



## 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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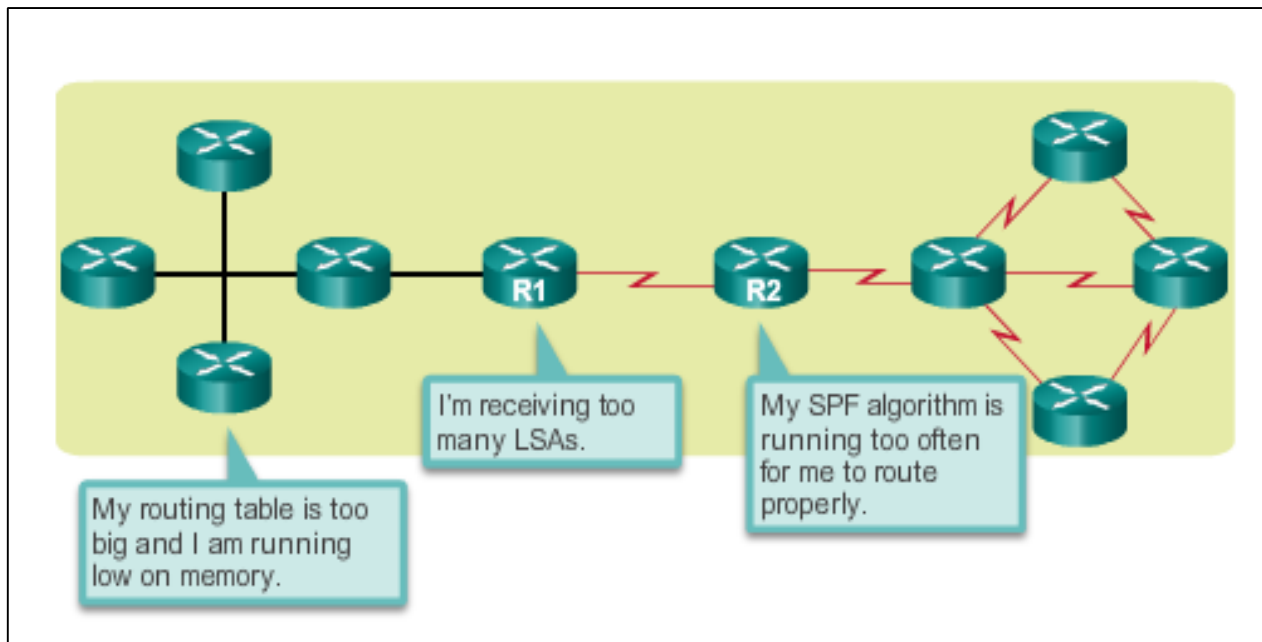


# Why Multiarea OSPF?

## 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

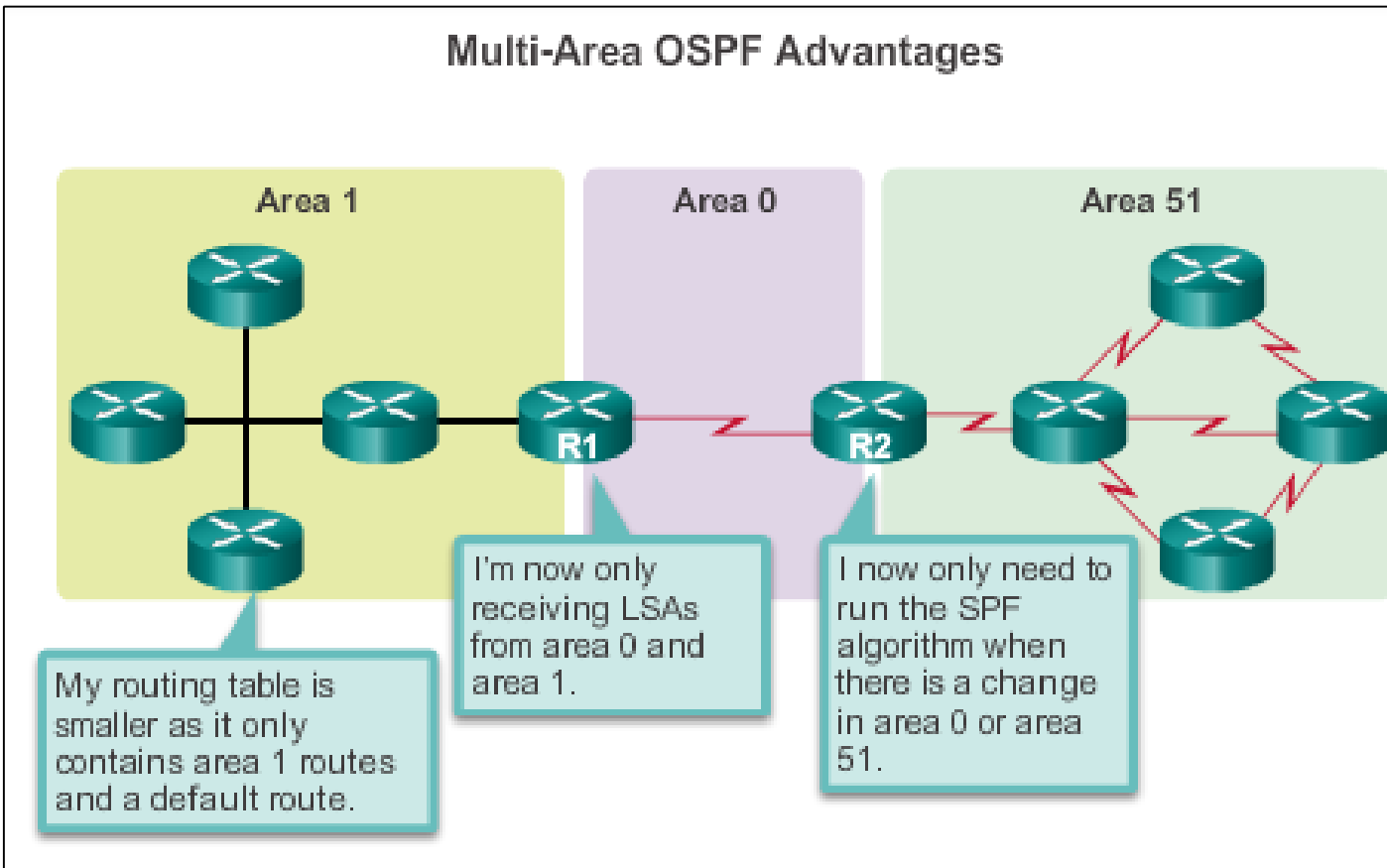




# Why Multiarea OSPF?

## 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.





## Why Multiarea OSPF?

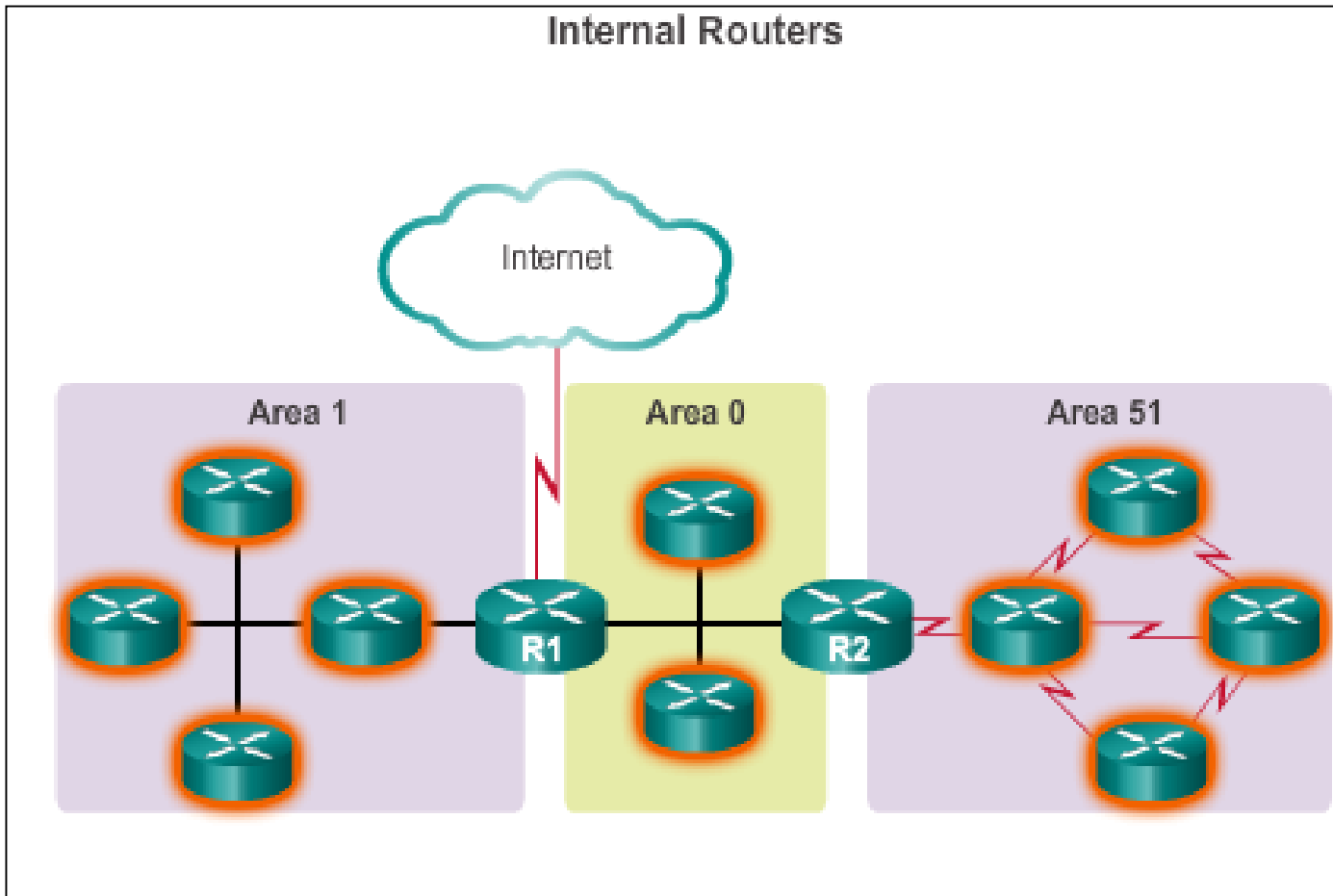
# OSPF Two-Layer Area Hierarchy

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

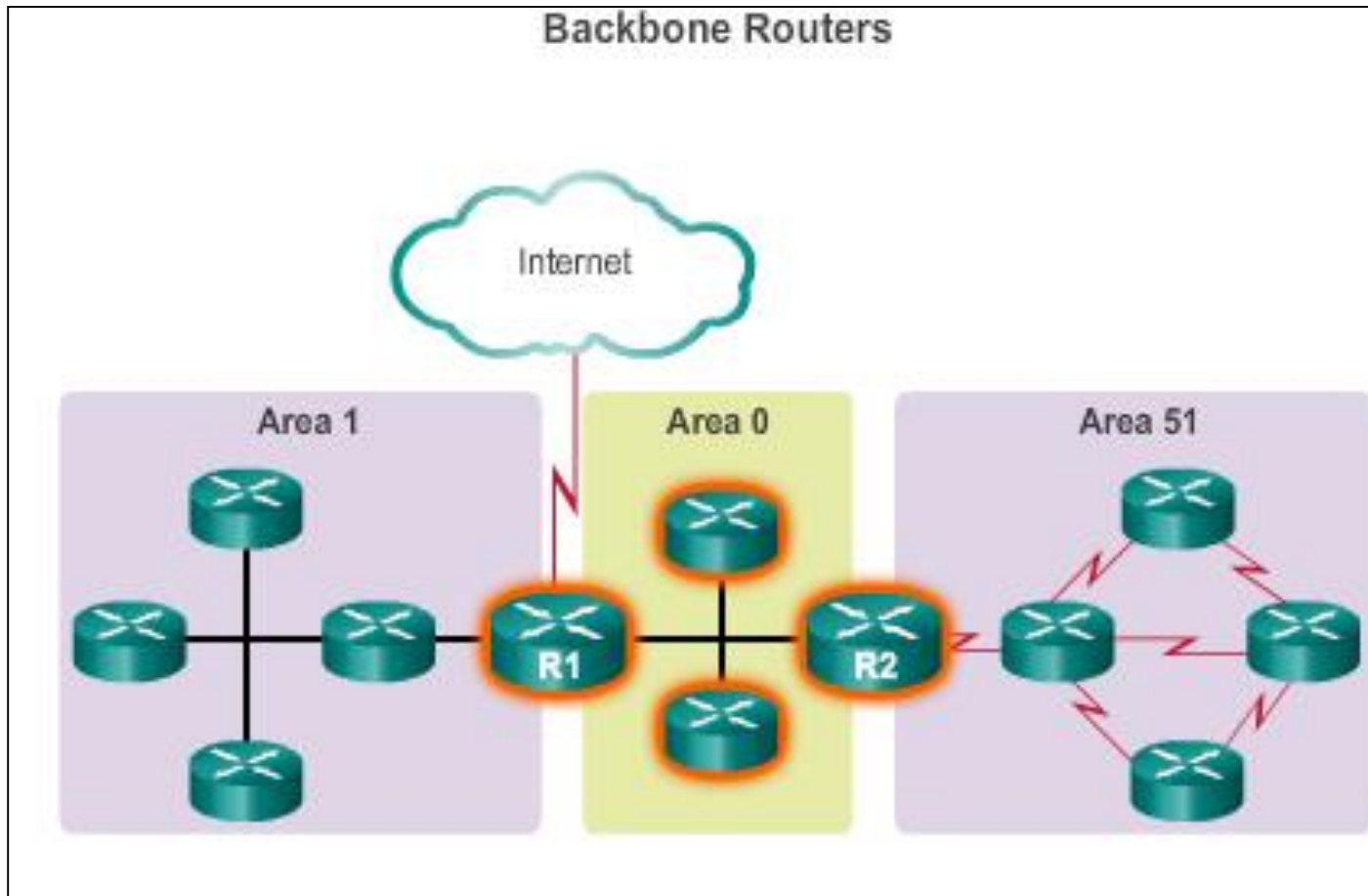






Why Multiarea OSPF?

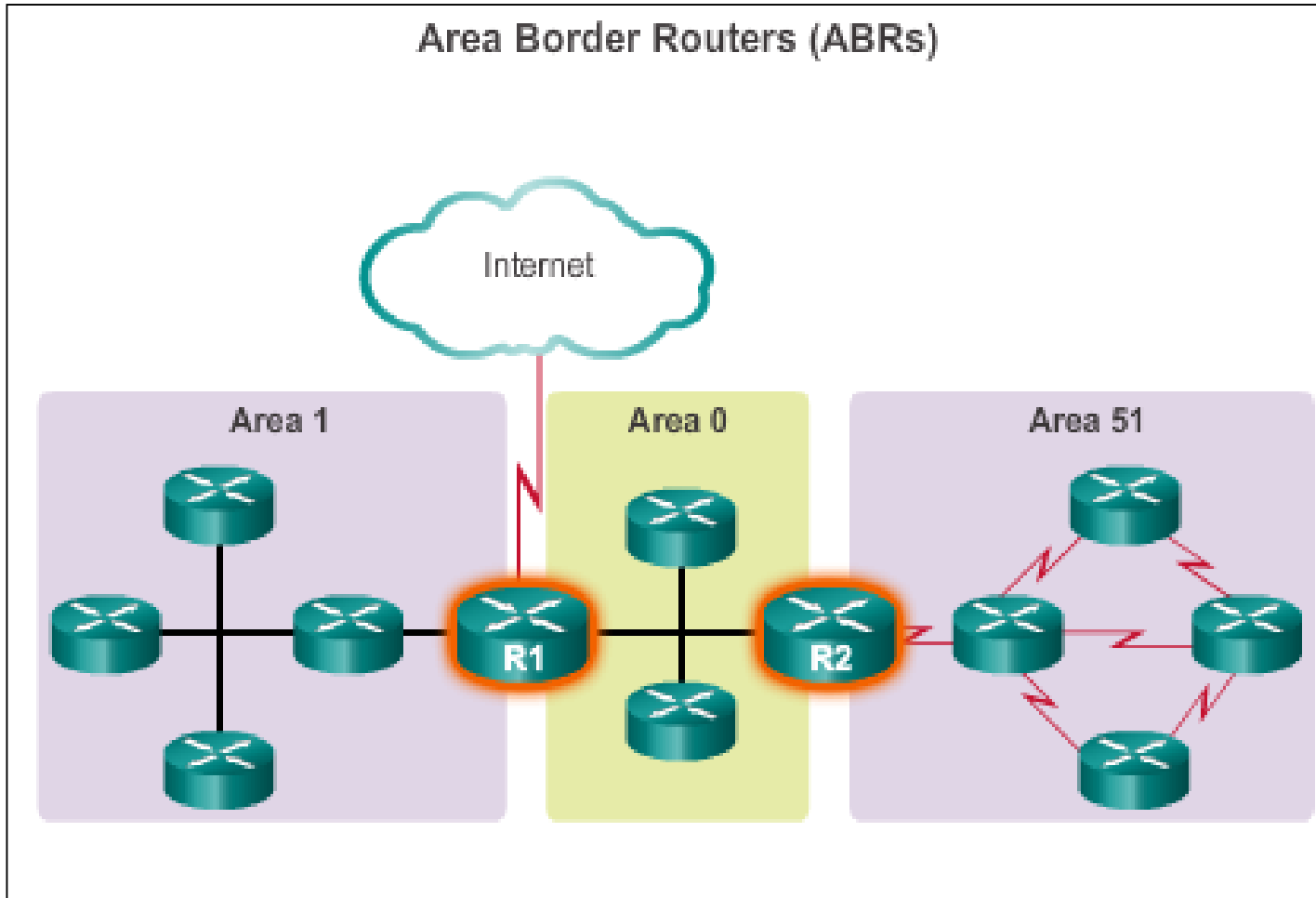
# Types of OSPF Routers (cont.)





Why Multiarea OSPF?

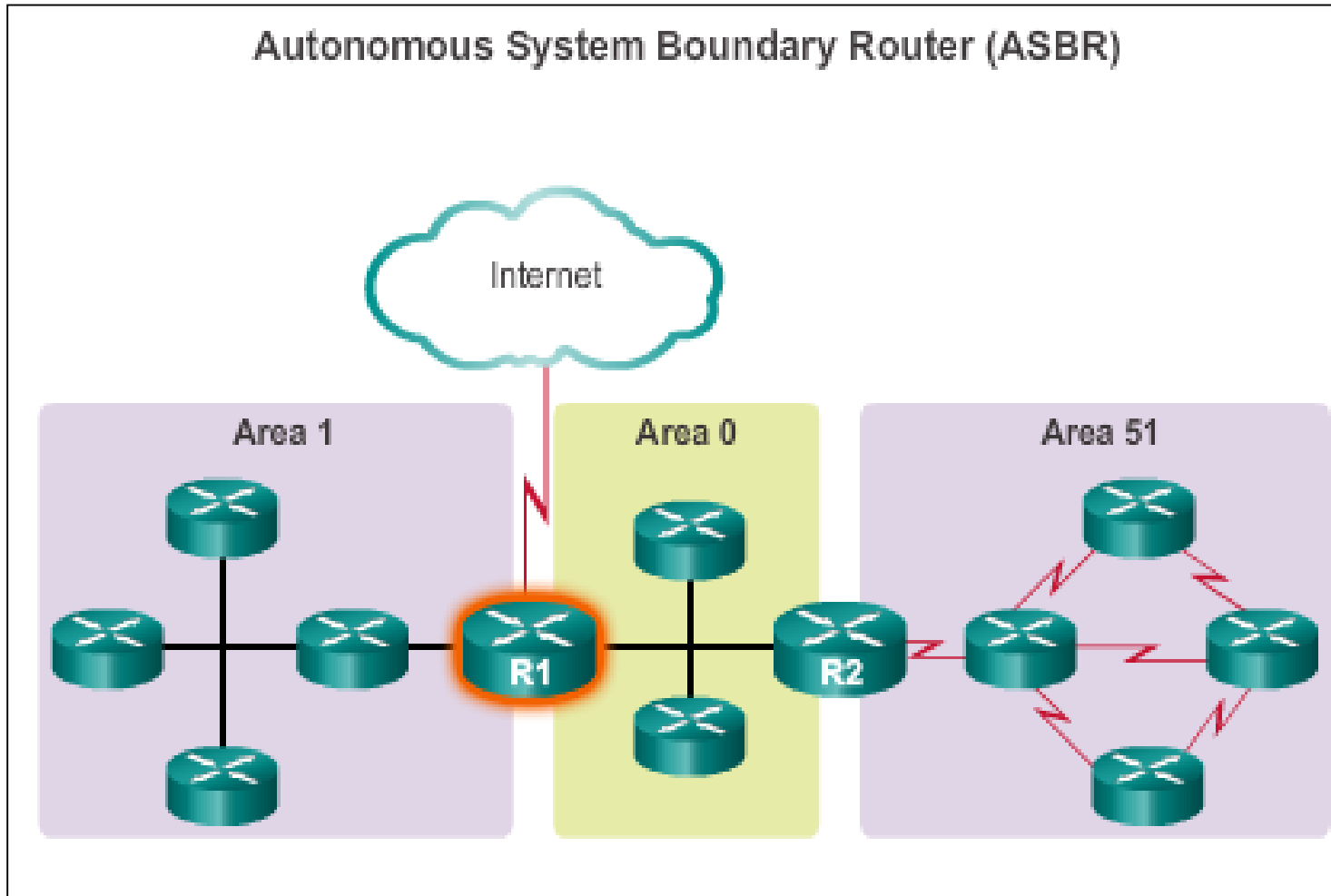
# Types of OSPF Routers (cont.)





Why Multiarea OSPF?

# Types of OSPF Routers (cont.)





# Multiarea OSPF LSA Operation

## OSPF LSA Types

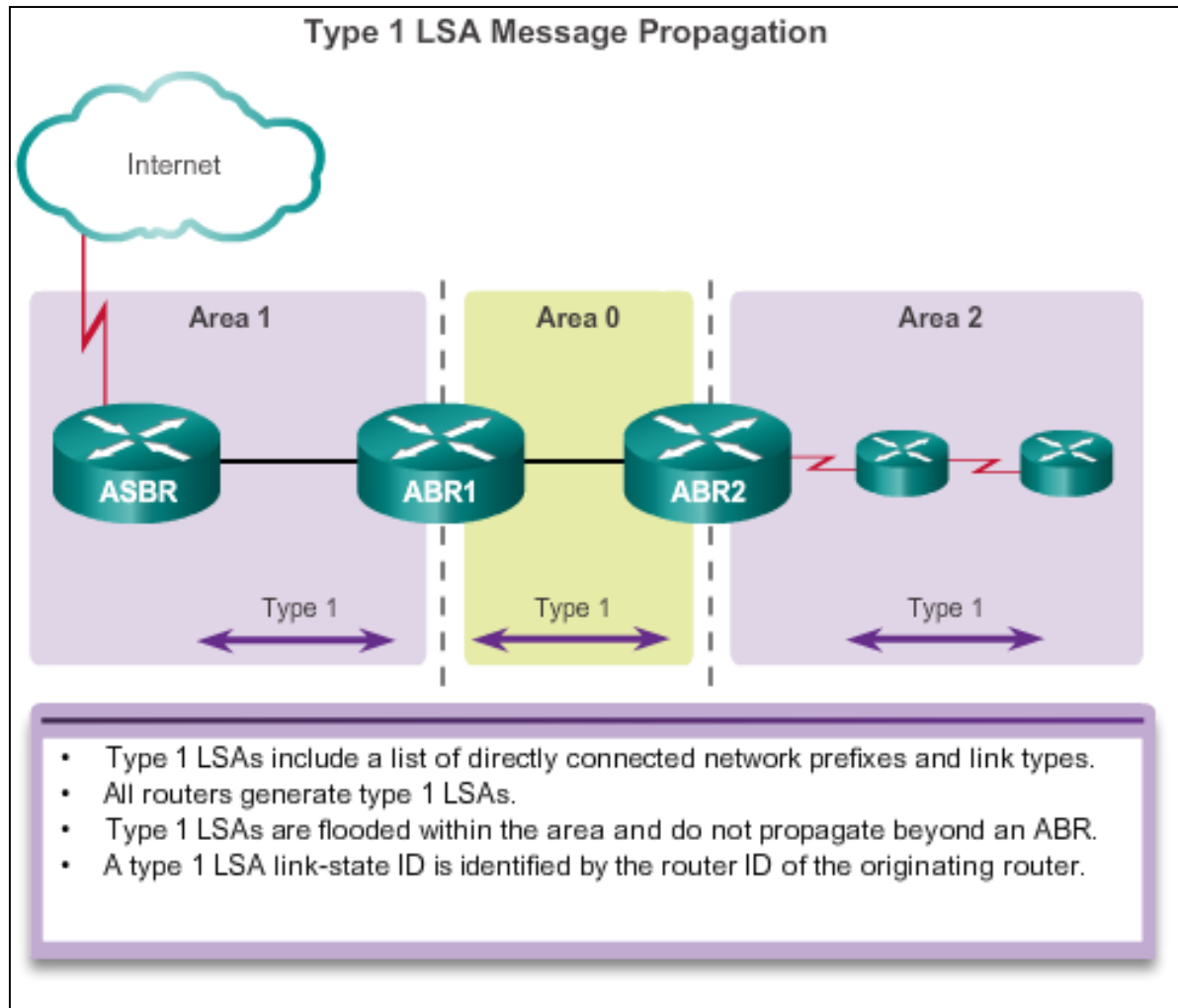
LSA Type	Description
1	Router LSA
2	Network LSA
3 and 4	Summary LSAs
5	AS External LSA
6	Multicast OSPF LSA
7	Defined for NSSAs
8	External Attributes LSA for Border Gateway Protocol (BGP)
9, 10, or 11	Opaque LSAs

Most common and covered in this course – 1 thru 5



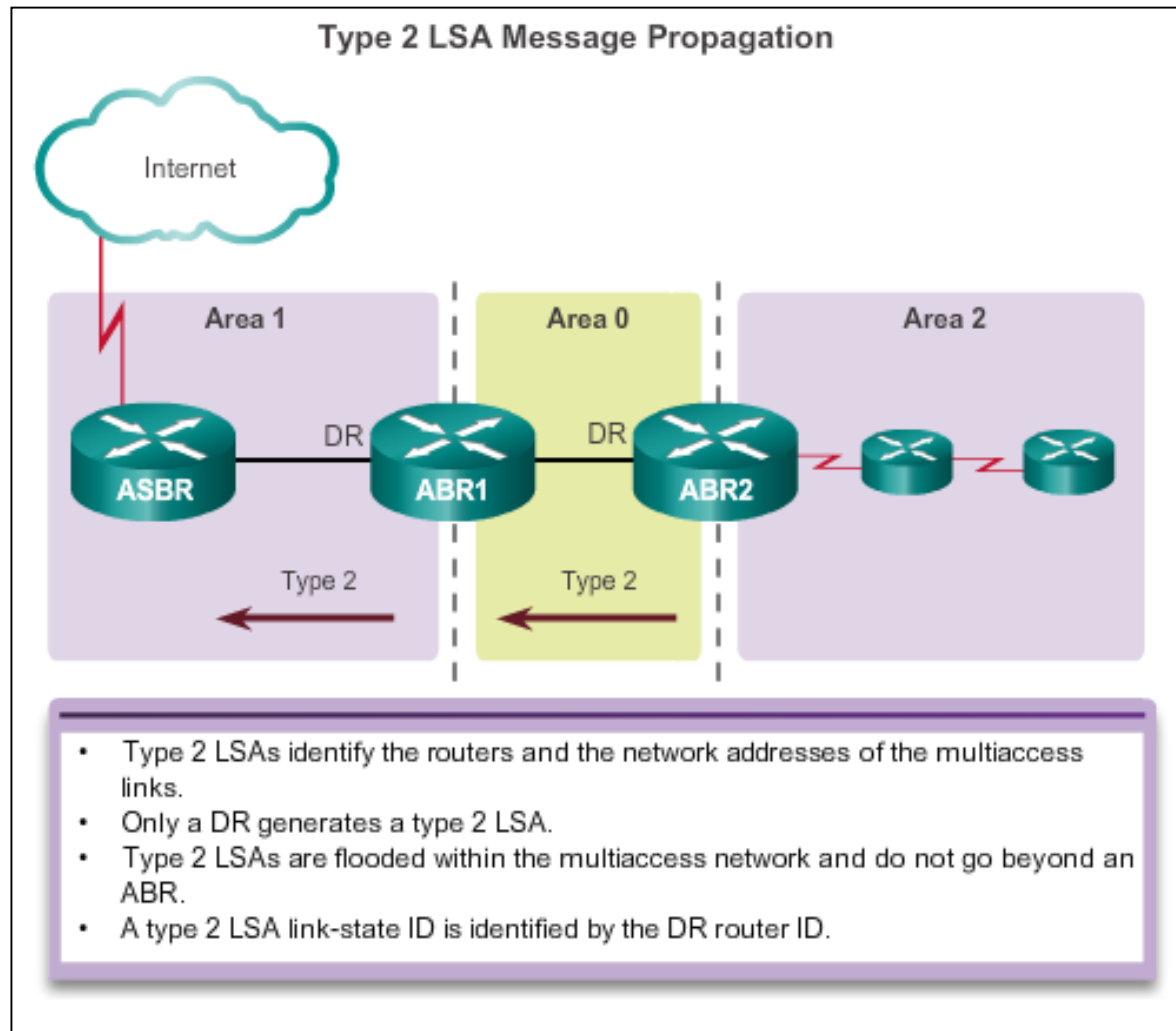
# Multiarea OSPF LSA Operation

## OSPF LSA Type 1



# Multiarea OSPF LSA Operation

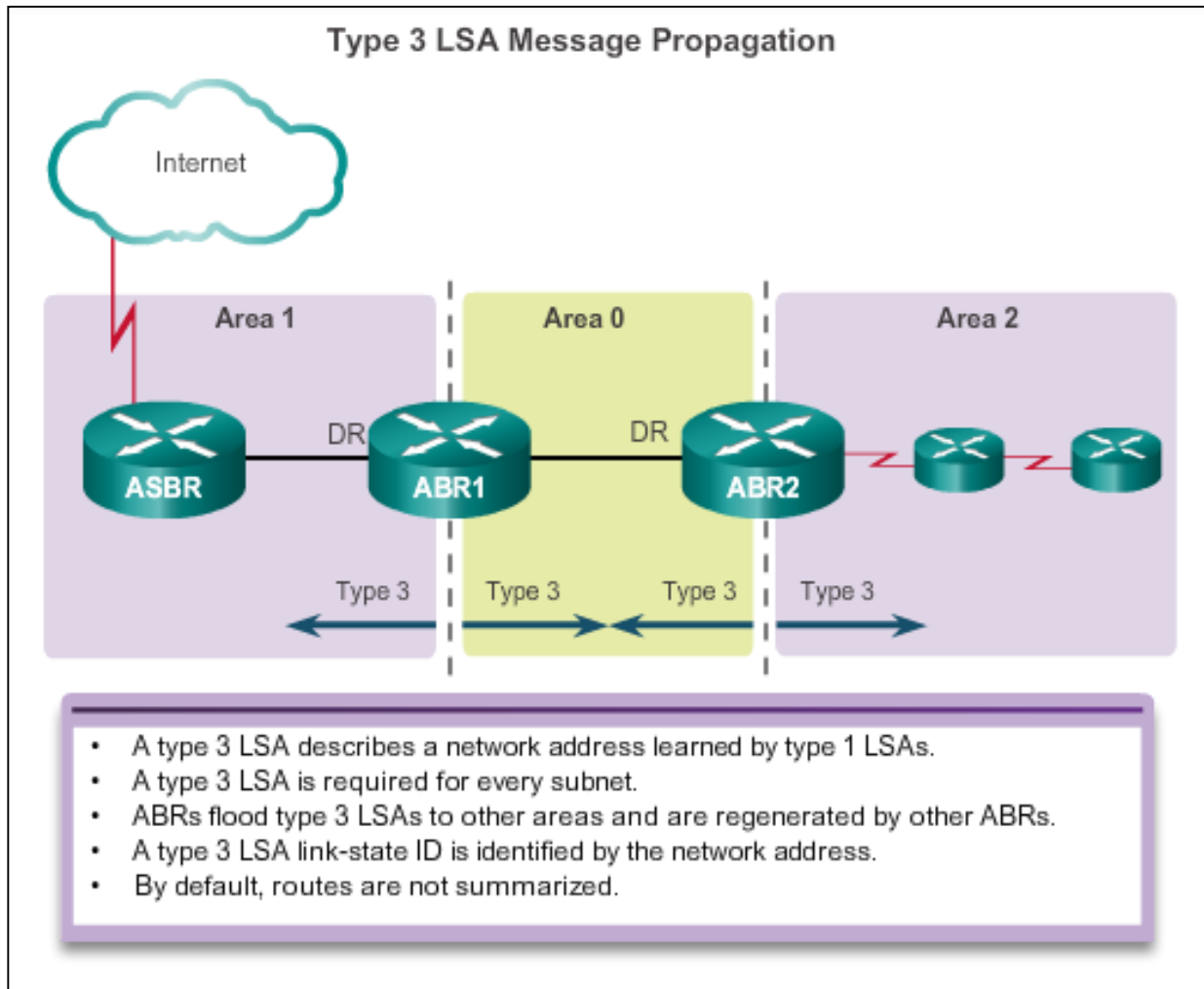
## OSPF LSA Type 2





# Multiarea OSPF LSA Operation

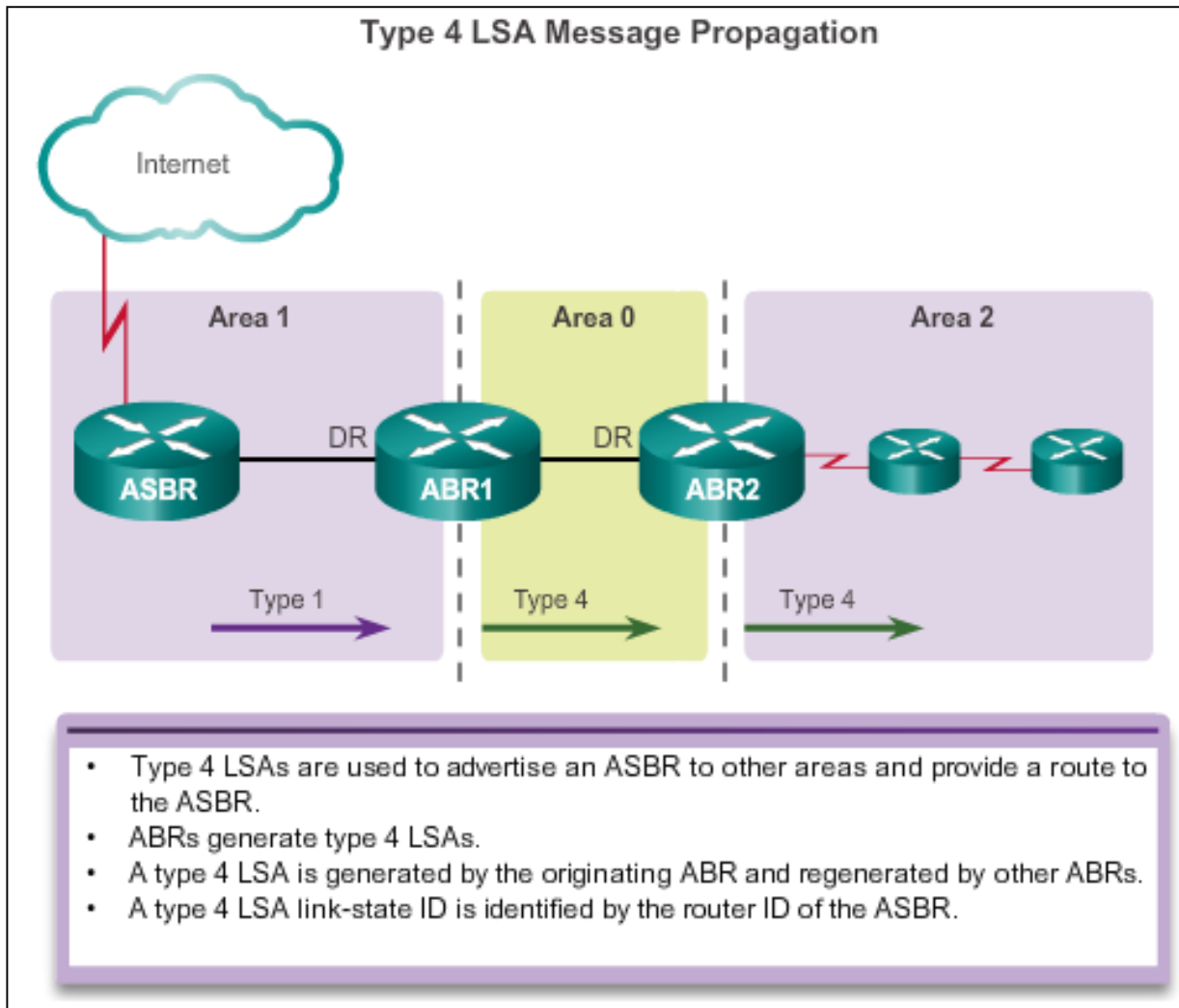
## OSPF LSA Type 3





# Multiarea OSPF LSA Operation

## OSPF LSA Type 4

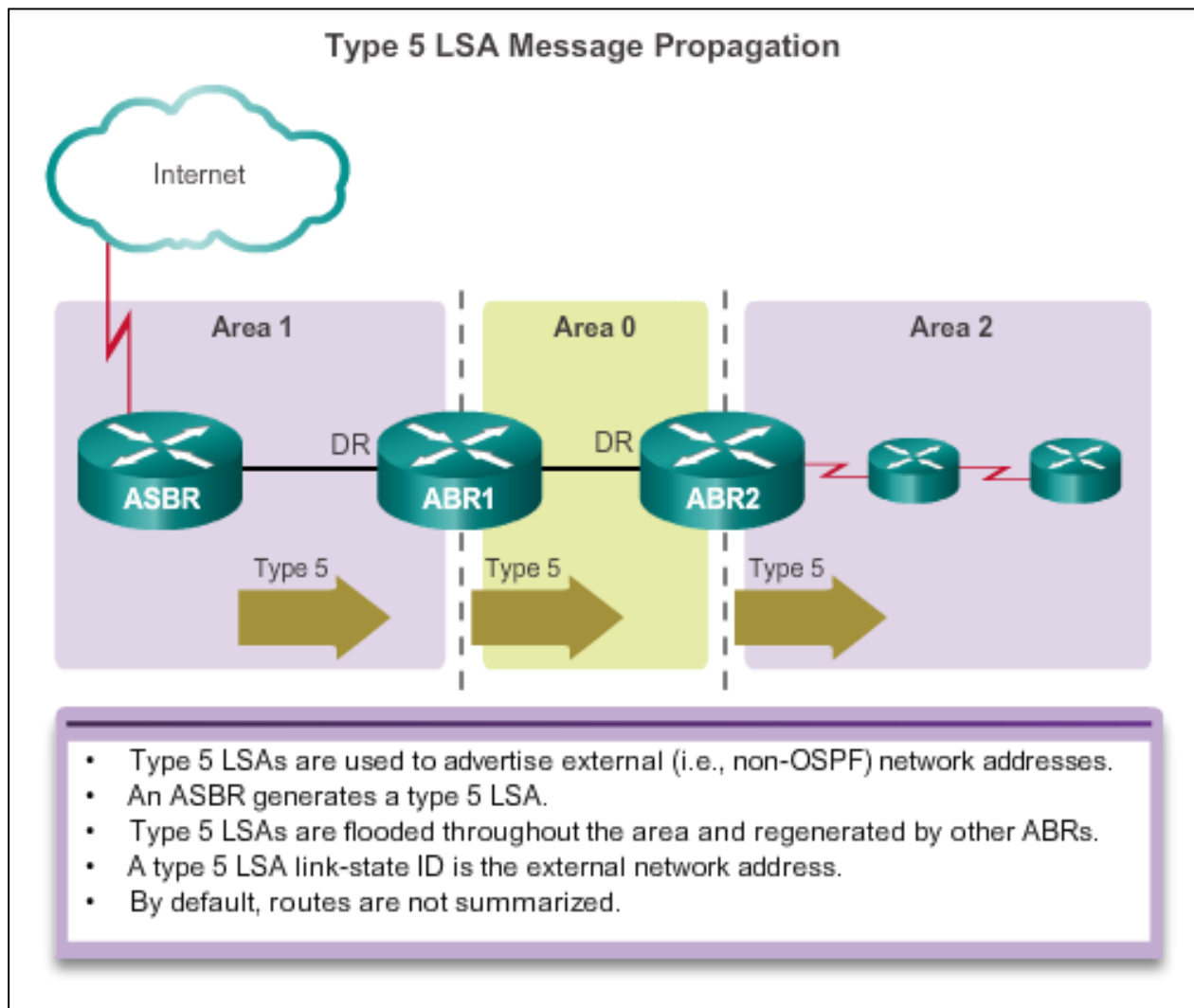






# Multiarea OSPF LSA Operation

## OSPF LSA Type 5





# OSPF Routing Tables and Route Types

## 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 Tables and Route Types

# 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 - MHRP, 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 Routing Tables and Route Types

## 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.

### 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
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#
  
```

- Calculate intra-area OSPF routes.
- Calculate best path to interarea OSPF routes.
- Calculate best path route to external non-OSPF networks.



## 6.2 Configuring Multiarea OSPF



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## Configuring Multiarea OSPF

# Implementing Multiarea OSPF

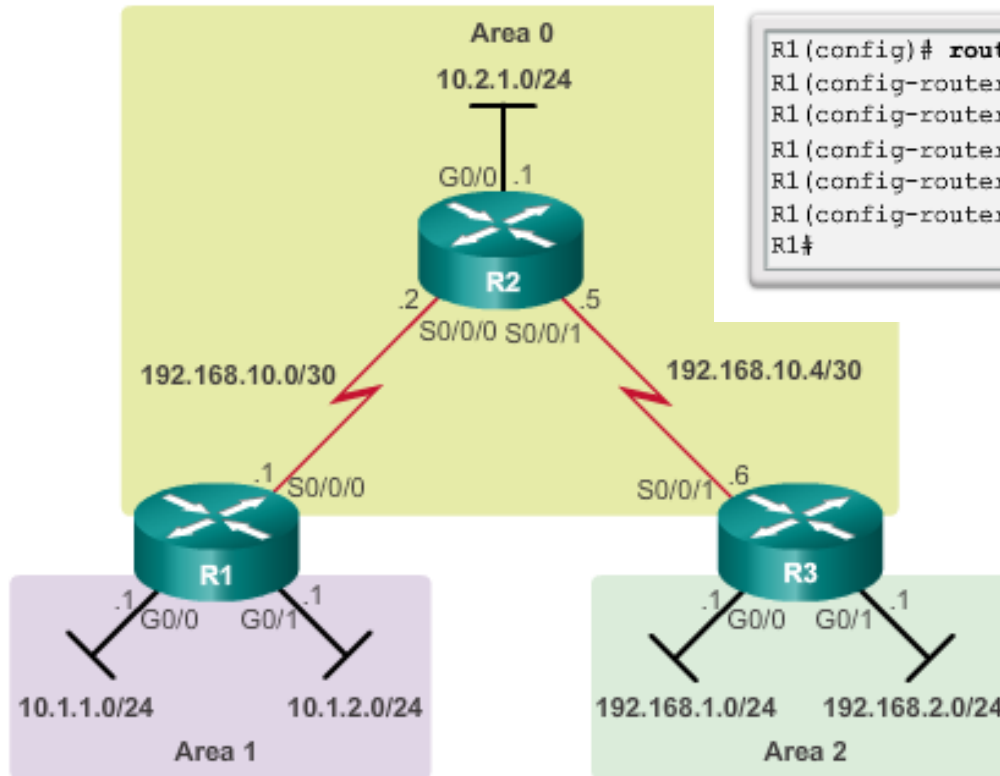
### Implementation Plan Steps

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



# Configuring Multiarea OSPF

## Configuring Multiarea OSPF



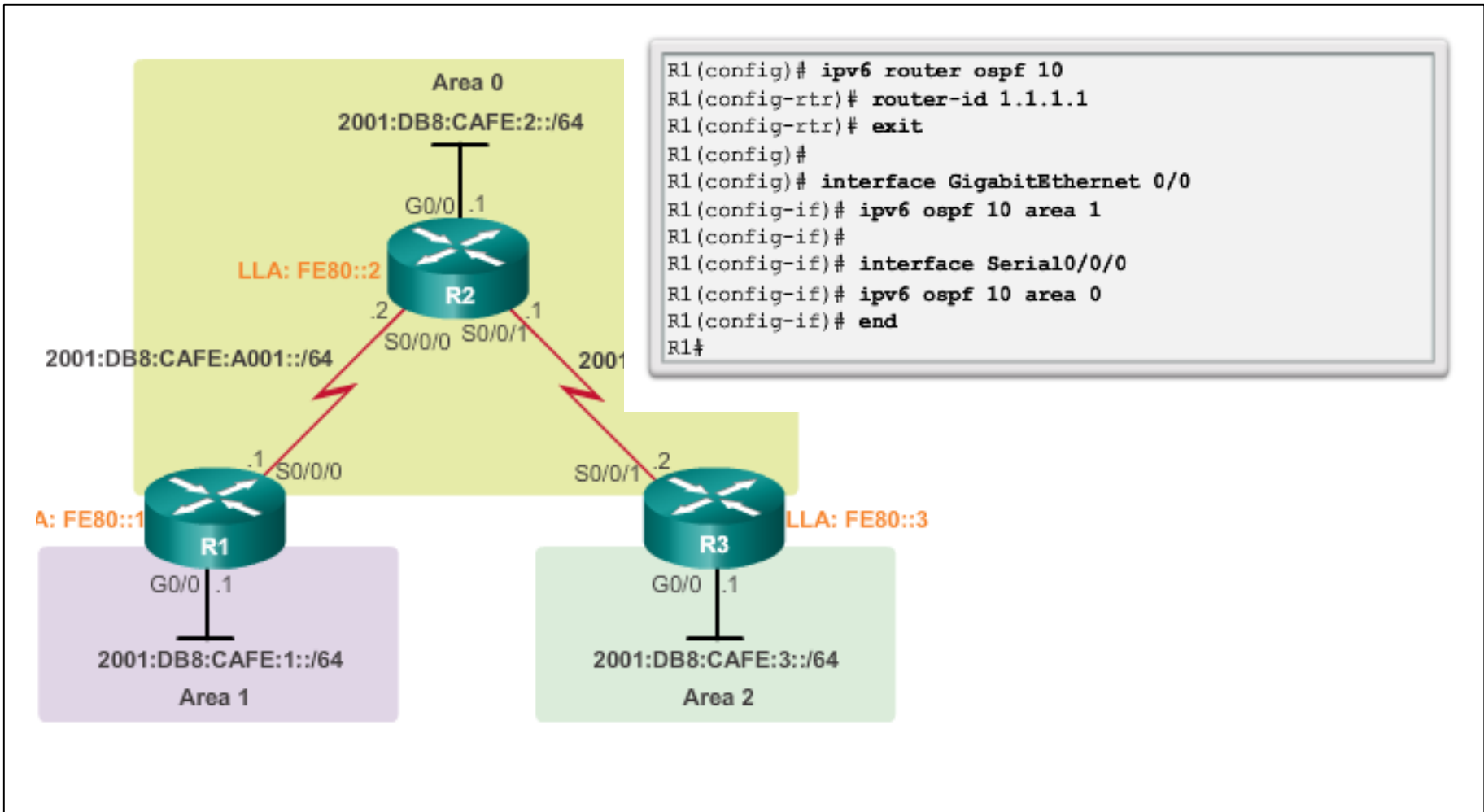
```

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 OSPF

## Configuring Multiarea OSPFv3



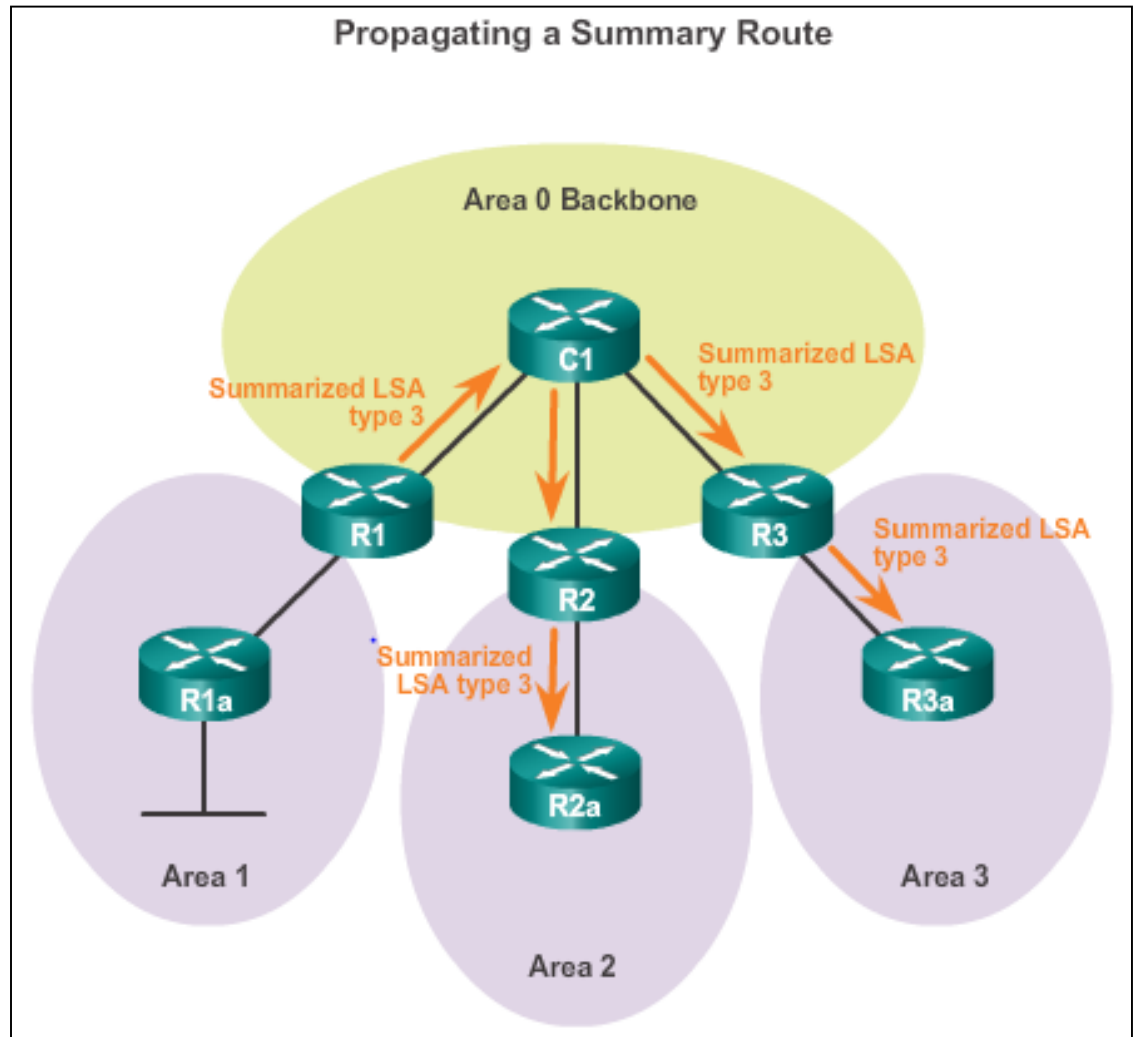




## OSPF Route Summarization

# 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.

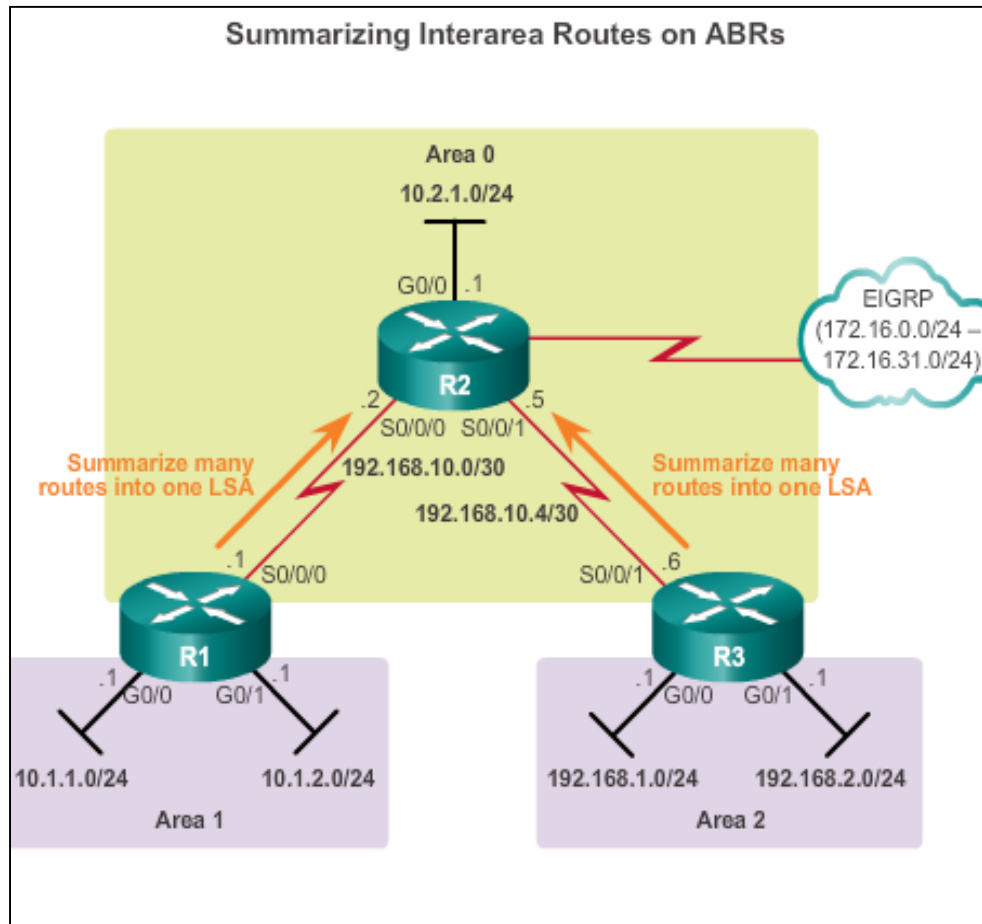




# OSPF Route Summarization

## Interarea and External Route Summarization

Occurs on ABRs and applies to routes from within each area

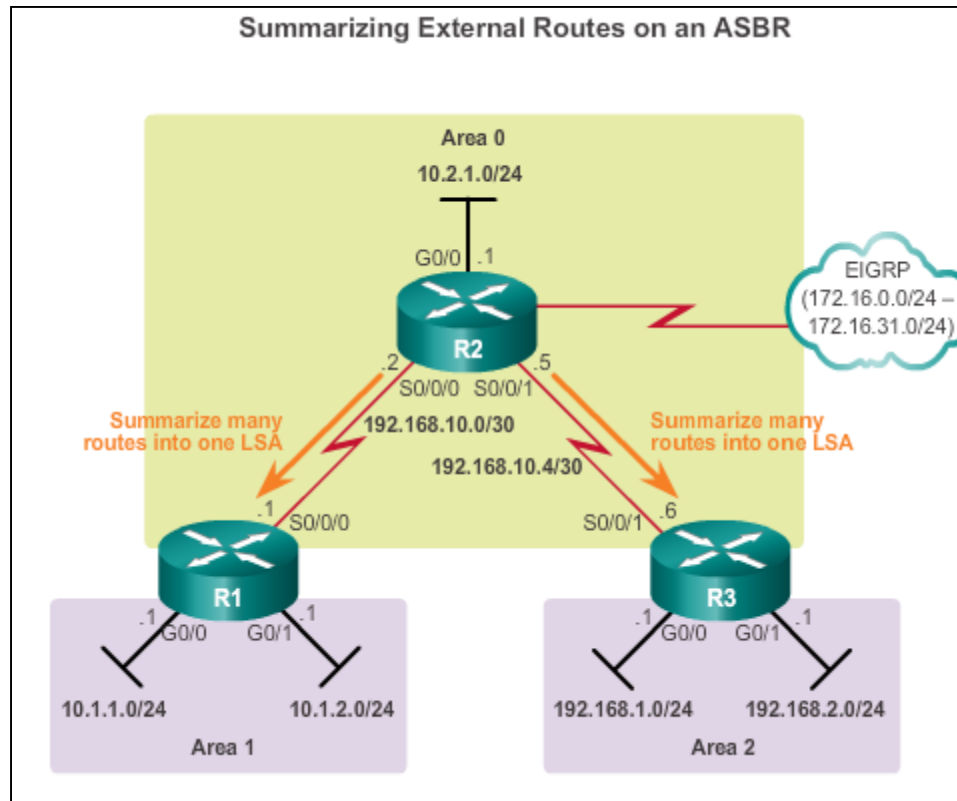




# OSPF Route Summarization

## Interarea and External Route Summarization (cont.)

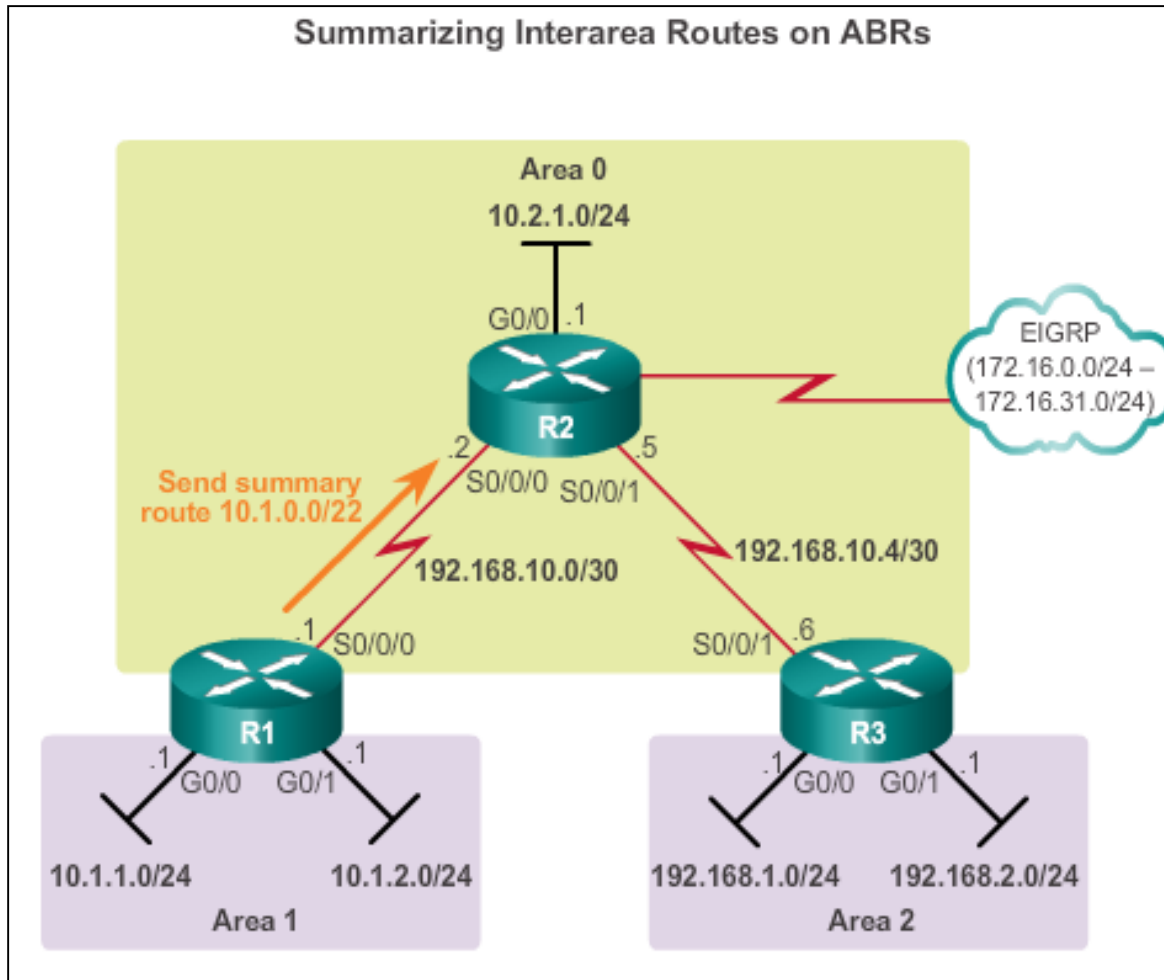
Specific to external routes that are injected into OSPF via route redistribution; ASBRs summarize external routes





# 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 192.168.10.5, 00:00:49, Serial0/0/0
R1#
```

### Verify the R3 Routing Table Before Summarization

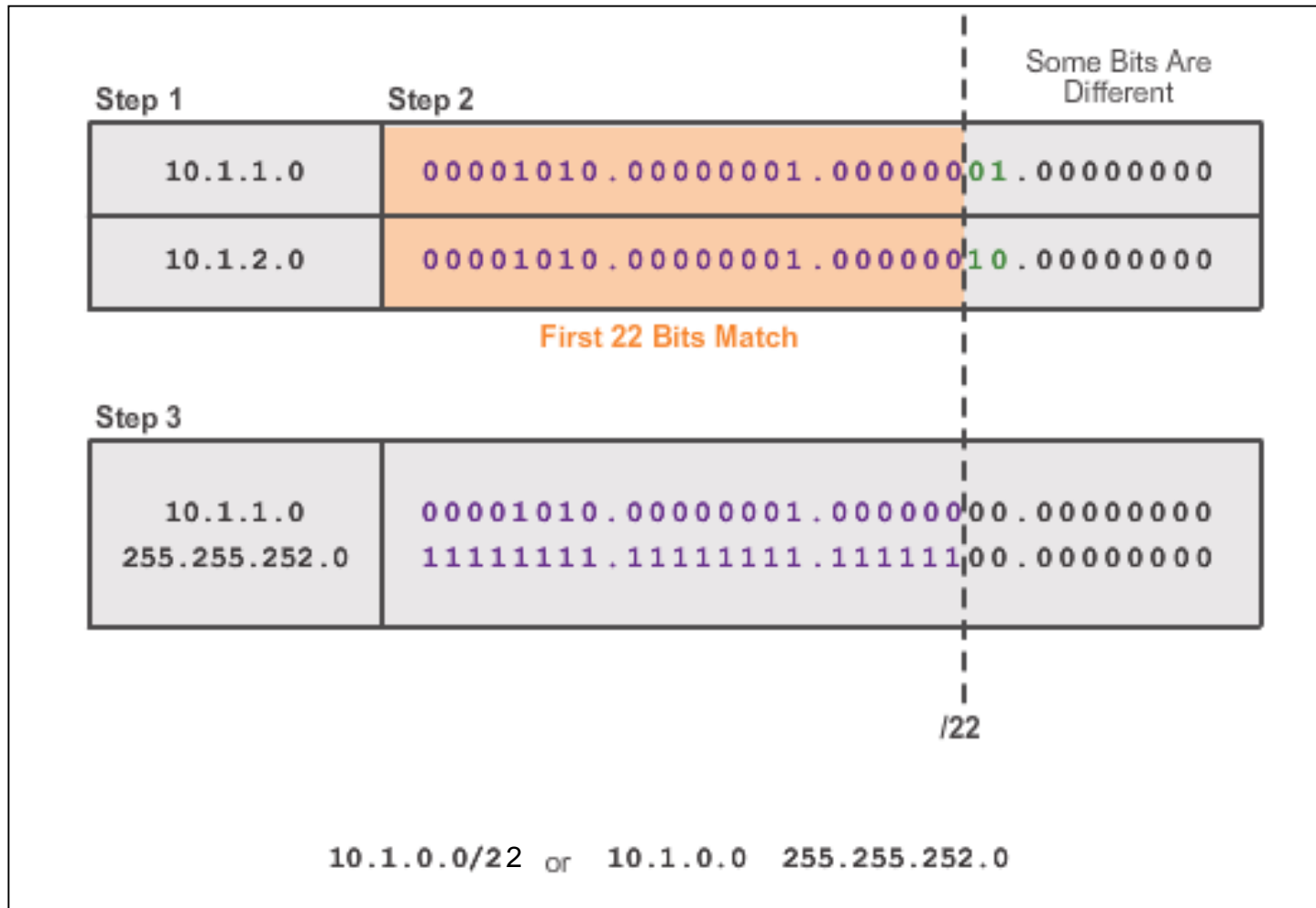
```
R3# show ip route ospf | begin Gateway
Gateway of last resort is not set

    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**

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

```
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

# 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 Multiarea OSPF

# 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)

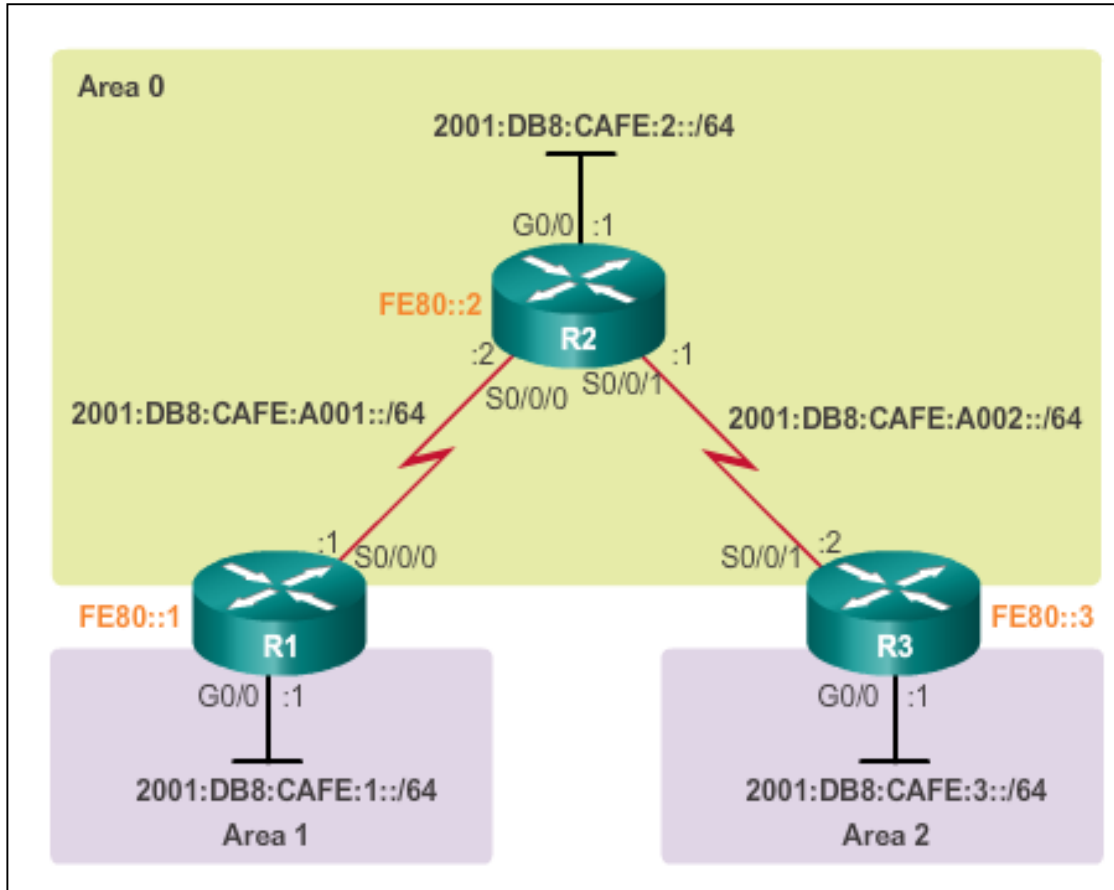
Link ID	ADV Router	Age	Seq#	Checksum
10.2.1.0	1.1.1.1	725	0x80000005	0x004A9C
192.168.1.0	1.1.1.1	725	0x80000005	0x00B593
192.168.2.0	1.1.1.1	725	0x80000005	0x00AA9D
192.168.10.0	1.1.1.1	725	0x80000005	0x00B3D0
192.168.10.4	1.1.1.1	725	0x80000005	0x000E32

```
R1#
```



# Verifying Multiarea OSPF

## Verifying Multiarea OSPFv3



```

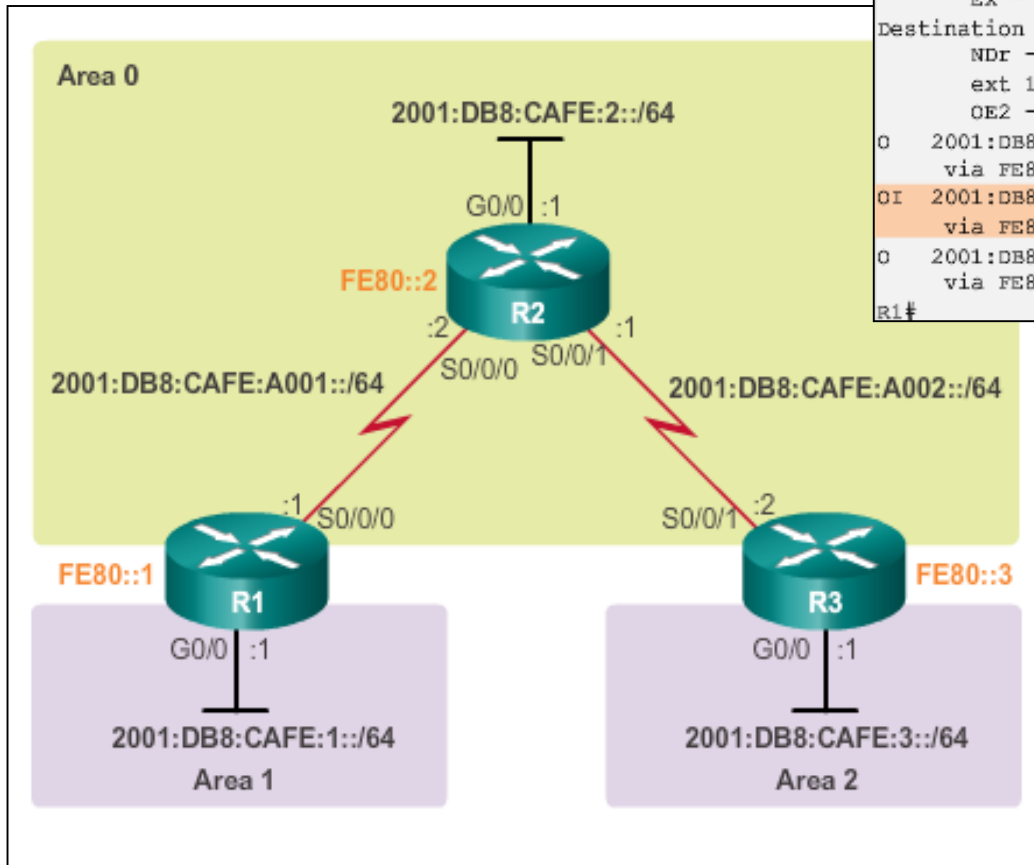
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Area border router
  Number of areas: 2 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Serial0/0/0
  Interfaces (Area 1):
    GigabitEthernet0/0
  Redistribution: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

```

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

# Verifying Multiarea OSPF

## 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

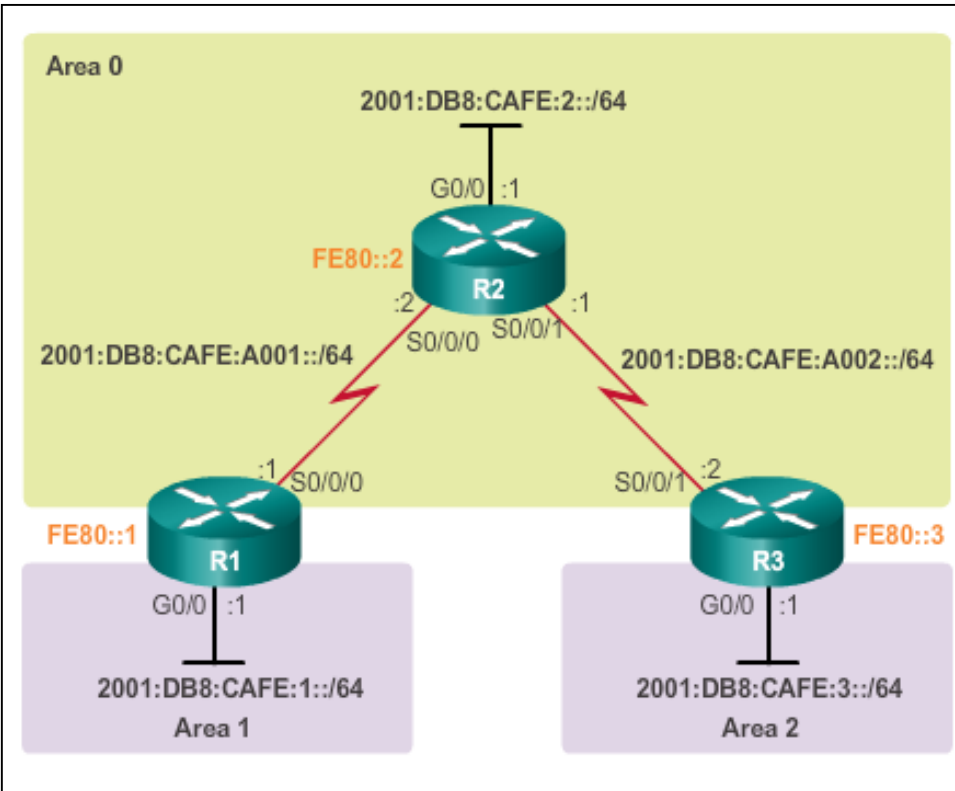
    B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
    I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D -
    EIGRP

    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 OSPF

## 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)
```



## Chapter 6: Summary

# 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.



## Chapter 6: Summary

# 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.





## Chapter 6: Summary

# 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



## Chapter 6: Summary

# 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`

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