Cisco Networking Academy
Mind Wide Open

Multiarea OSPF

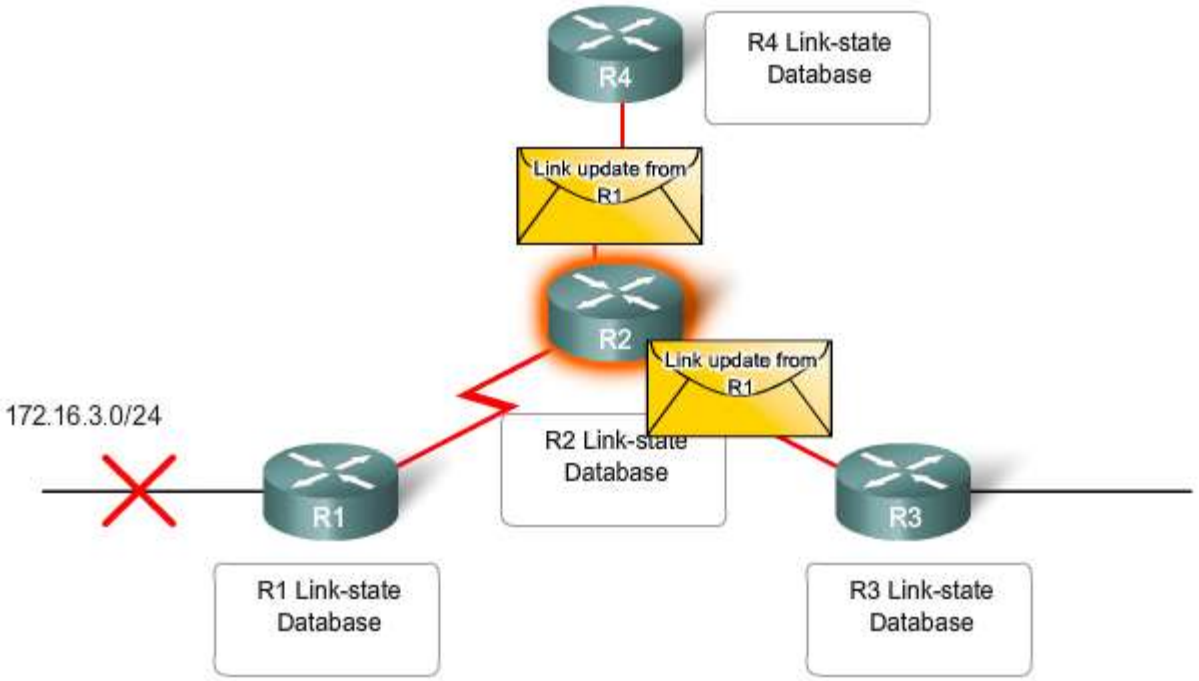
Objectives

- Review OSPF Single Area
- Multiarea OSPF Implementation
- Types of LSAs Exchanged Between Areas
- Configuring Multiarea OSPFv2 and OSPFv3
- Verifying an OSPFv2 and OSPFv3 Configuration
- Review OSPF Key Points

OSPF Single Area - Review

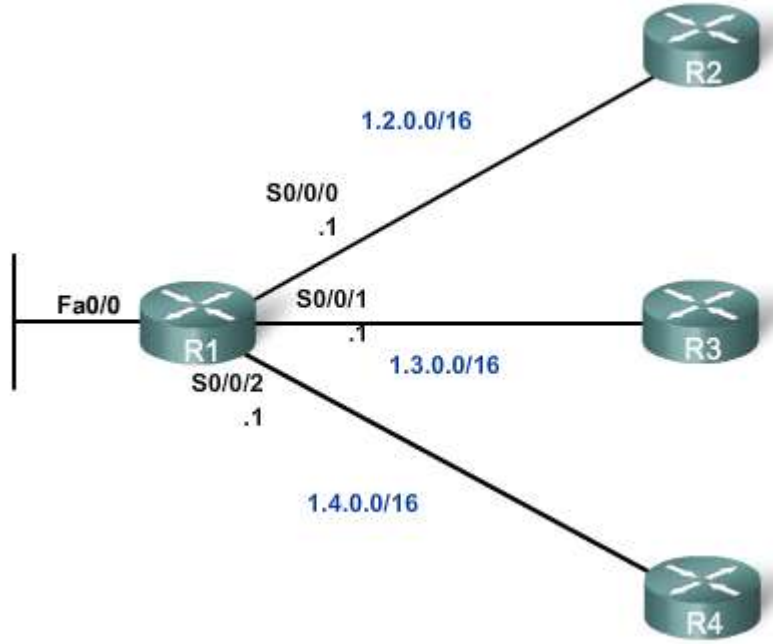
OSPF Single Area - Review

- Link State Routing Protocol
- Faster Convergence
- Cost Metric (Cisco – Bandwidth)
- Identical Link-State Databases (LSDBs)
- SPF – Dijkstra's Algorithm
- Determine Neighbors on Directly-connected links
- Use Link-State Packets (LSP) for each directly-connected link
- Flood LSPs to neighbors



OSPF Packet Types

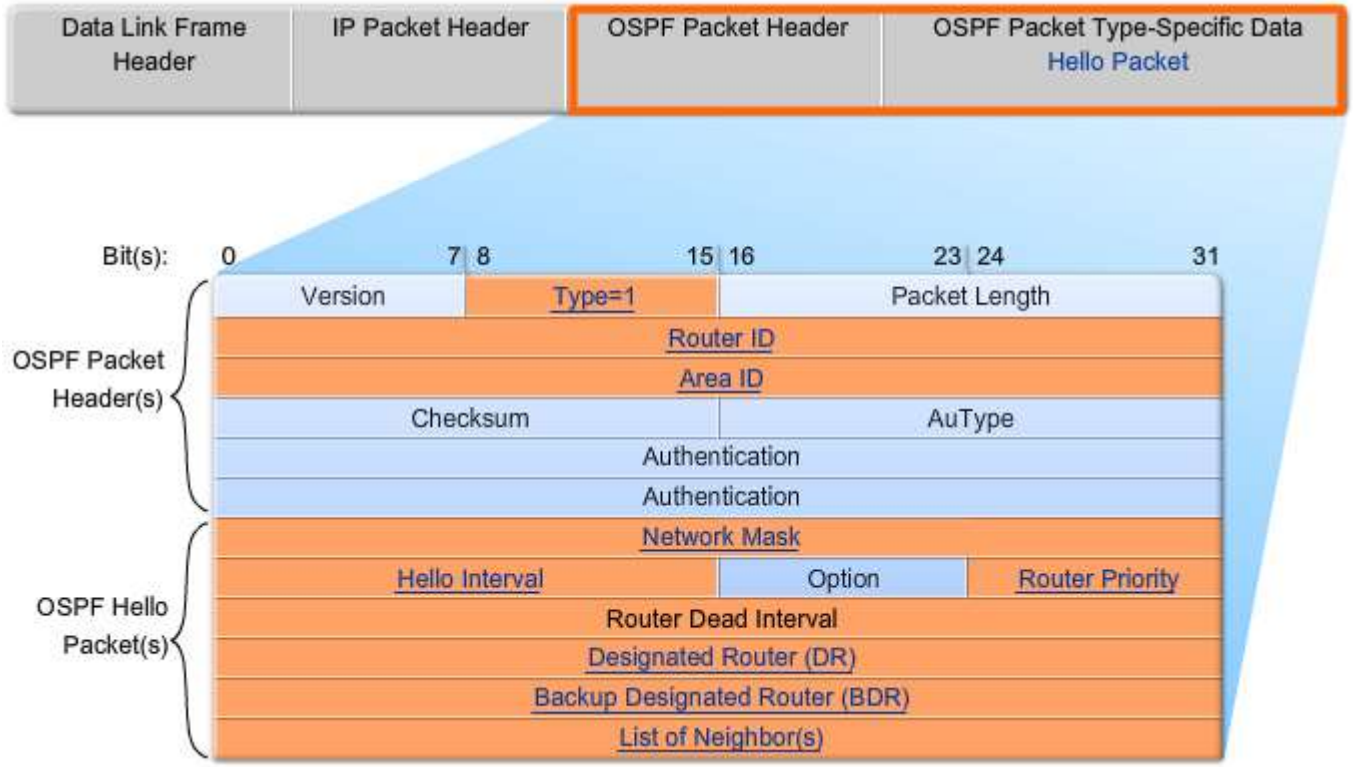
- Type 1 - Hello
- Type 2 - Database Description (DBD)
- Type 3 - Link-State Request (LSR)
- Type 4 - Link-State Update (LSU) – Multiple Types
- Type 5 - Link-State Acknowledgement (LSAck)



Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	Database Description (DBD)	Checks for database synchronization between routers
3	Link-State Request (LSR)	Requests specific link-state records from router to router
4	Link-State Update (LSU)	Sends specifically requested link-state records
5	Link-State Acknowledgement (LSAck)	Acknowledges the other packet types

OSPF – Hello Packet

- Discover OSPF Neighbors
- Establish Neighbor Adjacencies
- Advertise Parameters
  - Hello Interval (Default 10 or 30 seconds)
  - Dead Interval (Default 4 x Hello)
  - Network Type
- Elect DR & BDR (multi-access network)



OSPF – Link State Updates (LSU)

- Link-State Update (LSU)
- Link-State Advertisement (LSA)
- (Interchangeable)
- Multiple LSA Types

LSUs Contain Link-State Advertisements (LSAs)

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	DBD	Checks for database synchronization between router
3	LSR	Requests specific link-state records from router to router
4	LSU	Sends specifically requested link-state records
5	LSAck	Acknowledges the other packet types

- The acronyms LSA and LSU are often used interchangeably.
- An LSU contains one or more LSAs.
- LSAs contain route information for destination networks.
- LSA specifics are discussed in CCNP.

LSA Type	Description
1	Router LSAs
2	Network LSAs
3 or 4	Summary LSAs
5	Autonomous System Extrenal LSAs
6	Multicast OSPF LSAs
7	Defined for Not-So-Stubby Areas
8	External Attributes LSA for Border Gatway Protocol (BGP)
9, 10, 11	Opaque LSAs

Basic OSPF Configuration

R1(config)#int fa 0/0

R1(config-if)#ip address 172.16.1.17 255.255.255.240

R1(config)#int s 0/0/0

R1(config-if)#ip address 192.168.10.1 255.255.255.252

R1(config)#int s 0/0/1

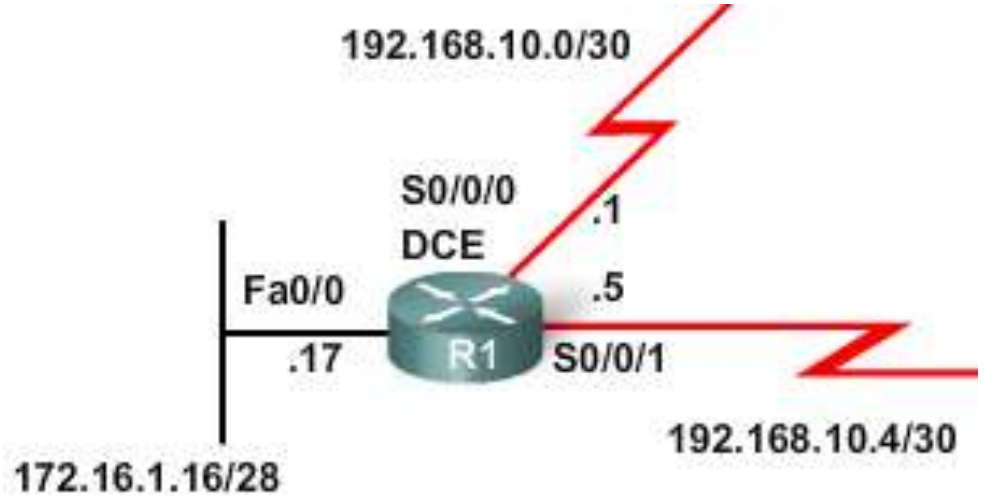
R1(config-if)#ip address 192.168.10.5 255.255.255.252

R1(config-if)#router ospf 1

R1(config-router)#network 172.16.1.16 0.0.0.15 area 0

R1(config-router)#network 192.168.10.0 0.0.0.3 area 0

R1(config-router)#network 192.168.10.4 0.0.0.3 area 0



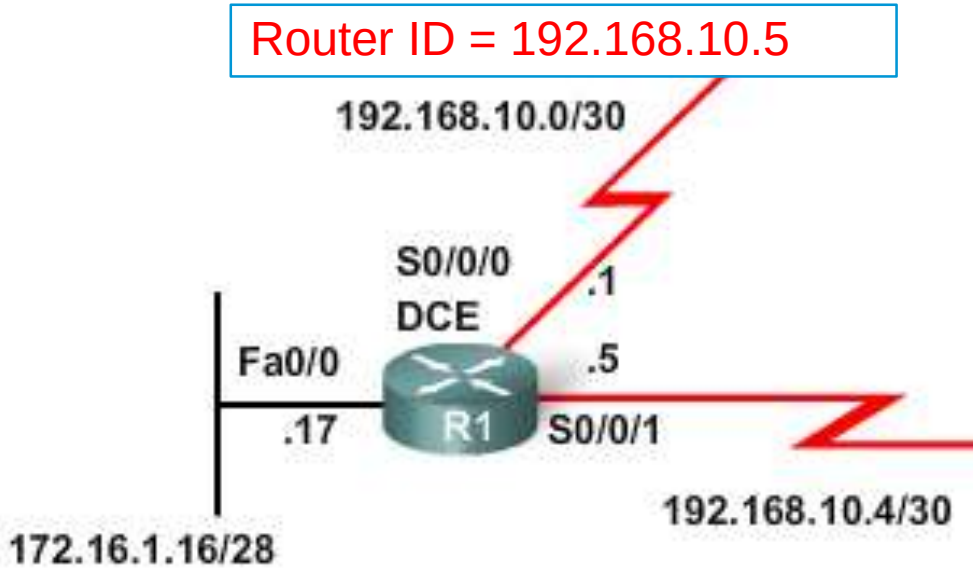
Command syntax:

router ospf *process-id*

network *network-address wildcard-mask* **area** *area-id*

OSPF Router ID

1. Use the IP address configured with the OSPF `router-id` command.
2. If the router-id is not configured, the router chooses highest IP address of any of its loopback interfaces.
3. If no loopback interfaces are configured, the router chooses highest active IP address of any of its physical interfaces.



Verification

```
R1#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.5
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
***output omitted***
```

OSPF Router ID

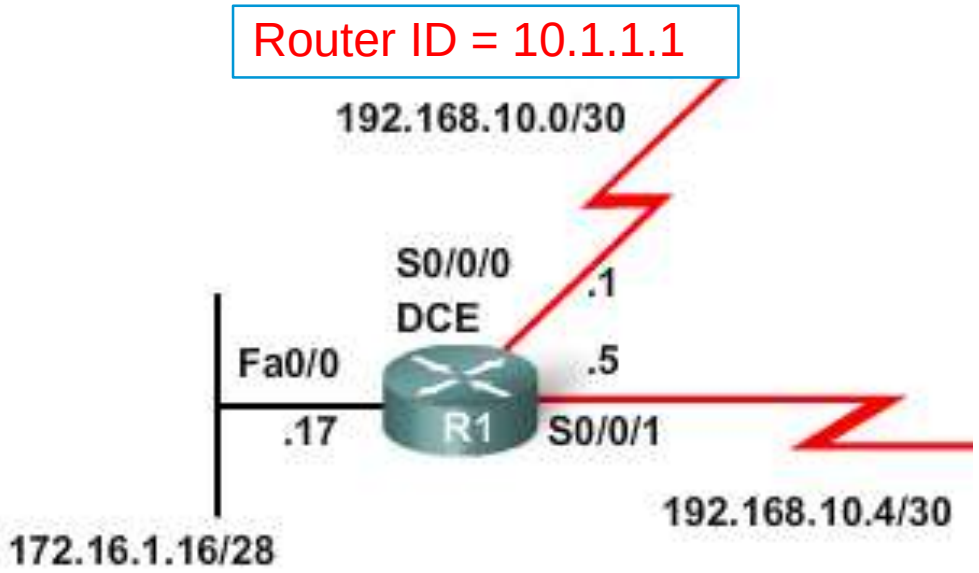
R1(config)#interface loopback 0

R1(config-if)#ip address 10.1.1.1 255.255.255.255

R1(config)#router ospf 1

R1(config-router)#router-id 10.1.1.1

Reload or use "**clear ip ospf process**" command, for this to take effect



Verification

```
R1#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
***output omitted***
```

OSPF Metric - Cost

- Cisco IOS uses the cumulative bandwidths of the outgoing interfaces from the router to the destination network as the cost value
- Cost for an interface is calculated as 10 to the 8th power divided by bandwidth in bps
- Results in interfaces with a bandwidth of 100 Mbps and higher having the same OSPF cost of 1
- Reference bandwidth can be modified to accommodate networks with links faster than 100 Mbps using the OSPF command *auto-cost reference-bandwidth*
- OR – Directly specify the cost for a link:

  R1(config)#interface serial 0/0/0

  R1(config-if)#ip ospf cost 1562

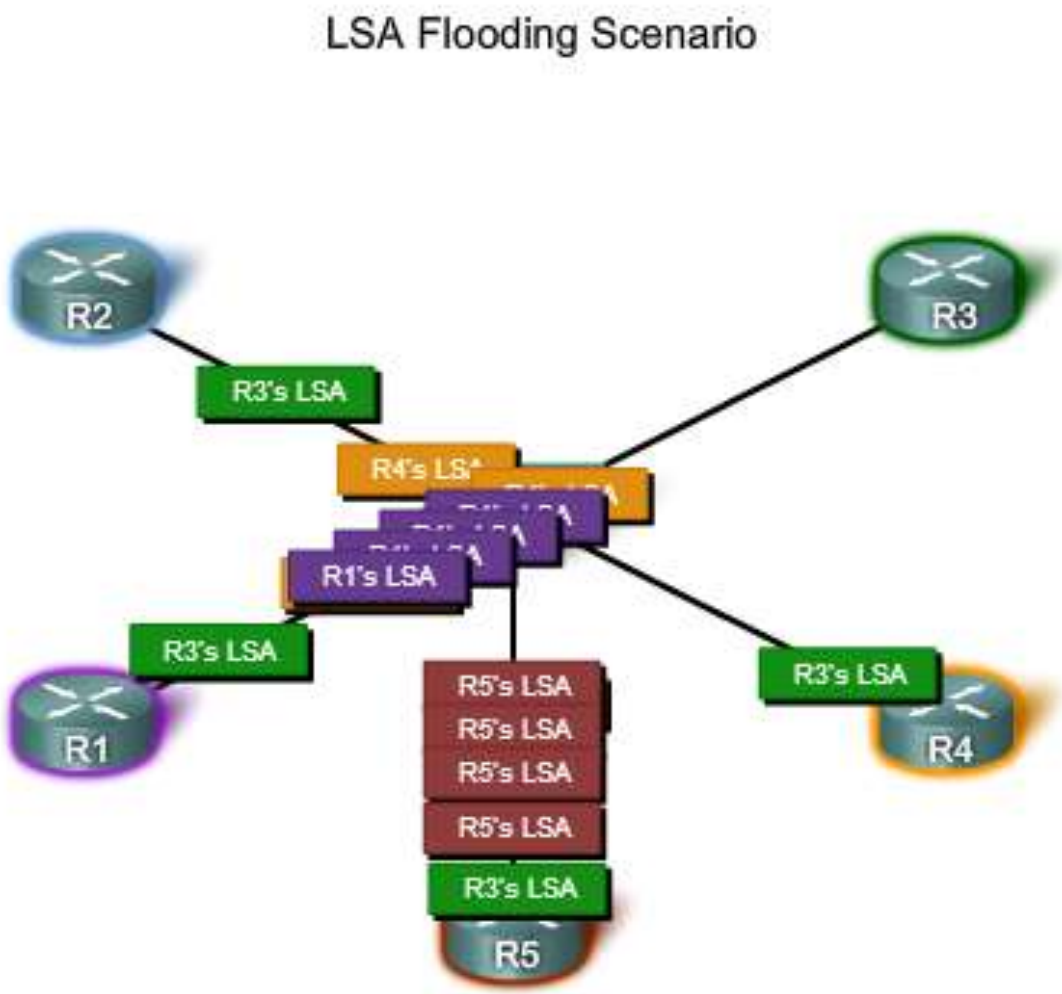
Default Cisco OSPF Cost Values

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
Gigabit Ethernet 10 Gbps	100,000,000	÷	10,000,000,000	1
Gigabit Ethernet 1 Gbps	100,000,000	÷	1,000,000,000	1
Fast Ethernet 100 Mbps	100,000,000	÷	100,000,000	1
Ethernet 10 Mbps	100,000,000	÷	10,000,000	10
Serial 1.544 Mbps	100,000,000	÷	1,544,000	64
Serial 128 kbps	100,000,000	÷	128,000	781
Serial 64 kbps	100,000,000	÷	64,000	1562

Same Cost due to reference bandwidth

OSPF and Multiaccess Networks

- Link-state routers flood their link-state packets when OSPF is initialized or when there is a change in the topology.
- In a multiaccess network this flooding can become excessive.
- On multiaccess networks, OSPF elects a Designated Router (DR) and a Backup Designated Router (BDR) in case the Designated Router fails.
- All other routers become DROthers
- DROthers only form full adjacencies with the DR and BDR in the network, and send their LSAs to the DR and BDR using the multicast address 224.0.0.6 (IPv6 FF02::06)



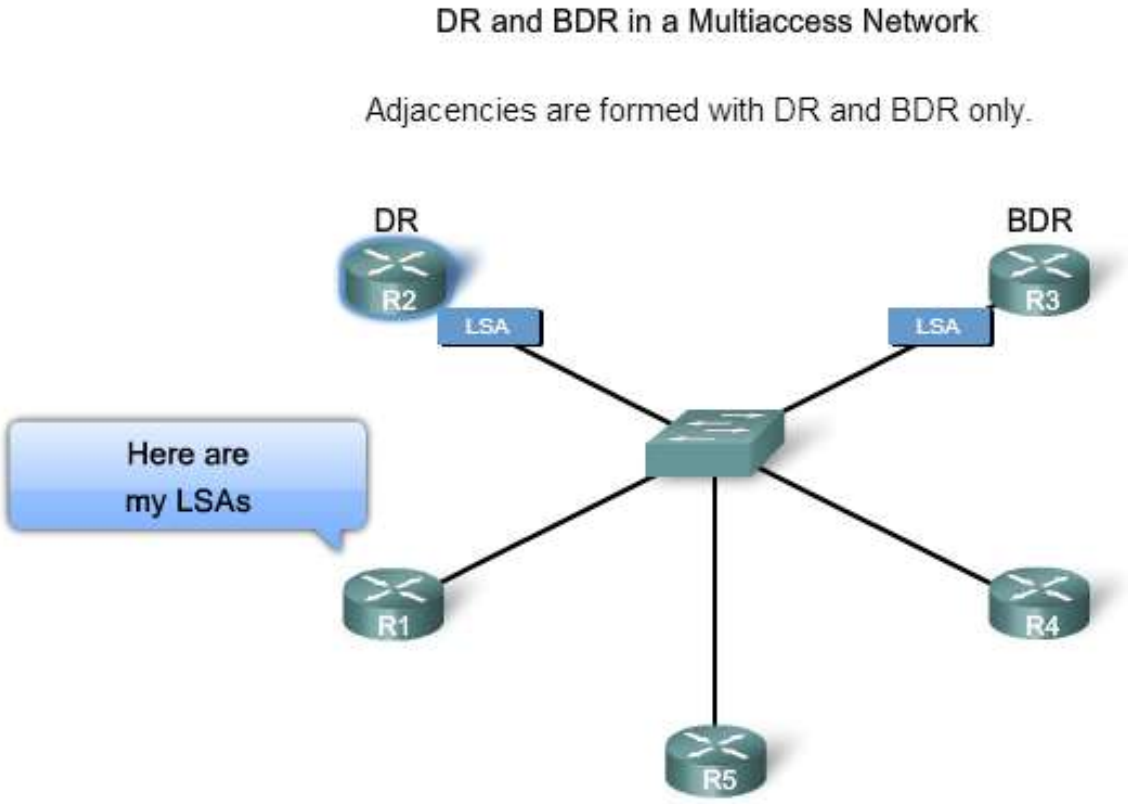
OSPF and Multiaccess Networks

DR/BDR Election

How do the DR and BDR get elected?

The following criteria are applied:

1. DR: Router with the highest OSPF interface priority.
2. BDR: Router with the second highest OSPF interface priority.
3. If OSPF interface priorities are equal, the highest router ID is used to break the tie.



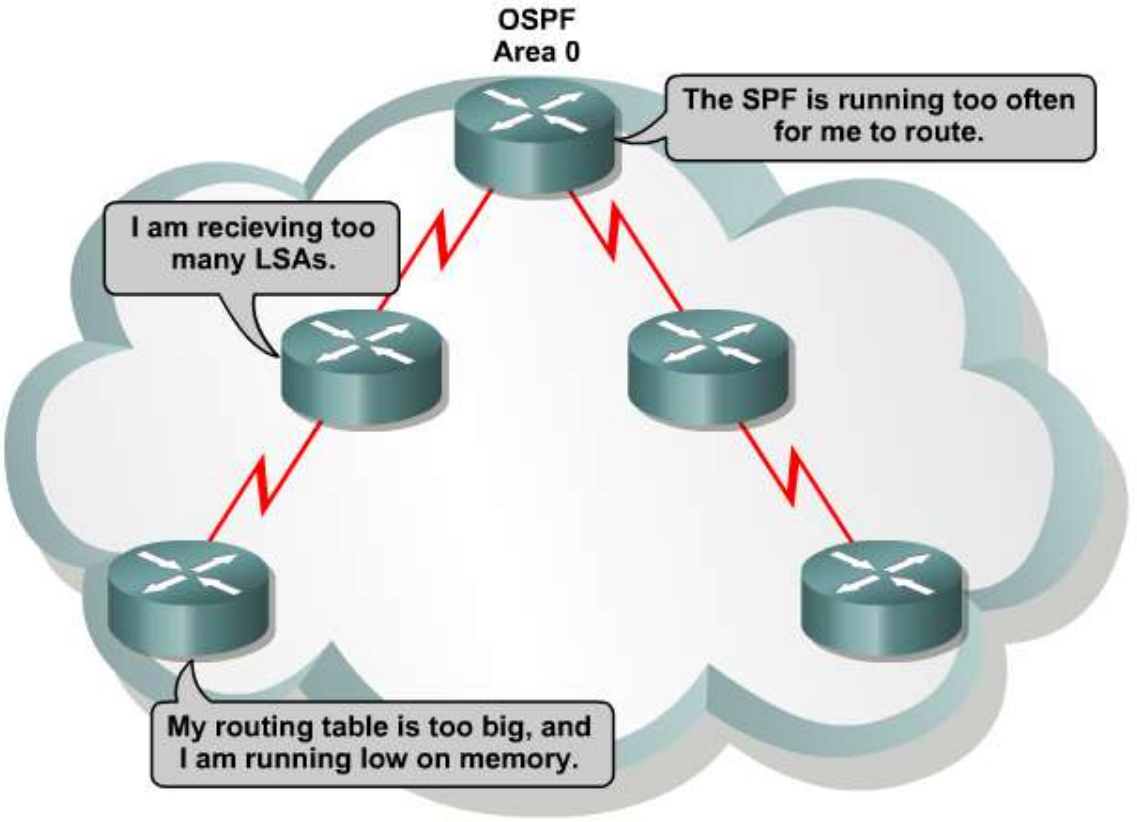
Multiarea OSPF Implementation

OSPF Issues with Large Networks

- Frequent SPF algorithm calculations
- Large routing table
- Large LSDB

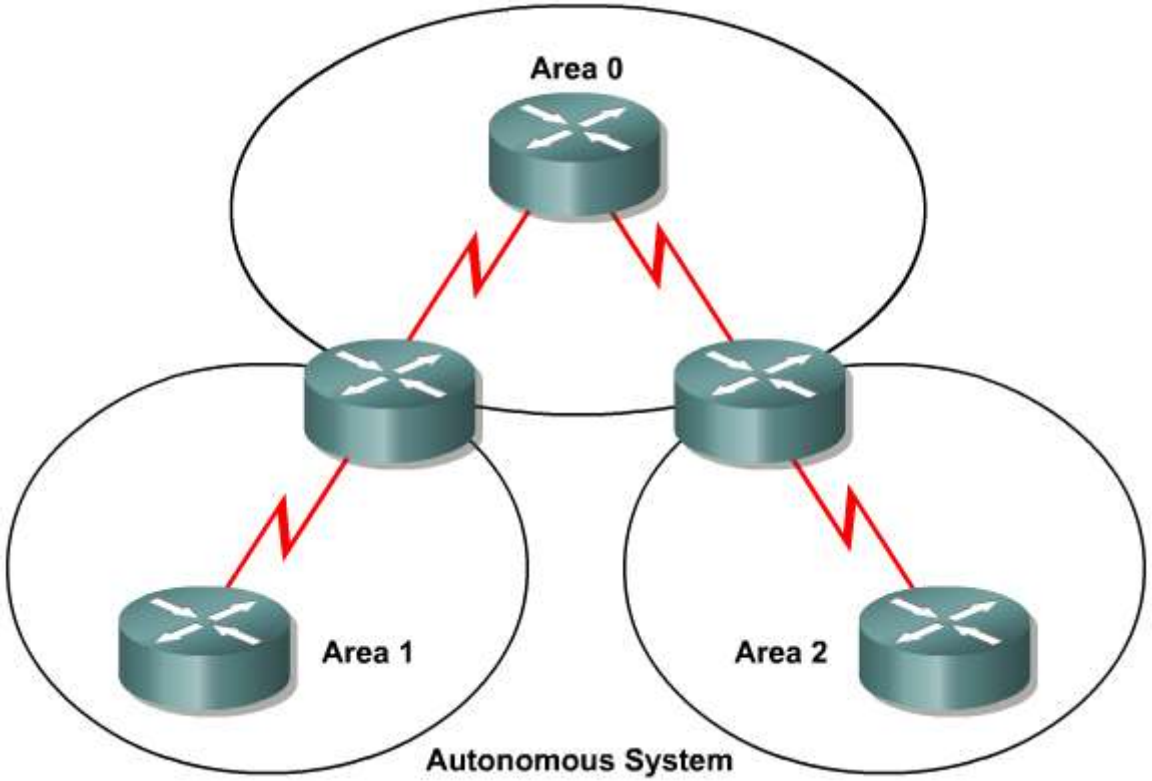
Solution:

- Divide the network into multiple OSPF areas



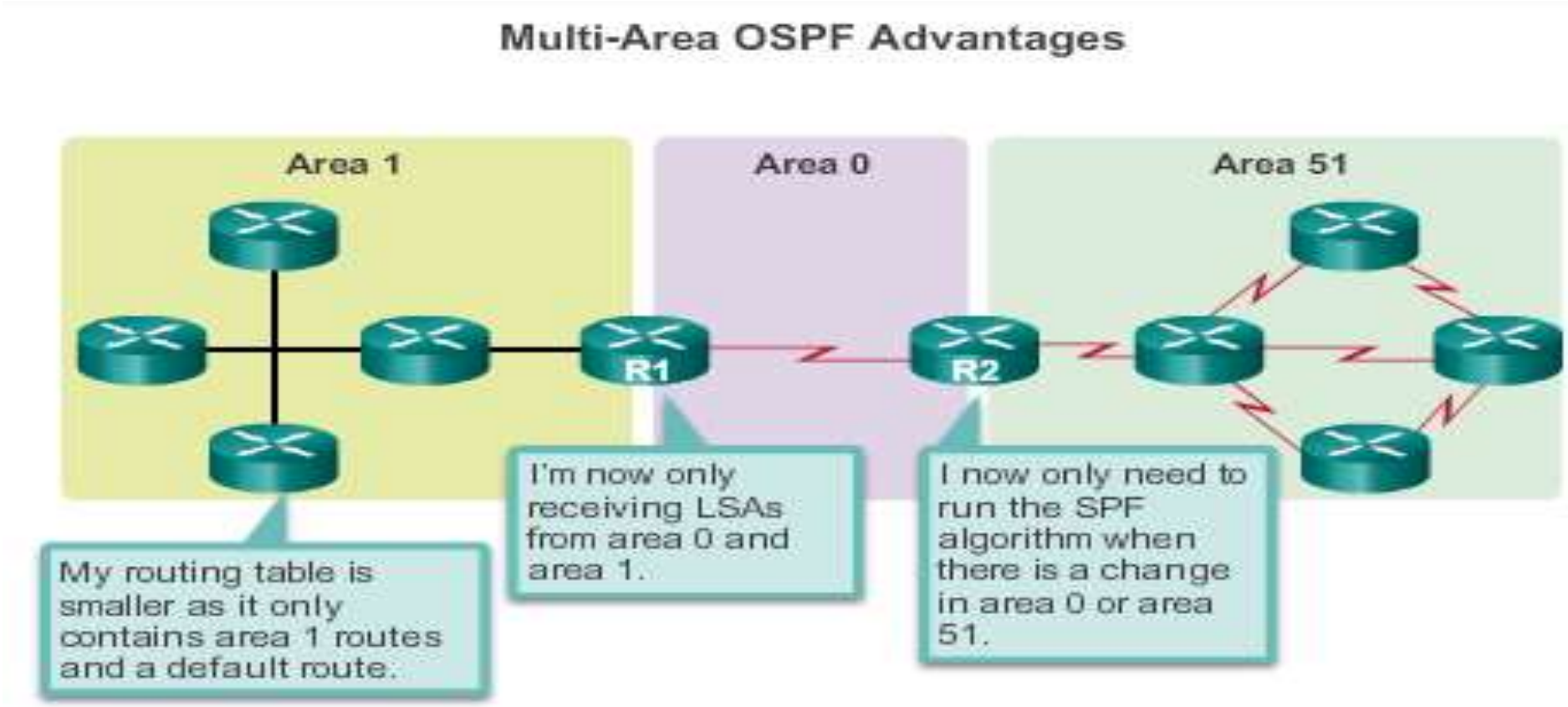
OSPF Areas

- **Reduced frequency of SPF calculations**: Detailed route information exists within each area, link-state changes not flooded to other areas.
- **Smaller routing tables**: Instead of advertising these explicit routes outside the area, routers can be configured to summarize the routes into one or more summary addresses.
- **Reduced LSU overhead**: Rather than send an LSU about each network within an area, a router can advertise a single summarized route or small number of routes between areas.

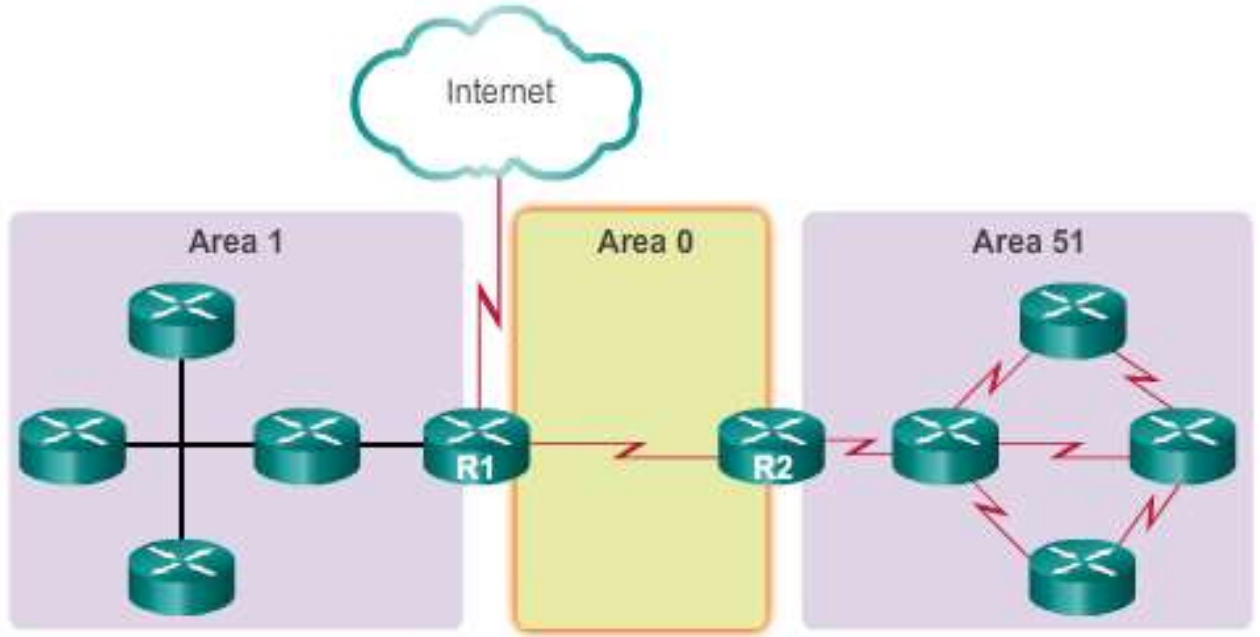


Why Multiarea OSPF?

Multiarea OSPF requires a hierarchical network design and the main area is called the backbone area (area 0) and all other areas must connect to the backbone area.



OSPF Two-Layer Area Hierarchy



Multiarea OSPF is implemented in a two-layer area hierarchy:

Backbone (Transit) area -

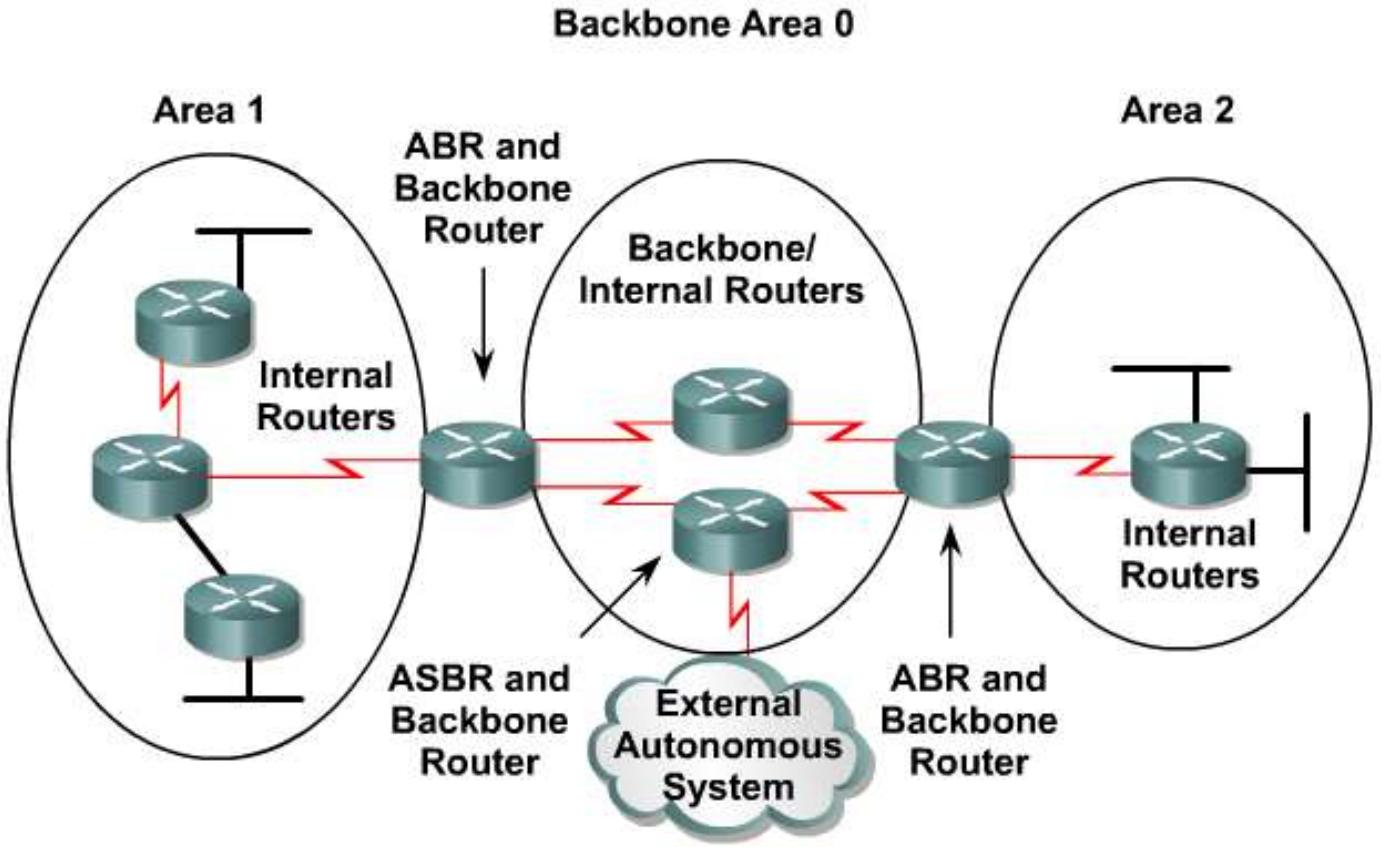
- Area whose primary function is the fast and efficient movement of IP packets.
- Interconnect with other OSPF area types
- Called OSPF area 0 which all other areas directly connect

Regular (Non-backbone) area -

- Connects users and resources
- A regular area does not allow traffic from another area to use its links to reach other areas

Types of OSPF Routers

- Internal Routers
  - All interfaces in same area
  - Identical LSDBs
- Backbone Routers
  - At least 1 interface in area 0
- Area Border Routers (ABR)
  - Interfaces in multiple areas
- Autonomous System Boundary Routers (ASBR)
  - At least 1 interface in non-OSPF network



Types of LSAs Exchanged Between Areas

OSPF LSA Types (Revisited)

LSUs Contain Link-State Advertisements (LSAs)

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	DBD	Checks for database synchronization between router
3	LSR	Requests specific link-state records from router to router
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8	External Attributes LSA for Border Gatway Protocol (BGP)
9, 10, 11	Opaque LSAs

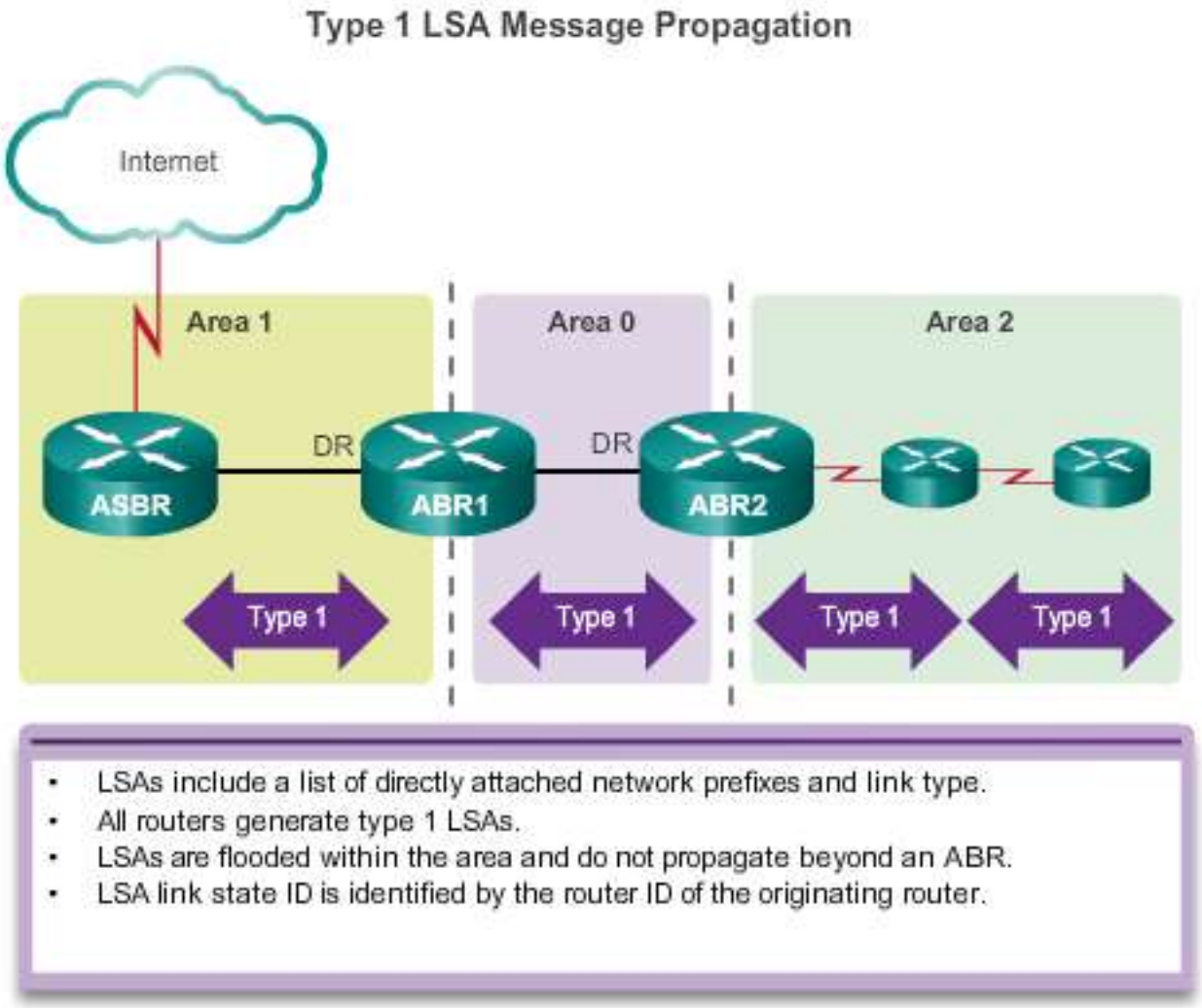
OSPF LSA Types

Common OSPFs LSA Types

LSA Type	Description
1	Router LSA
2	Network LSA
3 and 4	Summary LSAs
5	AS external LSA

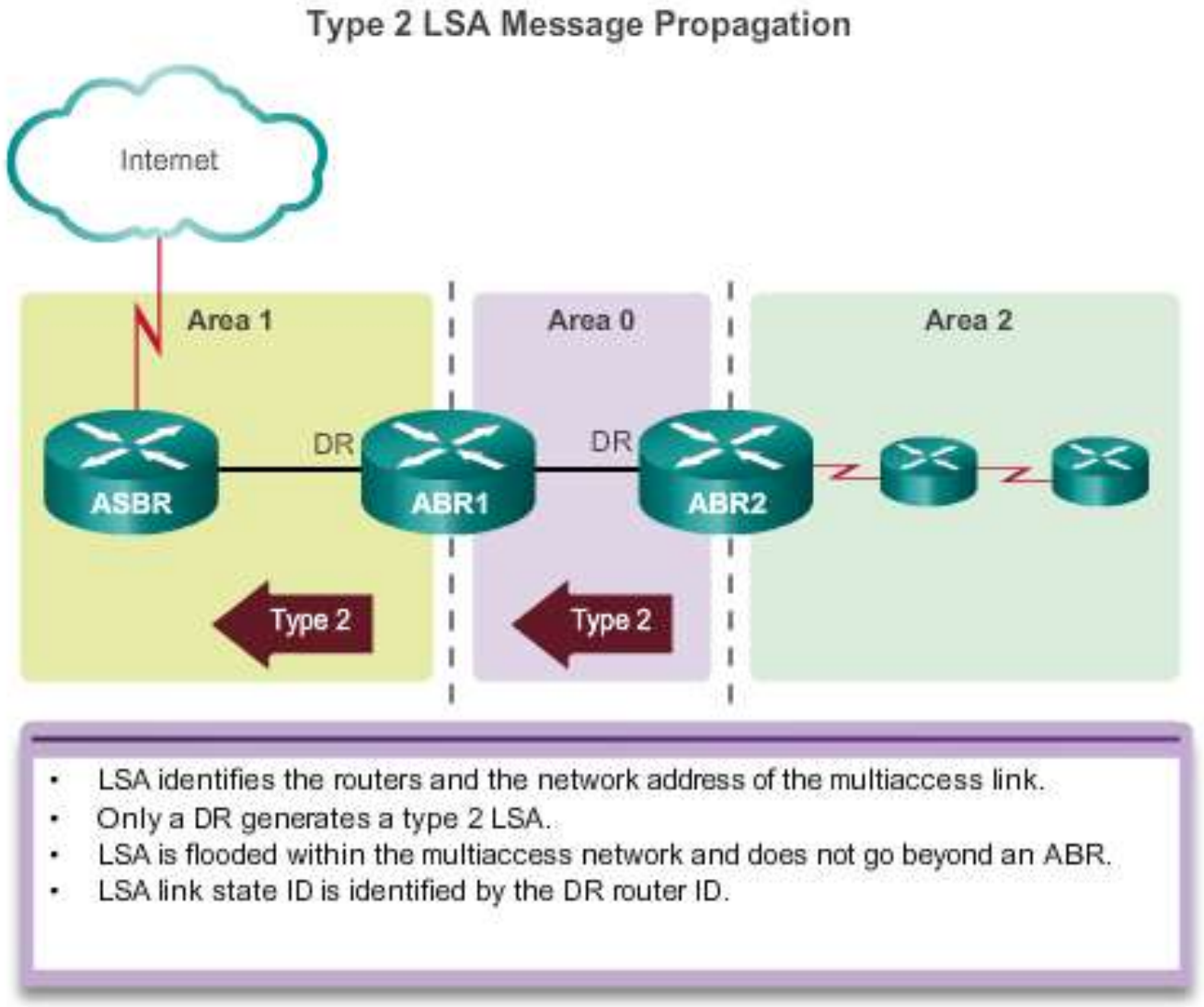
OSPF LSA Type 1 – Router LSA

- One router LSA (type 1) for every router in an area
  - Includes list of directly attached links
  - Each link identified by IP prefix assigned to link, and link type
- Identified by the router ID of the originating router
- Floods within its area only; does not cross ABR



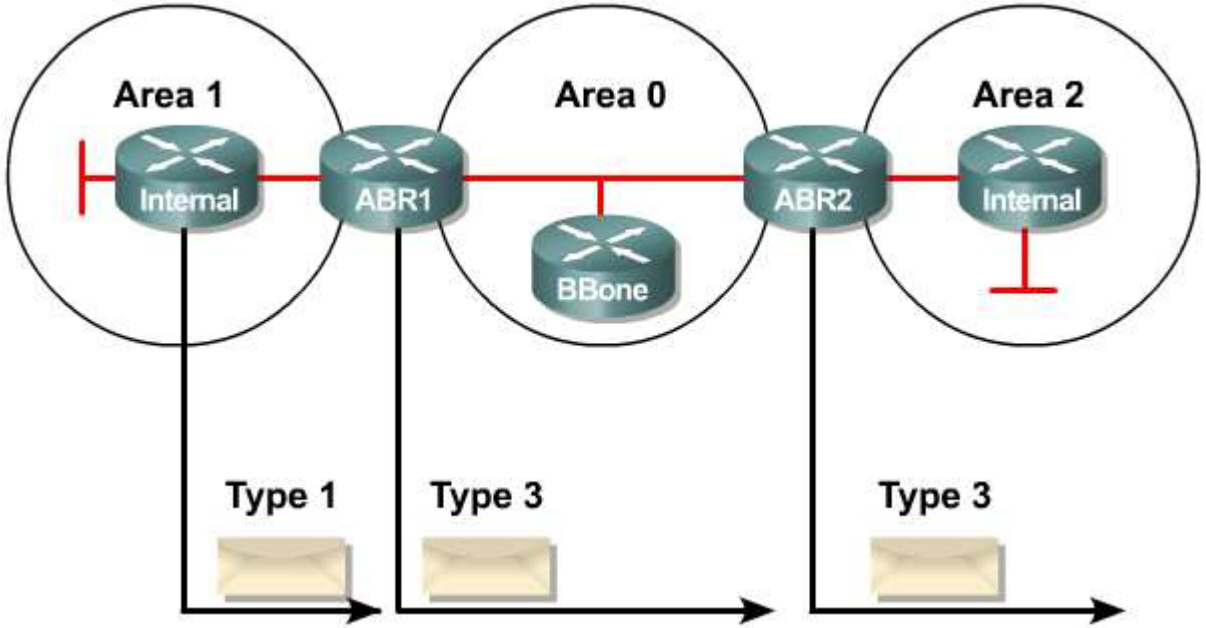
OSPF LSA Type 2 – Network LSA

- One router LSA (type 2) LSA for each transit broadcast or NBMA network in an area
  - Includes list of attached routers on the transit link
  - Includes subnet mask of link
- Advertised by the DR of the broadcast network
- Floods within its area only; does not cross ABR



OSPF LSA Type 3 – Summary LSA

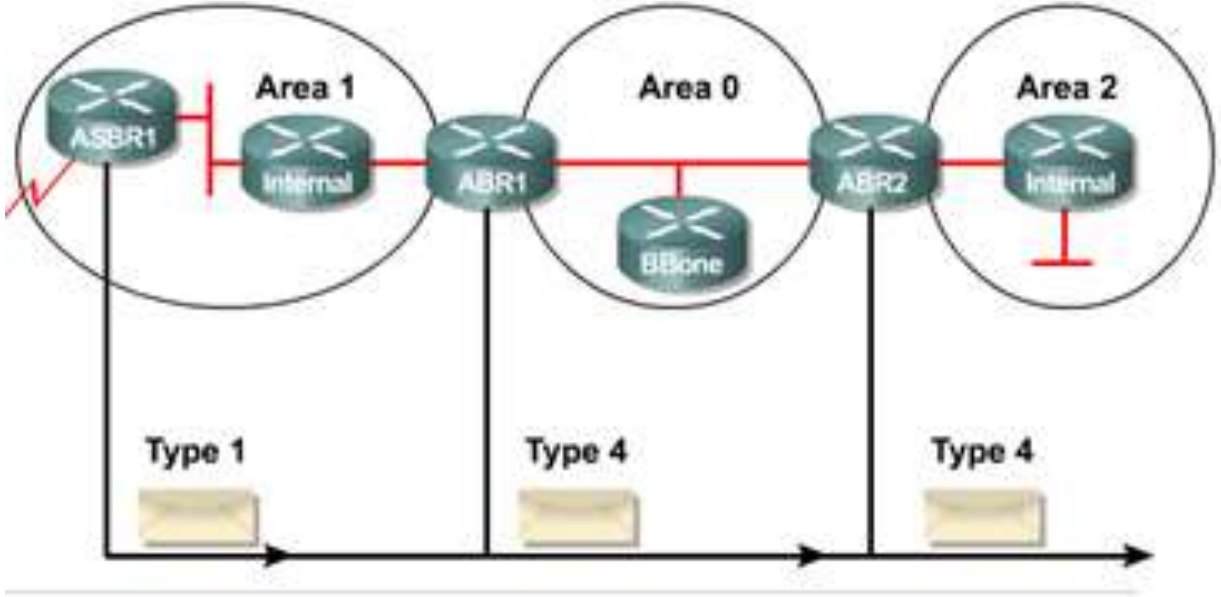
- Used to flood network information to areas outside the originating area (interarea)
  - Describes the network number and mask of link
- Advertised by the ABR of originating area
- Regenerated by subsequent ABRs to flood through the AS
- By default, routes are not summarized; Type 3 LSA advertised for every subnet



- LSA describes a network address learned by type 1 LSAs.
- An LSA is required for every subnet.
- ABRs flood type 3 LSAs to other areas and are regenerated by other ABRs.
- LSA link state ID is identified by the network address.
- By default, routes are not summarized but should be summarized.

OSPF LSA Type 4 – Summary LSA

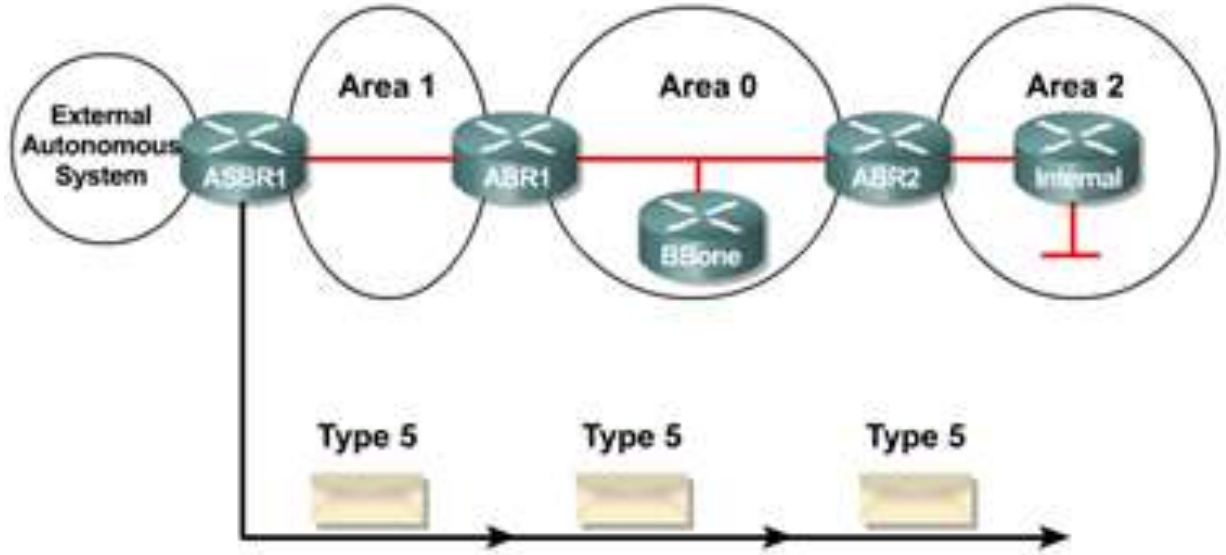
- Used to advertise an ASBR to all other areas in the AS
- Generated by the ABR of the originating area
- Regenerated by all subsequent ABRs to flood through out the AS
- Contain the router ID of the ASBR



- LSA is used to advertise an ASBR to other areas and provide a route to it.
- ABRs generate type 4 LSAs.
- LSA is generated by the originating ABR and regenerated by other ABRs.
- LSA link state ID is identified by the router ID of the ASBR.

OSPF LSA Type 5 – External LSA

- Used to advertise networks from other autonomous systems.
- Advertised and owned by originating ASBR
- Flood throughout entire AS
- Advertising router (ASBR) not changed throughout the AS
- Type 4 LSA needed to find ASBR
- By default, routes are not summarized



- LSA is used to advertise external (i.e., non-OSPF) network addresses.
- An ASBR generates a type 5 LSA.
- LSA is flooded throughout the area and regenerated by other ABRs.
- LSA link state ID is the external network address.
- By default, routes are not summarized but should be summarized.

OSPF LSA Types

Common OSPFs LSA Types

LSA Type	Description
1	Router LSA
2	Network LSA
3 and 4	Summary LSAs
5	AS external LSA

OSPF Routes – Routing Table

	Route Designator	Description
O	OSPF intra-area (router LSA) and Network LSA	• Networks from within the area of the router • Advertised by the way of the router LSAs and network LSA
O IA	OSPF interarea (summary LSA)	• Networks from outside the area of the router, but within the OSPF autonomous system • Advertised by way of summary LSAs
O E1	Type 1 external routes	• Networks outside of the autonomous system of the router • Advertised by way of external LSAs
O E2	Type 2 external routes	

OSPF Routing Table Entries

Router and Network Routing Table Entries

```
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 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 the details within an area (the route is intra-area)
- O IA - Summary LSAs appear in the routing table as IA (interarea routes)
- O E1 or OE 2 - External LSAs external type 1 (E1) or external type 2 (E2)

OSPF Routing Table Entries

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#
```

- O - Router (type 1) and network (type 2) LSAs describe the details within an area (the route is intra-area)
- OI - Summary LSAs appear in the routing table as IA (interarea routes)
- O E1 or OE 2 - External LSAs external type 1 (E1) or external type 2 (E2) routes

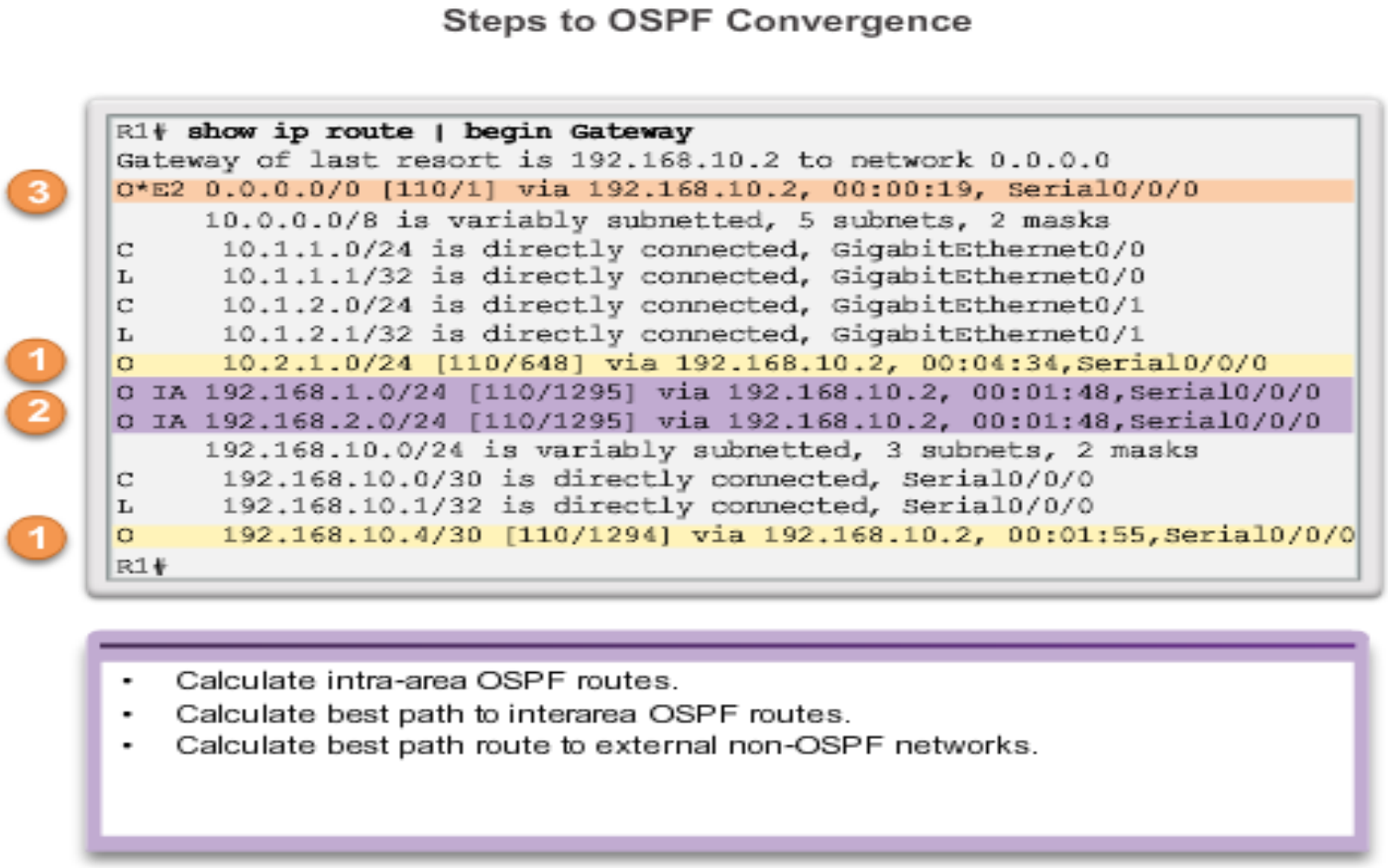
OSPF Routes – Routing Table

External Routes

- **E2 (default)**: The cost of O E2 packet routes is just the external cost. Use this type if only one ASBR is advertising an external route to the AS.
- **E1:** Calculate cost by adding the external cost to the internal cost of each link that the packet crosses.

```
RouterB>show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       R1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1,
       L2 - IS-IS level-2, ia - IS-IS inter area,
       * - candidate default, U - per-user static route, o - ODR,
       P - periodic downloaded static route

Gateway of last resort is not set

      172.31.0.0/24 is subnetted, 2 subnets
O IA  172.31.2.0 [110/1563] via 10.1.1.1, 00:12:35, FastEthernet0/0
O IA  172.31.1.0 [110/782] via 10.1.1.1, 00:12:35, FastEthernet0/0
      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C     10.200.200.13/32 is directly connected, Loopback0
C     10.1.3.0/24 is directly connected, Serial0/0/0
O     10.1.2.0/24 [110/782] via 10.1.3.4, 00:12:35 Serial0/0/0
C     10.1.1.0/24 is directly connected, FastEthernet0/0
O     10.1.0.0/24 [110/782] via 10.1.1.1, 00:12:37, FastEthernet0/0
O E2  10.254.0.0/24 [110/50] via 10.1.1.1, 00:12:37, FastEthernet0/0
```

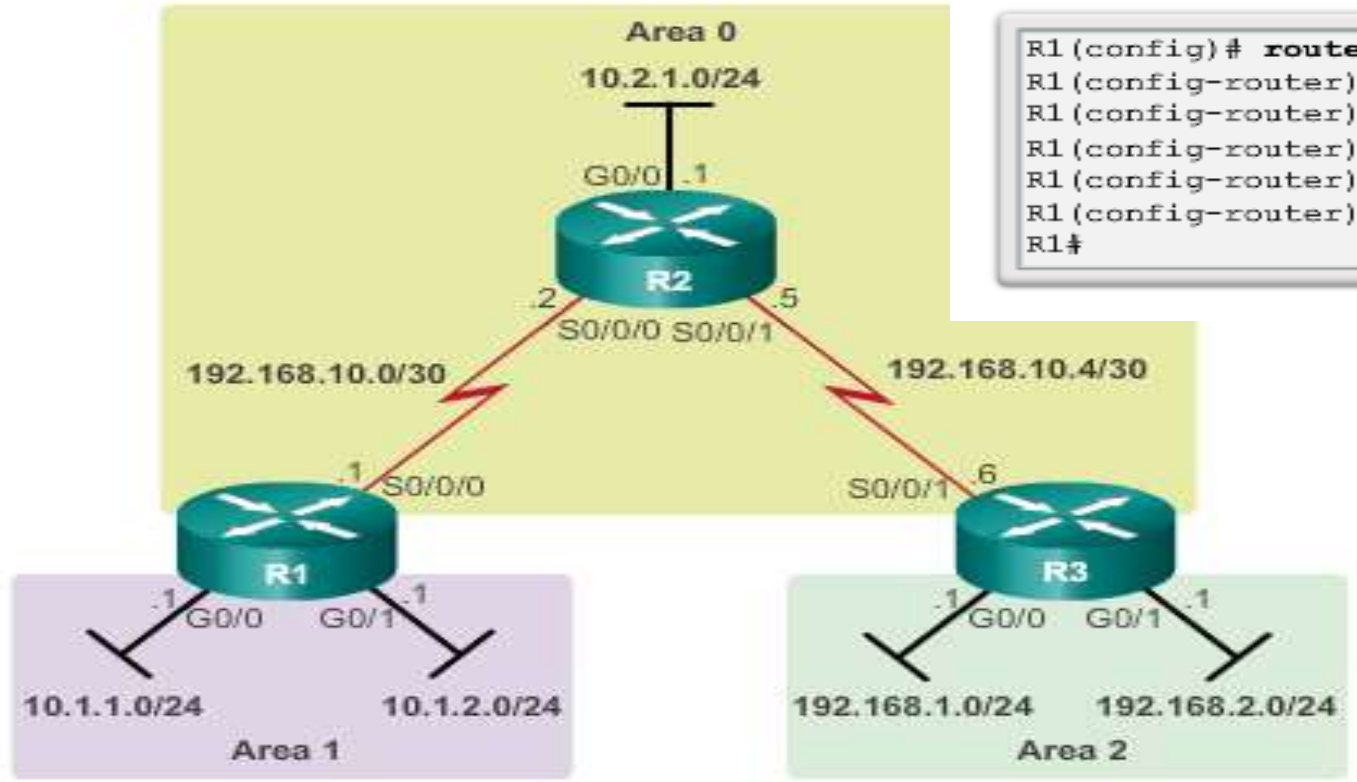
OSPF Route Calculation



1. All routers calculate the best paths to destinations within their area (intra-area) and add these entries to the routing table.
2. All routers calculate the best paths to the other areas within the internetwork (interarea) or type 3 and type 4 LSAs.
3. All routers calculate the best paths to the external autonomous system (type 5) destinations. These are noted with either an O E1 or an O E2 route designator.

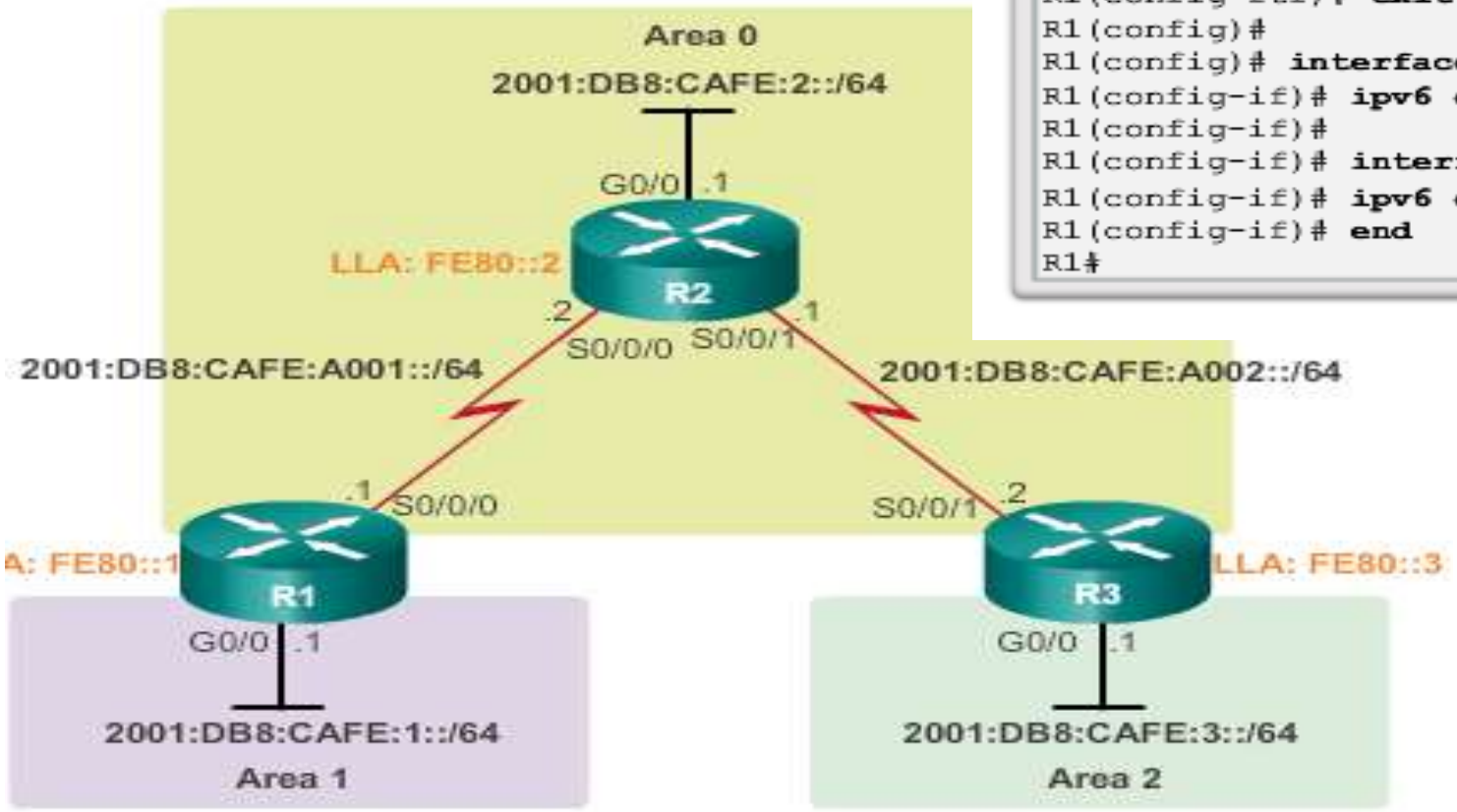
Configuring Multiarea OSPF

Configuring Multiarea OSPFv2




```
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
R1(config-router)# end
R1#
```

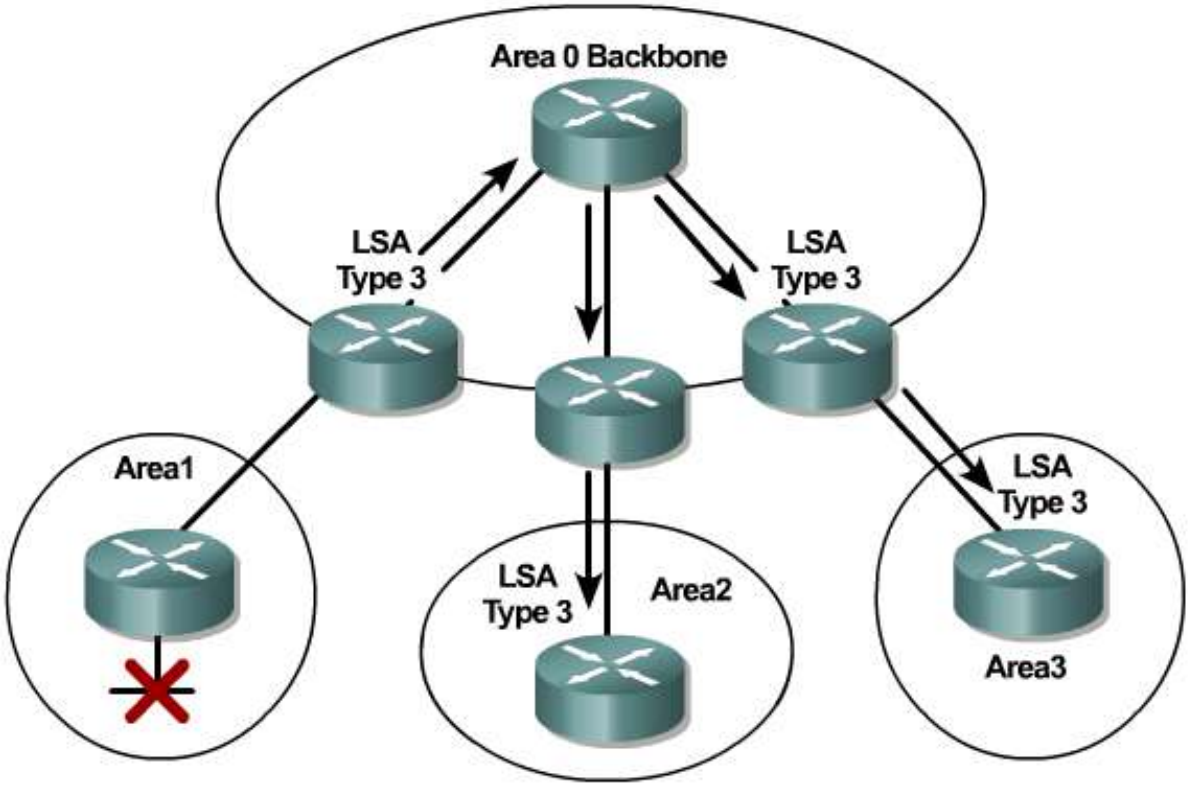
Configuring Multiarea OSPFv3



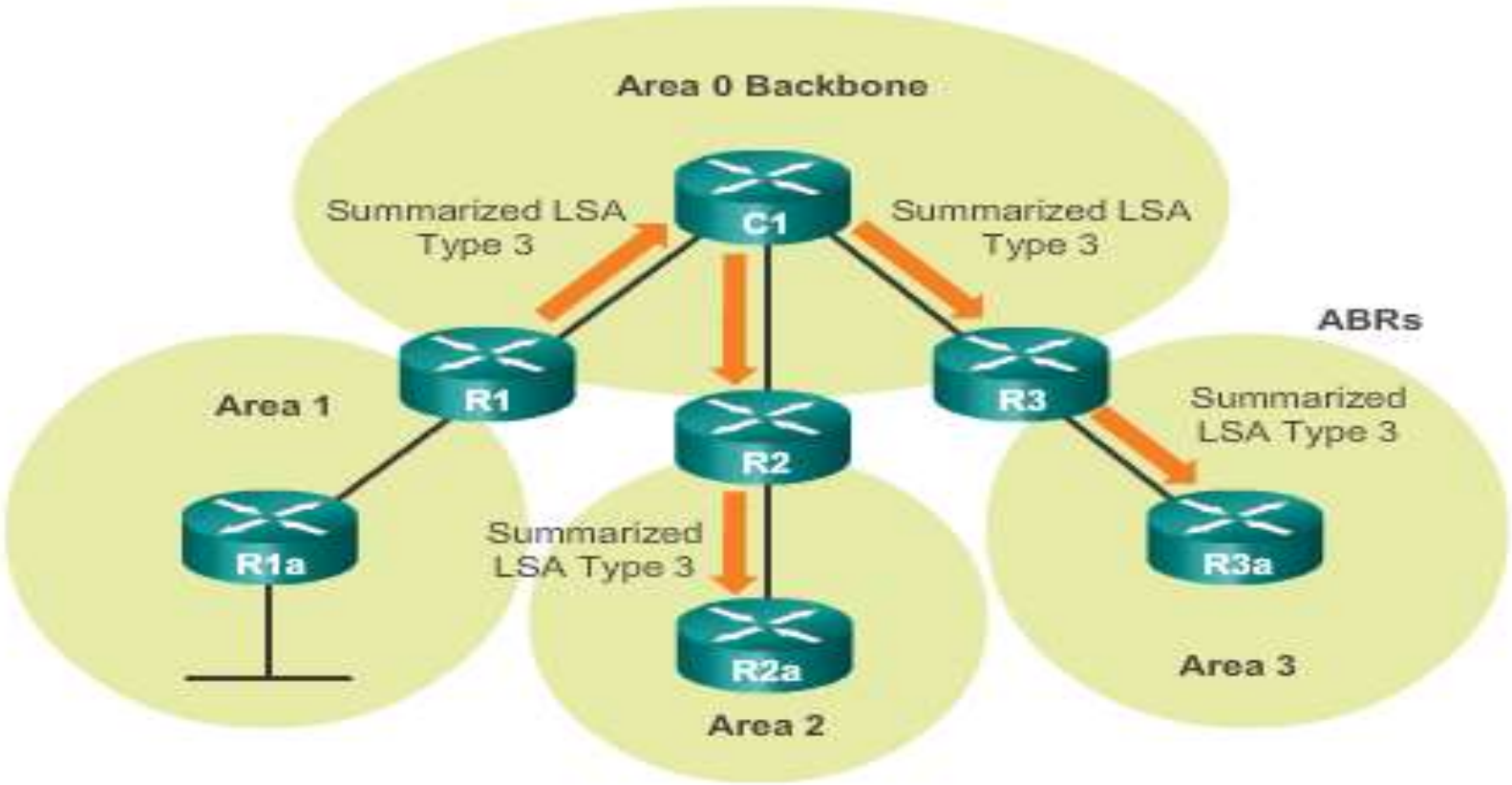

```
R1(config)# ipv6 router ospf 10
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)# exit
R1(config)#
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# ipv6 ospf 10 area 1
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)# end
R1#
```

OSPF Route Summarization

- Large OSPF Networks – Large number of LSAs sent
- All affected OSPF routers have to recompute their LSDB and the SPF tree
- **Interarea route summarization**: Configured on ABRs and applies to routes from within each area
- **External route summarization**: External routes that are injected into OSPF via route redistribution - configured on ASBRs only
- Address ranges that are being summarized must be contiguous



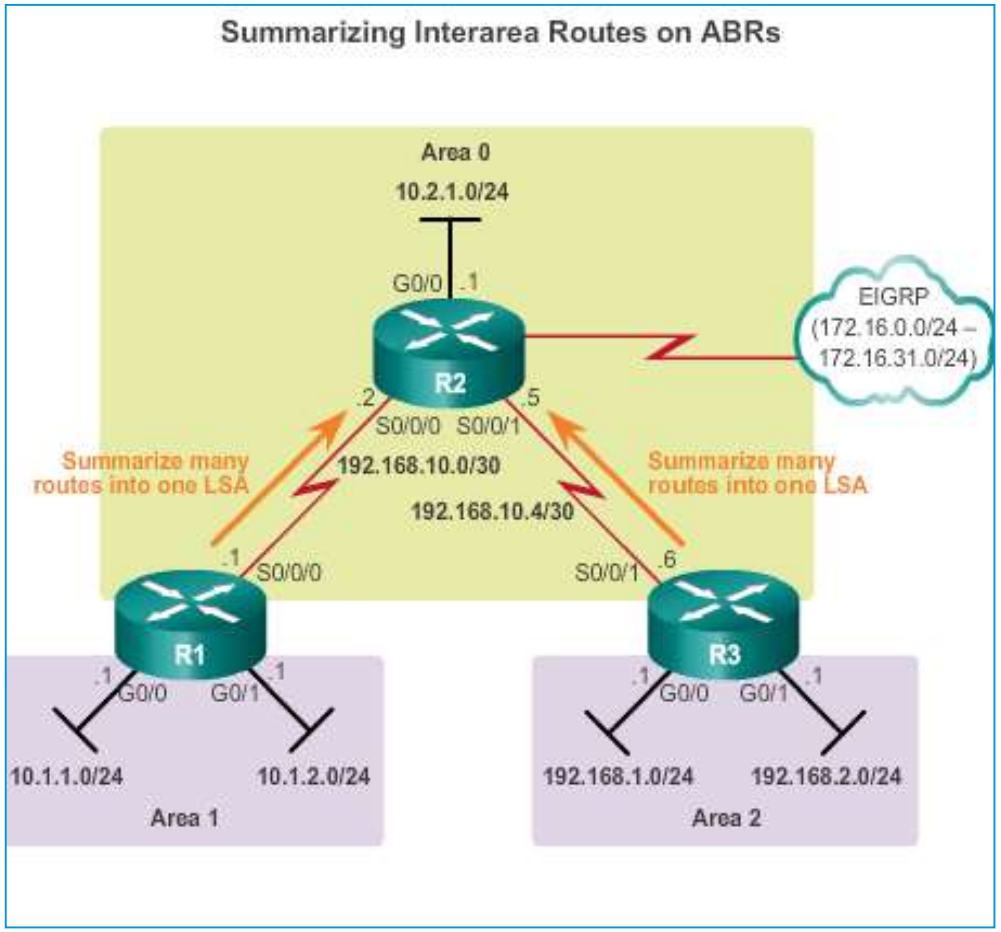
OSPF Route Summarization



- R1 forwards a summary LSA to the core router C1.
- C1 in turn, forwards the summary LSA to R2 and R3.
- R2 and R3 then forward it to their respective internal routers.

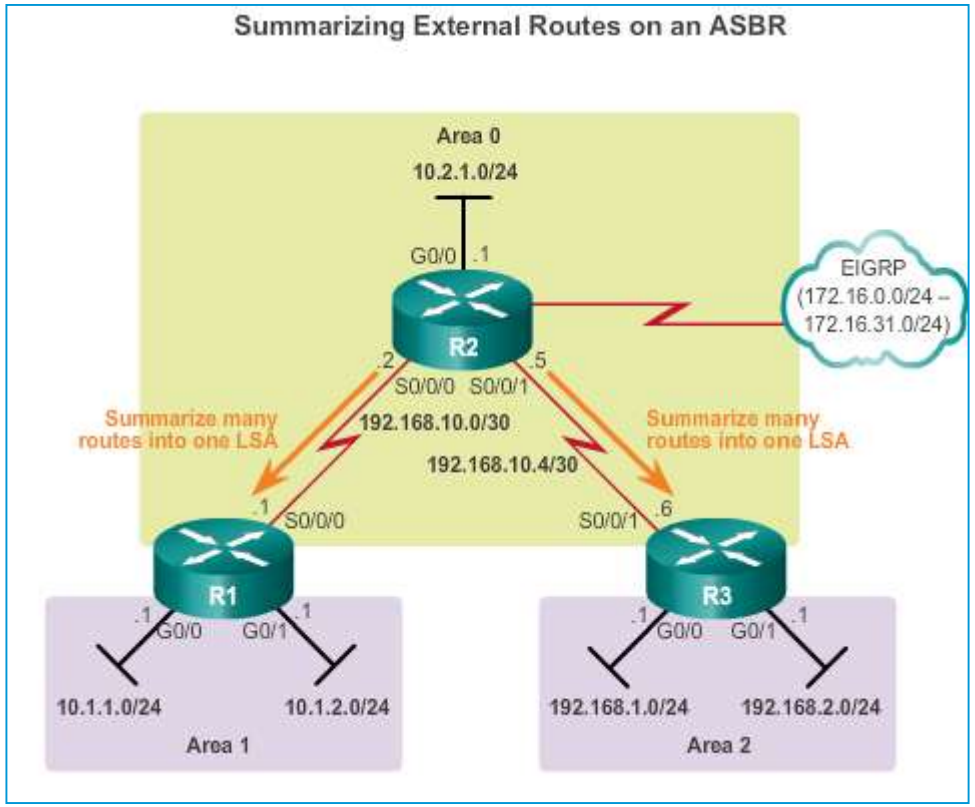
OSPF Route Summarization

Occurs on ABRs and applies to routes from within each area

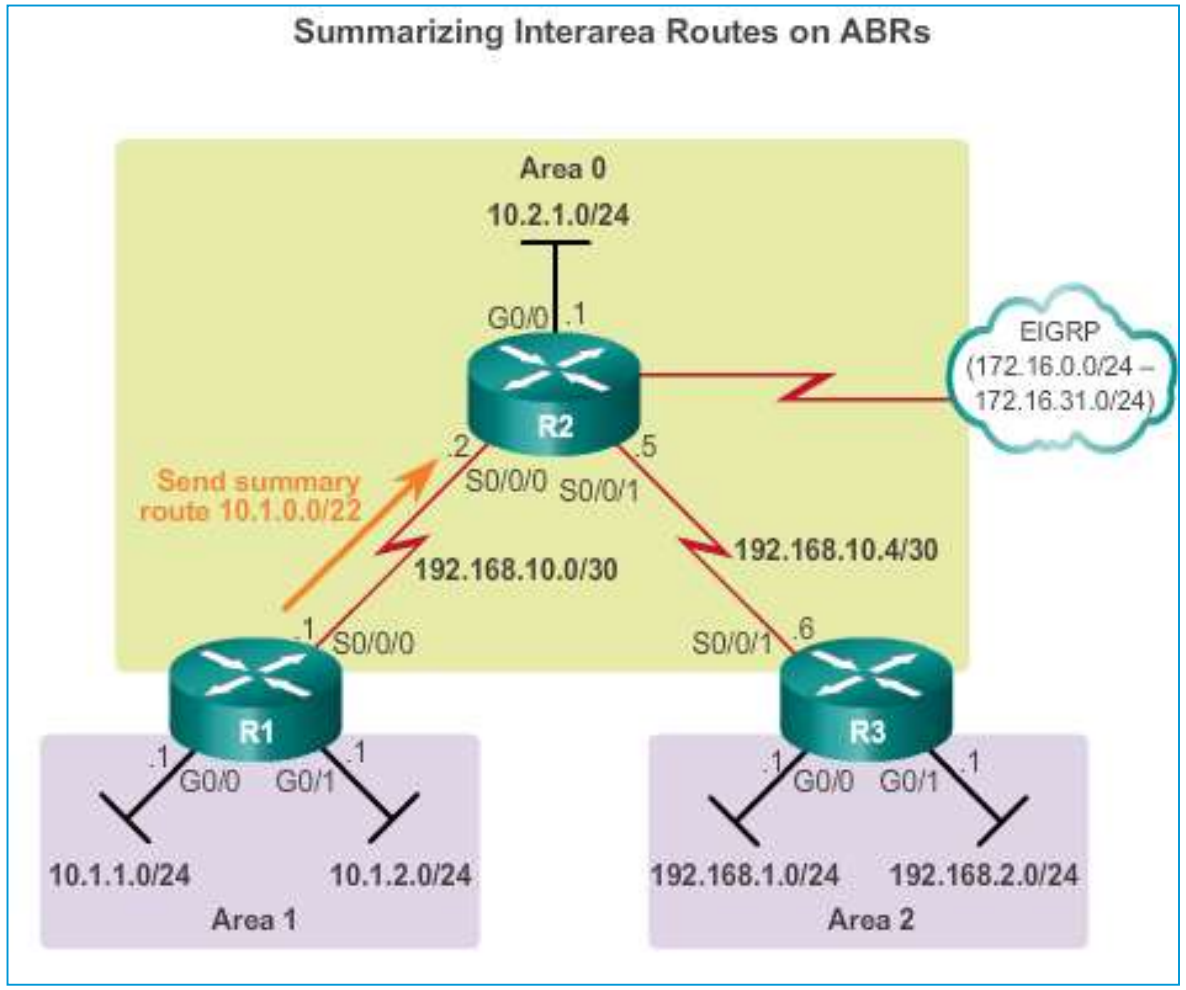


OSPF Route Summarization

Specific to external routes that are injected into OSPF via route redistribution; ASBRs summarize external routes

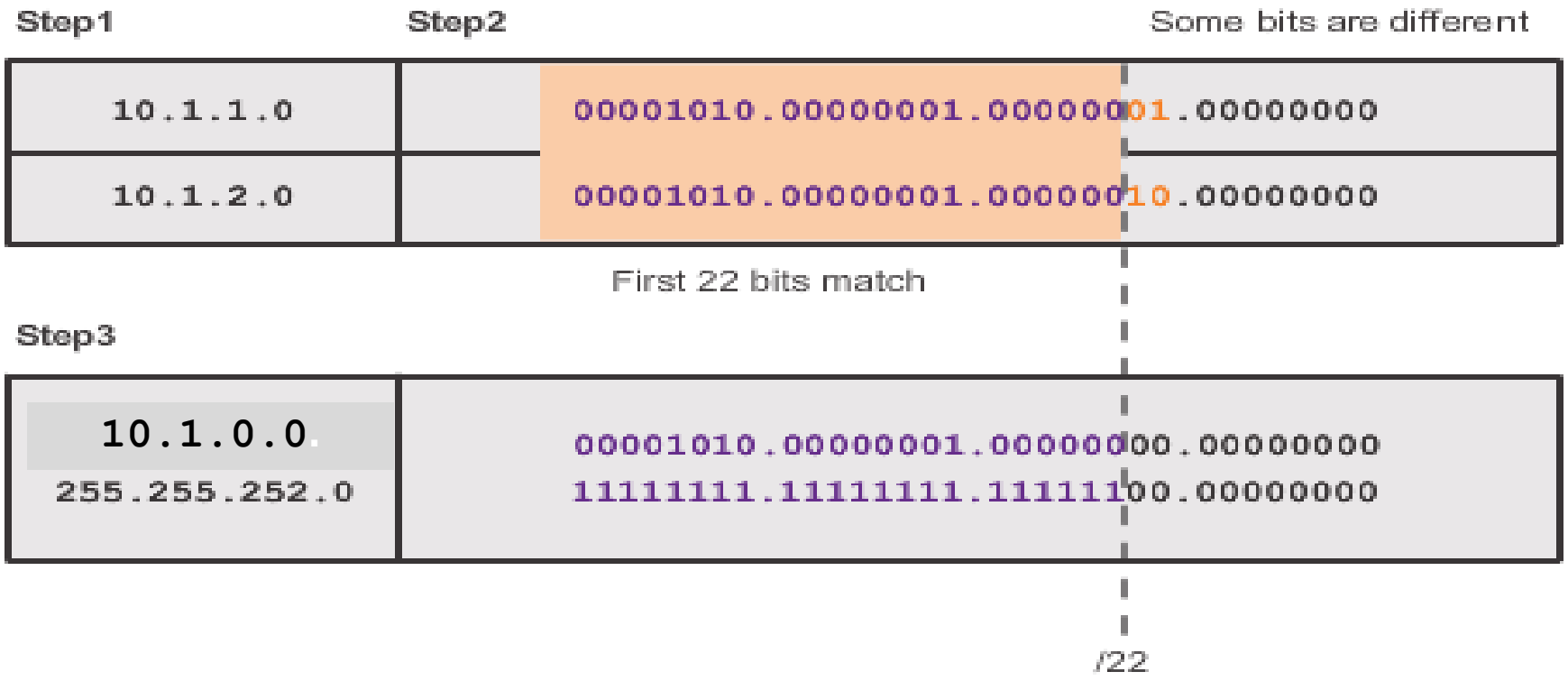


OSPF Route Summarization



Calculating the Summary Route

Summarize 10.1.1.0/24 and 10.1.2.0/24



10.1.0.0/22 or 10.1.0.0 255.255.252.000

Configuring Interarea Route Summarization

Verify the 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#
```

Verify the 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#
```

Configuring Interarea Route Summarization

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

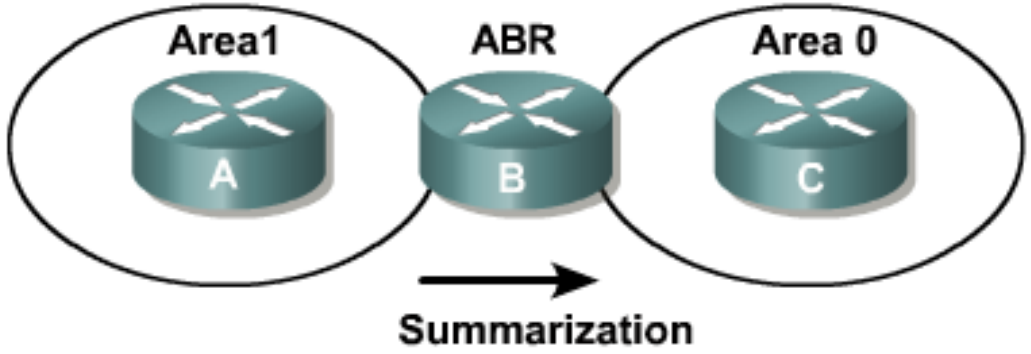
R1

```
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, 00:0
Serial0/0/0
      192.168.10.0/24 is variably subnetted, 3 subnets
masks
O        192.168.10.4/30 [110/1294] via 192.168.10.2,
00:00:09, Serial0/0/0
R1#
```

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, 00:00:06,
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#
```

OSPF Route Summarization - VLSM



Routing Table for B

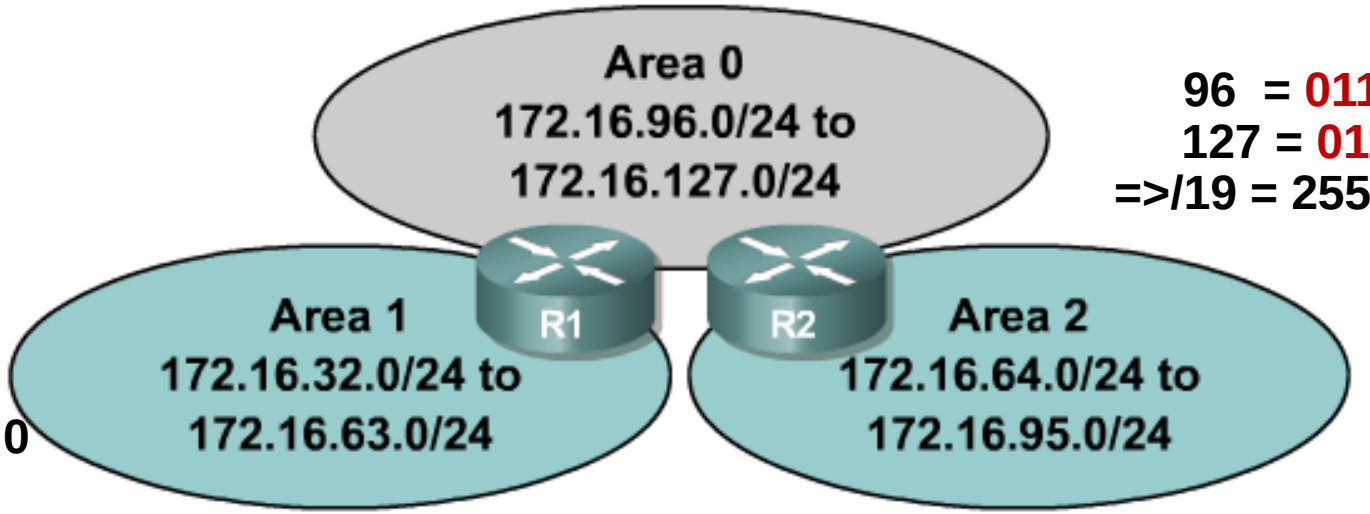
```
0 172.16.8.0 255.255.255.0
0 172.16.9.0 255.255.255.0
0 172.16.10.0 255.255.255.0
0 172.16.11.0 255.255.255.0
0 172.16.12.0 255.255.255.0
0 172.16.13.0 255.255.255.0
0 172.16.14.0 255.255.255.0
0 172.16.15.0 255.255.255.0
0 172.16.16.0 255.255.255.0
0 172.16.17.0 255.255.255.0
0 172.16.18.0 255.255.255.0
0 172.16.19.0 255.255.255.0
```

LSAs Sent to Router C

```
IA 172.16.8.0 255.255.248.0
```

```
IA 172.16.16.0 255.255.252.0
```

OSPF Interarea Route Summarization



96 = 0110 0000
127 = 0111 1111
=>/19 = 255.255.224.0

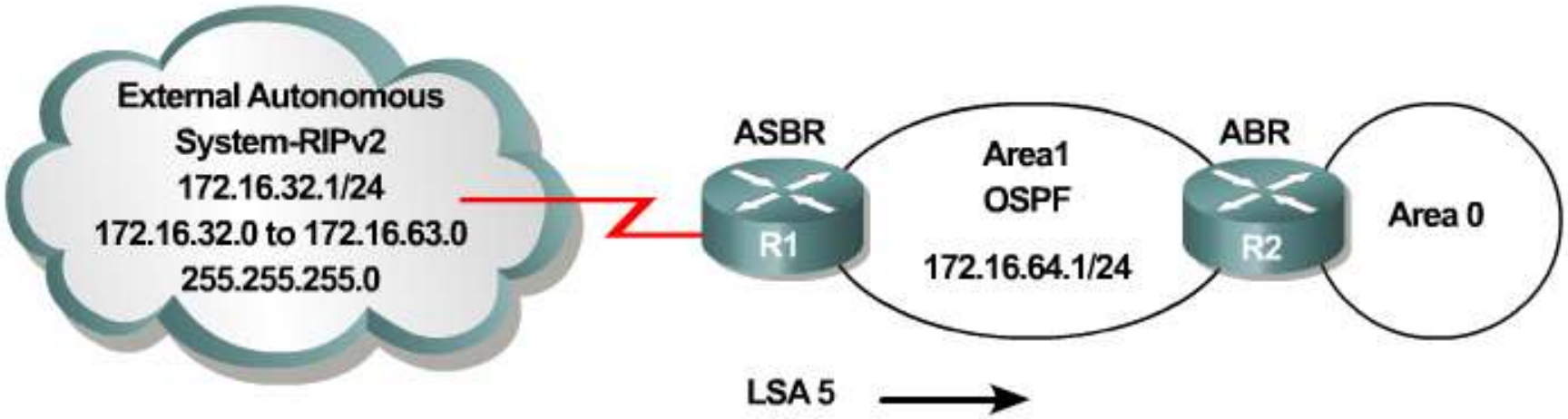
32 = 0010 0000
63 = 0011 1111
=>/19 = 255.255.224.0

64 = 0100 0000
95 = 0101 1111
=>/19 = 255.255.224.0

```
R1(config)# router ospf 100
R1(config-router)#network 172.16.32.1 0.0.0.0 area 1
R1(config-router)#network 172.16.96.1 0.0.0.0 area 0
R1(config-router)#area 0 range 172.16.96.0 255.255.224.0
R1(config-router)#area 1 range 172.16.32.0 255.255.224.0
```

```
R2(config)# router ospf 100
R2(config-router)#network 172.16.64.1 0.0.0.0 area 2
R2(config-router)#network 172.16.127.1 0.0.0.0 area 0
R2(config-router)#area 0 range 172.16.96.0 255.255.224.0
R2(config-router)#area 2 range 172.16.64.0 255.255.224.0
```

OSPF ASBR Route Summarization

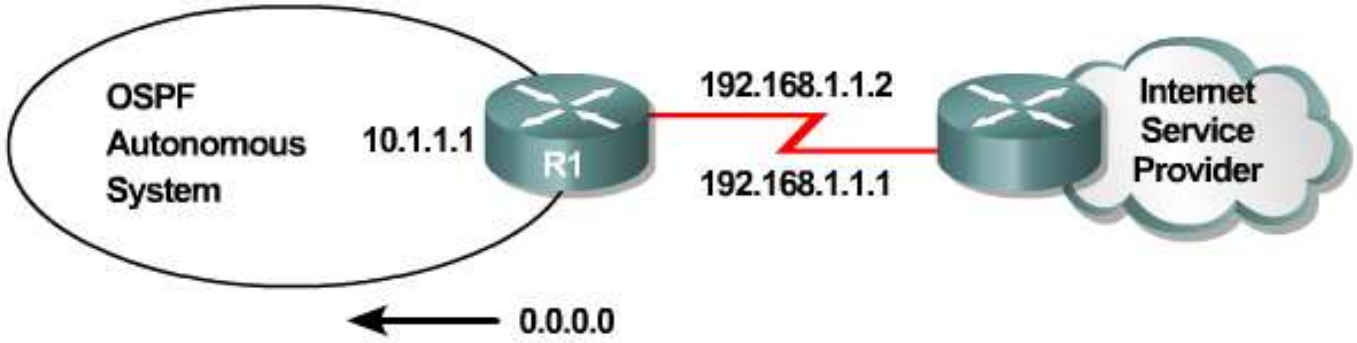



```
R1#
router ospf 100
network 172.16.64.1 0.0.0.0 area 1
summary-address 172.16.32.0 255.255.224.0
```

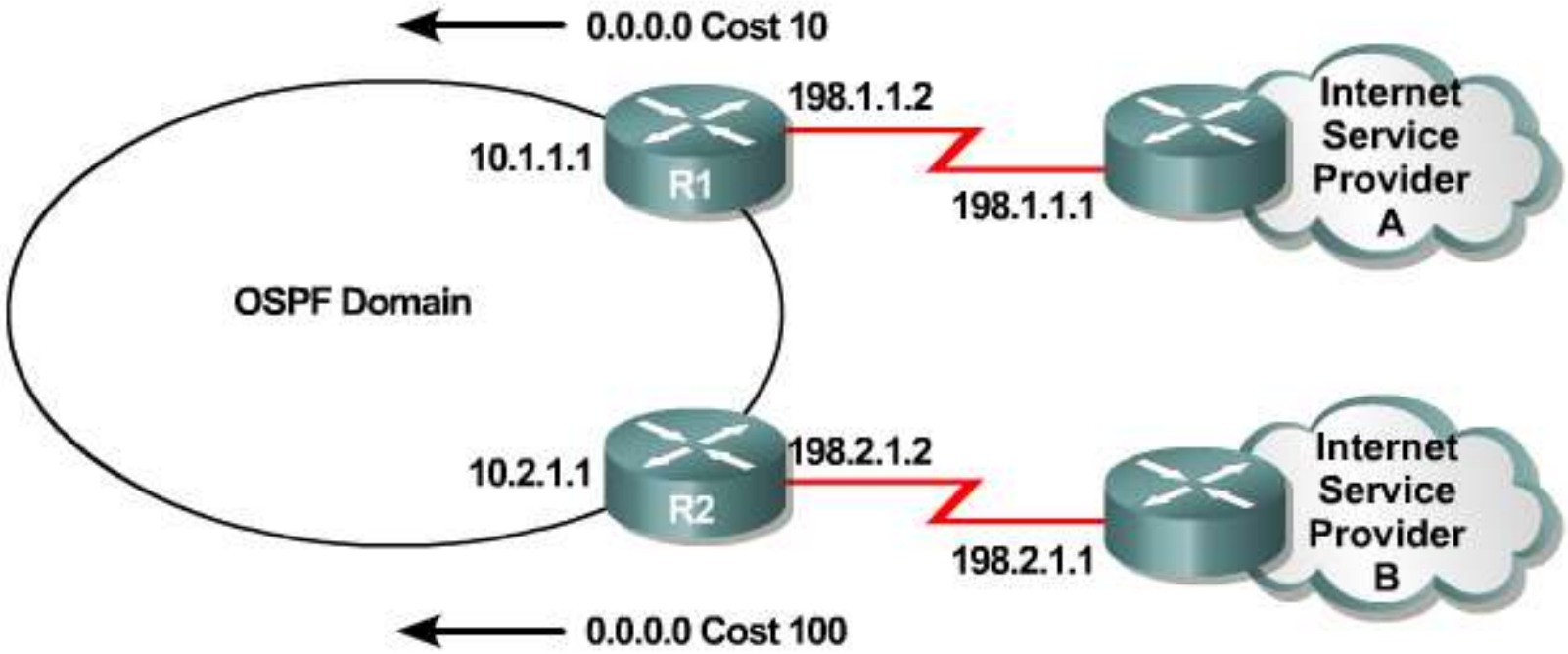
Note - RIPv2 routes must also be redistributed into OSPF in this example

OSPF Default Route

- Two methods:
  - default-information originate
  - default-information originate always
- Key word “always” allows default route to be advertised even if advertising router does not have default route
- Optional metric value to indicate preference



OSPF Default Route Example




```
R1#
router ospf 100
network 10.1.1.1 0.0.0.0 area 0
default-information originate metric 10
ip route 0.0.0.0 0.0.0.0 198.1.1.1
```

```
R2#
router ospf 100
network 10.2.1.1 0.0.0.0 area 0
default-information originate metric 100
ip route 0.0.0.0 0.0.0.0 198.2.1.1
```

Verifying an OSPFv2 and OSPFv3 Configuration

Verifying Multiarea OSPFv2

Commands for verification:

- **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**

For OSPFv3 simply substitute ip with ipv6

Verifying General Multiarea OSPF Setting

```
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#
```

```
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#
```

Verify the OSPF Routes

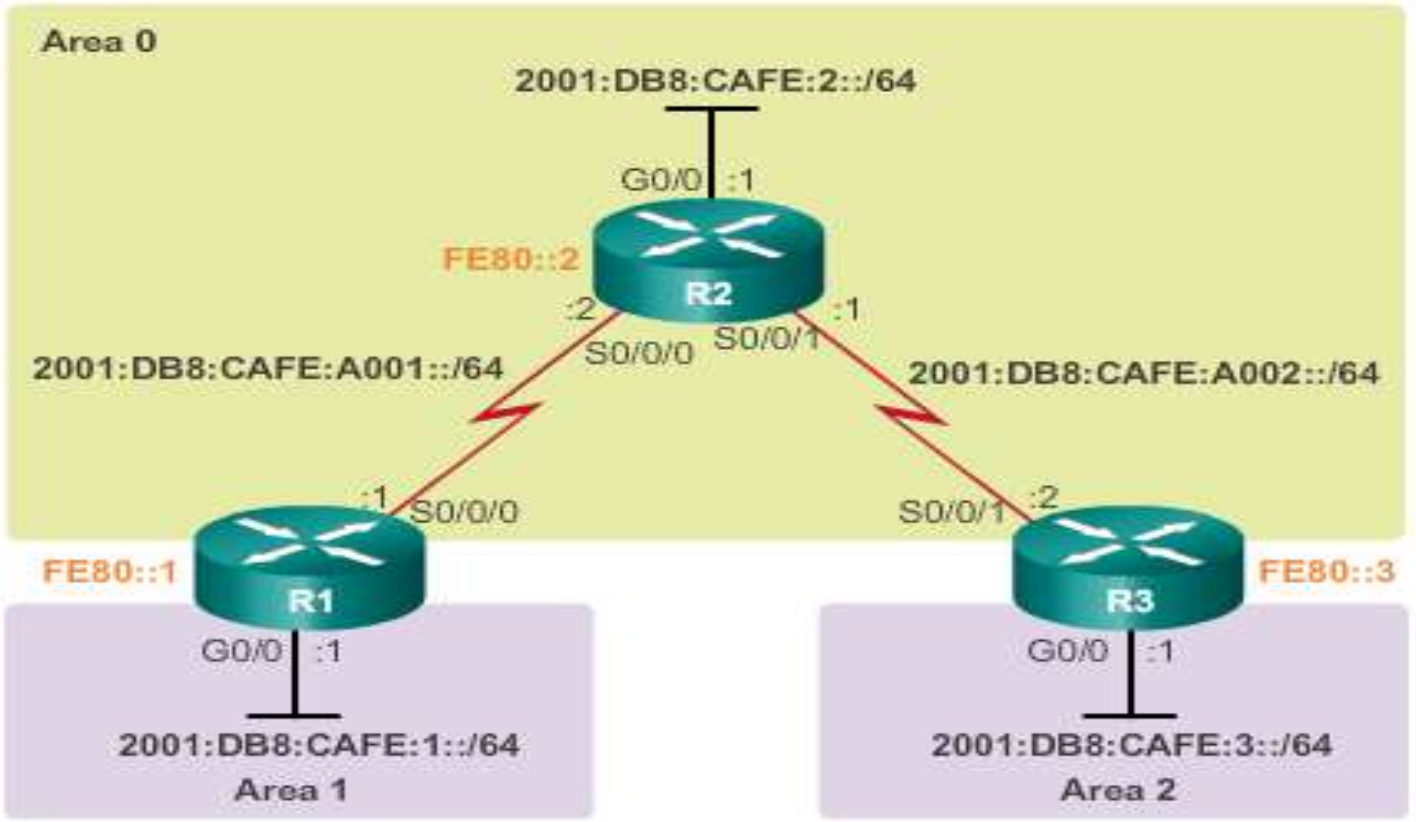
```
R1# show ip route ospf | begin Gateway
Gateway of last resort is not set

     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#
```

Verify the Multiarea OSPF LSDB

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#
```

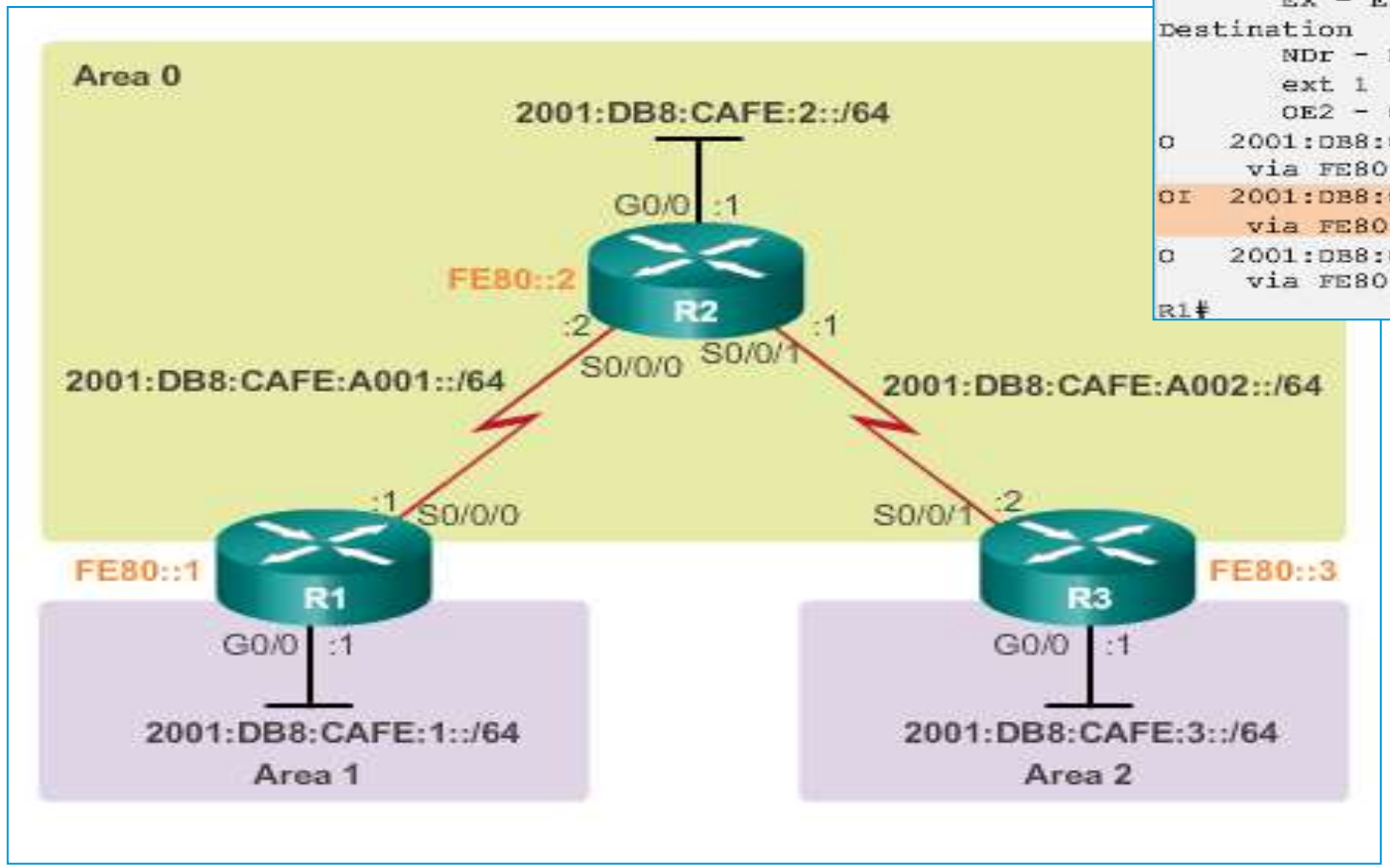
Verifying Multiarea OSPFv3




```
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#
```

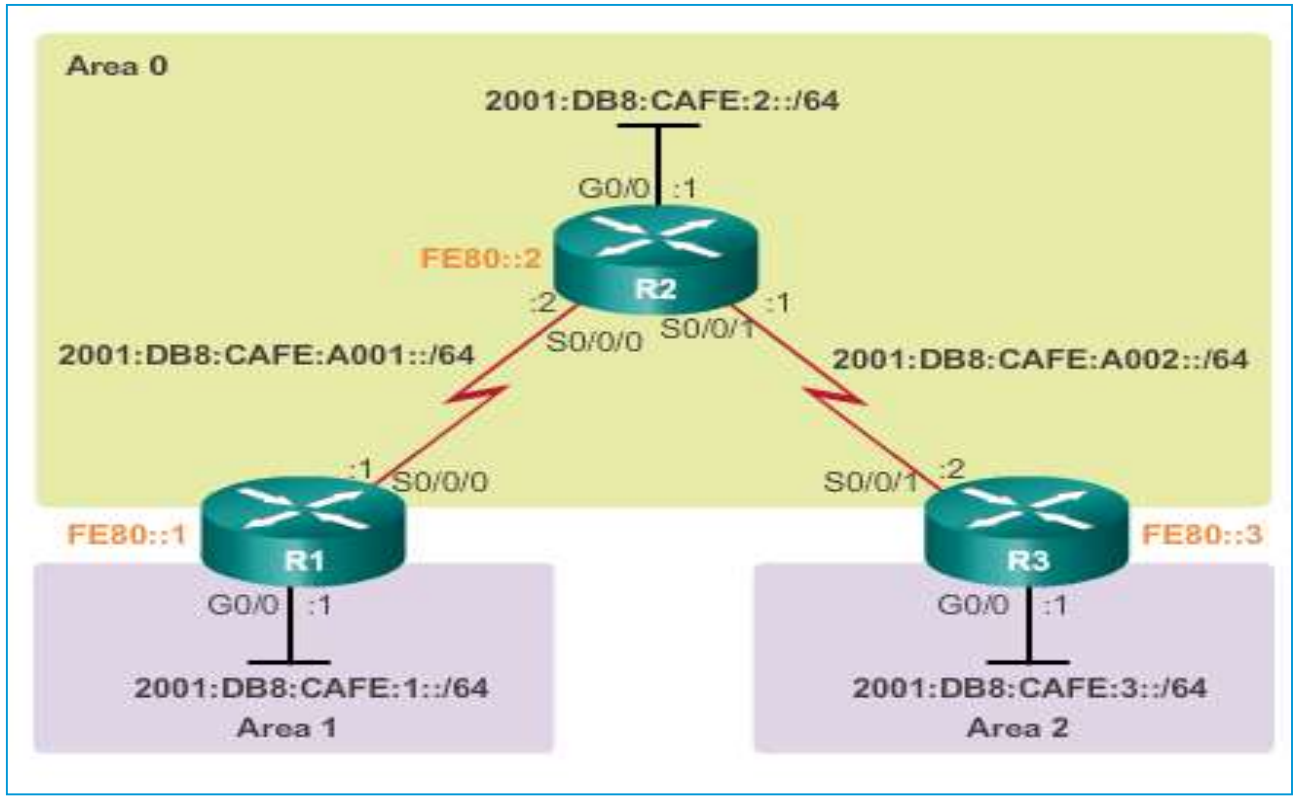
```
R1# show ipv6 ospf interface brief
Interface    PID   Area            Intf ID    Cost  State Nbrs F/C
Se0/0/0      10    0               6          647   P2P   1/1
Gi0/0        10    1               3          1     DR    0/0
R1#
```

Verifying Multiarea OSPFv3 (cont.)




```
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#
```

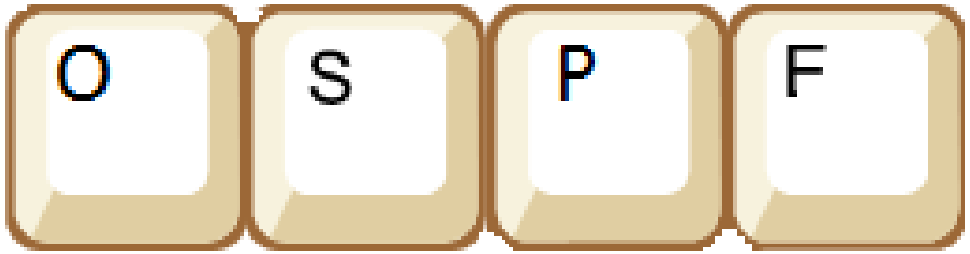
Verifying Multiarea OSPFv3 (cont.)




```
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      14      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)
```

OSPF Key Points

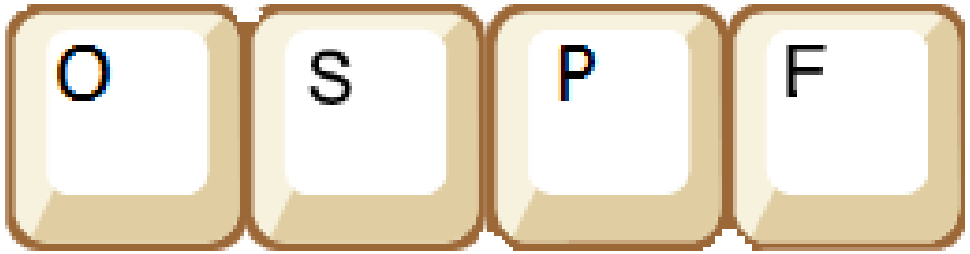
Summary



Multiarea OSPF:

- Better choice for larger network than single-area
- Solves the issues of large routing tables, large link-state databases, and frequent SPF algorithm calculations
- Main area is called the backbone area (area 0)
- Recalculating the database is kept within an area
- Four different types of OSPF routers:
  - Internal router
  - Backbone router
  - Area Border Router (ABR)
  - Autonomous System Boundary Router (ASBR)
- A router simply becomes an ABR when it has two network statements in different areas

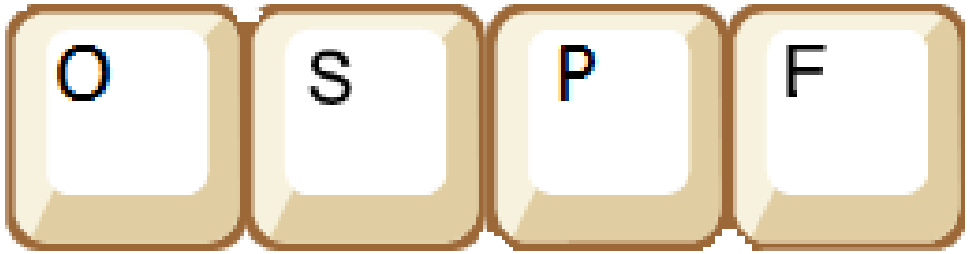
Summary



Multiarea OSPF:

- 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 or IPv6 routing table are identified using the following descriptors: O, O IA (OI), O E1 or O E2.

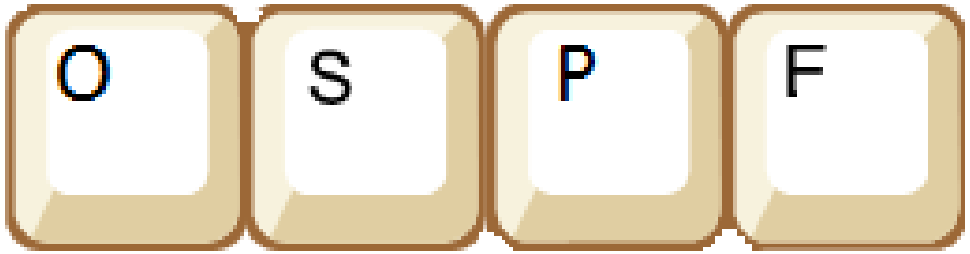
Summary



Multiarea OSPFv2:

- An example of multiarea OSPFv2 configuration:
  - R1(config)#**router ospf 10**
  - R1(config-router)#**router-id 1.1.1.1**
  - R1(config-router)#**network 10.1.1.0 0.0.0.15 area 1**
  - R1(config-router)#**network 10.1.2.0 0.0.0.3 area 1**
  - R1(config-router)#**network 192.168.10.1 0.0.0.0 area 0**
- Does not perform auto summarization but can be manually configured using the **`area X range`** or **`summary-address`** router configuration command

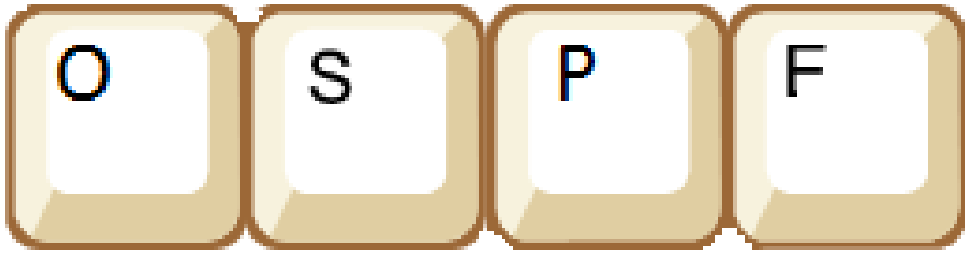
Summary



Multiarea OSPFv3:

- An example of multiarea OSPFv2 configuration:
  - R1(config)#**ipv6 unicast-routing**
  - R1(config)#**ipv6 router ospf 10**
  - R1(config-rtr)# **ipv6 router-id 1.1.1.1**
  - R1(config-rtr)# **int fa0/0**
  - R1(config-if)# **ipv6 ospf 10 area 0**
- Does not perform auto summarization but can be manually configured using the **`area X range`** or **`summary-address`** router configuration command

Summary

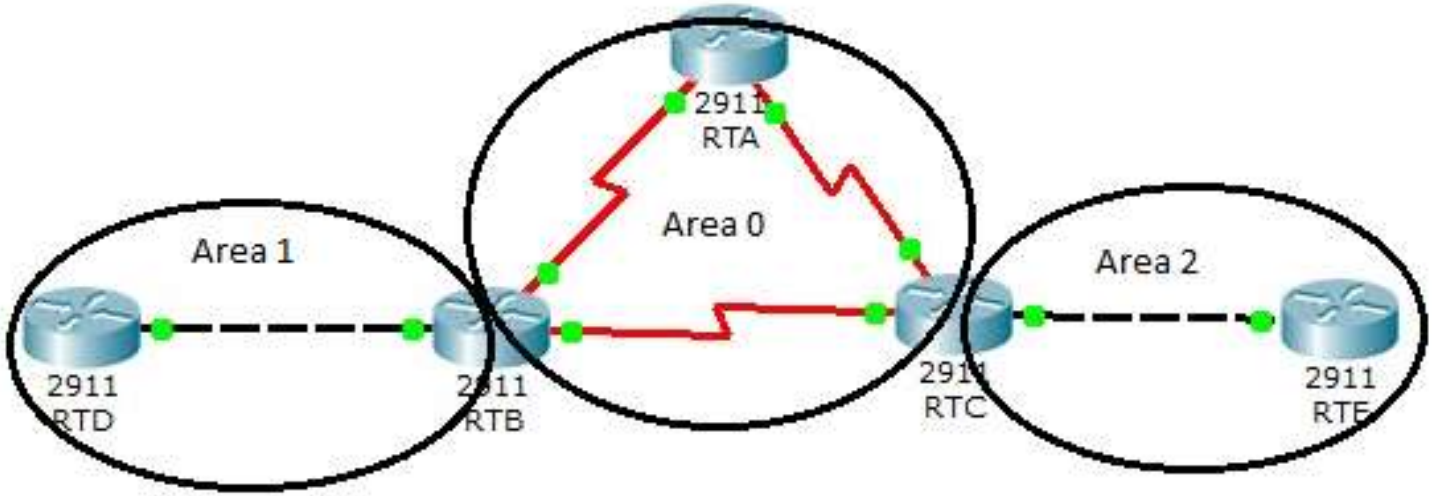


Multiarea OSPFv2:

- Commands that are used to verify OSPF configuration consist of the following:
  - 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

Packet Tracer Activity

Multi-area OSPF Practice Lab



Final exam

- 2 parts:
  - Quiz: Multiple choices answers and Short answer questions: 20 minutes
    - Cover all topics
  - Practice with Packet Tracer: 30 minutes
    - IP addressing: IPv4, IPv6
    - Routing
    - Submit your .pkt file in submission box in course website
    - You need to sign-up to have account to use Packet Tracer
- Closed-book
- Open only **ONE tab** in **ONE web browser** to do the exam
- No calculator, no mobile phone

Thank you.

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Mind Wide Open