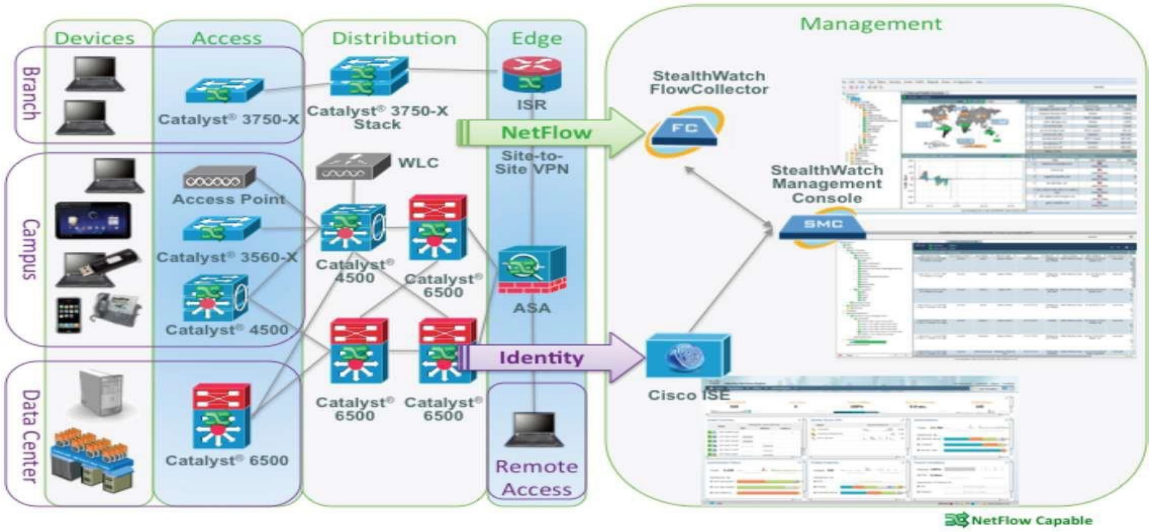
CIS 3250
Multi-Area and Advanced OSPF

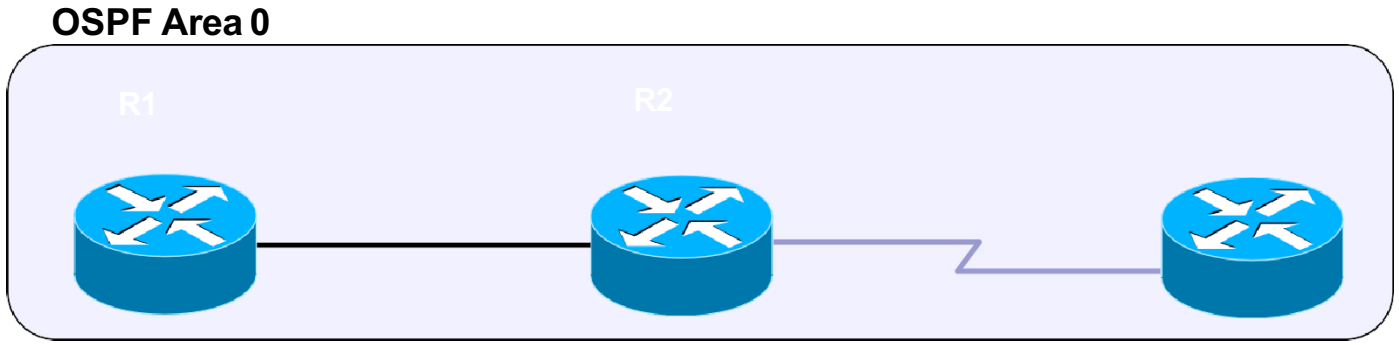


Multiarea OSPF Operations

Single Area OSPF

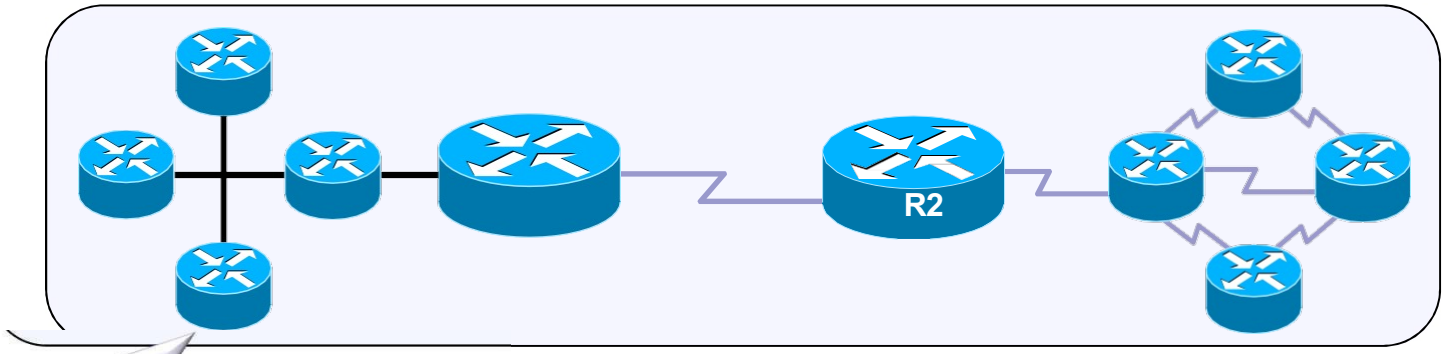
- In single area OSPF, all routers are in area 0.
  - Area 0 is also called the *backbone area* and is treated in a special way when multiple areas are involved.
  - Technically, in single-area OSPF the one (and only) area need not be called area 0, but it is recommended.

- Single-area OSPF is useful in smaller networks with few routers.



Issues With a Large OSPF Area

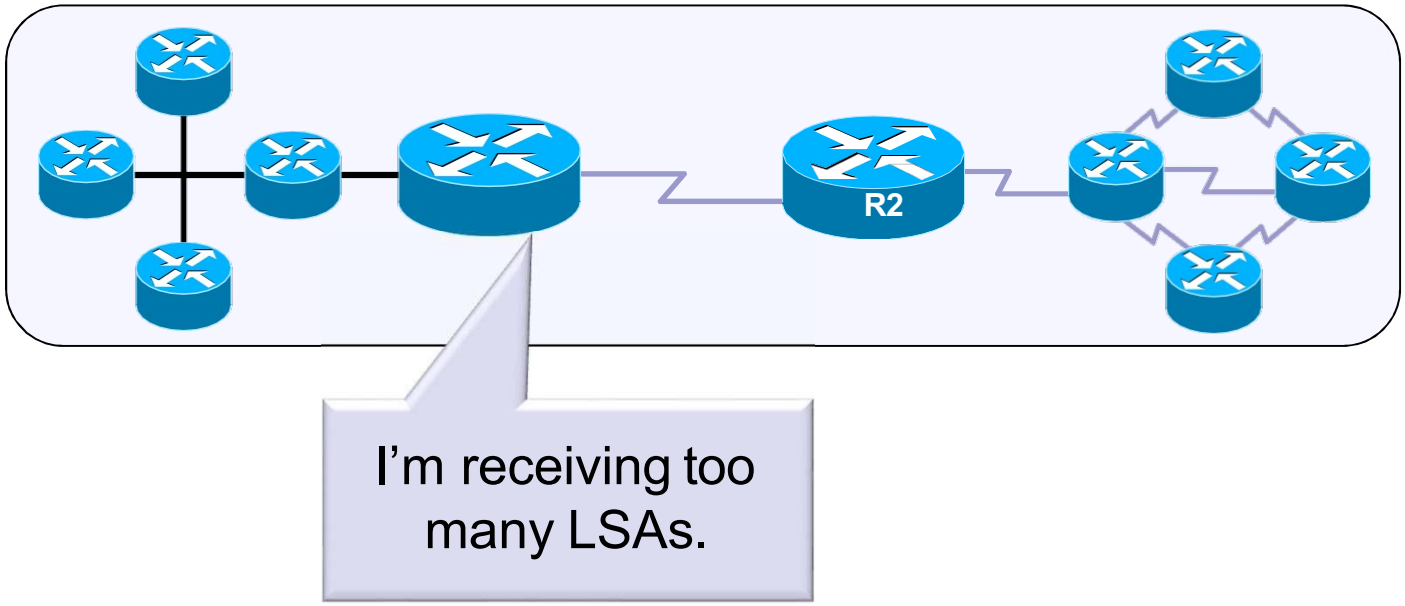
- Large routing table:
  - OSPF does not automatically summarize routes, and therefore, routing tables can become very large, depending on the size of the network.



My routing table is too big, and I am running low on memory.

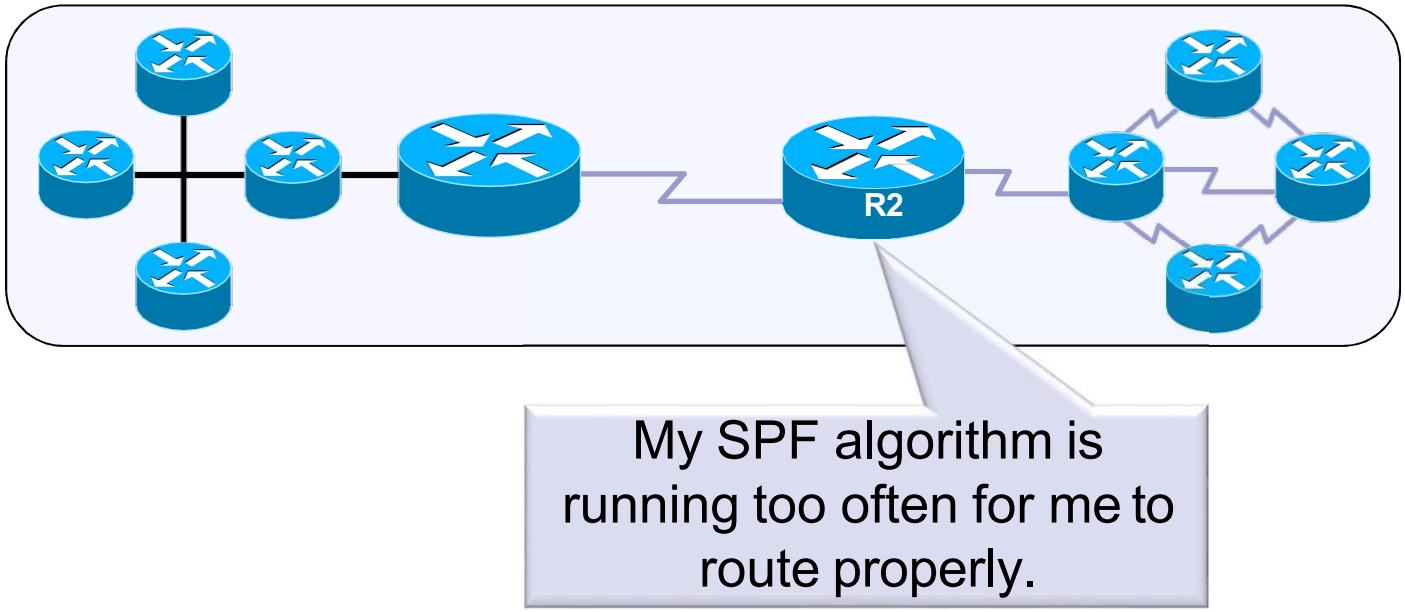
Issues With a Large OSPF Area (Part 1)

- Large link-state database (LSDB):
  - The LSDB maintains an entry for every network in the area, even if not every route is selected for the routing table.
  - Too many routers in one area would make the LSDBs very large and increase the load on the CPU.



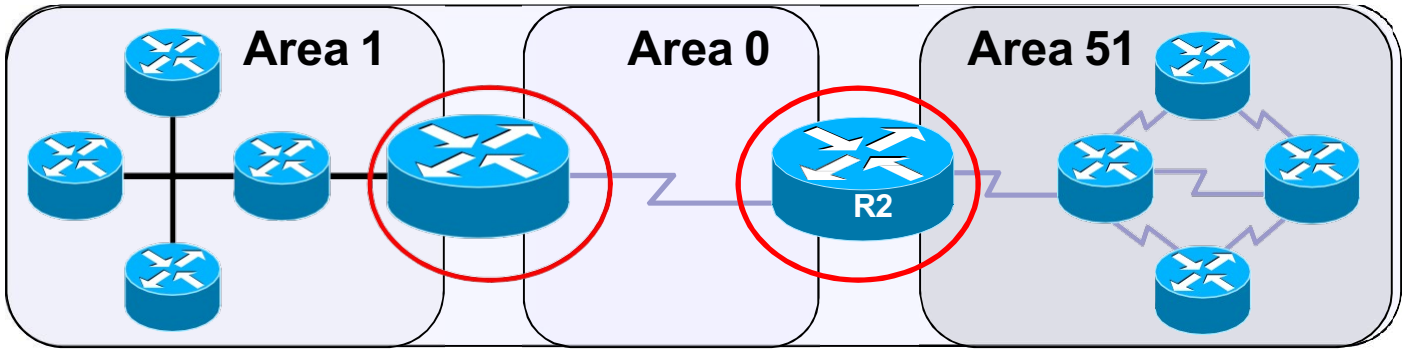
Issues With a Large OSPF Area (Part 2)

- Frequent SPF algorithm calculations:
  - In a large network, changes are inevitable, so the routers spend many CPU cycles recalculating the SPF algorithm and updating the routing table.



Multi-Area OSPF

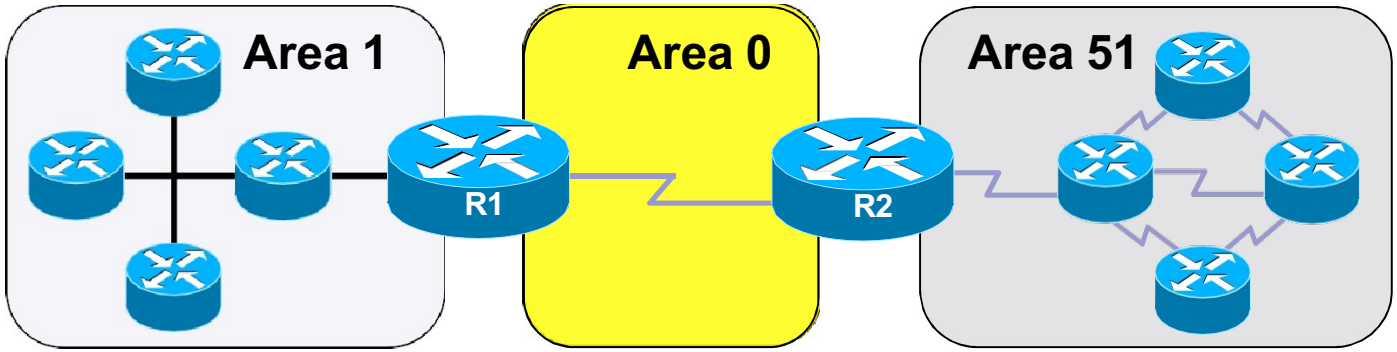
- Multiarea OSPF uses a two-layer area hierarchy using a backbone area interconnecting regular areas.
  - Useful in larger network deployments to reduce processing and memory overhead.



- *All regular areas must interconnect to the backbone area* (area 0).
  - Interconnecting routers are called **Area Border Routers (ABR).**

Backbone (Transit) Area

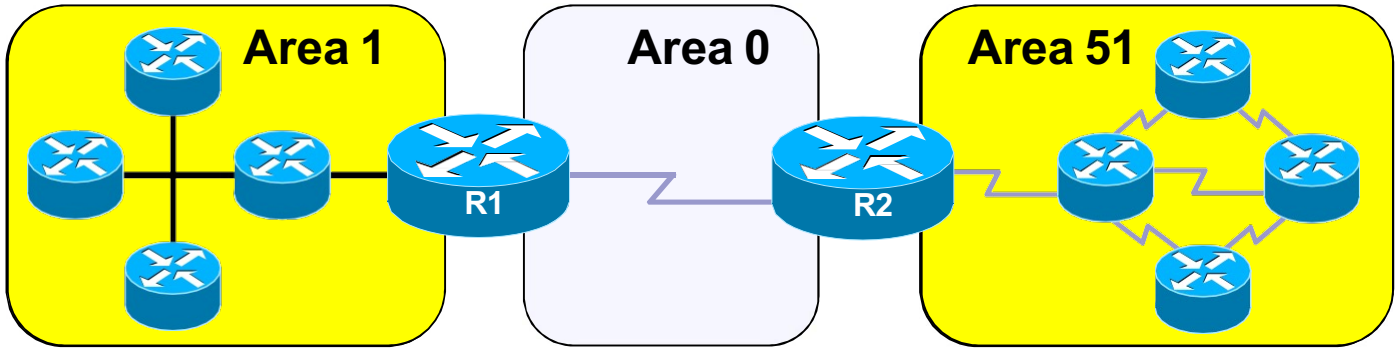
- OSPF area whose primary function is the fast and efficient movement of IP packets.
  - Backbone areas interconnect with other OSPF area types.
  - Generally, end users are not found within a backbone area.



- The backbone area is also called OSPF area 0.
  - Hierarchical networking defines area 0 as the core to which all other areas directly connect.

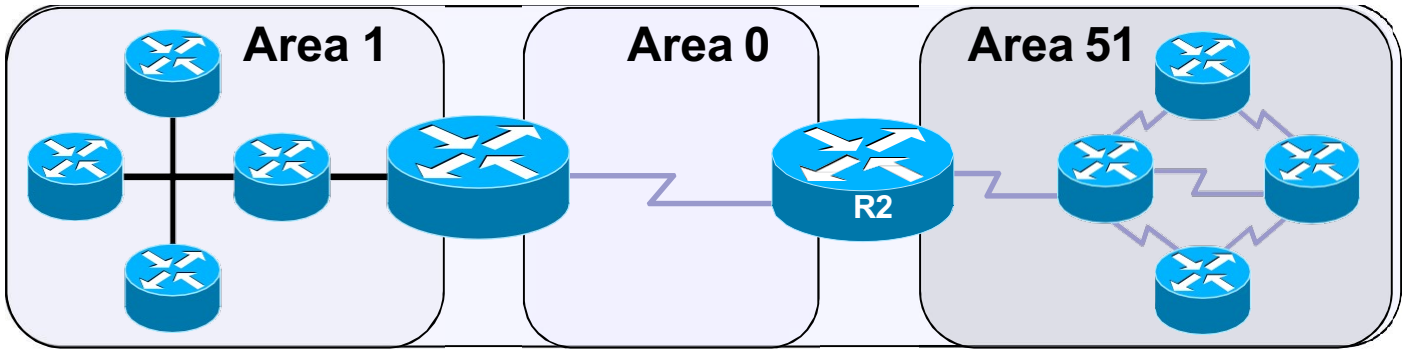
Regular or Normal Areas

- Connects users and resources.
  - Areas are usually set up along functional or geographical groupings.



- By default, all traffic from other areas must cross a transit area.
  - A regular area does not allow traffic from another area to use its links to reach other areas.

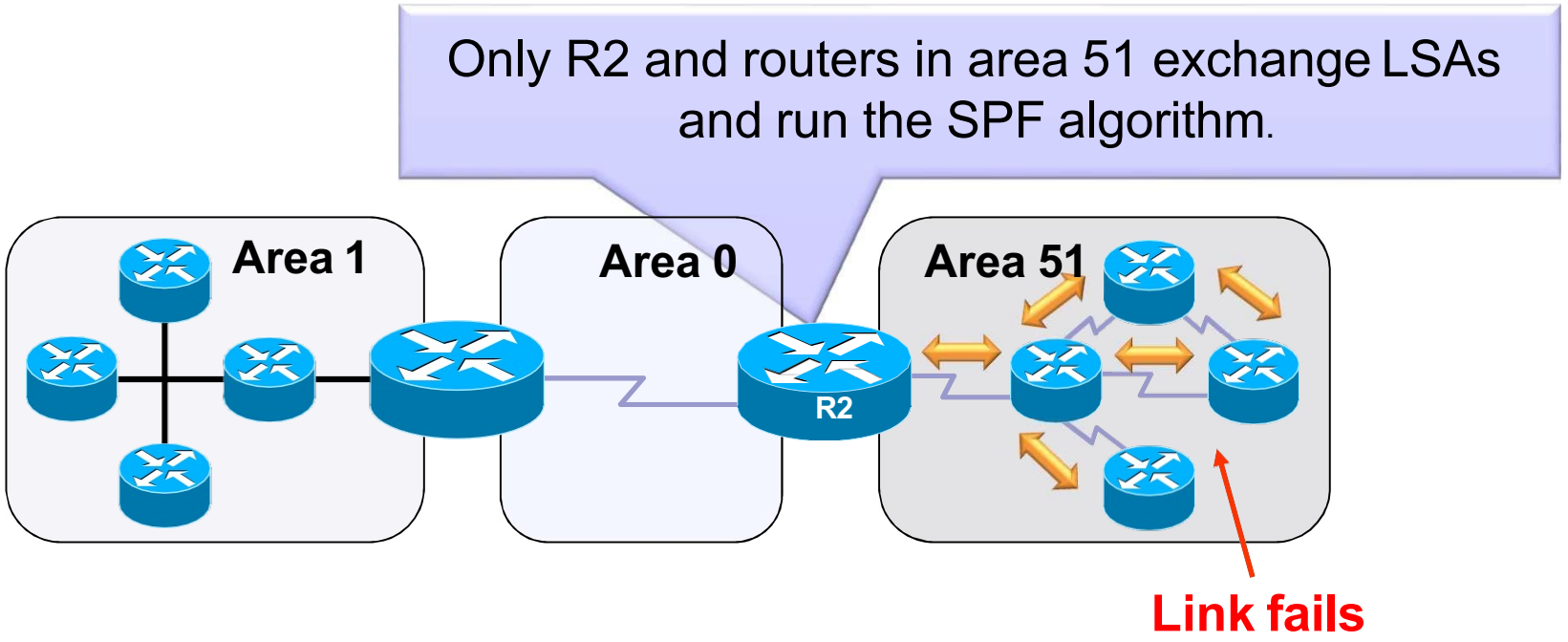
Multiarea OSPF Advantages



- **Smaller routing tables:**
  - Fewer routing table entries because network addresses can be summarized between areas.
  - Route summarization is not enabled by default.
- **Reduced link-state update overhead:**
  - Minimizes processing and memory requirements.
- **Reduced frequency of SPF calculations:**
  - Localizes the impact of a topology change within an area.
  - For instance, it minimizes routing update impact because LSA flooding stops at the area boundary.

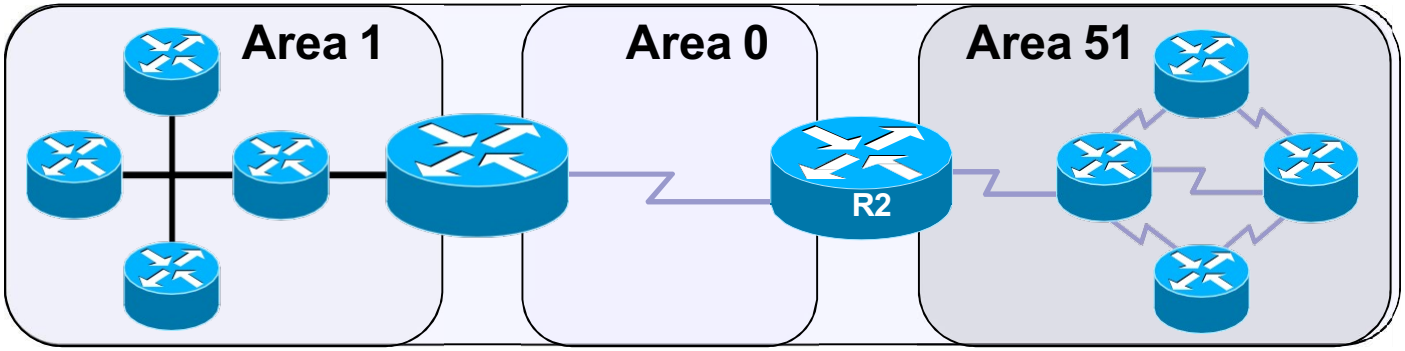
Topology Change Impacts Local Area Only

- The ABR (R2) isolates the fault to area 51 only.
  - Link failure affects the local area only (area 51)



- Routers in areas 0 and 1 do not need the run the SPF algorithm.

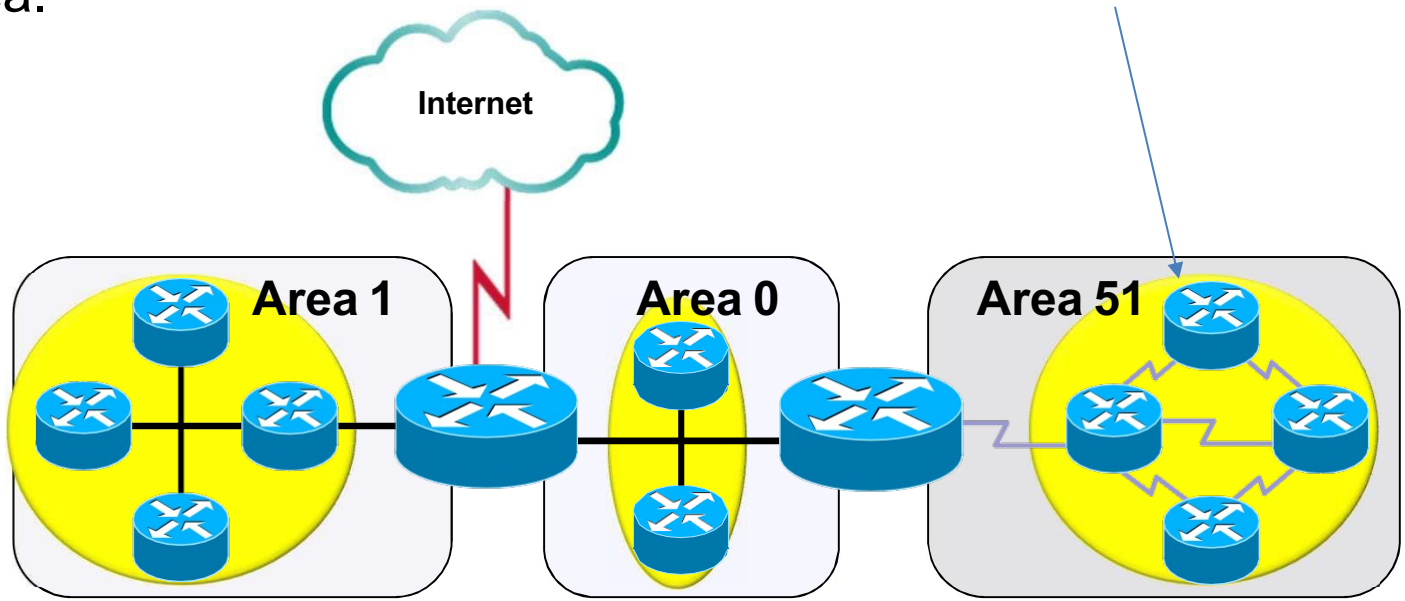
Cisco OSPF Implementation Guidelines



- The optimal number of routers per area varies based on factors such as network stability.
- However, Cisco guidelines recommend:
  - A router should be in at most three areas.
  - An area should have at most 50 routers.
  - Any single router should have at most 60 neighbors.

Internal Routers

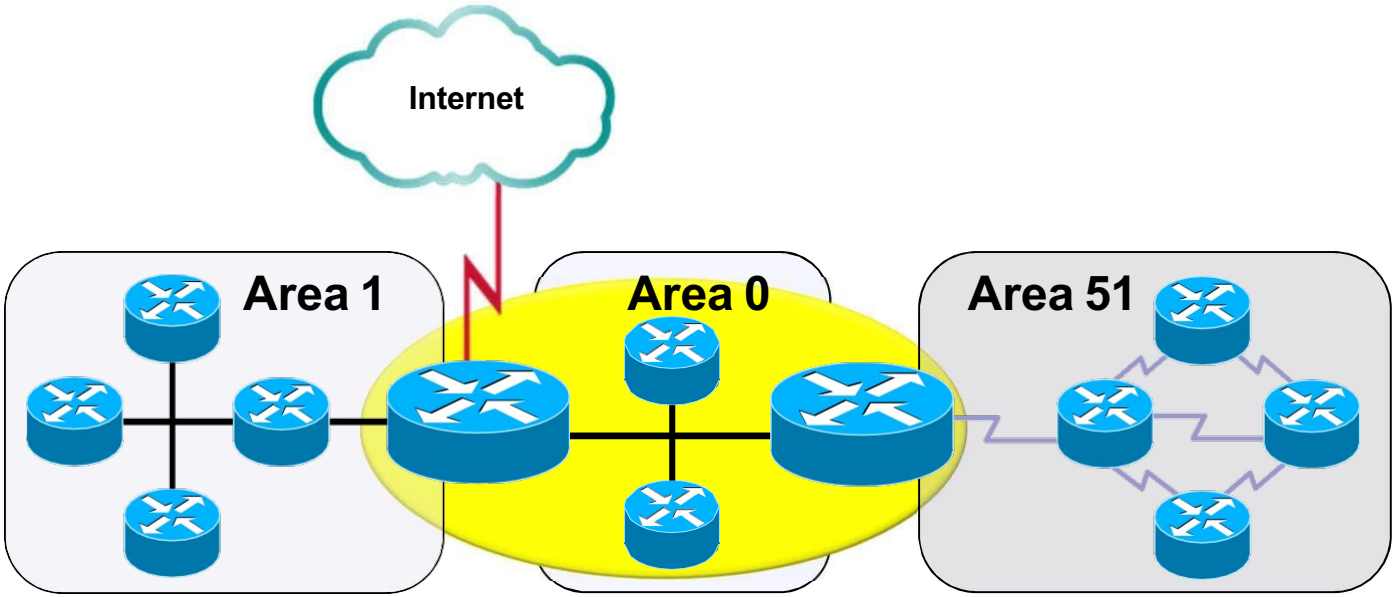
- An *internal router router* has all its interfaces in the same area.



- All internal routers in an area have identical LSDBs.

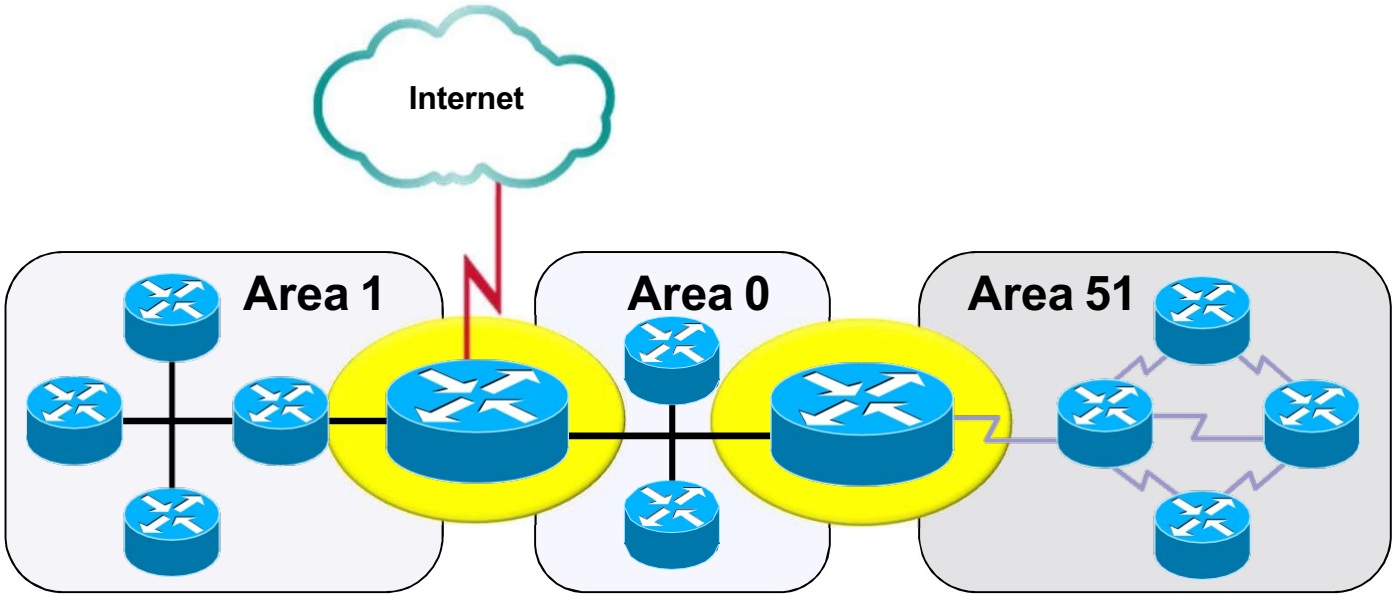
Backbone Routers

- A backbone routers have at least one interface in Area 0.



Area Border Router (ABR)

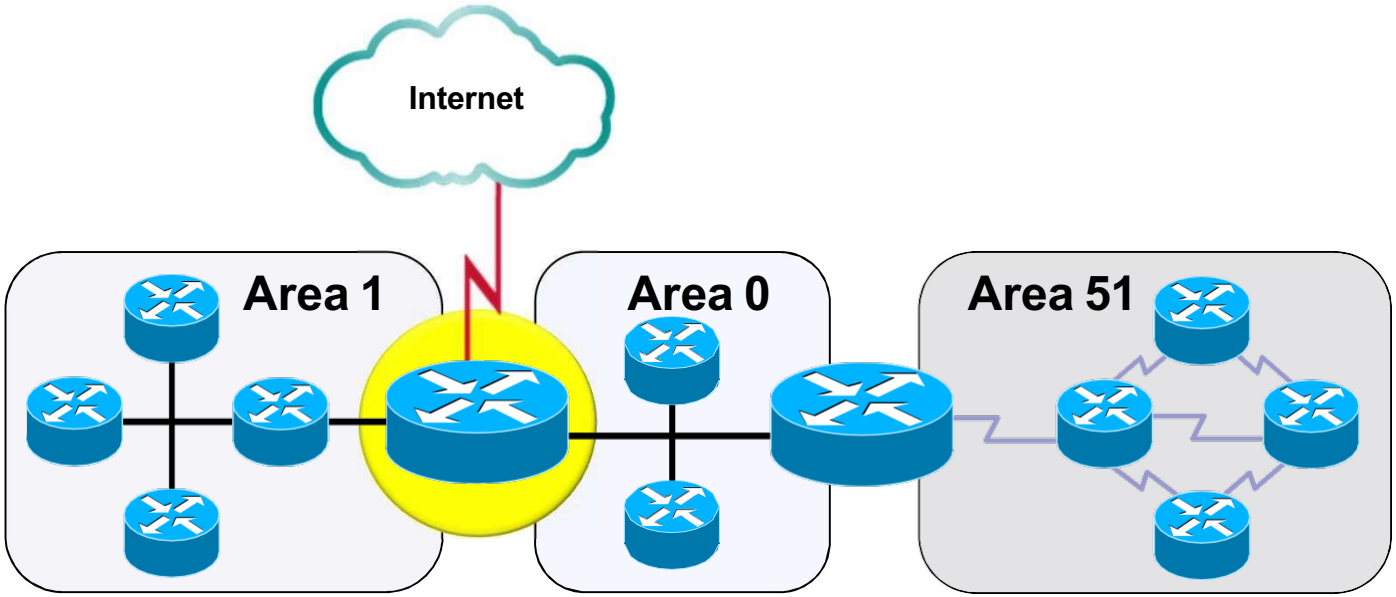
- This is a router that has interfaces attached to multiple areas.



- ABRs:
  - Maintain separate LSDBs for each area it is connected to.
  - Are exit points for the area.
  - Distribute the routing information into the backbone and the backbone routers then forward the information to the other ABRs.

Autonomous System Boundary Router (ASBR)

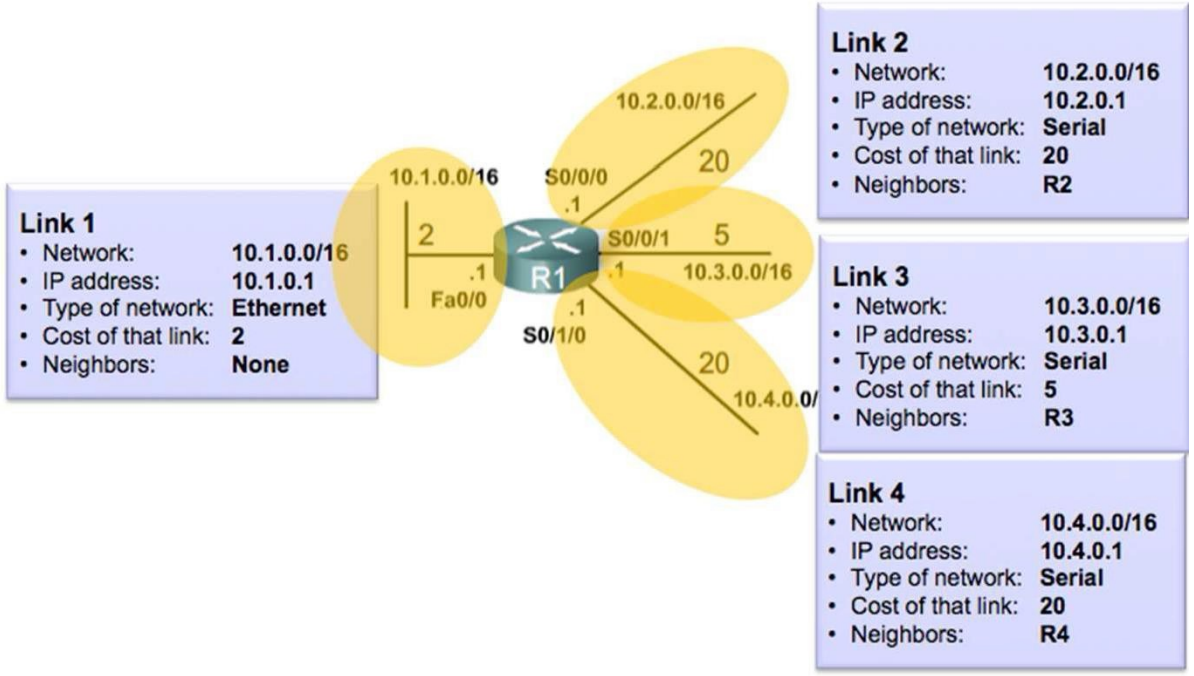
- This is a router that has at least one interface attached to an external non-OSPF network.



- An ASBR can redistribute non-OSPF network information into and out of the OSPF network.

OSPF LSAs

Link-State Advertisements (LSAs)



- LSAs are the building blocks of the OSPF LSDB.
  - Individually, they are database records providing specific OSPF network details.
  - Combined, they describe the entire topology of an OSPF area.
- Each router link is defined as an LSA type.
  - The LSA includes a link ID field that identifies, by network number and mask, the object to which the link connects.
  - Depending on the type, the link ID has different meanings.

OSPF LSA Types

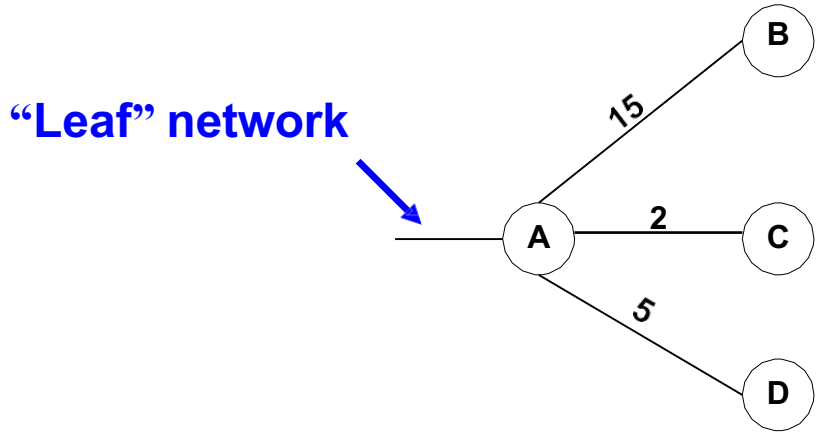
- There 11 different LSA types.
  - All multiarea OSPF implementations must support the first 5 LSAs.

LSA Type	Description
1	Router LSA
2	Network LSA
3 and 4	Summary LSAs
5	AS External LSA
6	Multicast OSPF LSA
7	Defined for NSSAs
8	External Attributes LSA for Border Gateway Protocol (BGP)
9, 10, or 11	Opaque LSAs

- The focus of this topic is on these first five LSAs.

LSA 1 - Router Link States

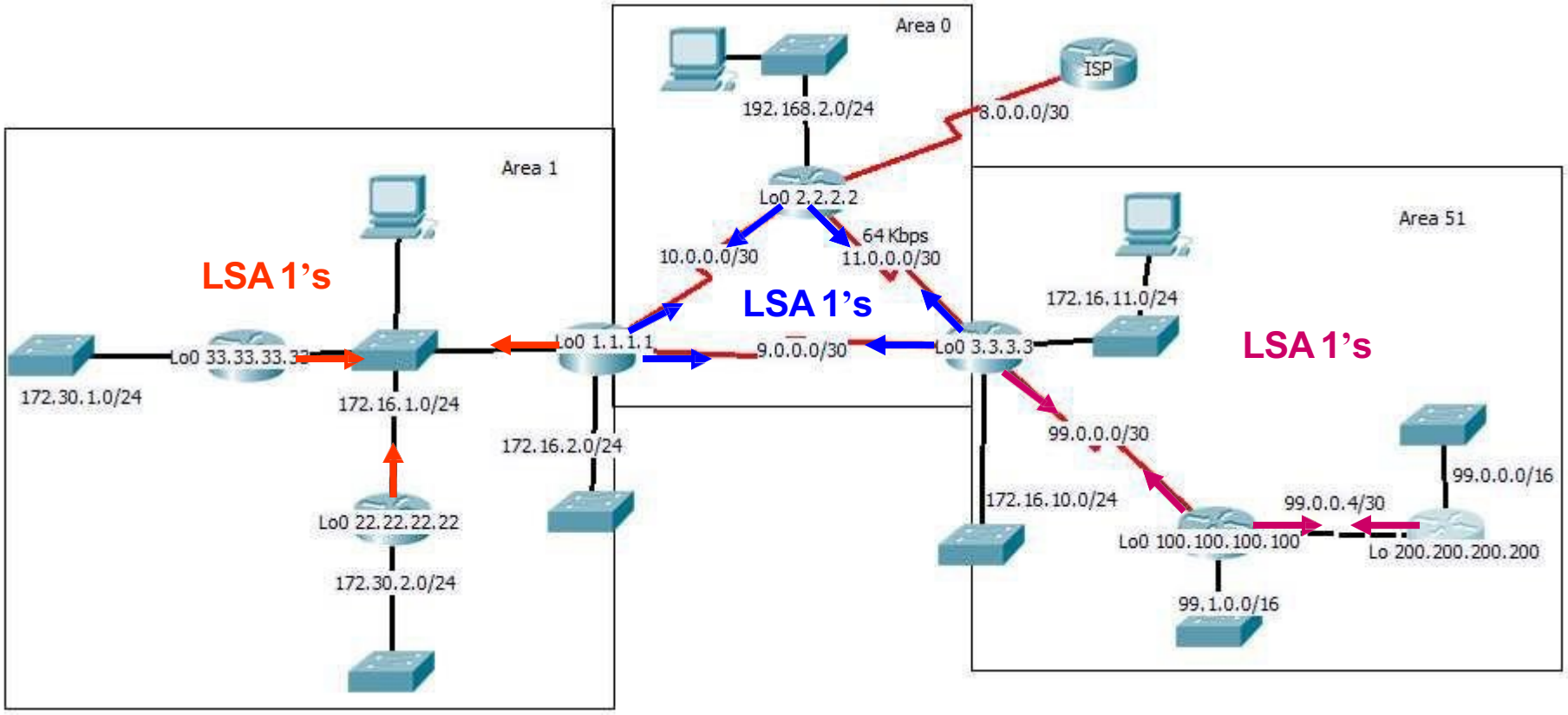
- **LSA 1 – Router LSA**
- Generated by each router for each area it belongs to.
- Describes the states of the links in the area to which this router belongs.



Router A's LSA 1s which are flooded to all other routers in this area.

- Flooded only within the area. *On multi-access networks, sent to the DR.*
- Denoted by just an "**O**" in the routing table or "**C**" if the network is directly connected.
- ABR will include a set of LSA 1's for each area it belongs to.
- When a new LSA 1 is received and installed in the LSDB, the router forwards that LSA, using hop-by-hop or asynchronous flooding.

LSA 1 – Router Link States



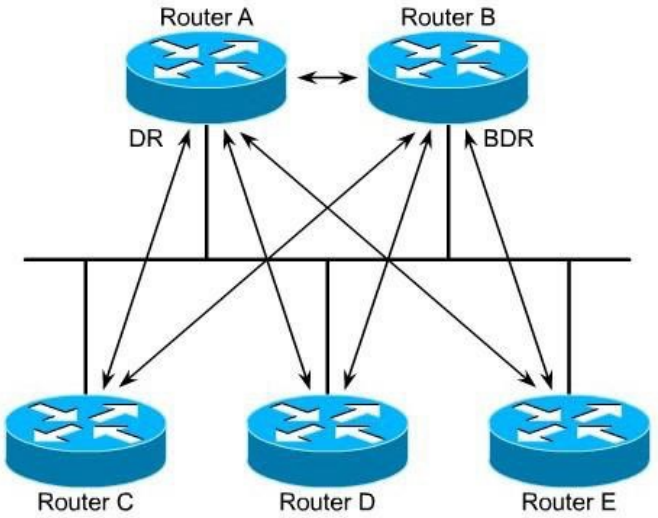
- Each router floods their LSA 1s ONLY within their own area.
- LSA 1s only announce the links (networks) within the area.
- Router receives LSA 1s from neighbor, floods those LSA 1s to other neighbors within the same area.

LSA 1 - Router Link States

```
R100# show ip route

172.16.0.0/24 is subnetted, 4 subnets
O       172.16.10.0 [110/65] via 99.0.0.1, 00:08:30, Serial0/0
O       172.16.11.0 [110/65] via 99.0.0.1, 00:08:30, Serial0/0
```

- Denoted by just an "O" in the routing table, or a "C"
- Note: Only partial routing tables will be shown

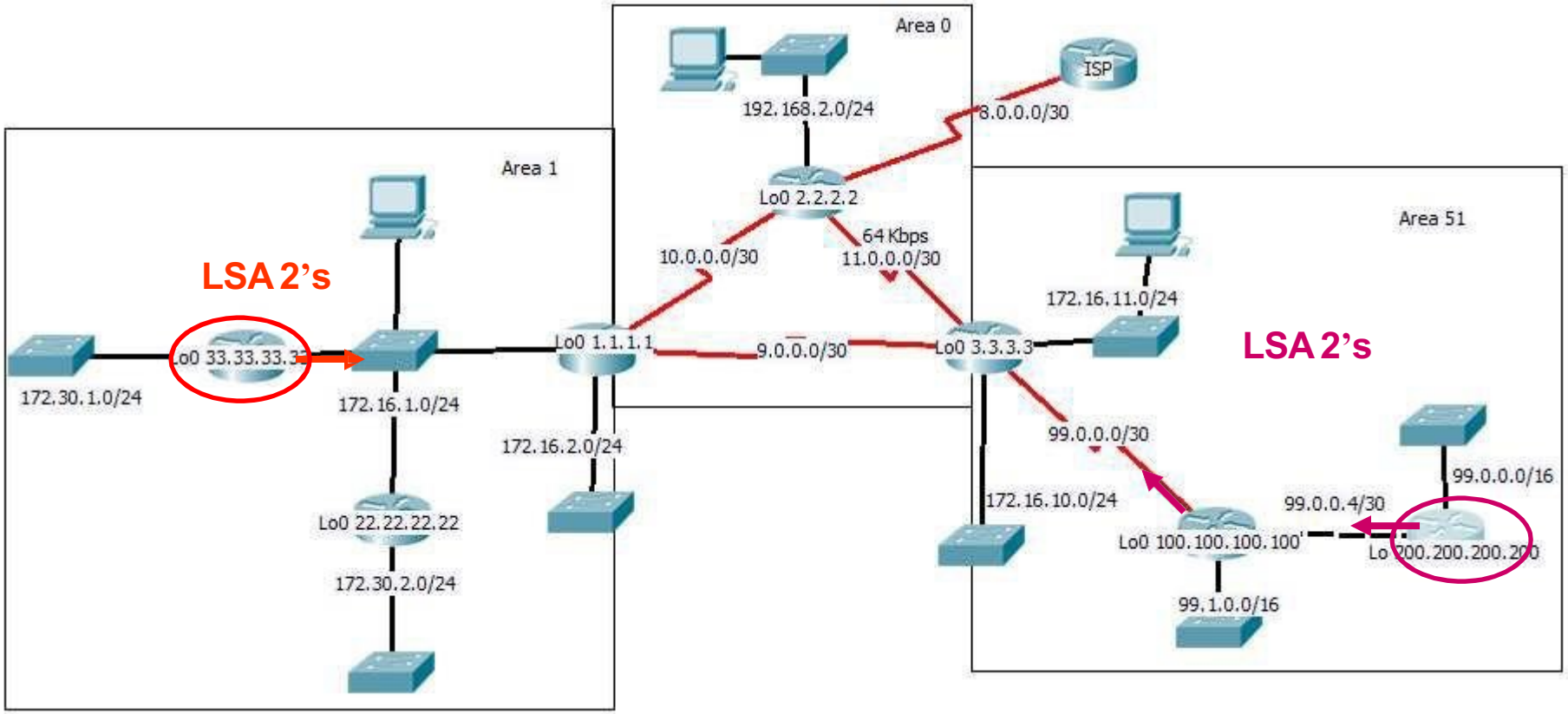
LSA 2 - Network Link States



LSA 2 – Network LSA

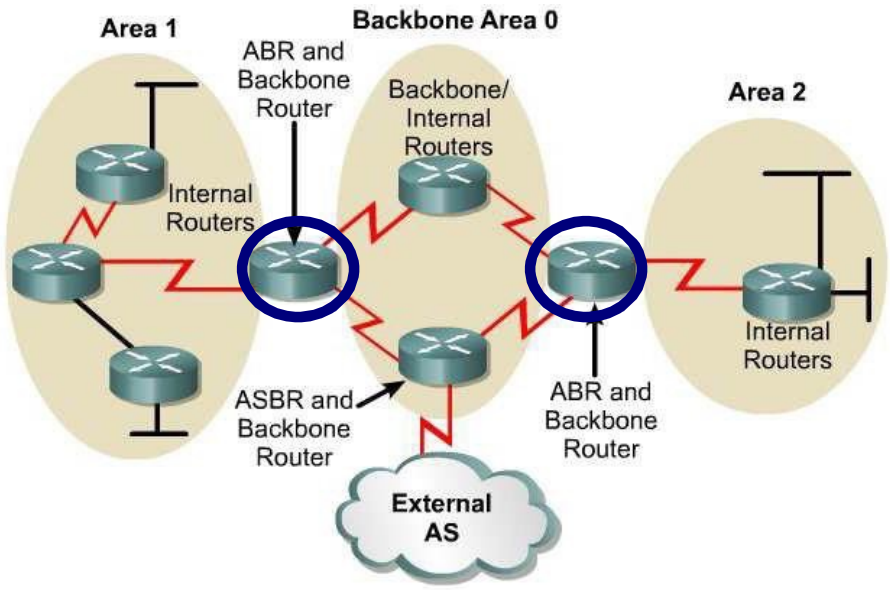
- **Generated by the DR** on every multi-access network
- Denoted by just an **"O"** in the routing table or **"C"** if the network is directly connected.
- **Flooded only within the originating area**.
- LSA 2's are in link state database for **all** routers within area, even those routers on not on multi-access networks or DRs on other multi-access networks in the same area.
- ABR may include a set of LSA 2s for each area it belongs to.

LSA 2s



- LSA 2s flooded within area by DR.

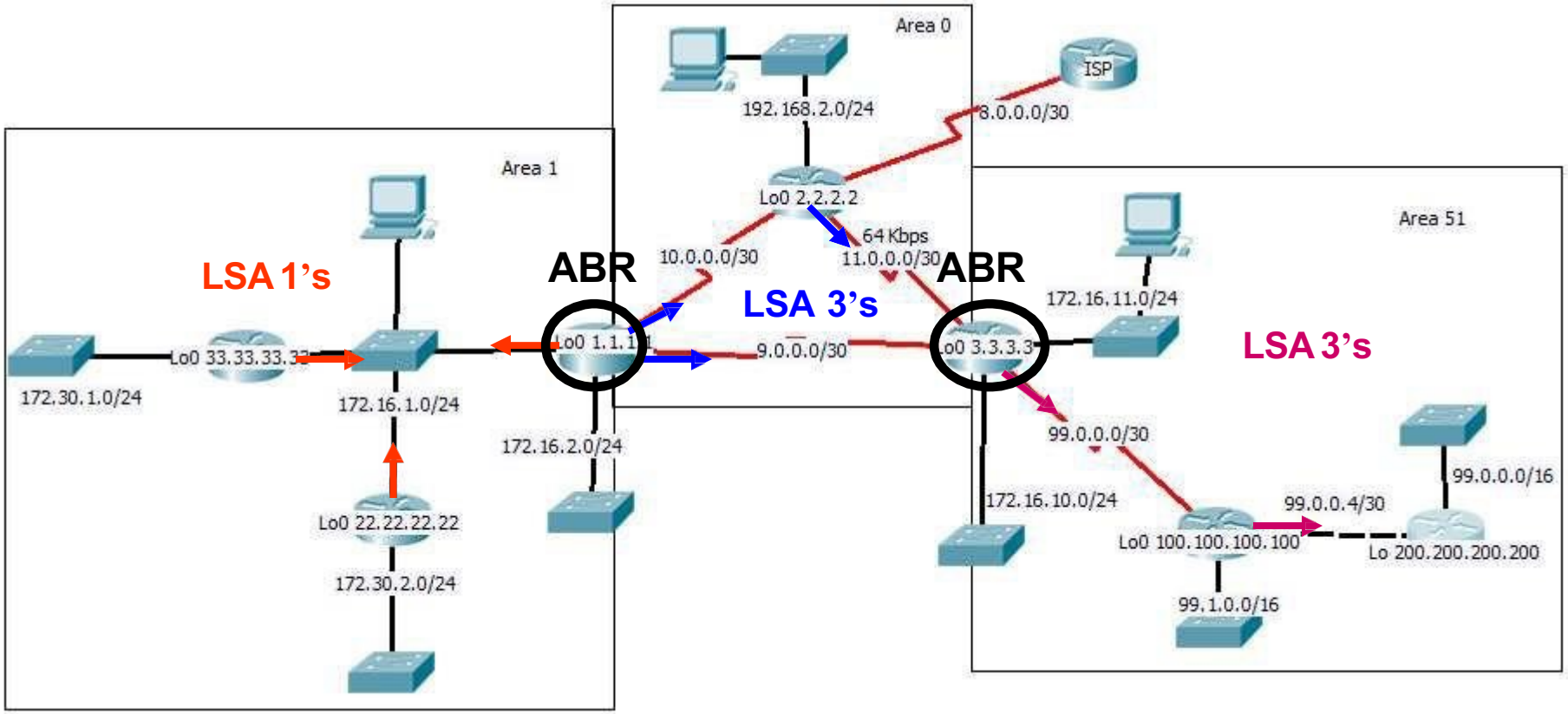
LSA 3 – Summary Net Link States



LSA 3 – Summary LSA

- Originated by the **ABR**.
- Describes links between **ABR** and **Internal Routers** of the Local Area
- ABR will include a set of LSA type 3s for each area it belongs to.
- LSA 3s are flooded throughout the backbone (Area 0) and to other ABRs.
- Routes learned via LSA type 3s are denoted by an "IA" (Inter-area) in the routing table.

LSA 3 – Summary LSAs

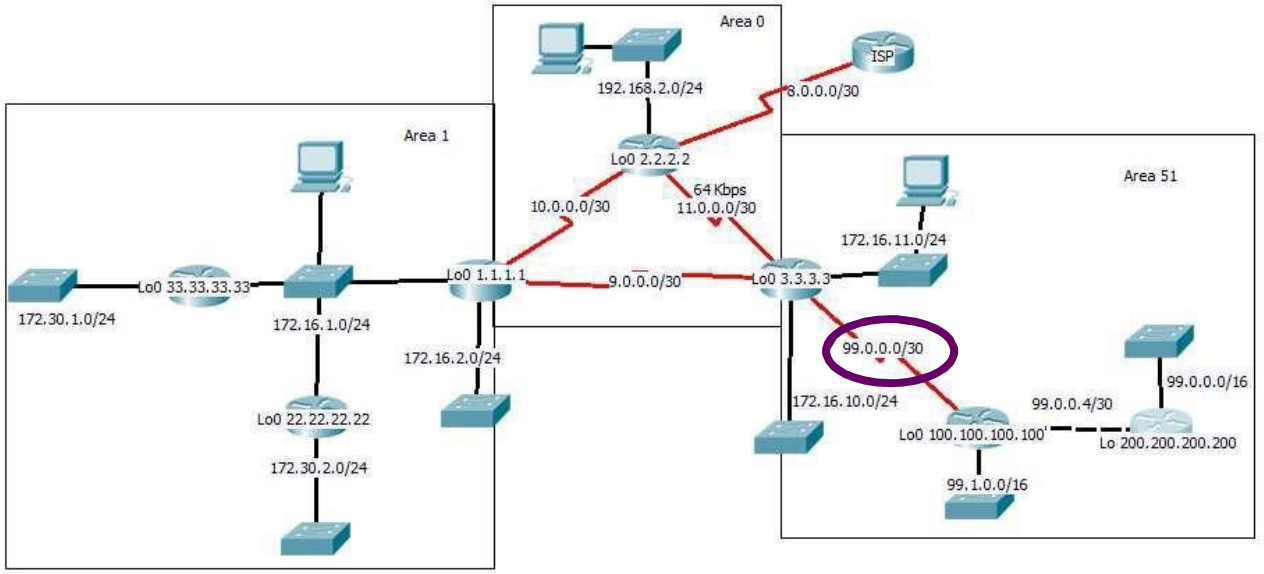


LSA 3 – Summary LSA

- Originated by the **ABR**.
- Describes links between **ABR** and **Internal Routers** of the Local Area
- ABR will include a set of LSA type 3s for each area it belongs to.
- LSA type 3s are flooded throughout the backbone (Area 0) and to other ABRs.
- Routes learned via LSA type 3s are denoted by an "IA" (Inter-area) in the routing table.

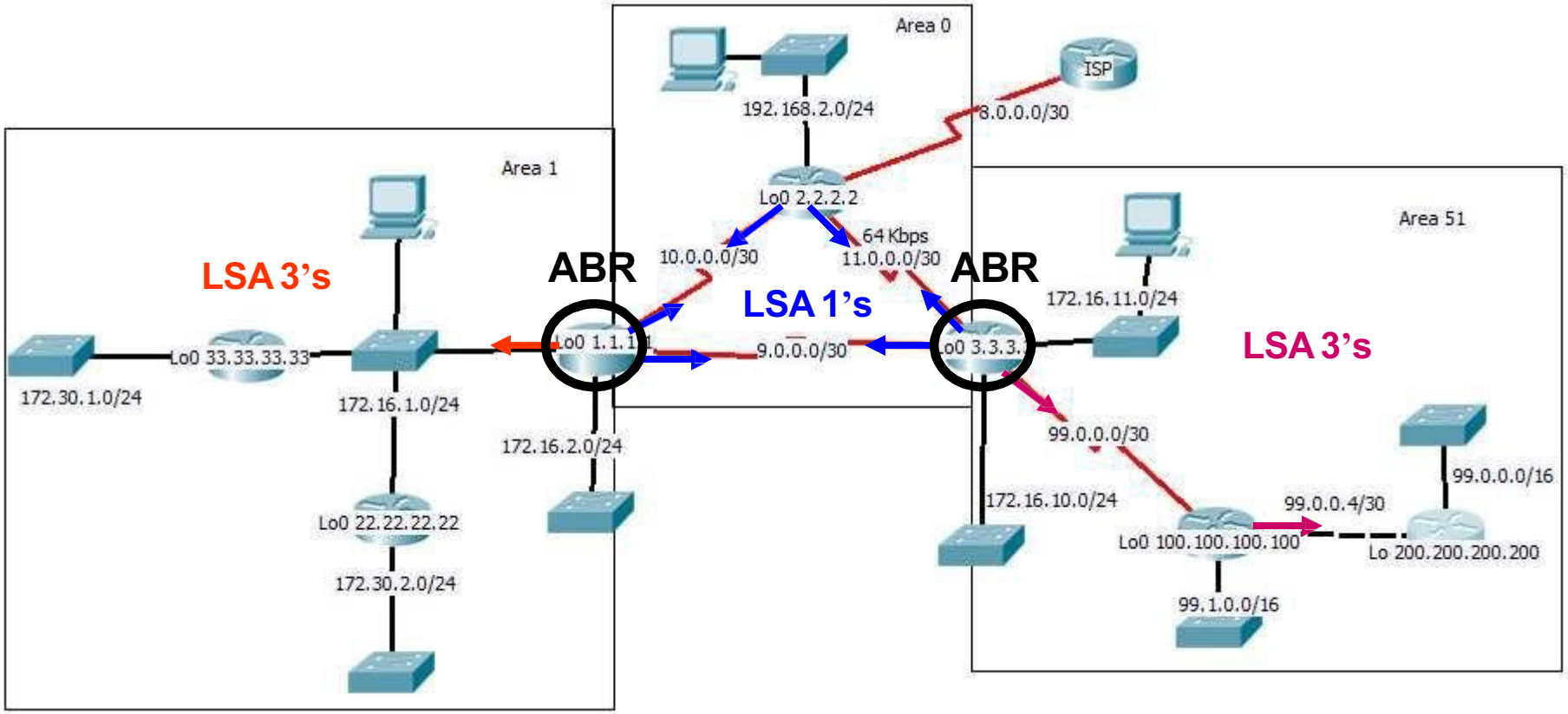
LSA 3 – Summary Net Link States

```
R2# show ip route

 99.0.0.0/8 is variably s
O IA     99.0.0.0/30 [110/
O IA     99.0.0.4/30 [110/
O IA     99.1.0.0/16 [110/
     172.16.0.0/24 is sub
O IA     172.16.1.0 [110/6
O IA     172.16.2.0 [110/6
O IA     172.16.10.0 [110/
O IA     172.16.11.0 [110/
     172.30.0.0/24 is subnetted, 2 subnets
O IA     172.30.1.0 [110/66] via 10.0.0.1, 00:42:21,  Serial0/0
O IA     172.30.2.0 [110/66] via 10.0.0.1, 00:42:21,  Serial0/0
```

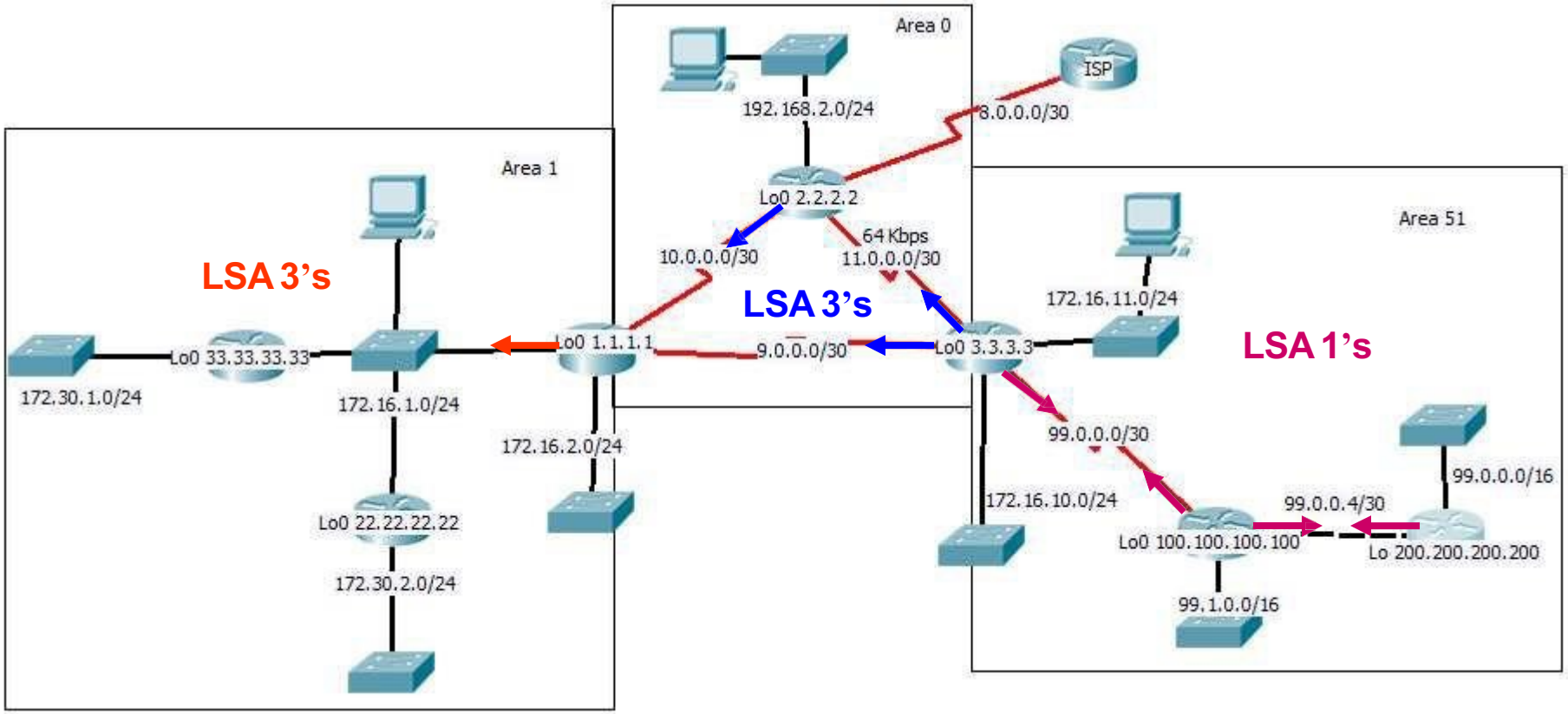


- Routes learned via LSA type 3s are denoted by an “IA” (Inter-Area Routes) in the routing table.

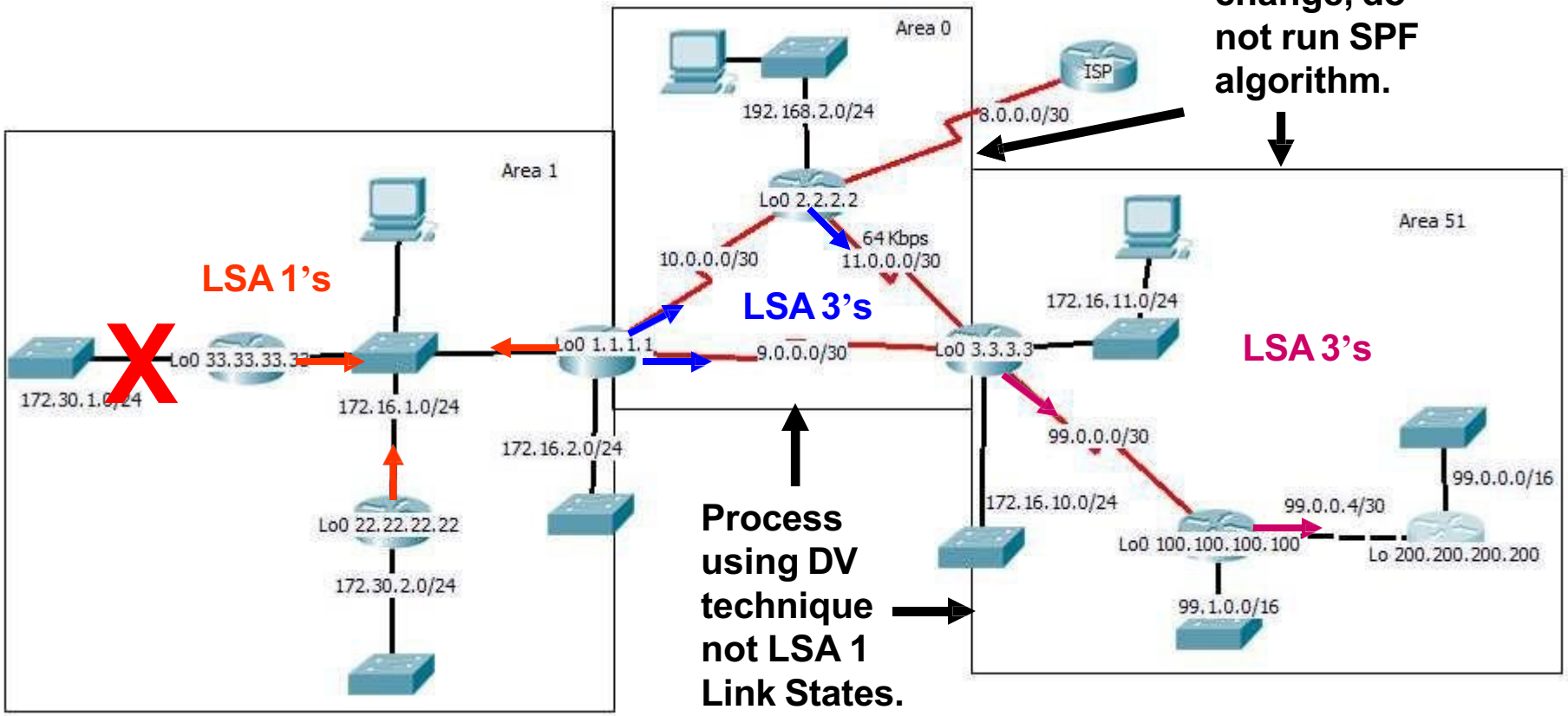
LSA 3 – Summary LSAs



LSA 3 – Summary LSAs

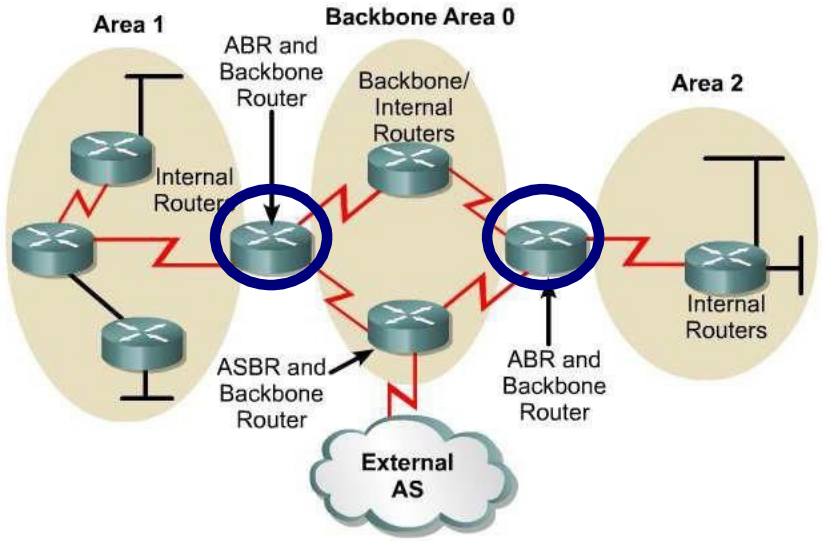


LSA 3 – Summary Net Link States



- Routers only see the topology of the area they belong to.
- When a link in one area changes, the adjacent routers originate in LSA 1's and flood them within the area, causing intra-area (internal) routers to re-run the SPF and recalculate the routing table.
- ABRs do not announce topological information between areas.
- ABRs only inject routing information into other areas, which is basically a distance-vector technique.

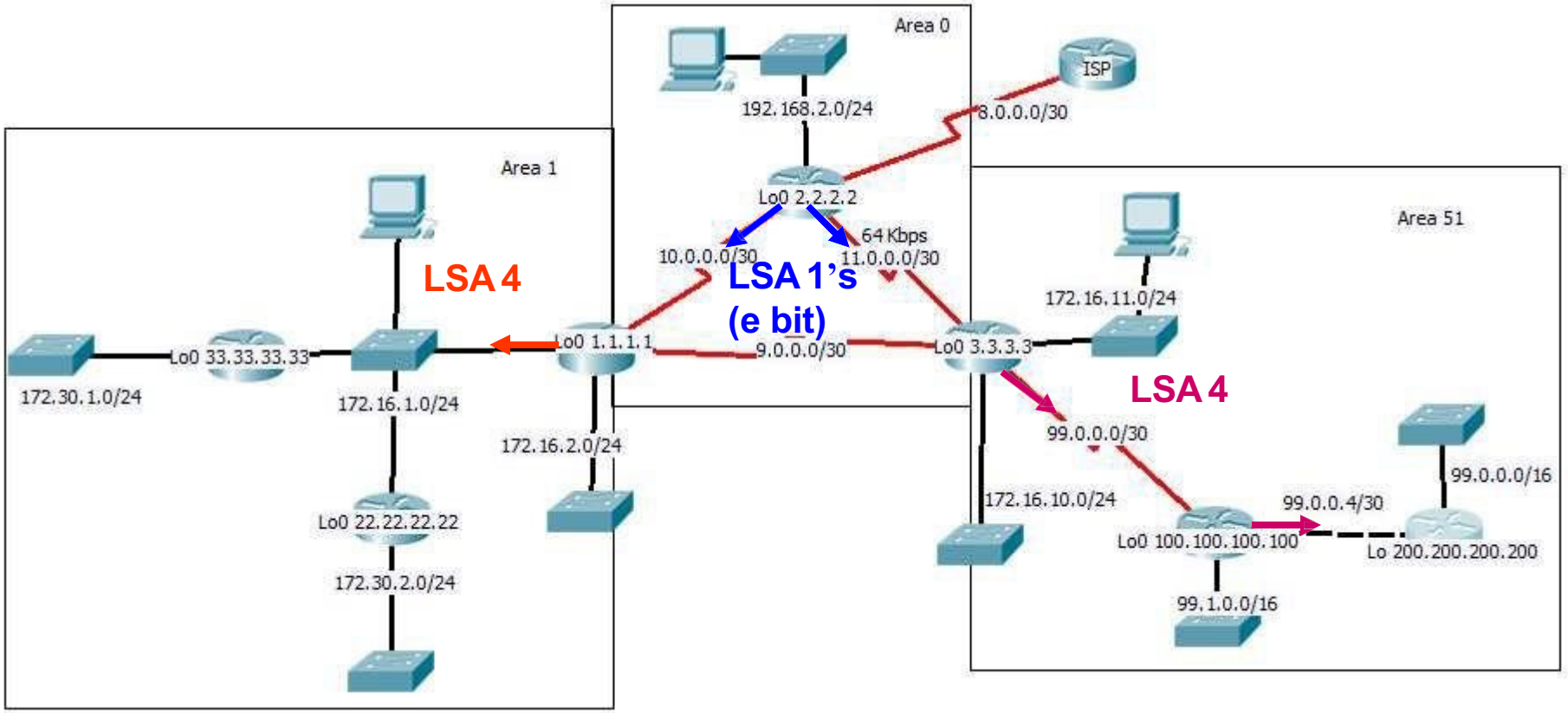
LSA 4 – ASBR Summary Link States



LSA 4 – ASBR Summary LSA

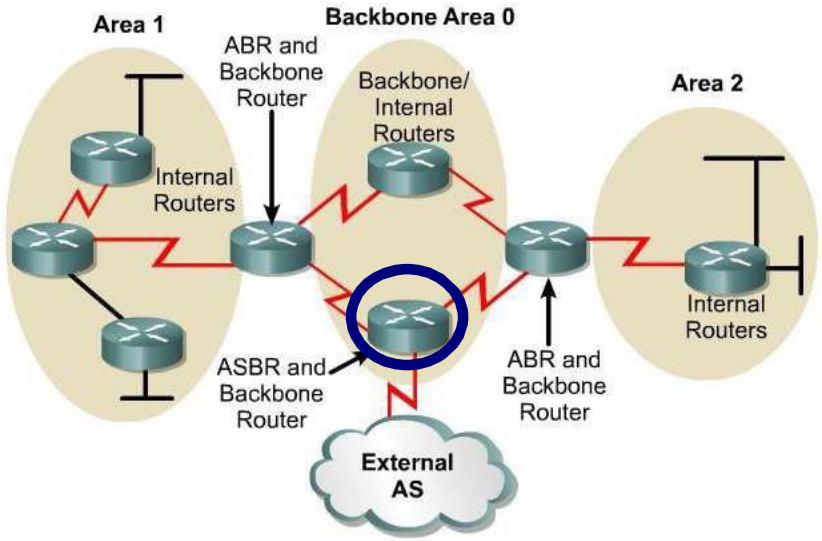
- **Originated by the ABR.**
- Flooded throughout the area.
- Describes the **reachability to the ASBRs**
  - Advertises an ASBR (Router ID) not a network
- Included in routing table as an "IA" route.

LSA 4 – ASBR Summary Link States



- How does the ABRs know about the ASBR?
- ASBR sends a type 1 Router LSA with a bit (external bit – e bit) that is set to identify itself as the ASBR.

LSA 5 - AS External Link States

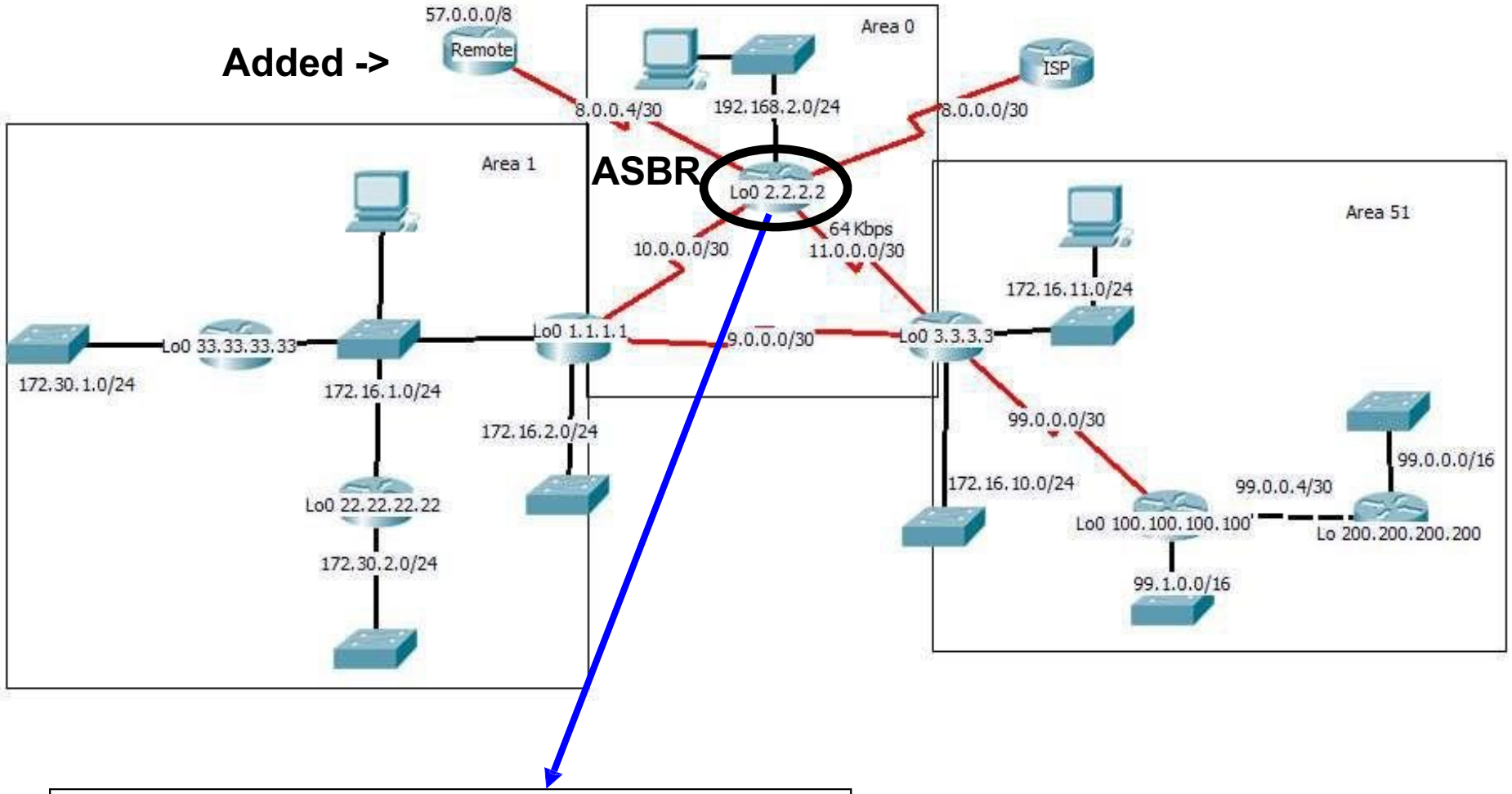


LSA 5 – AS External LSA

- **Originated by the ASBR**.
- Describes destination **networks external to the Autonomous System (This OSPF Routing Domain)**
- Flooded throughout the OSPF AS except to stub and totally stubby areas
- Denoted in routing table as E1 or E2 (default) route (soon)
- **ASBR** – Router which "redistributes" routes into the OSPF domain.

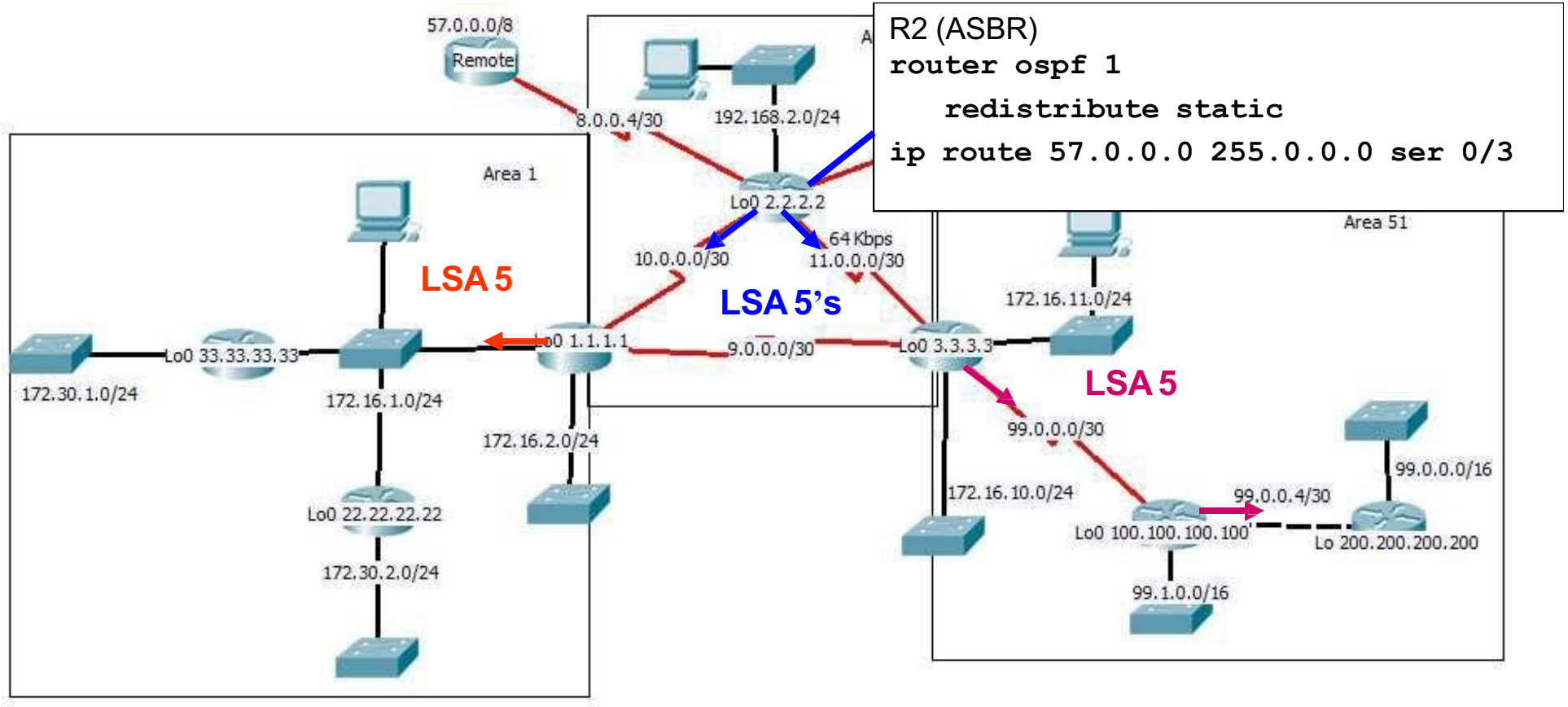
Exceptions

- **Not** flooded to Stub and Totally Stubby networks.
- More on this later



R2 (ASBR)

```
router ospf 1
   redistribute static
ip route 57.0.0.0 255.0.0.0 ser 0/3
```



- "Redistribute" command creates an ASBR router.
- LSA 5s
  - Originated by the ASBR.
  - Describes destination networks external to the OSPF Routing Domain
  - Flooded throughout the OSPF AS except to stub and totally stubby areas

LSA 5 - AS External Link States

E1 vs. E2 External Routes

- External routes fall under two categories:
  - external type 1
  - external type 2 (**default)**
- The difference between the two is in the way the cost (metric) of the route is being calculated.
- The cost of a **type 2** route is always the external cost, irrespective of the interior cost to reach that route.
- A **type 1** cost is the addition of the external and internal costs used to reach that route.
- A type 1 route is always preferred over a type 2 route for the same destination.
- More later…

OSPF Routing Table

Router and Network Routing Table Entries

```
R1# show ip route | begin Gateway

Gateway of last resort is 192.168.10.2 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 192.168.10.2, 00:00:19, Serial0/0/0
      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C  10.1.1.0/24  is  directly  connected,  GigabitEthernet0/0    L
10.1.1.1/32  is  directly  connected,  GigabitEthernet0/0    C
10.1.2.0/24  is  directly  connected,  GigabitEthernet0/1    L
10.1.2.1/32 is directly connected, GigabitEthernet0/1
O        10.2.1.0/24 [110/648] via 192.168.10.2, 00:04:34, Serial0/0/0
O IA  192.168.1.0/24 [110/1295] via 192.168.10.2, 00:01:48, Serial0/0/0
O IA  192.168.2.0/24 [110/1295] via 192.168.10.2, 00:01:48, Serial0/0/0
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C        192.168.10.0/30 is directly connected, Serial0/0/0
L        192.168.10.1/32 is directly connected, Serial0/0/0
O        192.168.10.4/30 [110/1294] via 192.168.10.2, 00:01:55, Serial0/0/0
R1#
```

- **O** - Router (type 1) and network (type 2) LSAs describe intra-area details.
- **O IA** - Summary LSAs flooded into the area by an ABR.
- **O E1** or **O E2** - External LSAs describing a non-OSPF network.

Steps to OSPF Convergence

```
R1# show ip route | begin Gateway

Gateway of last resort is 192.168.10.2 to network 0.0.0.0

3  O*E2  0.0.0.0/0 [110/1] via 192.168.10.2, 00:00:19, Serial0/0/0
      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C  10.1.1.0/24 is directly connected, GigabitEthernet0/0    L
10.1.1.1/32 is directly connected, GigabitEthernet0/0     C
10.1.2.0/24 is directly connected, GigabitEthernet0/1     L
10.1.2.1/32 is directly connected, GigabitEthernet0/1
1  O        10.2.1.0/24 [110/648] via 192.168.10.2, 00:04:34, Serial0/0/0
2  O IA  192.168.1.0/24 [110/1295] via 192.168.10.2, 00:01:48, Serial0/0/0
2  O IA  192.168.2.0/24 [110/1295] via 192.168.10.2, 00:01:48, Serial0/0/0
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C        192.168.10.0/30 is directly connected, Serial0/0/0
L        192.168.10.1/32 is directly connected, Serial0/0/0
1  O        192.168.10.4/30 [110/1294] via 192.168.10.2, 00:01:55, Serial0/0/0
R1#
```

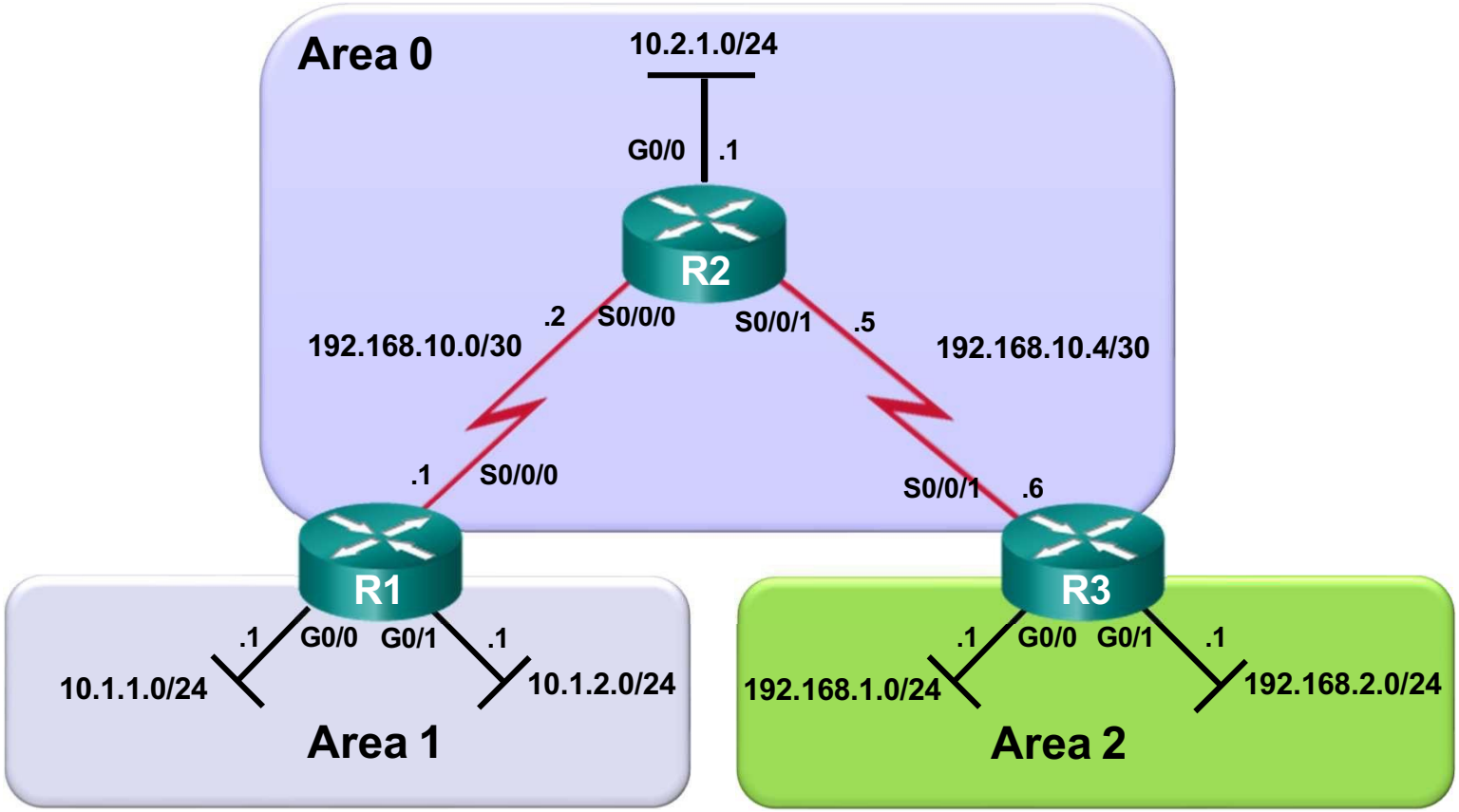
1. **Calculate intra-area OSPF routes.**
2. **Calculate best path to interarea OSPF routes.**
3. **Calculate best path route to external non-OSPF networks**

OSPFv3 Routing Table Entries

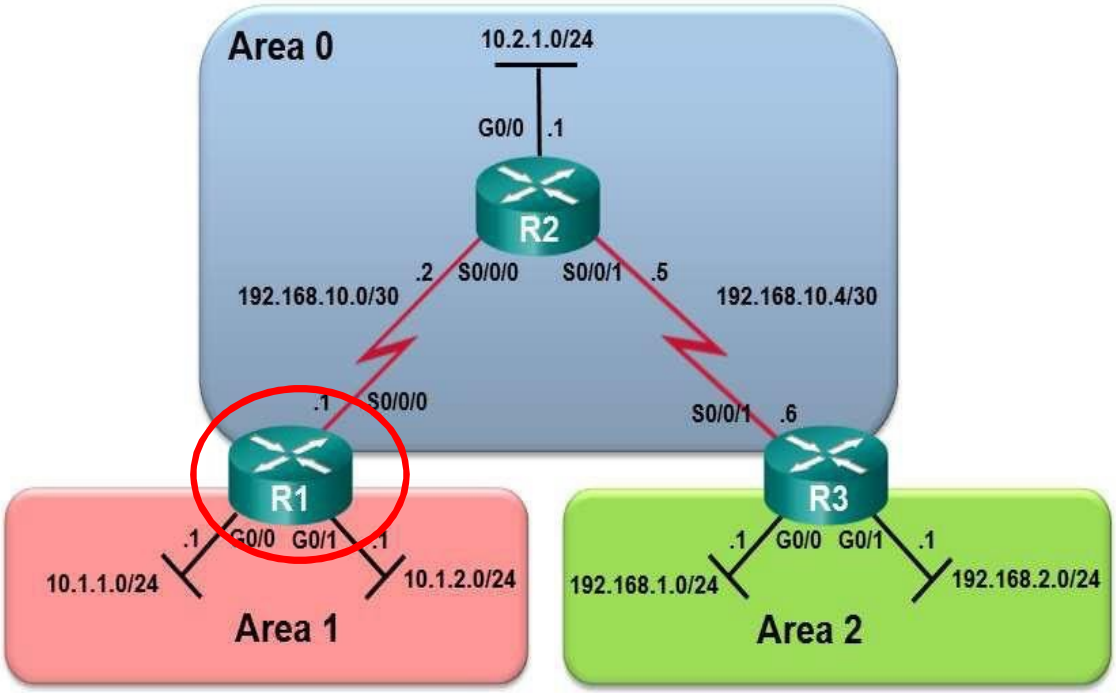
```
R1# show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext
2 OE2 ::/0 [110/1], tag 10
     via FE80::2, Serial0/0/0
C   2001:DB8:CAFE:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:CAFE:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
O   2001:DB8:CAFE:2::/64 [110/648]
     via FE80::2, Serial0/0/0
OI  2001:DB8:CAFE:3::/64 [110/1295]
     via FE80::2, Serial0/0/0
C   2001:DB8:CAFE:A001::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:CAFE:A001::1/128 [0/0]
     via Serial0/0/0, receive
O   2001:DB8:CAFE:A002::/64 [110/1294]
     via FE80::2, Serial0/0/0
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```

Configuring Multiarea OSPF

OSPF Multiarea OSPF Topology

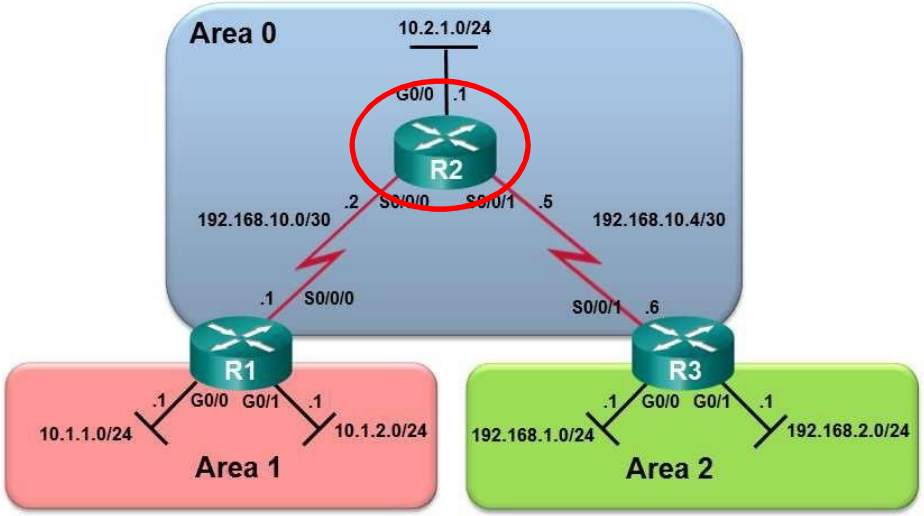


Configuring Multiarea OSPF on R1



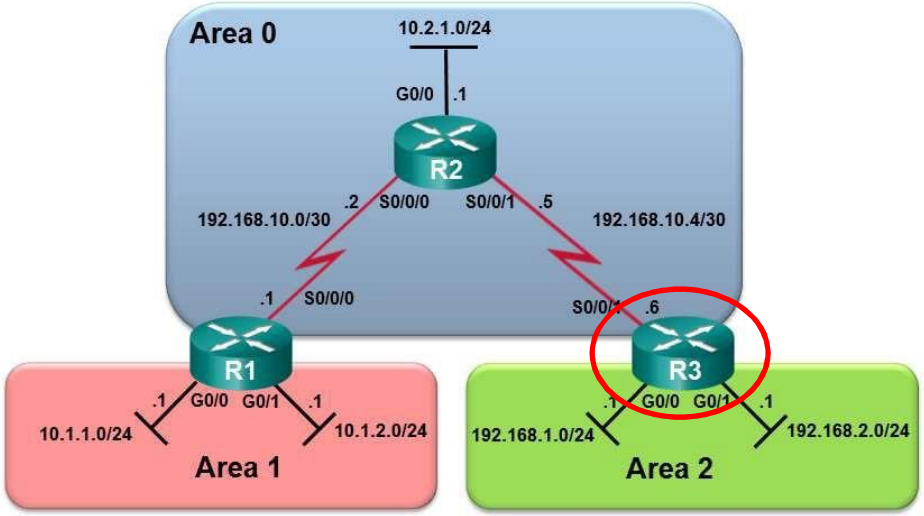

```
R1(config)# router ospf 10
R1(config-router)# router-id 1.1.1.1
R1(config-router)# network 10.1.1.0 0.0.0.255 area 1
R1(config-router)# network 10.1.2.0 0.0.0.255 area 1
R1(config-router)# network 192.168.10.0 0.0.0.3 area 0
R1(config-router)# end
R1#
```

Configuring Multiarea OSPF on R2



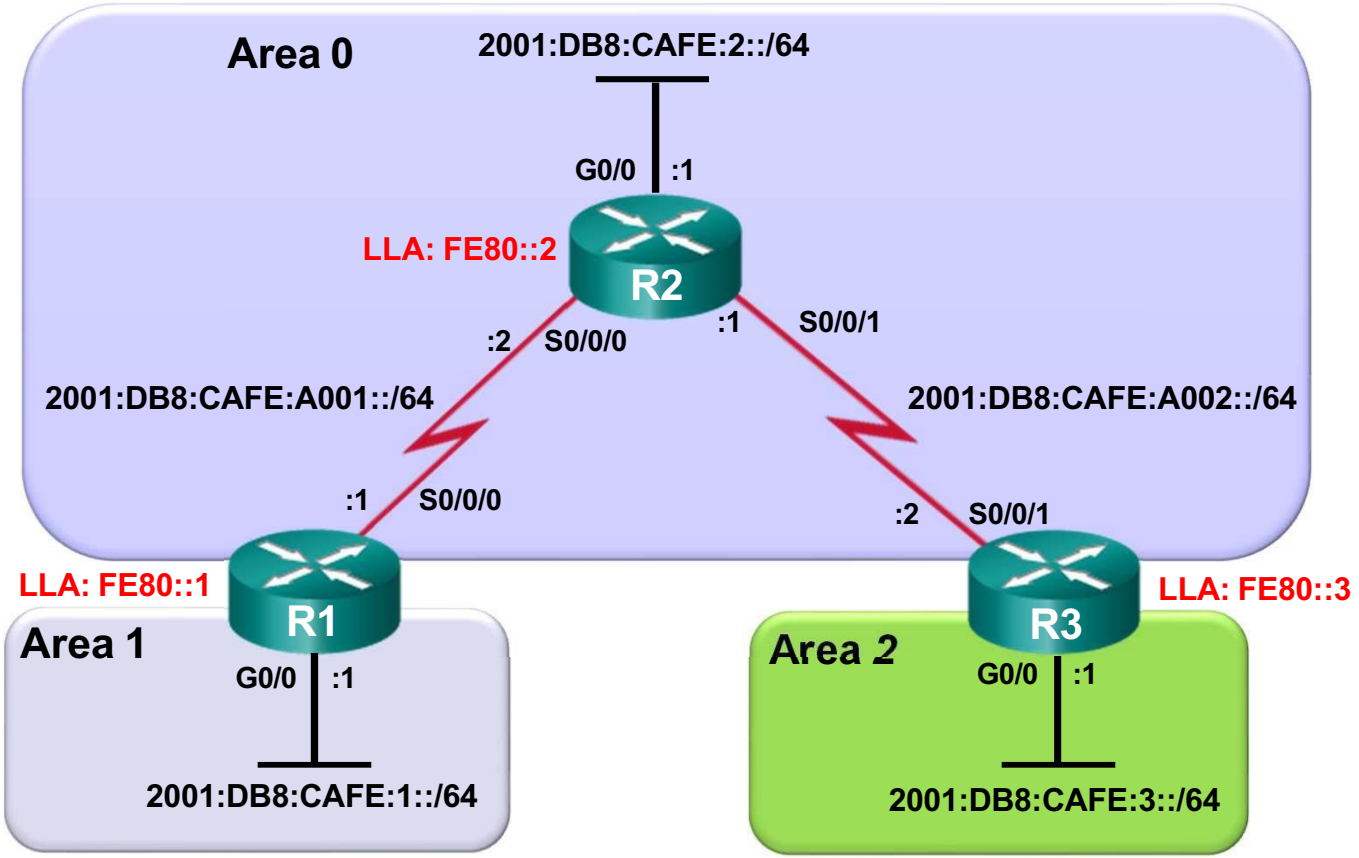

```
R2(config)# router ospf 10
R2(config-router)# router-id 2.2.2.2
R2(config-router)# network 192.168.10.0 0.0.0.7 area 0
R2(config-router)# network 10.2.1.0 0.0.0.255 area 0
R2(config-router)# end
*Apr 19 18:11:04.029: %OSPF-5-ADJCHG: Process 10, Nbr 1.1.1.1 on
Serial0/0/0 from LOADING to FULL, Loading Done
R2#
*Apr 19 18:11:06.781: %SYS-5-CONFIG_I: Configured from console
by console
R2#
```

Configuring Multiarea OSPF on R3

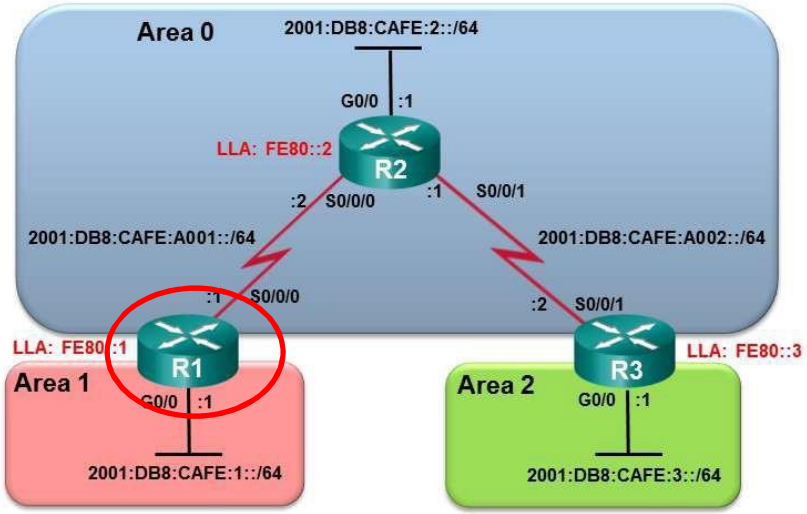



```
R3(config)# router ospf 10
R3(config-router)# router-id 3.3.3.3
R3(config-router)# network 192.168.10.6 0.0.0.3 area 0
R3(config-router)# network 192.168.1.1 0.0.0.0 area 2
R3(config-router)# network 192.168.2.1 0.0.0.0 area 2
R3(config-router)# end
*Apr 19 18:12:55.881: %OSPF-5-ADJCHG: Process 10, Nbr
2.2.2.2 on Serial0/0/1 from LOADING to FULL, Loading Done
R3#
```

OSPFv3 Topology

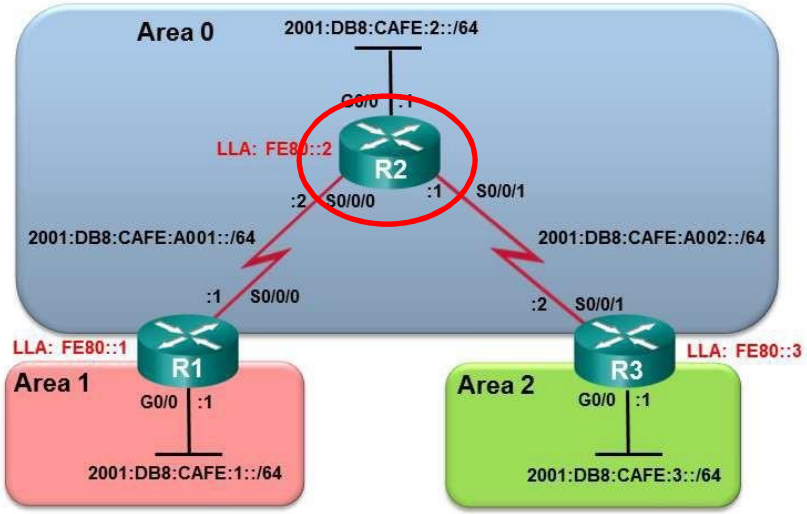


Configuring Multiarea OSPFv3 on R1



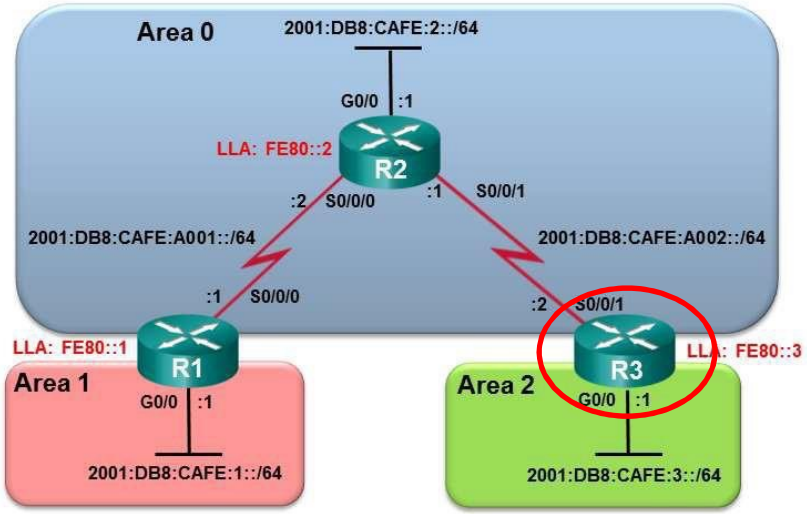

```
R1(config)# ipv6 router ospf 10
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)# exit
R1(config)#
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# ipv6 ospf 10 area 1
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)# end
R1#
```

Configuring Multiarea OSPFv3 on R2




```
R2(config)# ipv6 router ospf 10
*Apr 24 14:18:10.463: %OSPFv3-4-NORTRID: Process OSPFv3-10-IPv6
could not pick a router-id, please configure manually
R2(config-rtr)# router-id 2.2.2.2
R2(config-rtr)# exit
R2(config)# interface g0/0
R2(config-if)# ipv6 ospf 10 area 0
R2(config-if)# interface s0/0/0
R2(config-if)# ipv6 ospf 10 area 0
R2(config-if)# interface s0/0/1
R2(config-if)# ipv6 ospf 10 area 0
R2(config-if)# end
```

Configuring Multiarea OSPFv3 on R3



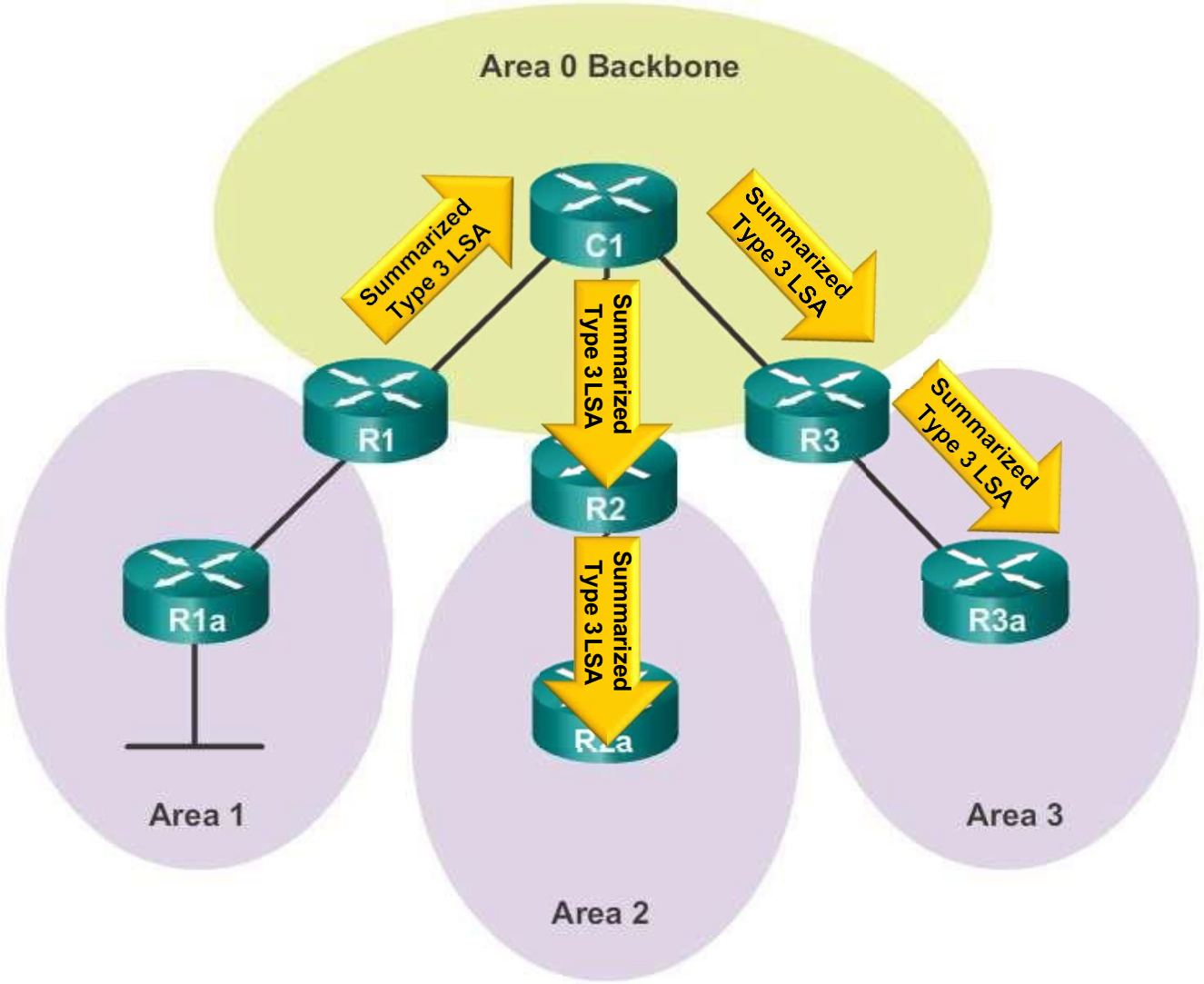

```
R3(config)# ipv6 router ospf 10
*Apr 24 14:20:42.463: %OSPFv3-4-NORTRID: Process OSPFv3-10-IPv6
could not pick a router-id, please configure manually
R3(config-rtr)# router-id 3.3.3.3
R3(config-rtr)# exit
R3(config)#
R3(config)# interface g0/0
R3(config-if)# ipv6 ospf 10 area 2
R3(config-if)# interface s0/0/1
R3(config-if)# ipv6 ospf 10 area 0
R3(config-if)# end
R3#
```

Configuring OSPF Route Summarization

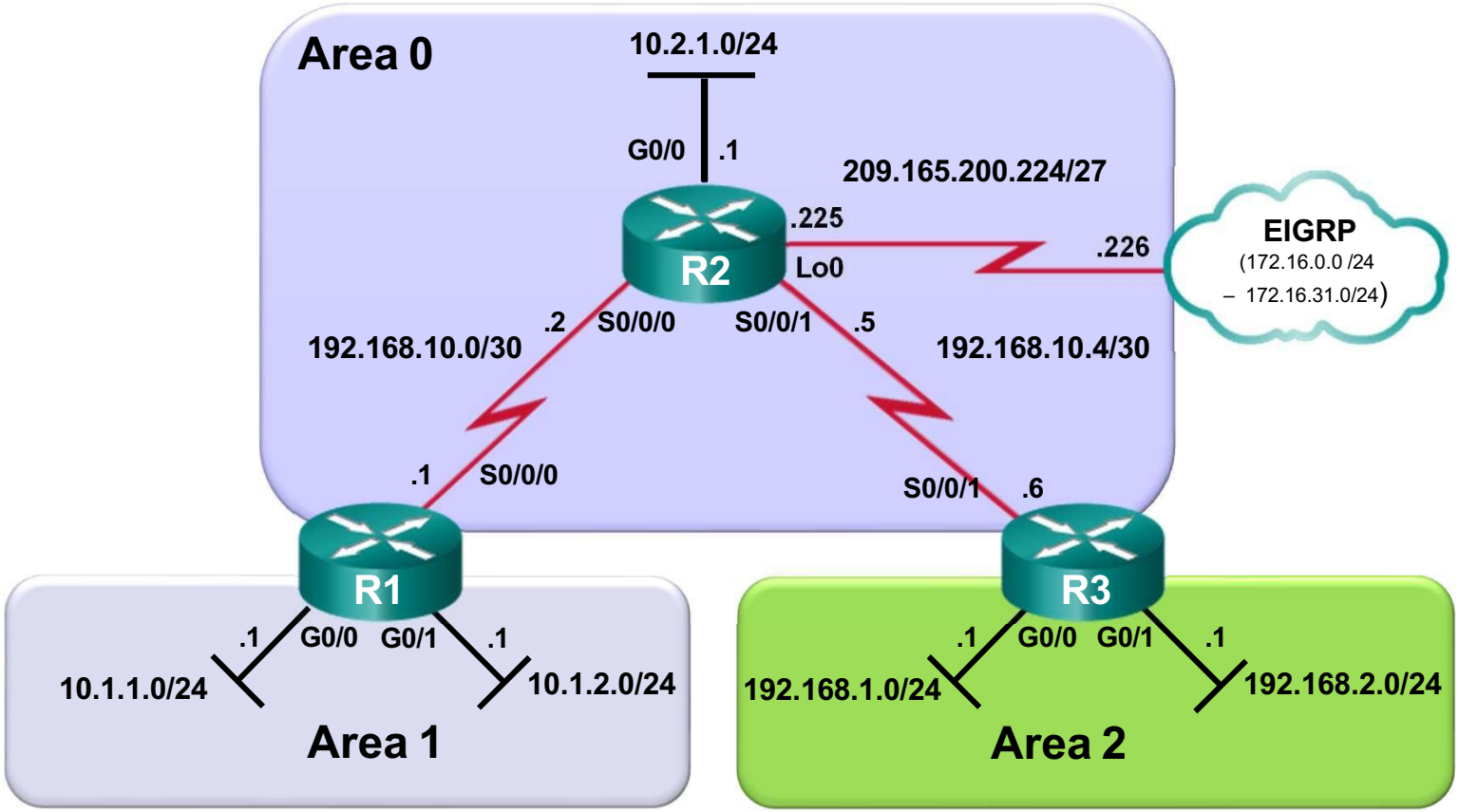
Why Summarize?

- Summarization helps keep routing tables small.
- Involves consolidating multiple routes into a single advertisement, which can then be propagated into the backbone area.
- Normally, type 1 and type 2 LSAs are generated inside each area, translated into type 3 LSAs, and sent to other areas.
  - If Area 1 had 30 networks to advertise, 30 type 3 LSAs would be forwarded into the backbone.
  - With route summarization, the ABR consolidates the 30 networks into one or a few advertisements.

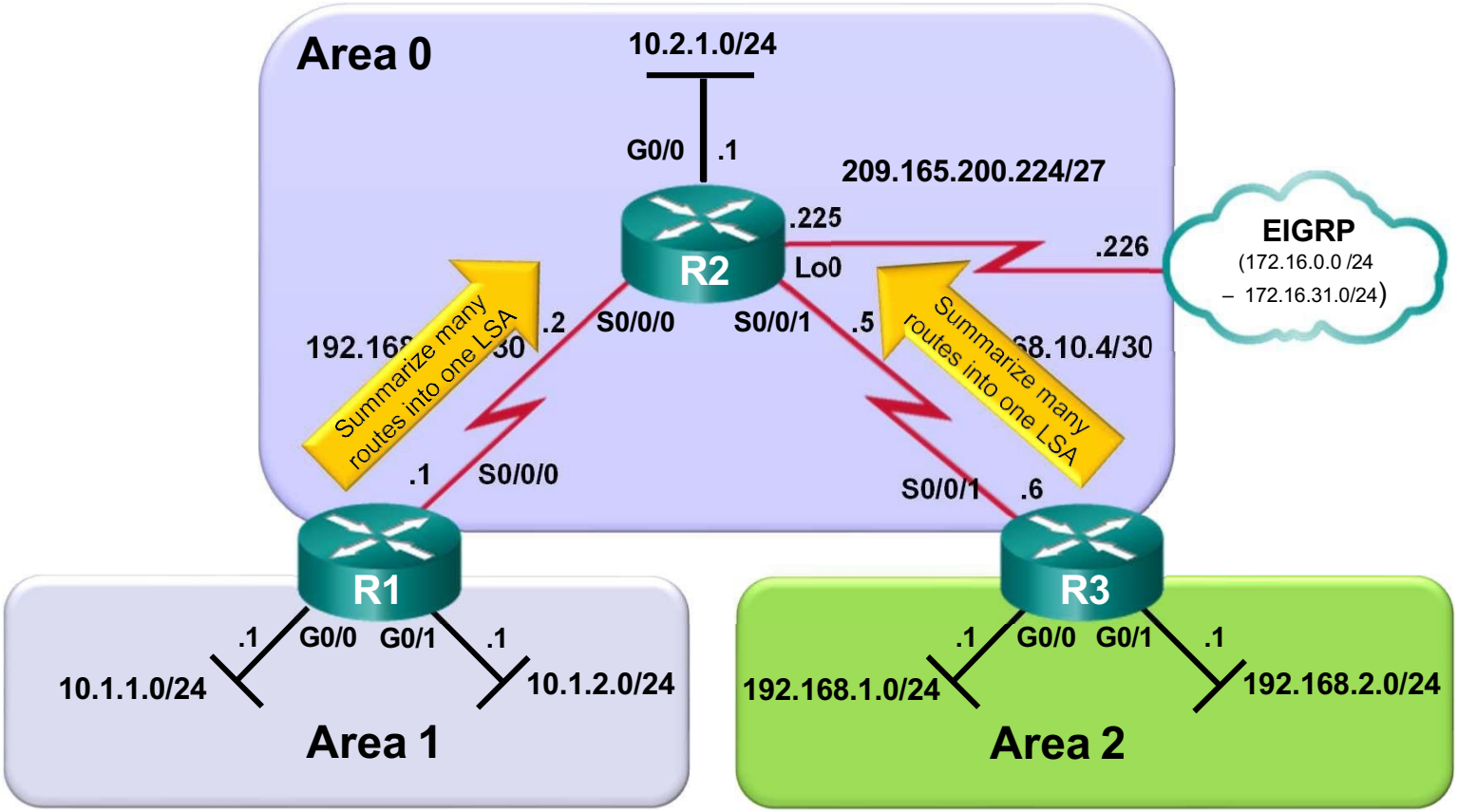
Propagating a Summary Route



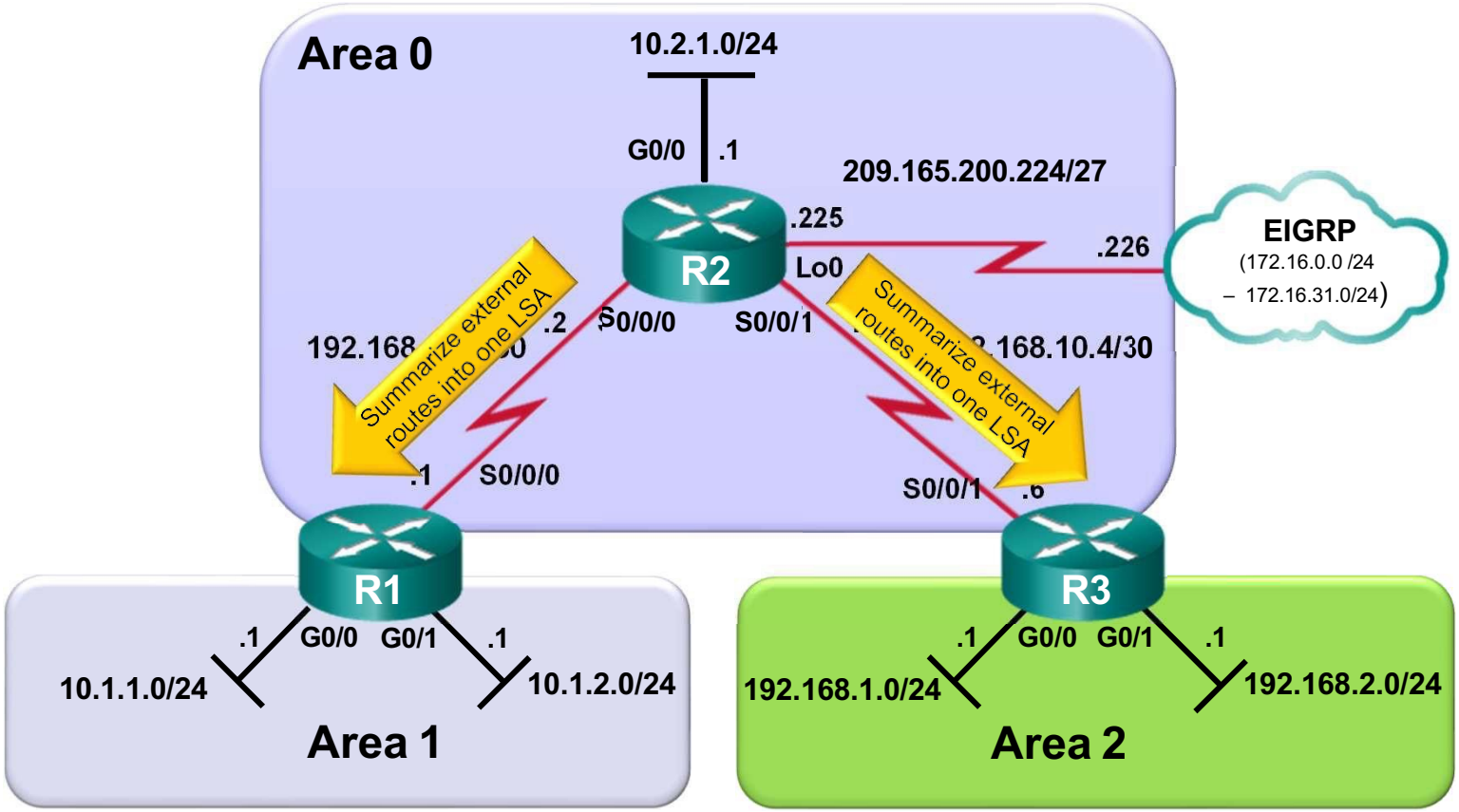
OSPF Route Summarization Topology



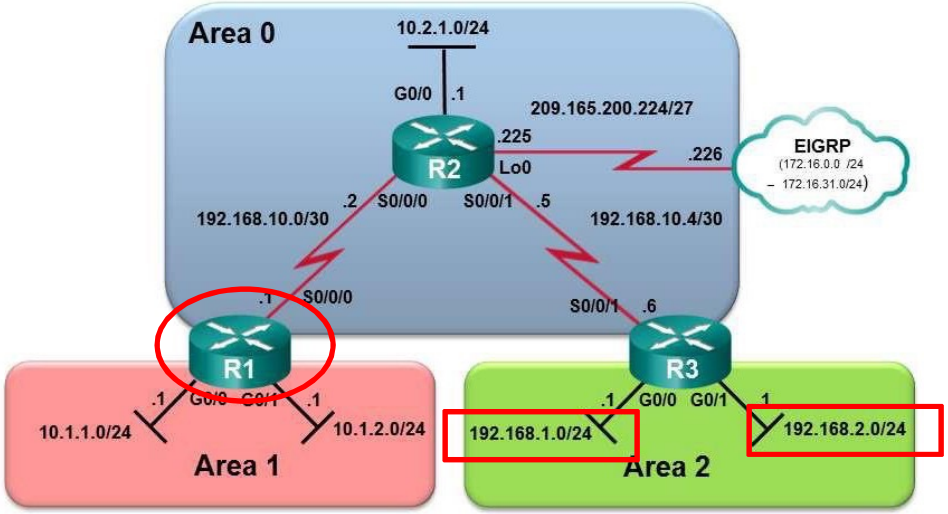
Interarea Route Summarization



External Route Summarization

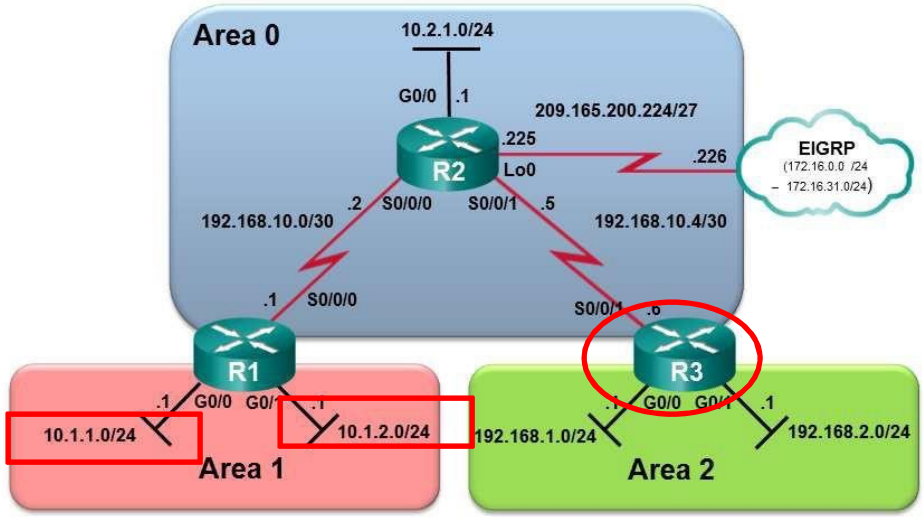


R1 Routing Table Before Summarization




```
R1# show ip route ospf | begin Gateway
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
O        10.2.1.0/24 [110/648] via 192.168.10.2, 00:00:49, Serial0/0/0
O IA  192.168.1.0/24 [110/1295] via 192.168.10.2, 00:00:49, Serial0/0/0
O IA  192.168.2.0/24 [110/1295] via 192.168.10.2, 00:00:49, Serial0/0/0
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O        192.168.10.4/30 [110/1294] via 192.168.10.2, 00:00:49, Serial0/0/0
R1#
```

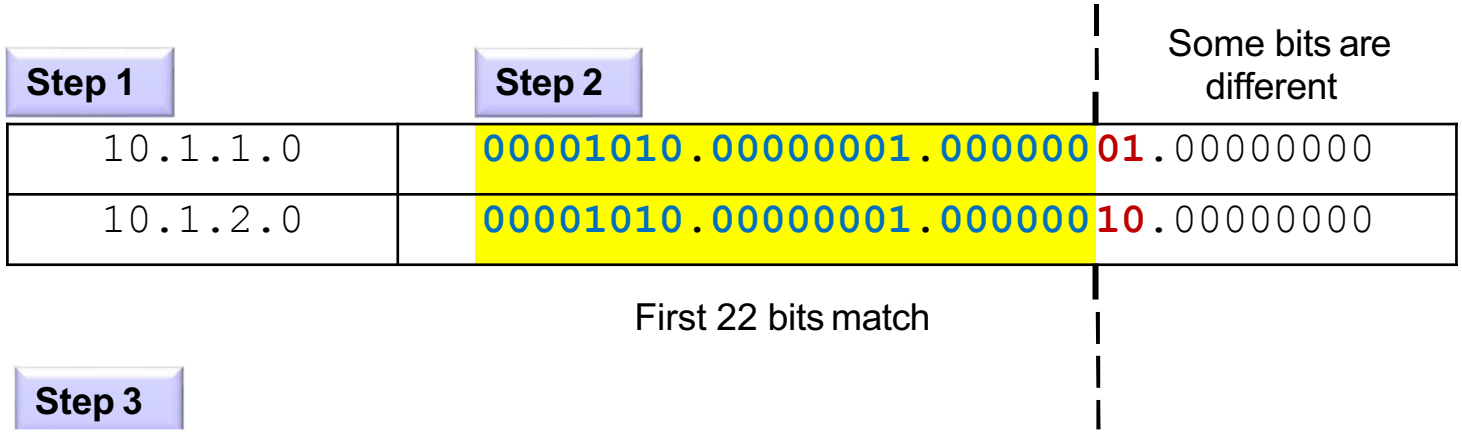
R3 Routing Table Before Summarization




```
R3# show ip route ospf | begin Gateway
Gateway of last resort is not set

      10.0.0.0/24 is subnetted, 3 subnets
O IA     10.1.1.0 [110/1295] via 192.168.10.5, 00:27:14, Serial0/0/1
O IA     10.1.2.0 [110/1295] via 192.168.10.5, 00:27:14, Serial0/0/1
O        10.2.1.0 [110/648] via 192.168.10.5, 00:27:57, Serial0/0/1
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O        192.168.10.0/30 [110/1294] via 192.168.10.5, 00:27:57, Serial0/0/1
R3#
```

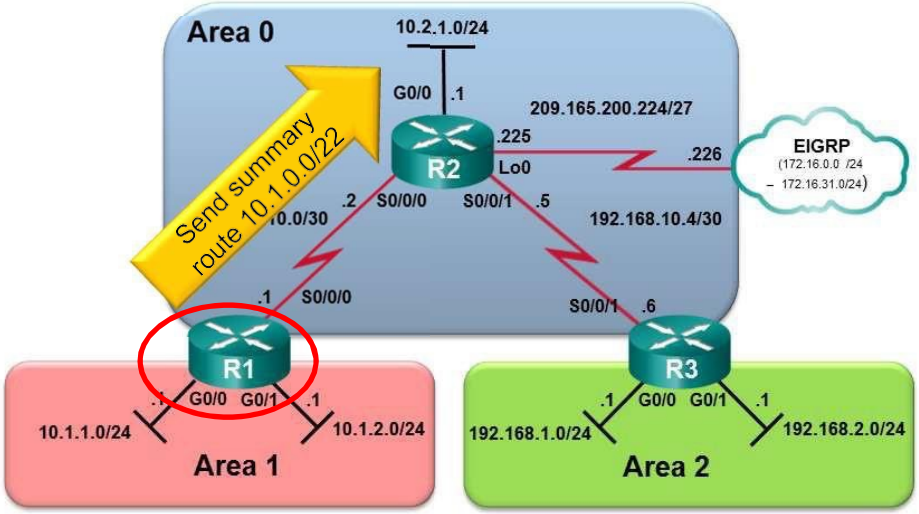
3 Steps to Calculating the Summary Route

1. List the networks in binary format.
2. Count the number of far left matching bits to determine the mask for the summary route.
3. Copy the matching bits and then add zero bits to determine the summarized network address.



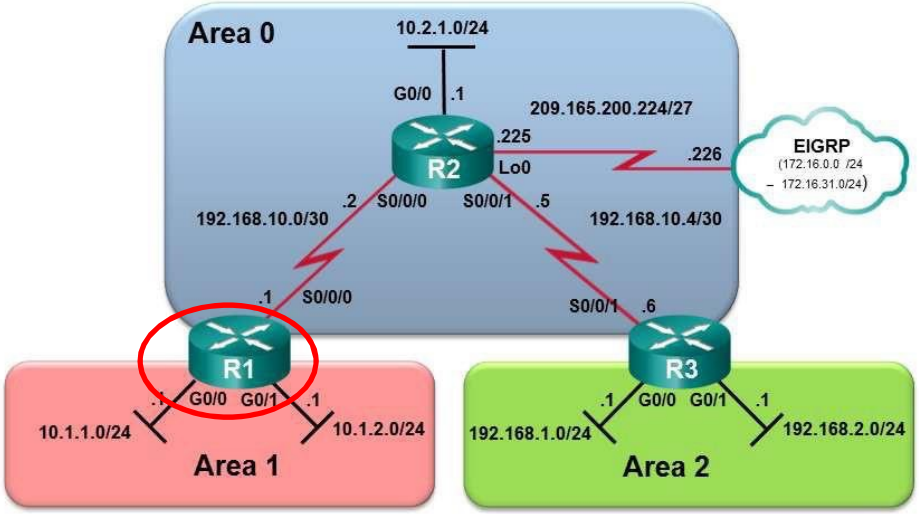
10.1.0.0/22 or **10.1.0.0 255.255.252.000**

Summarizing Area 1 Routes on R1



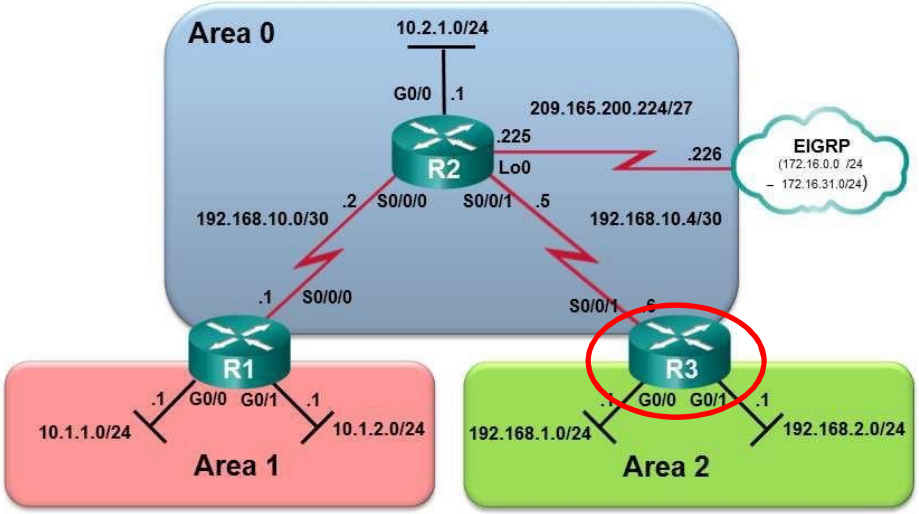

```
R1(config)# router ospf 10
R1(config-router)# area 1 range 10.1.0.0 255.255.252.0
R1(config-router)#
```

R1 Routing Table After Summarization



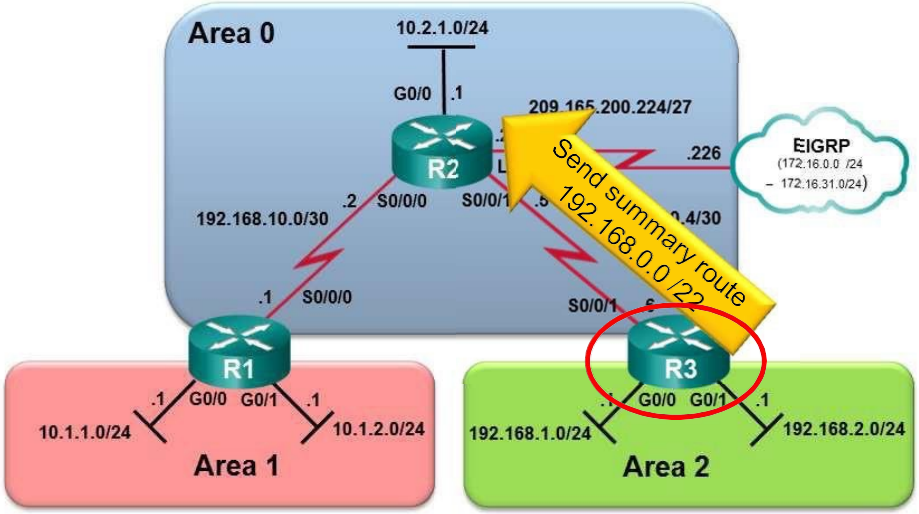

```
R1# show ip route ospf | begin Gateway
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 6 subnets, 3 masks
O        10.1.0.0/22 is a summary, 00:00:09, Null0
O        10.2.1.0/24 [110/648] via 192.168.10.2, 00:00:09, Serial0/0/0
O IA  192.168.1.0/24 [110/1295] via 192.168.10.2, 00:00:09, Serial0/0/0
O IA  192.168.2.0/24 [110/1295] via 192.168.10.2, 00:00:09, Serial0/0/0
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O        192.168.10.4/30 [110/1294] via 192.168.10.2, 00:00:09, Serial0/0/0
R1#
```

R3 Routing Table After Summarization




```
R3# show ip route ospf | begin Gateway
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O IA     10.1.0.0/22 [110/1295] via 192.168.10.5, 00:00:06, Serial0/0/1
O        10.2.1.0/24 [110/648] via 192.168.10.5, 00:29:23, Serial0/0/1
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O        192.168.10.0/30 [110/1294] via 192.168.10.5, 00:29:23, Serial0/0/1
R3#
```

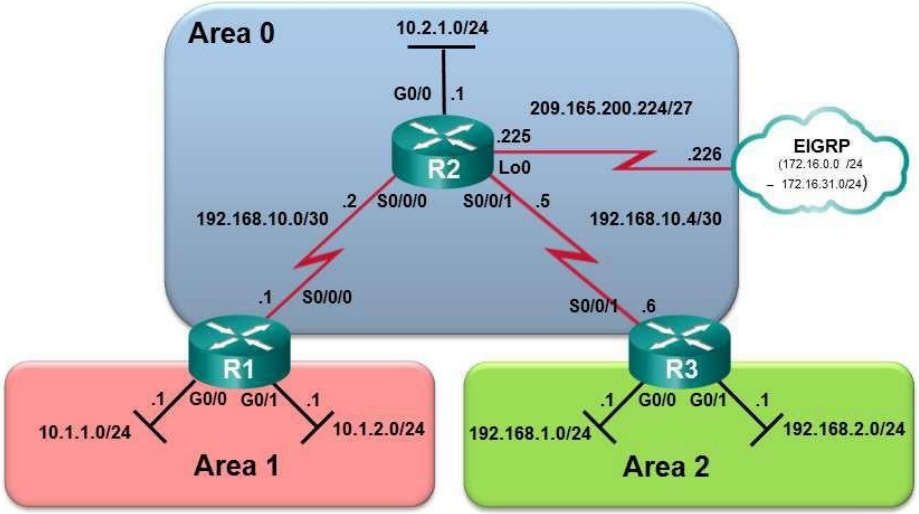
Summarizing Area 2 Routes on R3




```
R3(config)# router ospf 10
R3(config-router)# area 2 range 192.168.0.0 255.255.252.0
R3(config-router)# end
R3#
R3# show ip route ospf | begin Gateway

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O IA     10.1.0.0/22 [110/1295] via 192.168.10.5, 00:01:07, Serial0/0/1
O        10.2.1.0/24 [110/648] via 192.168.10.5, 00:01:07, Serial0/0/1
O     192.168.0.0/22 is a summary, 00:01:07, Null0
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O        192.168.10.0/30 [110/1294] via 192.168.10.5, 00:01:07, Serial0/0/1
R3#
```

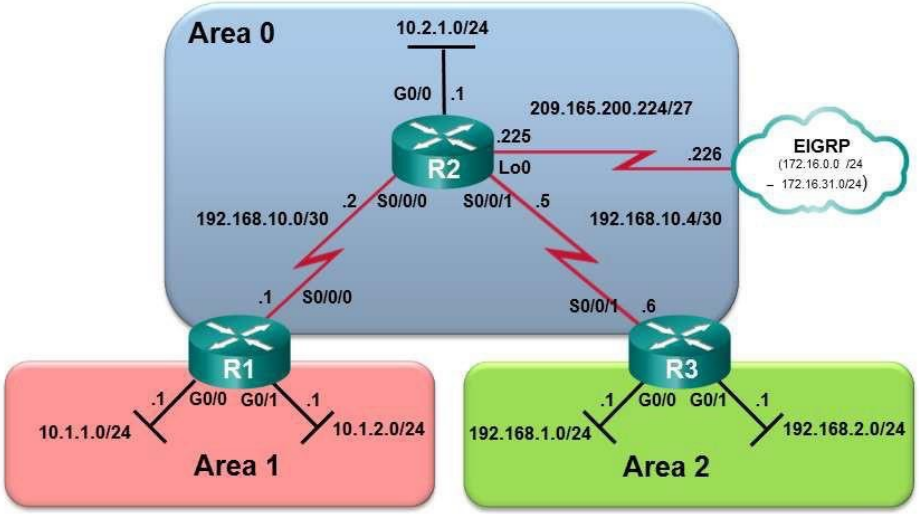
Verifying Multiarea OSPF

Verifying OSPF Status on R1



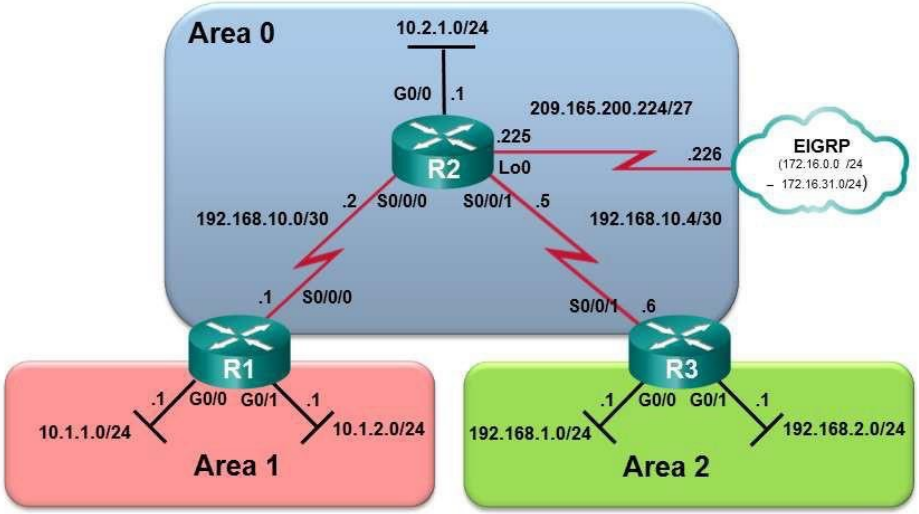

```
R1# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 10"
  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:
    10.1.1.1 0.0.0.0 area 1
    10.1.2.1   0.0.0.0   area   1
    192.168.10.1 0.0.0.0 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      02:20:36
    2.2.2.2              110      02:20:39
  Distance: (default is 110)
R1#
```

Verifying OSPF Enabled Interface on R1




```
R1# show ip ospf interface brief
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Se0/0/0      10    0               192.168.10.1/30    64    P2P   1/1
Gi0/1        10    1               10.1.2.1/24        1     DR    0/0
Gi0/0        10    1               10.1.1.1/24        1     DR    0/0
R1#
```

Verifying OSPF Routes on R1

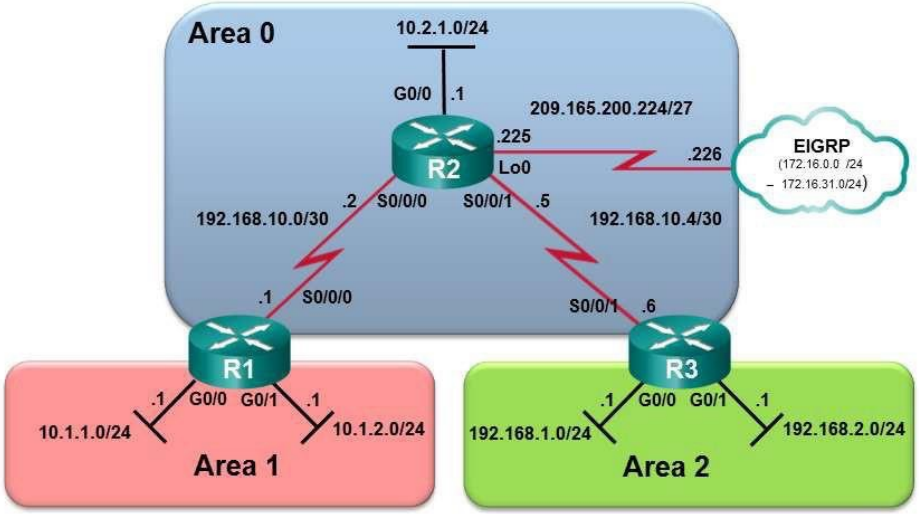



```
R1# show ip route ospf | begin Gateway
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
O        10.2.1.0/24 [110/648] via 192.168.10.2, 00:26:03, Serial0/0/0
O IA  192.168.1.0/24 [110/1295] via 192.168.10.2, 00:26:03, Serial0/0/0
O IA  192.168.2.0/24 [110/1295] via 192.168.10.2, 00:26:03, Serial0/0/0
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O        192.168.10.4/30 [110/1294] via 192.168.10.2, 00:26:03, Serial0/0/0
R1#
```

Verifying the OSPF LSDB on R1

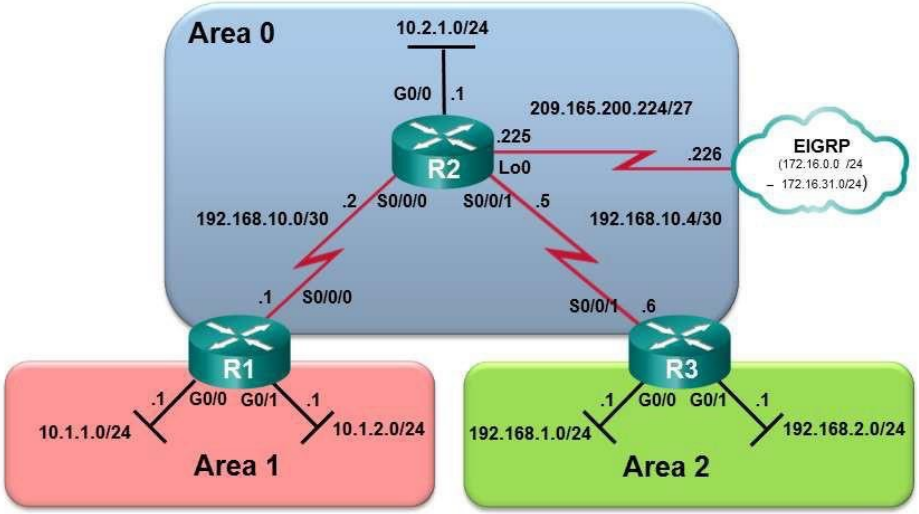
```
R1# show ip ospf database

            OSPF Router with ID (1.1.1.1) (Process ID 10)

                    Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         725         0x80000005 0x00F9B0 2
2.2.2.2         2.2.2.2         695         0x80000007 0x003DB1 5
3.3.3.3         3.3.3.3         681         0x80000005 0x00FF91 2

                    Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.1.0        1.1.1.1         725         0x80000006 0x00D155
10.1.2.0        1.1.1.1         725         0x80000005 0x00C85E
192.168.1.0     3.3.3.3         681         0x80000006 0x00724E
192.168.2.0     3.3.3.3         681         0x80000005 0x006957

                    Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         725         0x80000006 0x007D7C 2

                    Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.2.1.0        1.1.1.1         725         0x80000005 0x004A9C
192.168.1.0     1.1.1.1         725         0x80000005 0x00B593
192.168.2.0     1.1.1.1         725         0x80000005 0x00AA9D
192.168.10.0    1.1.1.1         725         0x80000005 0x00B3D0
192.168.10.4    1.1.1.1         725         0x80000005 0x000E32
R1#
```

Verifying OSPF Status on R2



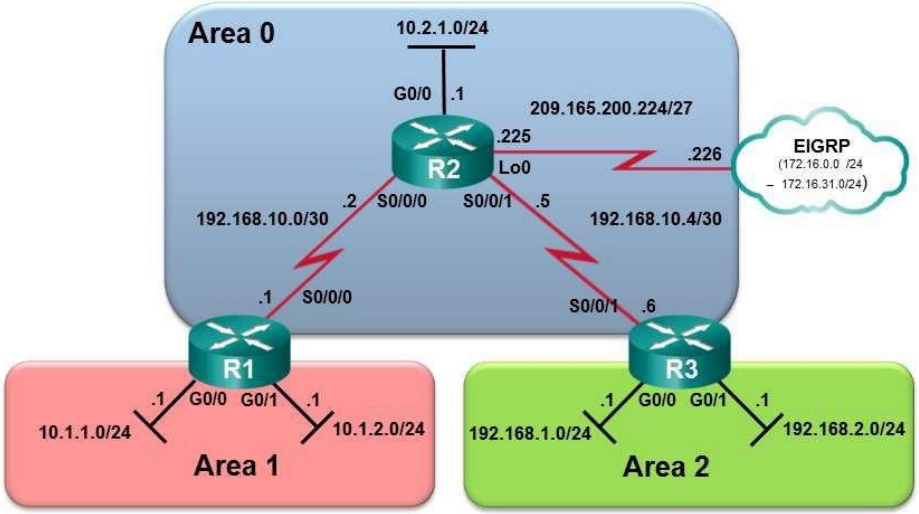

```
R2# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 10"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 2.2.2.2
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.2.1.0  0.0.0.255  area  0
    192.168.10.0 0.0.0.7 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      00:05:34
    1.1.1.1              110      00:05:34
   Distance:  (default is 110)

R2#
```

Verifying OSPF Enabled Interface on R2




```
R2# show ip ospf in  terface bri ef
Interface     PID     Area            IP Address/Mask     Cost   State Nbrs F/C
Se0/0/1       10      0               192.168.10.5/30     647    P2P   1/1
Se0/0/0       10      0               192.168.10.2/30     647    P2P   1/1
Gi0/0         10      0               10.2.1.1/24         1      DR    0/0
R2#
```

Verifying OSPF Routes on R2

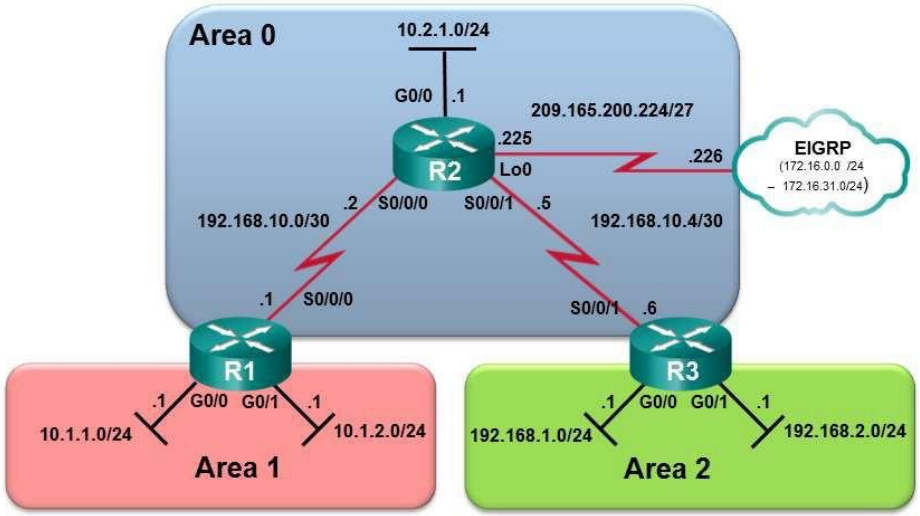



```
R2# show ip route ospf | begin Gateway

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
O  IA  10.1.1.0/24  [110/648]  via  192.168.10.1,  00:07:52,  Serial0/0/0
O IA 10.1.2.0/24 [110/648] via 192.168.10.1, 00:07:52, Serial0/0/0  O
IA 192.168.1.0/24 [110/648] via 192.168.10.6, 00:07:52, Serial0/0/1  O
IA
192.168.2.0/24 [110/648] via 192.168.10.6, 00:07:52, Serial0/0/1  R2#
```

Verifying the OSPF LSDB on R2

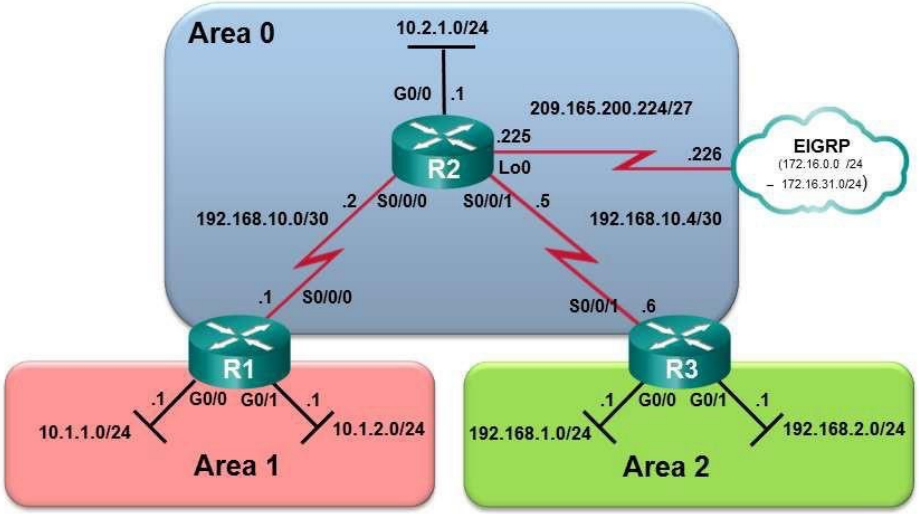
```
R2# show ip ospf database

            OSPF Router with ID (2.2.2.2) (Process ID 10)

                    Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1          843        0x80000002 0x00B961 2
2.2.2.2         2.2.2.2          839        0x80000004 0x007458 5
3.3.3.3         3.3.3.3          834        0x80000002 0x00BF42 2

                    Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.1.0        1.1.1.1         117         0x80000002 0x00D951
10.1.2.0        1.1.1.1         117         0x80000002 0x00CE5B
192.168.1.0     3.3.3.3         103         0x80000003 0x00784B
192.168.2.0     3.3.3.3         103         0x80000002 0x006F54
R2#
```

Verifying OSPF Status on R3



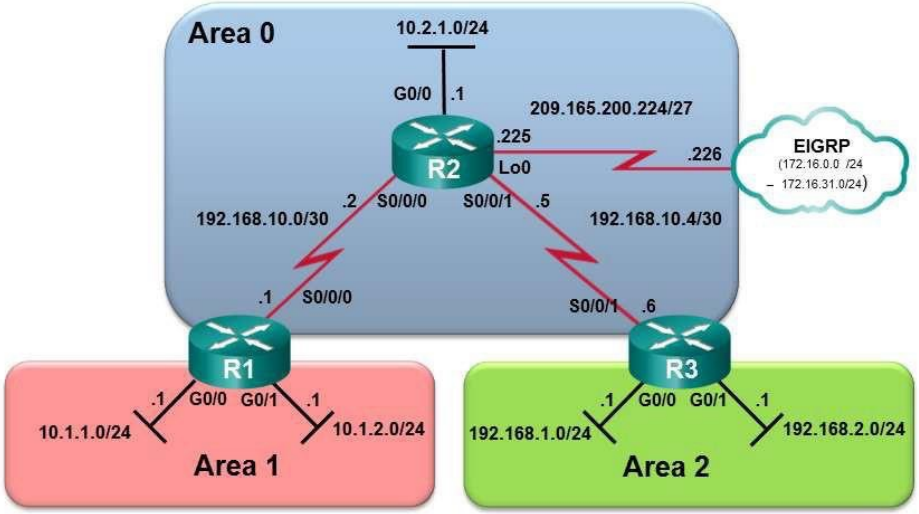

```
R3# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 10"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 3.3.3.3
  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:
    192.168.1.1 0.0.0.0 area 2
    192.168.2.1 0.0.0.0 area 2
    192.168.10.4 0.0.0.3 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    1.1.1.1              110      00:06:25
    2.2.2.2              110      00:06:25
  Distance: (default is 110)
R3#
```

Verifying OSPF Enabled Interface on R3




```
R3# show ip ospf interface brief
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Se0/0/1      10    0               192.168.10.6/30    647   P2P   1/1
Gi0/1        10    2               192.168.2.1/24     1     DR    0/0
Gi0/0        10    2               192.168.1.1/24     1     DR    0/0
R3#
```

Verifying OSPF Routes on R3

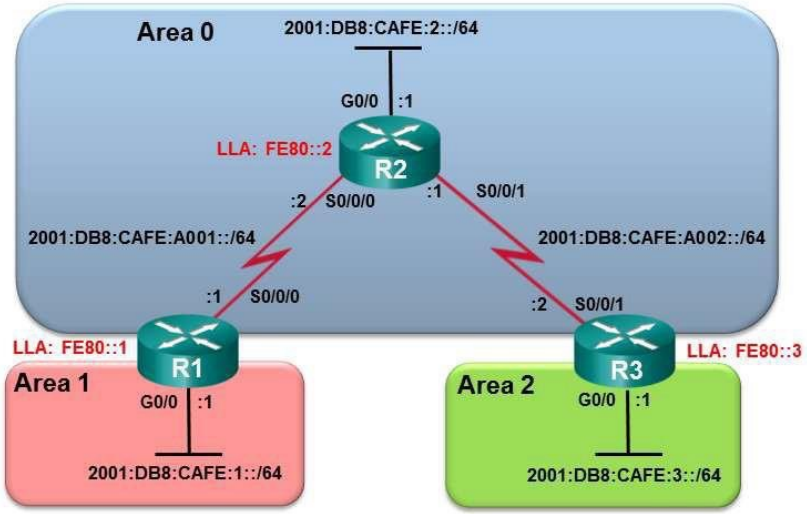



```
R3# show ip route ospf | begin Gateway

Gateway of last resort is not set

      10.0.0.0/24 is subnetted, 3 subnets
O IA     10.1.1.0 [110/1295] via 192.168.10.5, 00:12:36, Serial0/0/1
O IA     10.1.2.0 [110/1295] via 192.168.10.5, 00:12:36, Serial0/0/1
O        10.2.1.0 [110/648] via 192.168.10.5, 00:12:36, Serial0/0/1
      192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O        192.168.10.0/30 [110/1294] via 192.168.10.5, 00:12:36, Serial0/0/1
R3#
```

Verifying the OSPF LSDB on R3

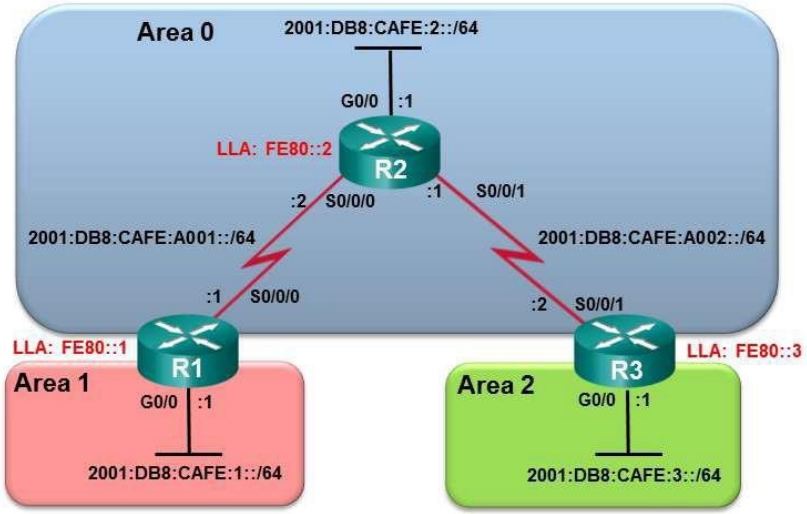
```
R3# show ip ospf database

            OSPF Router with ID (3.3.3.3) (Process ID 10)

                    Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         904         0x80000002 0x00B961 2
2.2.2.2         2.2.2.2         900         0x80000004 0x007458 5
3.3.3.3         3.3.3.3         893         0x80000002 0x00BF42 2

                    Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.1.0        1.1.1.1         178         0x80000002 0x00D951
10.1.2.0        1.1.1.1         178         0x80000002 0x00CE5B
192.168.1.0     3.3.3.3         162         0x80000003 0x00784B
192.168.2.0     3.3.3.3         162         0x80000002 0x006F54

                    Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
3.3.3.3         3.3.3.3         162         0x80000003 0x00CF60 2

                    Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.1.0        3.3.3.3         892         0x80000003 0x0055B9
10.1.2.0        3.3.3.3         892         0x80000003 0x004AC3
10.2.1.0        3.3.3.3         892         0x80000002 0x00EEA9
192.168.10.0    3.3.3.3         892         0x80000003 0x00B2F8
192.168.10.4    3.3.3.3         892         0x80000002 0x003002
R3#
```

Verifying Multiarea OSPFv3 Status on R1



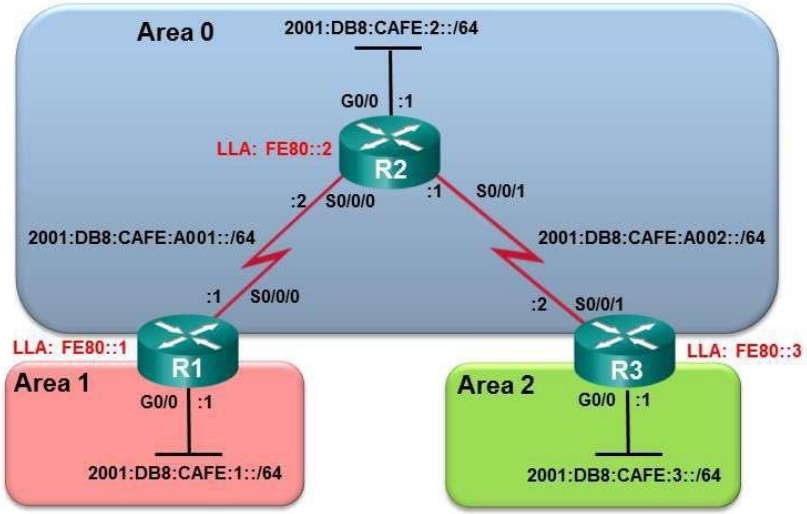

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Area border router
  Number of areas: 2 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Serial0/0/0
  Interfaces (Area 1):
    GigabitEthernet0/0
  Redistribution:
    None
R1#
```

Verifying OSPFv3 Enabled Interface on R1




```
R1# show ipv6 ospf interface brief
Interface    PID   Area            Intf ID    Cost  State Nbrs F/C
Se0/0/0      10    0               6          647   P2P   1/1
Gi0/0        10    1               3          1     DR    0/0
R1#
```

Verifying OSPFv3 Routes on R1




```
R1# show ipv6 route ospf
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static
       route B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
O   2001:DB8:CAFE:2::/64 [110/648]
     via FE80::2, Serial0/0/0
OI  2001:DB8:CAFE:3::/64 [110/1295]
     via FE80::2, Serial0/0/0
O   2001:DB8:CAFE:A002::/64 [110/1294]
     via FE80::2, Serial0/0/0
R1#
```

Verifying the OSPF LSDB on R1

```
R1# show ipv6 ospf database

            OSPFv3 Router with ID (1.1.1.1) (Process ID 10)

                    Router Link States (Area 0)

ADV Router       Age         Seq#         Fragment ID  Link count  Bits
 1.1.1.1         1617        0x80000002   0            1           B
 2.2.2.2         1484        0x80000002   0            2           None
 3.3.3.3         1485        0x80000001   0            1           B

                    Inter Area Prefix Link States (Area 0)

ADV Router       Age         Seq#         Prefix
 1.1.1.1         1833        0x80000001   2001:DB8:CAFE:1::/64
 3.3.3.3         1476        0x80000001   2001:DB8:CAFE:3::/64

                    Link (Type-8) Link States (Area 0)

ADV Router       Age         Seq#         Link ID    Interface
 1.1.1.1         1843        0x80000001   6          Se0/0/0
 2.2.2.2         1619        0x80000001   6          Se0/0/0

                    Intra Area Prefix Link States (Area 0)

ADV Router       Age         Seq#         Link ID    Ref-lstype  Ref-LSID
 1.1.1.1         1843        0x80000001   0          0x2001      0
 2.2.2.2         1614        0x80000002   0          0x2001      0
 3.3.3.3         1486        0x80000001   0          0x2001      0

Continued …
```

Verifying the OSPF LSDB on R1 Cont …

```
Continued ….

                    Router Link States (Area 1)

ADV Router      Age         Seq#         Fragment ID  Link count  Bits
 1.1.1.1        1843        0x80000001   0            0           B

                    Inter Area Prefix Link States (Area 1)

ADV Router      Age         Seq#         Prefix
 1.1.1.1        1833        0x80000001   2001:DB8:CAFE:A001::/64
 1.1.1.1        1613        0x80000001   2001:DB8:CAFE:A002::/64
 1.1.1.1        1613        0x80000001   2001:DB8:CAFE:2::/64
 1.1.1.1        1474        0x80000001   2001:DB8:CAFE:3::/64

                    Link (Type-8) Link States (Area 1)

ADV Router      Age         Seq#         Link ID    Interface
 1.1.1.1        1844        0x80000001   3          Gi0/0

                    Intra Area Prefix Link States (Area 1)

ADV Router      Age         Seq#         Link ID    Ref-lstype  Ref-LSID
 1.1.1.1        1844        0x80000001   0          0x2001      0
R1#
```

Summary

Multiarea OSPF Summary

- Link-state advertisements (LSAs) are the building blocks of OSPF.
  - Type 1 LSAs are referred to as the router link entries.
  - Type 2 LSAs are referred to as the network link entries and are flooded by a DR.
  - Type 3 LSAs are referred to as the summary link entries and are created and propagated by ABRs.
  - A type 4 summary LSA is generated by an ABR only when an ASBR exists within an area.
  - Type 5 external LSAs describe routes to networks outside the OSPF autonomous system, originated by the ASBR, and are flooded to the entire autonomous system.
- SPF tree is used to determine the best paths.
- OSPF routes in an IPv4 routing table are identified using the following descriptors: O, O IA, O E1, or O E2.

Multiarea OSPF Summary (cont.)

- The following example displays a multiarea OSPF configuration:
  - `R1(config)# router ospf 10`
  - `R1(config-router)# router-id 1.1.1.1`
  - `R1(config-router)# network 10.1.1.1 0.0.0.0 area 1`
  - `R1(config-router)# network 10.1.2.1 0.0.0.0 area 1`
  - `R1(config-router)# network 192.168.10.1 0.0.0.0 area 0`
- It does not perform auto summarization but can be manually configured using the summary-address address mask router configuration mode command.

Multiarea OSPF Summary (cont.)

- The following commands are used to verify OSPF configurations:
  - **`show ip ospf neighbor`**
  - **`show ip ospf`**
  - **`show ip ospf interface`**
  - **`show ip protocols`**
  - **`show ip ospf interface brief`**
  - **`show ip route ospf`**
  - **`show ip ospf database`**