Chapter 6: Multiarea OSPF

Scaling Networks

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Chapter 6

6.0 Introduction

6.1 Multiarea OSPF

6.2 Configuring Multiarea OSPF

6.3 Summary

Chapter 6: Objectives

After completing this chapter, students will be able to:

- Explain why multiarea OSPF is used.
- Explain how multiarea OSPF uses link-state advertisements in order to maintain routing tables.
- Explain how OSPF established neighbor adjacencies in a multiarea OSPF implementation.
- Configure multiarea OSPFv2 in a routed network.
- Configure multiarea route summarization in a routed network.
- Verify multiarea OSPFv2 operations.

6.1 Multiarea OSPF Operation

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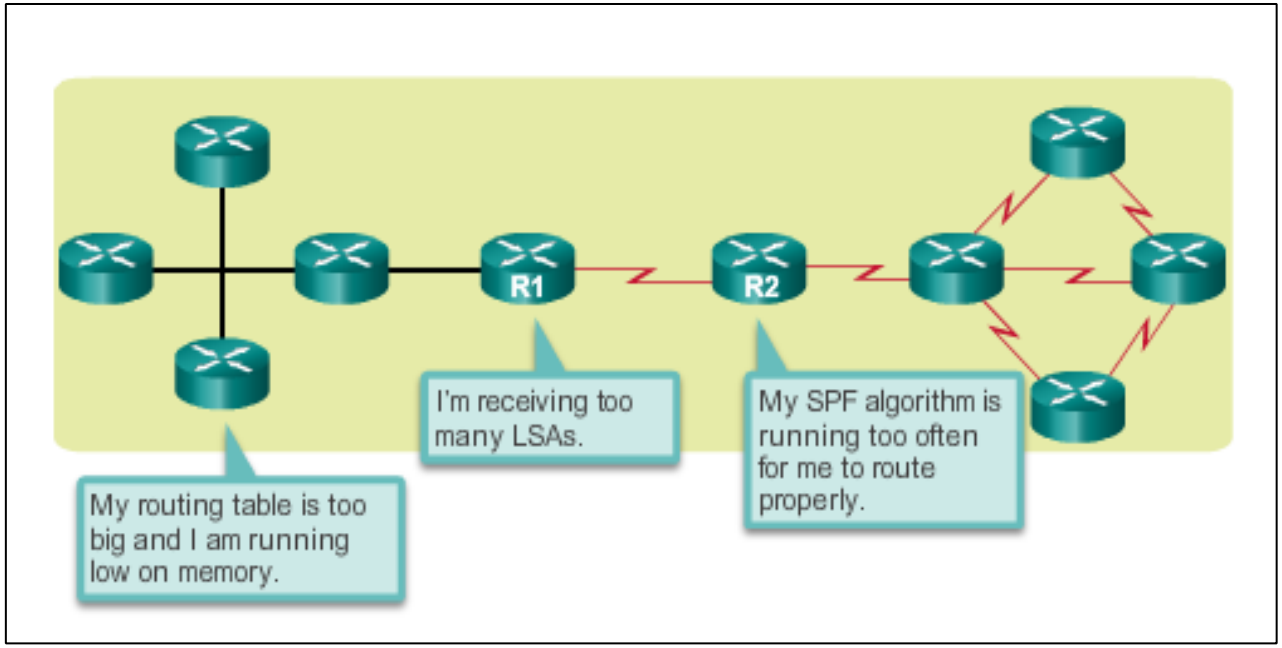
Why Multiarea OSPF?

Single-Area OSPF

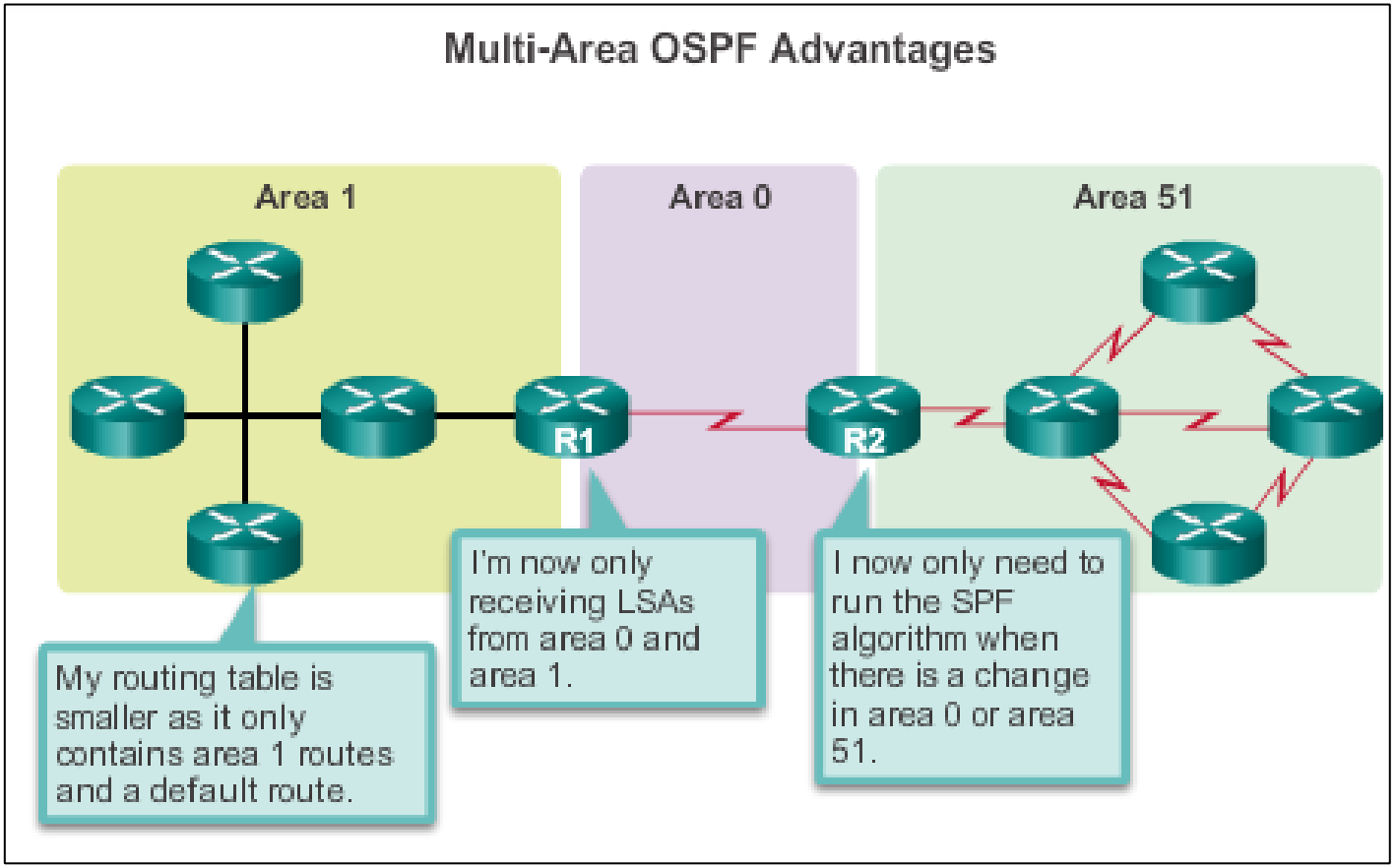
Single-area OSPF is useful in smaller networks. If an area becomes too big, the following issues must be addressed:

- Large routing table (no summarization by default)
- Large link-state database (LSDB)
- Frequent SPF algorithm calculations



Multiarea OSPF

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



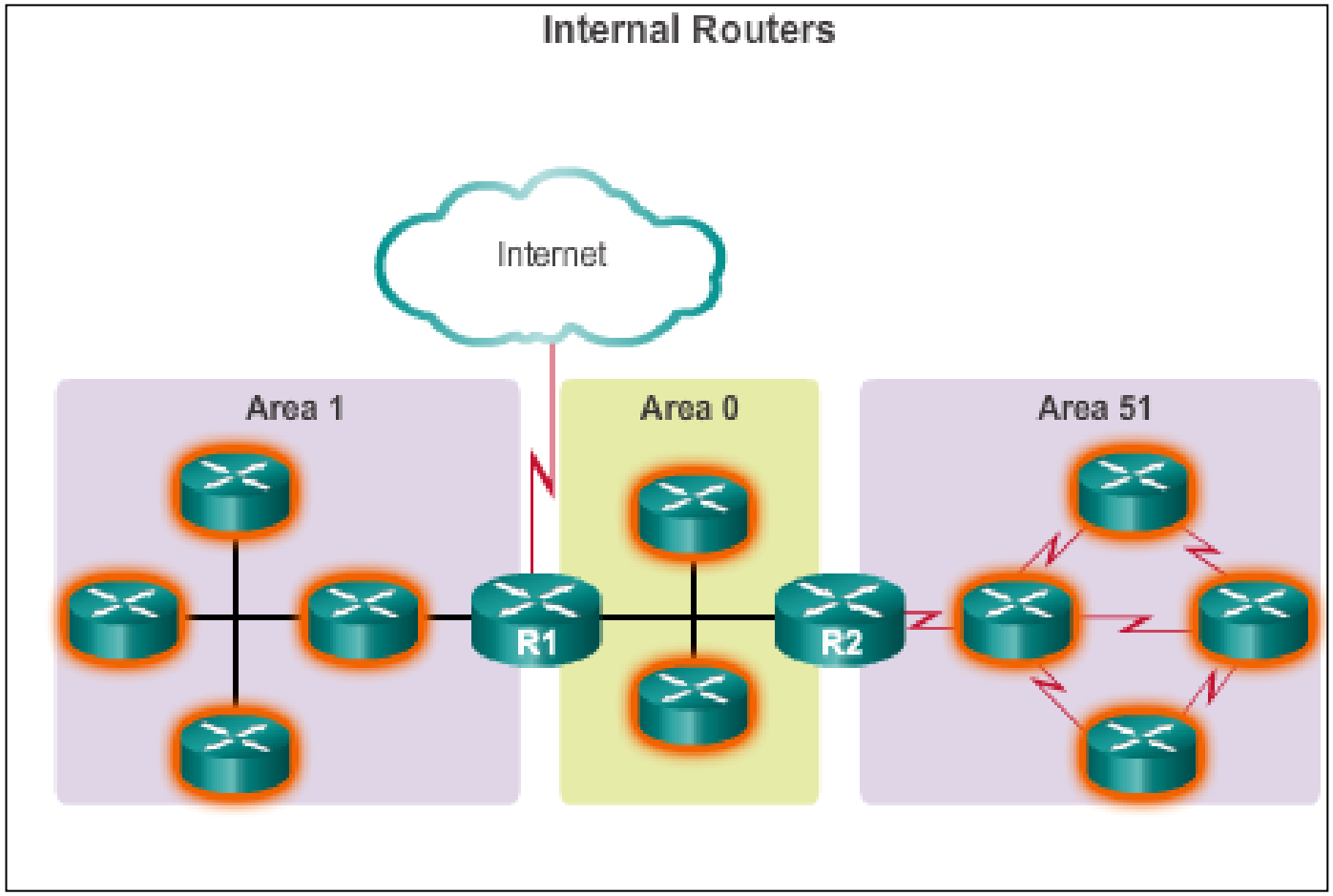
OSPF Two-Layer Area Hierarchy

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

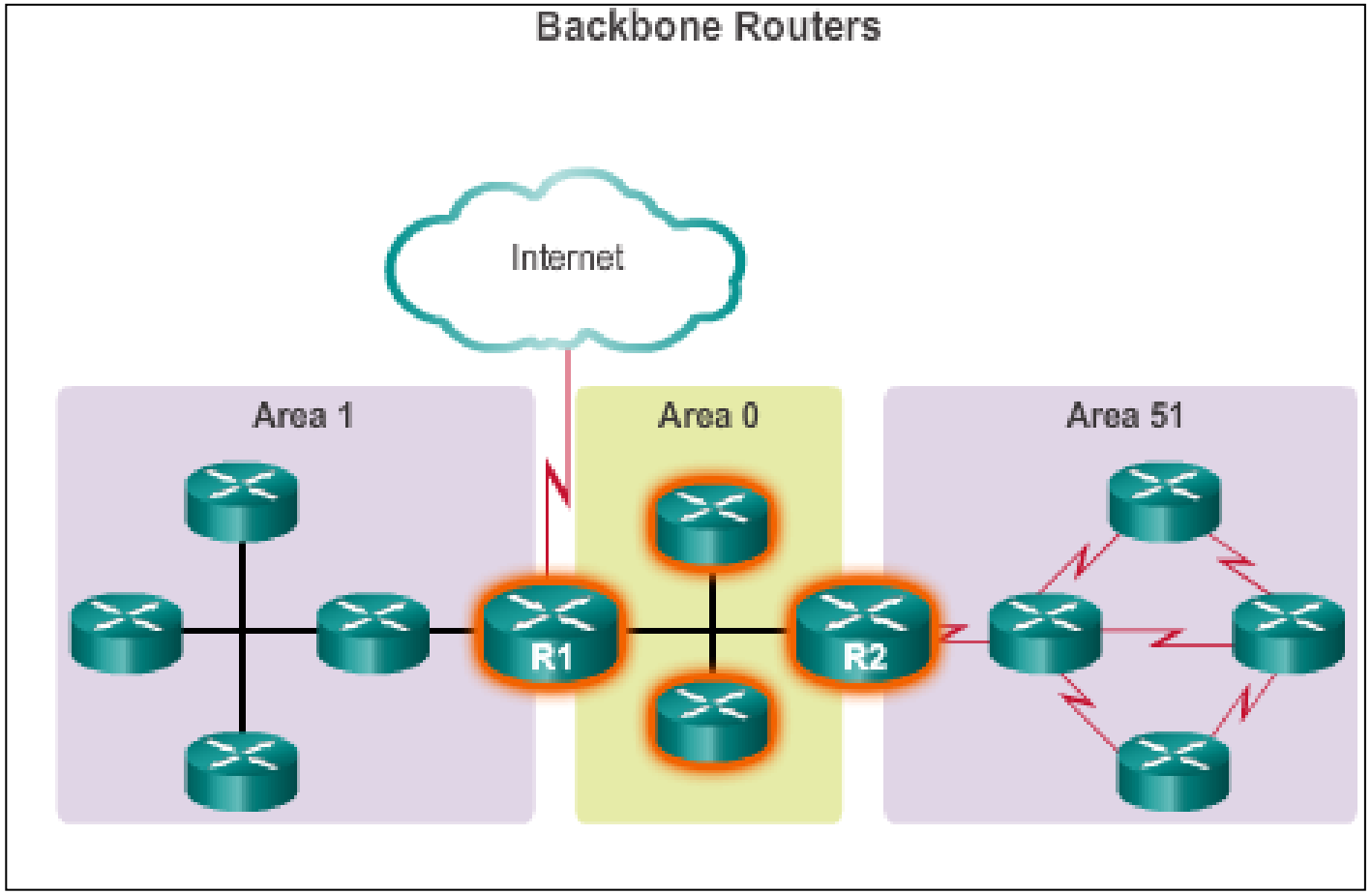
- **Backbone (transit) area**
  - Area whose primary function is the fast and efficient movement of IP packets.
  - Interconnects with other OSPF area types.
  - Called OSPF area 0, to which all other areas directly connect.
- **Regular (nonbackbone) area**
  - Connects users and resources.
  - A regular area does not allow traffic from another area to use its links to reach other areas.

Why Multiarea OSPF?

Types of OSPF Routers

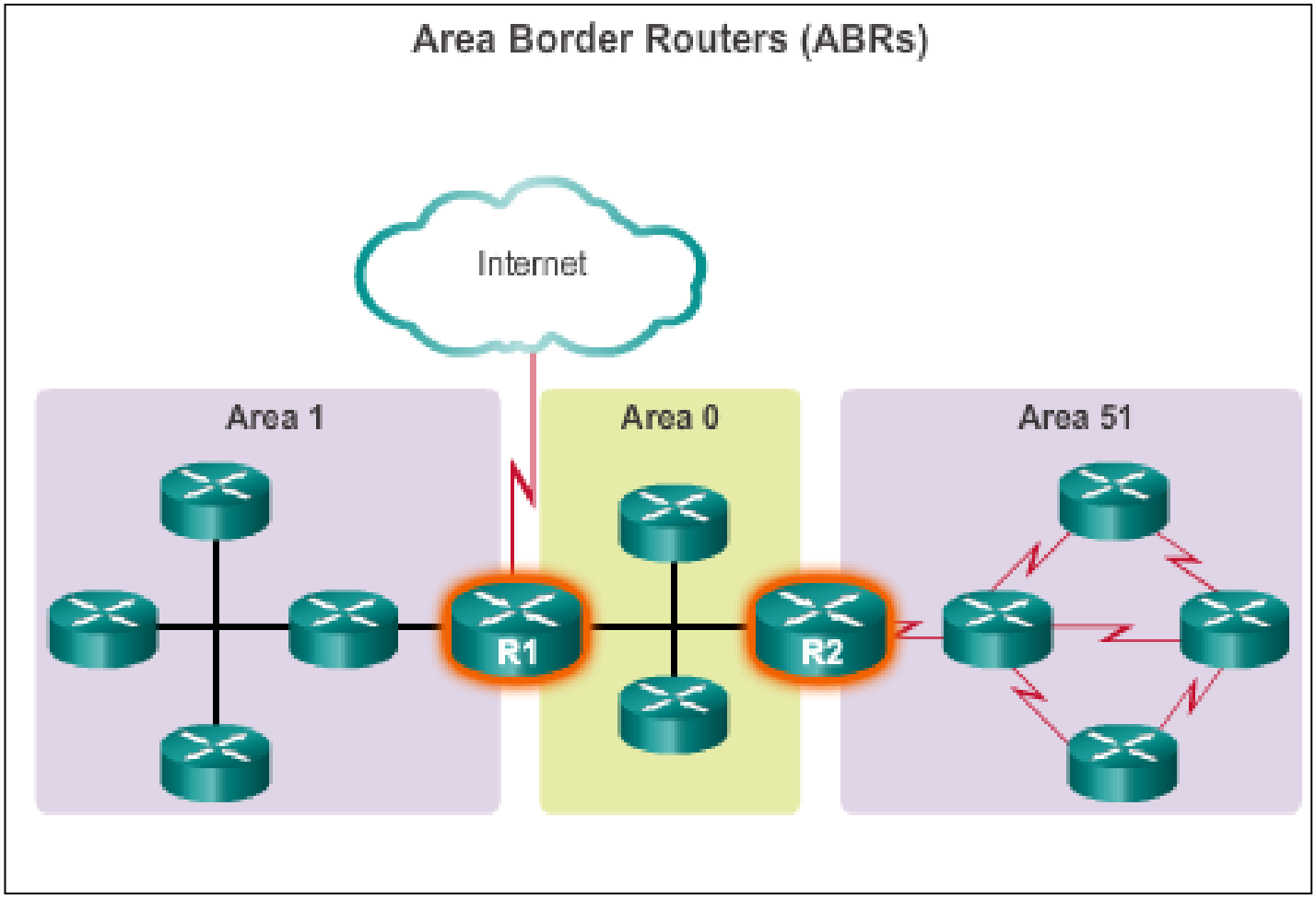


Types of OSPF Routers (cont.)

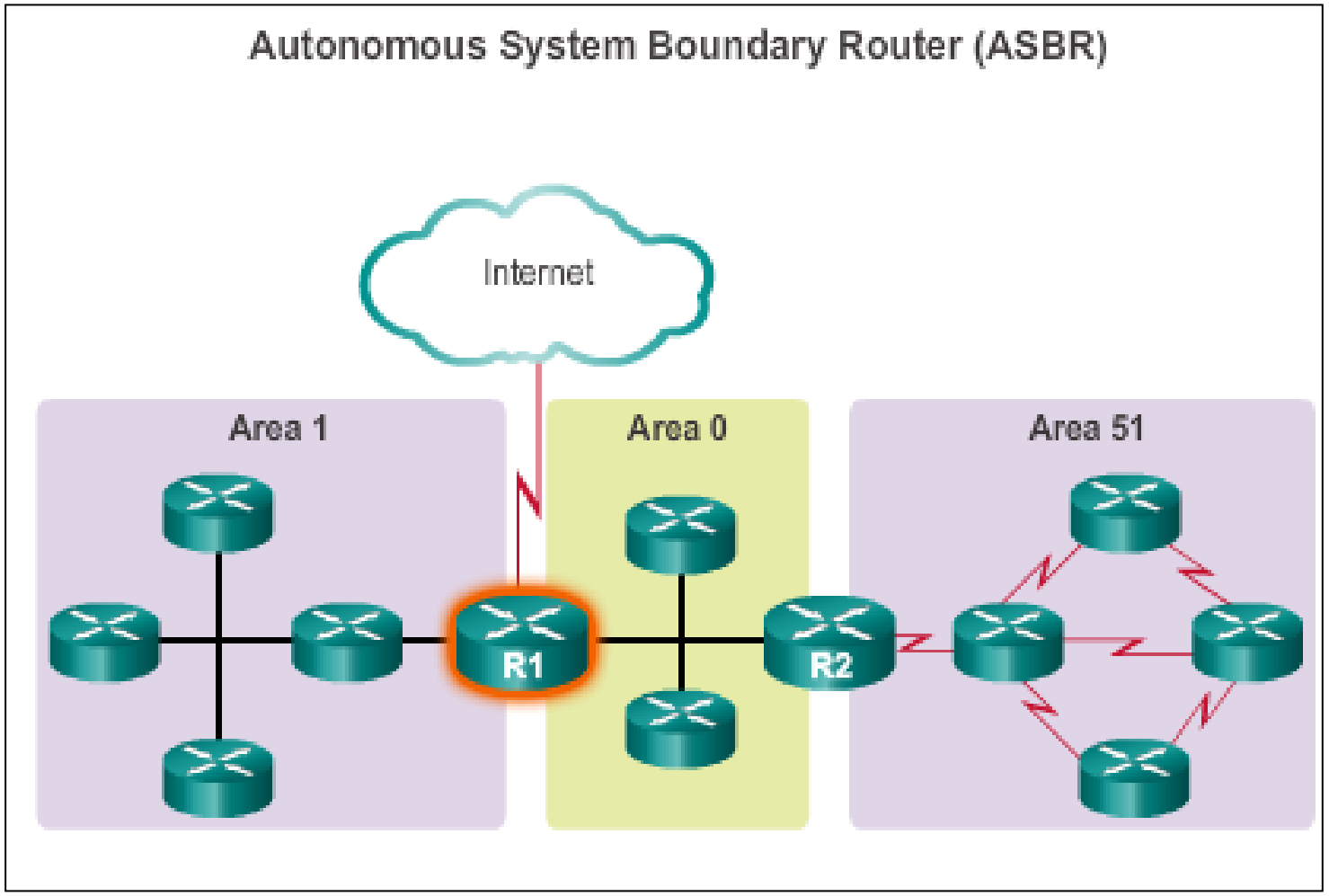


Why Multiarea OSPF?

Types of OSPF Routers (cont.)



Types of OSPF Routers (cont.)



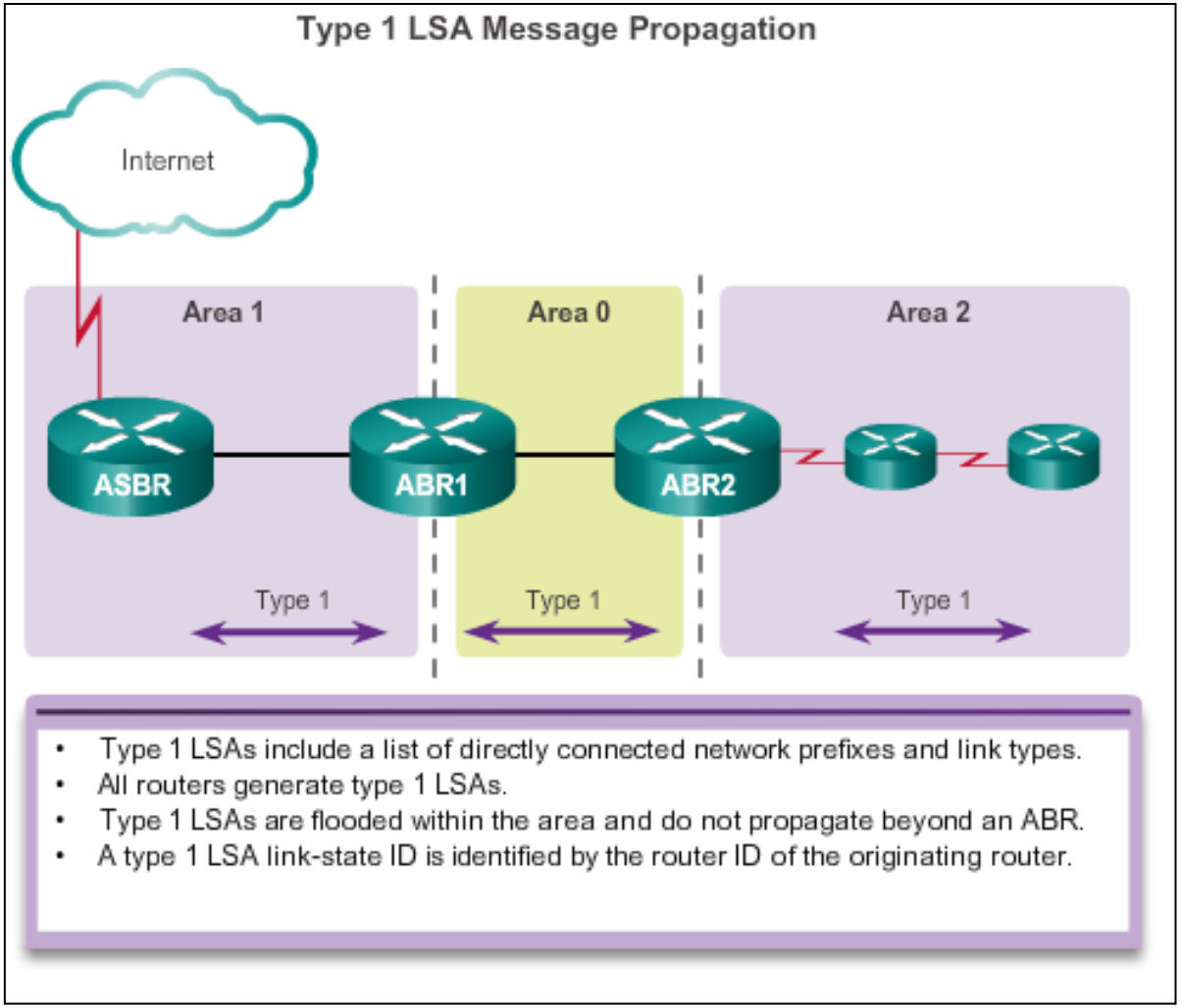
Multiarea OSPF LSA Operation

OSPF LSA Types

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

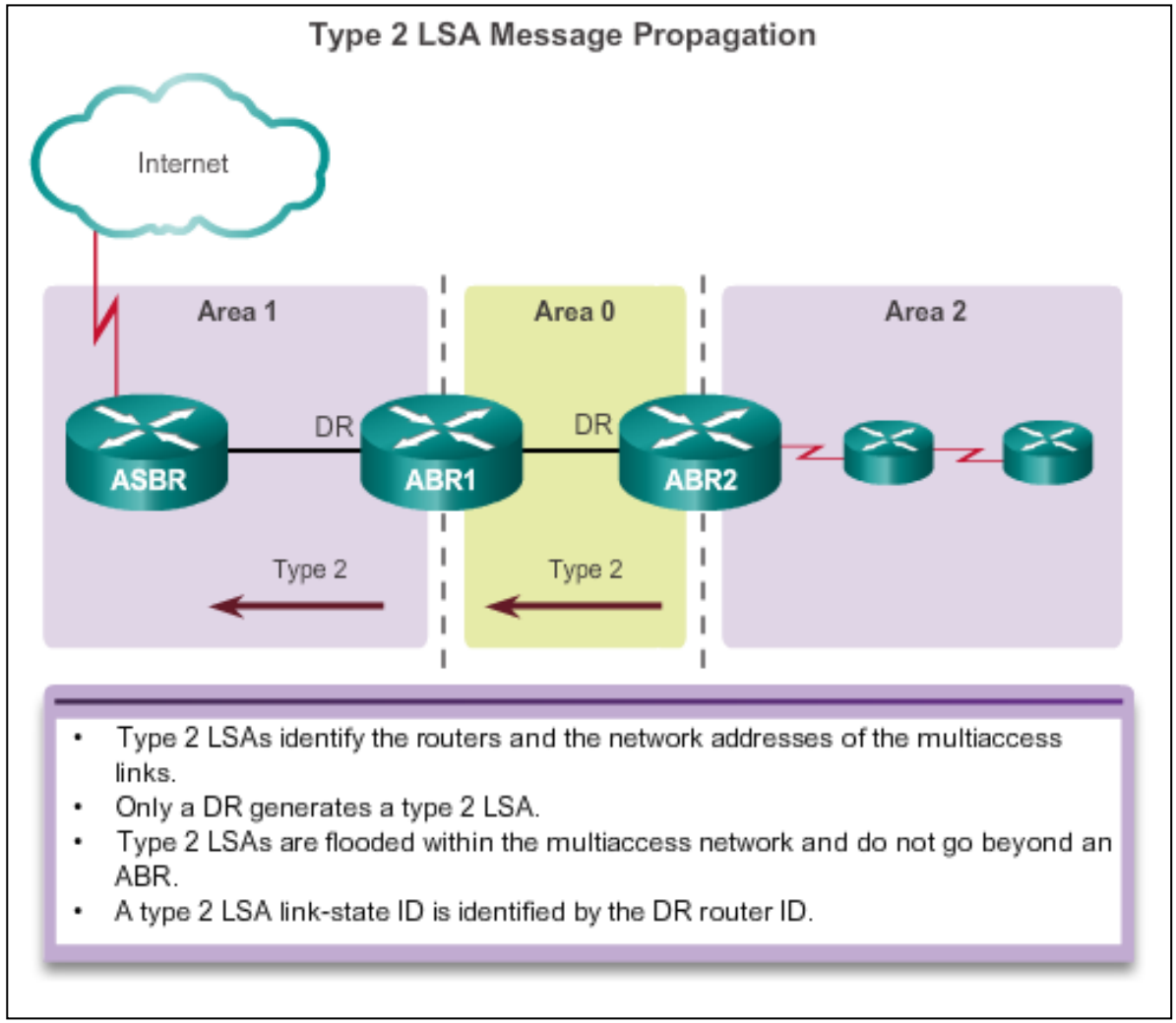
Most common and covered in this course – 1 thru 5

OSPF LSA Type 1



Multiarea OSPF LSA Operation

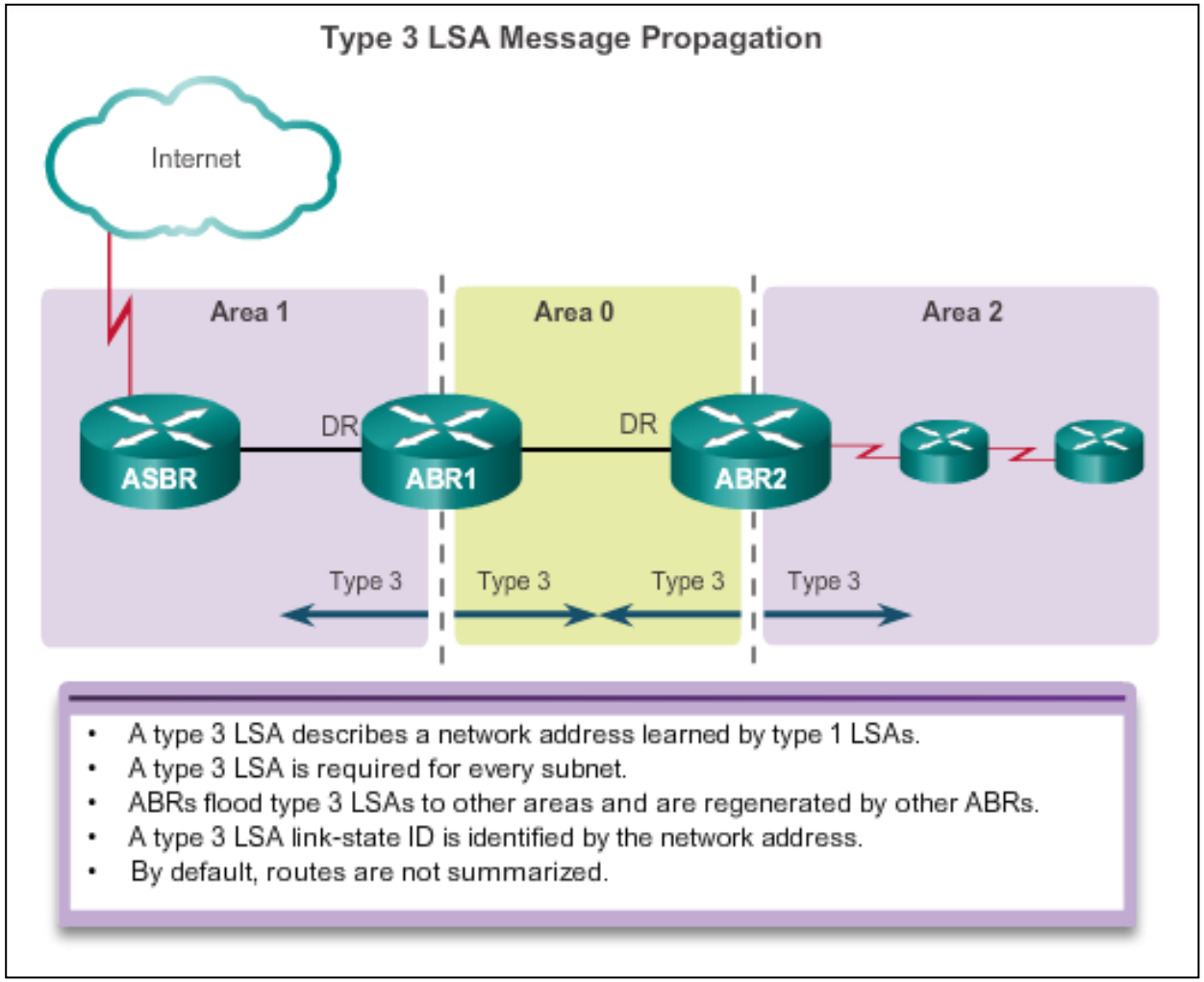
OSPF LSA Type 2



- Type 2 LSAs identify the routers and the network addresses of the multiaccess links.
- Only a DR generates a type 2 LSA.
- Type 2 LSAs are flooded within the multiaccess network and do not go beyond an ABR.
- A type 2 LSA link-state ID is identified by the DR router ID.

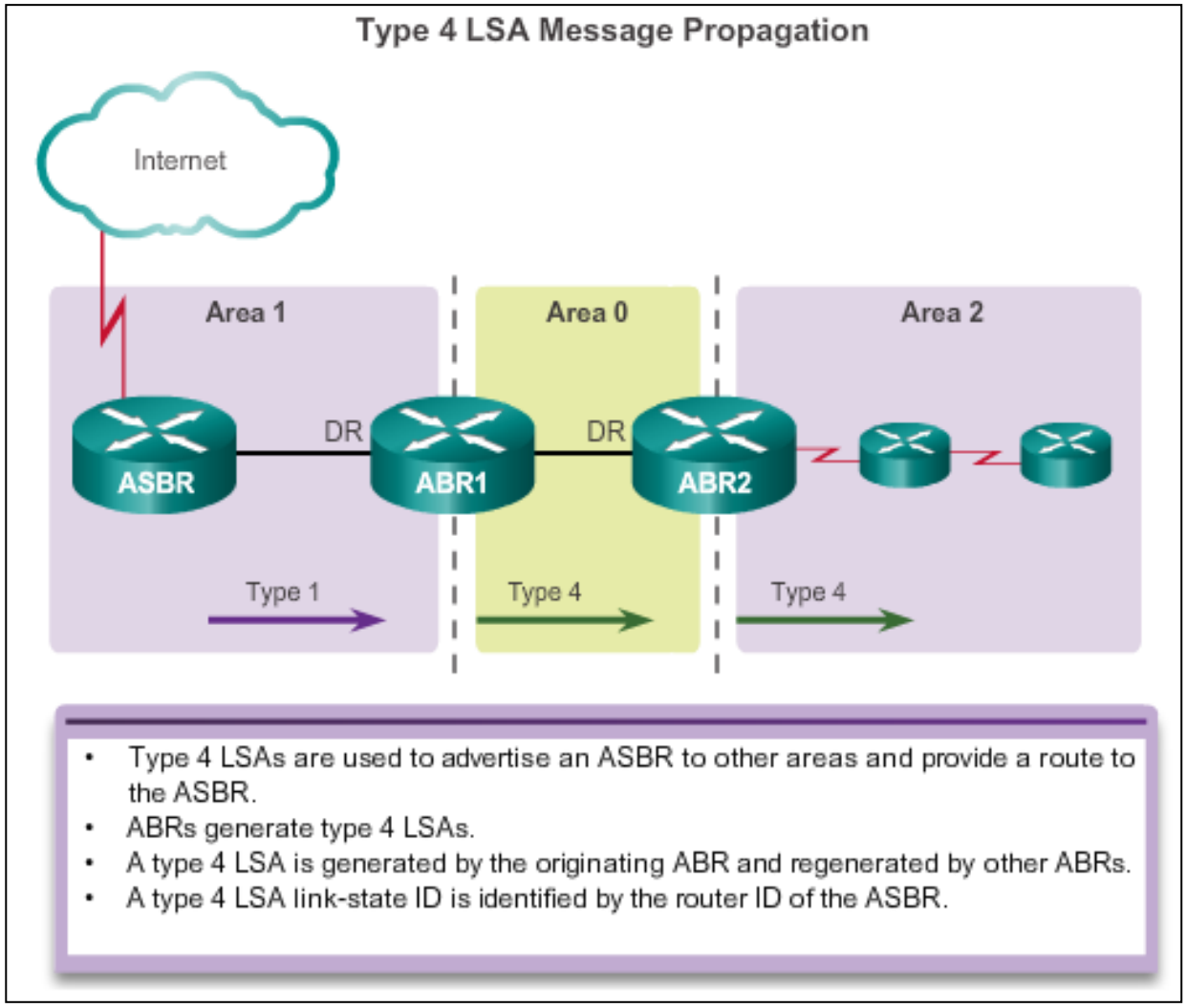
Multiarea OSPF LSA Operation

OSPF LSA Type 3



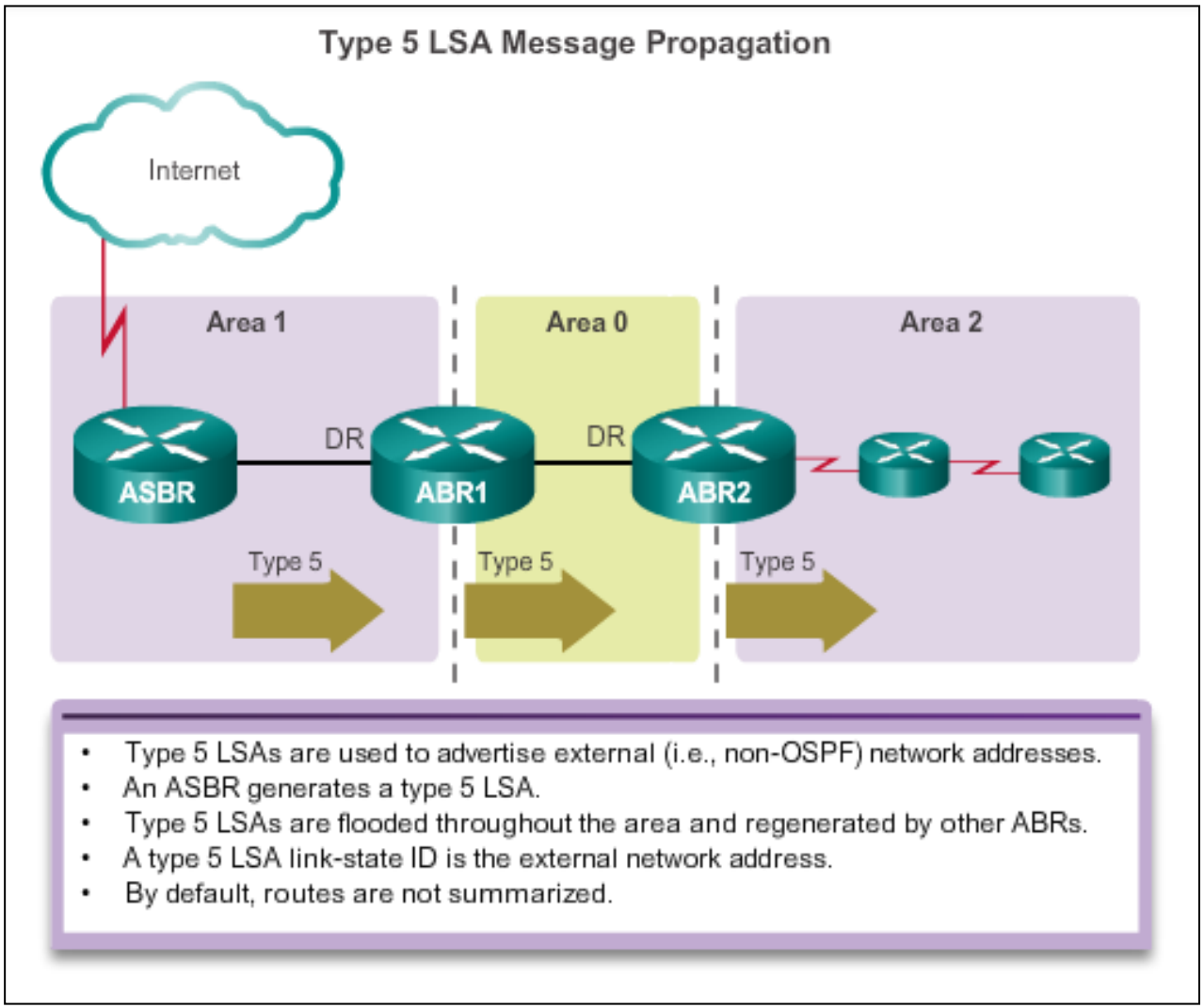
Multiarea OSPF LSA Operation

OSPF LSA Type 4



Multiarea OSPF LSA Operation

OSPF LSA Type 5



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

OSPF Routing Table Entries

- **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) routes

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#
```

OSPF Routing Table Entries (cont.)

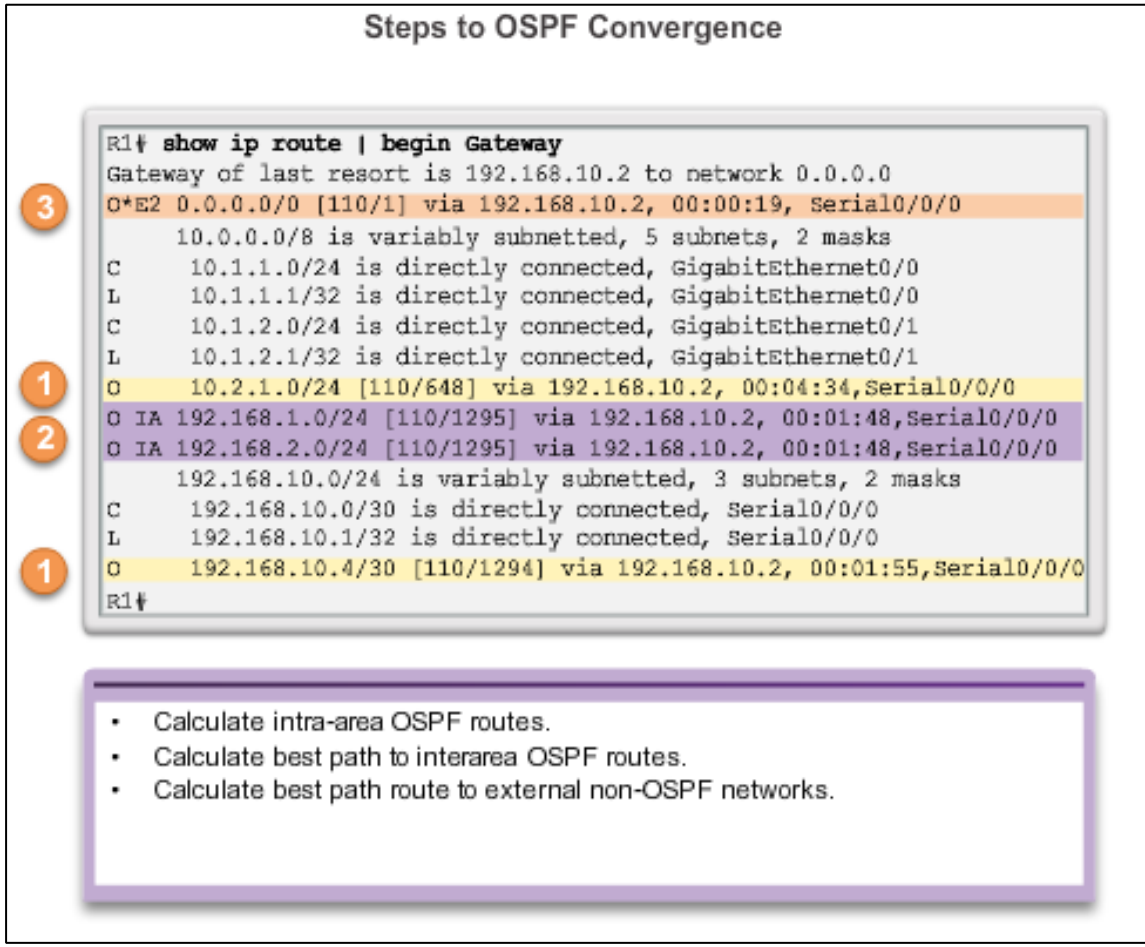
- **O** – Router (type 1) and network (type 2) LSAs describe the details within an area (the route is intra-area)
- **O IA** – Summary LSAs appear in the routing table as IA (interarea routes)
- **O E1** or **OE 2** – External LSAs external type 1 (E1) or external type 2 (E2) routes

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#
```

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.



6.2 Configuring Multiarea OSPF

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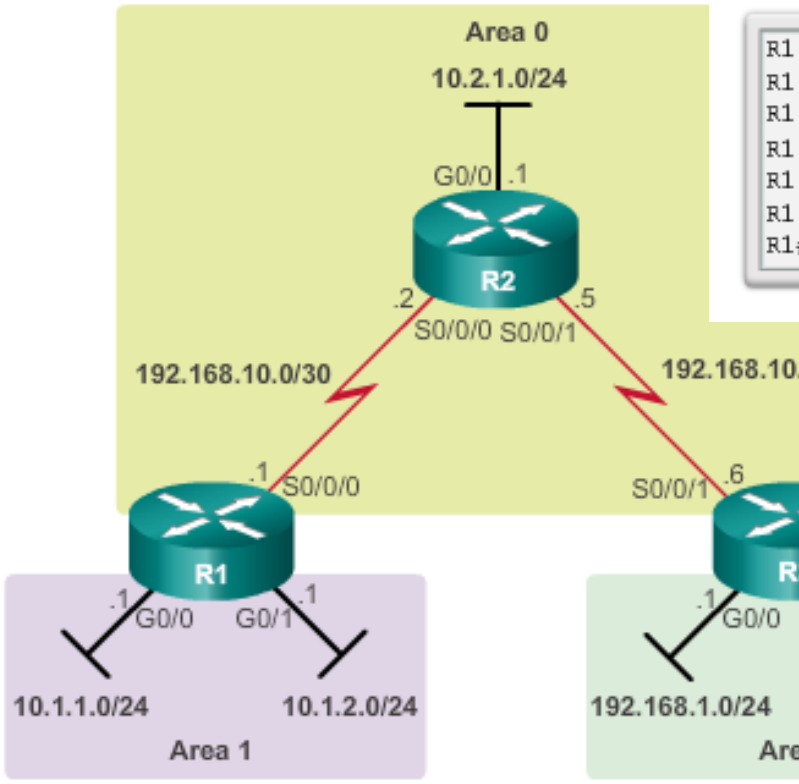
Implementing Multiarea OSPF

Implementation Plan Steps

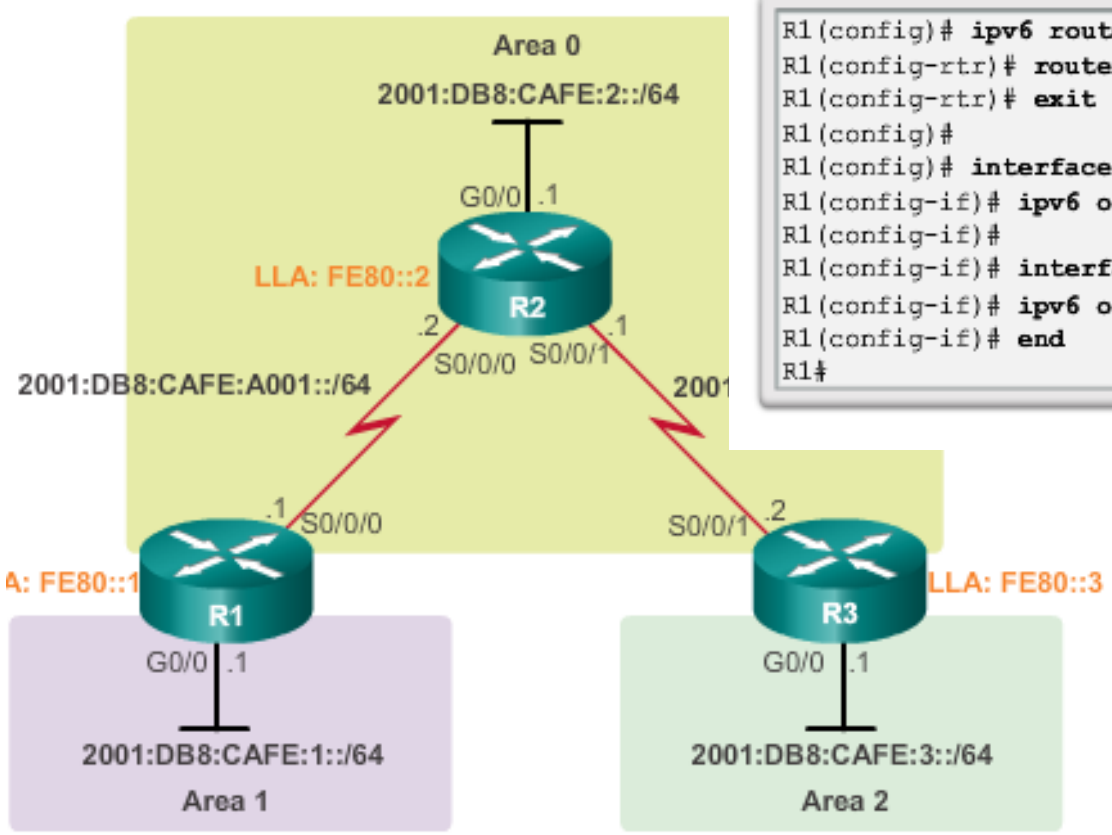
1. Gather the network requirements and parameters.
2. Define the OSPF parameters.
3. Configure OSPF.
4. Verify OSPF.

Configuring Multiarea OSPF




```
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#
```

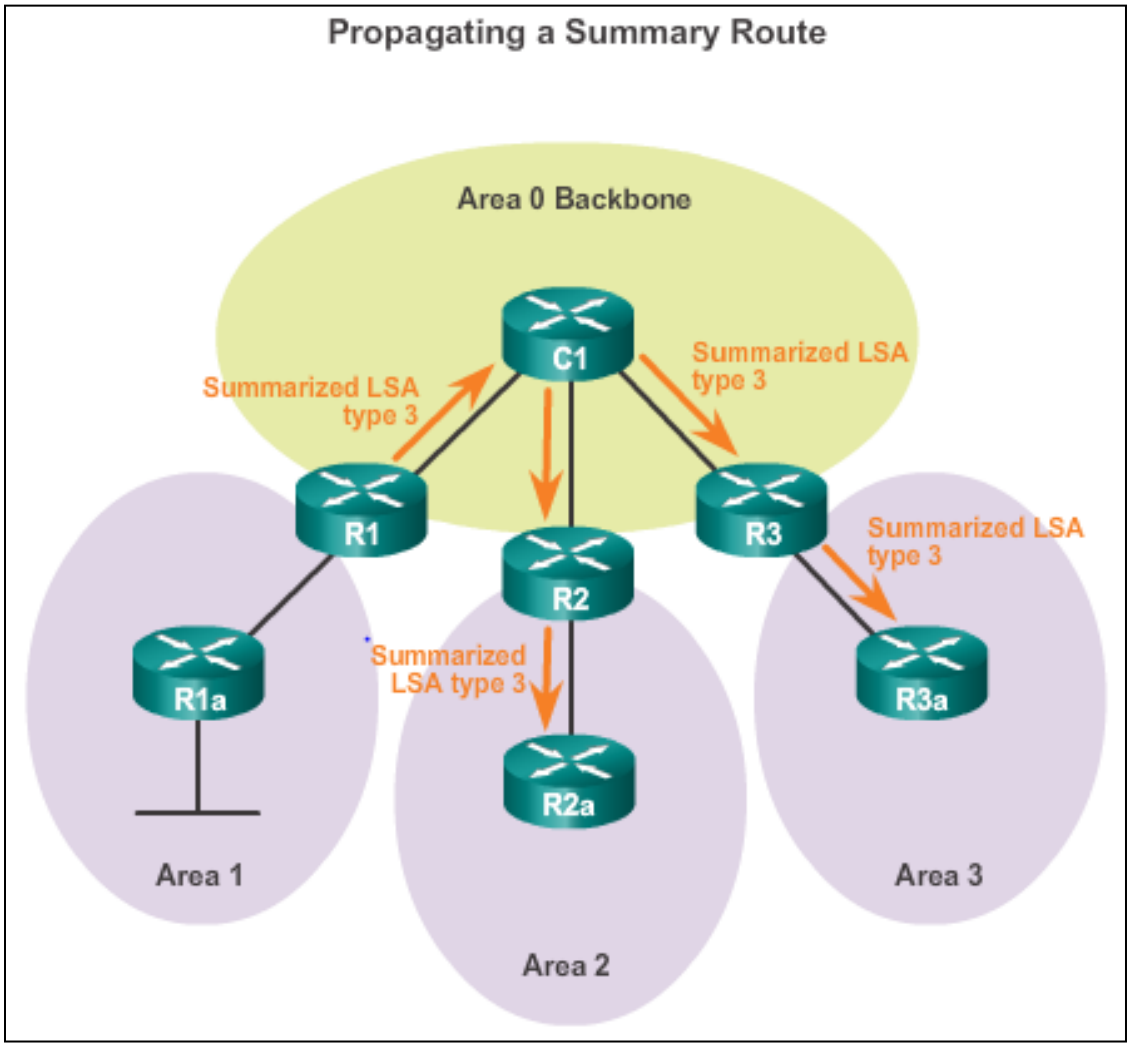
Configuring Multiarea OSPFv3




```
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

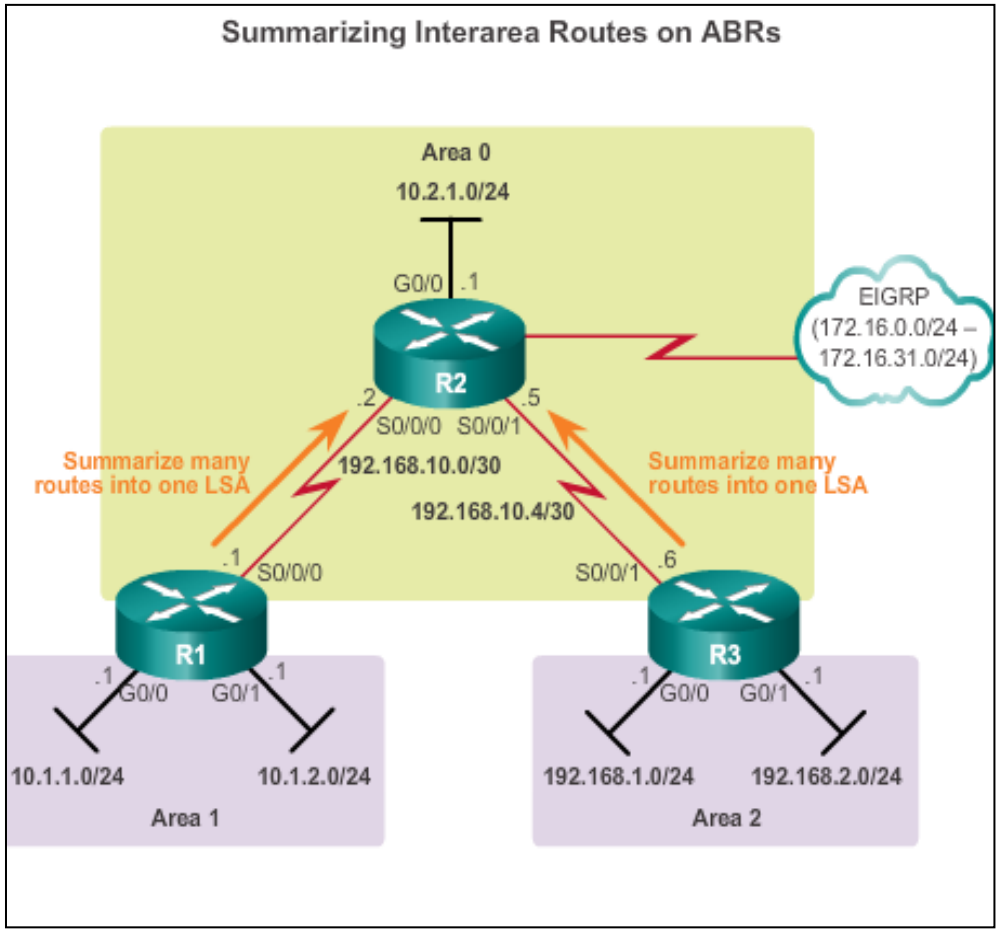
- R1 forwards a summary LSA to the core router C1.
- C1, in turn, forwards the summary LSA to R2 and R3.
- R2 and R3 then forward it to their respective internal routers.



OSPF Route Summarization

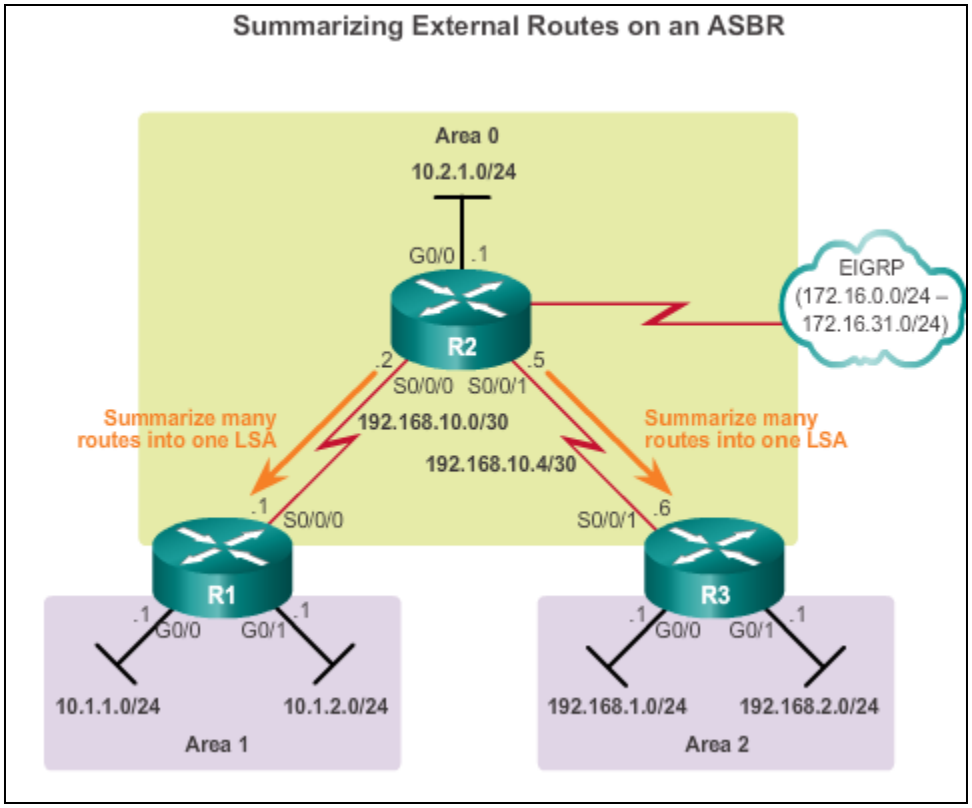
Interarea and External Route Summarization

Occurs on ABRs and applies to routes from within each area



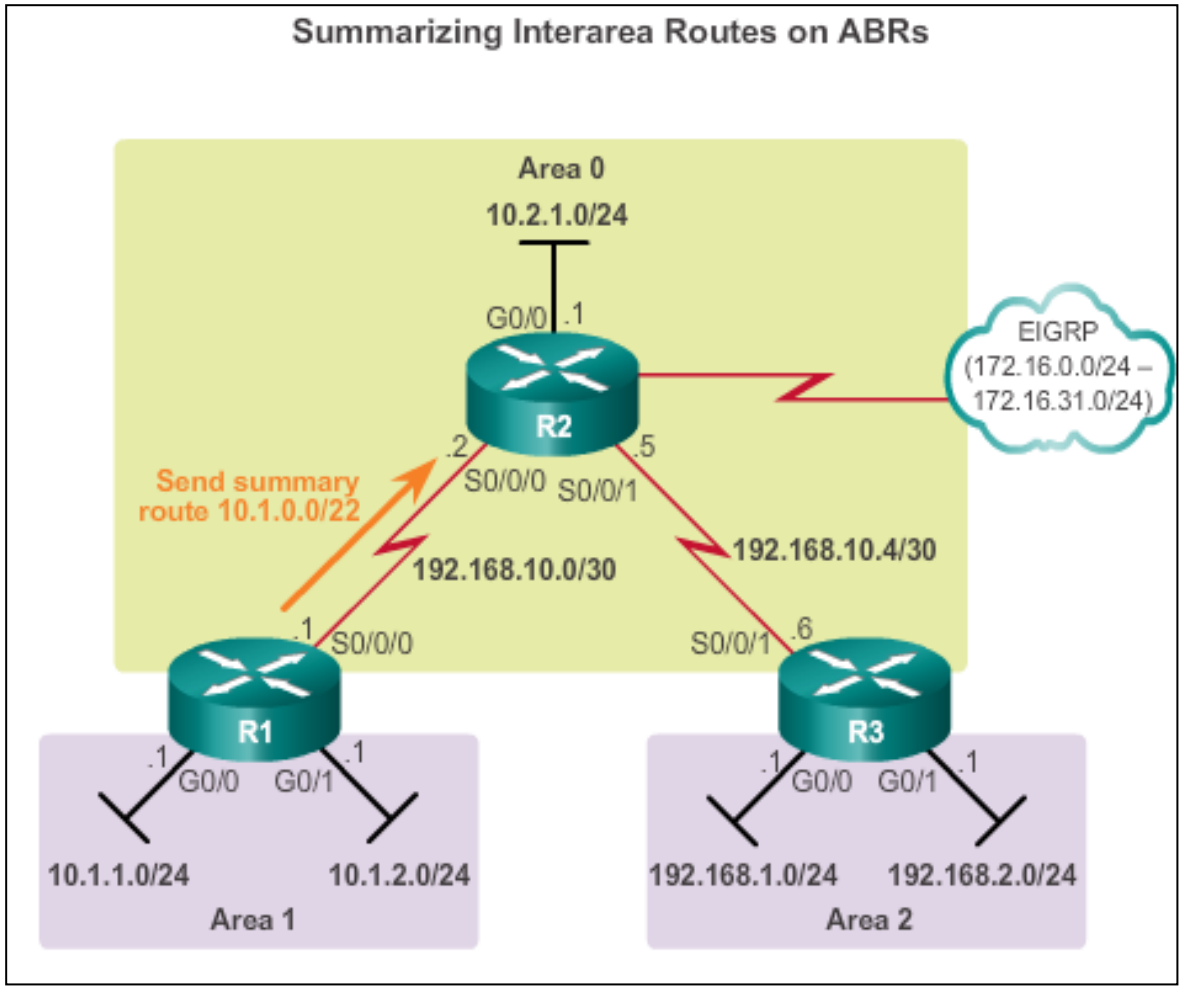
Interarea and External Route Summarization (cont.)

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



OSPF Route Summarization

Interarea Route Summarization



OSPF Route Summarization

Interarea Route Summarization (cont.)

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
      masks
O        192.168.10.4/30 [110/1294] via 192.16
         00:00:49, Serial0/0/0
R1#
```

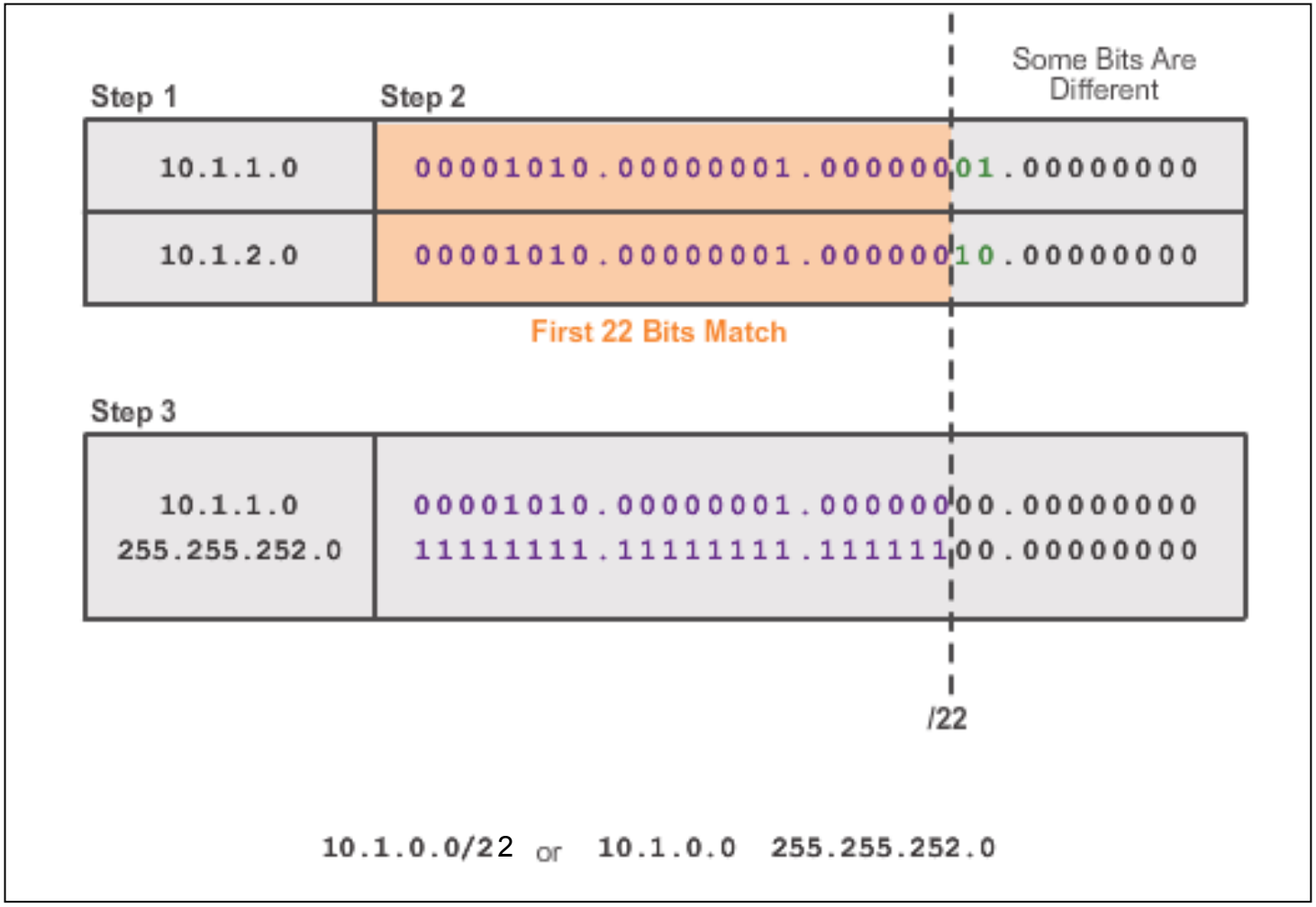
Verify the R3 Routing Table Before Summarization

```
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#
```

OSPF Route Summarization

Calculating the Summary Route



OSPF Route Summarization

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#
```

Verifying Multiarea OSPF

The same verification commands are used to verify single-area OSPF and can be used to verify multiarea OSPF:

- **`show ip ospf neighbor`**
- **`show ip ospf`**
- **`show ip ospf interface`**

Commands specific to multiarea information include:

- **`show ip protocols`**
- **`show ip ospf interface brief`**
- **`show ip route ospf`**
- **`show ip ospf database`**

Note: For OSPFv3, substitute **`ip`** with **`ipv6`**.

Verifying Multiarea OSPF

Verifying General Multiarea OSPF Settings

```
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#
```

Verifying Multiarea OSPF

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#
```

Verifying the Multiarea OSPF LSDB

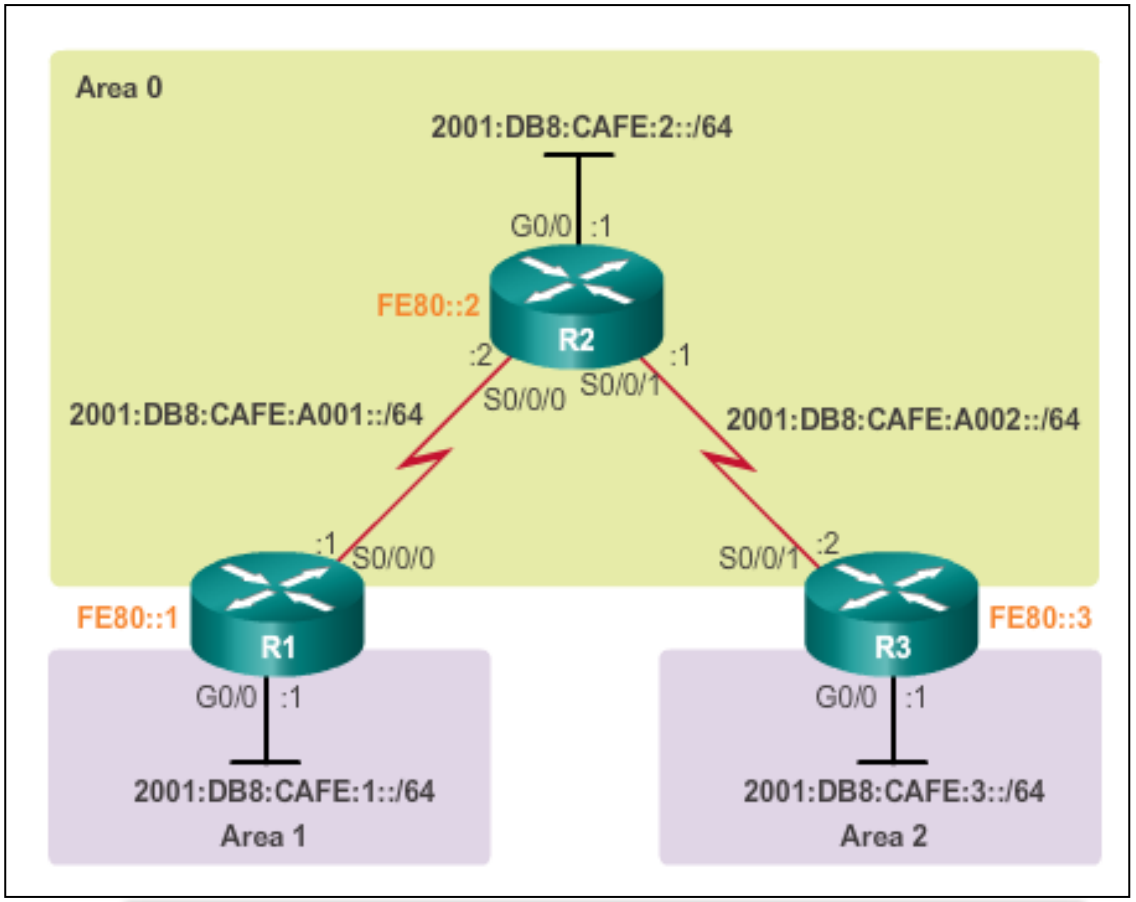
Verifying the OSPF LSDB on R1

```
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

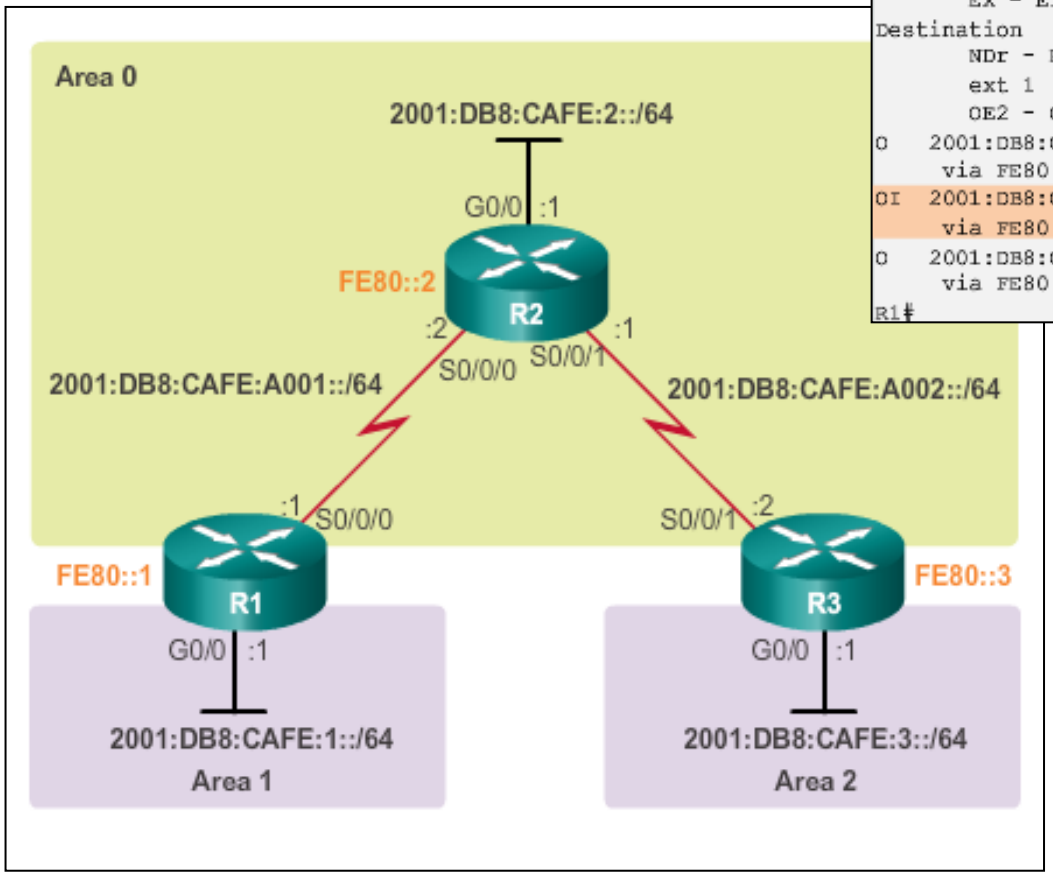



```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Area border router
  Number of areas: 2 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Serial0/0/0
  Interfaces (Area 1):
    GigabitEthernet0/0
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

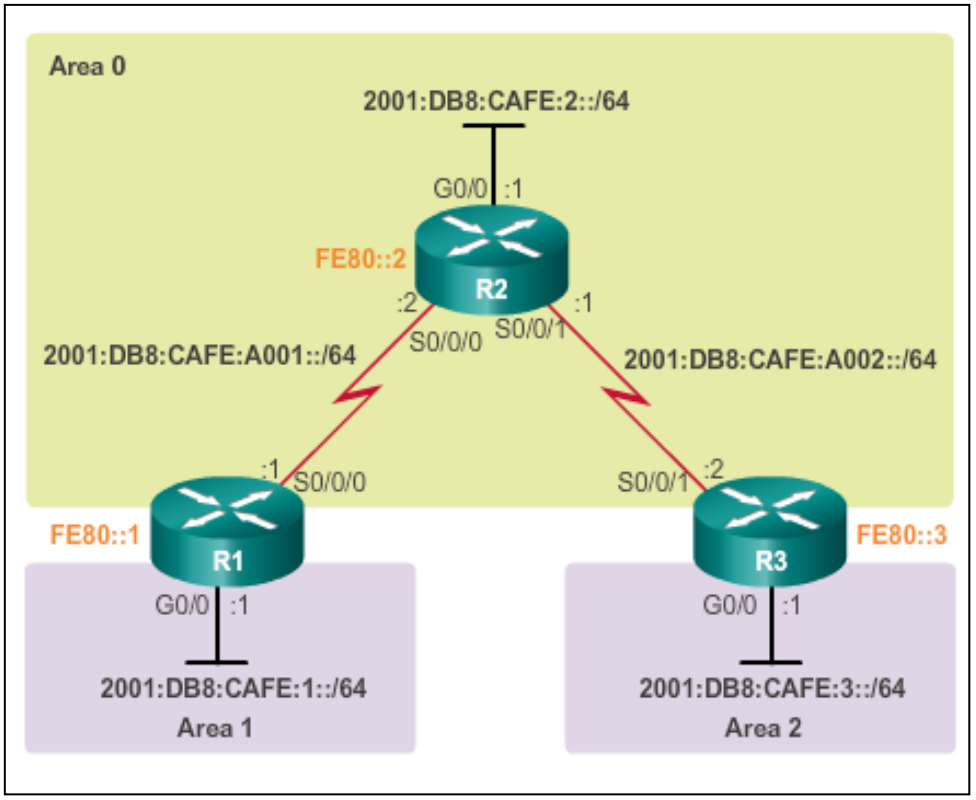
```
R1# show ipv6 ospf interface brief
Interface    PID   Area            Intf ID    Cost  State Nbrs F/C
Se0/0/0      10    0               6          647   P2P   1/1
Gi0/0        10    1               3          1     DR    0/0
R1#
```

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)
```

Multiarea OSPF Summary

- Better choice for larger networks than single-area.
- Solves the issues of large routing table, large LSDB, and frequent SPF algorithm calculations.
- Main area is called the backbone area, or area 0.
- Recalculating the database is kept within an area.
- Four different types of OSPF routers:
  - Internal router
  - Backbone router
  - ABR
  - ASBR
- A router simply becomes an ABR when it has two network statements in different areas.

Multiarea OSPF Summary (cont.)

- 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
```

- Does not perform autosummarization, 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**