

# OSPF

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# Objectives

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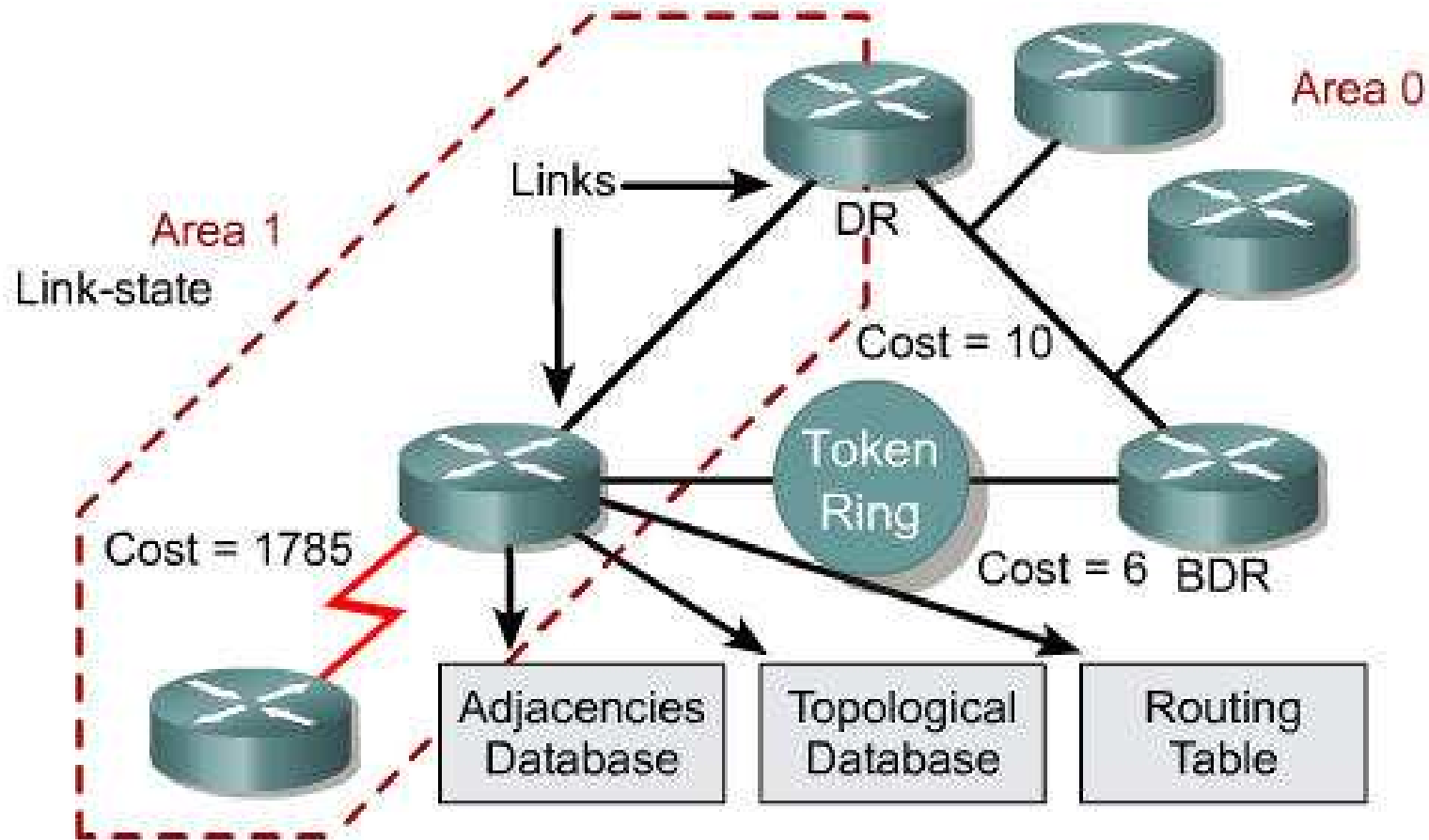
- **OSPF Overview**
- **OSPF Operation**
- **OSPF Configuration and Verification**
- **Multiarea OSPF Operation**
- **Multiarea OSPF Configuration and Verification**
- **Stub, Totally Stubby, and Not-So-Stubby Areas**
- **Virtual Links**

# Issues Addressed by OSPF

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- **Fast convergence**
- **Supports Variable-Length Subnet Masking (VLSM)**
- **Network size, no distance limitations**
- **Processes updates efficiently**
- **Selects paths based on bandwidth**
- **Supports equal-cost multipath**
- **Grouping of members (area)**

# OSPF Terminology



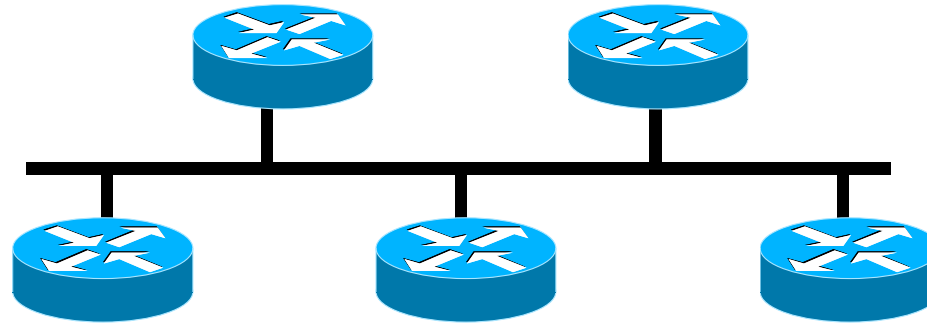
# OSPF Terminology (Cont.)

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- **Adjacencies database**
  - Lists neighbors
- **Topological database**
  - Lists all routes
- **Routing table**
  - Lists best routes

# OSPF Topologies

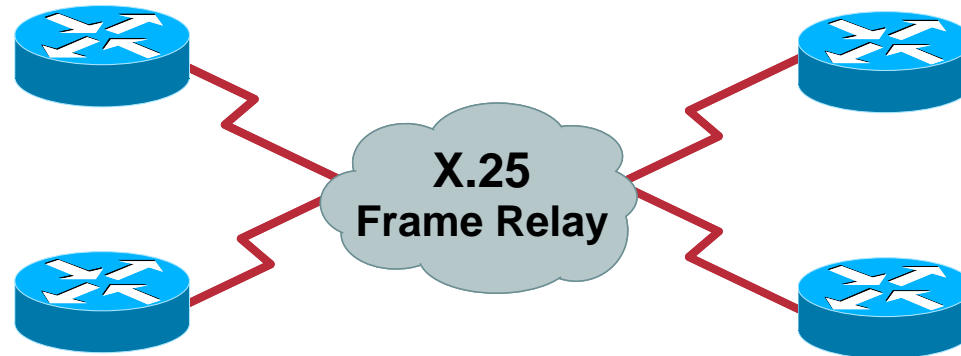
**Broadcast  
Multiaccess**



**Point-to-Point**



**NBMA**



# OSPF States

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- **Down**
- **Init**
- **Two-way**
- **ExStart**
- **Exchange**
- **Loading**
- **Full adjacency**

# OSPF Packet Types

OSPF Packet Type	Description
Type 1 - Hello	Establishes and maintains adjacency information with neighbors
Type 2 - Database description packet (DBD)	Describes the content of the link-state database on an OSPF router
Type 3 - Link-state request (LSR)	Requests specific pieces of a link-state database
Type 4 - Link-state update (LSU)	Transports link-state advertisements (LSAs) to neighbor routers
Type 5 - Link-state acknowledgement (LSAck)	Acknowledges receipt of a neighbor's LSA



# The OSPF Hello Protocol

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- **At Layer 3 of the OSI model, Hello packets are addressed to the multicast address 224.0.0.5. This address effectively means all OSPF routers.**
- **OSPF routers use Hello packets to initiate new adjacencies and to ensure that adjacent neighbors have not disappeared.**
- **Hellos are sent every ten seconds by default on multiaccess and point-to-point networks.**
- **On interfaces that connect to NBMA networks, such as Frame Relay, Hellos are sent every 30 seconds.**

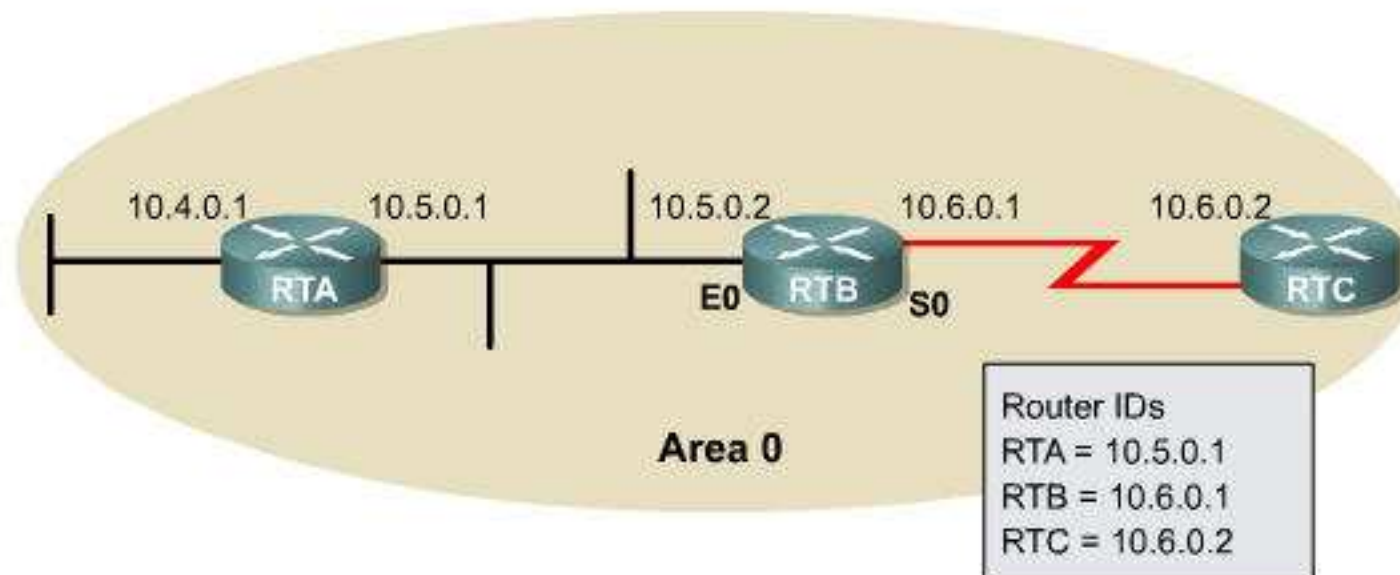
# Steps of OSPF Operation

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- **Step 1: Establish router adjacencies**
- **Step 2: Elect a DR and a BDR**
- **Step 3: Discover routes**
- **Step 4: Select appropriate routes**
- **Step 5: Maintain routing information**

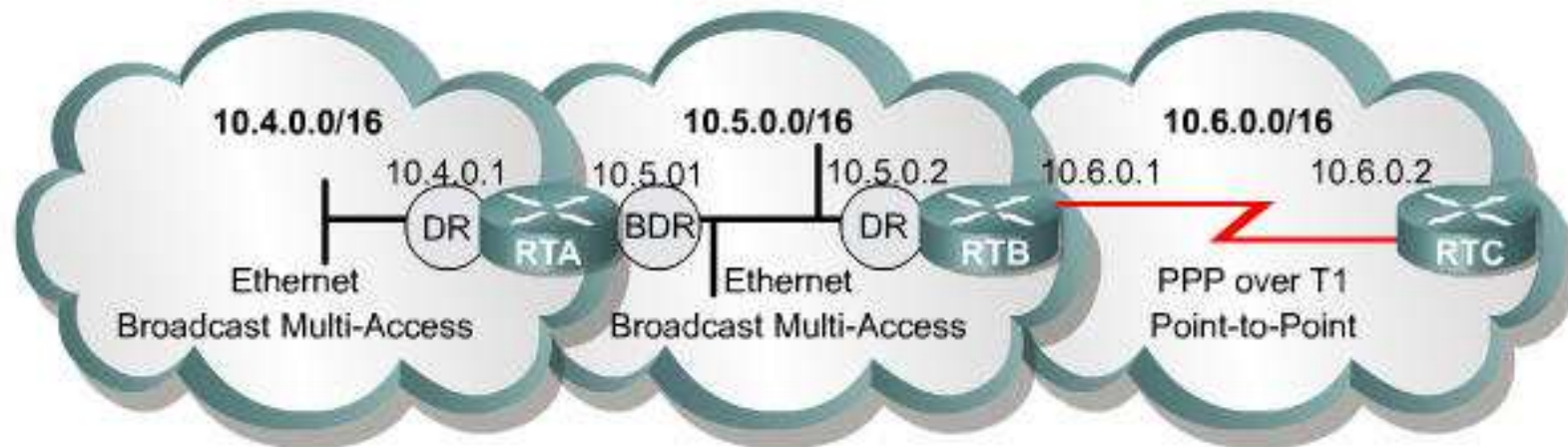
# Step 1: Establish Router Adjacencies

Router ID = highest IP address on router



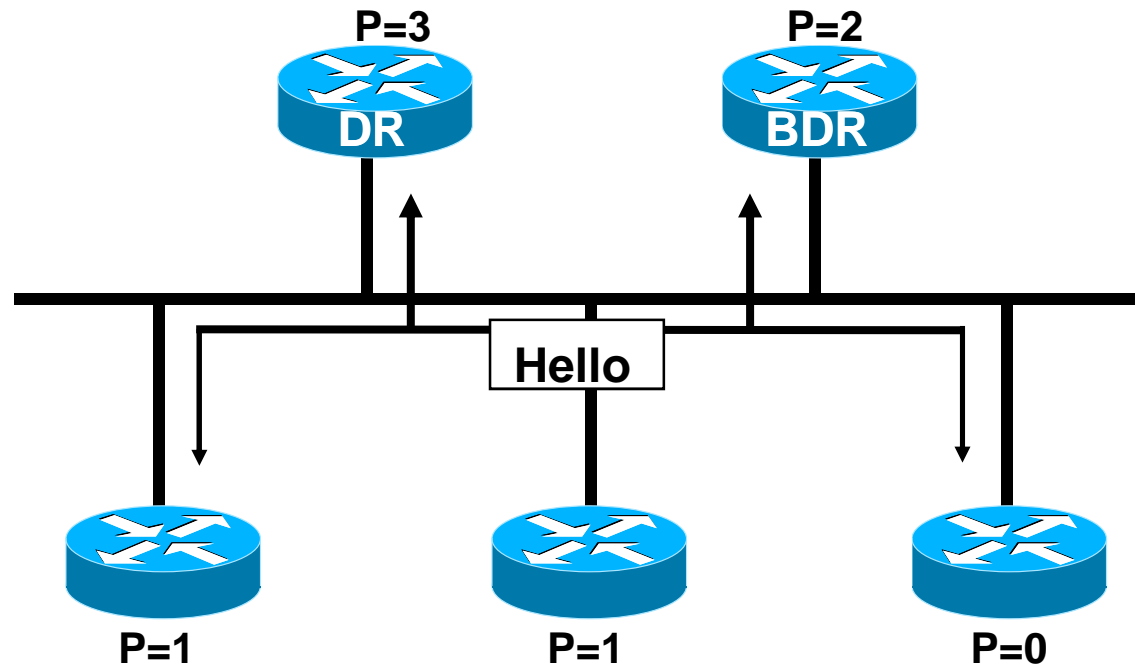
An OSPF router tries to form an adjacency with at least one neighbor for each IP network to which it is connected.

# Step 2: Elect a DR and a BDR



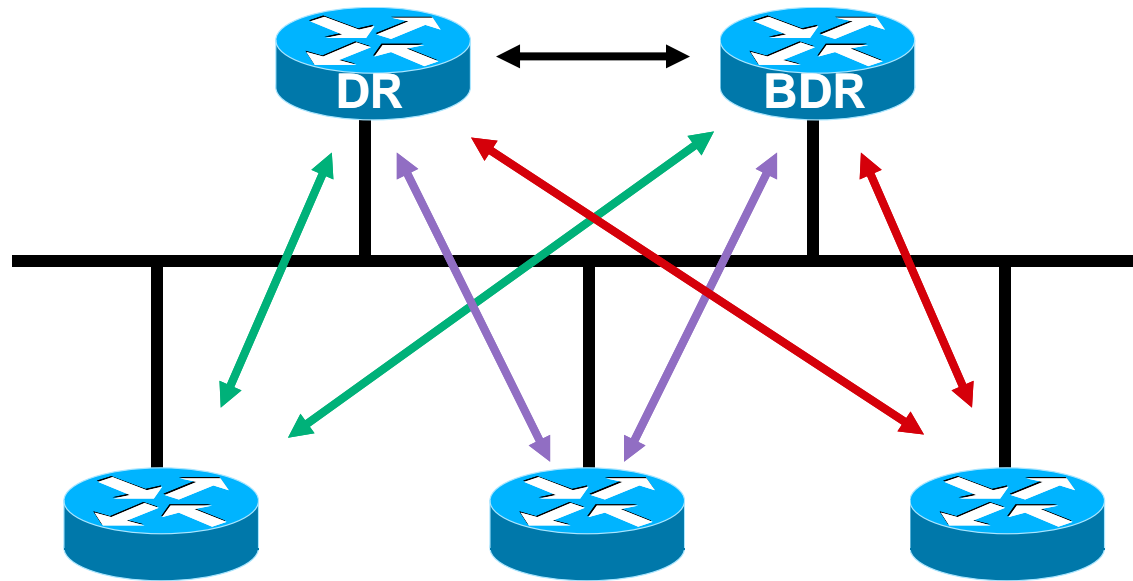
OSPF routers perform DR and BDR elections only on multiaccess IP networks.

# Electing the DR and BDR



- Hello packets exchanged via IP multicast
- A lot of Hello packets sent on multiaccess network

# DR and BDR



- Hellos elect DR and BDR to represent segment
- Router with highest ID elected
- Each router then forms adjacency with DR and BDR

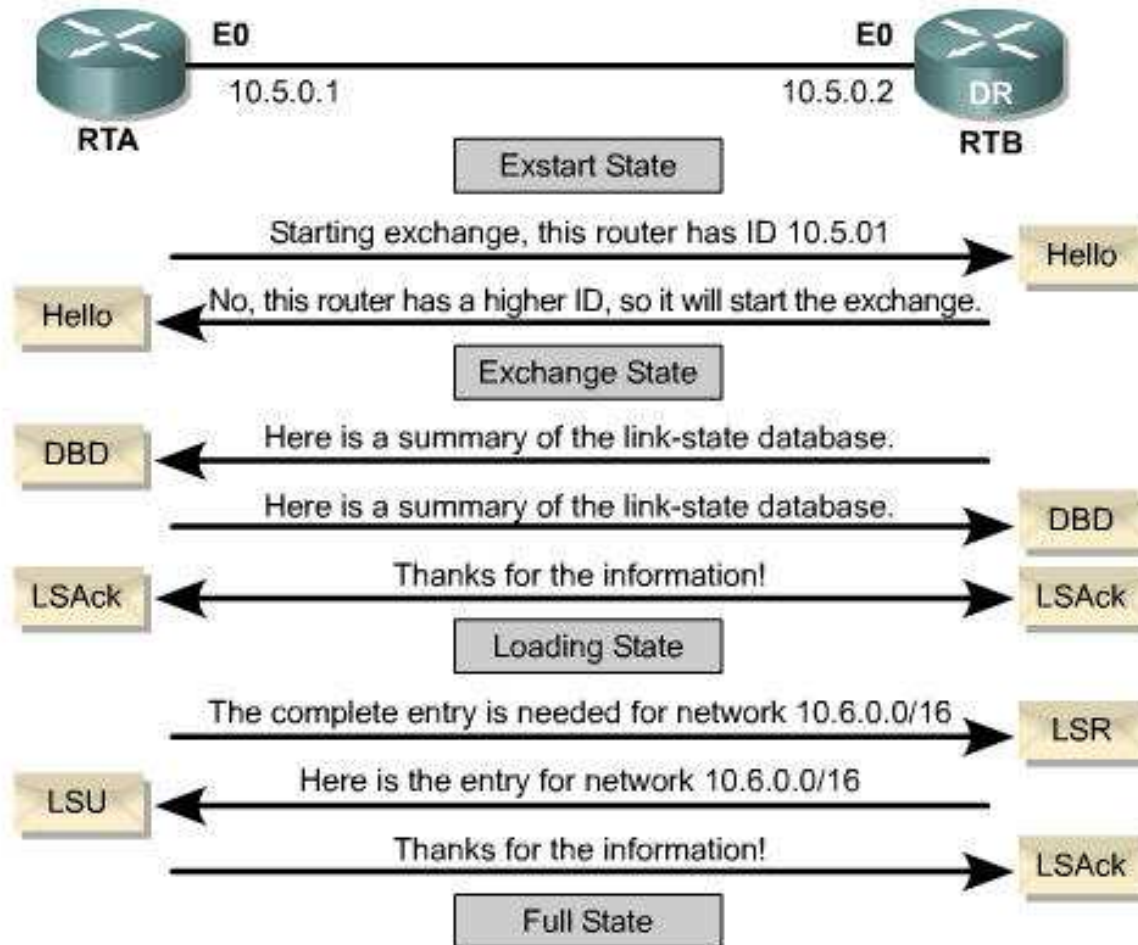
# Point-to-Point Neighborhood

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- Router dynamically detects its neighboring router using the Hello protocol
- No election: Adjacency is automatic as soon as the two routers can communicate
- OSPF packets are always sent as multicast 224.0.0.5

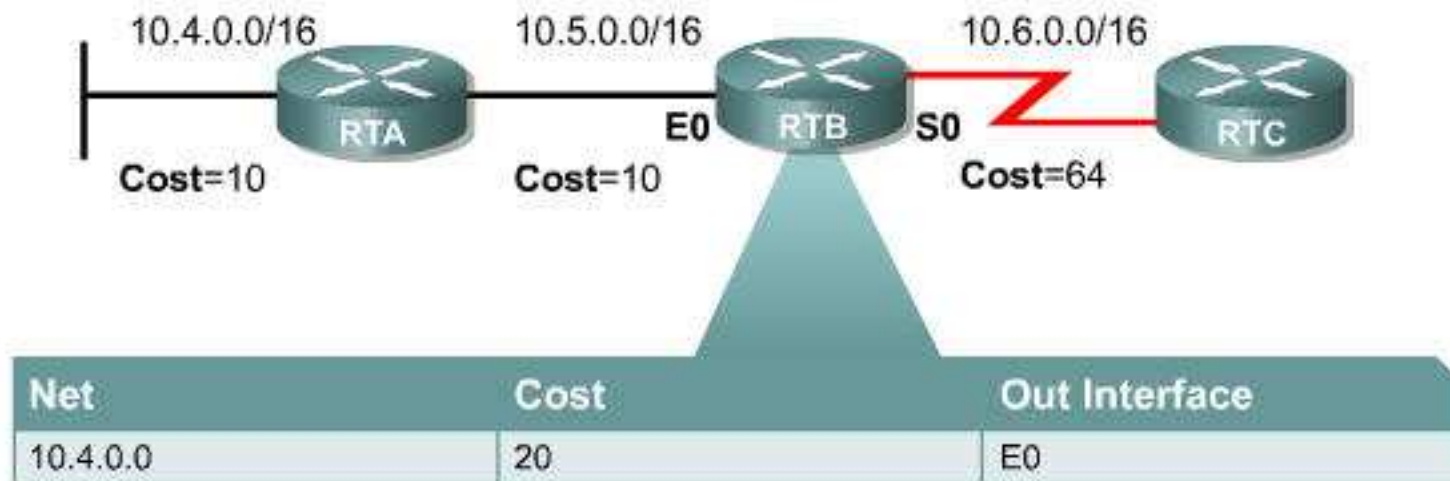
# Step 3: Discover routes



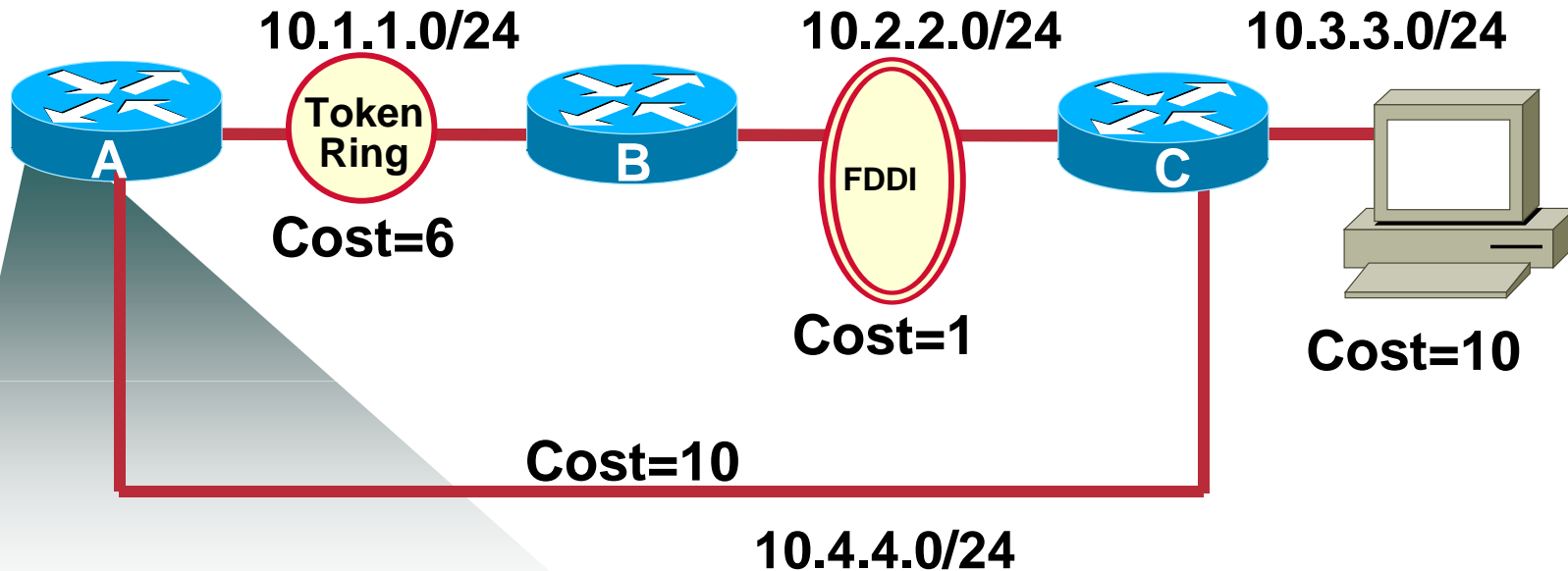


# Step 4: Select Appropriate Routes

SPF algorithm selects the best route



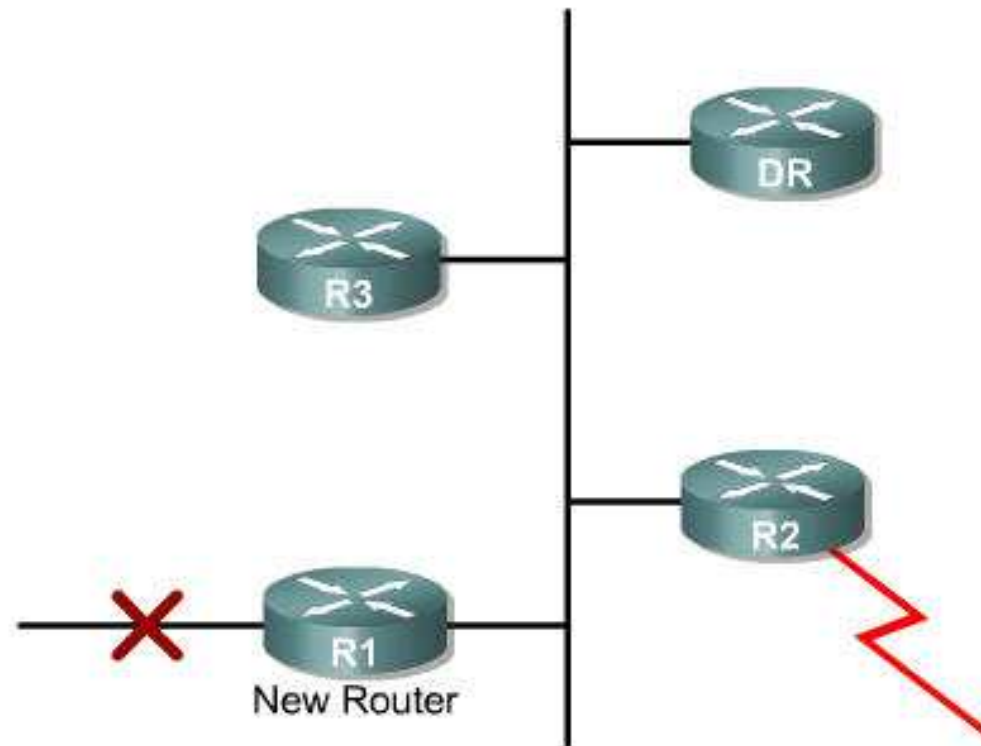
# Choosing Routes



Net	Cost	Out Interface
10.2.2.0	7	To0
10.3.3.0	17	To0
10.3.3.0	20	E0

This is the best route to 10.3.3.0.

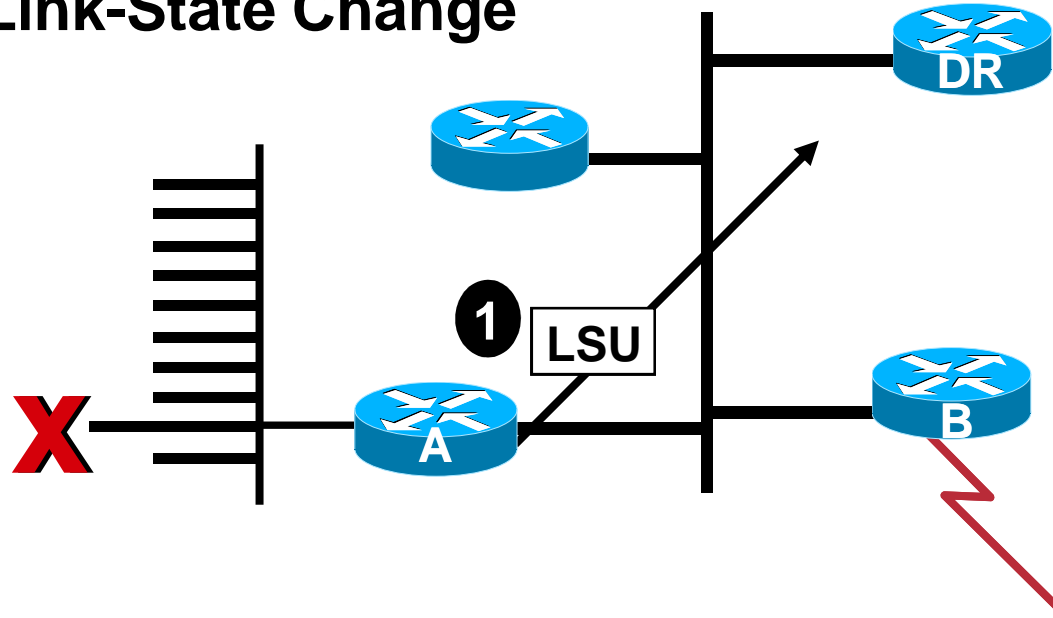
# Step 5: Maintain Routing Information



The DR acknowledges the receipt of the change and floods the LSU to others on the network using the OSPF multicast address 224.0.0.5.

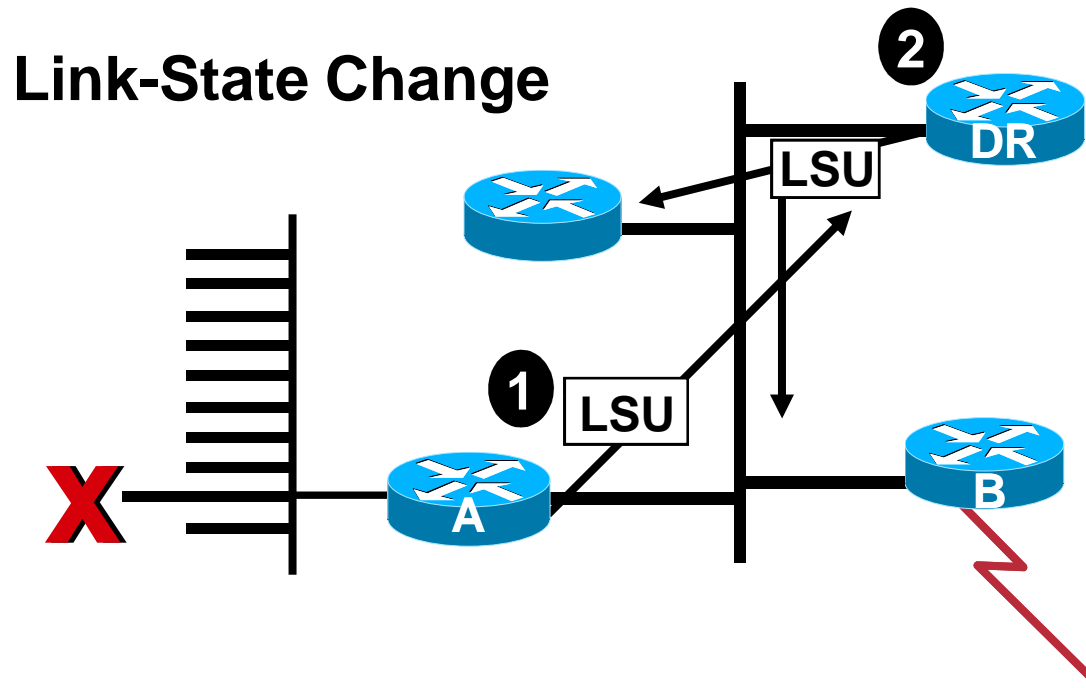
# Maintaining Routing Information

## Link-State Change



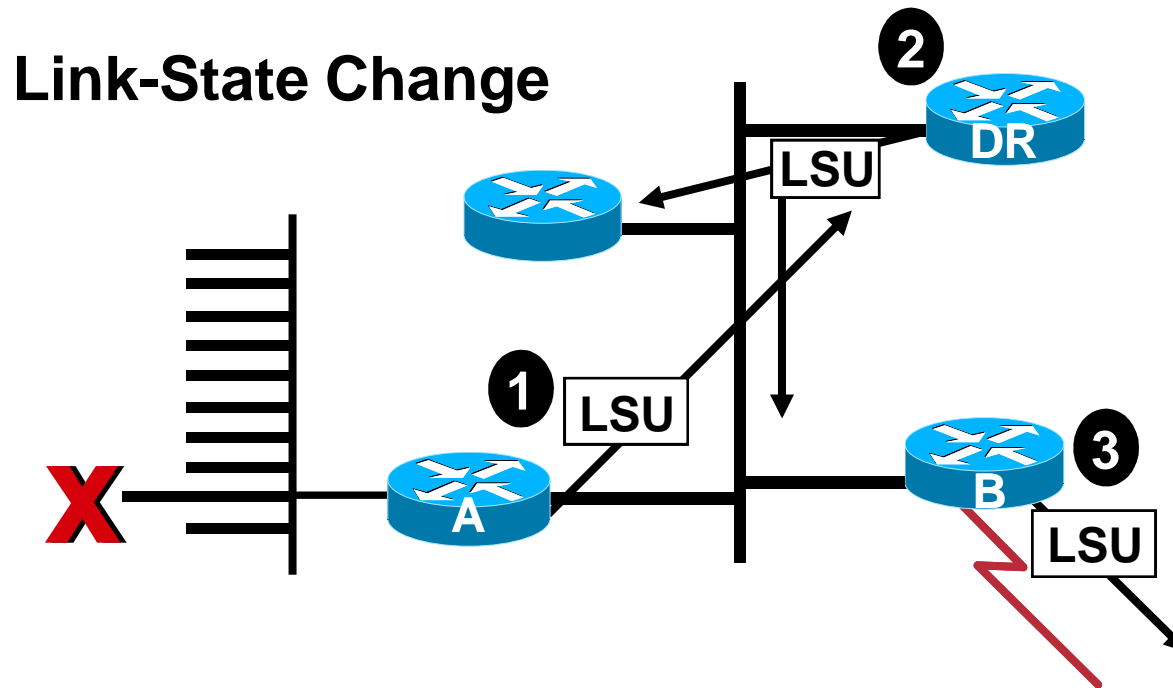
**Router A notifies all OSPF DRs on 224.0.0.6**

# Maintaining Routing Information



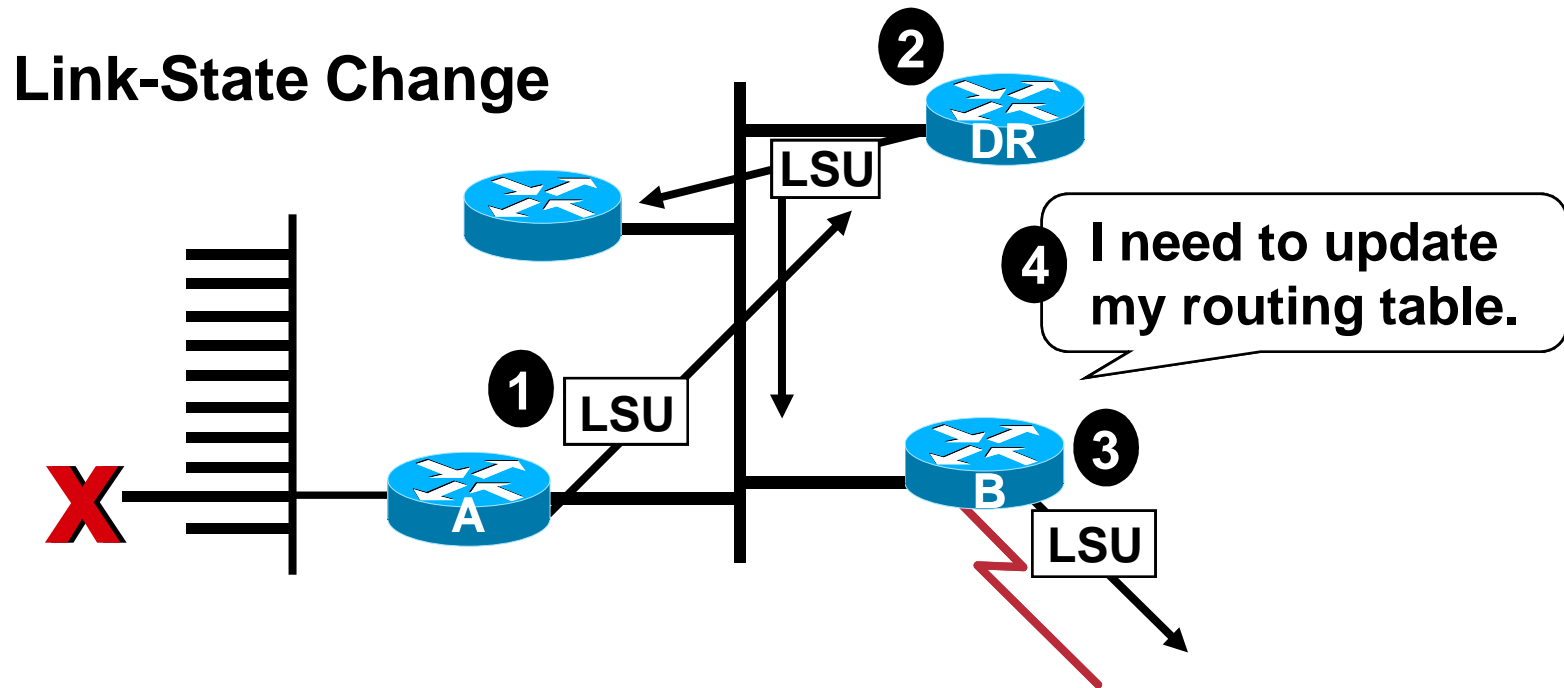
- Router A notifies all OSPF DRs on 224.0.0.6
- DR notifies others on 224.0.0.5

# Maintaining Routing Information



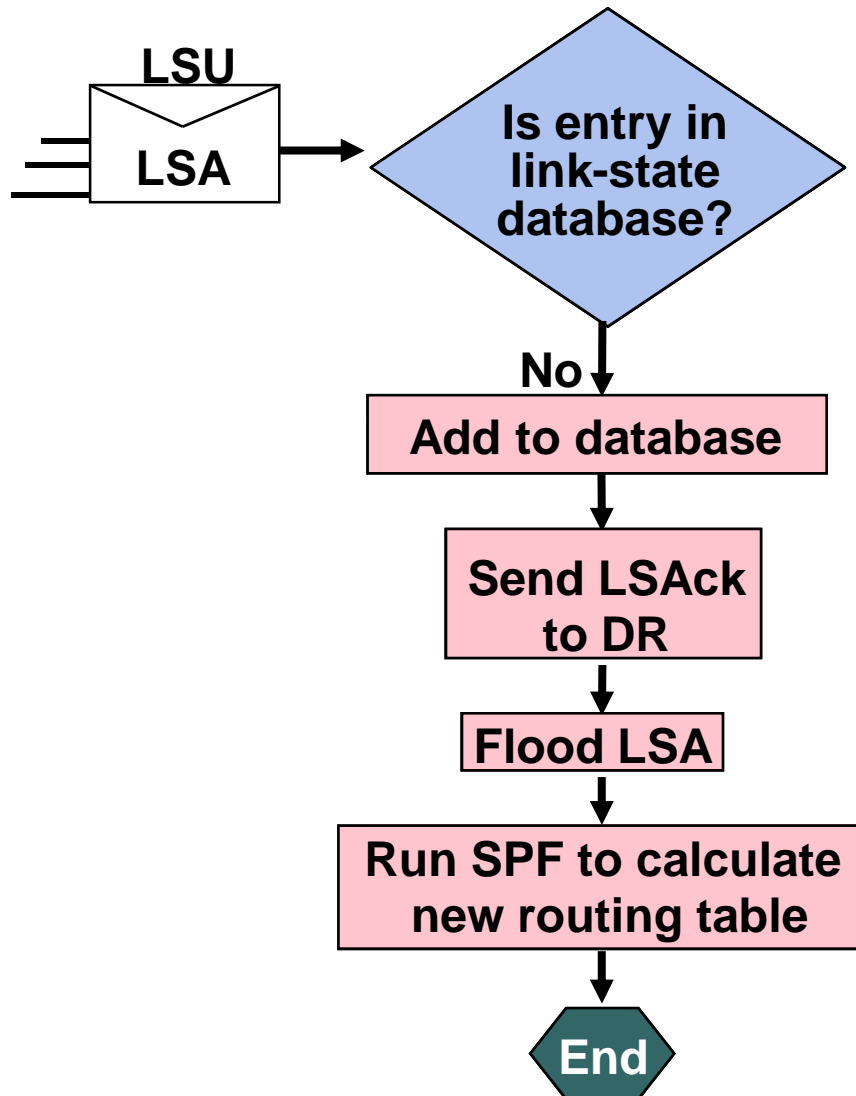
- Router A notifies all OSPF DRs on 224.0.0.6
- DR notifies others on 224.0.0.5

# Maintaining Routing Information



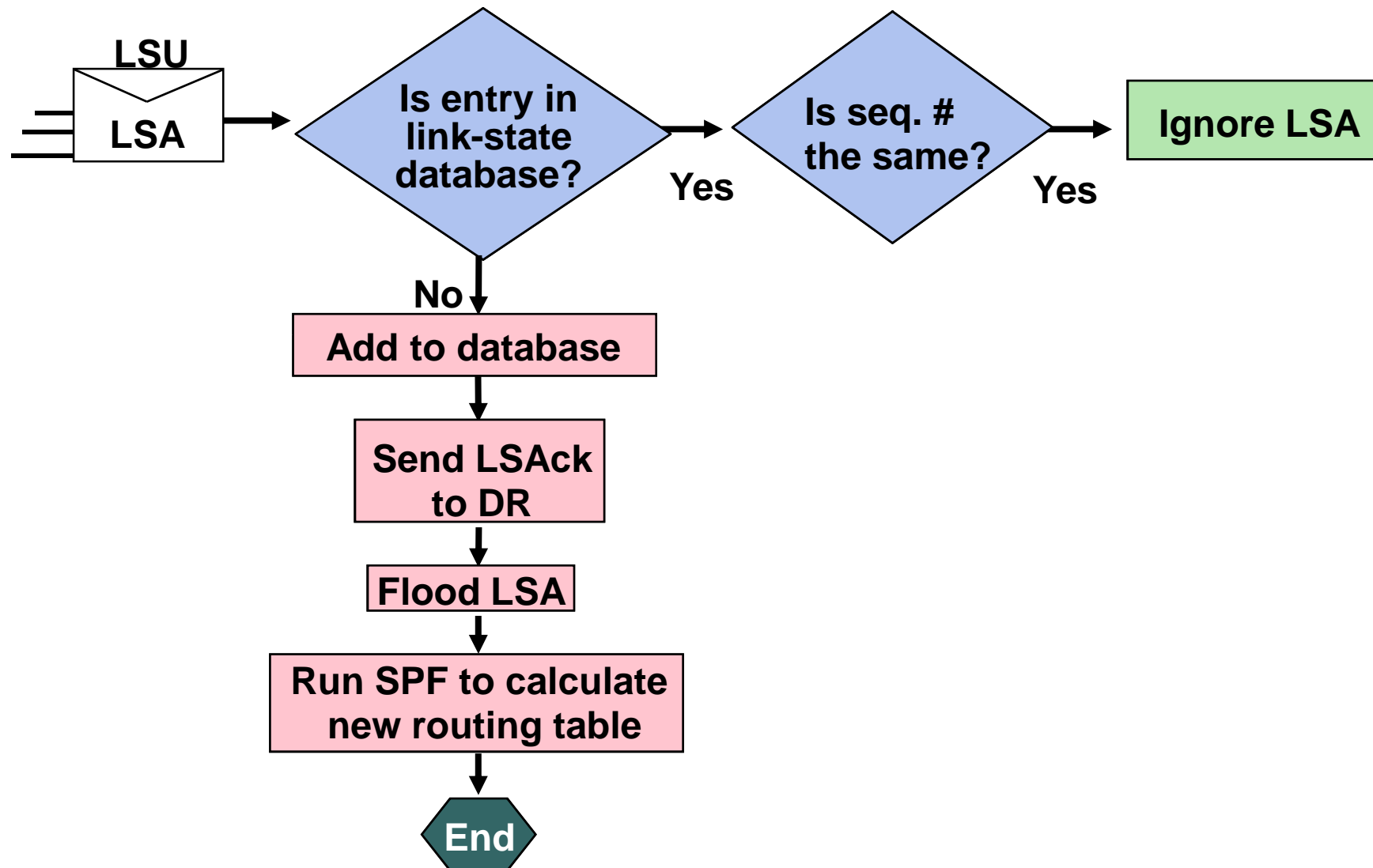
- Router A notifies all OSPF DRs on 224.0.0.6
- DR notifies others on 224.0.0.5

# Maintaining Routing Information (cont.)

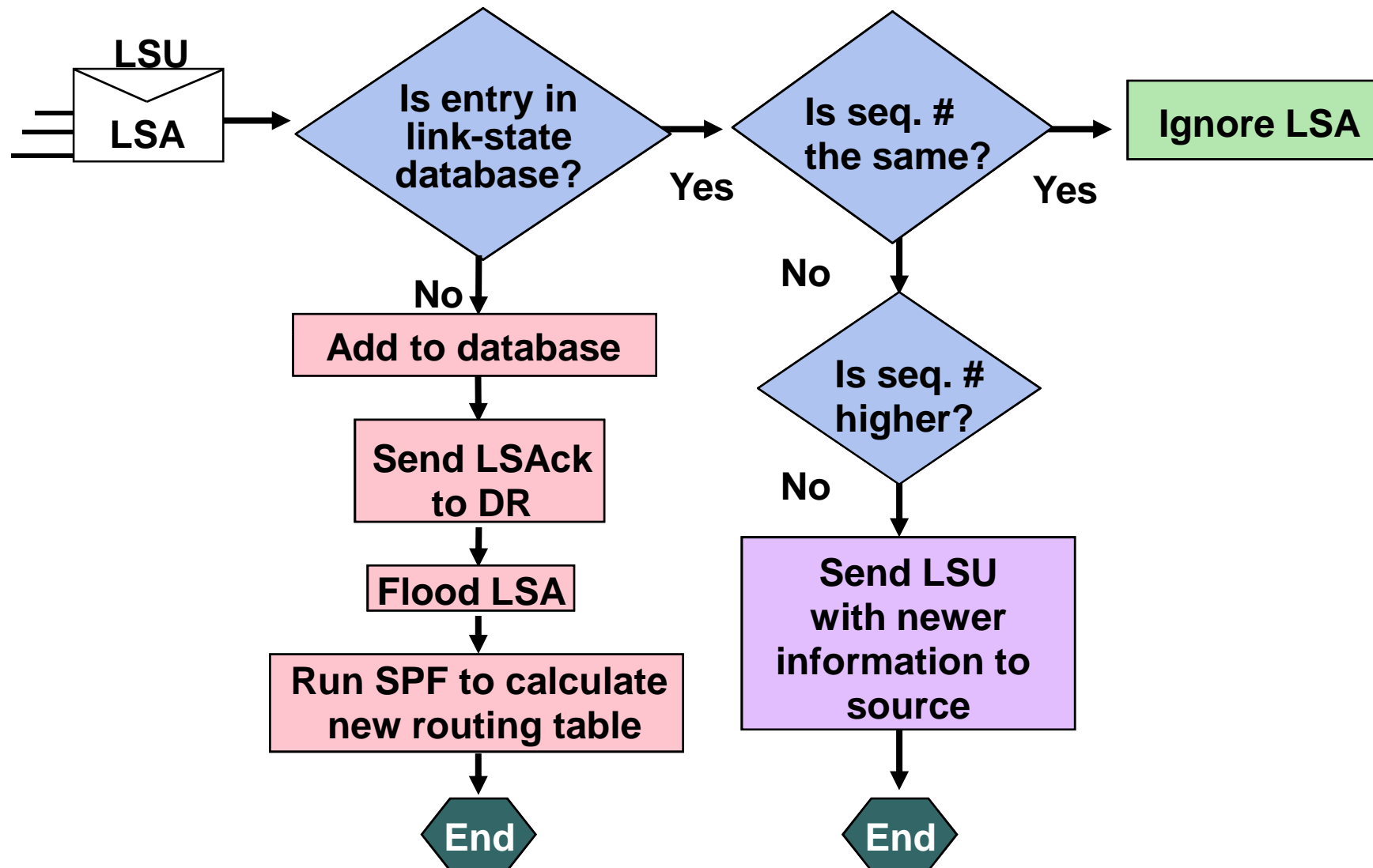




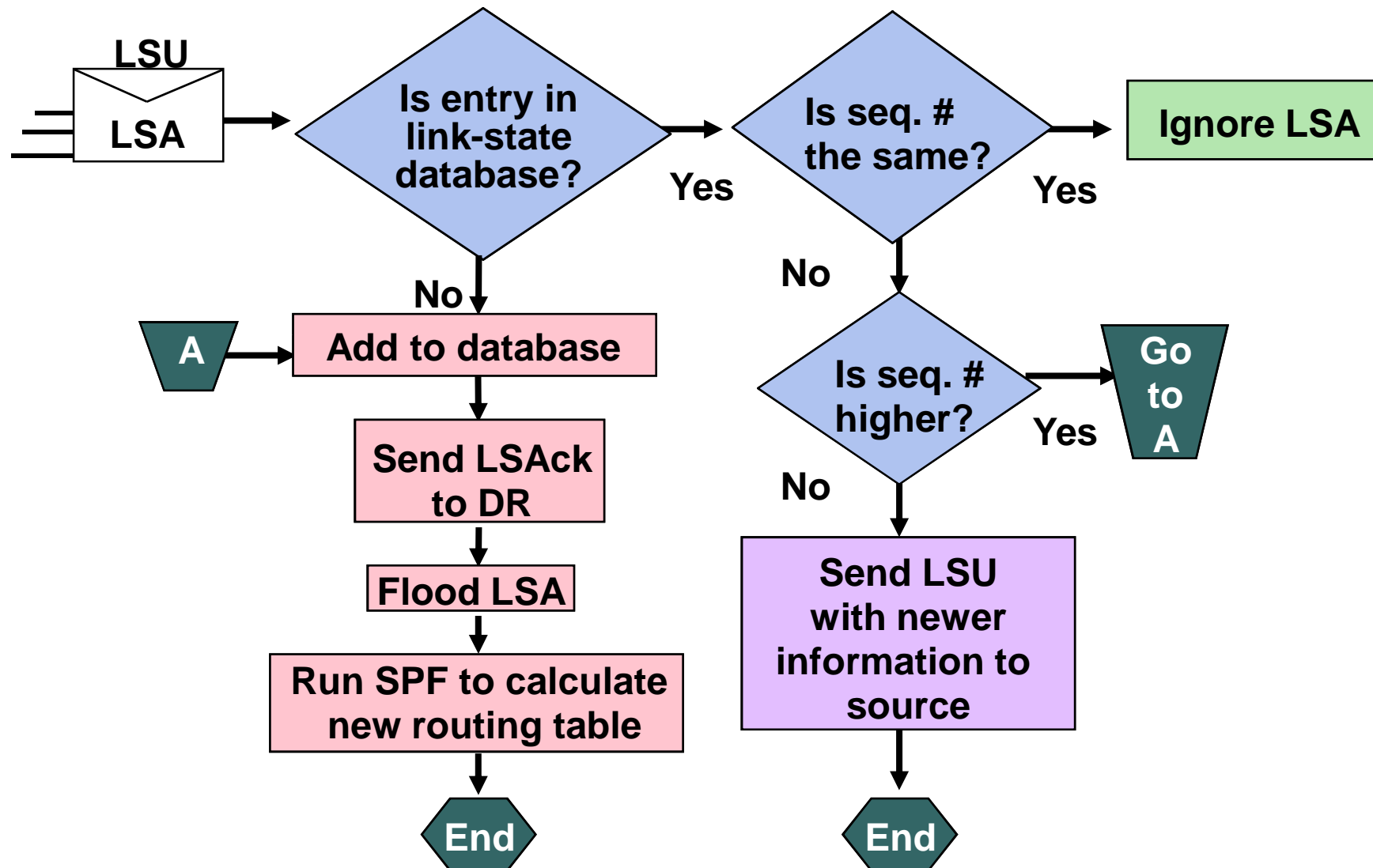
# Maintaining Routing Information (cont.)



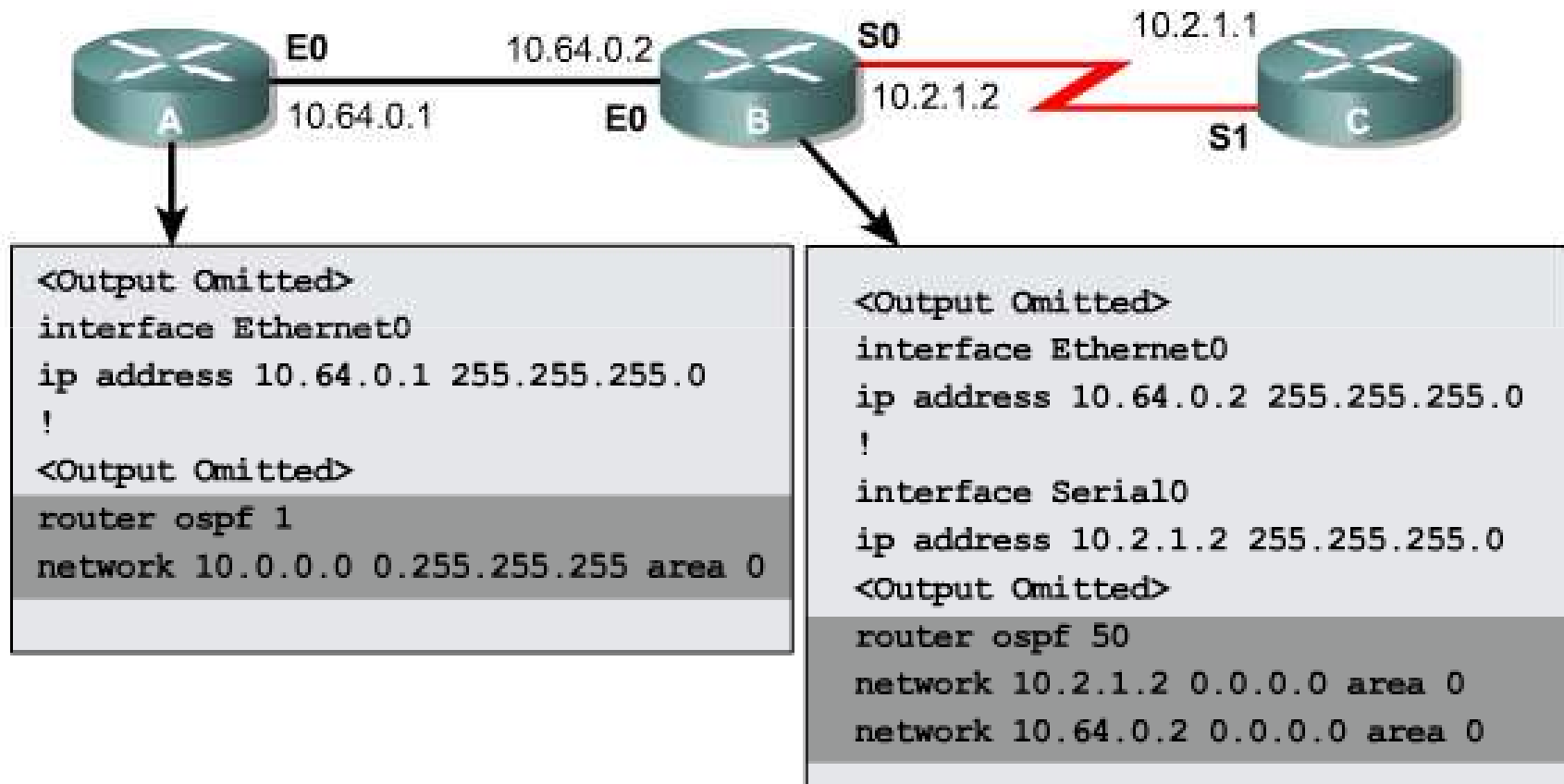
# Maintaining Routing Information (cont.)



# Maintaining Routing Information (cont.)



# Configuring OSPF on Routers Within a Single Area



# Optional Configuration Commands

For DR/BDR election:

- **Configuring a Loopback Address**

```
-Router(config)#interface loopback0  
Router(config-if)#ip address  
192.168.1.1 255.255.255.255
```

- **Modifying OSPF Router Priority**

```
-RTB(config)#interface e0  
RTB(config-if)#ip ospf priority 0
```

# Monitoring OSPF with `show ip ospf interface` command

```
Cisco - Router
Router>show ip ospf interface e0

Ethernet0 is up, line protocol is up
 Internet Address 10.5.0.2, Area 0
 Process ID 1, Router ID 10.6.0.1, Network Type BROADCAST, Cost: 10
 Transmit Delay is 1 sec, State DR, Priority 1
 Designated Router (ID) 10.6.0.2, Interface address 10.6.0.1
 Backup Designated router (ID) 10.5.0.1, Interface address 10.5.0.1
 Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
   Hello due in 00:00:03
 Index 1/1, flood queue length 0
 Next 0x0 (0)/0x0(0)
 Last flood scan length is 1, maximum is 1
 Last flood scan time is 0 msec, maximum is 0 msec
 Neighbor Count is 2, Adjacent neighbor count is 2
   Adjacent with neighbor 10.5.0.1 (Backup Designated Router)
 Suppress hello for 0 neighbor(s)
```

# Default OSPF Path Costs

Medium	Cost
56-kbps serial link	1785
T1 (1.544-Mbps serial link)	64
E1 (2.048-Mbps serial link)	48
4-Mbps Token Ring	25
Ethernet	10
16-Mbps Token Ring	6
100-Mbps Fast Ethernet, FDDI	1

**Cost =  $10^8$ /bandwidth**

**Router(config-if)#ip ospf cost *number***

# The ip ospf message-digest-key Command Parameters

Command Parameter	Description
key_id	An identifier in the range 1 to 255, which allows for multiple keys. The keys ID configuration on each router must match to authenticate.
md5	A required value that specifies that the MD5 algorithm will be used.
encryption-type	An option value that specifies that type of encryption to use (0 to 7). An encryption type value of 7 indicates Cisco proprietary encryption. Type 0 is the default.
password	An alphanumeric password to be used as the message-digest key.

**Router(config-if)#ip ospf message-digest-key *key-id* md5  
[*encryption-type*] *password***



# show commands

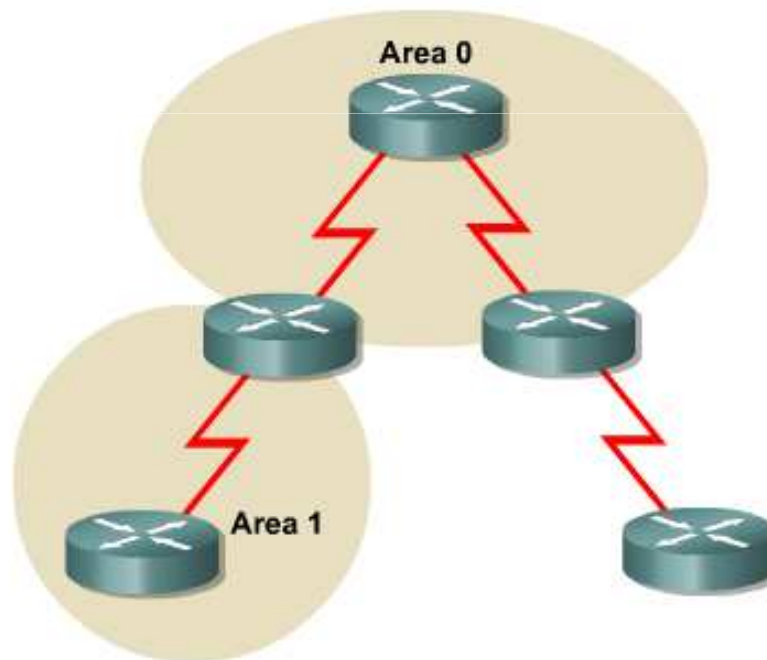
Command	Description
<code>show ip protocol</code>	Displays parameters about timers, filters, metrics, networks, and other information for the entire router.
<code>show ip route</code>	Displays the routes known to the router and how they were learned. This is one of the best ways to determine connectivity between the local router and the rest of the internetwork.
<code>show ip ospf interface</code>	Verifies that interfaces have been configured in the intended areas. If no loopback address is specified, the interface with the highest address is taken as the router ID. It also gives the timer intervals including the hello interval and shows the neighbor adjacencies.
<code>show ip ospf</code>	Displays the number of times the shortest path first (SPF) algorithm has been executed. It also shows the link-state update interval, assuming no topological changes have occurred.
<code>show ip ospf neighbor detail</code>	Displays details list of neighbors, their priorities, and their state. As an example: init, exstart, or full.
<code>show ip ospf database</code>	Displays the contents of the topological database maintained by the router. The command also shows the router ID and the OSPF process ID. A number of database types can be shown with this command using keywords. Refer to <a href="http://www.cisco.com">www.cisco.com</a> for details about the keywords.

# debug commands

```
Cisco - Router
Router#debug ip ospf ?
adj          OSPF adjacency events
events      OSPF events
flood       OSPF flooding
lsa-generation OSPF lsa generation
packet      OSPF packets
retransmission OSPF retransmission events
spf         OSPF spf
tree        OSPF database tree
```

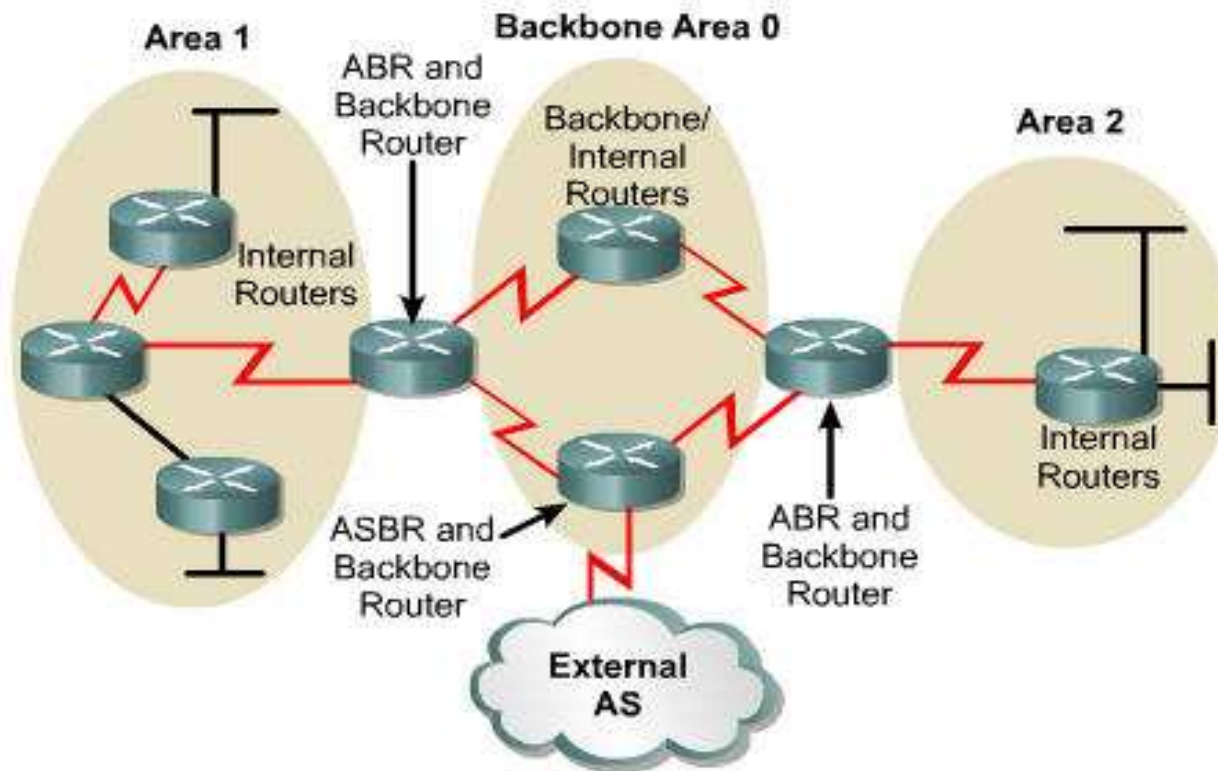
# Creating Multiple OSPF Areas

- Reduce size of routing table (summarization)
- Smaller topology tables
- All areas need to be connected to Area 0 (backbone)



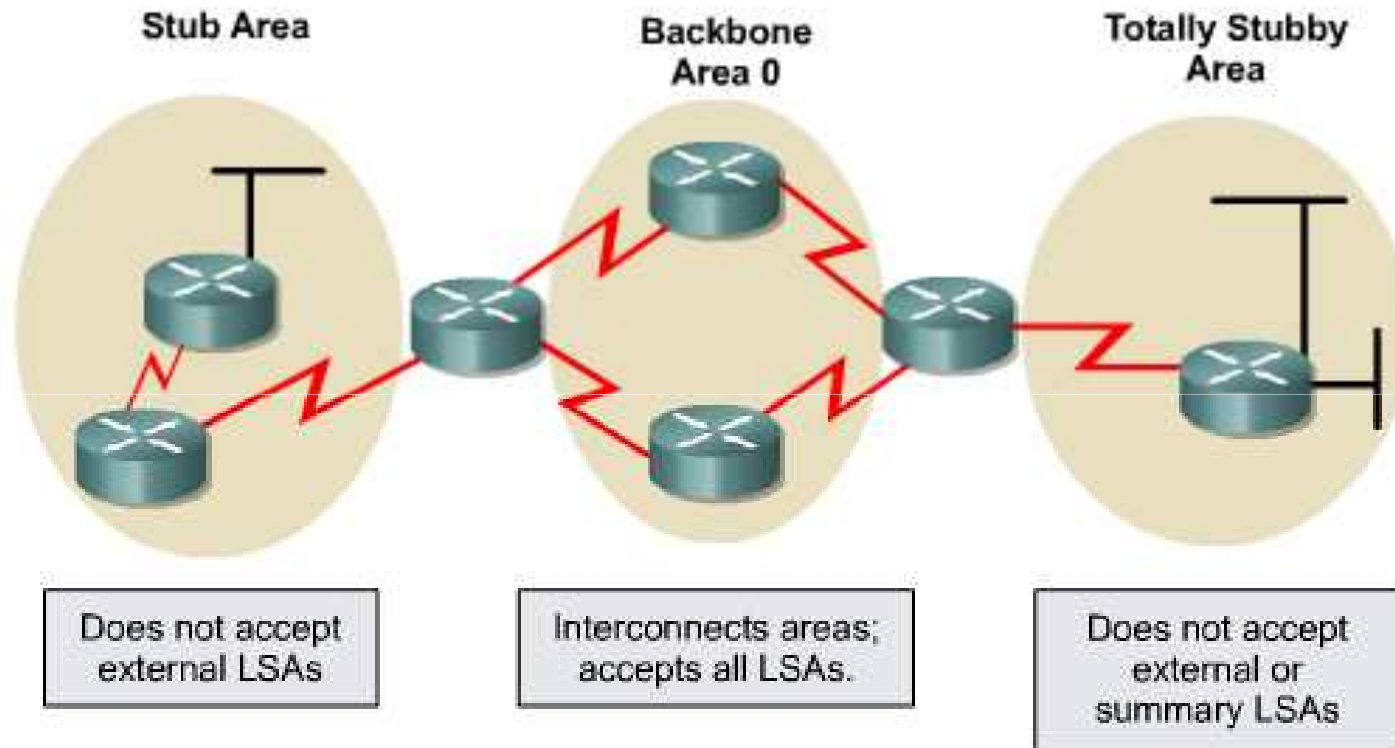
By dividing an OSPF domain into multiple areas, problems such as route flapping can be isolated.

# OSPF Router Types



An OSPF router can serve as an internal router, a backbone router, an ABR, or an ASBR.

# OSPF Area Types



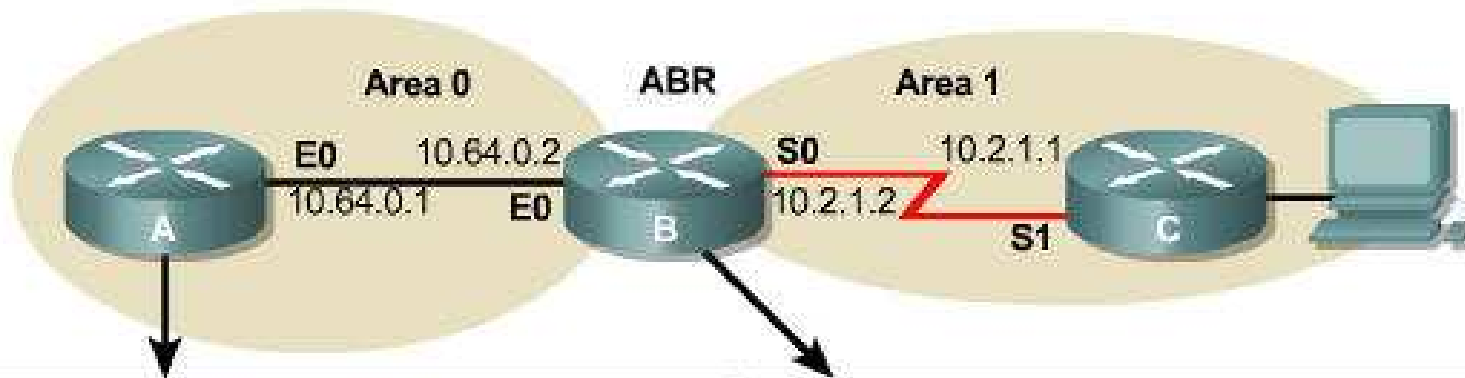
OSPF routers can be configured to exist in a backbone, stub, and totally stubby area.

# Updating the Routing Table

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- **Path calculation order**
  - **Intra-area routes**
  - **Interarea routes**
  - **External destinations**

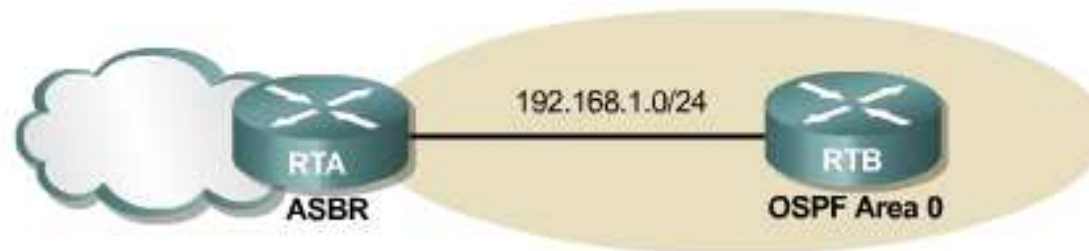
# Configuring OSPF ABRs



```
<Output Omitted>
interface Ethernet0
ip address 10.64.0.1 255.255.255.0
!
<Output Omitted>
router ospf 77
network 10.0.0.0 0.255.255.255 area 0
```

```
<Output Omitted>
interface Ethernet0
ip address 10.64.0.2 255.255.255.0
!
interface Serial0
ip address 10.2.1.2 255.255.255.0
<Output Omitted>
router ospf 50
network 10.0.0.0 0.255.255.255 area 1
network 10.0.0.0 0.255.255.255 area 0
```

# Configuring an ASBR



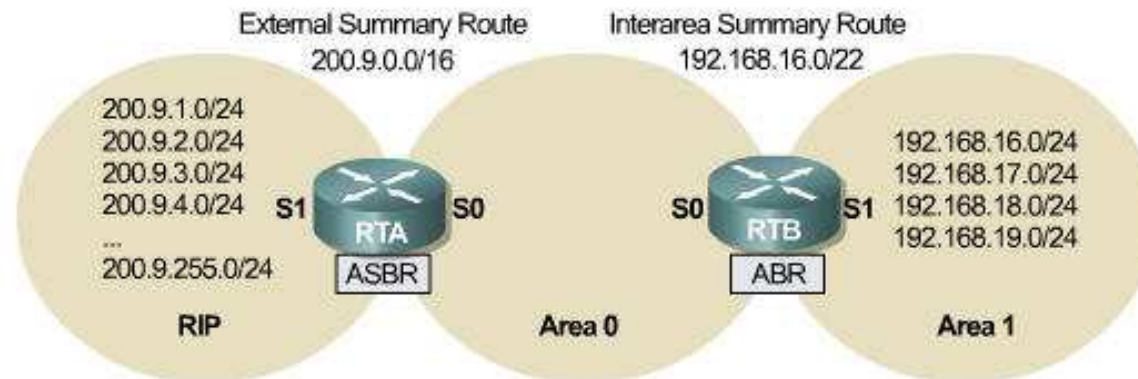
```
RTA(config)#router rip
RTA(config-router)#network 10.0.0.0
RTA(config-router)#exit
RTA(config)#router ospf 1
RTA(config-router)#network 192.168.1.0 0.0.0.255 area 0
RTA(config-router)#redistribute rip
RTA(config-router)#^z

RTA#show ip ospf
Routing Process "ospf 1" with ID 192.168.1.2
Supports only single TOS(TOSO) routes
It is an autonomous system boundary router (ASBR)
redistributing external routes from rip, including
subnets in redistribution.
<output omitted>
```



# Configuring OSPF Route Summarization

```
RTA(config)#router ospf 1
RTA(config-router)#summary-address 200.9.0.0 255.255.0.0
RTB(config)#router ospf 1
RTB(config-router)#area 1 range 192.168.16.0 255.255.252.0
```

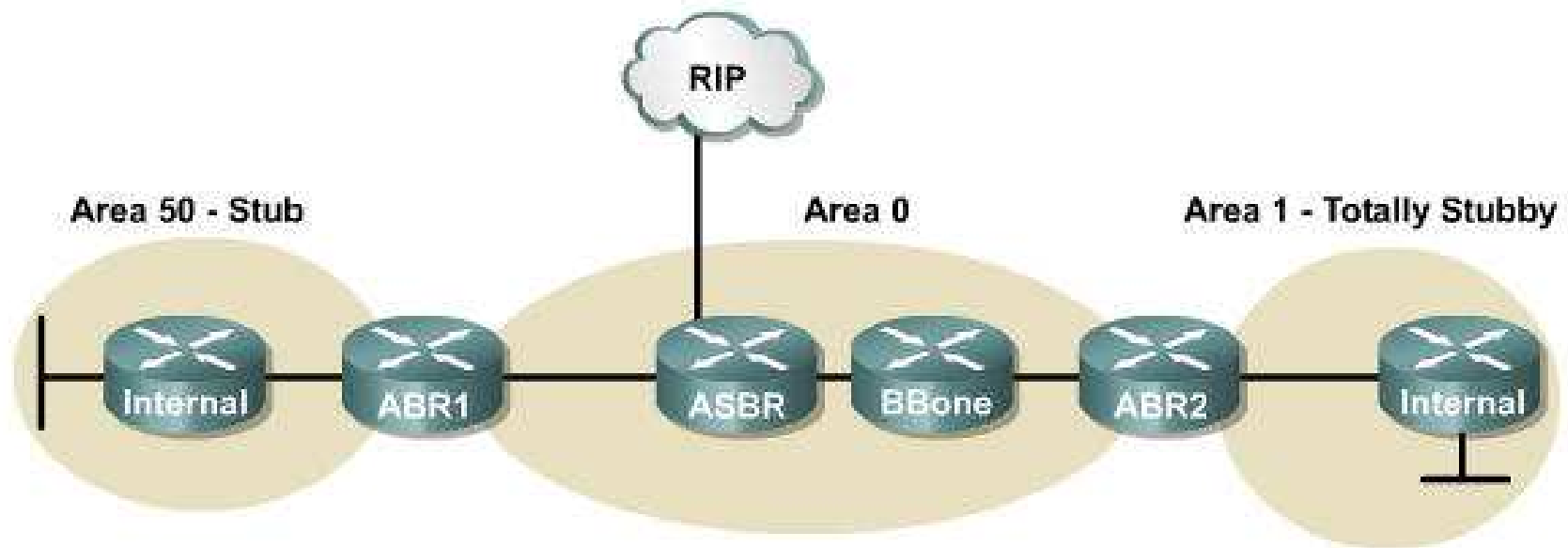


Only ASBRs, such as RTA, can summarize external routes.

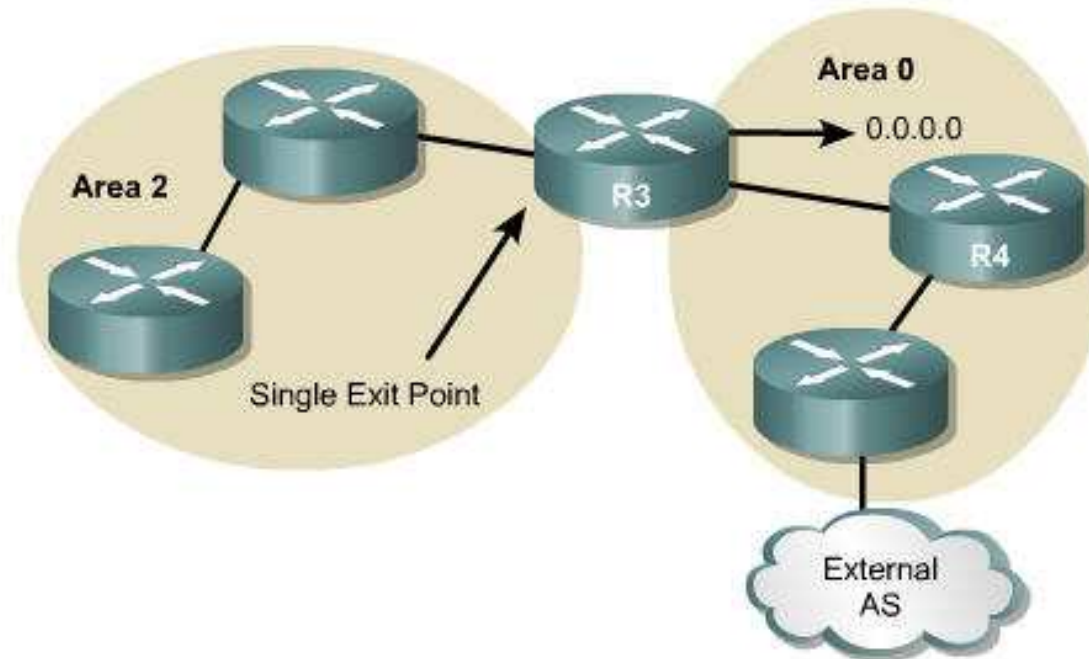
# Verifying Multiarea OSPF Operation

Command	Description
<code>show ip ospf border-routers</code>	Displays the internal OSPF routing table entries to an ABR.
<code>show ip ospf virtual-links</code>	Displays parameters about the current state of OSPF virtual links.
<code>show ip ospf process-id</code>	Displays information about each area to which the router is connected, and indicates whether the router is an ABR, an ASBR, or both. The process ID is a user-defined identification parameter. It is locally assigned and can be any positive integer number. The number used here is the number assigned administratively when enabling the OSPF routing process.
<code>show ip ospf database</code>	Displays the link-state database. This command can include 12 different optional keywords. For a complete description of these keywords, see <a href="http://www.cisco.com/univercd">www.cisco.com/univercd</a>

# Using Stub and Totally Stubby Areas



# Stub and Totally Stubby Area Criteria

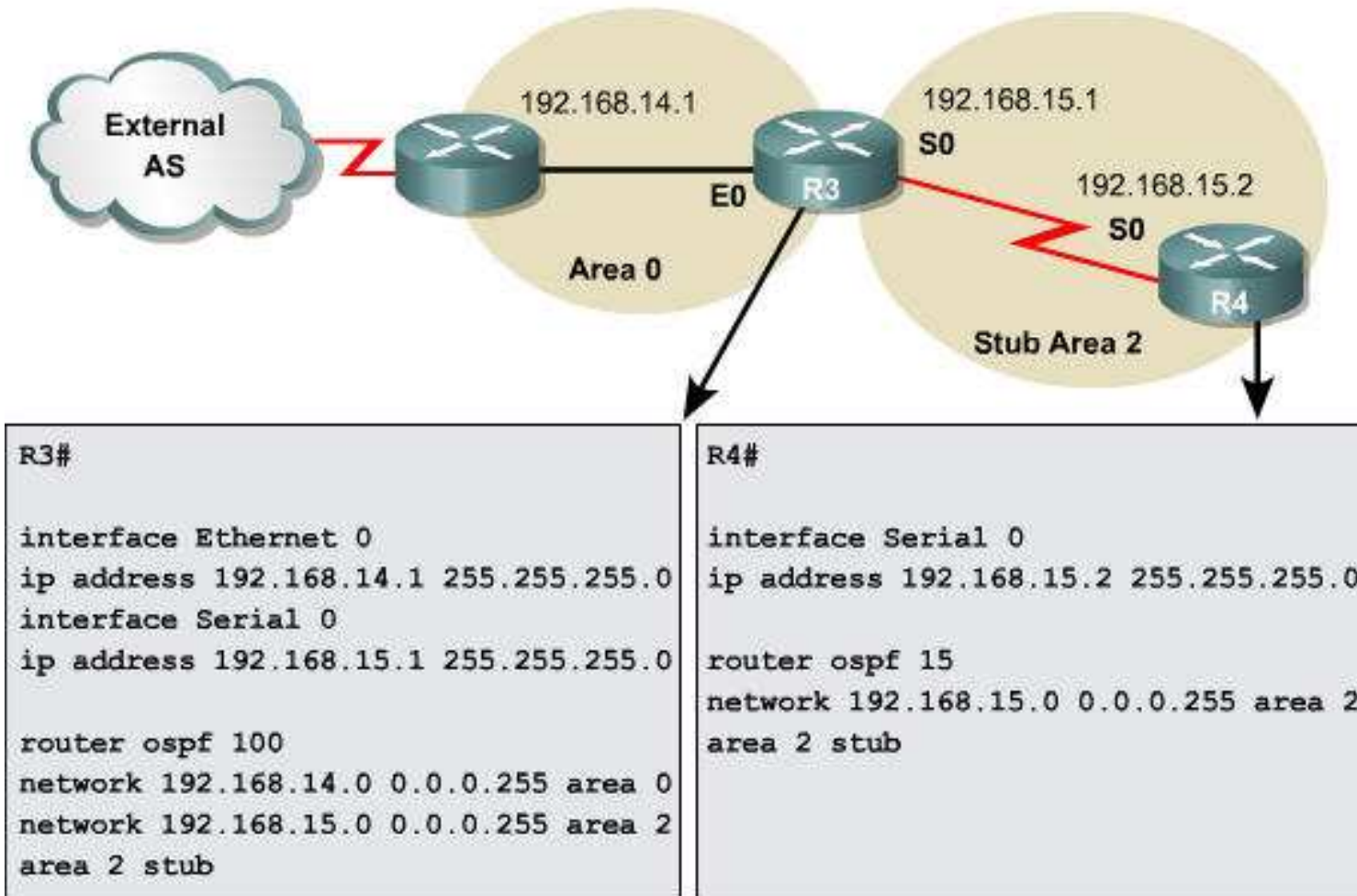


A stub or totally stubby area typically has a single exit point out of the area.

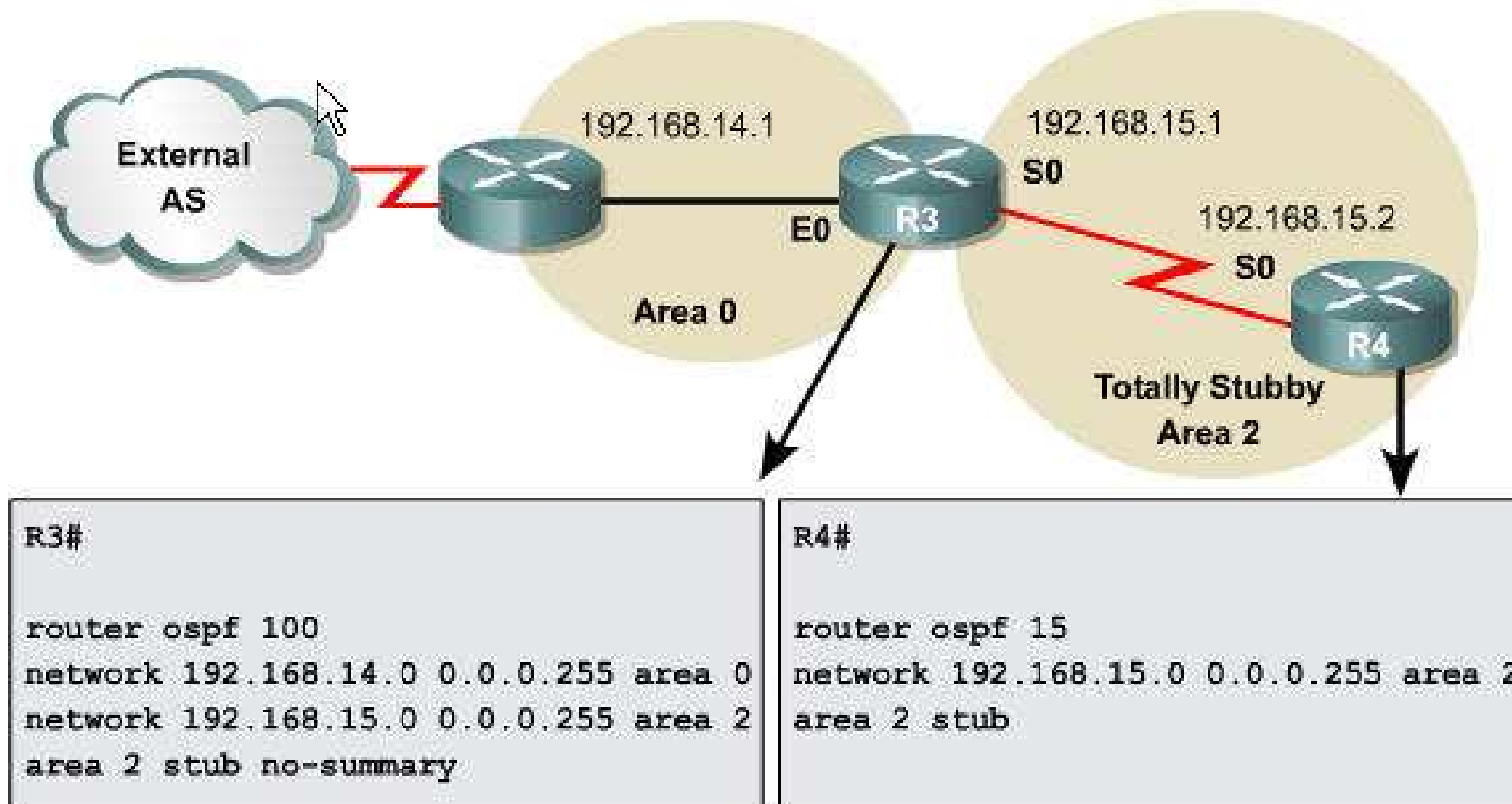
An ASBR cannot be internal to a stub area

Area is not the backbone Area 0.

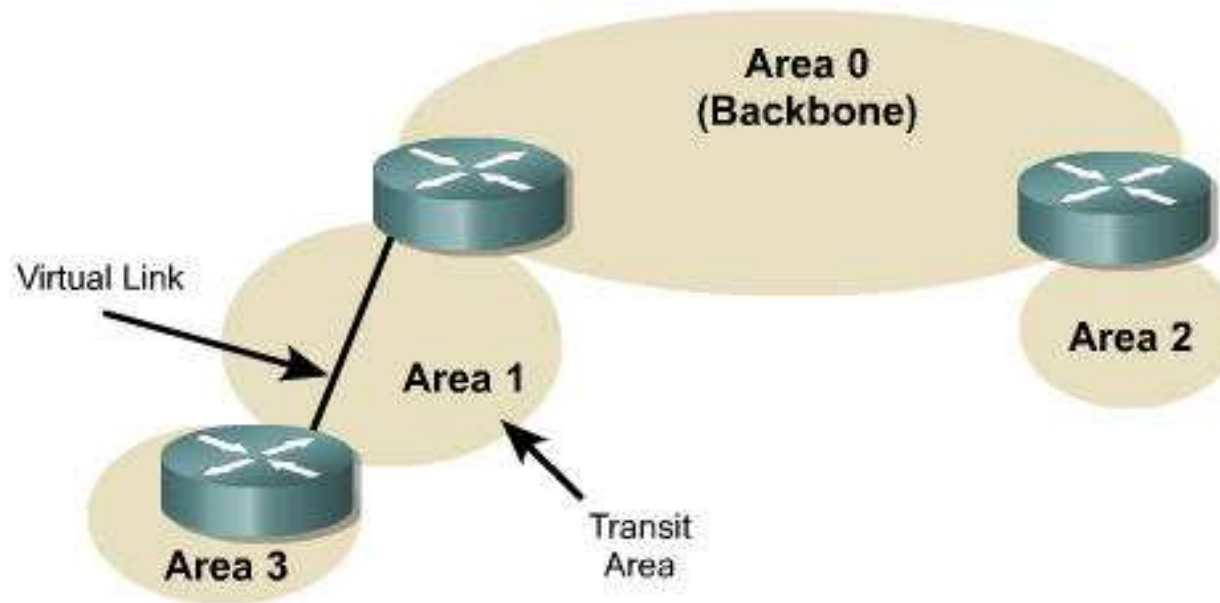
# OSPF Stub Area Configuration Example



# OSPF Totally Stubby Area Configuration Example



# Meeting the Backbone Area Requirements



- The backbone is the center of communication.
- Virtual links provide a path to the backbone area.
- Avoid configuring virtual links if possible.



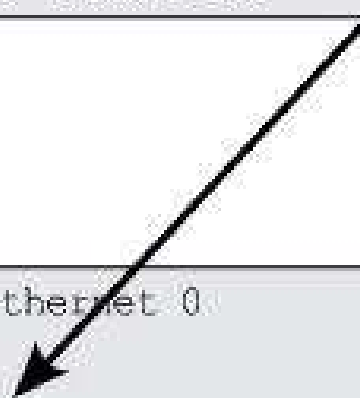
# Configuring Virtual Links

```
Router(config-router)#
```

```
area area-id virtual-link router-id
```

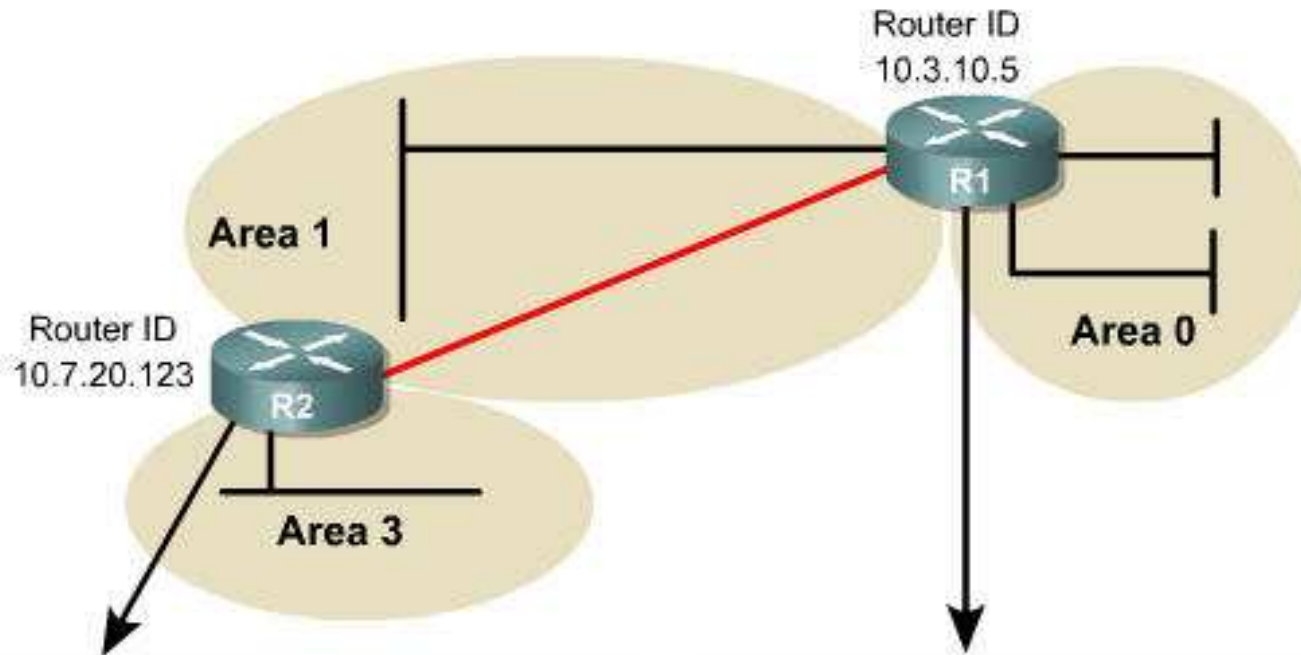
- **Creates a virtual link**

```
remoterouter#show ip ospf interface ethernet 0  
Ethernet0 is up, line protocol is up  
Internet Address 10.64.0.2/24, Area 0  
Process ID 1, Router ID 10.64.1.2, Network Type BROADCAST, Cost:10  
Transmit Delay is 1 sec, State DR, Priority 1  
Designated Router (ID) 10.64.0.2, Interface address 10.64.0.2  
Backup Designated router (ID) 10.64.0.1, Interface address 10.64.0.1
```





# OSPF Virtual Link Configuration Example



```
R2:  
router ospf 63  
network 10.3.0.0 0.0.0.255 area 1  
network 10.7.0.0 0.0.0.255 area 3  
area 1 virtual-link 10.3.10.5
```

```
R1:  
router ospf 100  
network 10.2.0.0 0.0.0.255 area 0  
network 10.3.0.0 0.0.0.255 area 1  
area 1 virtual-link 10.7.20.123
```