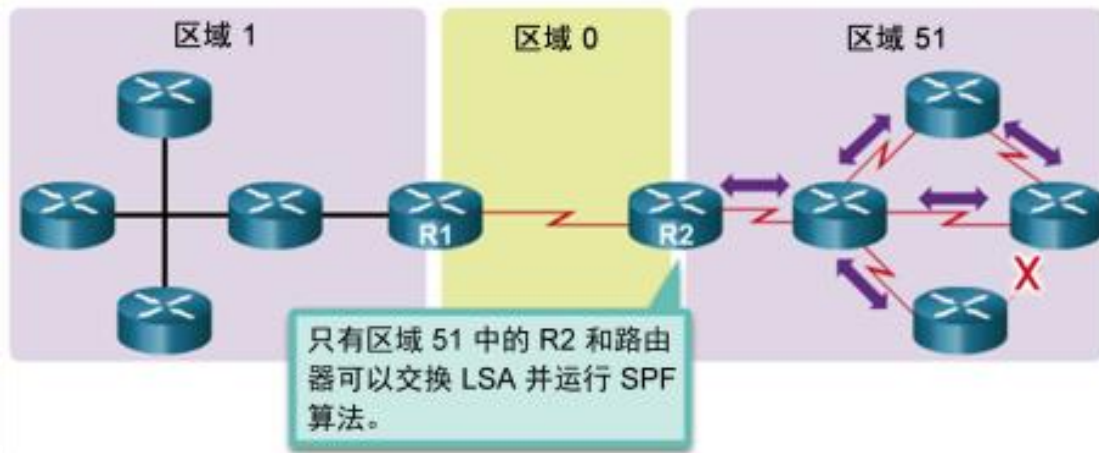# 19 多区域 OSPF

19.1 多区域 OSPF 操作
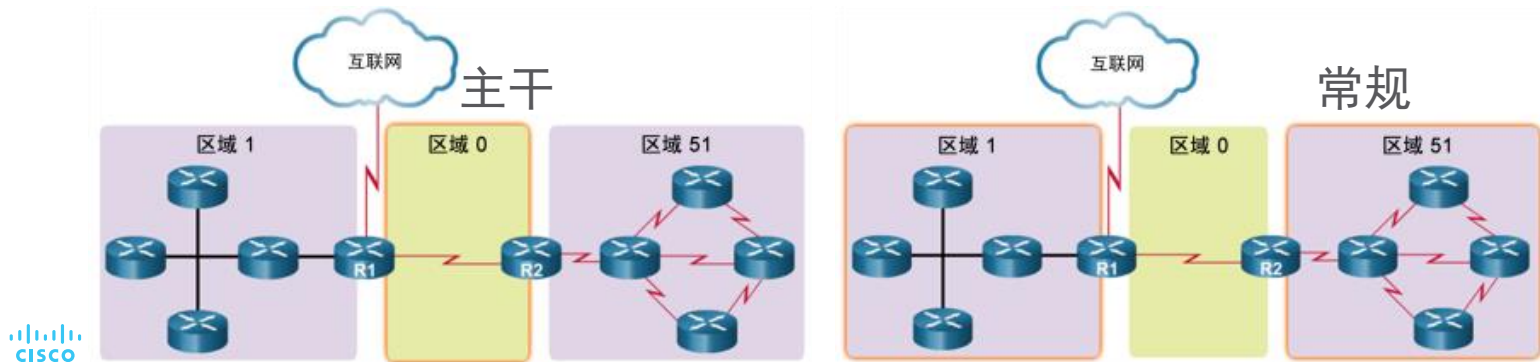
为什么采用多区域 OSPF？

- 单区域 OSPF
  - 如果没有汇总路由，路由表会变得非常大。
  - 每台路由器必须保留关于路由域中的每个网络的详细信息。
- 多区域 OSPF
  - 路由表减小
  - 链路状态更新开销降低
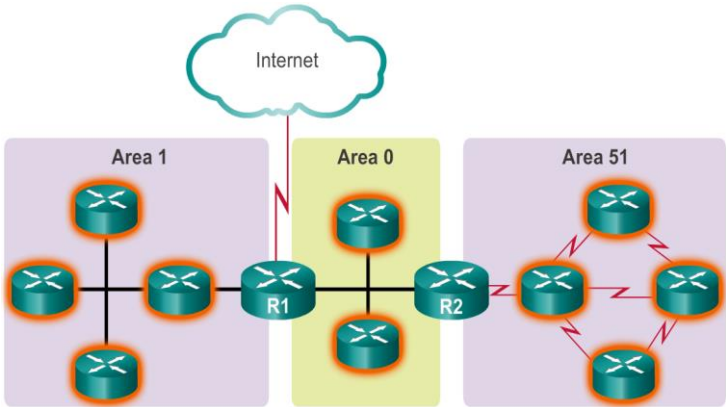 - SPF 计算次数减少

只有区域 51 中的 R2 和路由器可以交换 LSA 并运行 SPF 算法。

为什么采用多区域 OSPF？

- OSPF 两级区域层次结构
  - 主干（中转）区域和常规（非主干）区域
- OSPF 路由器的类型
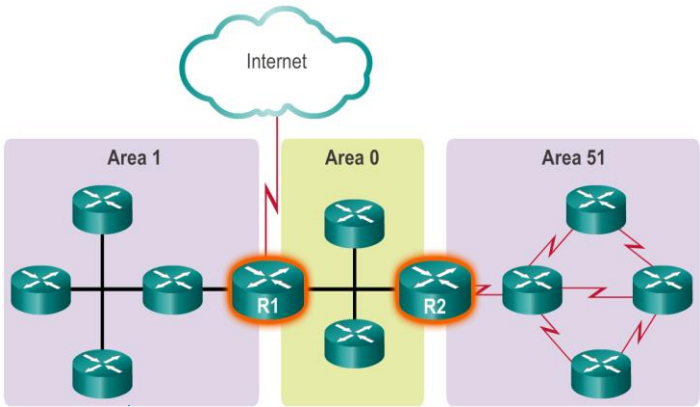 - 内部路由器
  - 主干路由器
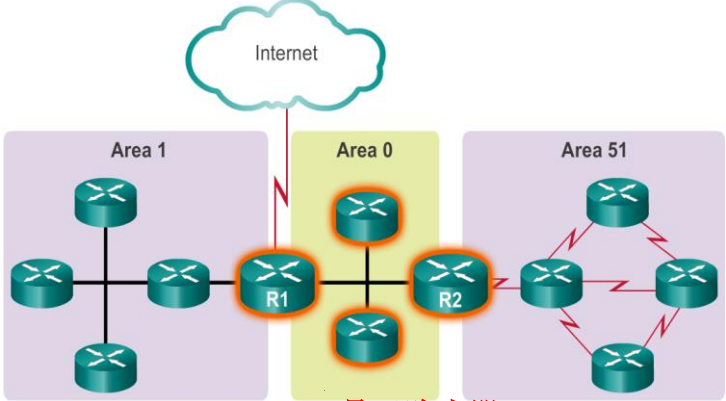 - 区域边界路由器 (ABR)
  - 自治系统边界路由器 (ASBR)

为什么采用多区域 OSPF？
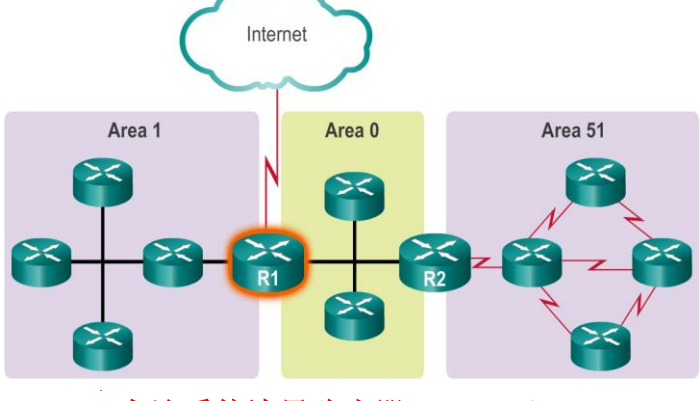

内部路由器

区域边界路由器（ABR）

骨干路由器

自治系统边界路由器（ASBR）

多区域 OSPF LSA 操作

- OSPF LSA 类型

  - 单独使用时，它们充当数据库记录并提供特定 OSPF 网络的详细信息。组合使用时，它们描述 OSPF 网络或区域的完整拓扑。

LSA 类型	说明
1	路由器 LSA
2	网络 LSA
3 和 4	汇总 LSA
5	AS 外部 LSA
6	组播 OSPF LSA
7	为 NSSA 定义
8	用于边界网关协议 (BGP) 的外部属性 LSA
9、10 或 11	不透明 LSA

LSA Type 1: Router LSA
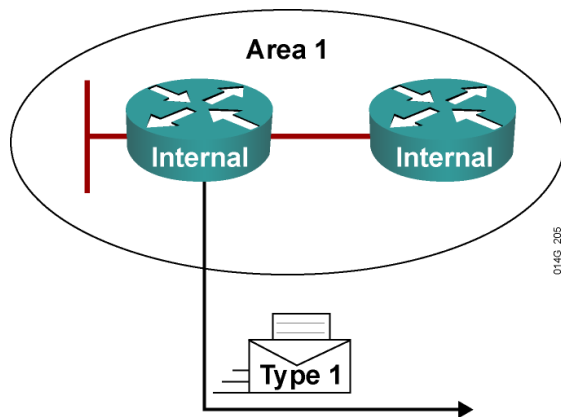
- One router LSA (type 1) for every router in an area区域中每台路由器都通告LSA 1
  - Includes list of directly attached links 包括所有直连链路的列表
  - Each link identified by IP prefix assigned to link and link type
  - 每个链路用链路的IP和链路类型来标识
- Identified by the router ID of the originating router
- 用初始路由器的路由器ID来识别
- Floods within its area only; does not cross ABR
- 区域内泛洪，不穿越ABR

LSA Type 2: Network LSA
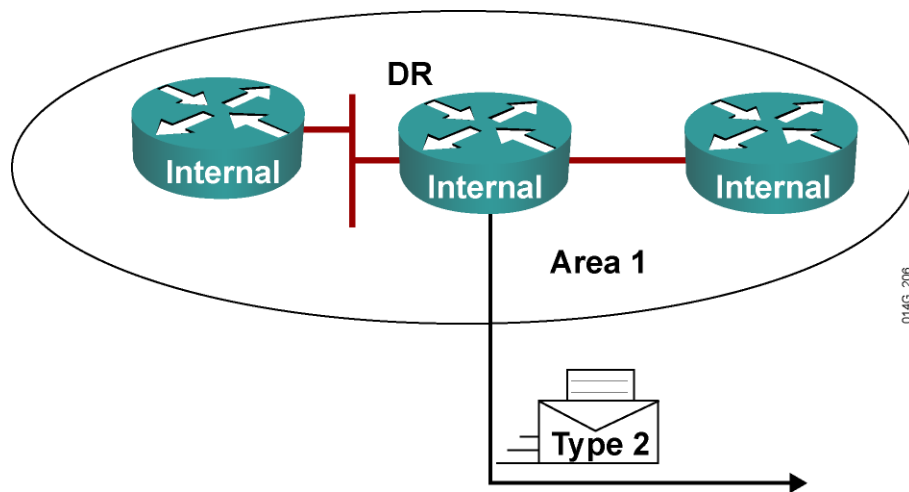
- One network (type 2) LSA for each transit broadcast or NBMA network in an area
- 类型2的LSA在区域中每个转接广播和NBMA网络中生成
  - Includes list of attached routers on the transit link 包含了在转接链路上路由器列表
  - Includes subnet mask of link 包括链路的子网掩码
- Advertised by the DR of the broadcast network 被广播网络的DR通告
- Floods within its area only; does not cross ABR 区域内泛洪，不穿越ABR

LSA Type 3: Summary LSA
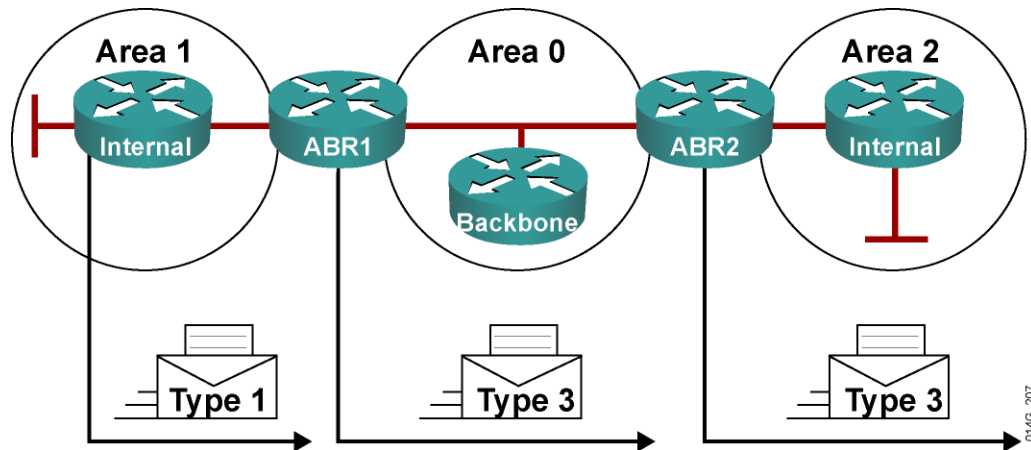
- Type 3 LSAs are used to flood network information to areas outside the originating area (interarea)

  - Describes network number and mask of link.描述链路的网络号和掩码

- Advertised by the ABR of originating area. 被起源区域的ABR通告

- Regenerated by subsequent ABRs to flood throughout the autonomous system. 被后续的 ABR重新生成，泛洪到整个AS

- By default, routes are not summarized, and type 3 LSA is advertised for every subnet.默认 时，路由不被汇总，3类LSA通告每个子网

9

LSA Type 4: Summary LSA
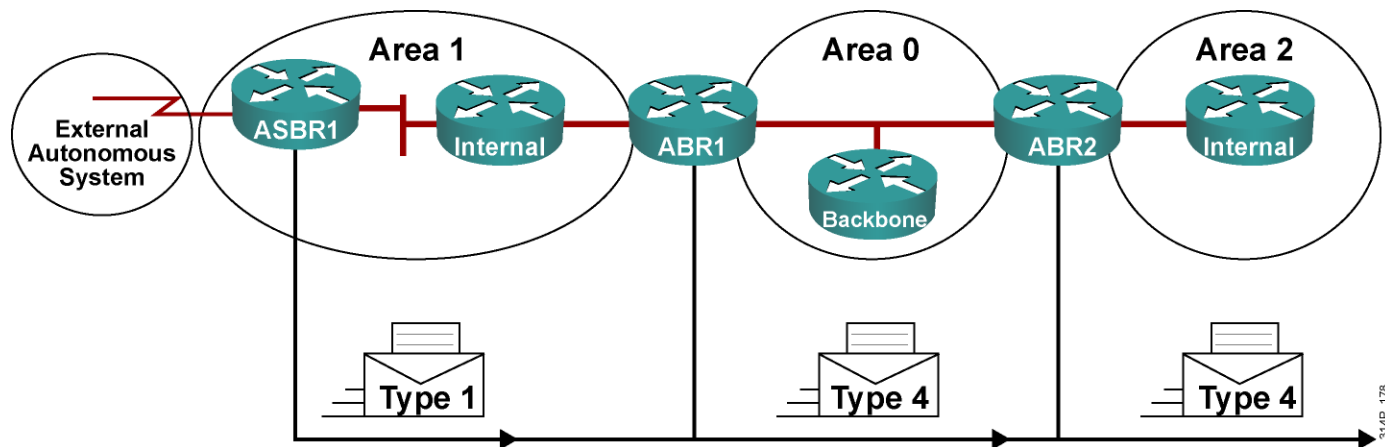
- Summary (type 4) LSAs are used to advertise an ASBR to all other areas in the autonomous system. 4类LSA用来向AS内的所有路由器通告ASBR

- They are generated by the ABR of the originating area.被起源区域的ABR产生

- They are regenerated by all subsequent ABRs to flood throughout the autonomous system.被后续的ABR重新生成，泛洪到整个AS

- Type 4 LSAs contain the router ID of the ASBR.

- 4类LSA包含ASBR的路由器ID

LSA Type 5: External LSA
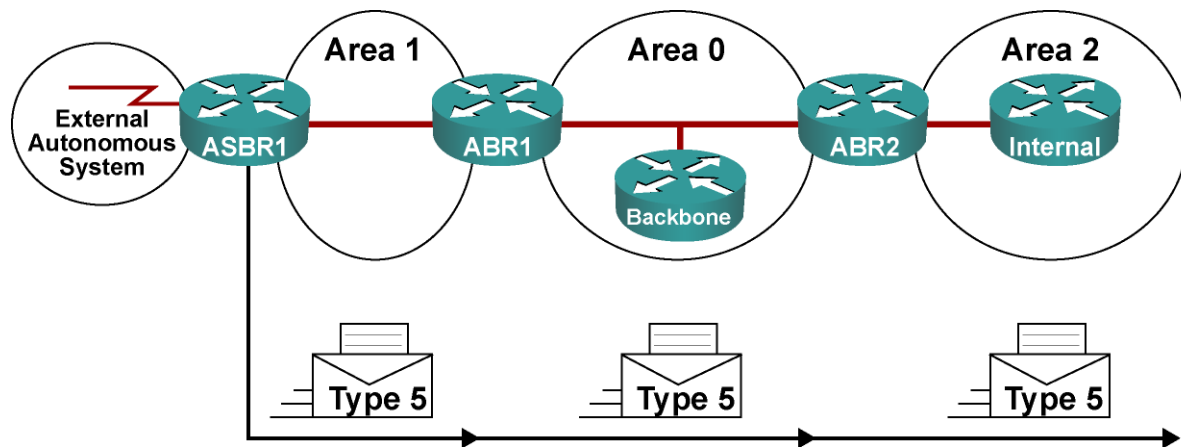
- External (type 5) LSAs are used to advertise networks from other autonomous systems. 类型5的LSA用来通告其他AS的网路

- Type 5 LSAs are advertised and owned by the originating ASBR. ASBR产生

- Type 5 LSAs flood throughout the entire autonomous system. 泛洪到整个AS

- The advertising router ID (ASBR) is unchanged throughout the autonomous system.通告路由器ID不变

- Type 4 LSA is needed to find the ASBR. 需要类型4LSA来发现ASBR

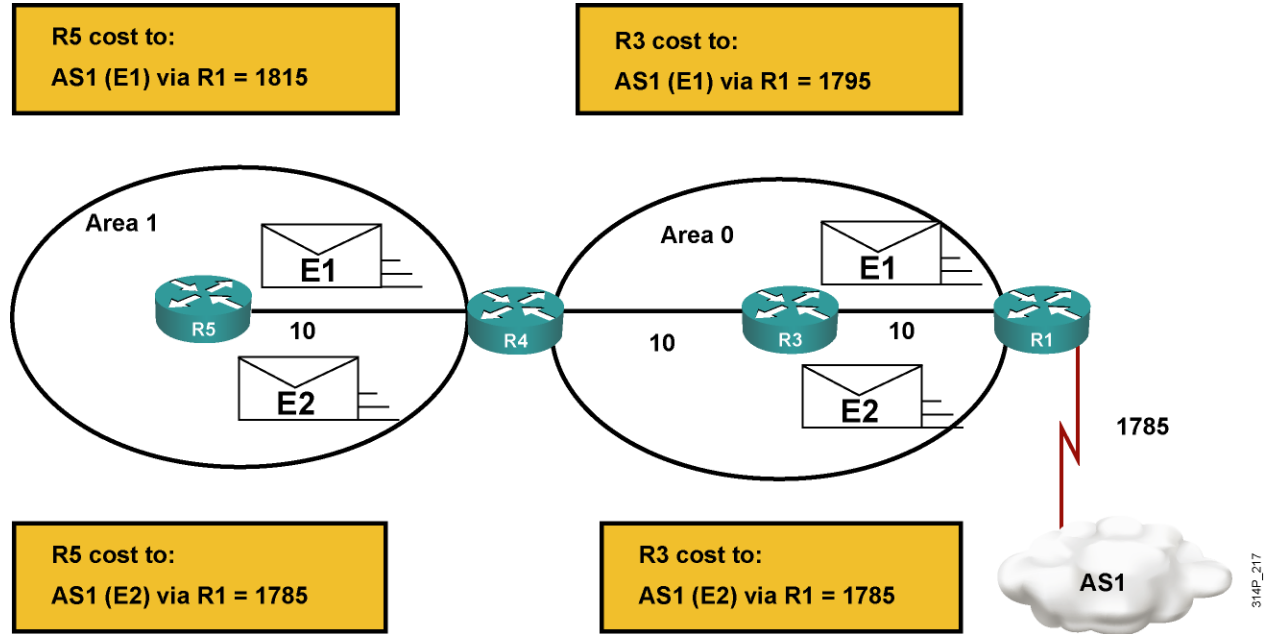- By default, routes are not summarized.默认时，路由不被汇总

OSPF 路由表和路由类型

- OSPF 路由表条目
  - O – 表示路由是区域内路由。
  - O IA – 表示汇总 LSA。
  - O E1 或 O E2 – 表示外部 LSA。

```
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#
```

OSPF E1和E2路由类型

R5 cost to:

AS1 (E1) via R1 = 1815

R3 cost to:

AS1 (E1) via R1 = 1795

Area 1

E1

R5   10

E2

R4   10   R3   10   R1

Area 0

E1

E2

1785

AS1

314P_217

R5 cost to:

AS1 (E2) via R1 = 1785

R3 cost to:

AS1 (E2) via R1 = 1785

OSPF 路由计算

OSPF 收敛步骤

```
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#
```

- 计算区域内 OSPF 路由。
- 计算通往区域间 OSPF 路由的最佳路径。
- 计算通往外部非 OSPF 网络的最佳路径。

O>O IA>OE1>OE2

OSPF Special Area Types

- The OSPF standard area can be further divided into four types of stub areas:
  - Stub area
  - Totally stubby area
  - NSSA
  - Totally stubby NSSA

Stub Area

Backbone Area 0

Totally Stubby Area

Does not accept external LSAs

Interconnects areas; accepts all LSAs

Does not accept external or summary LSAs

OSPF 区域类型-标准区域

Backbone Area 0

Interconnects areas; accepts all LSAs

014G_220

OSPF 区域类型-末节区域

Stub Area

Backbone Area 0

Does not accept external LSAs

Interconnects areas; accepts all LSAs
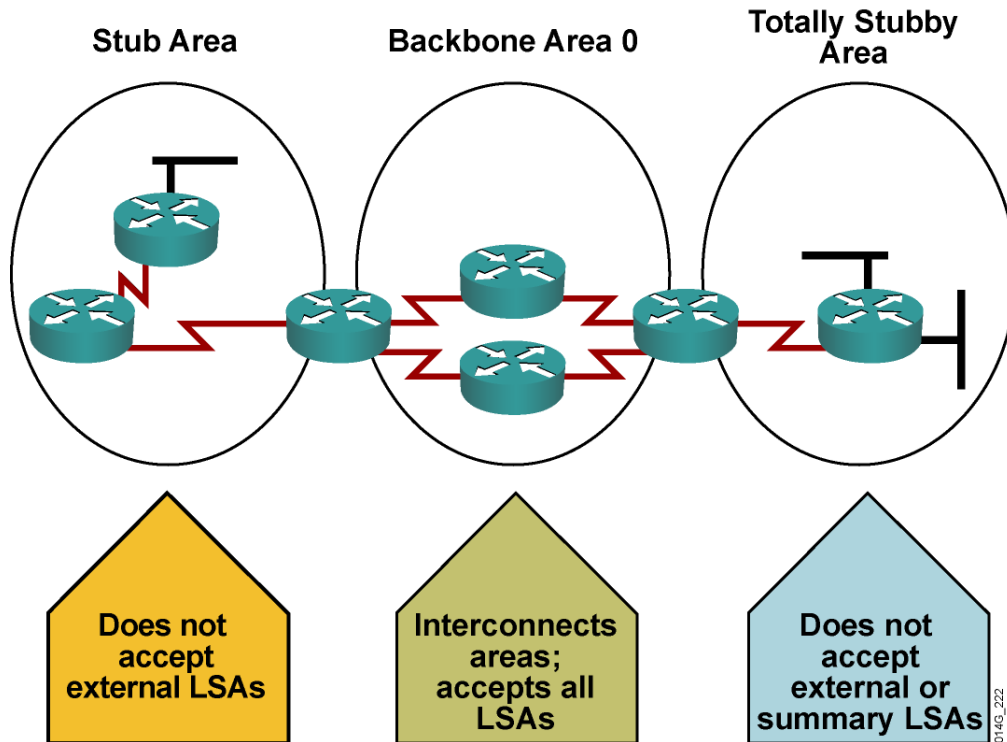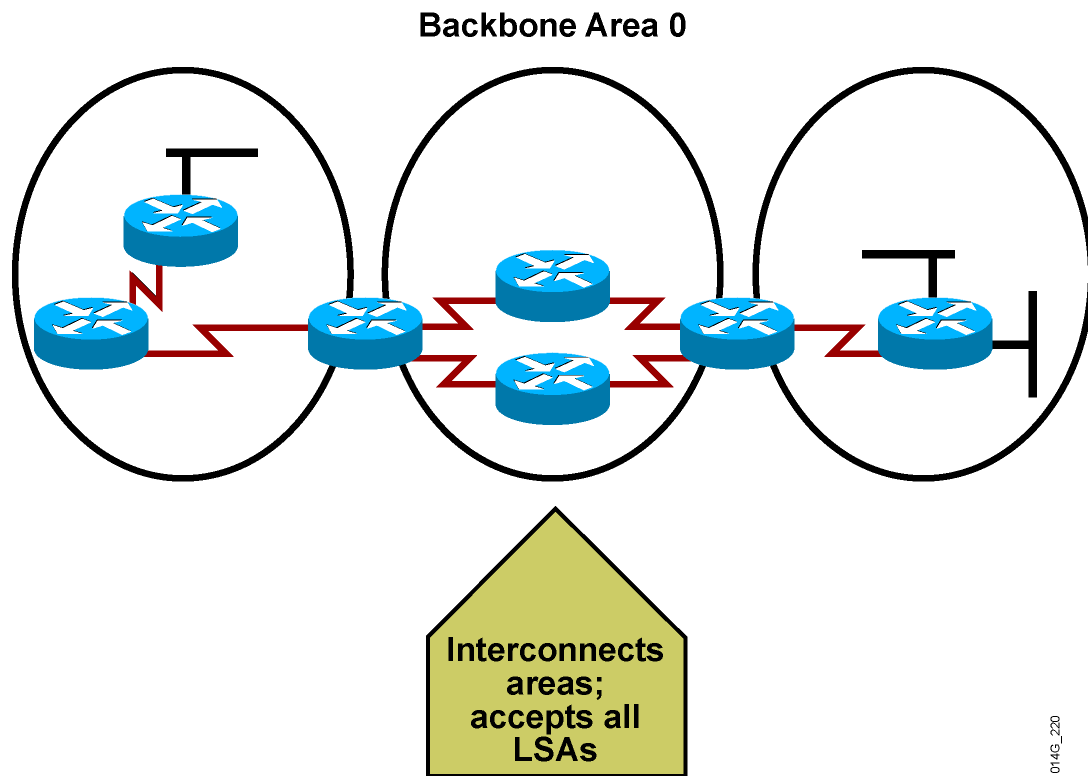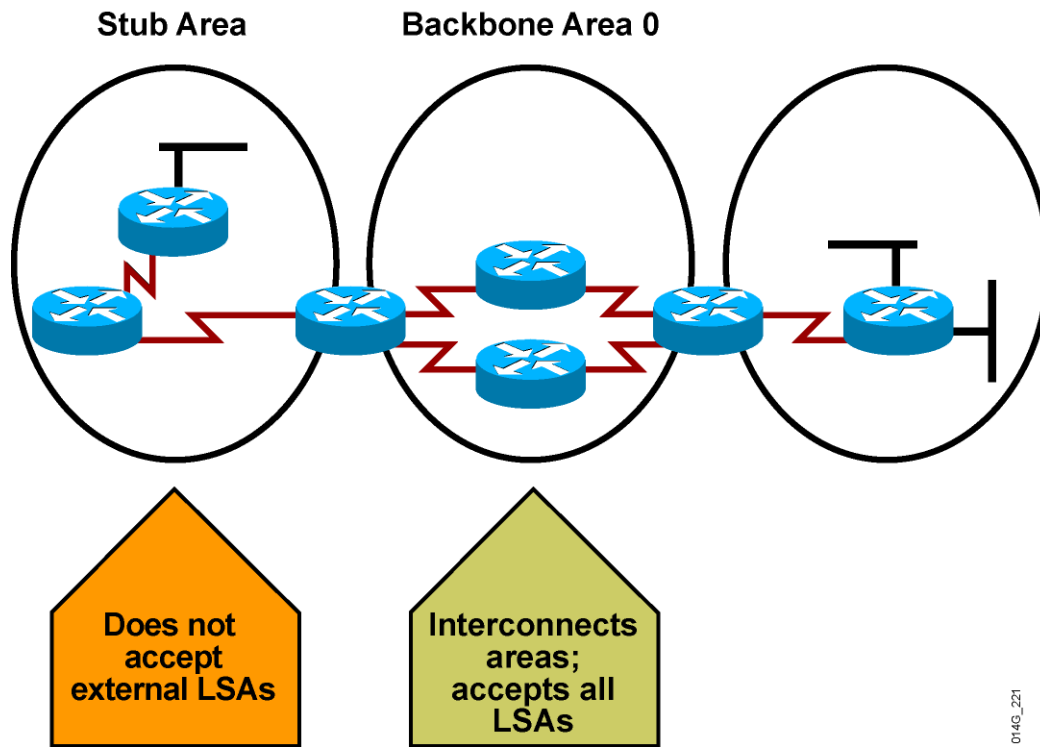
014G_221

OSPF 区域类型-末节区域

- **External LSAs are stopped.**

- **Default route is advertised into stub area by the ABR.**
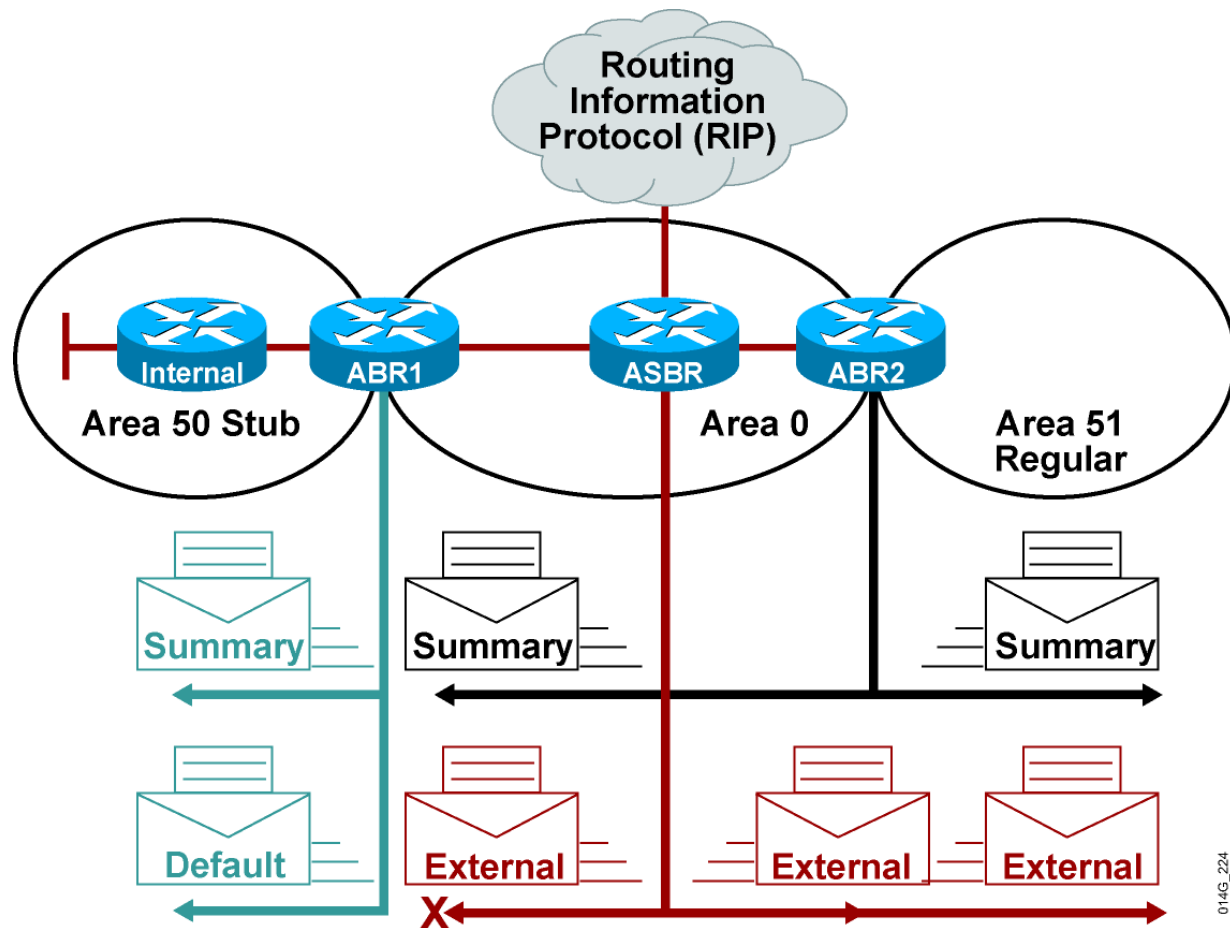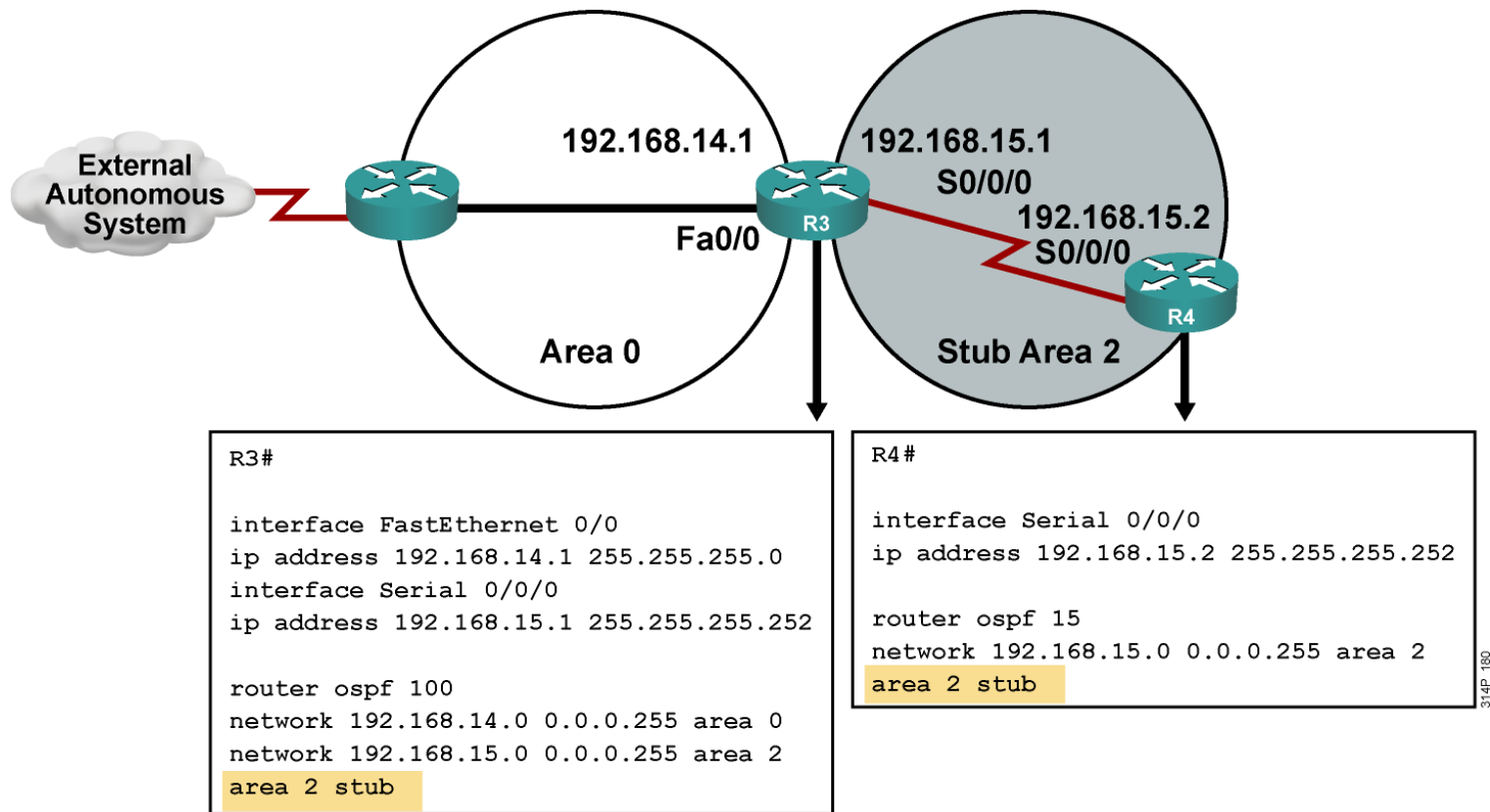
- **All routers in area 50 must be configured as stub.**

OSPF Stub Area Configuration Example

External Autonomous System

192.168.14.1

192.168.15.1
S0/0/0

192.168.15.2
S0/0/0

Fa0/0 R3

R4

Area 0

Stub Area 2

```
R3#

interface FastEthernet 0/0
ip address 192.168.14.1 255.255.255.0
interface Serial 0/0/0
ip address 192.168.15.1 255.255.255.252

router ospf 100
network 192.168.14.0 0.0.0.255 area 0
network 192.168.15.0 0.0.0.255 area 2
area 2 stub
```

```
R4#

interface Serial 0/0/0
ip address 192.168.15.2 255.255.255.252

router ospf 15
network 192.168.15.0 0.0.0.255 area 2
area 2 stub
```

314P_180

OSPF 区域类型-完全末节区域

Stub Area

Backbone Area 0

Totally Stubby Area

Does not accept external LSAs

Interconnects areas; accepts all LSAs

Does not accept external or summary LSAs
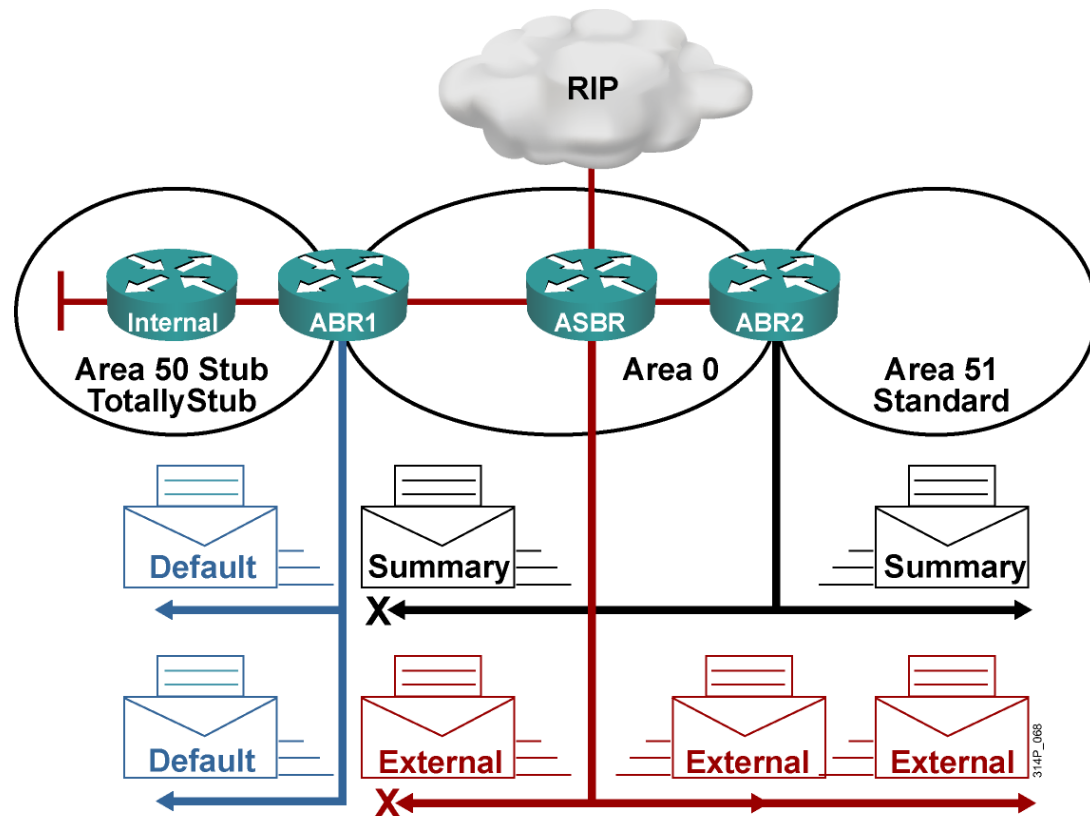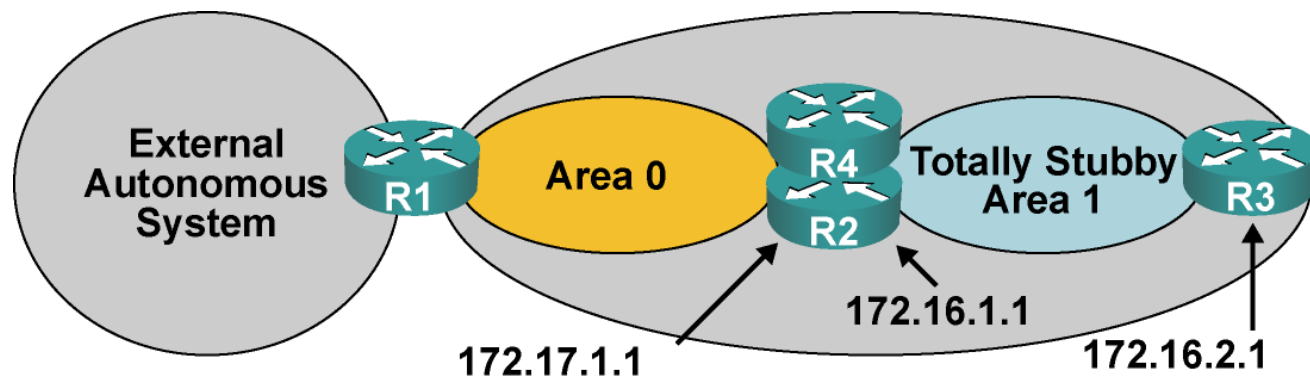
014G_222

OSPF 区域类型-完全末节区域

- **External LSAs and Summary LSAs are stopped.**
- **Routing table is reduced to a minimum.**
- **All routers must be configured as stub.**
- **ABR must be configured as totally stubby.**
- **This is a Cisco proprietary feature.**

Totally Stubby Configuration Example

External Autonomous System

R1

Area 0

R4

R2

Totally Stubby Area 1

R3

172.16.1.1

172.17.1.1

172.16.2.1

```
Router2(config)# router ospf 10
Router2(config-router)# network 172.17.0.0 0.0.255.255 area 0
Router2(config-router)# network 172.16.0.0 0.0.255.255 area 1
Router2(config-router)#area 1 stub no-summary
Router2(config-router)#area 1 default-cost 5
Router2(config-router)# ! R2 is the preferred ABR
```

```
Router3(config)# router ospf 10
Router3(config-router)# network 172.16.0.0 0.0.255.255 area 1
Router3(config-router)# area 1 stub
```
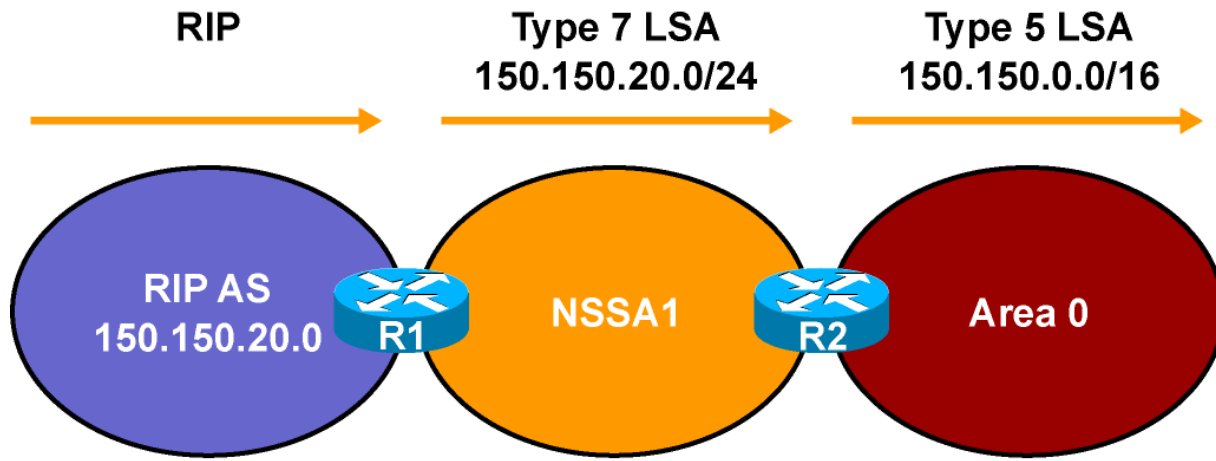
```
Router4(config)# router ospf 10
Router4(config-router)# network 172.17.0.0 0.0.255.255 area 0
Router4(config-router)# network 172.16.0.0 0.0.255.255 area 1
Router4(config-router)#area 1 stub no-summary
Router4(config-router)#area 1 default-cost 10
```
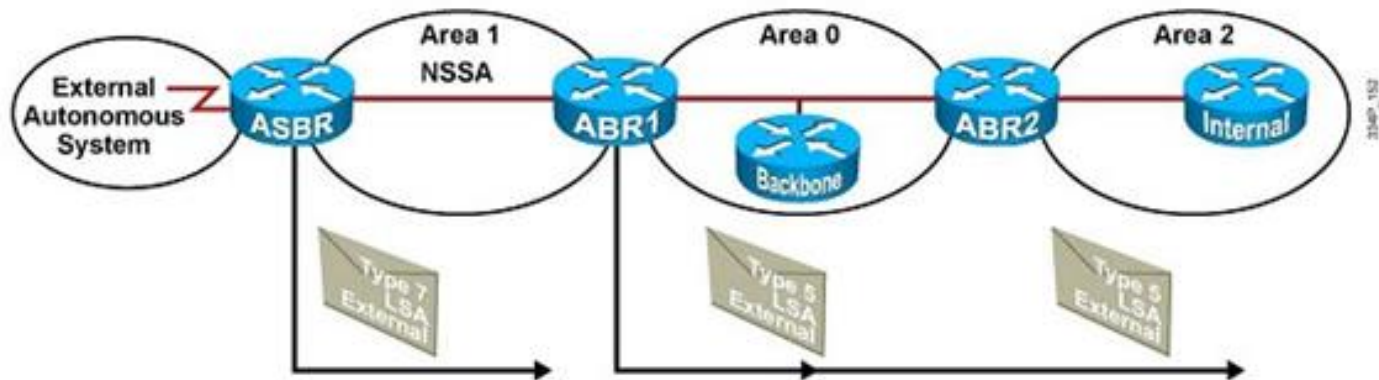
OSPF 区域类型-NSSA区域

RIP

Type 7 LSA
150.150.20.0/24

Type 5 LSA
150.150.0.0/16

RIP AS
150.150.20.0
**R1**

NSSA1
R2

Area 0

014G_231

- NSSA breaks stub area rules.
- ASBR (R1) is allowed in NSSA.
- Special LSA type 7 defined, sent by ASBR.

- ABR (R2) converts LSA type 7 to LSA type 5.
- ABR sends default route into NSSA instead of external routes from other ASBRs.
- NSSA is an RFC addendum.

LSA Type 7: NSSA LSA

- Generated by an ASBR inside a Not-so-stubby area (NSSA) to describe routes redistributed into the NSSA.

  - LSA 7 is translated into LSA 5 as it leaves the NSSA.

  - Much like LSA 5, N2 is a static cost while N1 is a cumulative cost that includes the cost up to the ASBR.

Configuring a NSSA Area
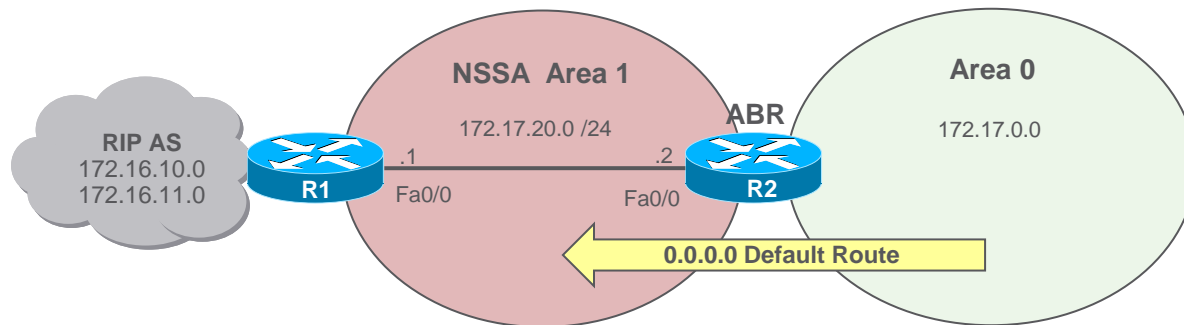

```
R1(config)# router ospf 10
R1(config-router)# redistribute rip subnets
R1(config-router)# default metric 150
R1(config-router)# network 172.17.0.0 0.0.255.255 area 1
R1(config-router)# area 1 nssa
R1(config-router)#
```

```
R2(config)# router ospf 10
R2(config-router)# summary-address 172.16.0.0 255.255.0.0
R2(config-router)# network 172.17.20.0 0.0.0.255 area 1
R2(config-router)# network 172.17.0.0 0.0.255.255 area 0
R2(config-router)# area 1 nssa default-information-originate
R2(config-router)#
```

OSPF 虚链路
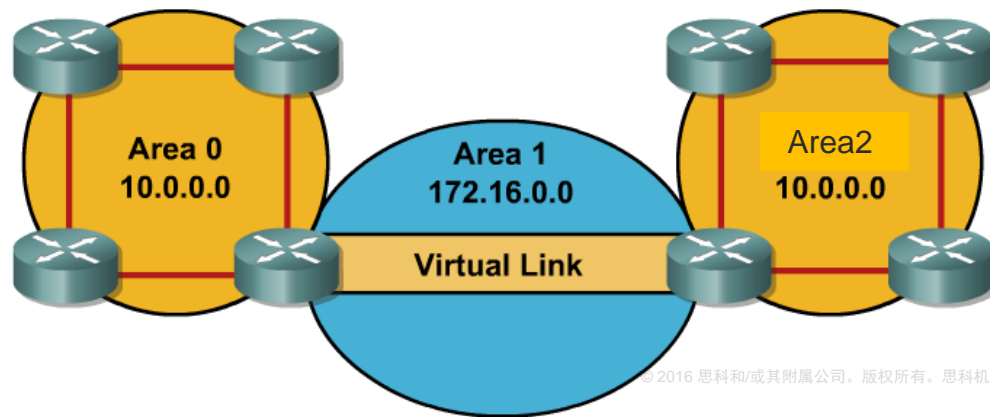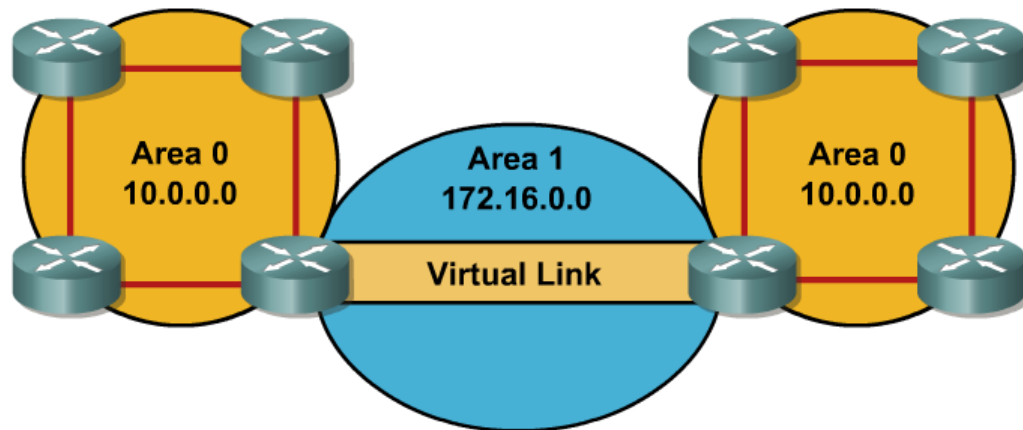
19.2 配置多区域 OSPF

配置多区域 OSPF

配置多区域 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#
```
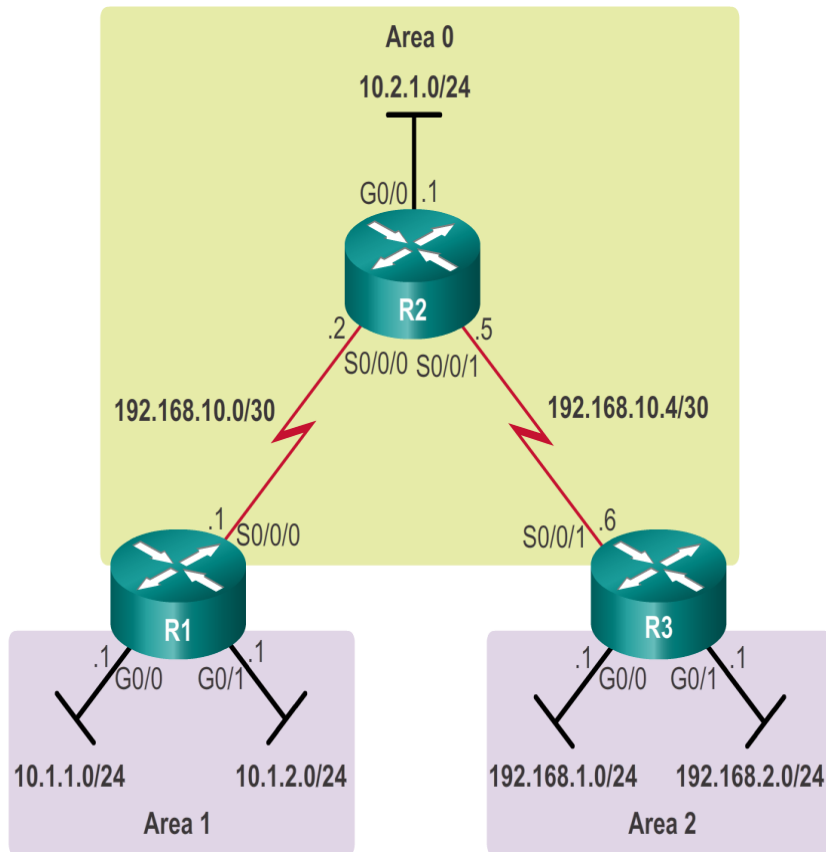
验证多区域 OSPF

- 验证多区域 OSPF v2

  - 用于验证单区域 OSPFv2 的相同验证命令也可用于验证多区域 OSPF 拓扑。

  - 对于对应的 OSPFv3 命令，只要用 ipv6 代替 ip 即可。

- 验证常规的多区域 OSPFv2 设置

  - 使用 show ip protocols 命令验证 OSPFv2 状态。

  - "网络路由" 部分标识网络及其各自区域。

- 验证 OSPFv2 路由

  - 用于验证多区域 OSPFv2 配置的最常用命令是 show ip route 命令。添加 ospf 参数以仅显示与 OSPFv2 相关的信息。

验证多区域 OSPF（续）

```
RouterA#show ip ospf database
     OSPF Router with ID (10.0.0.11) (Process ID 1)
               Router Link States (Area 0)
Link ID          ADV Router       Age        Seq#        Checksum Link count
10.0.0.11        10.0.0.11        548        0x80000002 0x00401A 1
10.0.0.12        10.0.0.12        549        0x80000004 0x003A1B 1
100.100.100.100 100.100.100.100 548        0x800002D7 0x00EEA9 2
               Net Link States (Area 0)
Link ID          ADV Router       Age        Seq#        Checksum
172.31.1.3       100.100.100.100 549        0x80000001 0x004EC9
               Summary Net Link States (Area 0)
Link ID          ADV Router       Age        Seq#        Checksum
10.1.0.0         10.0.0.11        654        0x80000001 0x00FB11
10.1.0.0         10.0.0.12        601        0x80000001 0x00F516
<output omitted>
```

show ip ospf database router -----LSA1
show ip ospf database network -----LSA2
show ip ospf database summary -----LSA3
show ip ospf database asbr-summary -----LSA4
show ip ospf database external -----LSA5
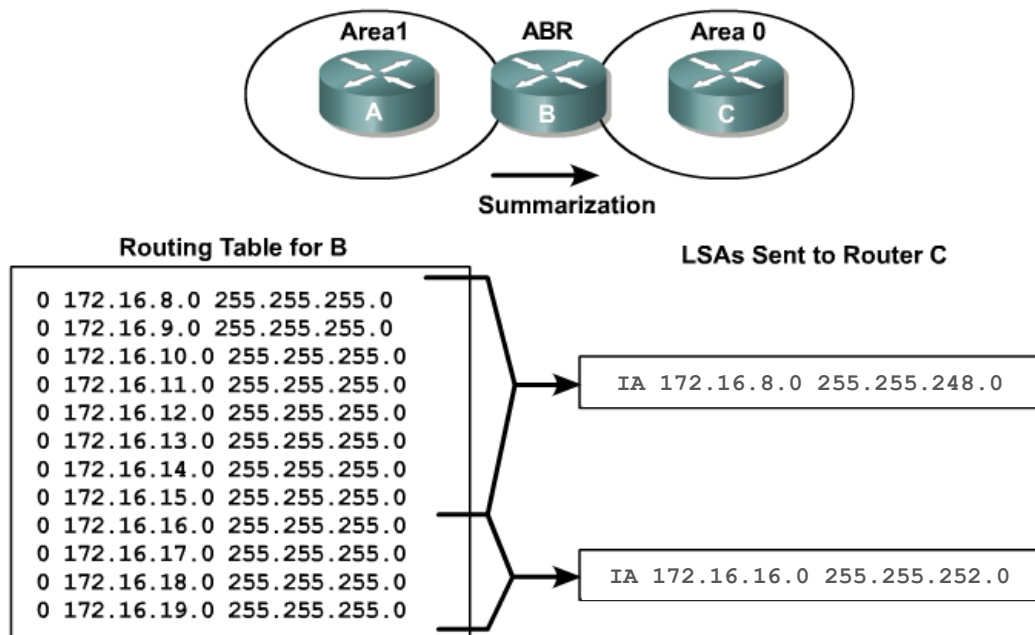**show ip ospf database nssa-external-----LSA7**

Benefits of Route Summarization
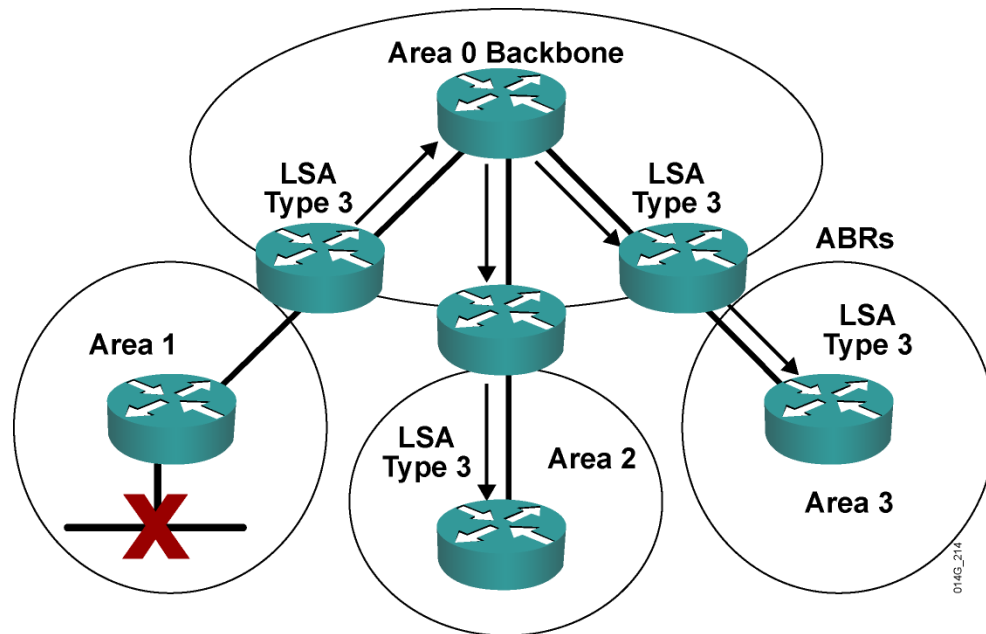
- Minimizes number of routing table entries
- Localizes impact of a topology change
- Reduces LSA type 3 and 5 flooding and saves CPU resources

Using Route Summarization

Routing Table for B

```
O 172.16.8.0 255.255.255.0
O 172.16.9.0 255.255.255.0
O 172.16.10.0 255.255.255.0
O 172.16.11.0 255.255.255.0
O 172.16.12.0 255.255.255.0
O 172.16.13.0 255.255.255.0
O 172.16.14.0 255.255.255.0
O 172.16.15.0 255.255.255.0
O 172.16.16.0 255.255.255.0
O 172.16.17.0 255.255.255.0
O 172.16.18.0 255.255.255.0
O 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
```
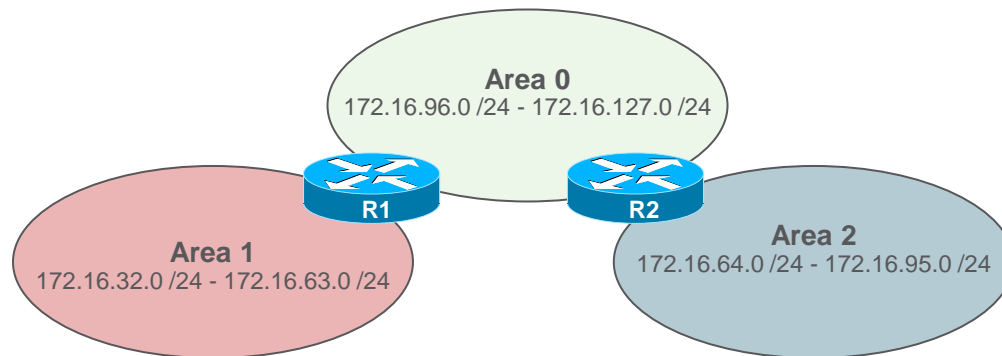
- Interarea summary link carries mask.
- One or more entries can represent several subnets.

Types of Route Summarization

- Inter-area summarization

  - Performed at the ABR and creates Type 3 LSAs.

- External summarization

  - Performed at the ASBR and creates Type 5 LSAs.

- Both have the same fundamental requirement of contiguous addressing.

- If summarization is not configured correctly and there are multiple ASBRs, or multiple ABRs in an area, suboptimal routing is possible.

  - For example, summarizing overlapping ranges from two different routers can cause packets to be sent to the wrong destination.

Intra-Area Summarization Example

Area 0
172.16.96.0 /24 - 172.16.127.0 /24

R1

R2

Area 1
172.16.32.0 /24 - 172.16.63.0 /24

Area 2
172.16.64.0 /24 - 172.16.95.0 /24

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

```
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
R2(config-router)#
```