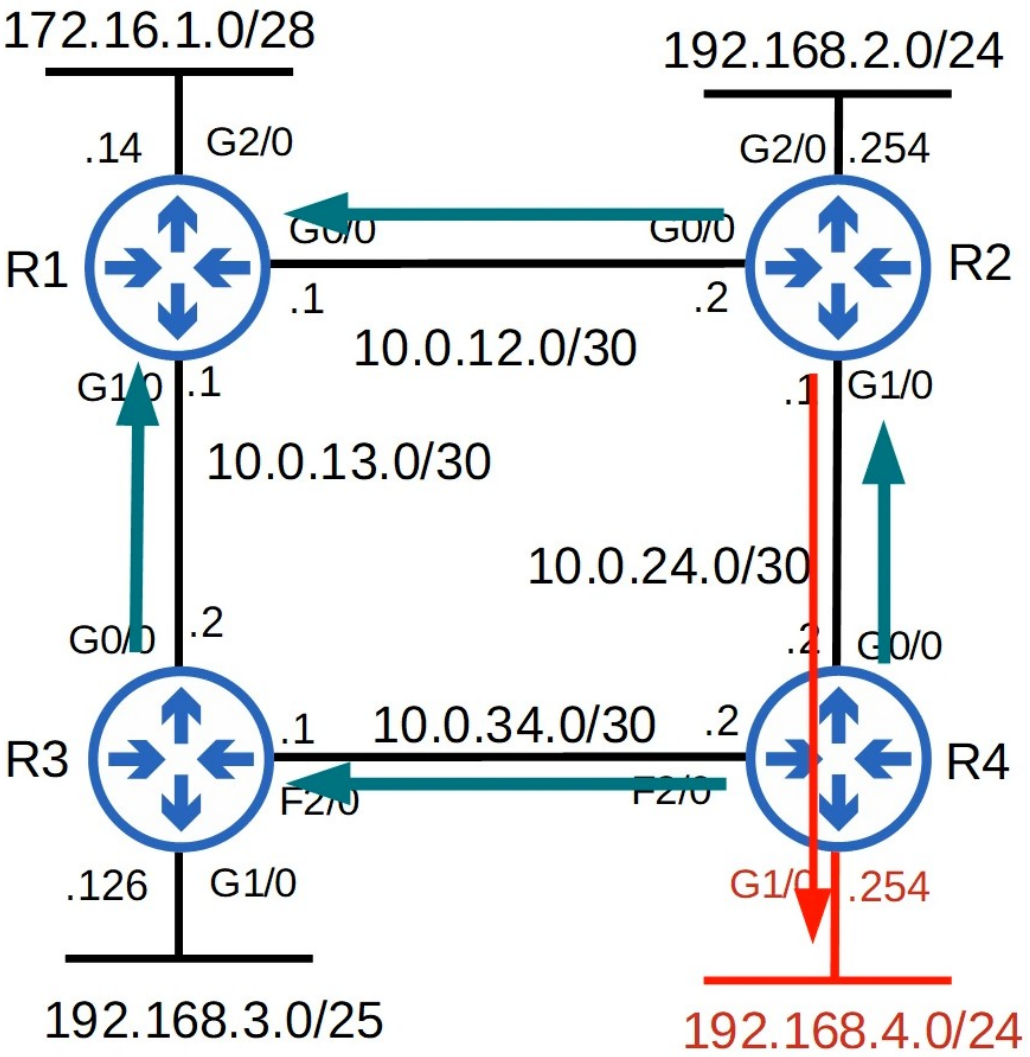
- When using a **link state** routing protocol, every router creates a 'connectivity map' of the network.
- To allow this, each router advertises information about its interfaces (connected networks) to its neighbors. These advertisements are passed along to other routers, until all routers in the network develop the same map of the network.
- Each router independently uses this map to calculate the best routes to each destination.
- Link state protocols use more resources (CPU) on the router, because more information is shared.
- However, link state protocols tend to be faster in reacting to changes in the network than distance vector protocols.

OSPF

- Stands for **Open Shortest Path First**
- Uses the **Shortest Path First** algorithm of Dutch computer scientist Edsger Dijkstra. (aka **Dijkstra's algorithm** ← remember that name!)
- Three versions:
  OSPFv1 (1989): OLD, not in use anymore
  OSPFv2 (1998): Used for IPv4
  OSPFv3 (2008): Used for IPv6 (can also be used for IPv4, but usually v2 is used)
- Routers store information about the network in LSAs (Link State Advertisements), which are organized in a structure called the LSDB (Link State Database).
- Routers will **flood** LSAs until all routers in the OSPF *area* develop the same map of the network (LSDB).



LSA FLOODING



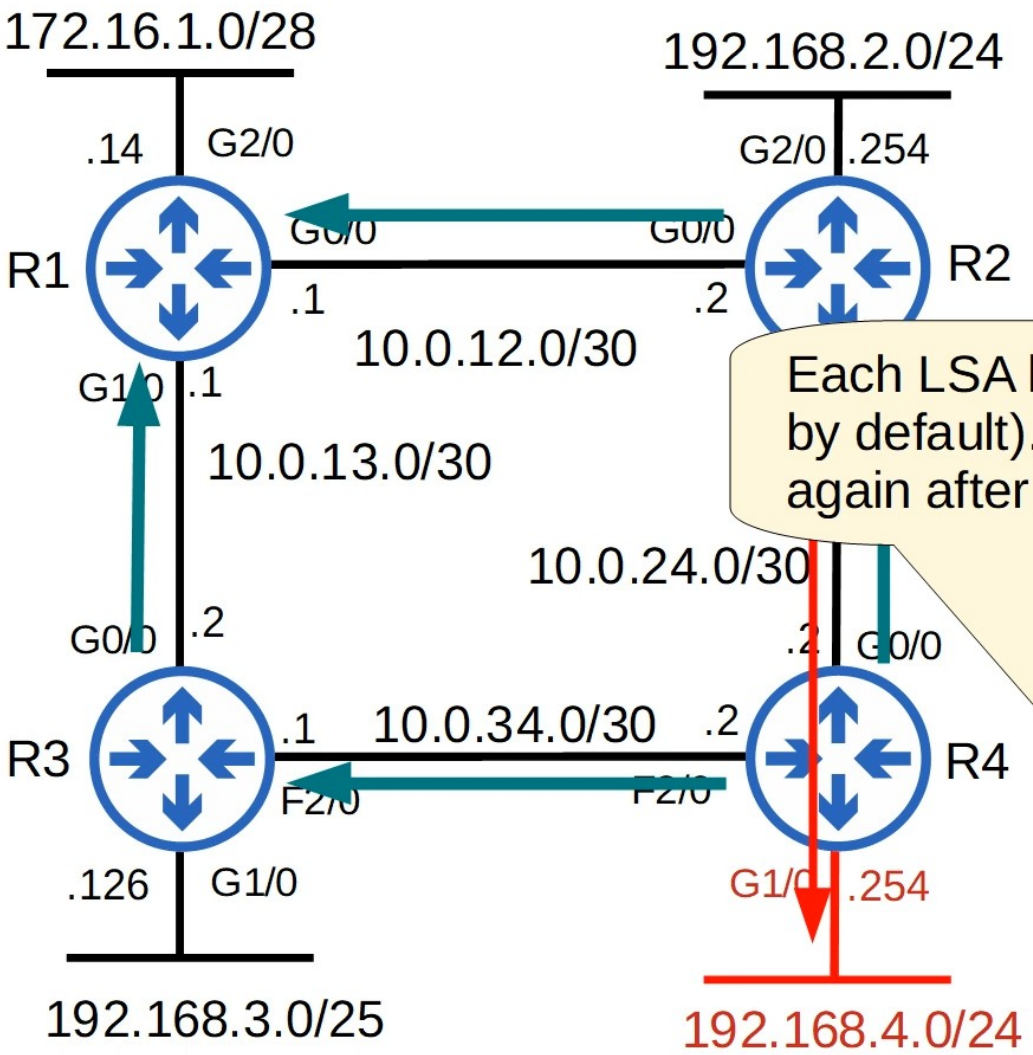
- OSPF is enabled on R4's G1/0 interface.
- R4 creates an LSA to tell its neighbors about the network on G1/0.
- The LSA is flooded throughout the network until all routers have received it.
- This results in all routers sharing the same LSDB.
- Each router then uses the SPF algorithm to calculate its best route to 192.168.4.0/24.

LSA
RID: 4.4.4.4
IP: 192.168.4.0/24
Cost: 1

LSDB

LSA	LSA	LSA	LSA
LSA	LSA	LSA	LSA

LSA FLOODING



- OSPF is enabled on R4's G1/0 interface.
- R4 creates an LSA to tell its neighbors about the network on G1/0.
- The LSA is flooded throughout the network ...ived it.

Each LSA has an aging timer (30 min by default). The LSA will be flooded again after the timer expires.

...haring the same

...Each router then uses the SPF algorithm to ...calculate its best route to 192.168.4.0/24.

LSA
RID: 4.4.4.4
IP: 192.168.4.0/24
Cost: 1

LSDB

LSA	LSA	LSA	LSA
LSA	LSA	LSA	LSA

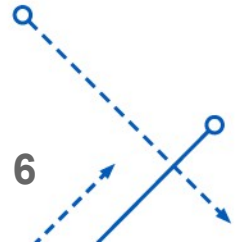
OSPF

- In OSPF, there are three main steps in the process of sharing LSAs and determining the best route to each destination in the network.

1) **Become neighbors** with other routers connected to the same segment.

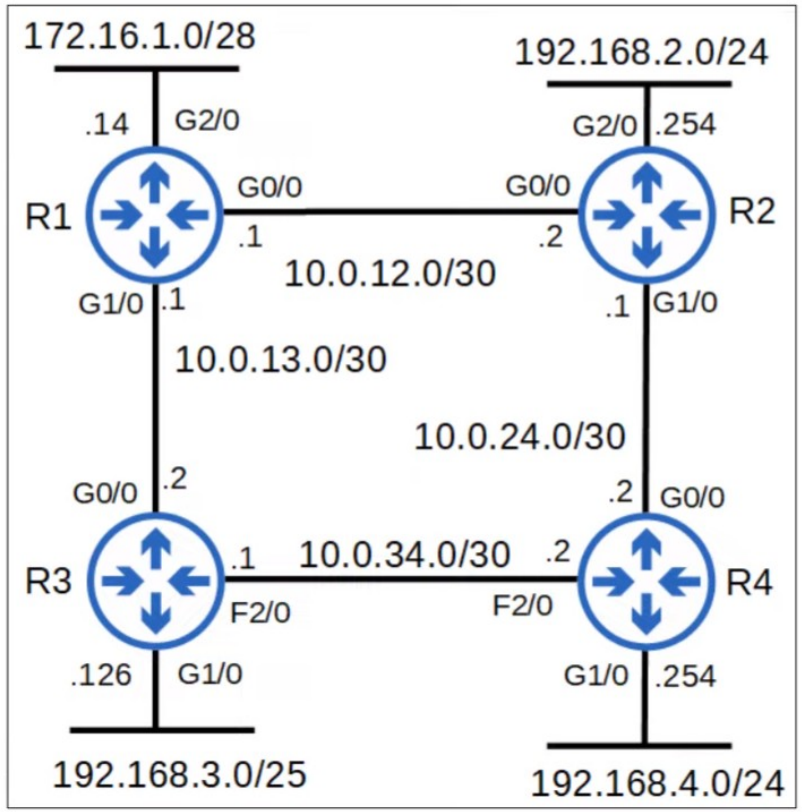
2) **Exchange LSAs** with neighbor routers.

3) **Calculate the best routes** to each destination, and insert them into the routing table.



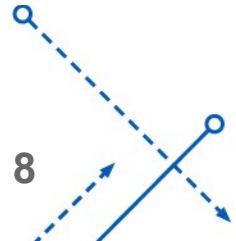
OSPF AREAS

- OSPF uses **areas** to divide up the network.
- Small networks can be *single-area* without any negative effects on performance.

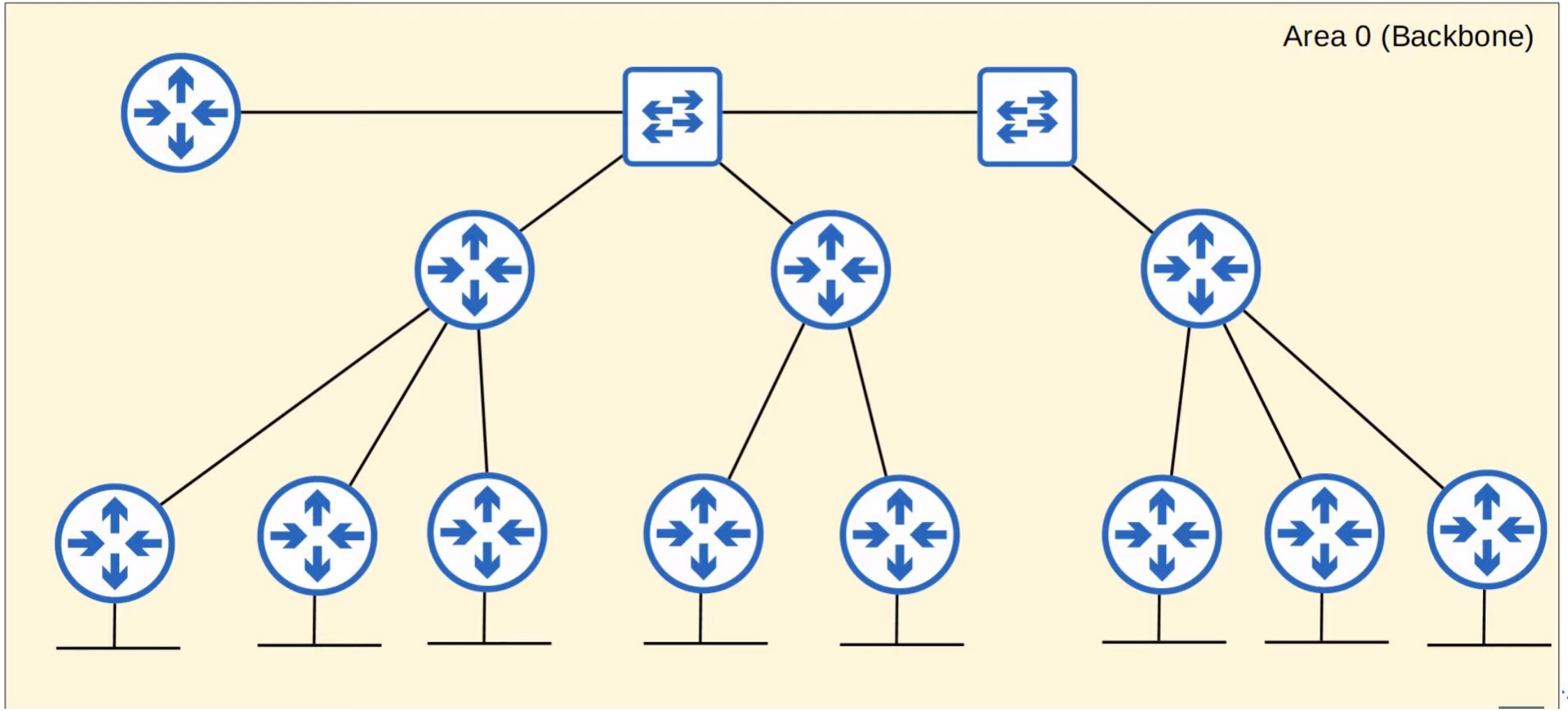


OSPF AREAS

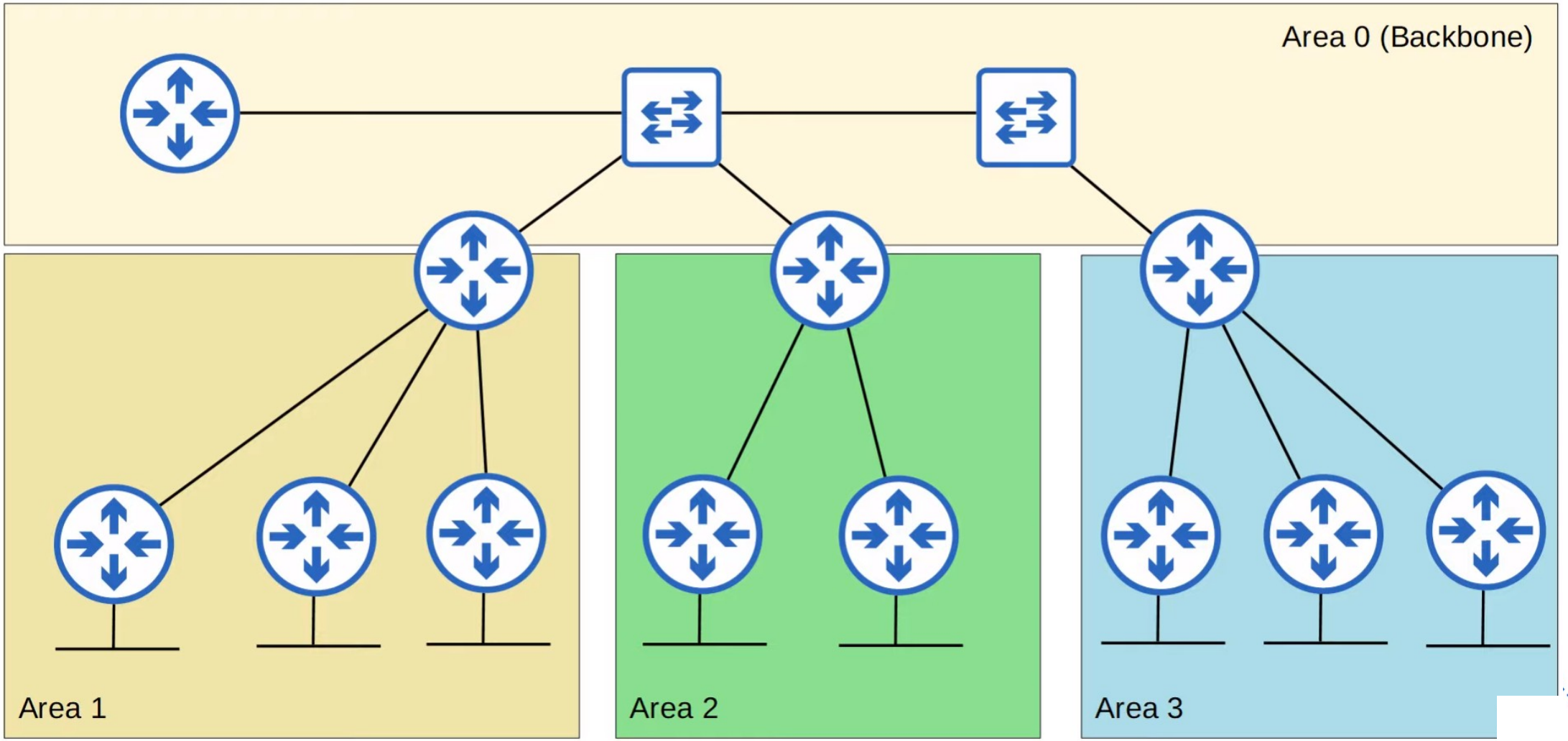
- OSPF uses **areas** to divide up the network.
- Small networks can be *single-area* without any negative effects on performance.
- In larger networks, a single-area design can have negative effects:
  -the SPF algorithm takes more time to calculate routes
  -the SPF algorithm requires exponentially more processing power on the routers
  -the larger LSDB takes up more memory on the routers
  -any small change in the network causes every router to flood LSAs and run the SPF algorithm again
- By dividing a large OSPF network into several smaller areas, you can avoid the above negative effects.



OSPF AREAS

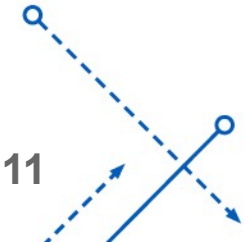


OSPF AREAS



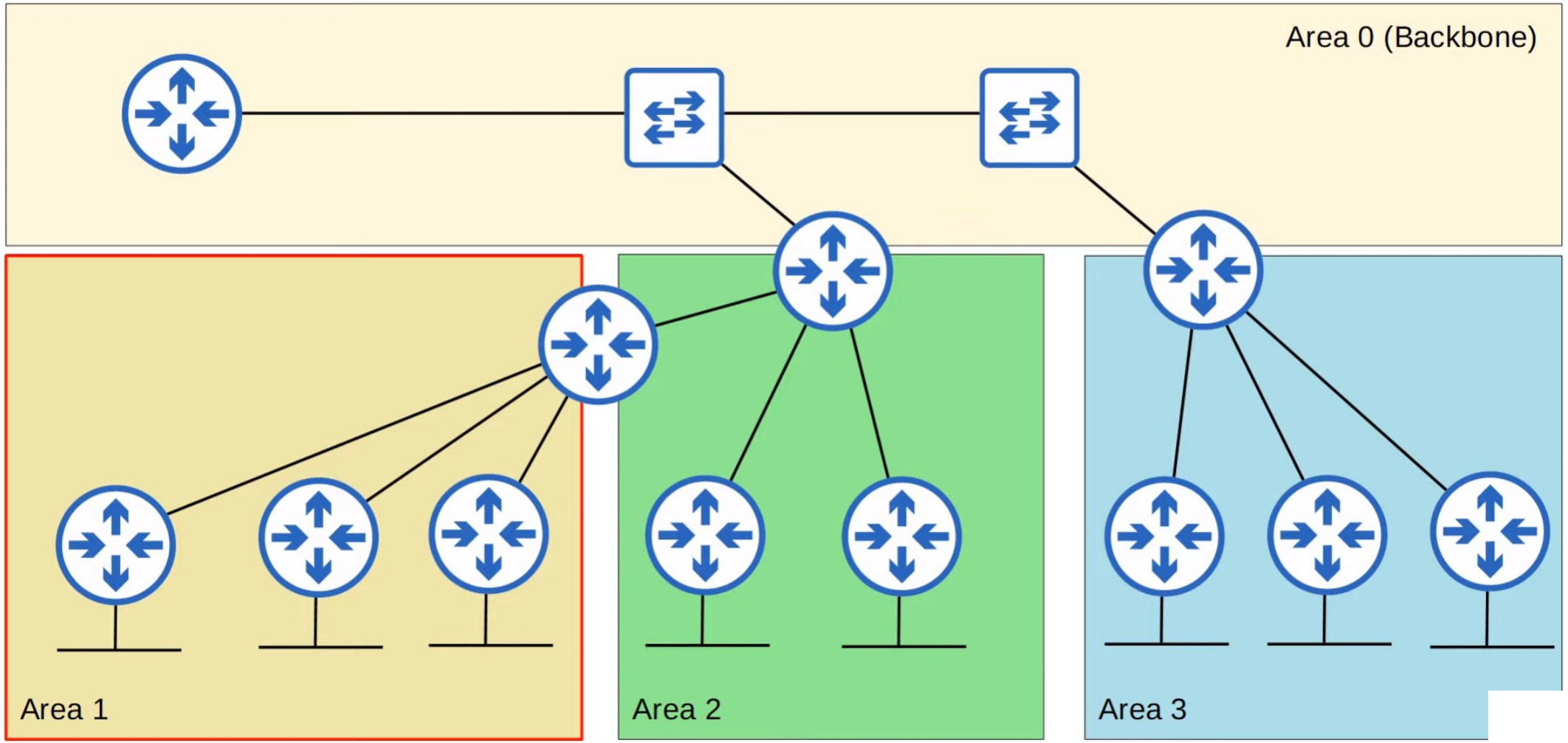
OSPF AREAS

- An **area** is a set of routers and links that share the same LSDB.
- The **backbone area** (area 0) is an area that all other areas must connect to.
- Routers with all interfaces in the same area are called **internal routers**.
- Routers with interfaces in multiple areas are called **area border routers** (**ABRs**).
- Routers connected to the backbone area (area 0) are called **backbone routers**.
- An **intra-area route** is a route to a destination inside the same OSPF area.
- An **interarea route** is a route to a destination in a different OSPF area.
- OSPF areas should be *contiguous*.
- All OSPF areas must have at least one ABR connected to the backbone area.
- OSPF interfaces in the same subnet must be in the same area.

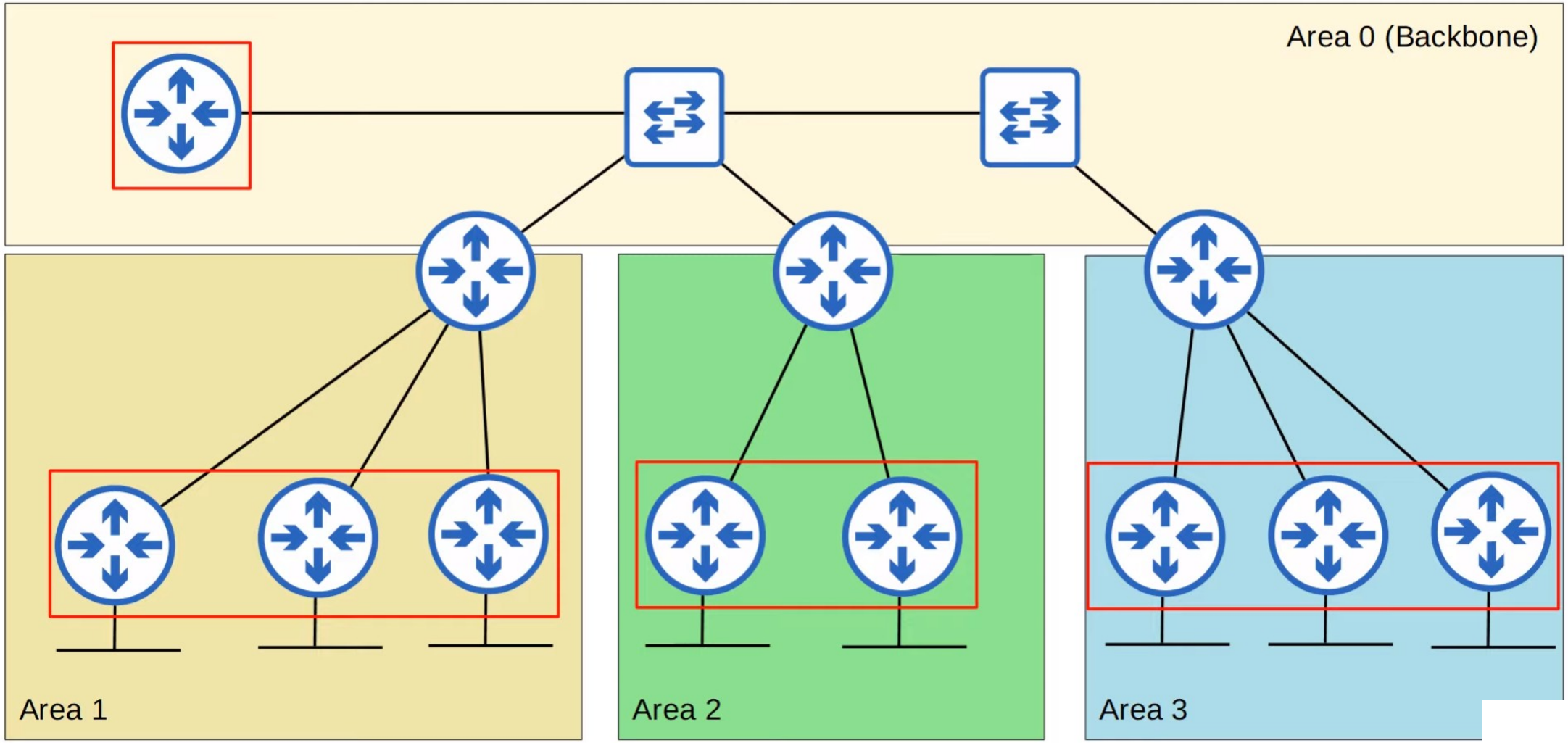


OSPF AREAS

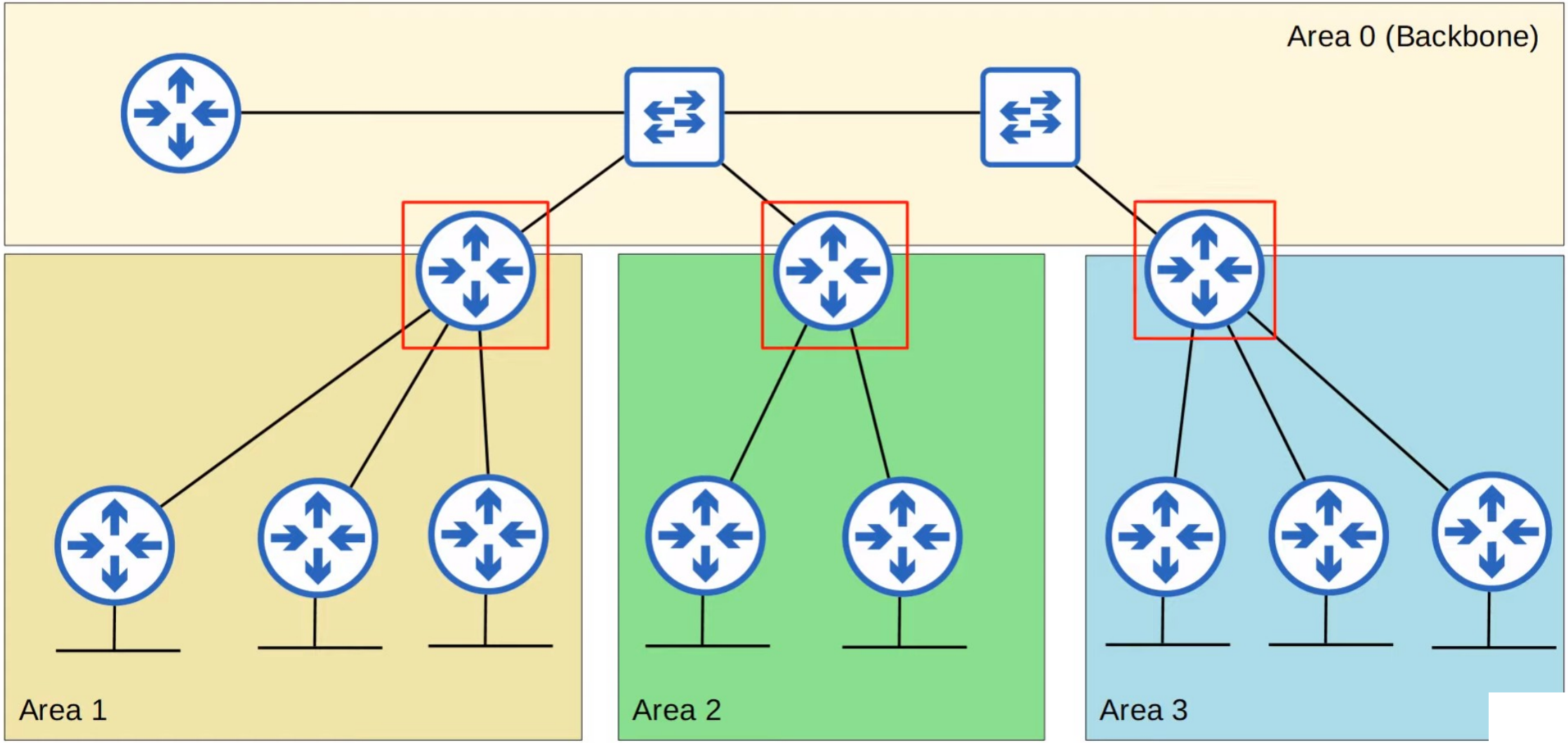
NOT ALLOWED!!!



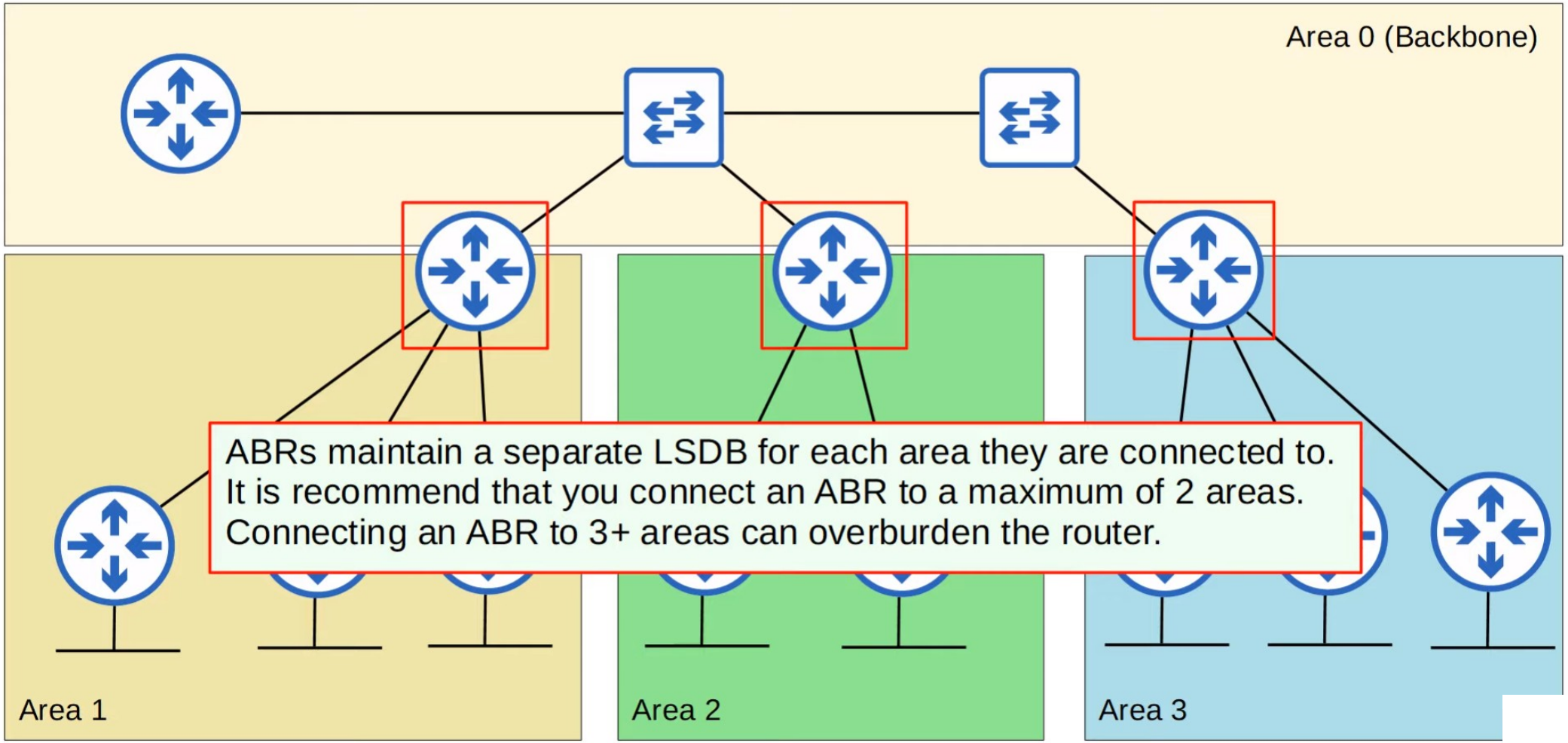
OSPF AREAS – INTERNAL ROUTERS



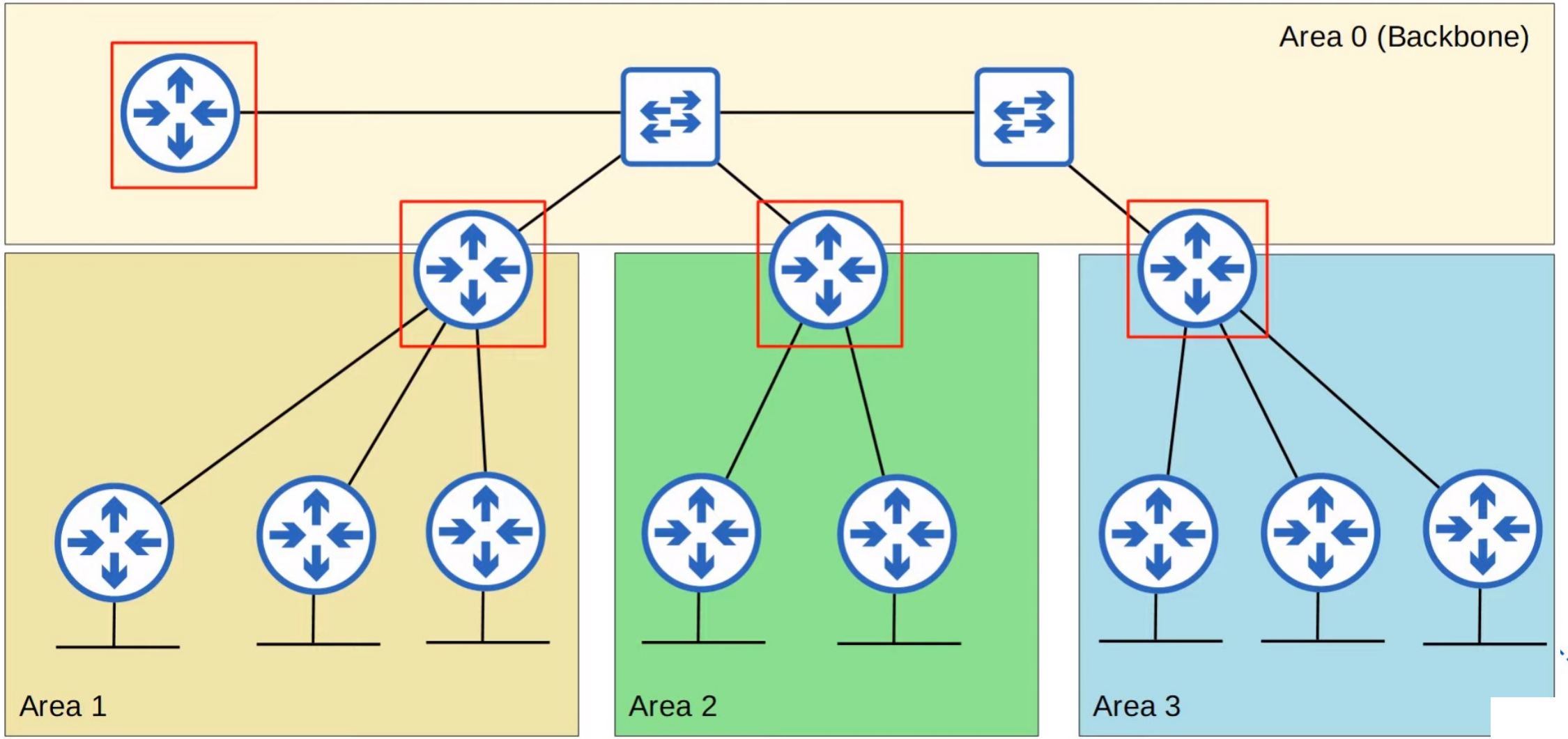
OSPF AREAS – AREA BORDER ROUTERS



OSPF AREAS – AREA BORDER ROUTERS

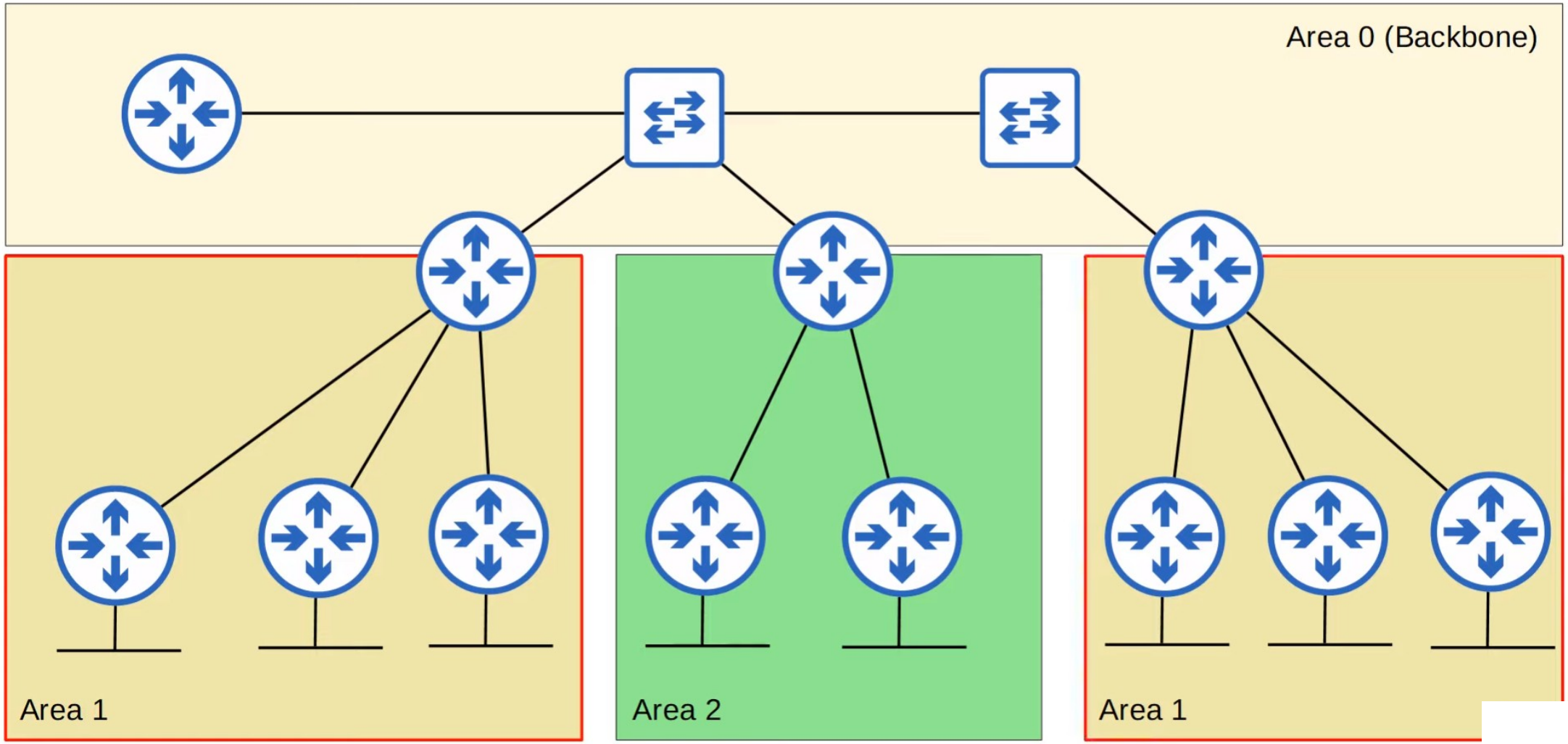


OSPF AREAS – BACKBONE ROUTERS

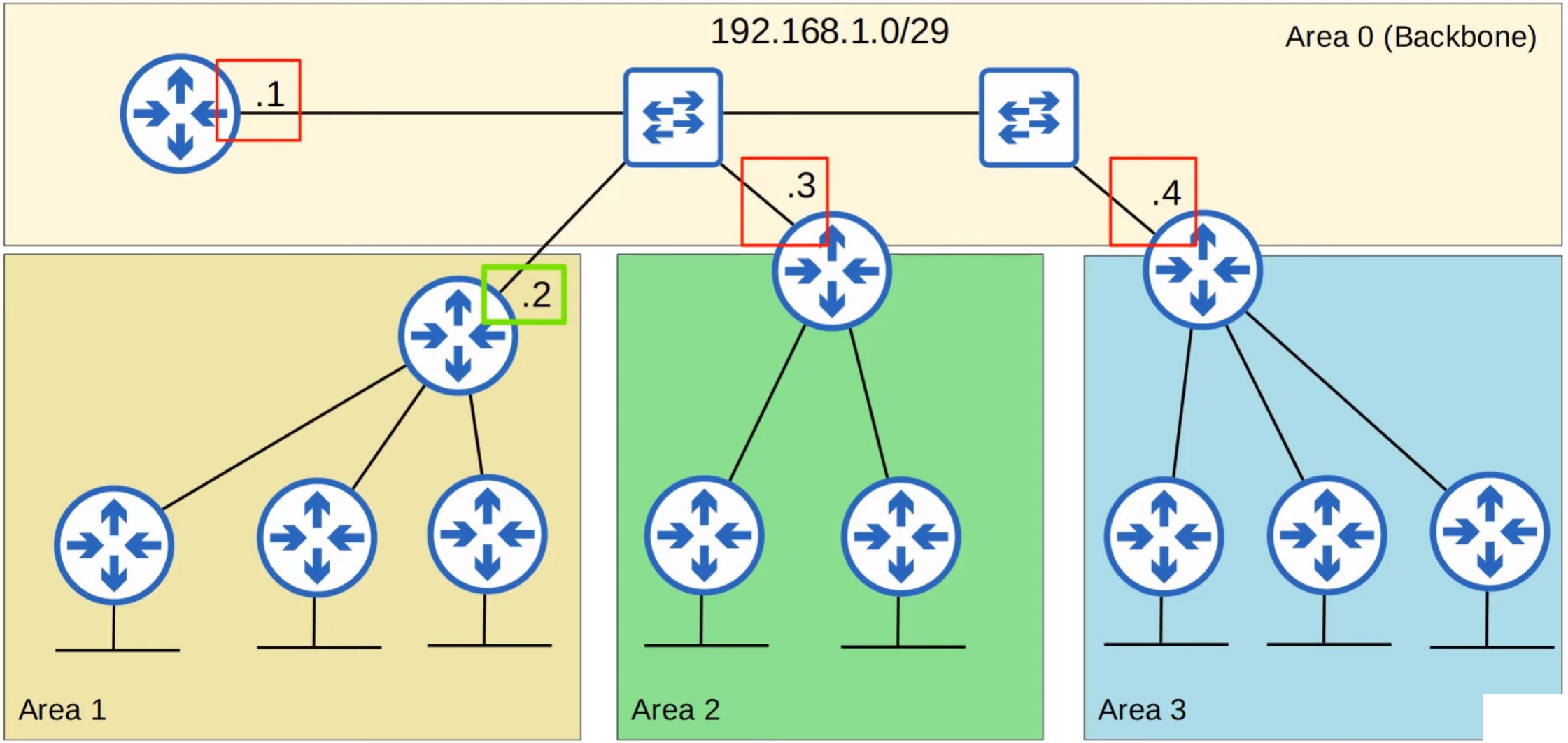


OSPF AREAS - CONTIGUOUS

NOT ALLOWED!!!



OSPF AREAS - SUBNET



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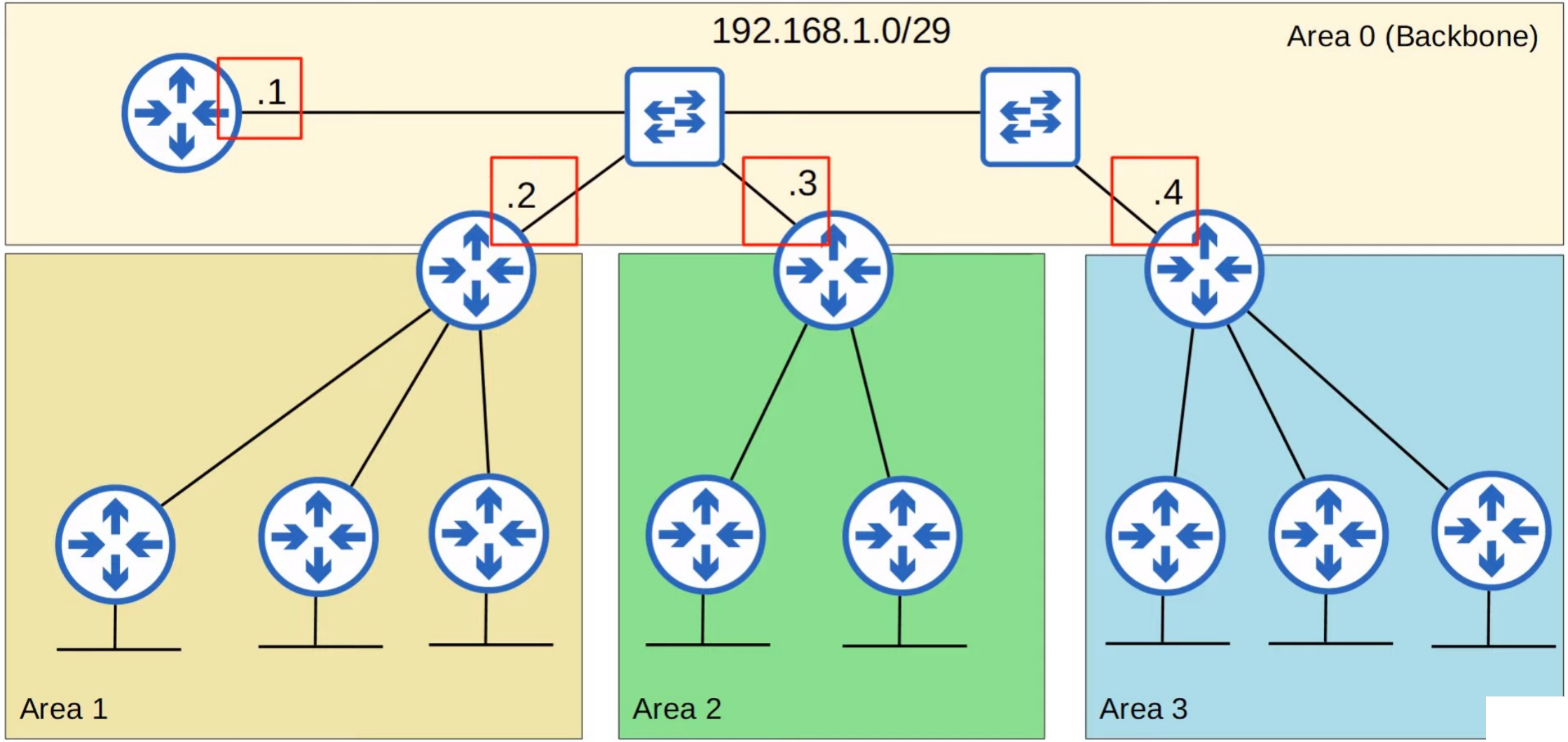
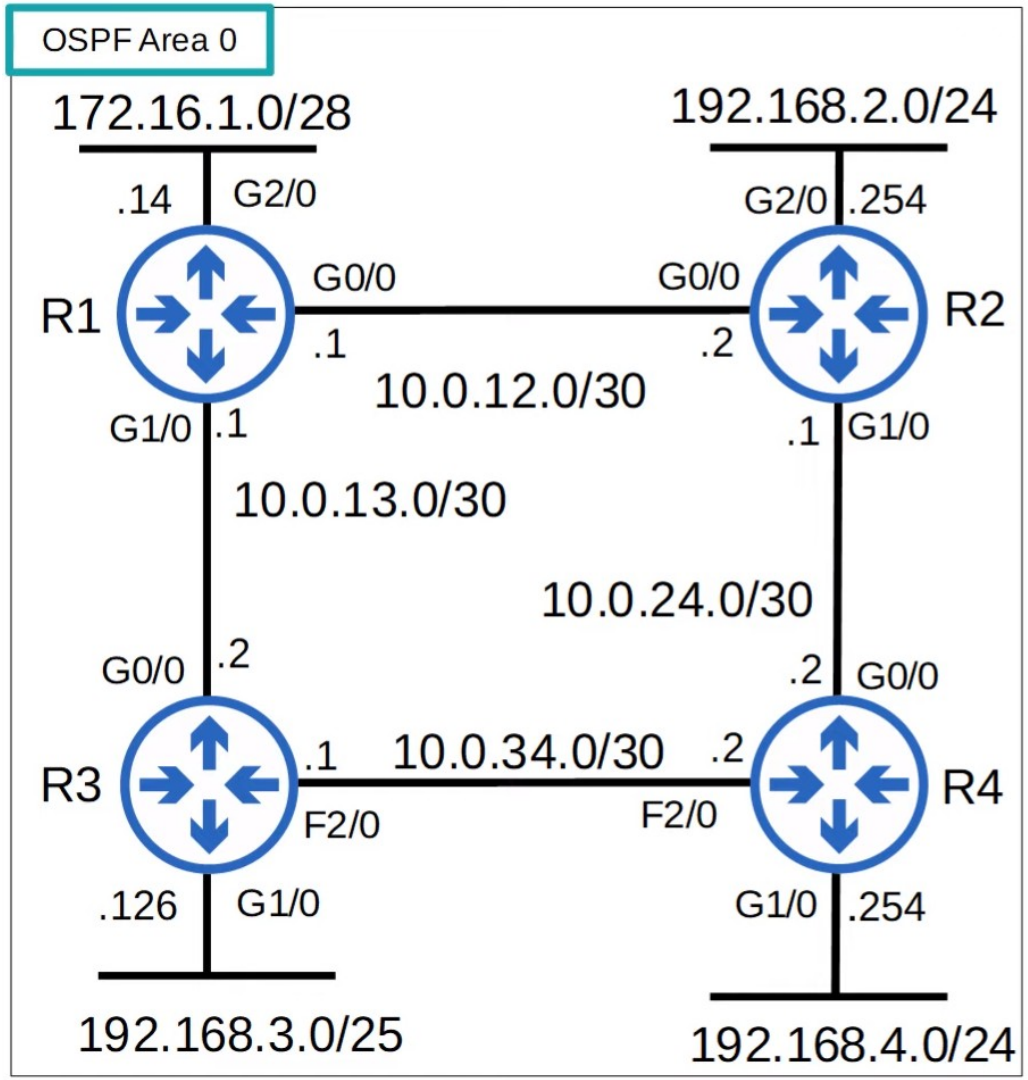


BASIC OSPF CONFIGURATION



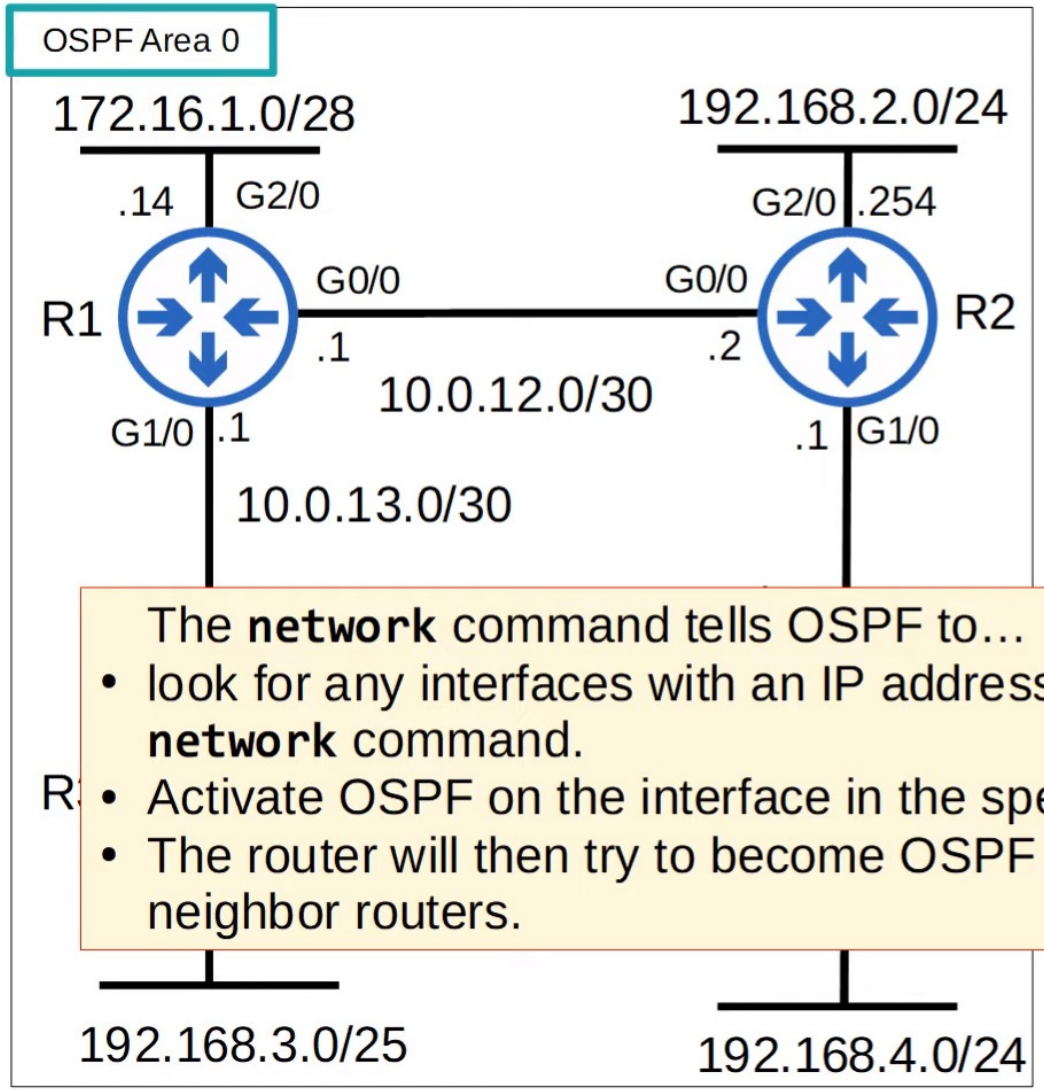

```
R1(config)#router ospf ?
  <1-65535>  Process ID

R1(config)#router ospf 1
R1(config-router)#network 10.0.12.0 0.0.0.3
% Incomplete command.

R1(config-router)#network 10.0.12.0 0.0.0.3 area 0
R1(config-router)#network 10.0.13.0 0.0.0.3 area 0
R1(config-router)#network 172.16.1.0 0.0.0.15 area 0
R1(config-router)#
```

- The OSPF *process ID* is **locally significant**. Routers with different process IDs can become OSPF neighbors.
- The OSPF **`network`** command requires you to specify the **`area`**.
- For the CCNA, you only need to configure single-area OSPF (area 0)

BASIC OSPF CONFIGURATION

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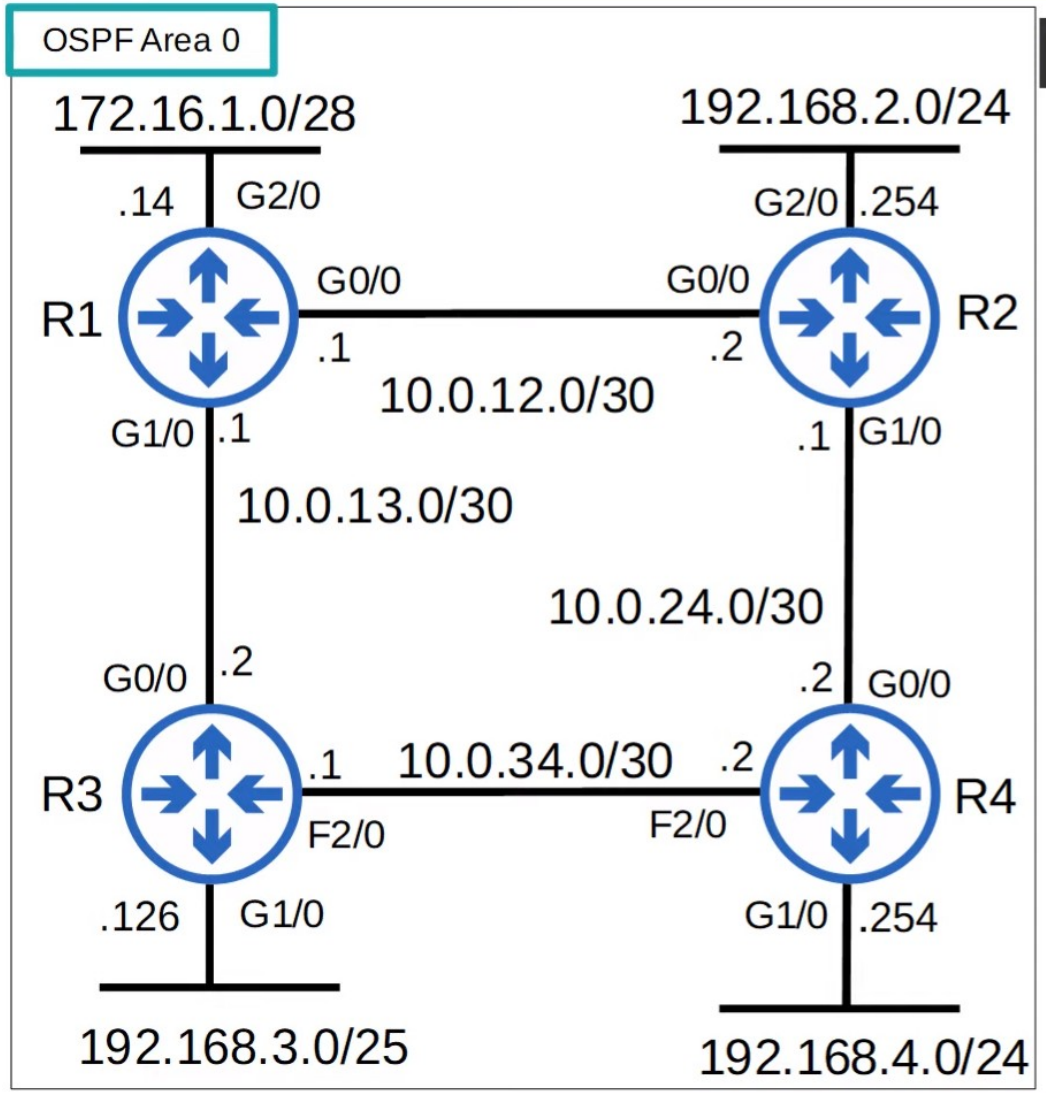
R1(config-router)#
```

The **network** command tells OSPF to…

- look for any interfaces with an IP address contained in the range specified in the **network** command.
- Activate OSPF on the interface in the specified **area**.
- The router will then try to become OSPF neighbors with other OSPF-activated neighbor routers.

- The OSPF process ID is **locally significant**.
- come
- ou to
- For the CCNA, you only need to configure single-area OSPF (area 0)

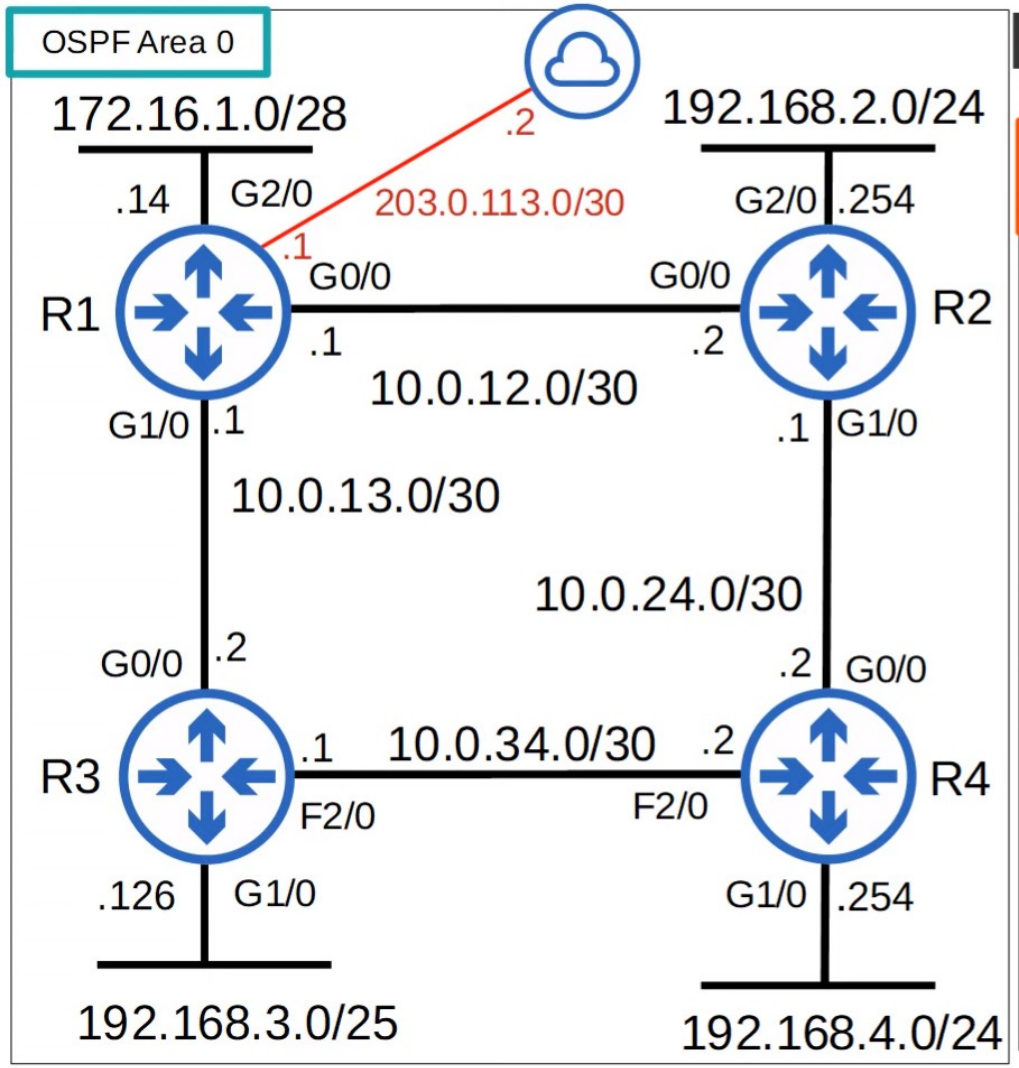
THE PASSIVE-INTERFACE COMMAND




```
R1(config-router)#passive-interface g2/0
```

- You already know this command from RIP and EIGRP.
- The **passive-interface** command tells the router to stop sending OSPF 'hello' messages out of the interface.
- However, the router will continue to send LSAs informing it's neighbors about the subnet configured on the interface.
- You should always use this command on interfaces which don't have any OSPF neighbors.

ADVERTISE A DEFAULT ROUTE INTO OSPF

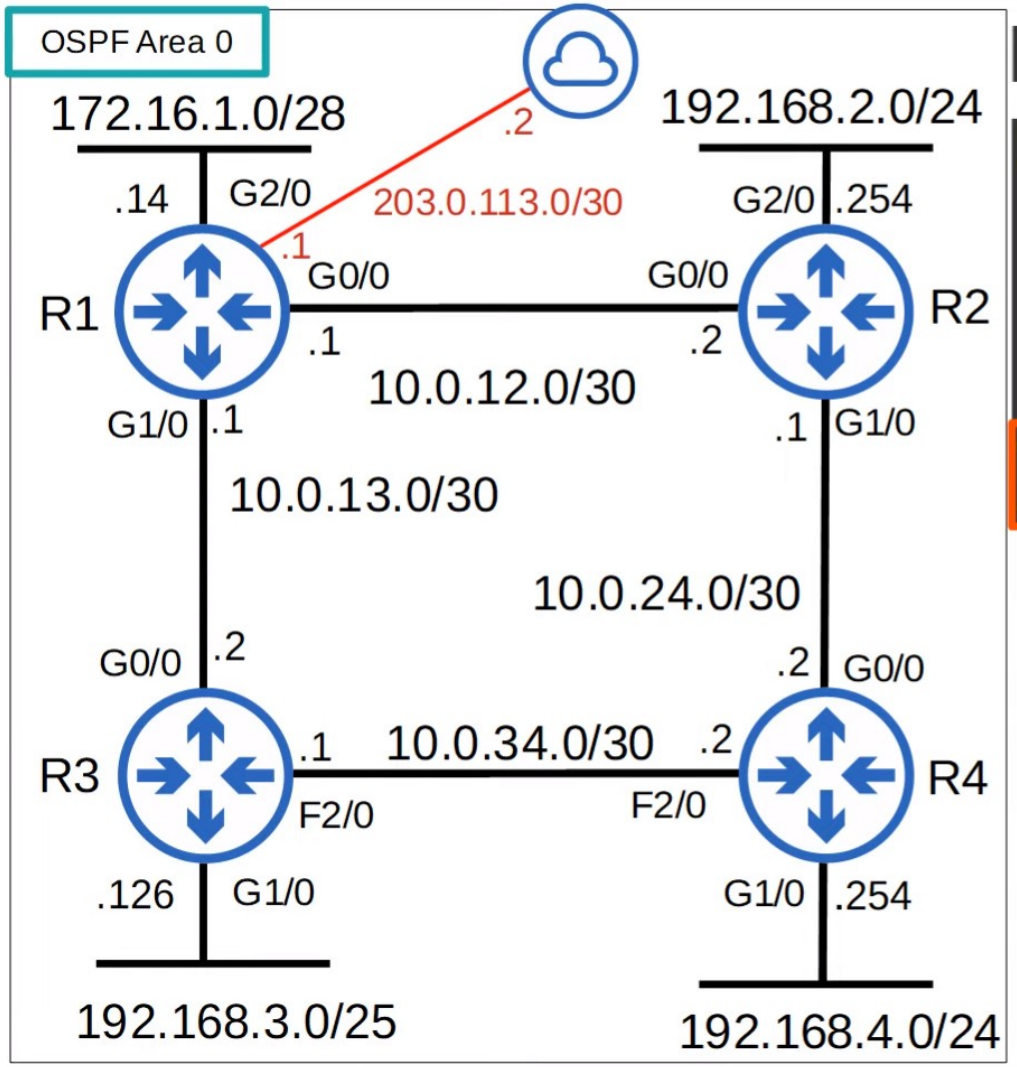



```
R1(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.2
```

```
Gateway of last resort is 203.0.113.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.2
      2.0.0.0/32 is subnetted, 1 subnets
O        2.2.2.2 [110/2] via 10.0.12.2, 01:22:21, GigabitEthernet0/0
      3.0.0.0/32 is subnetted, 1 subnets
O        3.3.3.3 [110/2] via 10.0.13.2, 01:22:11, GigabitEthernet1/0
      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/3] via 10.0.13.2, 00:00:06, GigabitEthernet1/0
                 [110/3] via 10.0.12.2, 00:00:06, GigabitEthernet0/0
      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.0.12.0/30 is directly connected, GigabitEthernet0/0
L        10.0.12.1/32 is directly connected, GigabitEthernet0/0
C        10.0.13.0/30 is directly connected, GigabitEthernet1/0
L        10.0.13.1/32 is directly connected, GigabitEthernet1/0
O        10.0.24.0/30 [110/2] via 10.0.12.2, 01:22:21, GigabitEthernet0/0
O        10.0.34.0/30 [110/2] via 10.0.13.2, 01:22:11, GigabitEthernet1/0
      172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.1.0/28 is directly connected, GigabitEthernet2/0
L        172.16.1.14/32 is directly connected, GigabitEthernet2/0
O     192.168.2.0/24 [110/2] via 10.0.12.2, 01:22:21, GigabitEthernet0/0
      192.168.3.0/25 is subnetted, 1 subnets
O        192.168.3.0 [110/2] via 10.0.13.2, 01:22:11, GigabitEthernet1/0
O     192.168.4.0/24 [110/3] via 10.0.13.2, 01:22:11, GigabitEthernet1/0
                     [110/3] via 10.0.12.2, 01:22:21, GigabitEthernet0/0
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/30 is directly connected, GigabitEthernet3/0
L        203.0.113.1/32 is directly connected, GigabitEthernet3/0
```

ADVERTISE A DEFAULT ROUTE INTO OSPF




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

```
R2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is 10.0.12.1 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 10.0.12.1, 00:01:38, GigabitEthernet0/0
```

SHOW IP PROTOCOLS

```
R1#show ip protocols
*** IP Routing is NSF aware ***

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 172.16.1.14
  It is an autonomous system boundary router
 Redistributing External Routes from,
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.0.12.0 0.0.0.3 area 0
    10.0.13.0 0.0.0.3 area 0
    172.16.1.0 0.0.0.15 area 0
  Passive Interface(s):
    GigabitEthernet2/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    4.4.4.4              110      00:00:08
    2.2.2.2              110      00:01:07
    3.3.3.3              110      00:01:07
    192.168.4.254        110      00:02:29
  Distance: (default is 110)
```

Router ID order of priority:

1) Manual configuration
2) Highest IP address on a loopback interface
3) Highest IP address on a physical interface

```
R1(config-router)#router-id ?
  A.B.C.D  OSPF router-id in IP address format

R1(config-router)#router-id 1.1.1.1
% OSPF: Reload or use "clear ip ospf process" command, for this to take effect
```

```
R1#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R1#show ip protocols
*** IP Routing is NSF aware ***

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
```

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    Gateway         Distance      Last Update
    4.4.4.4              110      00:00:08
    2.2.2.2              110      00:01:07
    3.3.3.3              110      00:01:07
    192.168.4.254        110      00:02:29
  Distance: (default is 110)
```

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R1#sh ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
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  Router ID 1.1.1.1
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  Routing for Networks:
    10.0.12.0 0.0.0.3 area 0
    10.0.13.0 0.0.0.3 area 0
    172.16.1.0 0.0.0.15 area 0
  Passive Interface(s):
    GigabitEthernet2/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    2.2.2.2              110      00:01:40
    3.3.3.3              110      00:01:40
    4.4.4.4              110      00:01:40
  Distance: (default is 110)
```

- An **autonomous system boundary router** (ASBR) is an OSPF router that connects the OSPF network to an external network.
- R1 is connected to the Internet. By using the **default-information originate** command, R1 becomes an ASBR.

```
R1(config-router)#maximum-paths ?
  <1-32>  Number of paths

R1(config-router)#maximum-paths 8
```

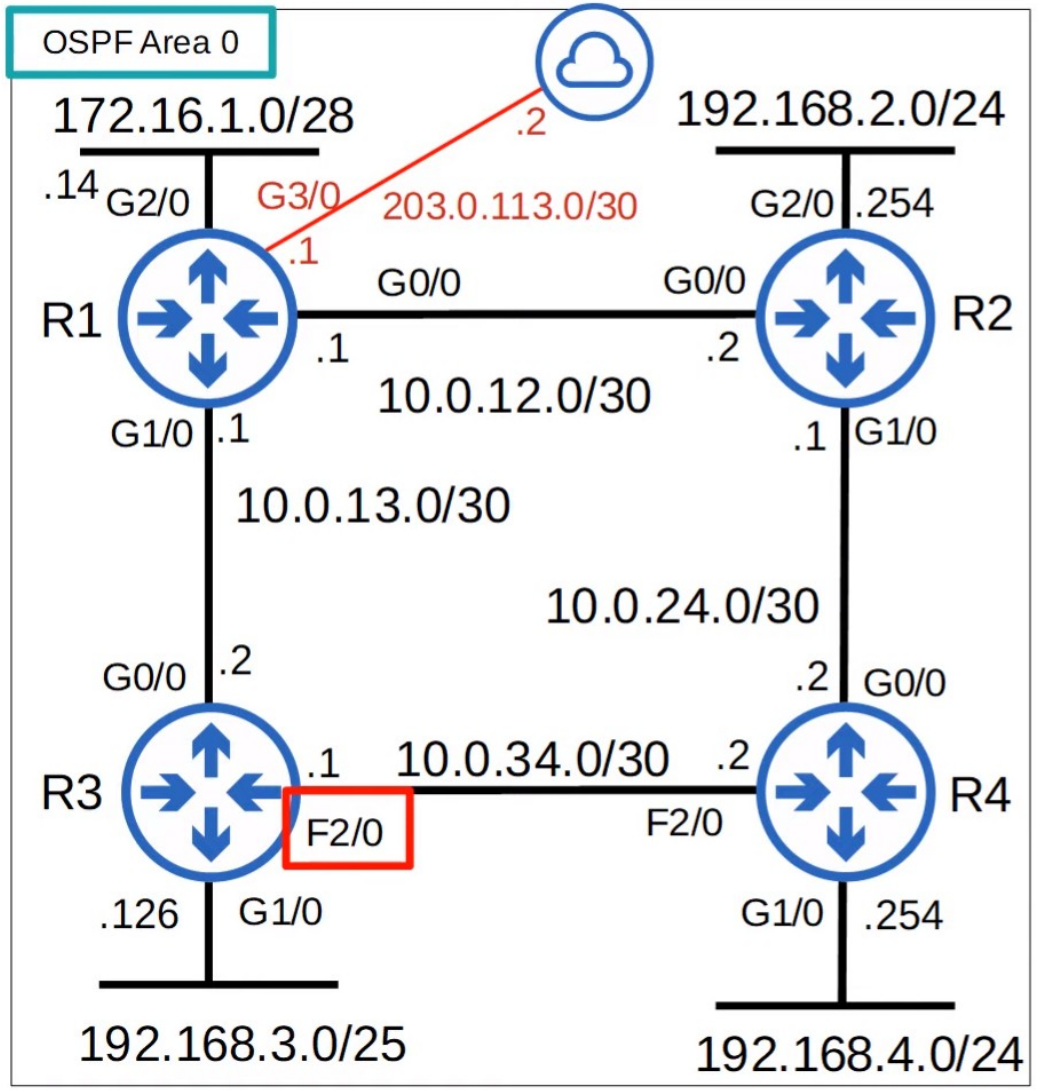
```
R1(config-router)#distance ?
  <1-255>  Administrative distance

R1(config-router)#distance 85
```

OSPF METRIC - COST

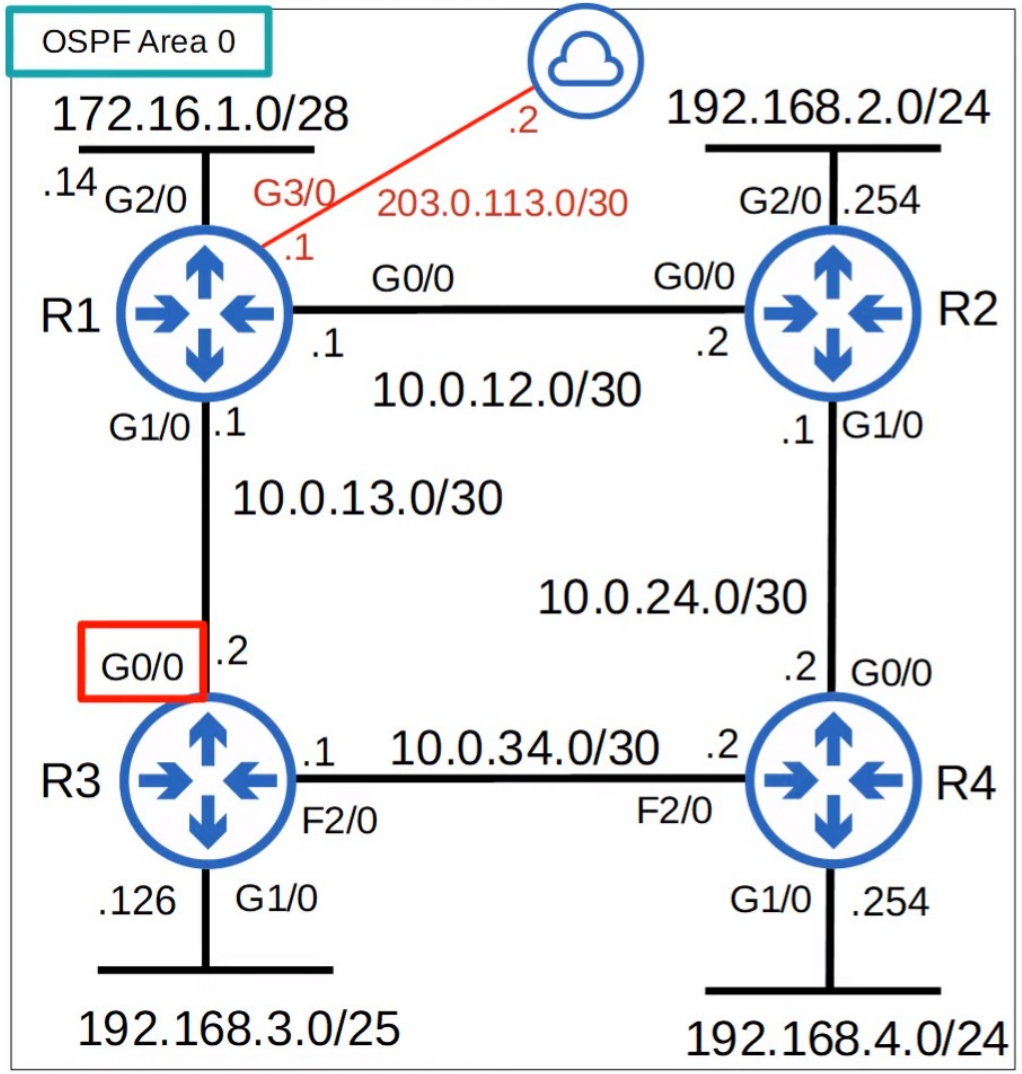
- OSPF's metric is called **cost**
- It is automatically calculated based on the bandwidth (speed) of the interface.
- It is calculated by dividing a **reference bandwidth** value by the interface's bandwidth.
- The default reference bandwidth is 100 mbps.
  Reference: 100 mbps / **Interface**: 10 mbps = cost of 10
  Reference: 100 mbps / **Interface**: 100 mbps = cost of 1
  Reference: 100 mbps / **Interface**: 1000 mbps = cost of 1??
  Reference: 100 mbps / **Interface**: 10000 mbps = cost of 1??
- All values less than 1 will be converted to 1.
- Therefore FastEthernet, Gigabit Ethernet, 10Gig Ethernet, etc. are equal and all have a cost of 1 by default.
- You can (and should!) change the reference bandwidth with this command:
  `R1(config-router)# auto-cost reference-bandwidth megabits-per-second`

OSPF METRIC - COST



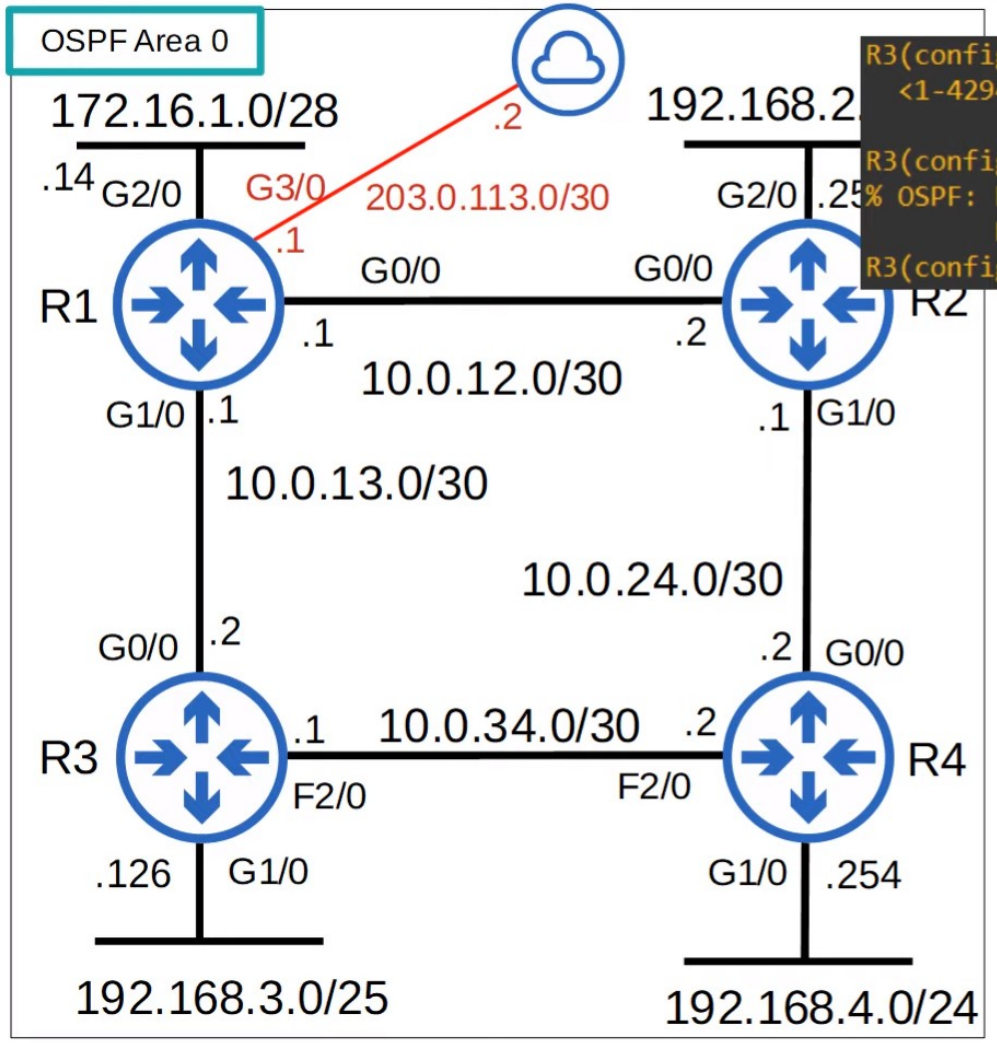

```
R3#show ip ospf interface f2/0
FastEthernet2/0 is up, line protocol is up
  Internet Address 10.0.34.1/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 3.3.3.3, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 4.4.4.4, Interface address 10.0.34.2
  Backup Designated router (ID) 3.3.3.3, Interface address 10.0.34.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:08
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 3/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 4.4.4.4  (Designated Router)
  Suppress hello for 0 neighbor(s)
R3#
```

OSPF METRIC - COST




```
R3#show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 10.0.13.2/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 3.3.3.3, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 3.3.3.3, Interface address 10.0.13.2
  Backup Designated router (ID) 1.1.1.1, Interface address 10.0.13.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:05
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 2
  Last flood scan time is 0 msec, maximum is 4 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 1.1.1.1  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
R3#
```

OSPF METRIC – CHANGE REFERENCE BANDWIDTH

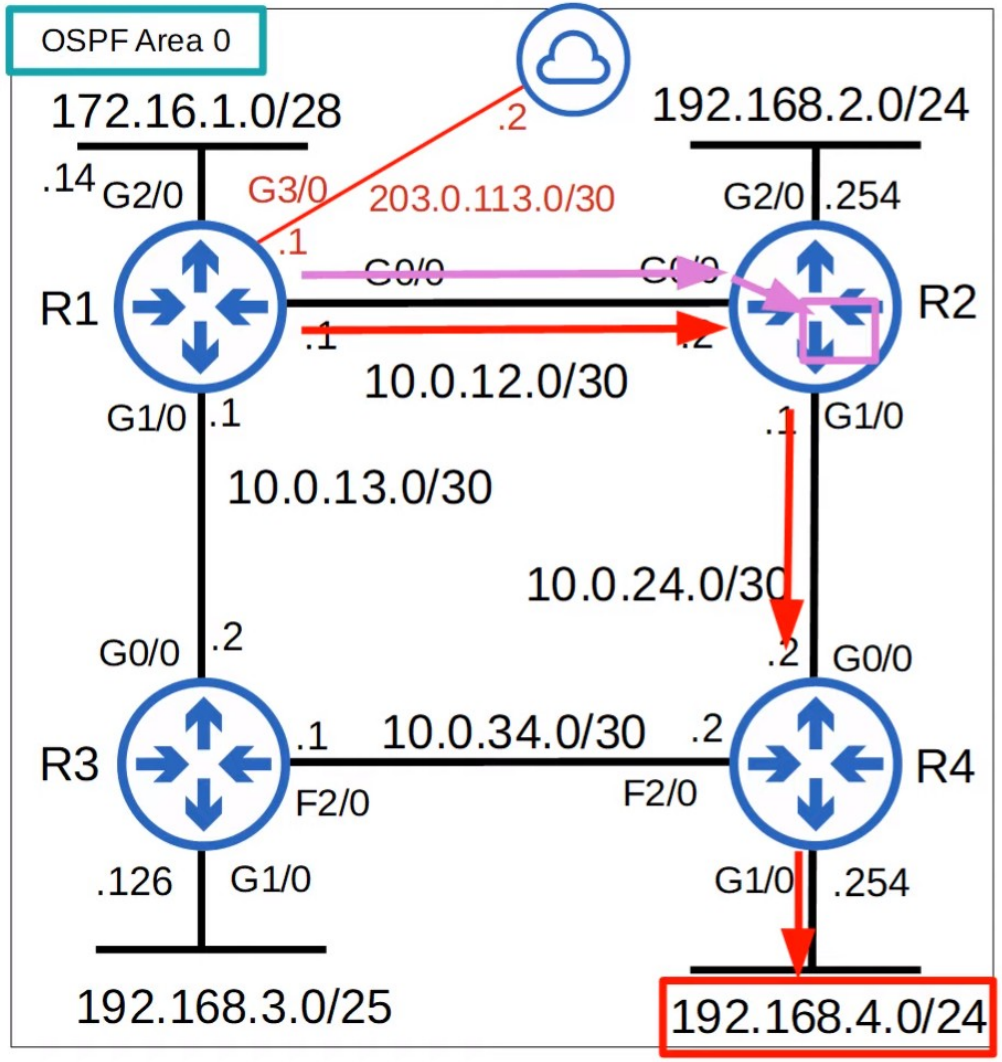



```
R3(config-router)#auto-cost reference-bandwidth ?
  <1-4294967>  The reference bandwidth in terms of Mbits per second

R3(config-router)#auto-cost reference-bandwidth 100000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
R3(config-router)#
```

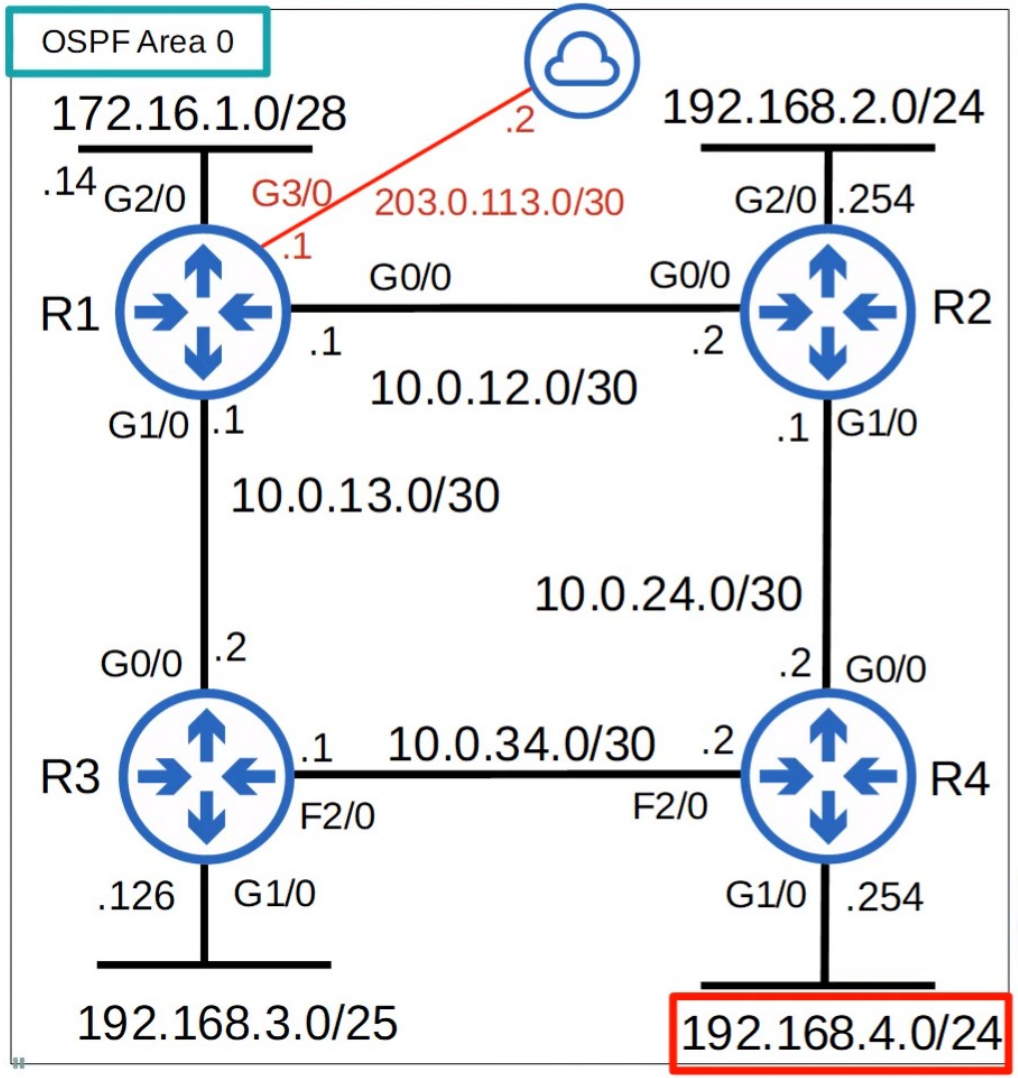
- The command is entered in megabits per second (default is 100)
- 100000 / 100 = cost of 1000 for FastEthernet
  100000 / 1000 = cost of 100 for Gig Ethernet
- You should configure a reference bandwidth greater than the fastest links in your network (to allow for future upgrades)

OSPF METRIC – CHANGE REFERENCE BANDWIDTH



- The OSPF cost to a destination is the total cost of the 'outgoing/exit interfaces'
- For example, R1's cost to reach 192.168.4.0/24 is :
  100 (R1 G0/0) + 100 (R2 G1/0) + 100 (R4 G1/0) = 300
- Loopback interfaces have a cost of 1
- What is R1's cost to reach 2.2.2.2 (R2's loopback0 interface)?

OSPF METRIC – CHANGE REFERENCE BANDWIDTH

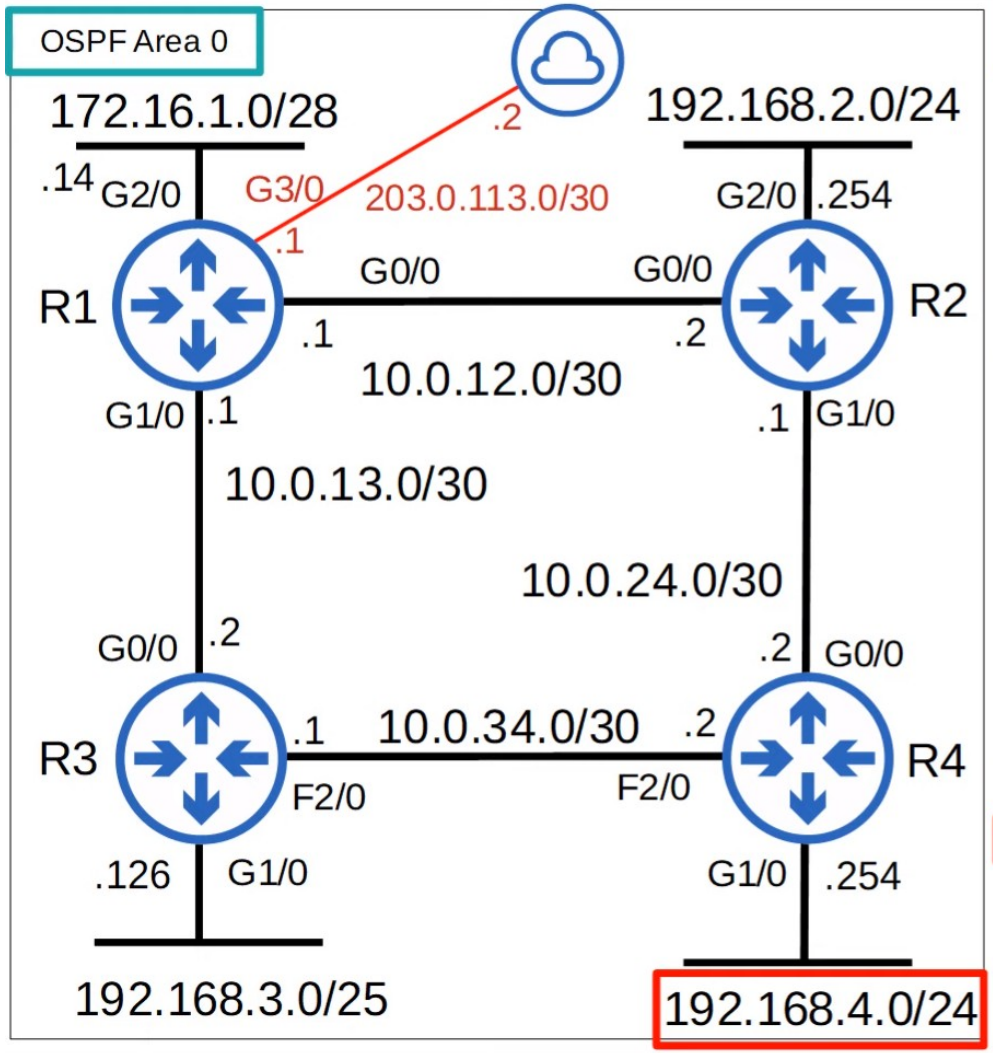


**BEFORE (reference bandwidth 100)

```
Gateway of last resort is 203.0.113.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.2
      1.0.0.0/32 is subnetted, 1 subnets
C        1.1.1.1 is directly connected, Loopback0
      2.0.0.0/32 is subnetted, 1 subnets
O        2.2.2.2 [110/2] via 10.0.12.2, 00:00:26, GigabitEthernet0/0
      3.0.0.0/32 is subnetted, 1 subnets
O        3.3.3.3 [110/2] via 10.0.13.2, 00:00:26, GigabitEthernet1/0
      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/3] via 10.0.13.2, 00:00:16, GigabitEthernet1/0
                 [110/3] via 10.0.12.2, 00:00:16, GigabitEthernet0/0
      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.0.12.0/30 is directly connected, GigabitEthernet0/0
L        10.0.12.1/32 is directly connected, GigabitEthernet0/0
C        10.0.13.0/30 is directly connected, GigabitEthernet1/0
L        10.0.13.1/32 is directly connected, GigabitEthernet1/0
O        10.0.24.0/30 [110/2] via 10.0.12.2, 00:00:16, GigabitEthernet0/0
O        10.0.34.0/30 [110/2] via 10.0.13.2, 00:00:16, GigabitEthernet1/0
      172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.1.0/28 is directly connected, GigabitEthernet2/0
L        172.16.1.14/32 is directly connected, GigabitEthernet2/0
O     192.168.2.0/24 [110/2] via 10.0.12.2, 00:00:16, GigabitEthernet0/0
      192.168.3.0/25 is subnetted, 1 subnets
O        192.168.3.0 [110/2] via 10.0.13.2, 00:00:16, GigabitEthernet1/0
O     192.168.4.0/24 [110/3] via 10.0.13.2, 00:00:04, GigabitEthernet1/0
                     [110/3] via 10.0.12.2, 00:00:04, GigabitEthernet0/0
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/30 is directly connected, GigabitEthernet3/0
L        203.0.113.1/32 is directly connected, GigabitEthernet3/0
```

OSPF METRIC – CHANGE REFERENCE BANDWIDTH

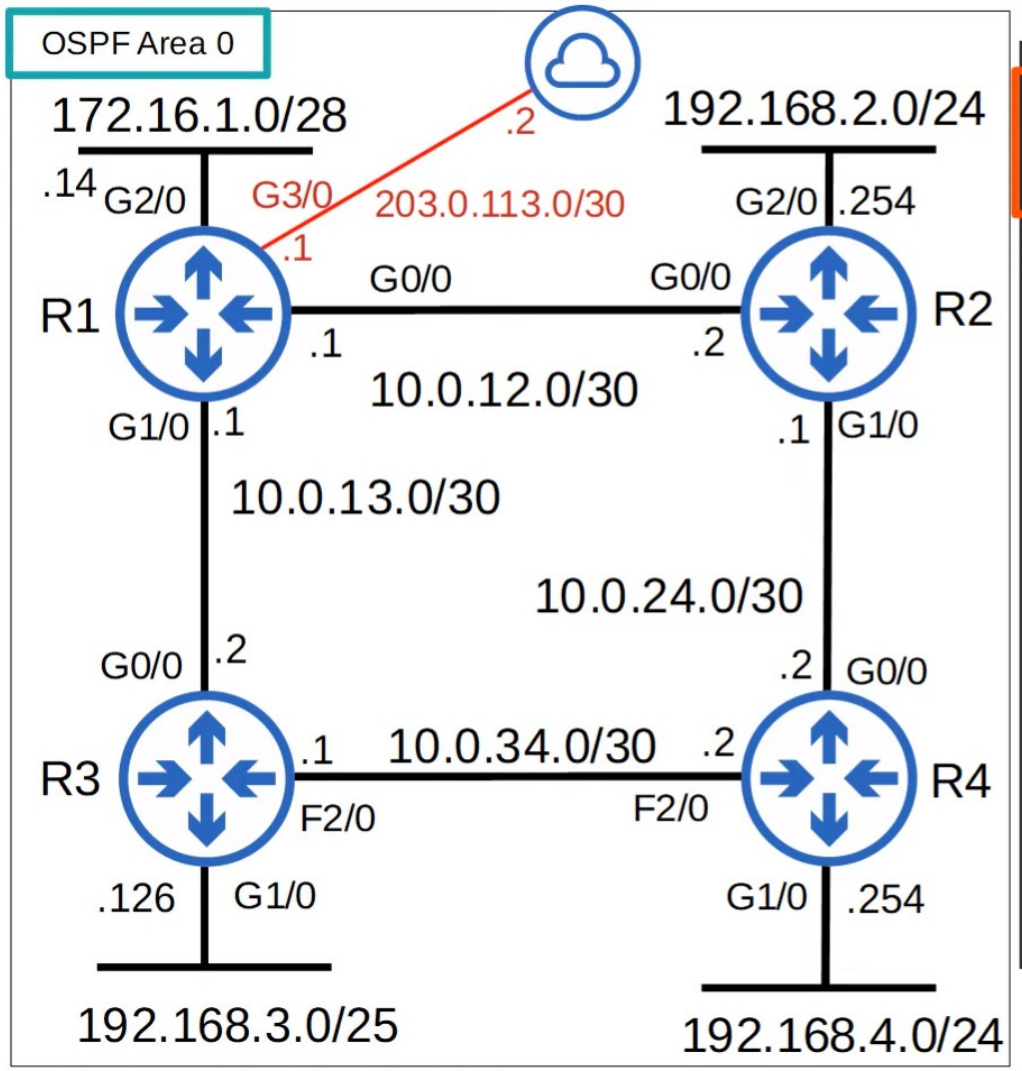


**AFTER (reference bandwidth 100,000)

```
Gateway of last resort is 203.0.113.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.2
      1.0.0.0/32 is subnetted, 1 subnets
C        1.1.1.1 is directly connected, Loopback0
      2.0.0.0/32 is subnetted, 1 subnets
O        2.2.2.2 [110/101] via 10.0.12.2, 00:34:04, GigabitEthernet0/0
      3.0.0.0/32 is subnetted, 1 subnets
O        3.3.3.3 [110/101] via 10.0.13.2, 00:33:54, GigabitEthernet1/0
      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/201] via 10.0.12.2, 00:33:54, GigabitEthernet0/0
      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.0.12.0/30 is directly connected, GigabitEthernet0/0
L        10.0.12.1/32 is directly connected, GigabitEthernet0/0
C        10.0.13.0/30 is directly connected, GigabitEthernet1/0
L        10.0.13.1/32 is directly connected, GigabitEthernet1/0
O        10.0.24.0/30 [110/200] via 10.0.12.2, 00:33:54, GigabitEthernet0/0
O        10.0.34.0/30 [110/1100] via 10.0.13.2, 00:33:44, GigabitEthernet1/0
      172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.1.0/28 is directly connected, GigabitEthernet2/0
L        172.16.1.14/32 is directly connected, GigabitEthernet2/0
O     192.168.2.0/24 [110/200] via 10.0.12.2, 00:34:04, GigabitEthernet0/0
      192.168.3.0/25 is subnetted, 1 subnets
O     192.168.4.0/24 [110/300] via 10.0.12.2, 00:26:46, GigabitEthernet0/0
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/30 is directly connected, GigabitEthernet3/0
L        203.0.113.1/32 is directly connected, GigabitEthernet3/0
```

OSPF METRIC – CHANGE COST MANUALLY




```
R1(config)#interface g0/0
R1(config-if)#ip ospf cost ?
  <1-65535>  Cost

R1(config-if)#ip ospf cost 10000
R1(config-if)#do show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 10.0.12.1/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 10000
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0          10000     no          no            Base
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 2.2.2.2, Interface address 10.0.12.2
  Backup Designated router (ID) 1.1.1.1, Interface address 10.0.12.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:01
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 4 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 2.2.2.2  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

OSPF METRIC – CHANGE COST MANUALLY

- One more option to change the OSPF cost of an interface is to change the bandwidth of the interface with the **bandwidth** command.
- The formula to calculate OSPF cost is **reference bandwidth / interface bandwidth**
- Although the bandwidth matches the interface speed by default, changing the interface bandwidth doesn't actually change the speed at which the interface operates.
- The bandwidth is just a value that is used to calculate OSPF cost, EIGRP metric, etc.
- To change the speed at which the interface operates, use the **speed** command.
- Because the bandwidth value is used in other calculations, it is not recommended to change this value to alter the interface's OSPF cost.
- It is recommended that you change the reference bandwidth, and then use the **ip ospf cost** command to change the cost of individual interfaces if you want.

```
R1(config-if)#bandwidth ?
  <1-10000000>   Bandwidth in kilobits
  inherit        Specify how bandwidth is inherited
  qos-reference  Reference bandwidth for QOS test
  receive        Specify receive-side bandwidth
```

OSPF METRIC – SUMMARY

- Three ways to modify the OSPF cost:

1) Change the **reference bandwidth**:
`R1(config-router)# auto-cost reference-bandwidth` *megabits-per-second*

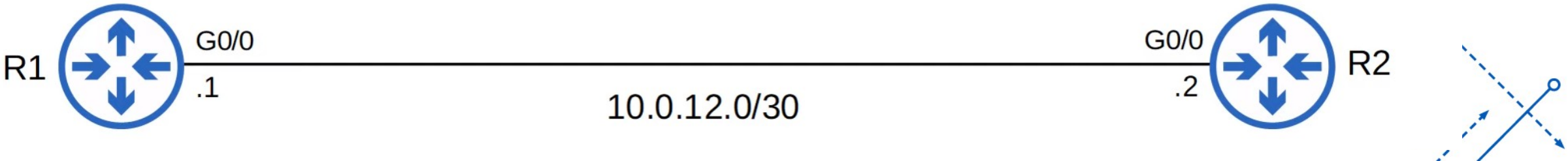
2) Manual configuration
`R1(config-if)# ip ospf cost` *cost*

3) Change the **interface bandwidth**
`R1(config-if)# bandwidth` *kilobits-per-second*

```
R3#show ip ospf interface brief
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Lo0          1     0               3.3.3.3/32         1     LOOP  0/0
Gi1/0        1     0               192.168.3.126/25   100   DR    0/0
Fa2/0        1     0               10.0.34.1/30       1000  BDR   1/1
Gi0/0        1     0               10.0.13.2/30       100   DR    1/1
```

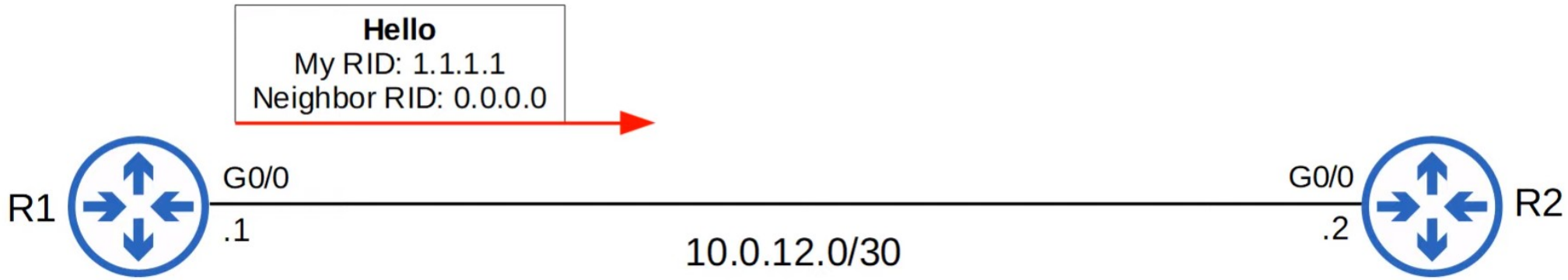
OSPF NEIGHBORS

- Making sure that routers successfully become OSPF neighbors is the main task in configuring and troubleshooting OSPF.
- Once routers become neighbors, they automatically do the work of sharing network information, calculating routes, etc.
- When OSPF is activated on an interface, the router starts sending OSPF **hello** messages out of the interface at regular intervals (determined by the **hello timer**). These are used to introduce the router to potential OSPF neighbors.
- The default hello timer is 10 seconds on an Ethernet connection.
- Hello messages are multicast to 224.0.0.5 (multicast address for all OSPF routers)
- OSPF messages are encapsulated in an IP header, with a value of 89 in the Protocol field.



OSPF NEIGHBORS – DOWN STATE

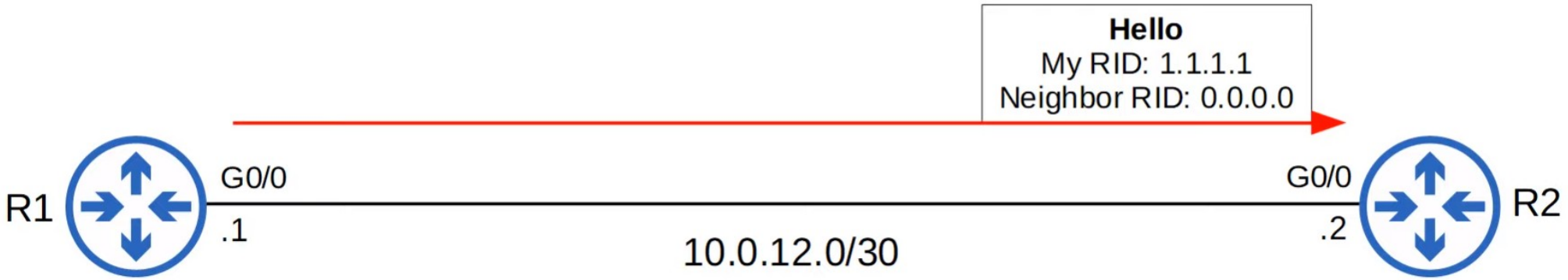
- OSPF is activated on R1's G0/0 interface.
- It sends an OSPF hello message to 224.0.0.5.
- It doesn't know about any OSPF neighbors yet, so the current neighbor state is **Down**.



Down

OSPF NEIGHBORS – INIT STATE

- When R2 receives the Hello packet, it will add an entry for R1 to its OSPF neighbor table.
- In R2's neighbor table, the relationship with R1 is now in the **Init** state.
- **Init** state = Hello packet received, but own router ID is not in the Hello packet



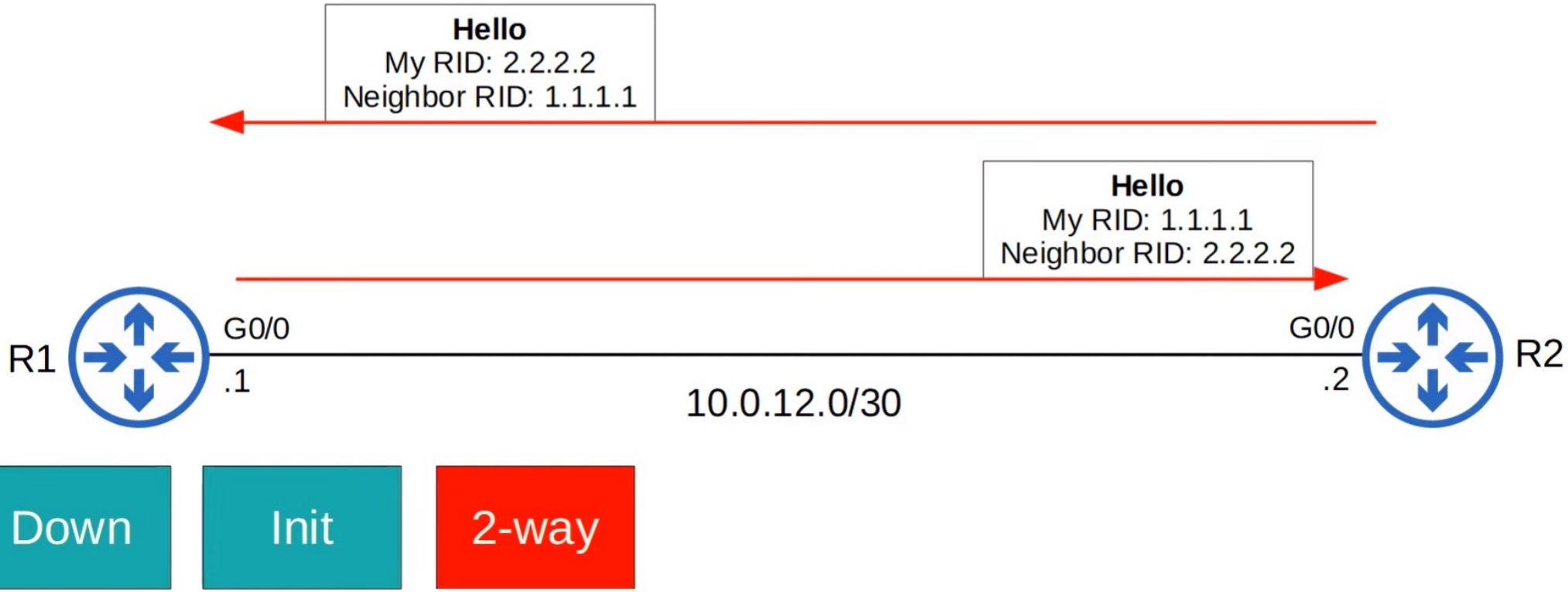
Down

Init

OSPF NEIGHBORS – 2-WAY STATE

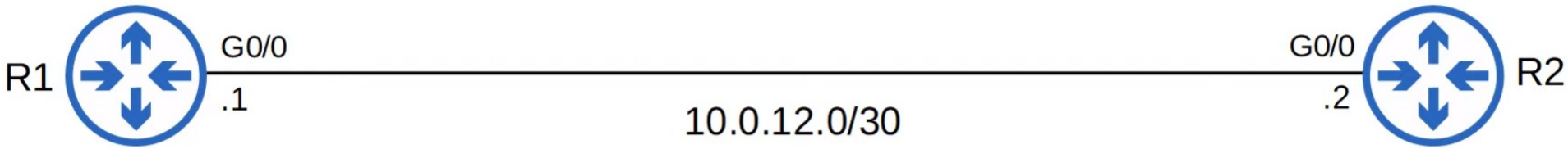
- R2 will send a Hello packet containing the RID of both routers.
  R1 will insert R2 into its OSPF neighbor table in the **2-way** state.

- R1 will send another Hello message, this time containing R2's RID.
  Now both routers are in the **2-way** state.



OSPF NEIGHBORS – 2-WAY STATE

- The 2-way state means the router has received a Hello packet with its own RID in it.
- If both routers reach the 2-way state, it means that all of the conditions have been met for them to become OSPF neighbors. They are now ready to share LSAs to build a common LSDB.
- In some network types, a DR (Designated Router) and BDR (Backup Designated Router) will be elected at this point.



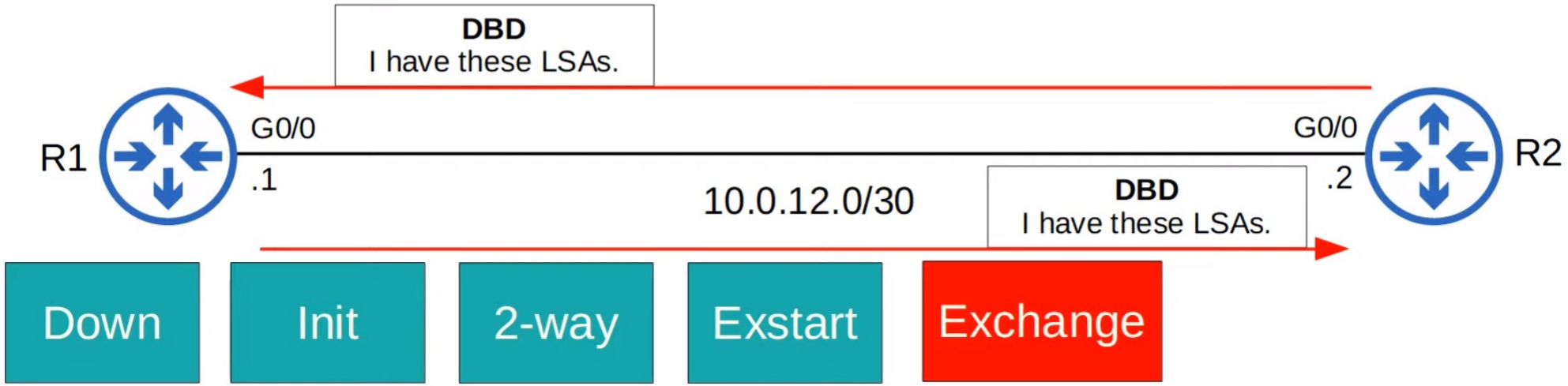
Down | Init | 2-way

OSPF NEIGHBORS – EXSTART STATE

- The two routers will now prepare to exchange information about their LSDB.
- Before that, they have to choose which one will start the exchange.
- They do this in the **Exstart** state.
- The router with the higher RID will become the **Master** and initiate the exchange. The router with the lower RID will become the **Slave**.
- To decide the Master and Slave, they exchange DBD (Database Description) packets.

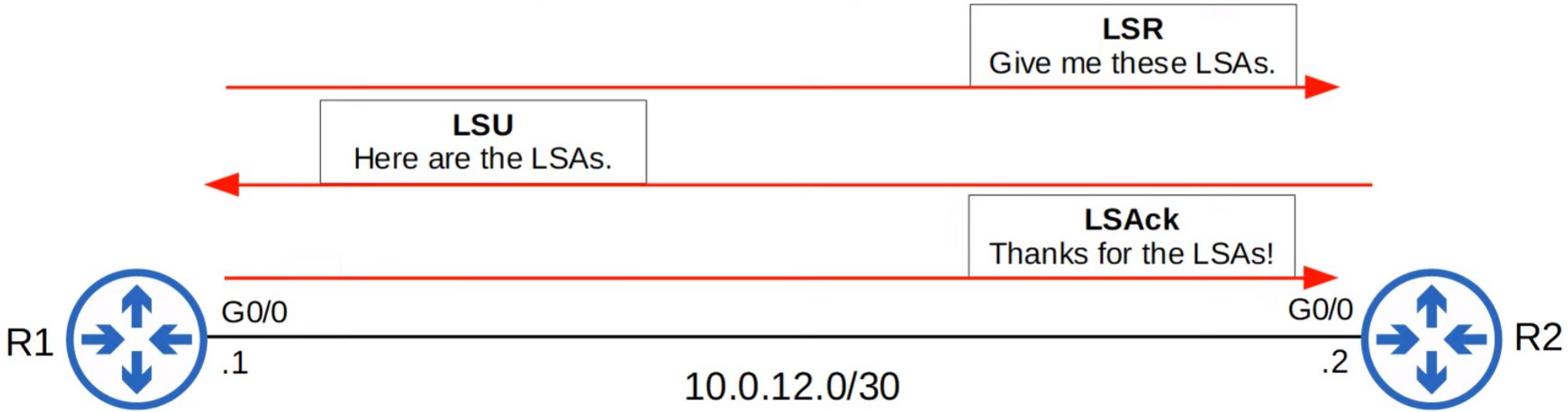
OSPF NEIGHBORS – EXCHANGE STATE

- In the **Exchange** state, the routers exchange DBDs which contain a list of the LSAs in their LSDB.
- These DBDs do not include detailed information about the LSAs, just basic information.
- The routers compare the information in the DBD they received to the information in their own LSDB to determine which LSAs they must receive from their neighbor.



OSPF NEIGHBORS – LOADING STATE

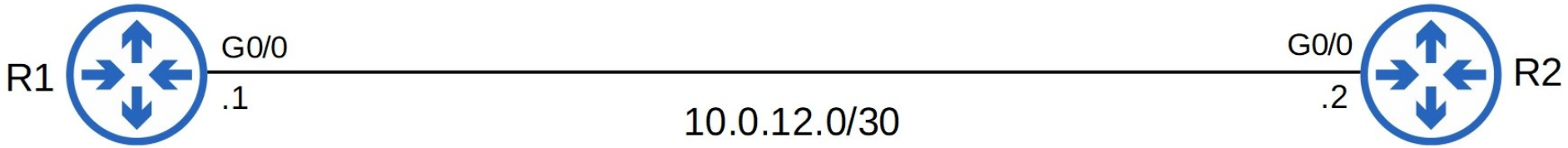
- In the **Loading** state, routers send Link State Request (LSR) messages to request that their neighbors send them any LSAs they don't have.
- LSAs are sent in Link State Update (LSU) messages.
- The routers send LSAck messages to acknowledge that they received the LSAs.



Down | Init | 2-way | Exstart | Exchange | **Loading**

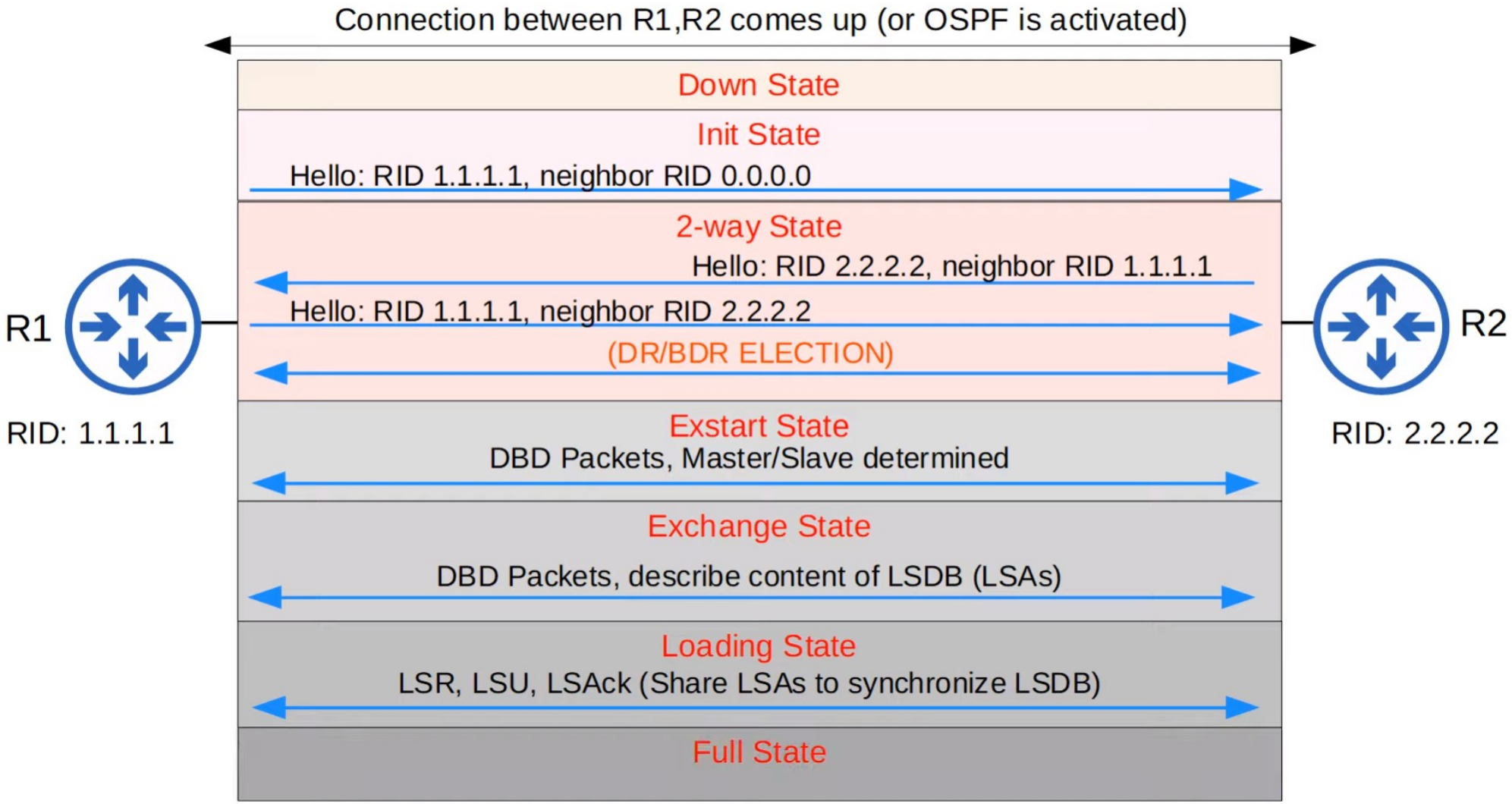
OSPF NEIGHBORS – FULL STATE

- In the **Full** state, the routers have a full OSPF adjacency and identical LSDBs.
- They continue to send and listen for Hello packets (every 10 seconds by default) to maintain the neighbor adjacency.
- Every time a Hello packet is received, the 'Dead' timer (40 seconds by default) is reset.
- If the Dead timer counts down to 0 and no Hello message is received, the neighbor is removed.
- The routers will continue to share LSAs as the network changes to make sure each router has a complete and accurate map of the network (LSDB).



Down → Init → 2-way → Exstart → Exchange → Loading → **Full**

OSPF NEIGHBORS – SUMMARY



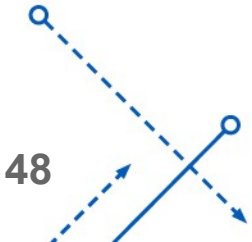
OSPF NEIGHBORS

- In OSPF, there are three main steps in the process of sharing LSAs and determining the best route to each destination in the network.

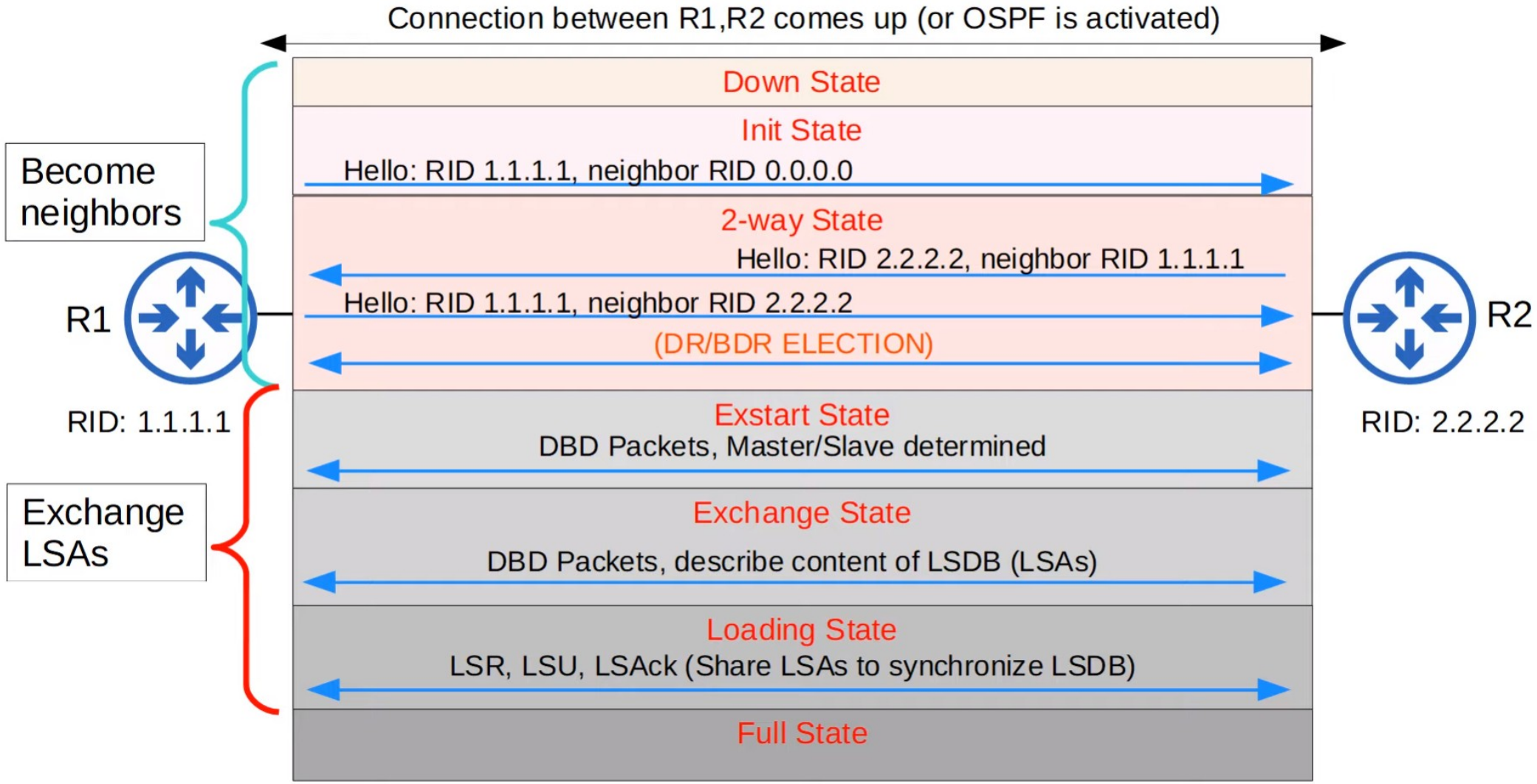
1) **Become neighbors** with other routers connected to the same segment.

2) **Exchange LSAs** with neighbor routers.

3) **Calculate the best routes** to each destination, and insert them into the routing table.



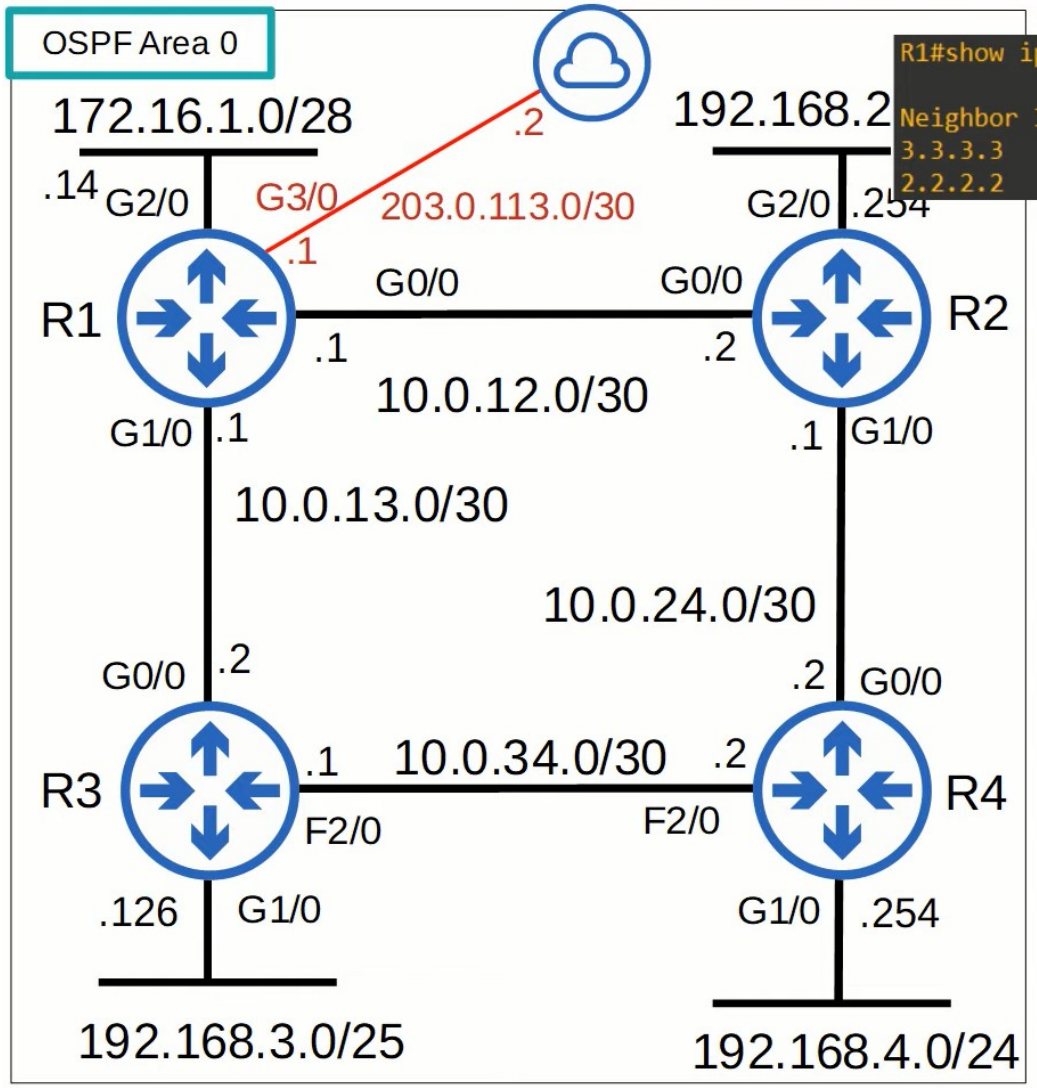
OSPF NEIGHBORS



OSPF NEIGHBORS

Type	Name	Purpose
1	**Hello**	Neighbor discovery and maintenance.
2	**Database Description (DBD)**	Summary of the LSDB of the router. Used to check if the LSDB of each router is the same.
3	**Link-State Request (LSR)**	Requests specific LSAs from the neighbor.
4	**Link-State Update (LSU)**	Sends specific LSAs to the neighbor.
5	**Link-State Acknowledgement (LSAck)**	Used to acknowledge that the router received a message.

OSPF NEIGHBORS

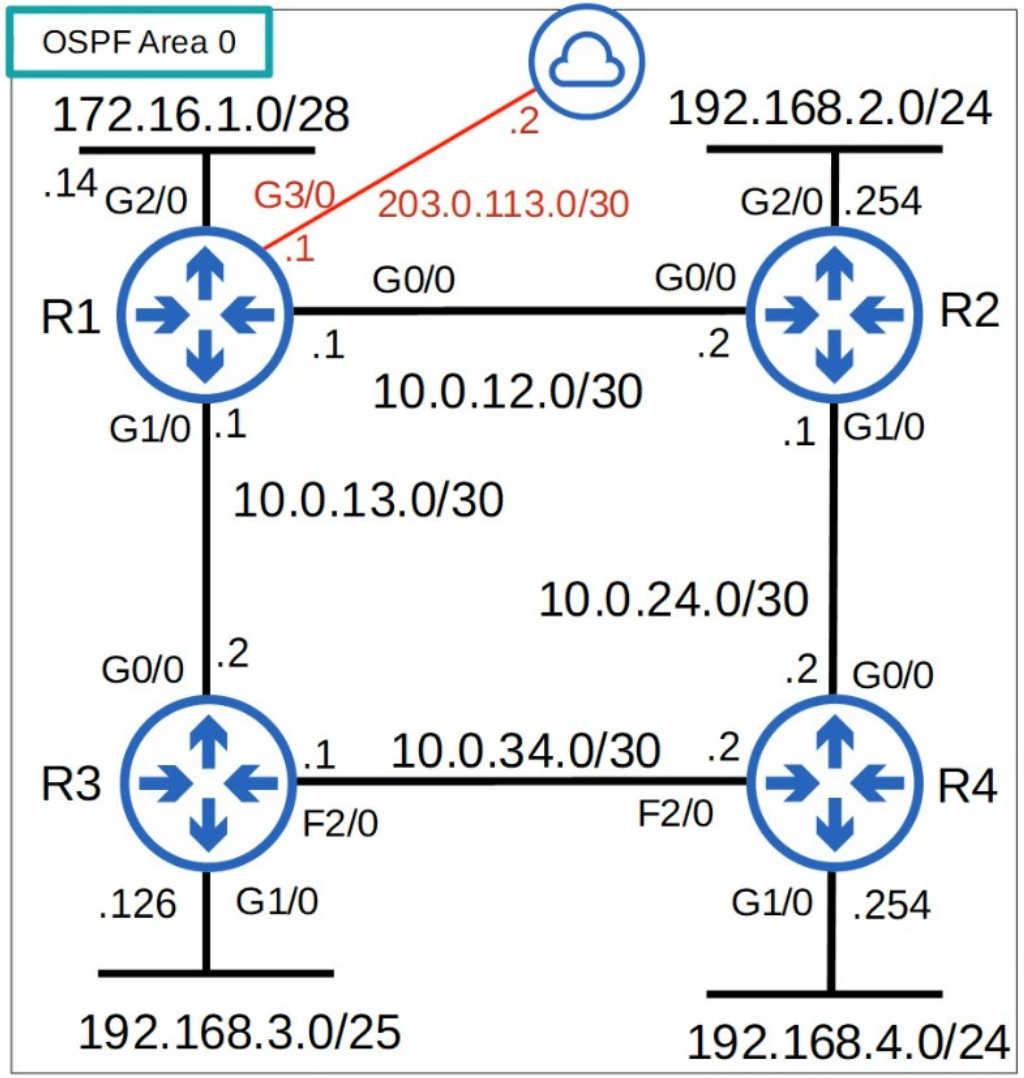



```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
3.3.3.3           1   FULL/DR         00:00:39    10.0.13.2       GigabitEthernet1/0
2.2.2.2           1   FULL/DR         00:00:31    10.0.12.2       GigabitEthernet0/0
```

```
R1#show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 10.0.12.1/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 2.2.2.2, Interface address 10.0.12.2
  Backup Designated router (ID) 1.1.1.1, Interface address 10.0.12.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:07
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 2.2.2.2  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

OSPF CONFIGURATION (Cont.)




```
R1(config)#int g0/0
R1(config-if)#ip ospf 1 area 0
R1(config-if)#int g1/0
R1(config-if)#ip ospf 1 area 0
R1(config-if)#int g2/0
R1(config-if)#ip ospf 1 area 0
R1(config-if)#int l0
R1(config-if)#ip ospf 1 area 0
```

- You can activate OSPF directly on an interface with this command:
  `R1(config-if)#ip ospf process-id area area`

```
R1(config-if)#router ospf 1
R1(config-router)#passive-interface default
R1(config-router)#no passive-interface g0/0
R1(config-router)#no passive-interface g1/0
```

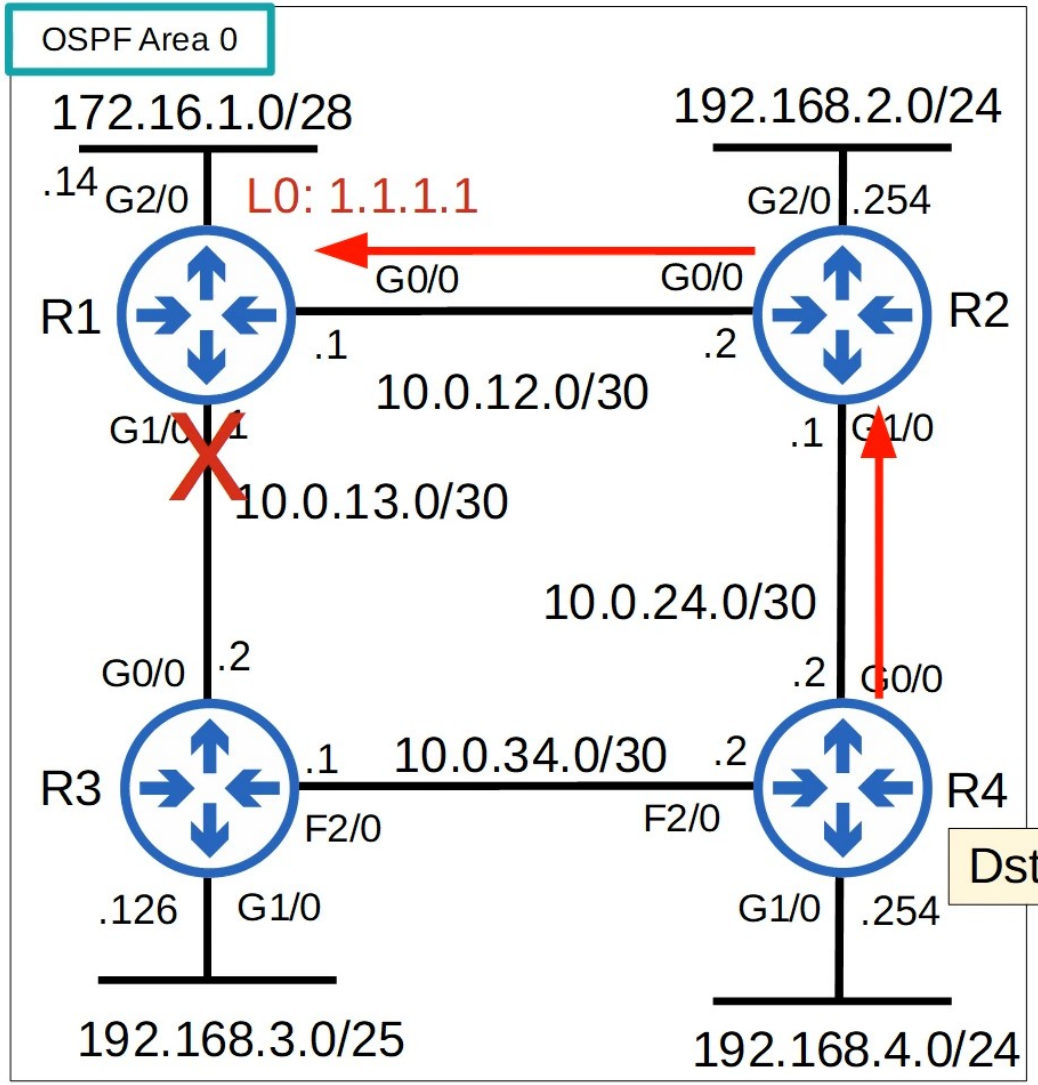
- Configure ALL interfaces as OSPF passive interfaces:
  `R1(config-router)#passive-interface default`
- Then configure specific interfaces as active:
  `R1(config-router)#no passive-interface int-id`

OSPF CONFIGURATION (Cont.)

```
R1#show ip protocols
*** IP Routing is NSF aware ***

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
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
  Routing on Interfaces Configured Explicitly (Area 0):
    Loopback0
    GigabitEthernet1/0
    GigabitEthernet0/0
    GigabitEthernet2/0
  Passive Interface(s):
    Ethernet0/0
    GigabitEthernet2/0
    GigabitEthernet3/0
    Loopback0
    VoIP-Null0
  Routing Information Sources:
    Gateway         Distance      Last Update
    2.2.2.2              110      00:09:53
    Gateway         Distance      Last Update
    3.3.3.3              110      00:09:54
    4.4.4.4              110      00:09:54
  Distance: (default is 110)
```

LOOPBACK INTERFACES



- A loopback interface is a virtual interface in the router.
- It is always up/up (unless you manually shut it down)
- It is not dependent on a physical interface.
- So, it provides a consistent IP address that can be used to reach/identify the router.

Dst: 1.1.1.1

OSPF NETWORK TYPES

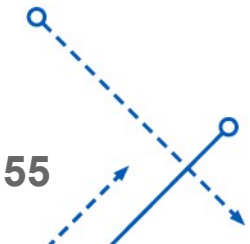
- The OSPF 'network type' refers to the type of connection between OSPF neighbors (Ethernet, etc)

- There are three main OSPF network types:

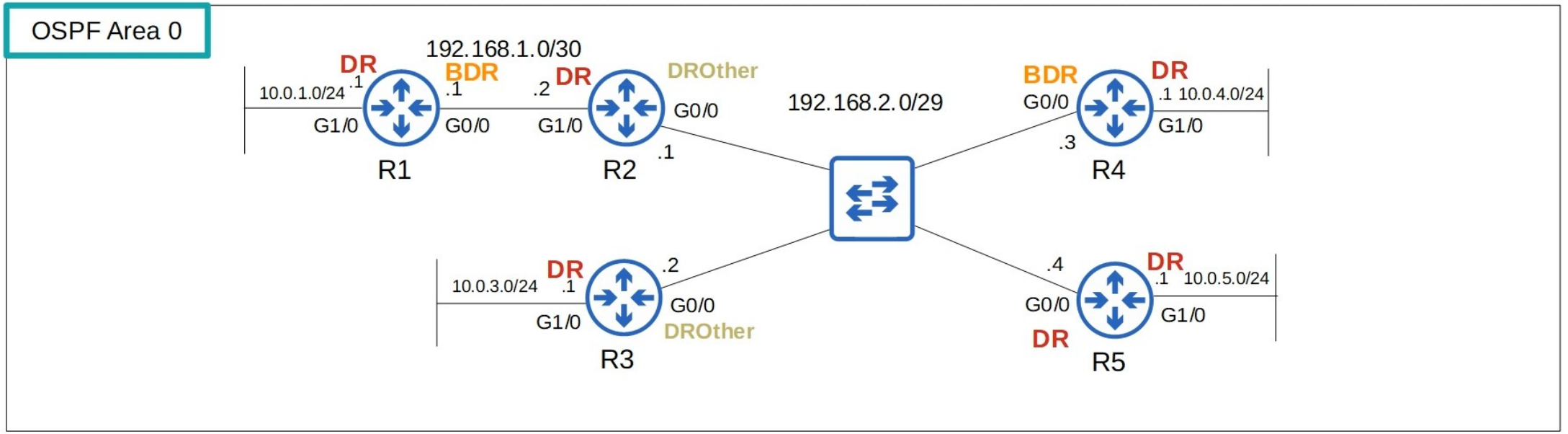
  Broadcast
  -enabled by default on **Ethernet** and **FDDI** (Fiber Distributed Data Interfaces) interfaces

  Point-to-point
  -enabled by default on **PPP** (Point-to-Point Protocol) and **HDLC** (High-Level Data Link Control) interfaces

  Non-broadcast
  -enabled by default on **Frame Relay** and **X.25** interfaces

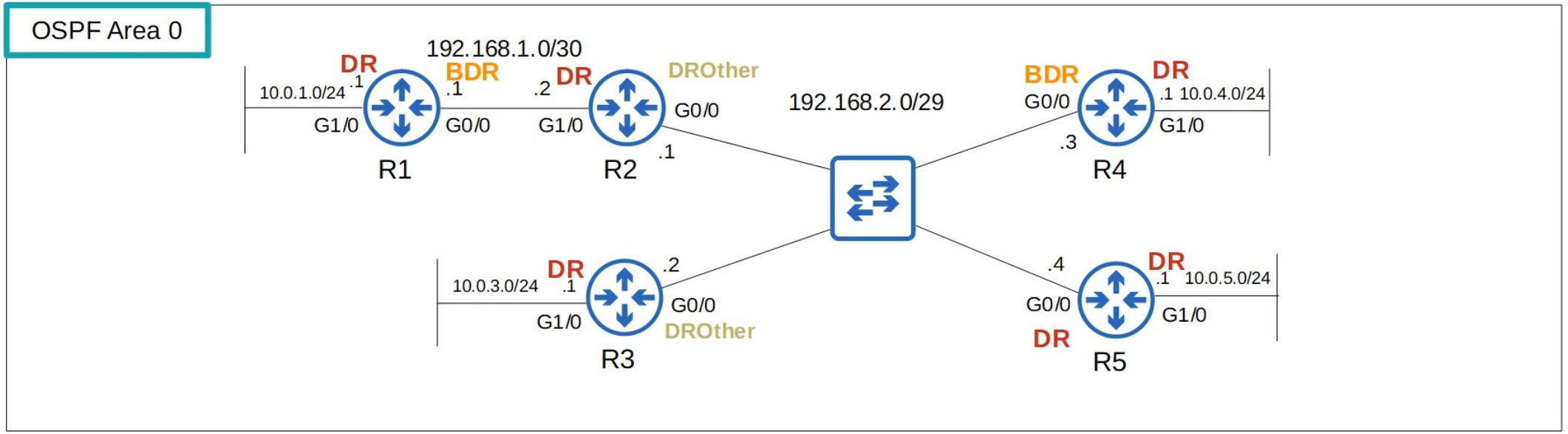


OSPF BROADCAST NETWORK TYPE



- Enabled on **Ethernet** and **FDDI** interfaces by default.
- Routers *dynamically discover* neighbors by sending/listening for OSPF Hello messages using multicast address 224.0.0.5.
- A **DR** (designated router) and **BDR** (backup designated router) must be elected on each subnet (only DR if there are no OSPF neighbors, ie. R1's G1/0 interface)
- Routers which aren't the DR or BDR become a **DROther**.

OSPF BROADCAST NETWORK TYPE

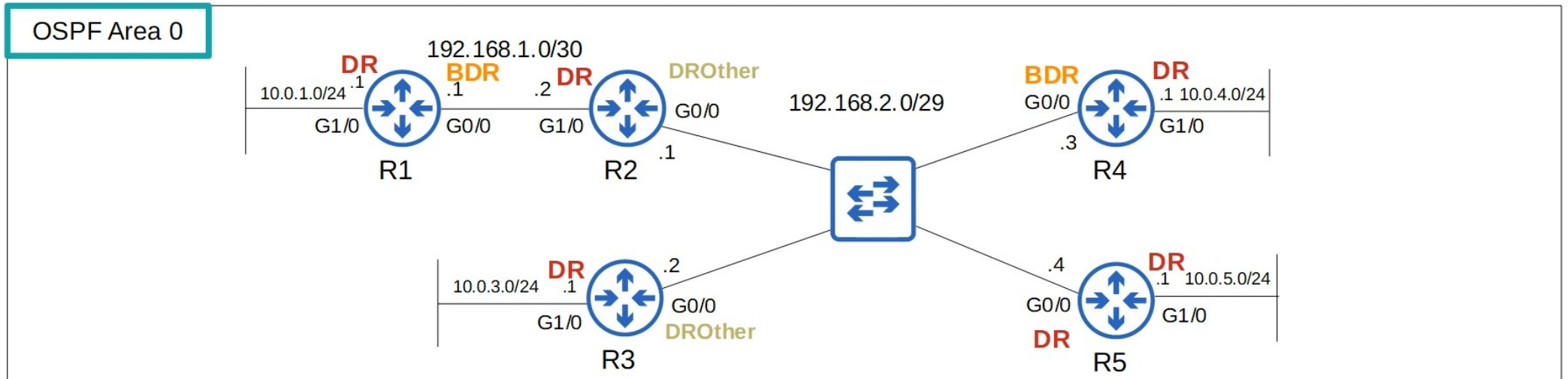


- The DR/BDR election order of priority:
  1: Highest **OSPF interface priority**
  2: Highest OSPF Router ID

- 'First place' becomes the DR for the subnet, 'second place' becomes the BDR

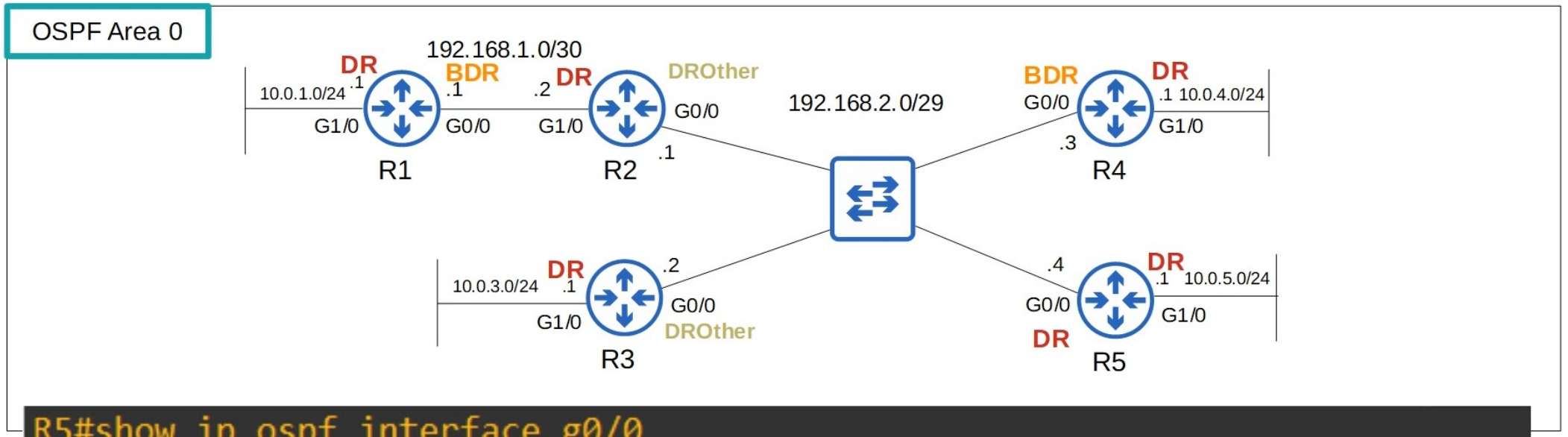
- The default OSPF interface priority is 1 on all interfaces

OSPF BROADCAST NETWORK TYPE



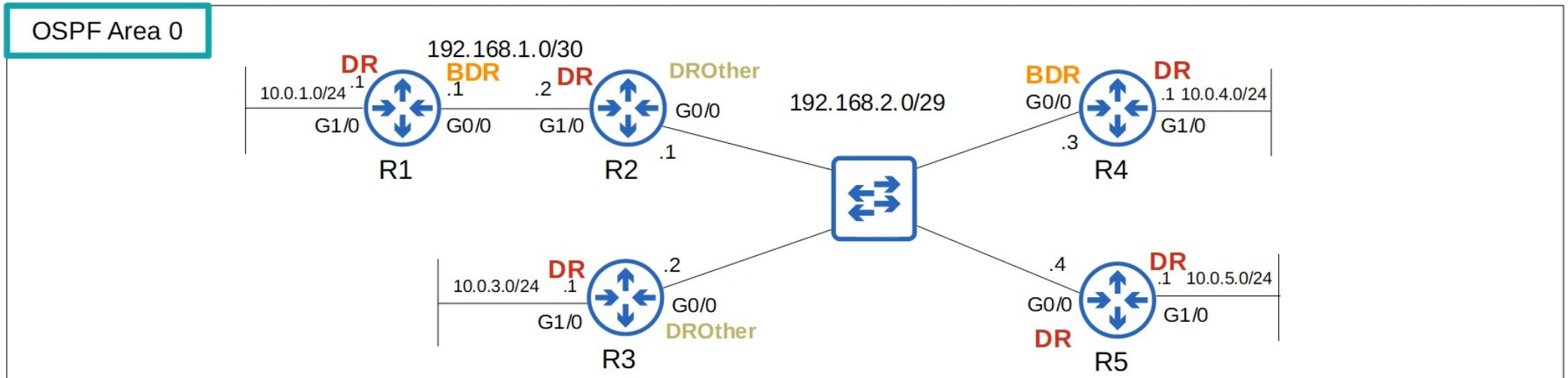

```
R5#show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.2.4/29, Area 0, Attached via Network Statement
  Process ID 1, Router ID 5.5.5.5, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1          no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 5.5.5.5, Interface address 192.168.2.4
  Backup Designated router (ID) 4.4.4.4, Interface address 192.168.2.3
```

OSPF BROADCAST NETWORK TYPE



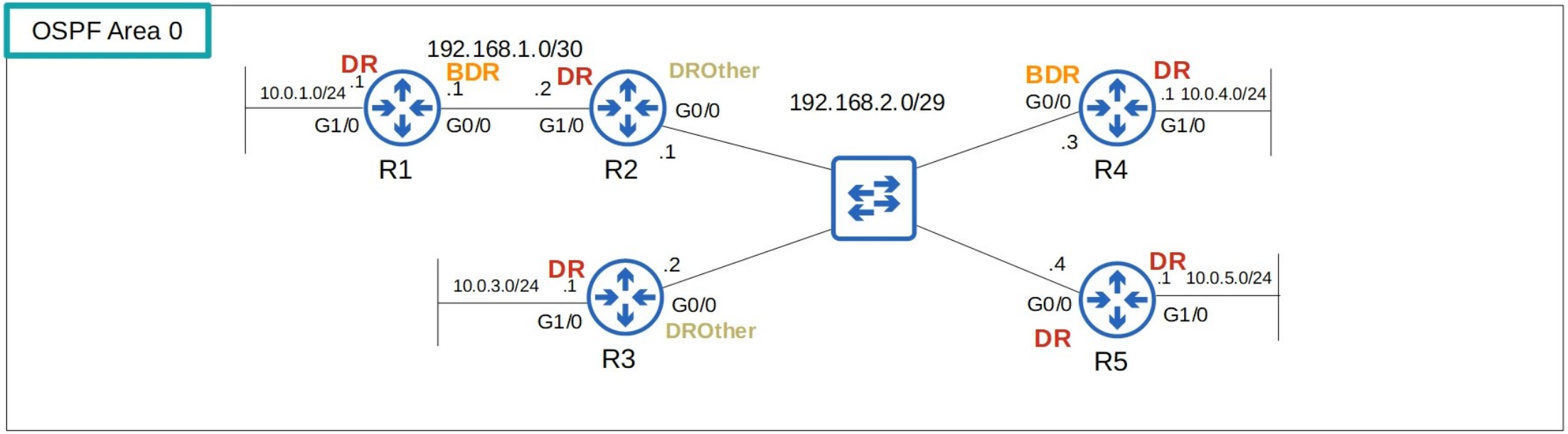

```
R5#show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.2.4/29, Area 0, Attached via Network Statement
  Process ID 1, Router ID 5.5.5.5, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1          no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 5.5.5.5, Interface address 192.168.2.4
  Backup Designated router (ID) 4.4.4.4, Interface address 192.168.2.3
```

OSPF BROADCAST NETWORK TYPE




```
R2#show ip ospf int g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.2.1/29, Area 0, Attached via Network Statement
  Process ID 1, Router ID 2.2.2.2, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1          no          no            Base
  Transmit Delay is 1 sec, State DROTHER, Priority 1
  Designated Router (ID) 5.5.5.5, Interface address 192.168.2.4
  Backup Designated router (ID) 4.4.4.4, Interface address 192.168.2.3
```

OSPF BROADCAST NETWORK TYPE

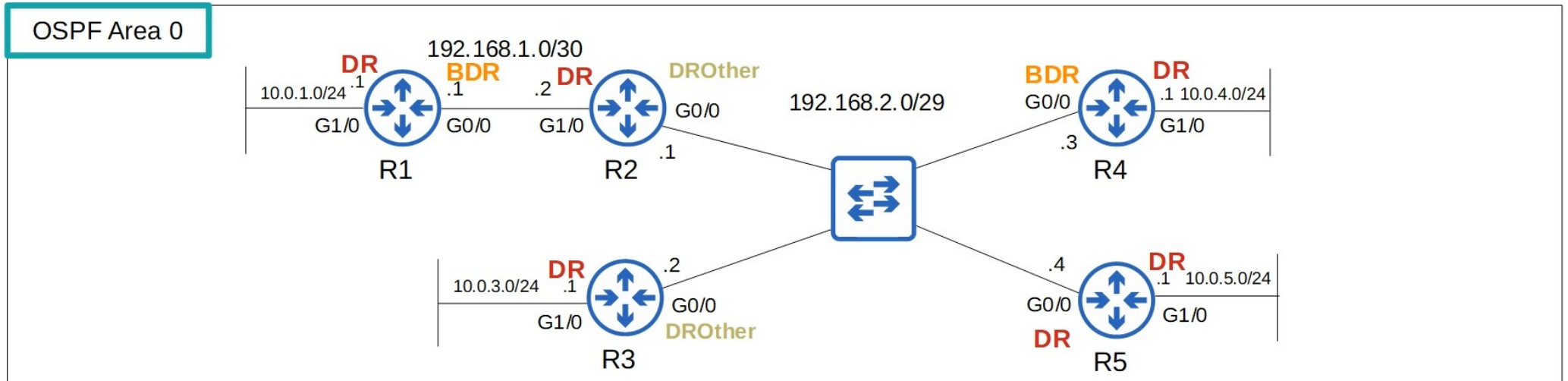



```
R2(config)#int g0/0
R2(config-if)#ip ospf priority ?
  <0-255>  Priority

R2(config-if)#ip ospf priority 255
```

If you set the OSPF interface priority to 0, the router CANNOT be the DR/BDR for the subnet.

OSPF BROADCAST NETWORK TYPE



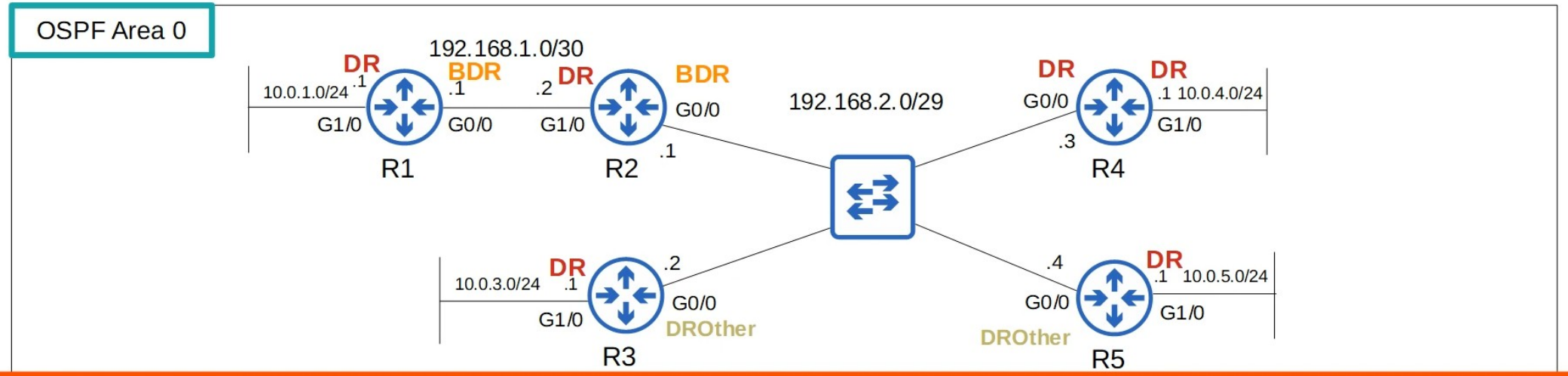
The DR/BDR election is 'non-preemptive'. Once the DR/BDR are selected they will keep their role until OSPF is reset, the interface fails/is shut down, etc.

```
R2(config)#int g0/0
R2(config-if)#ip ospf priority ?
  <0-255>  Priority

R2(config-if)#ip ospf priority 255
```

```
R2#show ip ospf int g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.2.1/29, Area 0, Attached via Network Statement
  Process ID 1, Router ID 2.2.2.2, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DROTHER, Priority 255
  Designated Router (ID) 5.5.5.5, Interface address 192.168.2.4
  Backup Designated router (ID) 4.4.4.4, Interface address 192.168.2.3
```

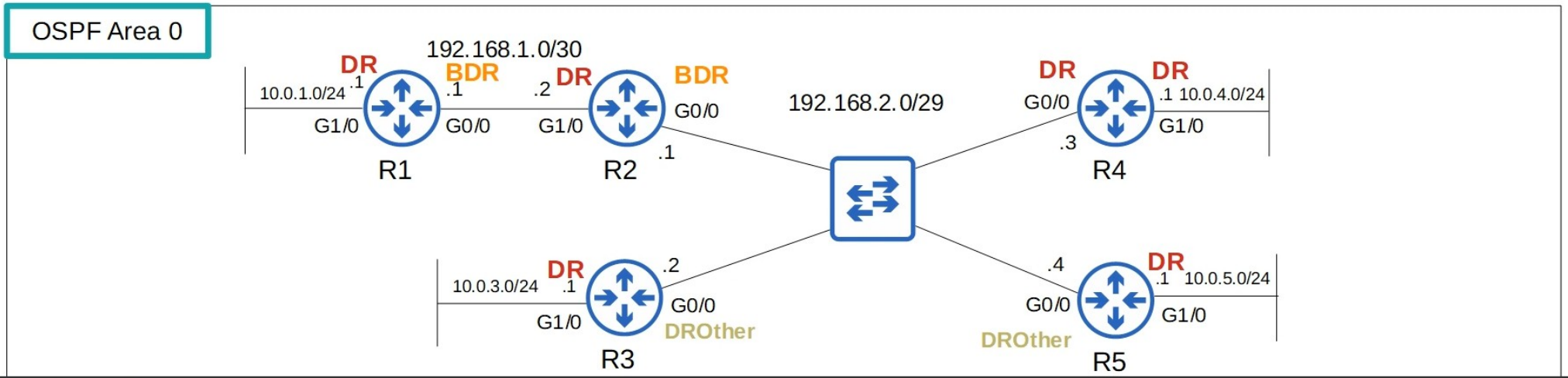
OSPF BROADCAST NETWORK TYPE




```
R5#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R5#
*Aug 22 04:25:05.307: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
R5#
*Aug 22 04:25:13.903: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
*Aug 22 04:25:13.907: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R5#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2         255   FULL/BDR        00:00:37    192.168.2.1     GigabitEthernet0/0
3.3.3.3           1   2WAY/DROTHER    00:00:37    192.168.2.2     GigabitEthernet0/0
4.4.4.4           1   FULL/DR         00:00:39    192.168.2.3     GigabitEthernet0/0
```

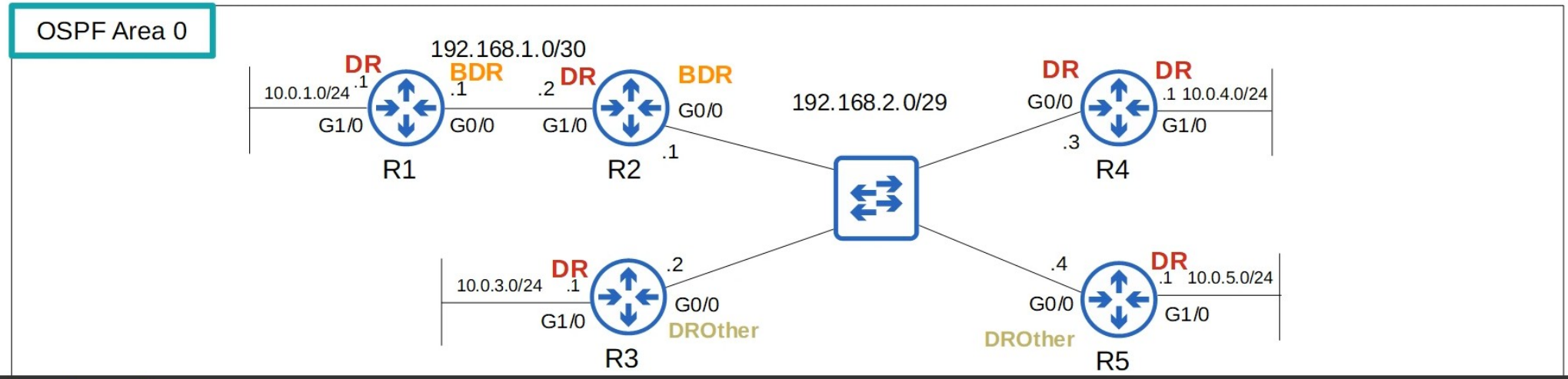
OSPF BROADCAST NETWORK TYPE




```
R5#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R5#
*Aug 22 04:25:05.307: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
R5#
*Aug 22 04:25:13.903: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
*Aug 22 04:25:13.907: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R5#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2         255   FULL/BDR        00:00:37    192.168.2.1     GigabitEthernet0/0
3.3.3.3           1   2WAY/DROTHER    00:00:37    192.168.2.2     GigabitEthernet0/0
4.4.4.4           1   FULL/DR         00:00:39    192.168.2.3     GigabitEthernet0/0
```

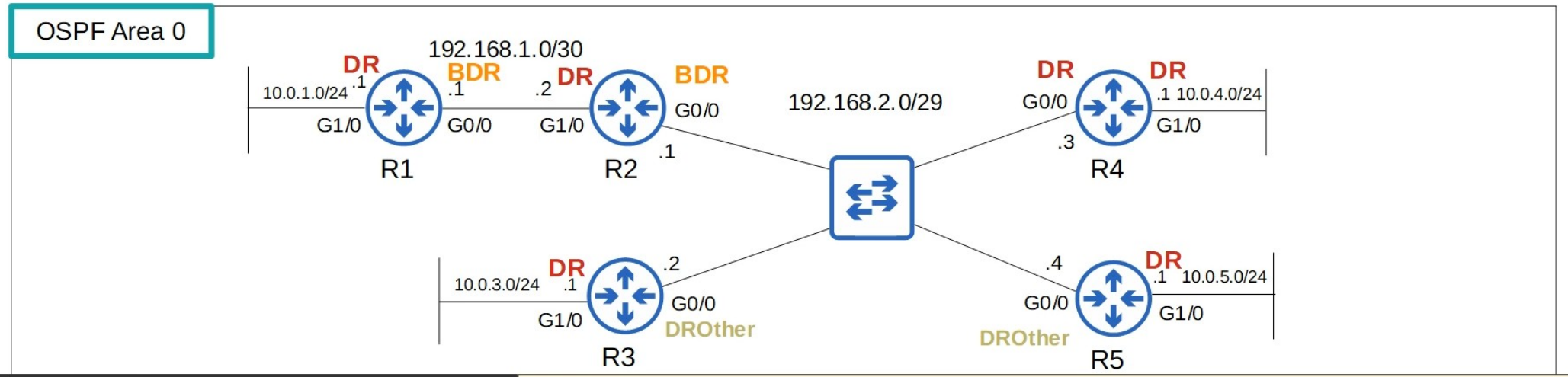
OSPF BROADCAST NETWORK TYPE




```
R5#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R5#
*Aug 22 04:25:05.307: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
R5#
*Aug 22 04:25:13.903: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
*Aug 22 04:25:13.907: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R5#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2         255   FULL/BDR        00:00:37    192.168.2.1     GigabitEthernet0/0
3.3.3.3           1   2WAY/DROTHER    00:00:37    192.168.2.2     GigabitEthernet0/0
4.4.4.4           1   FULL/DR         00:00:39    192.168.2.3     GigabitEthernet0/0
```

OSPF BROADCAST NETWORK TYPE

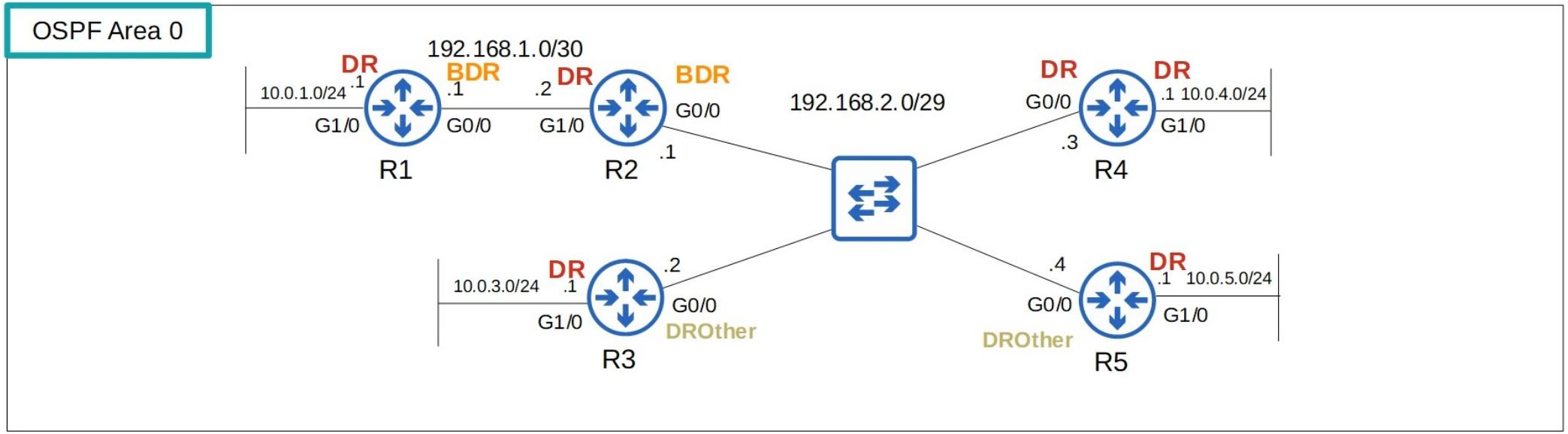



```
R5#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R5#
*Aug 22 04:25:05.307: %OSPF-5-ADJCHG: Process 1,
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1,
*Aug 22 04:25:05.311: %OSPF-5-ADJCHG: Process 1,
R5#
*Aug 22 04:25:13.903: %OSPF-5-ADJCHG: Process 1,
*Aug 22 04:25:13.907: %OSPF-5-ADJCHG: Process 1,
R5#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time
2.2.2.2         255   FULL/BDR        00:00:37
3.3.3.3           1   2WAY/DROTHER    00:00:37
4.4.4.4           1   FULL/DR         00:00:39    192.168.2.3     GigabitEthernet0/0
```

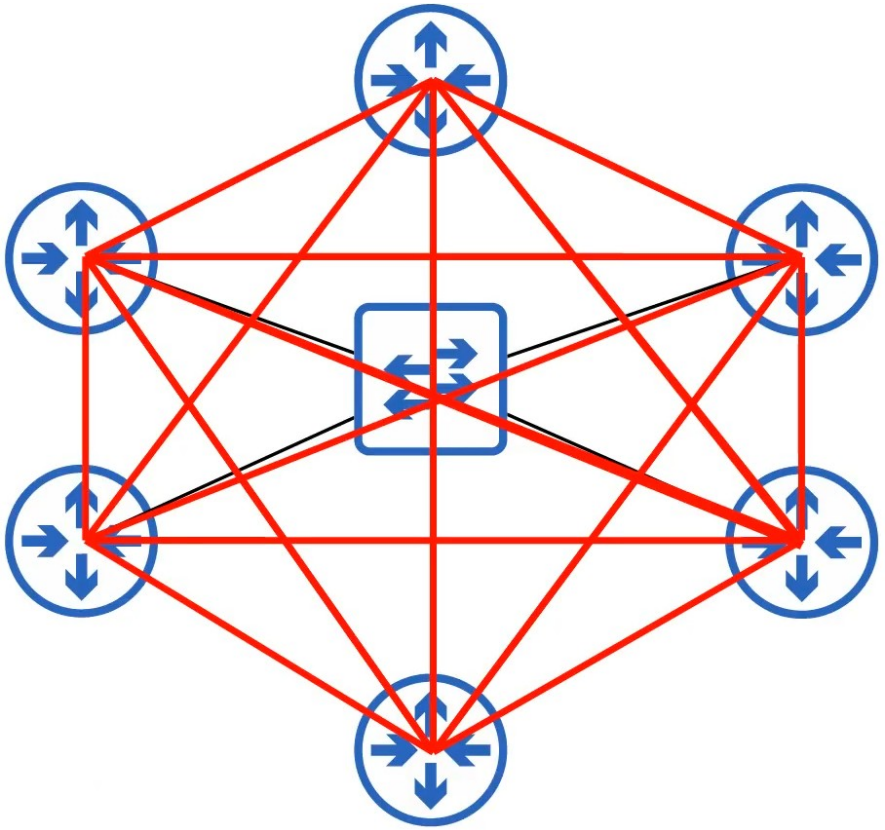
- **R4 became the DR, not R2. R2 became the BDR.**
  → When the DR goes down, the BDR becomes the new DR. Then an election is held for the next BDR.
- **R3 is a DROther, and is stable in the 2-way state.**
  → DROthers (R3 and R5 in this subnet) will only move to the FULL state with the DR and BDR. The neighbor state with other DROthers will be 2-way.

OSPF BROADCAST NETWORK TYPE

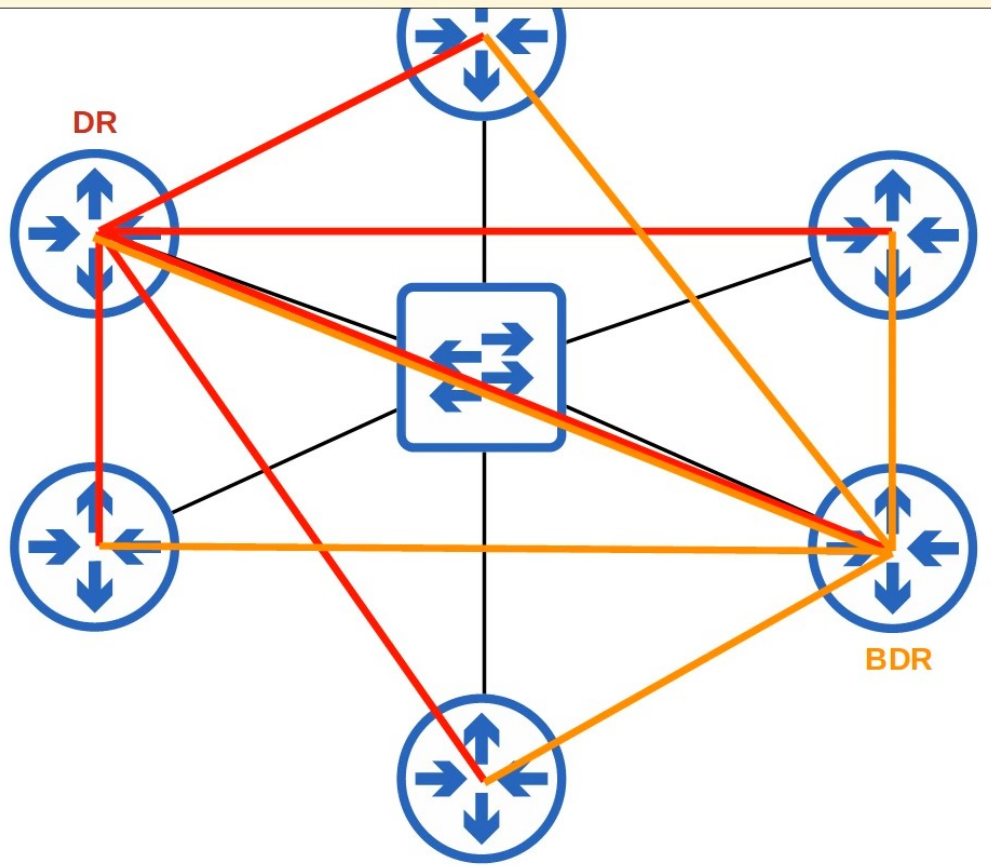


- In the broadcast network type, routers will only form a full OSPF adjacency with the DR and BDR of the segment.
- Therefore, routers only exchange LSAs with the DR and BDR. DROthers will not exchange LSAs with each other.
- All routers will still have the same LSDB, but this reduces the amount of LSAs flooding the network.

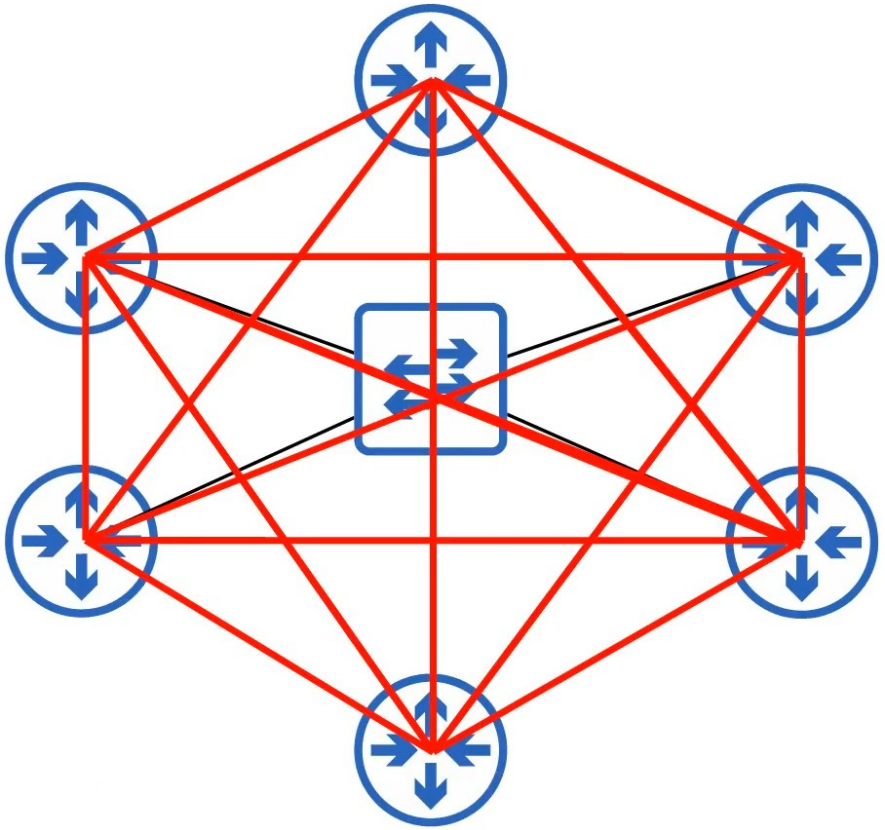
OSPF BROADCAST NETWORK TYPE



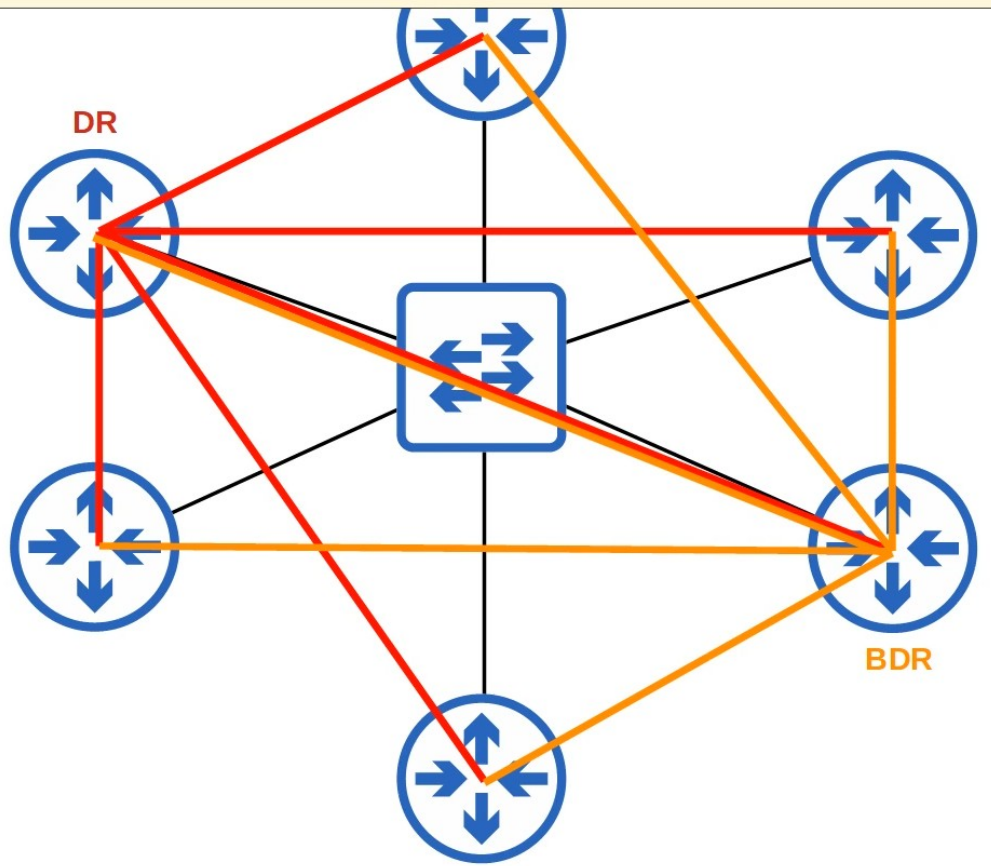
Messages to the DR/BDR are multicast using address 224.0.0.6



OSPF BROADCAST NETWORK TYPE

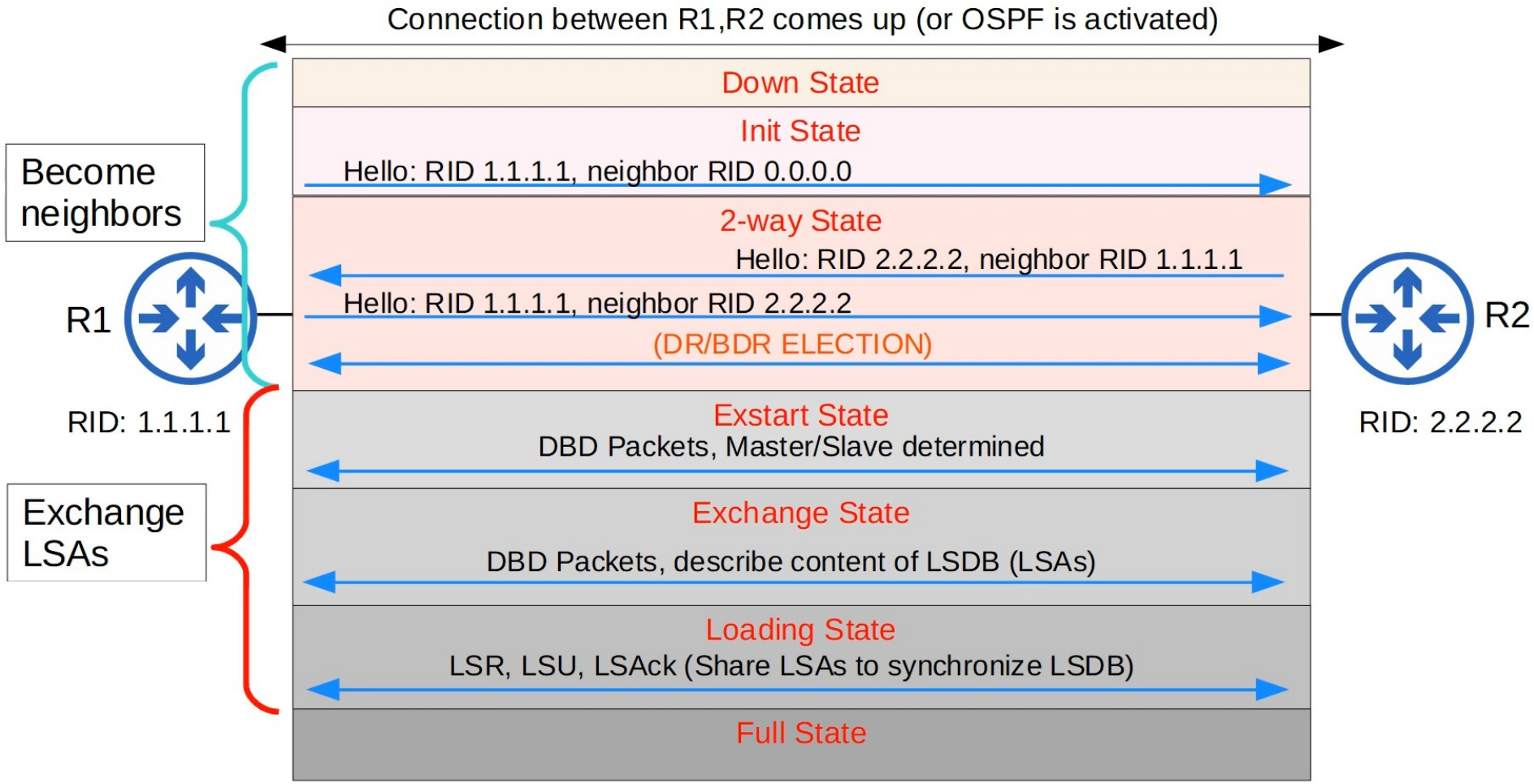


Messages to the DR/BDR are multicast using address 224.0.0.6

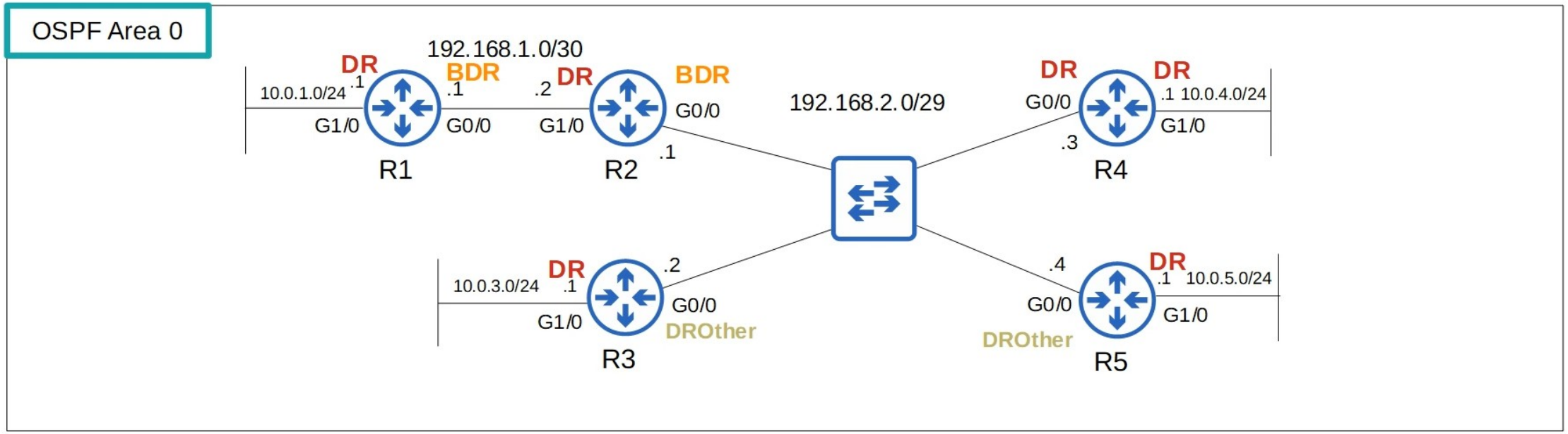


OSPF NEIGHBORS

The DR and BDR will form a FULL adjacency with ALL routers in the subnet.
DROthers will form a FULL adjacency only with the DR/BDR.



OSPF BROADCAST NETWORK TYPE

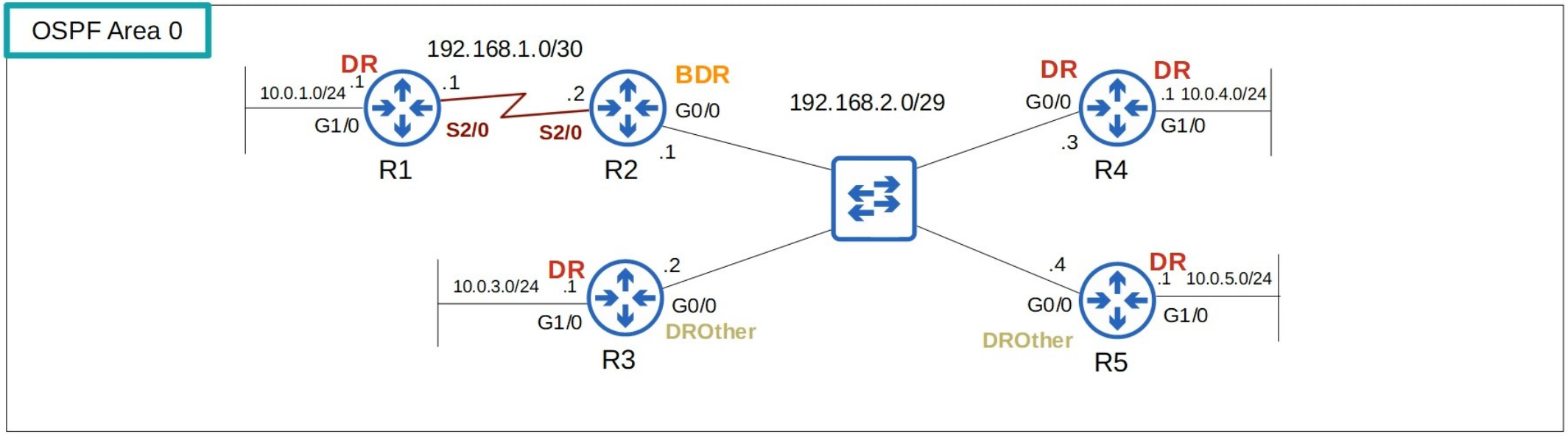



```
R3#show ip ospf interface brief
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Gi0/0        1     0               192.168.2.2/29     1     DROTH 2/3
Gi1/0        1     0               10.0.3.1/24        1     DR    0/0
```

OSPF BROADCAST NETWORK TYPE

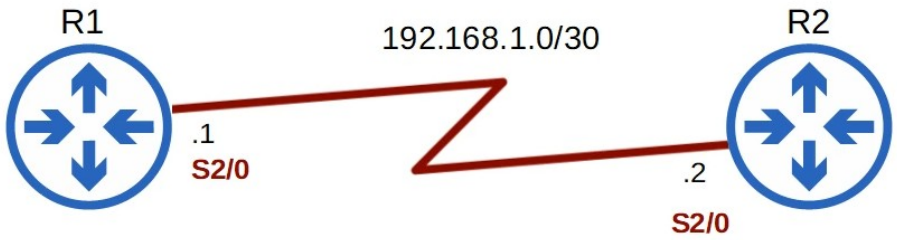
```
R3#show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.2.2/29, Area 0, Attached via Network Statement
  Process ID 1, Router ID 3.3.3.3, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DROTHER, Priority 1
  Designated Router (ID) 4.4.4.4, Interface address 192.168.2.3
  Backup Designated router (ID) 2.2.2.2, Interface address 192.168.2.1
  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)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 1
  Last flood scan time is 0 msec, maximum is 4 msec
  Neighbor Count is 3, Adjacent neighbor count is 2
    Adjacent with neighbor 2.2.2.2  (Backup Designated Router)
    Adjacent with neighbor 4.4.4.4  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

OSPF POINT-TO-POINT NETWORK TYPE



- Enabled on **serial** interfaces using the **PPP** or **HDLC** encapsulations by default.
- Routers *dynamically discover* neighbors by sending/listening for OSPF Hello messages using multicast address 224.0.0.5.
- A DR and BDR are **not** elected.
- These encapsulations are used for 'point-to-point' connections.
- Therefore there is no point in electing a DR and BDR.
- The two routers will form a Full adjacency with each other.

SERIAL INTERFACES




```
R1(config)#interface s2/0
R1(config-if)#clock rate ?
  With the exception of the following standard values not subject to rounding,

         1200 2400 4800 9600 14400 19200 28800 38400
         56000 64000 128000 2015232

  accepted clockrates will be bestfitted (rounded) to the nearest value
  supportable by the hardware.

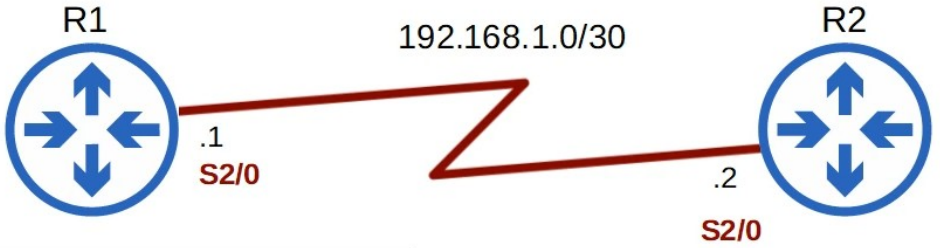
  <246-8064000>    DCE clock rate (bits per second)
```

```
R1(config-if)#clock rate 64000
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#no shut
```

Ethernet interfaces use the **speed** command to configure the interface's operating speed. Serial interfaces use the **clock rate** command.

- One side of a serial connection functions as DCE (Data Communications Equipment)
- The other side functions as DTE (Data Terminal Equipment)
- The DCE side needs to specify the *clock rate* (speed) of the connection

SERIAL INTERFACES




```
R1#show interface s2/0
Serial2/0 is up, line protocol is up
  Hardware is M4T
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, crc 16, loopback not set
```

- The default encapsulation on a serial interface is HDLC.
  **actually cHDLC (Cisco HDLC)

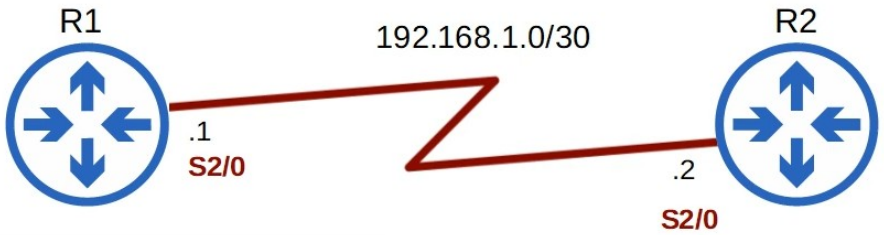
cHDLC frame structure [edit]

The following table describes the structure of a cHDLC frame on the wire.[*citation needed*]

Address	Control	Protocol Code	Information	Frame Check Sequence (FCS)	Flag
8 bits	8 bits	16 bits	Variable length, 0 or more bits, in multiples of 8	16 bits	8 bits

- The Address field is used to specify the type of packet contained in the cHDLC frame; 0x0F for Unicast and 0x8F for Broadcast packets.
- The Control field is always set to zero (0x00).
- The Protocol Code field is used to specify the protocol type encapsulated within the cHDLC frame (e.g. 0x0800 for Internet Protocol).

SERIAL INTERFACES




```
R1#show interface s2/0
Serial2/0 is up, line protocol is up
  Hardware is M4T
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, crc 16, loopback not set
```

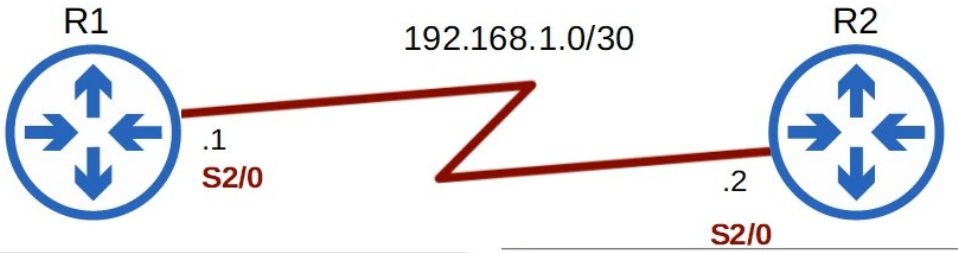
```
R1(config)#int s2/0
R1(config-if)#encapsulation ppp
R1(config-if)#do show interface s2/0
Serial2/0 is up, line protocol is up
  Hardware is M4T
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation PPP, LCP Open
```

- The default encapsulation on a serial interface is HDLC.
  **actually cHDLC (Cisco HDLC)
- If you change the encapsulation, it must match on both ends or the interface will go down.

SERIAL INTERFACES

- The default encapsulation is HDLC.
- You can configure PPP encapsulation with this command:
  `R1(config-if)# encapsulation ppp`
- One side is DCE, one side is DTE.
- Identify which side is DCE/DTE:
  `R1# show controllers interface-id`
- You must configure the clock rate on the DCE side:
  `R1(config-if)# clock rate bits-per-second`

OSPF POINT-TO-POINT NETWORK TYPE



R1

Physical Config CLI Attributes

IOS Command Line Interface

```
R1#
R1#show con
R1#show controllers s2/0
Interface Serial2/0
Hardware is PowerQUICC MPC860
DCE V.35, clock rate 64000
idb at 0x81081AC4, driver data structure at 0x81084AC0
SCC Registers:
General [GSMR]=0x2:0x00000000, Protocol-specific [PSMR]=0x8
Events [SCCE]=0x0000, Mask [SCCM]=0x0000, Status [SCCS]=0x00
Transmit on Demand [TODR]=0x0, Data Sync [DSR]=0x7E7E
Interrupt Registers:
Config [CICR]=0x00367F80, Pending [CIPR]=0x0000C000
Mask   [CIMR]=0x00200000, In-srv  [CISR]=0x00000000
Command register [CR]=0x580
```

Ctrl+F6 to exit CLI focus

Top

R2

Physical Config CLI Attributes

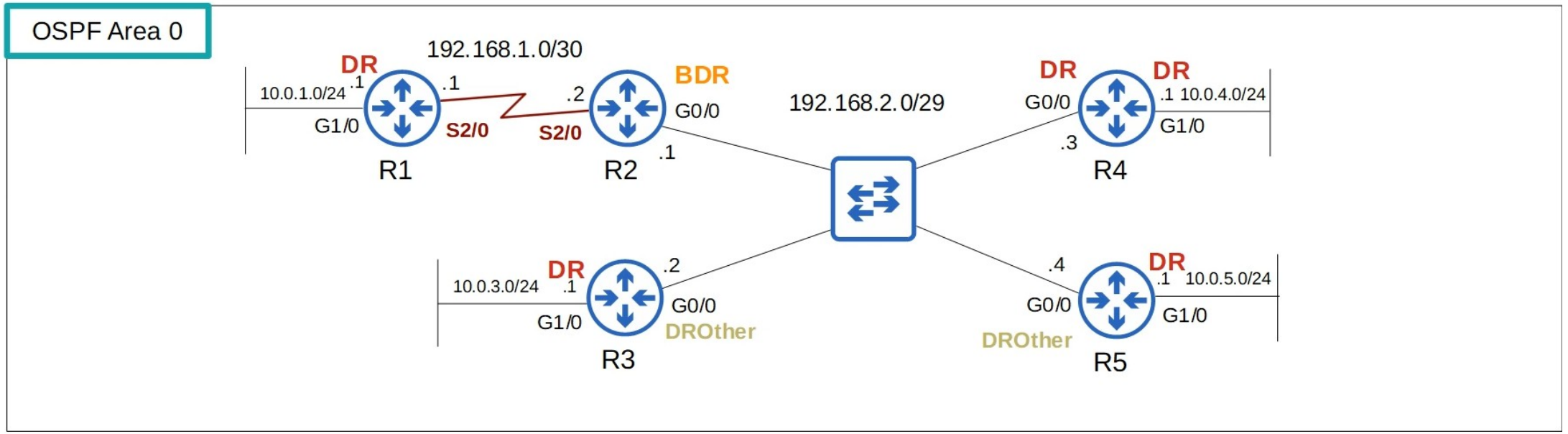
IOS Command Line Interface

```
R2#
R2#show controllers s2/0
Interface Serial2/0
Hardware is PowerQUICC MPC860
DTE V.35 TX and RX clocks detected
idb at 0x81081AC4, driver data structure at 0x81084AC0
SCC Registers:
General [GSMR]=0x2:0x00000000, Protocol-specific [PSMR]=0x8
Events [SCCE]=0x0000, Mask [SCCM]=0x0000, Status [SCCS]=0x00
Transmit on Demand [TODR]=0x0, Data Sync [DSR]=0x7E7E
Interrupt Registers:
Config [CICR]=0x00367F80, Pending [CIPR]=0x0000C000
Mask   [CIMR]=0x00200000, In-srv  [CISR]=0x00000000
Command register [CR]=0x580
Port A [PADIR]=0x1030  [PAPAR]=0xFFFF
```

Ctrl+F6 to exit CLI focus

Top

OSPF POINT-TO-POINT NETWORK TYPE



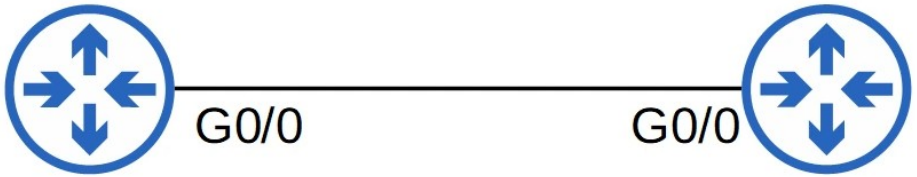

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
1.1.1.1           0   FULL/  -        00:00:31    192.168.1.1     Serial2/0
3.3.3.3           1   2WAY/DROTHER    00:00:39    192.168.2.2     GigabitEthernet0/0
4.4.4.4           1   FULL/DR         00:00:38    192.168.2.3     GigabitEthernet0/0
5.5.5.5           1   FULL/BDR        00:00:31    192.168.2.4     GigabitEthernet0/0
```

CONFIGURE THE OSPF NETWORK TYPE

```
R1(config-if)#ip ospf network ?
  broadcast            Specify OSPF broadcast multi-access network
  non-broadcast        Specify OSPF NBMA network
  point-to-multipoint  Specify OSPF point-to-multipoint network
  point-to-point       Specify OSPF point-to-point network
```

- You can configure the OSPF network type on an interface with **`ip ospf network`** *type*
- For example, if two routers are directly connected with an Ethernet link, there is no need for a DR/BDR. You can configure the point-to-point network type in this case.
- NOTE: Not all network types work on all link types (for example, a serial link cannot use the broadcast network type)



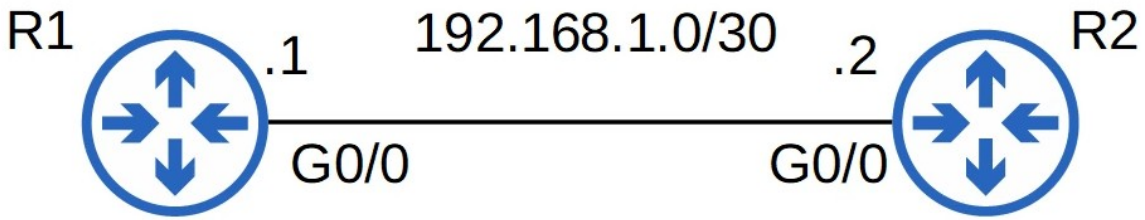
CONFIGURE THE OSPF NETWORK TYPE

Broadcast	Point-to-point
Default on **Ethernet**, **FDDI** interfaces	Default on **HDLC**, **PPP** (serial) interfaces
DR/DBR elected	No DR/BDR
Neighbors dynamically discovered	Neighbors dynamically discovered
Default timers: Hello 10, Dead 40	Default timers: Hello 10, Dead 40

(**Non-broadcast** network type default timers = Hello 30, Dead 120)

OSPF NEIGHBOR REQUIREMENTS

1) Area number must match




```
R1#show running-config | section ospf
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
```

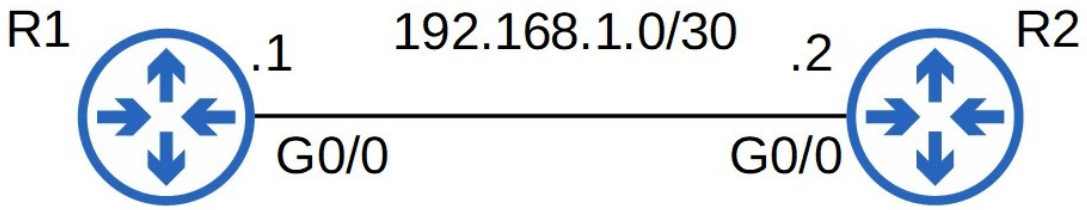
```
R2#show running-config | section ospf
router ospf 1
 network 192.168.1.0 0.0.0.3 area 1
```

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

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

OSPF NEIGHBOR REQUIREMENTS

1) Area number must match




```
R1#show running-config | section ospf
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
```

```
R2#show running-config | section ospf
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
```

```
R1#show ip ospf neighbor

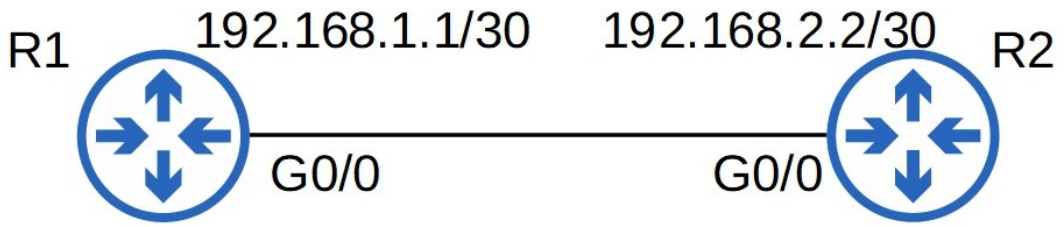
Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.2       1   FULL/BDR        00:00:34    192.168.1.2     GigabitEthernet0/0
R1#
```

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/DR         00:00:39    192.168.1.1     GigabitEthernet0/0
R2#
```

OSPF NEIGHBOR REQUIREMENTS

2) Interfaces must be in the same subnet




```
R1#show running-config | section ospf
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
R1#
```

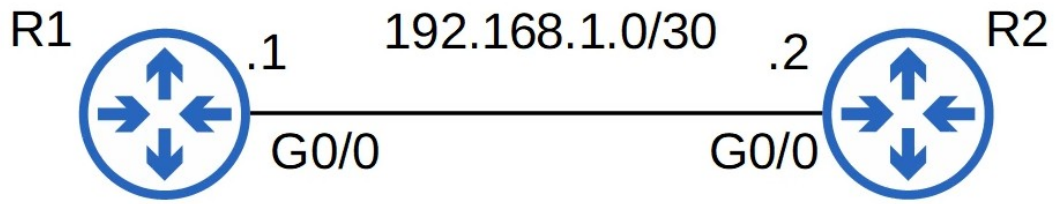
```
R2#show running-config | section ospf
router ospf 1
 network 192.168.2.0 0.0.0.3 area 0
R2#
```

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

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

OSPF NEIGHBOR REQUIREMENTS

2) Interfaces must be in the same subnet




```
R1#show running-config | section ospf
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
R1#
```

```
R2#show running-config | section ospf
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
R2#
```

```
R1#show ip ospf neighbor

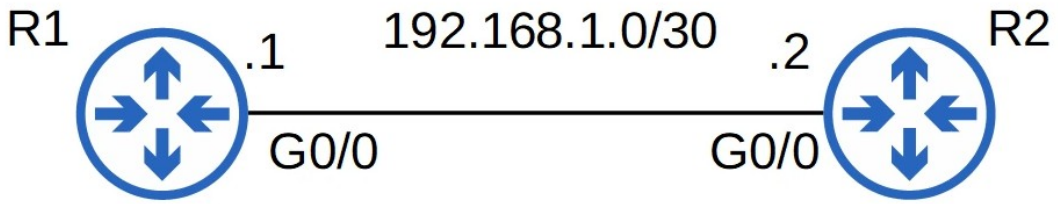
Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.2       1   FULL/BDR        00:00:34    192.168.1.2     GigabitEthernet0/0
R1#
```

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/DR         00:00:39    192.168.1.1     GigabitEthernet0/0
R2#
```

OSPF NEIGHBOR REQUIREMENTS

3) OSPF process must not be **shutdown**



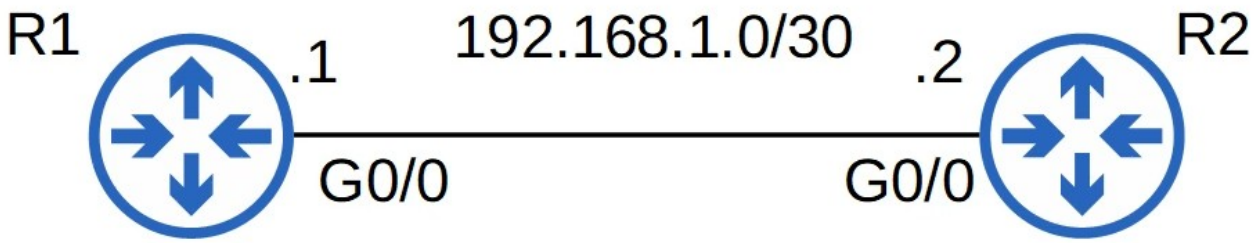

```
R2(config)#router ospf 1
R2(config-router)#shutdown
R2(config-router)#
*Aug 23 03:43:31.719: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Int
R2(config-router)#do show ip ospf neighbor
R2(config-router)#
```

```
R2(config-router)#no shutdown
R2(config-router)#
*Aug 23 03:49:52.931: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R2(config-router)#do show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/DR         00:00:38    192.168.1.1     GigabitEthernet0/0
R2(config-router)#
```

OSPF NEIGHBOR REQUIREMENTS

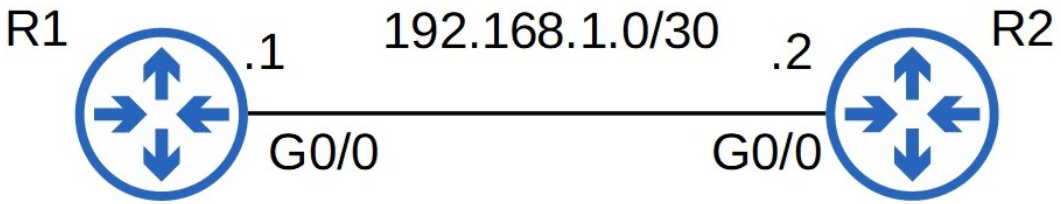
4) OSPF Router IDs must be unique




```
R2(config-router)#router-id 192.168.1.1
% OSPF: Reload or use "clear ip ospf process" command, for this to take effect
R2(config-router)#end
R2#clear ip
*Aug 23 03:57:58.835: %SYS-5-CONFIG_I: Configured from console by console
R2#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R2#
*Aug 23 03:58:04.055: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or d
R2#
*Aug 23 03:58:06.495: %OSPF-4-DUP_RTRID_NBR: OSPF detected duplicate router-id 192.168.1.1 from 192.168.1.1 on interface GigabitEthernet0/0
R2#show ip ospf neighbor
R2#
```

OSPF NEIGHBOR REQUIREMENTS

4) OSPF Router IDs must be unique



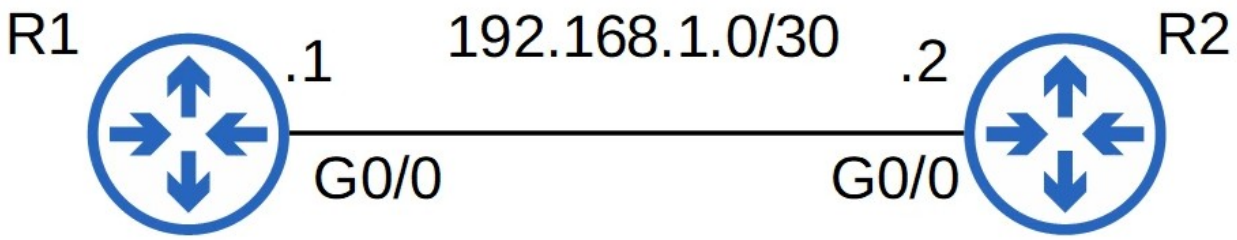

```
R2(config-router)#router-id 192.168.1.1
% OSPF: Reload or use "clear ip ospf process" command, for this to take effect
R2(config-router)#end
R2#clear ip
*Aug 23 03:57:58.835: %SYS-5-CONFIG_I: Configured from console by console
R2#clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R2#
*Aug 23 03:58:04.055: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or d
R2#
*Aug 23 03:58:06.495: %OSPF-4-DUP_RTRID_NBR: OSPF detected duplicate router-id 192.168.1.1 from 192.168.1.1 on interface GigabitEthernet0/0
R2#show ip ospf neighbor
R2#
```

```
R2(config-router)#no router-id
R2(config-router)#
*Aug 23 04:10:10.207: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R2(config-router)#do show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/DR         00:00:35    192.168.1.1     GigabitEthernet0/0
R2(config-router)#
```

OSPF NEIGHBOR REQUIREMENTS

5) Hello and Dead timers must match



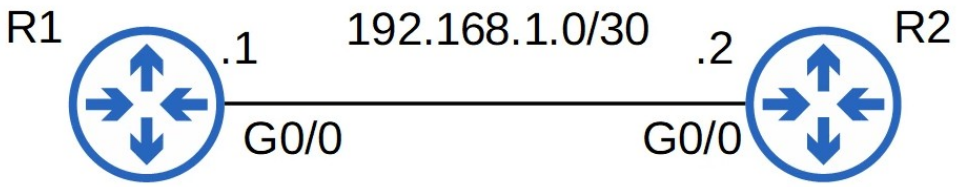

```
R2(config-if)#ip ospf hello-interval ?
  <1-65535>  Seconds

R2(config-if)#ip ospf hello-interval 5
R2(config-if)#ip ospf dead-interval ?
  <1-65535>  Seconds
  minimal    Set to 1 second

R2(config-if)#ip ospf dead-interval 20
R2(config-if)#
*Aug 23 04:29:30.623: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Dead timer expired
R2(config-if)#do show ip ospf neighbor
R2(config-if)#
```

OSPF NEIGHBOR REQUIREMENTS

5) Hello and Dead timers must match




```
R2(config-if)#ip ospf hello-interval ?
  <1-65535>  Seconds

R2(config-if)#ip ospf hello-interval 5
R2(config-if)#ip ospf dead-interval ?
  <1-65535>  Seconds
  minimal    Set to 1 second

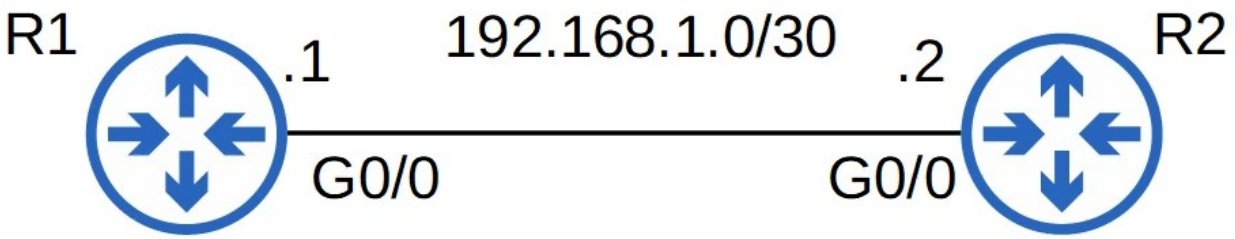
R2(config-if)#ip ospf dead-interval 20
R2(config-if)#
*Aug 23 04:29:30.623: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Dead timer expired
R2(config-if)#do show ip ospf neighbor
R2(config-if)#
```

```
R2(config-if)#no ip ospf hello-interval
R2(config-if)#no ip ospf dead-interval
R2(config-if)#
*Aug 23 04:31:32.727: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R2(config-if)#do show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/BDR        00:00:35    192.168.1.1     GigabitEthernet0/0
R2(config-if)#
```

OSPF NEIGHBOR REQUIREMENTS

6) Authentication settings must match



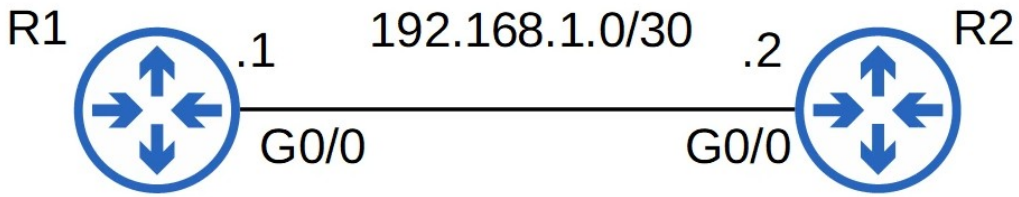

```
R2(config-if)#ip ospf authentication-key jeremy
R2(config-if)#ip ospf authentication
R2(config-if)#
*Aug 23 04:56:28.435: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: D
R2(config-if)#do show ip ospf neighbor
R2(config-if)#
```

```
R2(config-if)#no ip ospf authentication
R2(config-if)#no ip ospf authentication-key jeremy
*Aug 23 04:59:37.315: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R2(config-if)#do show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/BDR        00:00:34    192.168.1.1     GigabitEthernet0/0
R2(config-if)#
```

OSPF NEIGHBOR REQUIREMENTS

7) IP MTU settings must match




```
R2(config-if)#ip mtu ?
  <68-1500>  MTU (bytes)

R2(config-if)#ip mtu 1400
R2(config-if)#do show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/BDR        00:00:34    192.168.1.1     GigabitEthernet0/0
R2(config-if)#do clear ip ospf process
Reset ALL OSPF processes? [no]: yes
R2(config-if)#
*Aug 23 05:16:07.474: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or detached
R2(config-if)#do show ip ospf neighbor

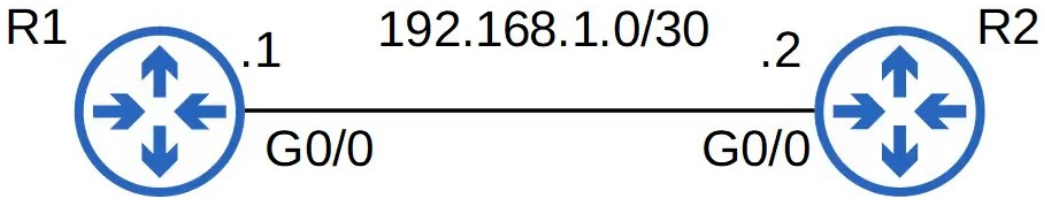
Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   EXSTART/DR      00:00:38    192.168.1.1     GigabitEthernet0/0
```

```
*Aug 23 05:21:12.946: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from EXSTART to DOWN, Neighbor Down: Too many retransmissions
R2(config-if)#
*Aug 23 05:22:12.946: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from DOWN to DOWN, Neighbor Down: Ignore timer expired
```

```
R2(config-if)#no ip mtu
R2(config-if)#
*Aug 23 05:25:49.362: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
```

OSPF NEIGHBOR REQUIREMENTS

8) OSPF Network Type must match

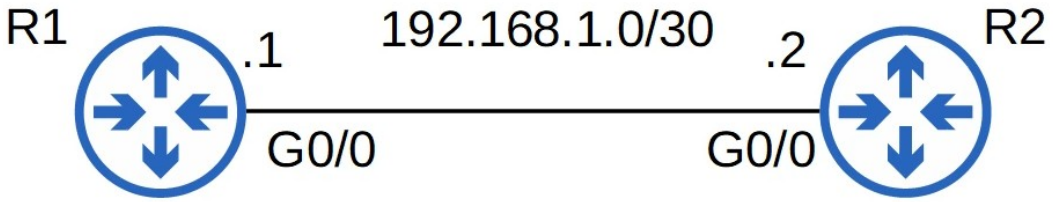



```
R2(config)#interface l0
R2(config-if)#
*Aug 23 05:52:53.898: %LINK-3-UPDOWN: Interface Loopback0, changed state to up
*Aug 23 05:52:54.898: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0, changed state to up
R2(config-if)#ip address 2.2.2.2 255.255.255.255
R2(config-if)#router ospf 1
R2(config-router)#network 2.2.2.2 0.0.0.0 area 0
R2(config-router)#interface g0/0
R2(config-if)#ip ospf network point-to-point
R2(config-if)#
*Aug 23 05:53:34.818: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from FULL to DOWN, Neighbor Down: Interfac
*Aug 23 05:53:34.914: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on GigabitEthernet0/0 from LOADING to FULL, Loading Done
R2(config-if)#do show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       0   FULL/  -        00:00:36    192.168.1.1     GigabitEthernet0/0
R2(config-if)#
```

OSPF NEIGHBOR REQUIREMENTS

8) OSPF Network Type must match



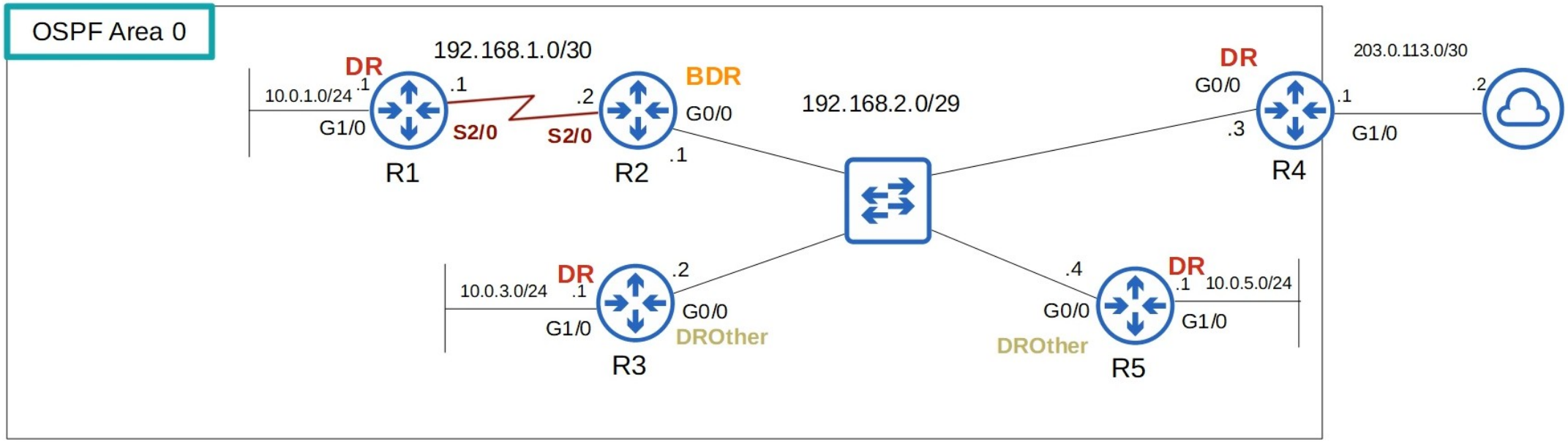

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.2       1   FULL/BDR        00:00:31    192.168.1.2     GigabitEthernet0/0
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/30 is directly connected, GigabitEthernet0/0
L        192.168.1.1/32 is directly connected, GigabitEthernet0/0
R1#
```

OSPF LSA TYPES



- The OSPF LSDB is made up of LSAs.
- There are 11 types of LSA, but there are only 3 you should be aware of
  Type 1 (Router LSA)
  Type 2 (Network LSA)
  Type 5 (AS External LSA)

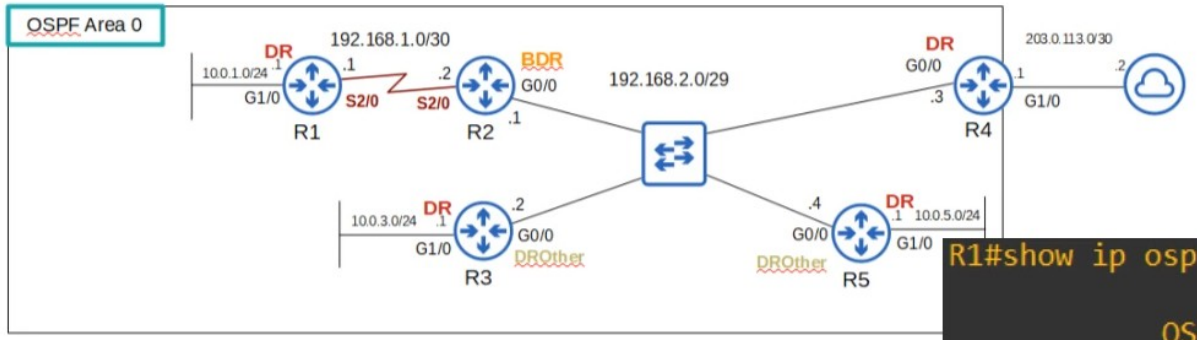
OSPF LSA TYPES

- **Type 1 (Router LSA)**
  -Every OSPF router generates this type of LSA.
  -It identifies the router using its router ID.
  -It also lists networks attached to the router's OSPF-activated interfaces.

- **Type 2 (Network LSA)**
  -Generated by the DR of each 'multi-access' network (ie. the **broadcast** network type).
  -Lists the routers which are attached to the multi-access network.

- **Type 5 (AS-External LSA)**
  -Generated by ASBRs to describe routes to destinations outside of the AS (OSPF domain).

OSPF LSA TYPES




```
R1#show ip ospf database

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

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1396        0x80000002 0x00FE8D 4
2.2.2.2         2.2.2.2         932         0x80000005 0x00753F 4
3.3.3.3         3.3.3.3         974         0x80000004 0x00AD70 2
4.4.4.4         4.4.4.4         975         0x80000005 0x004CC2 2
5.5.5.5         5.5.5.5         976         0x80000004 0x00D212 3

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.2.3     4.4.4.4         932         0x80000002 0x00740D

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         4.4.4.4         273         0x80000002 0x00C0E0 1
R1#
```