Chapter 2.3: Routing

1. Exploring the Functions of Routing
2. Enabling Static Routing
3. ICMP and Traceroute
4. RIP
5. OSPF
6. EIGRP
7. IPv6 Routing

Exploring the Functions of Routing

Routers

Cisco 2800 Series Router

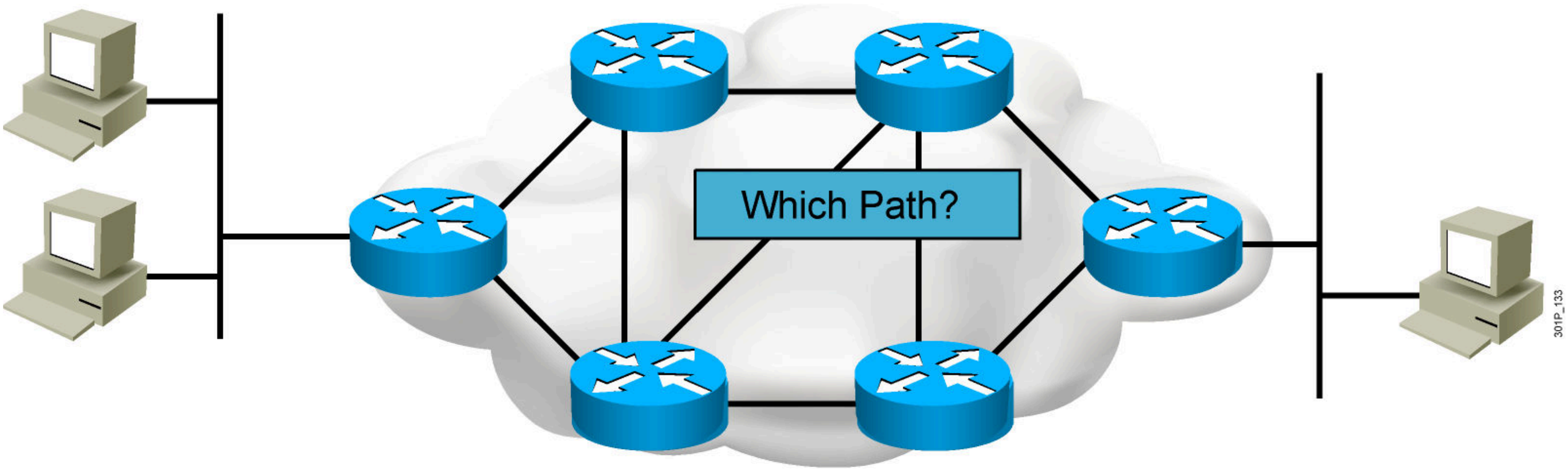
- Routers have the following components:
  - CPU
  - Motherboard
  - RAM
  - ROM
- Routers have network adapters to which IP addresses are assigned.
- Routers may have the following two kinds of ports:
  - Console: For the attachment of a terminal used for management
  - Network: Different LAN or WAN media ports
- Routers forward packets based upon a routing table.

Router Functions

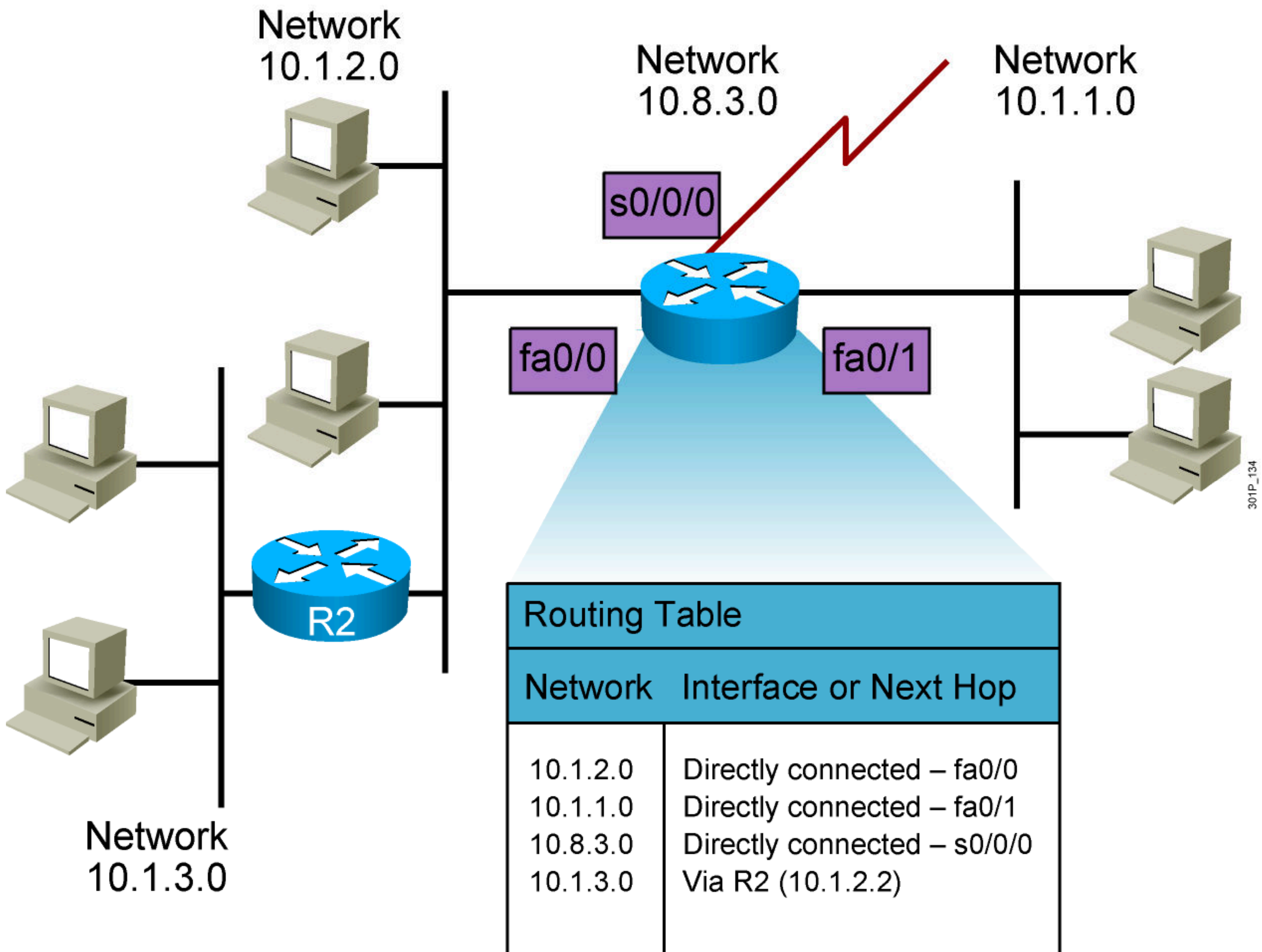
```
RouterX# show ip route
    D 192.168.1.0/24 [90/25789217] via 10.1.1.1
1   R 192.168.2.0/24 [120/4] via 10.1.1.2          2
    O 192.168.3.0/24 [110/229840] via 10.1.1.3
```

1. Lets other routers know about changes
2. Determines where to forward packets

Path Determination



Routing Tables



Routing Table

Network	Interface or Next Hop
10.1.2.0	Directly connected – fa0/0
10.1.1.0	Directly connected – fa0/1
10.8.3.0	Directly connected – s0/0/0
10.1.3.0	Via R2 (10.1.2.2)

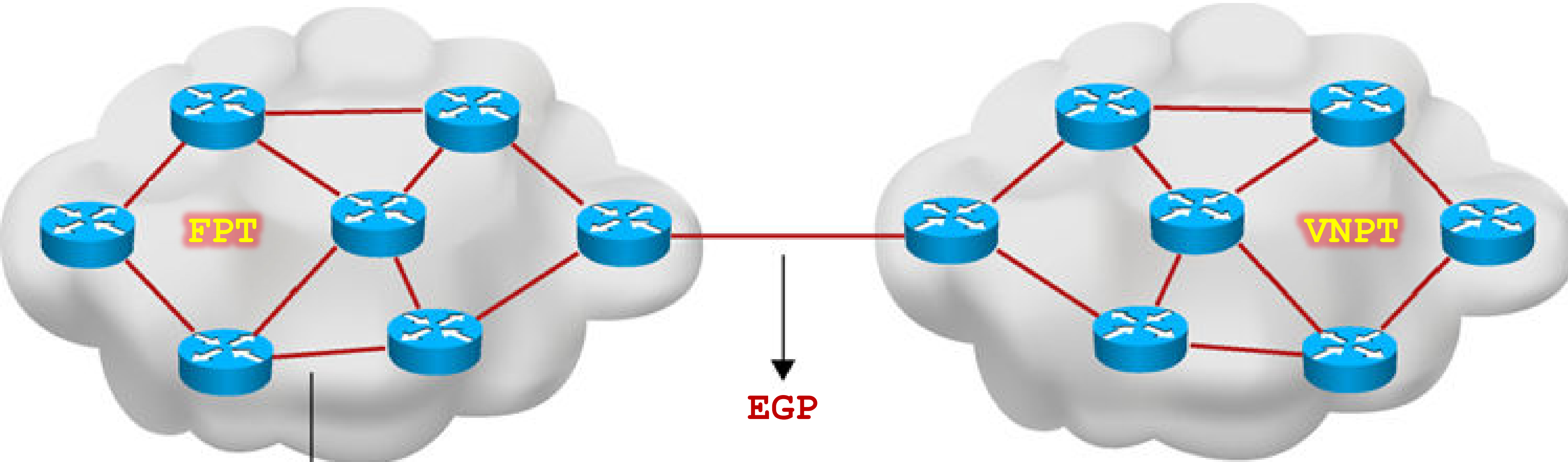
Routing Table Entries

- **Directly connected: Router attaches to this network**
- **Static routing: Entered manually by a system administrator**
- **Dynamic routing: Learned by exchange of routing information**
- **Default route: Statically or dynamically learned; used when no explicit route to network is known**

IGP vs EGP

Autonomous System 10 AS 10

Autonomous System 20 AS 20



IGP

Exterior Gateway Routing Protocols

BGP

Interior Gateway Routing Protocols

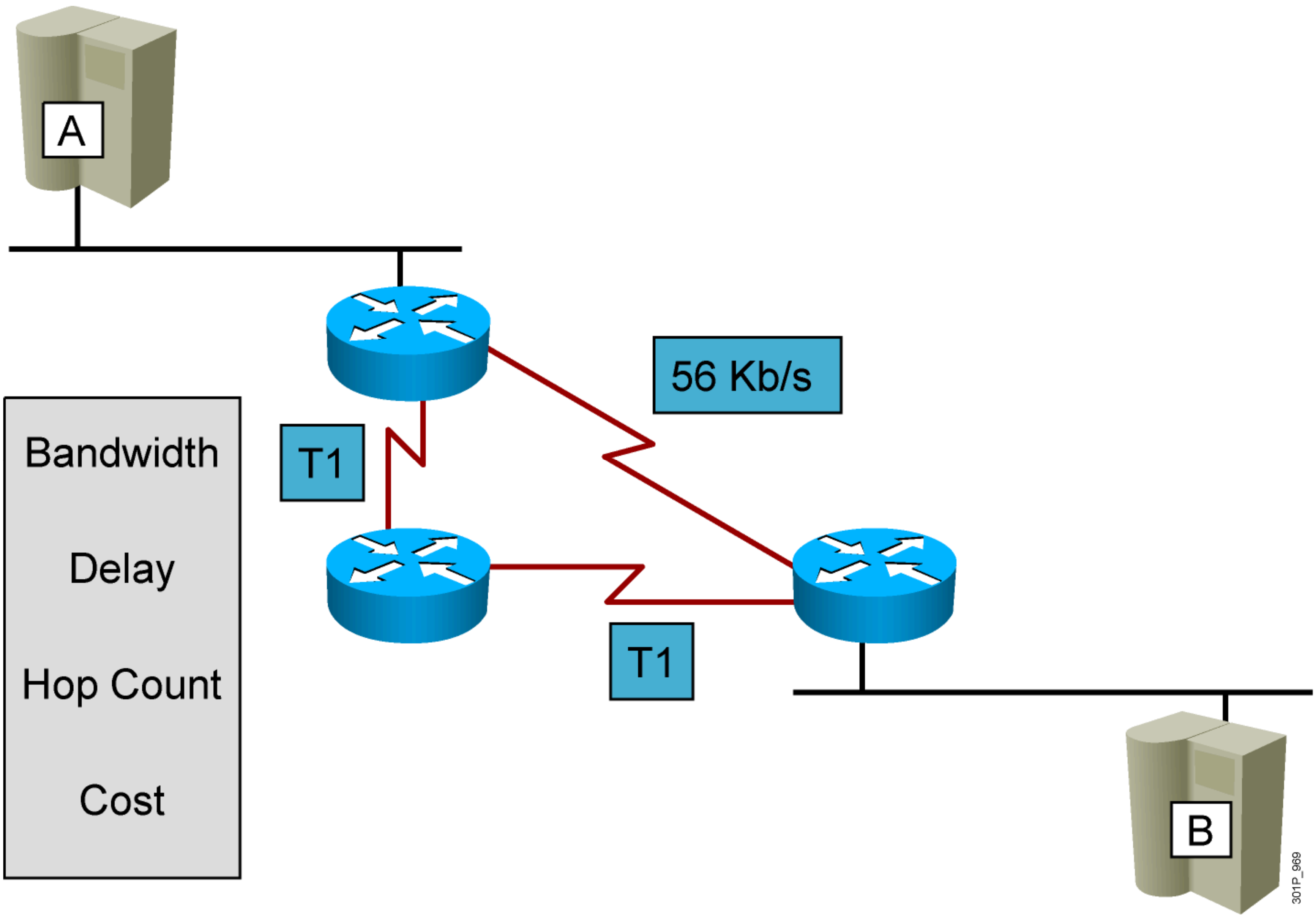
RIP, EIGRP, OSPF

Distance Vector

Hybrid

Link-state

Routing Metrics



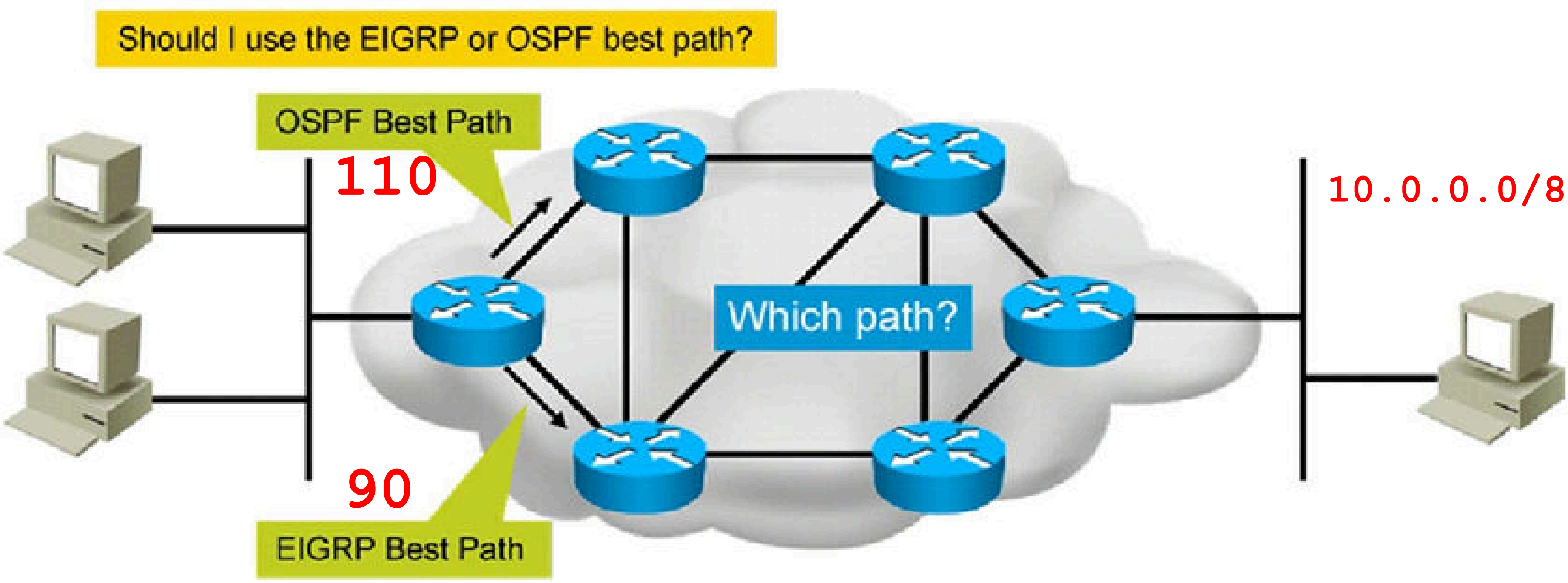
Bandwidth

Delay

Hop Count

Cost

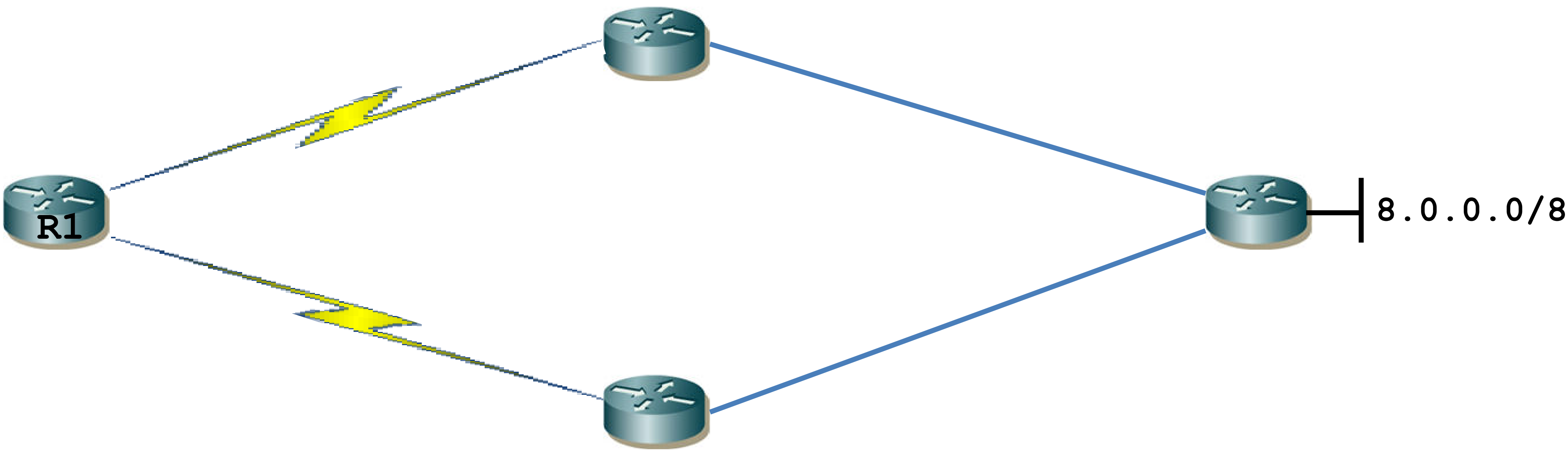
AD


Should I use the EIGRP or OSPF best path?
OSPF Best Path
110
Which path?
10.0.0.0/8
90
EIGRP Best Path

Administrative Distance

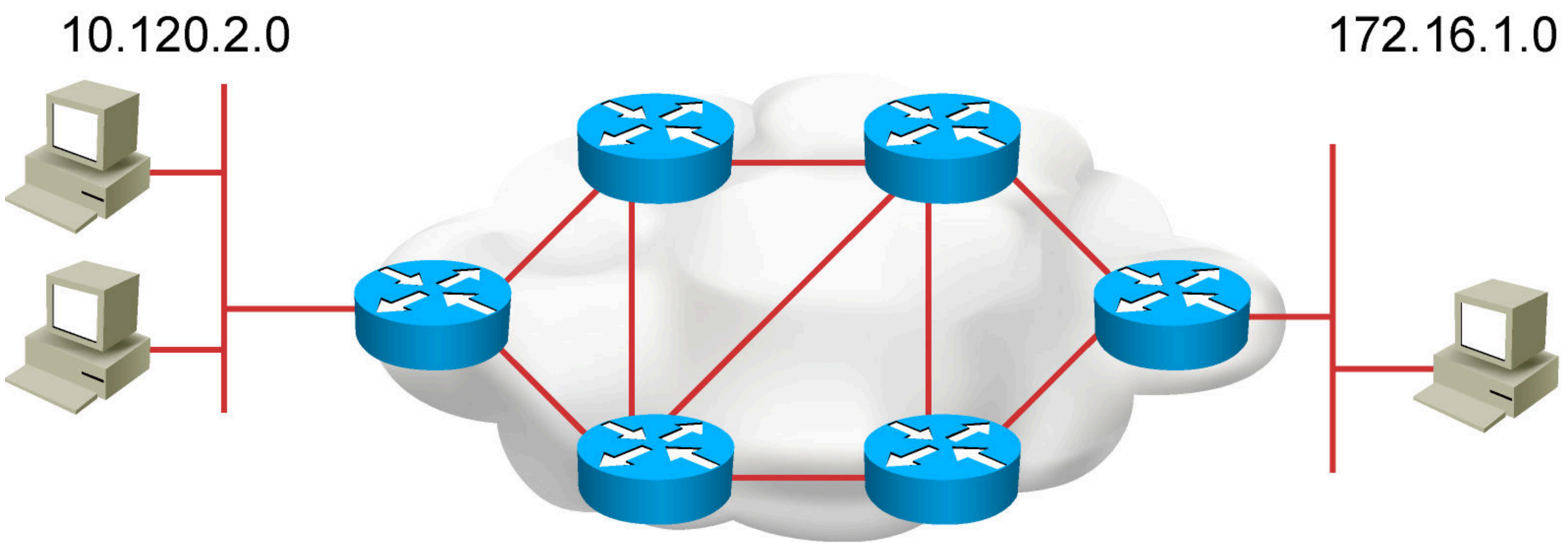
Protocol	AD Value (0-255)
Connected	0
Static	1
EIGRP	90
OSPF	110
RIP	120

Load Balancing



Enabling Static Routing

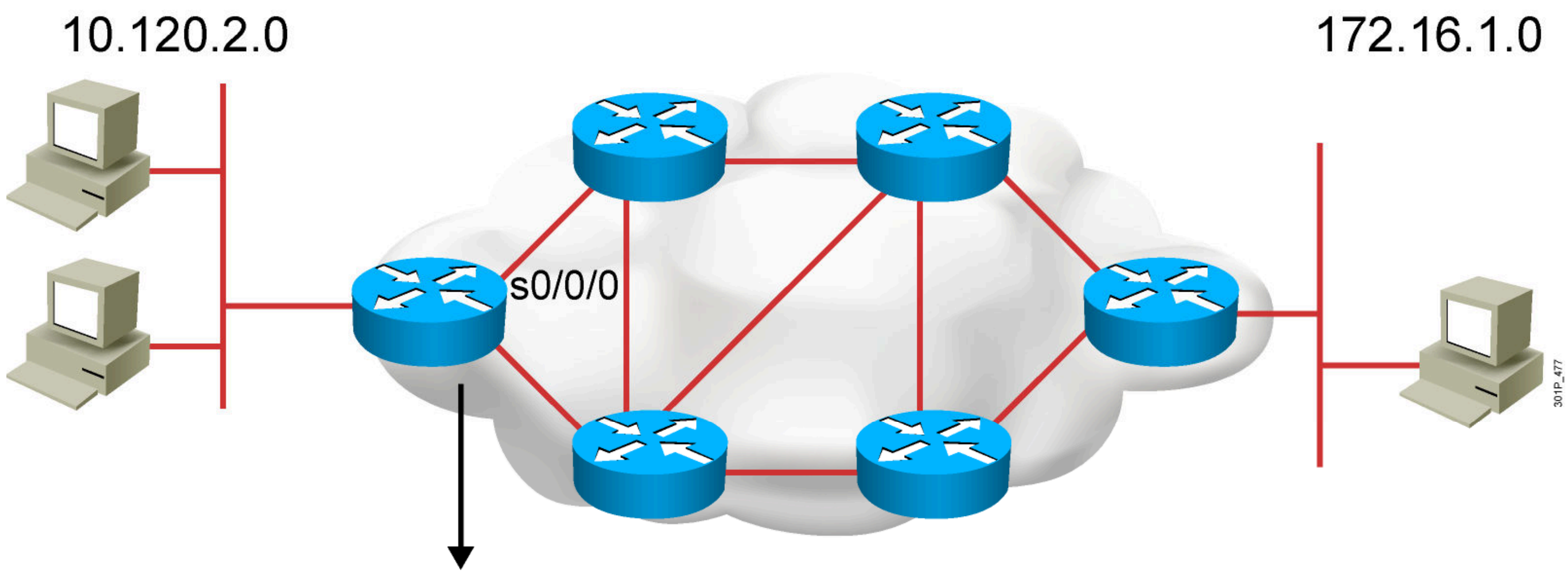
Router Operations



A router needs to do the following:

- Know the destination address.
- Identify the sources from which the router can learn.
- Discover possible routes to the intended destination.
- Select the best route.
- Maintain and verify routing information.

Router Operations (Cont.)



Network Protocol	Destination Network	Exit Interface
Connected	10.120.2.0	fa0/0
Learned	172.16.1.0	s0/0/0

Routed Protocol: IP?

- Routers must learn destinations that are not directly connected.

Identifying Static and Dynamic Routes

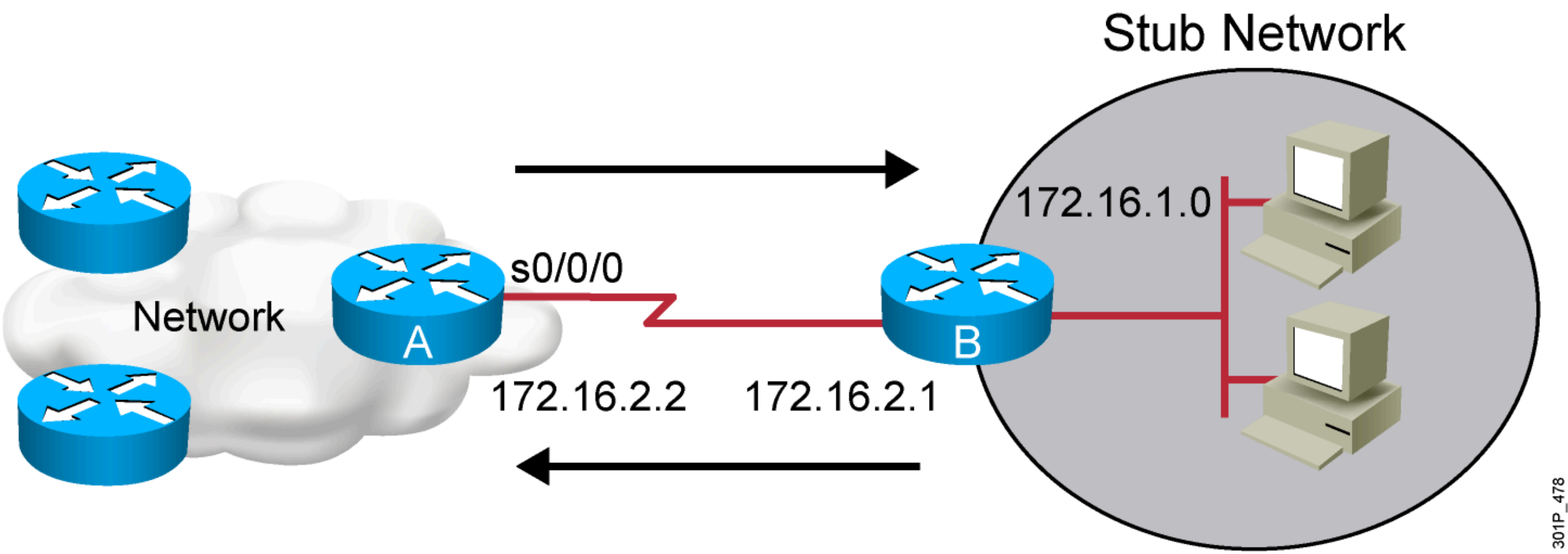
Static route

- Uses a route that a network administrator enters into the router manually

Dynamic route

- Uses a route that a network routing protocol adjusts automatically for topology or traffic changes

Static Routes



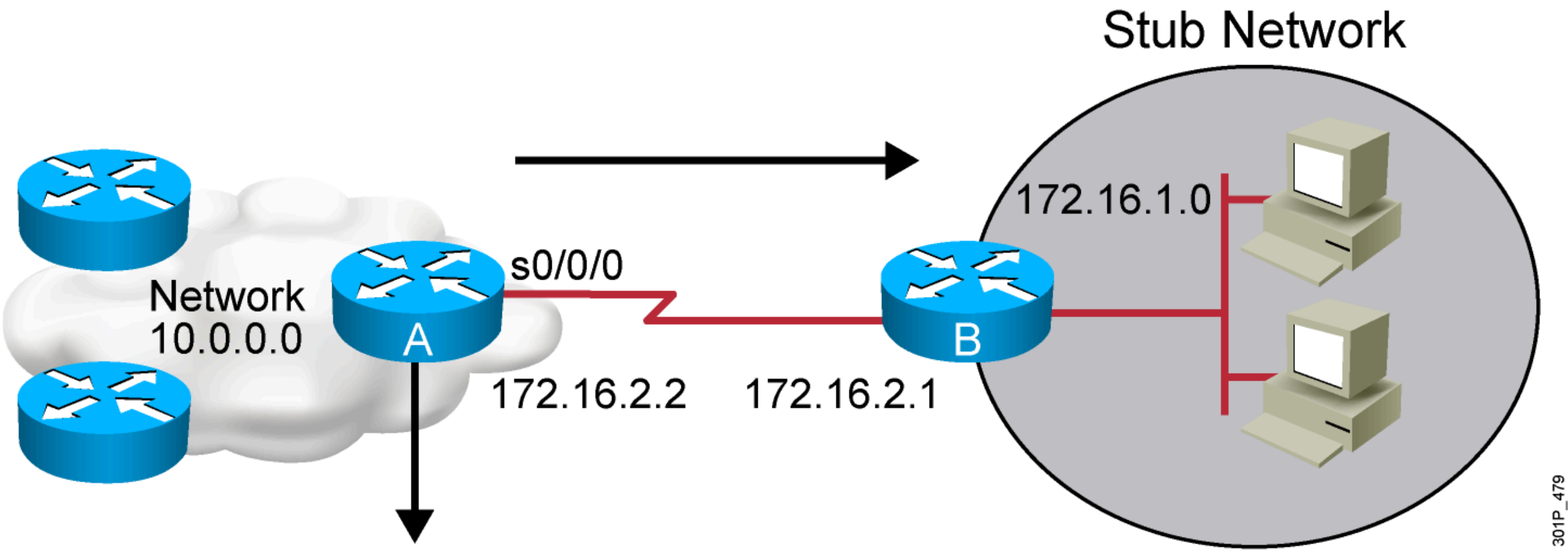
Configure unidirectional static routes to and from a stub network to allow communications to occur.

Static Route Configuration

```
RouterX(config)# ip route network  [mask]
{address | interface}[distance] [permanent]
```

- **Defines a path to an IP destination network or subnet or host**
- **Address = IP address of the next hop router**
- **Interface = outbound interface of the local router**

Static Route Example




```
RouterX(config)# ip route 172.16.1.0 255.255.255.0 172.16.2.1
```

or

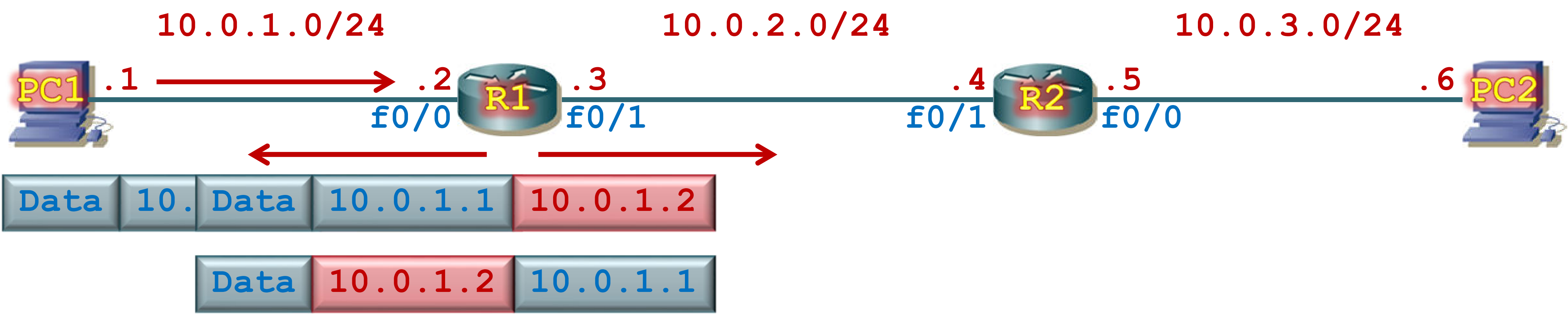
```
Router(config)#ip route 172.16.1.0 255.255.255.0 s0/0/0
```

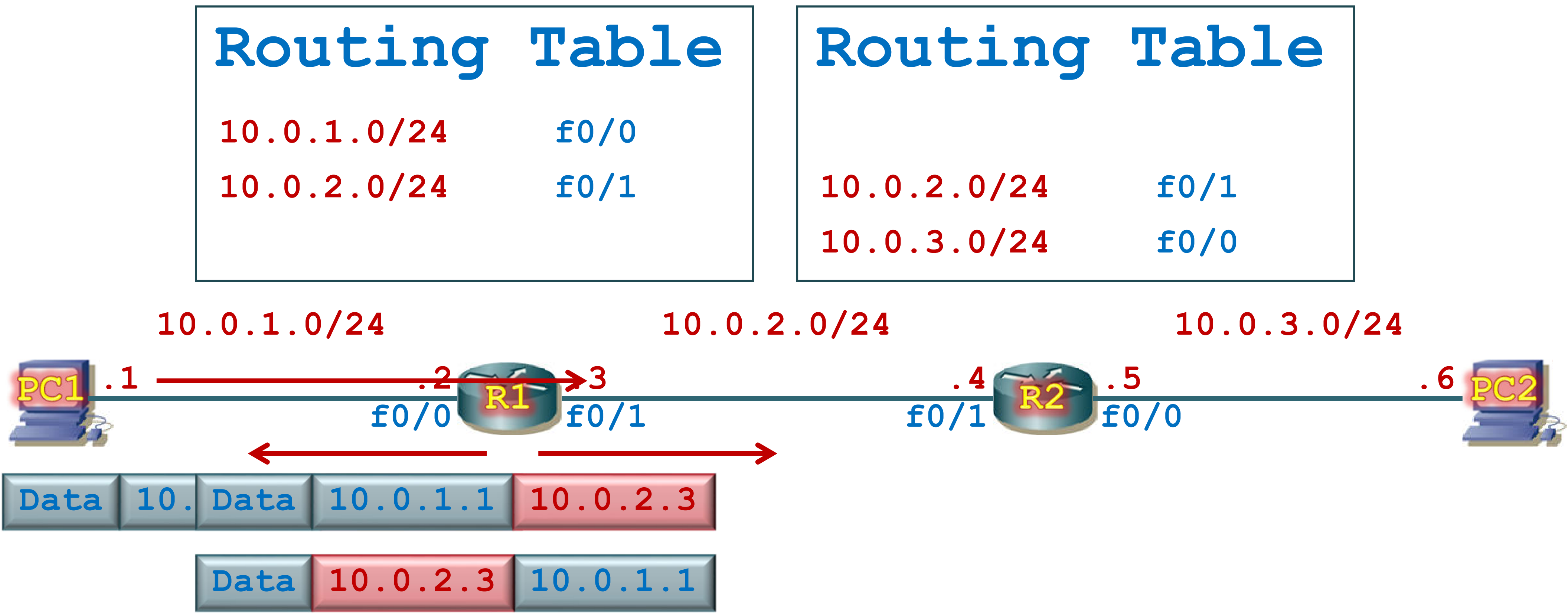
- This is a unidirectional route. You must have a route configured in the opposite direction.

Static Route

Routing Table	
10.0.1.0/24	f0/0
10.0.2.0/24	f0/1

Routing Table	
10.0.2.0/24	f0/1
10.0.3.0/24	f0/0



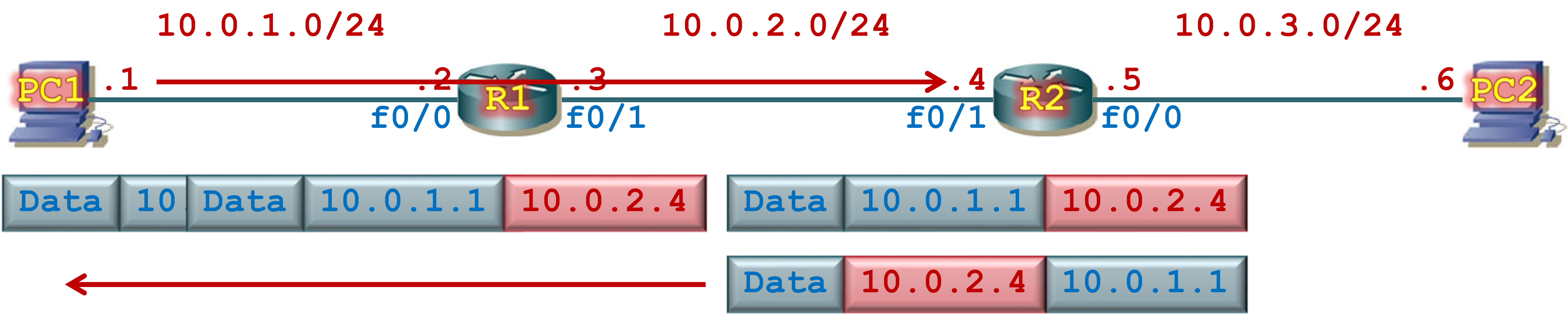

Routing Table
10.0.1.0/24 f0/0
10.0.2.0/24 f0/1
Routing Table
10.0.2.0/24 f0/1
10.0.3.0/24 f0/0
10.0.1.0/24
10.0.2.0/24
10.0.3.0/24
PC1
.1
.2
R1
.3
f0/0
f0/1
.4
R2
.5
f0/1
f0/0
.6
PC2
Data
10.
Data
10.0.1.1
10.0.2.3
Data
10.0.2.3
10.0.1.1

Routing Table

10.0.1.0/24	f0/0
10.0.2.0/24	f0/1

Routing Table

10.0.1.0/24 via	10.0.2.3
10.0.2.0/24	f0/1
10.0.3.0/24	f0/0

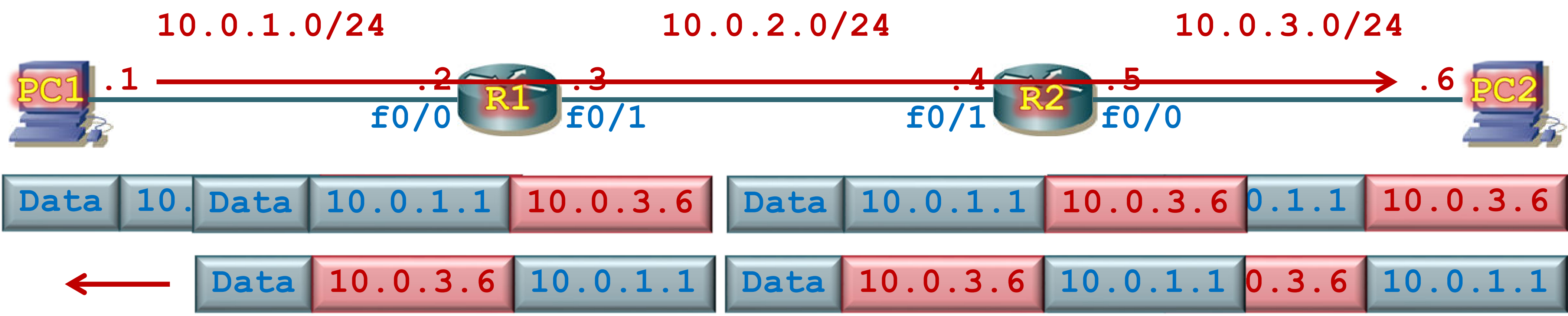


Routing Table (R1)

10.0.1.0/24		f0/0
10.0.2.0/24		f0/1
10.0.3.0/24	via	10.0.2.4

Routing Table (R2)

10.0.1.0/24	via	10.0.2.3
10.0.2.0/24		f0/1
10.0.3.0/24		f0/0

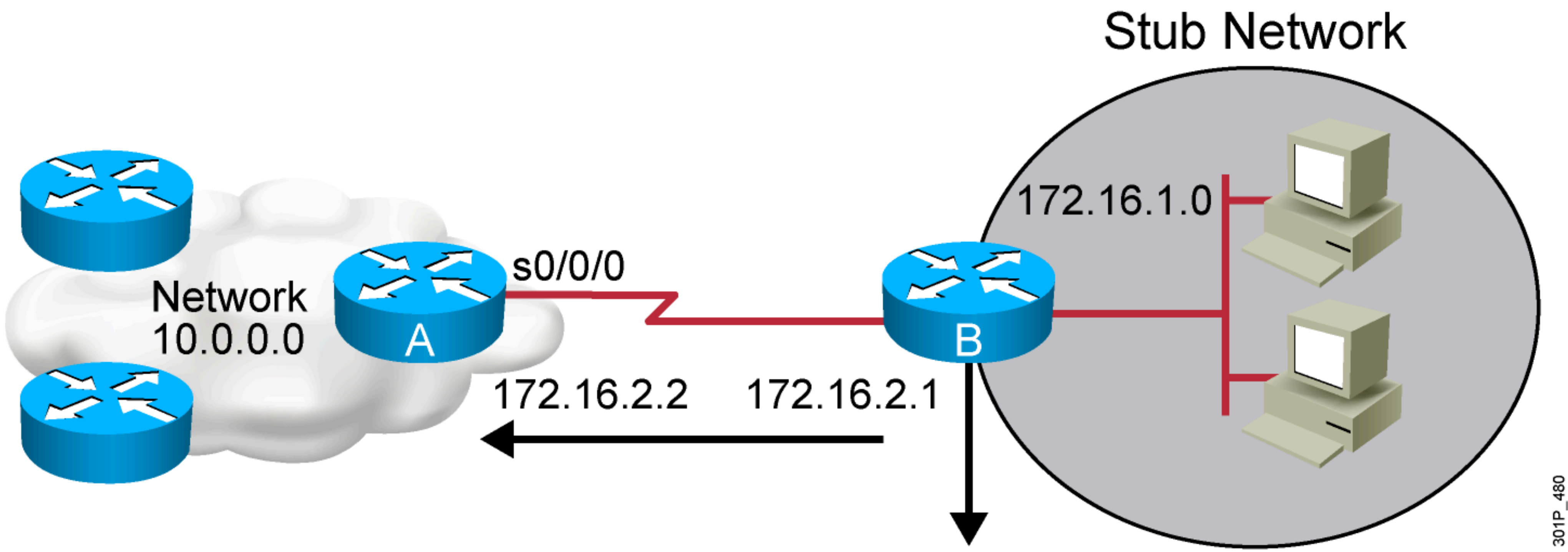


Routing Table

10.0.1.0/24		f0/0
10.0.2.0/24		f0/1
10.0.3.0/24	via	10.0.2.4


```
R1# show ip route
Codes: C - connected, S - static

     10.0.0.0/24 is subnetted, 3 subnets
C       10.0.1.0 is directly connected, F0/0
C       10.0.2.0 is directly connected, F0/1
S       10.0.3.0 [1/0] via 10.0.2.4
R1#
```

Default Routes




```
RouterX(config)# ip route 0.0.0.0 0.0.0.0 172.16.2.2
```

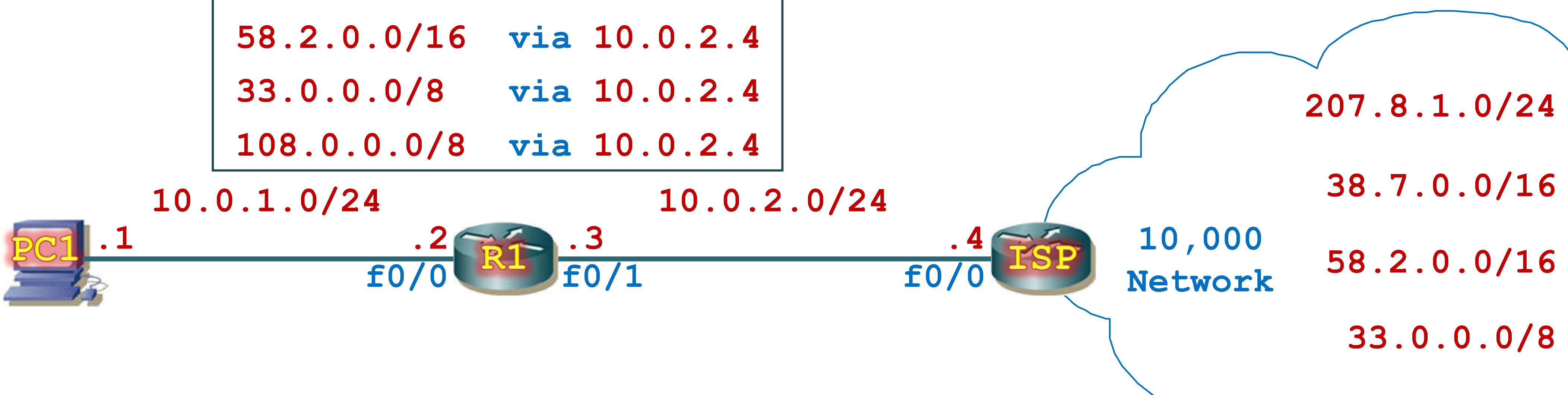
- This route allows the stub network to reach all known networks beyond Router A.

Verifying the Static Route Configuration

```
RouterX# show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, * - candidate default
       U - per-user static route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     10.0.0.0/8 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Serial0/0/0
S*   0.0.0.0/0 is directly connected, Serial0
```

Routing Table

10.0.1.0/24		f0/0
10.0.2.0/24		f0/1
207.8.1.0/24	via	10.0.2.4
0.0.0.0/0	via	f0/1
38.7.0.0/16	via	10.0.2.4
58.2.0.0/16	via	10.0.2.4
33.0.0.0/8	via	10.0.2.4
108.0.0.0/8	via	10.0.2.4



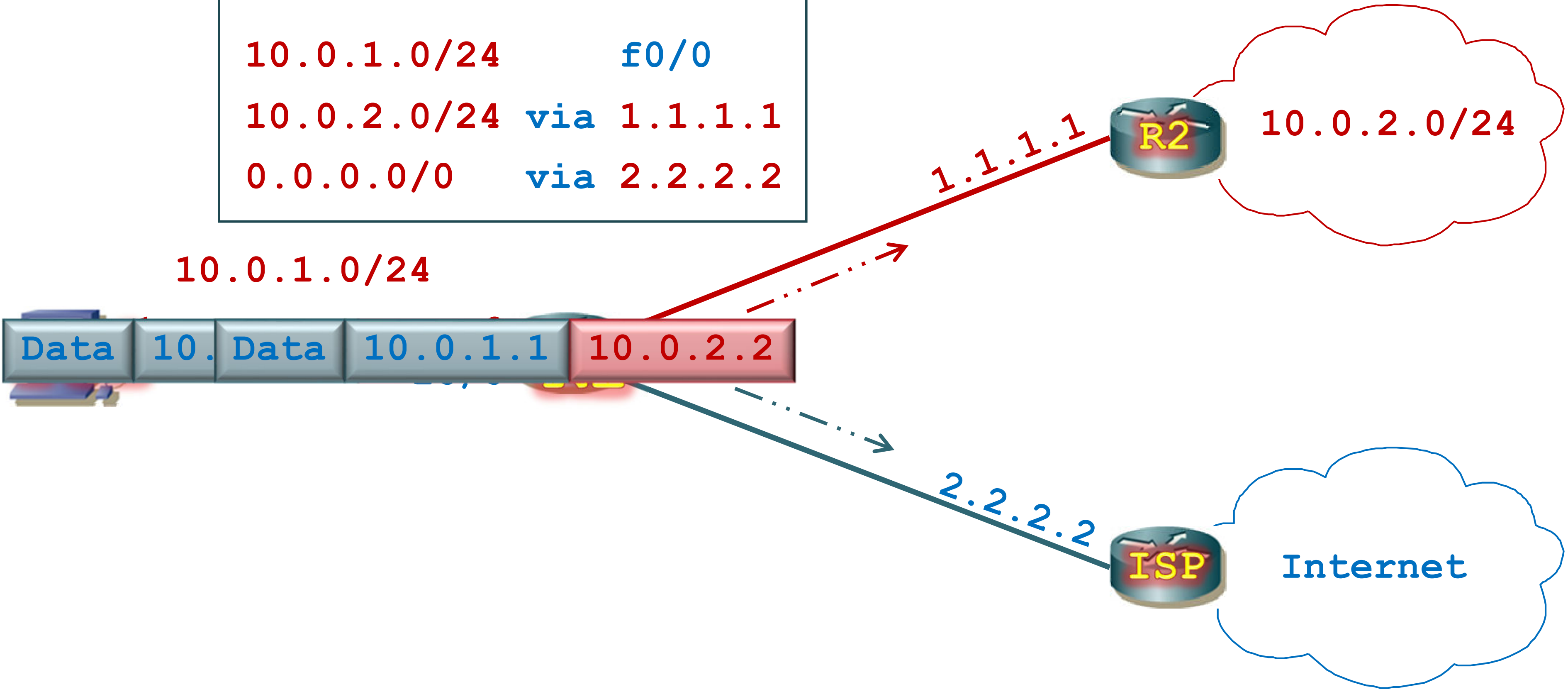

```
R1(config)# ip route 0.0.0.0    0.0.0.0          f0/1
R1(config)# ip route 38.7.0.0   255.255.0.0      10.0.2.4
R1(config)# ip route 58.2.0.0   255.255.0.0      10.0.2.4
R1(config)# ip route 33.0.0.0   255.0.0.0        10.0.2.4
R1(config)# ip route 108.0.0    255.0.0.0        10.0.2.4
```

Outbound interface
default route

Longest-match

Routing Table

10.0.1.0/24		f0/0
10.0.2.0/24	via	1.1.1.1
0.0.0.0/0	via	2.2.2.2



Floating Static Routes

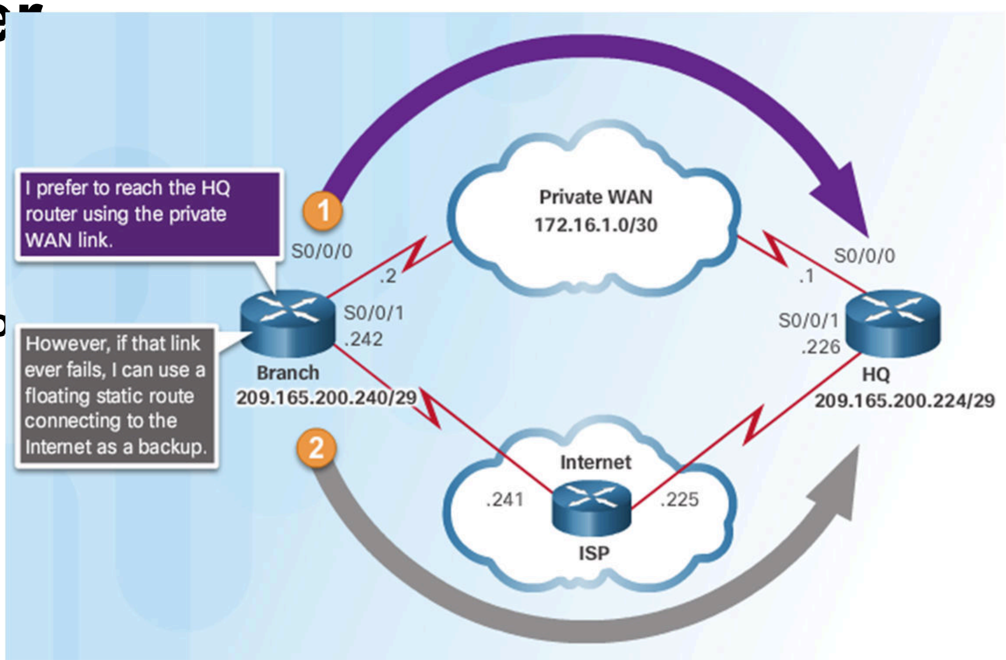
Floating static routes have an administrative distance greater than the dynamic routing protocol or other static route

Used as backup routes

Administrative distance of common routing protocols:

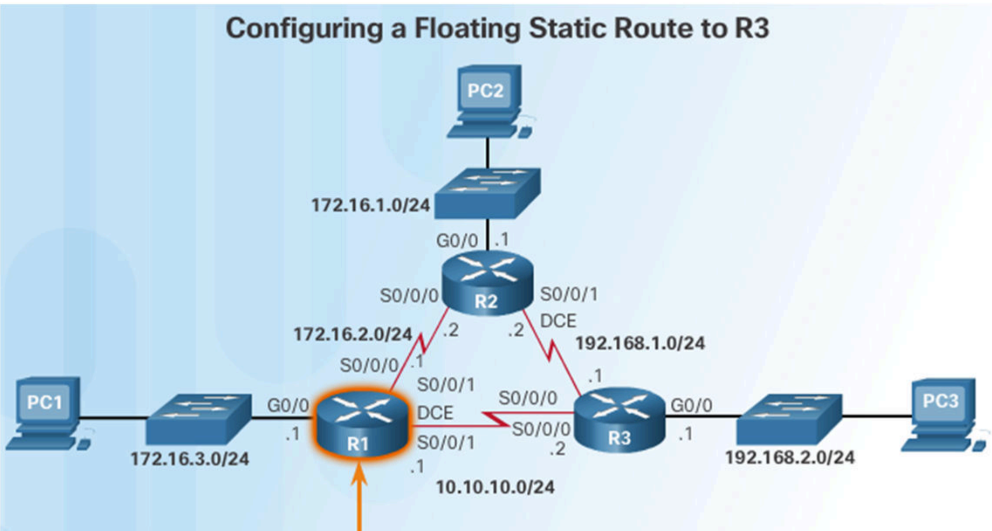
- EIGRP = 90
- IGRP = 100
- OSPF = 110
- IS-IS = 115
- RIP = 120

By default, AD of static route = 1



Static route AD can be increased to make route less desirable until preferred route is lost

Configure a Floating Static Route



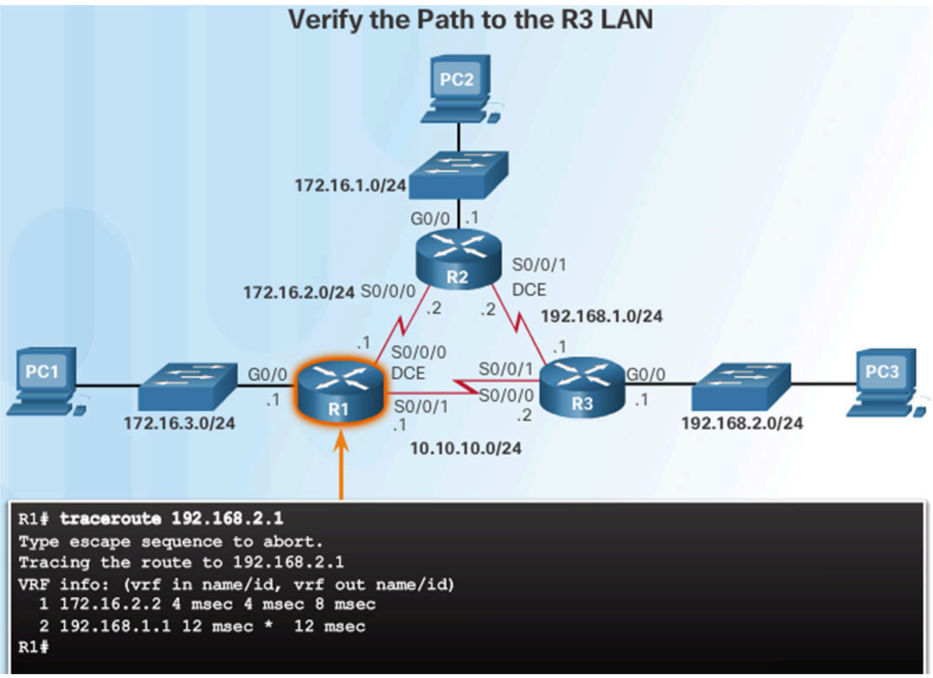

```
R1(config)# ip route 0.0.0.0 0.0.0.0 172.16.2.2
R1(config)# ip route 0.0.0.0 0.0.0.0 10.10.10.2 5
R1(config)#
```

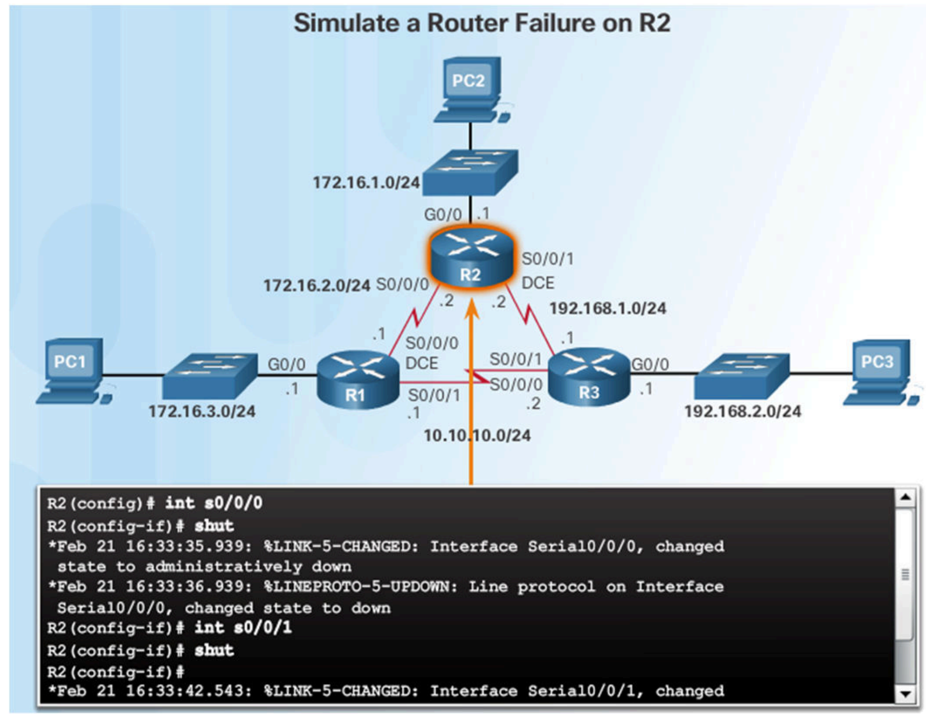
Preferred router from R1 is to R2 (AD = 1)

```
R1# show ip route static | begin Gateway
Gateway of last resort is 0.0.0.0 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 172.16.2.2`
R1#
```

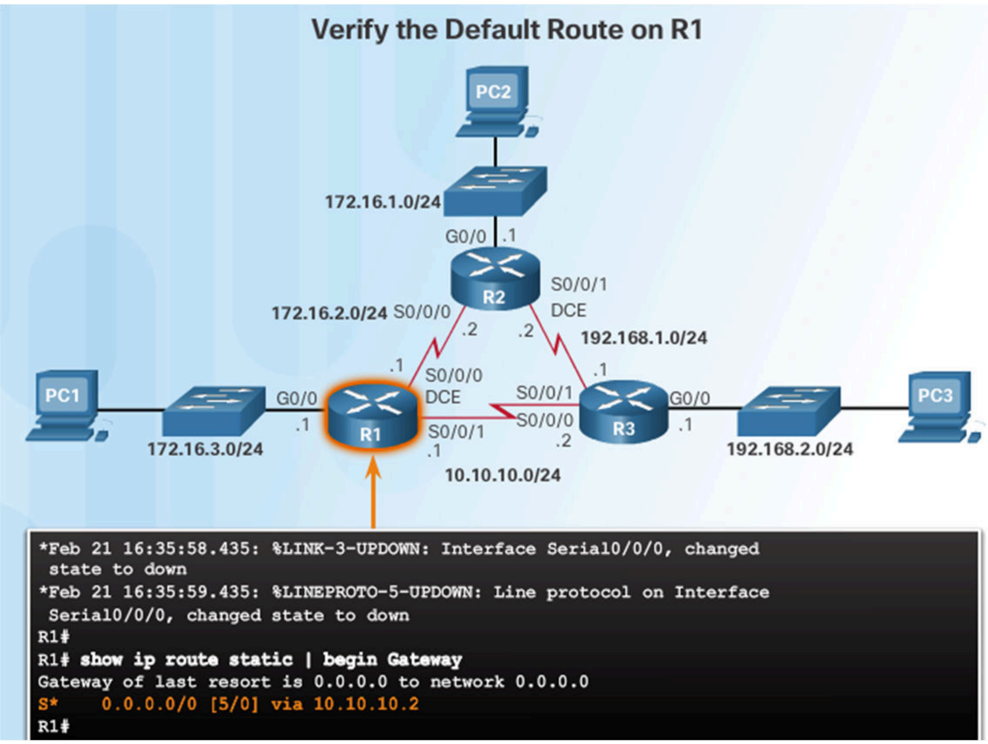
Configure Floating Static Routes

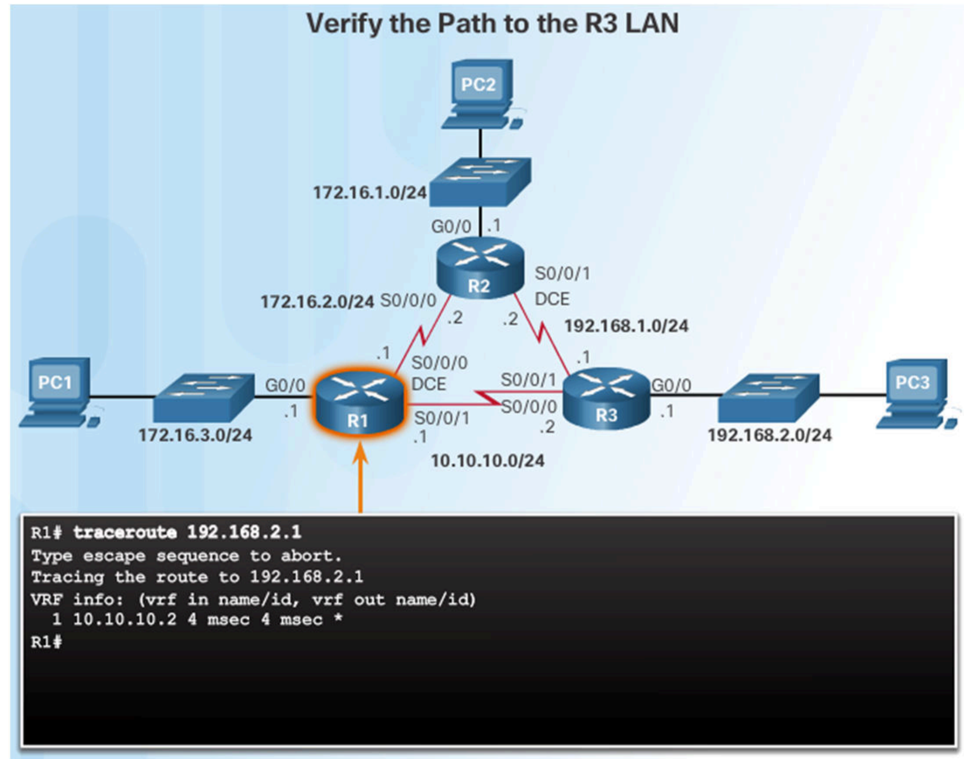
Test the IPv4 Floating Static Route





Test the IPv4 Floating Static Route (Cont.)





ICMP and Traceroute

Host-Based Tools: ping

C:\WINDOWS\system32\cmd.exe

```
C:\ping example.com

Pinging example.com [192.0.34.166] with 32 bytes of data:

Reply from 192.0.34.166: bytes=32 time=19ms TTL=45
Reply from 192.0.34.166: bytes=32 time=18ms TTL=45
Reply from 192.0.34.166: bytes=32 time=19ms TTL=45
Reply from 192.0.34.166: bytes=32 time=17ms TTL=45

Ping statistics for 192.0.34.166:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 17ms, Maximum = 19ms, Average = 18ms

C:\
```

ping

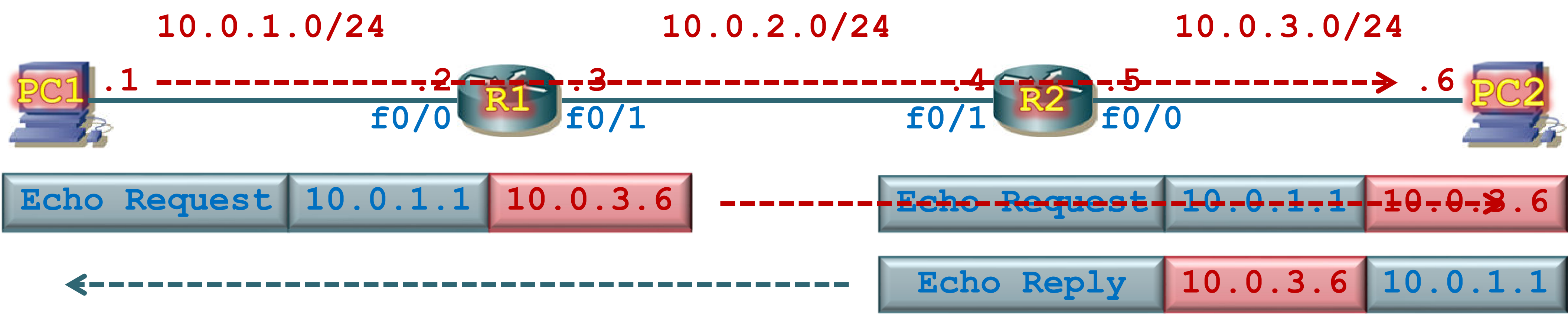
```
Router#
ping [[protocol {host-name | system-address}]
```

- **To diagnose basic network connectivity, use the ping command in user EXEC or privileged EXEC mode.**

ICMP Echo

Routing Table	
10.0.1.0/24	f0/0
10.0.2.0/24	f0/1
10.0.3.0/24 via 10.0.2.4	

Routing Table	
10.0.1.0/24 via 10.0.2.3	
10.0.2.0/24	f0/1
10.0.3.0/24	f0/0




```
C:\PC1> ping 10.0.3.6
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
```

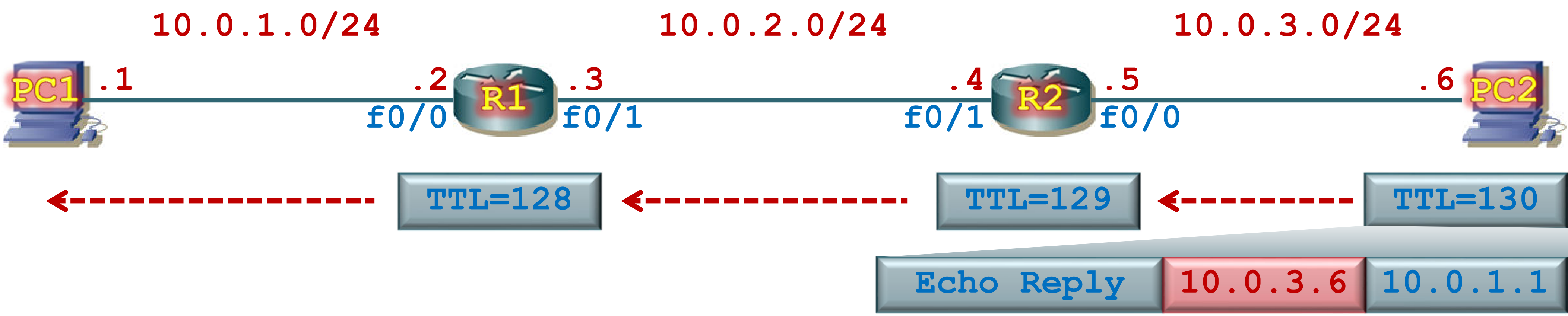
Time To Live

Routing Table (R1)

10.0.1.0/24	f0/0
10.0.2.0/24	f0/1
10.0.3.0/24	via 10.0.2.4

Routing Table (R2)

10.0.1.0/24	via 10.0.2.3
10.0.2.0/24	f0/1
10.0.3.0/24	f0/0




```
C:\PC1> ping 10.0.3.6
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
Reply from 10.0.3.6: bytes=32 time<1ms TTL=128
```

Destination Unreachable

Routing Table (R1)

10.0.1.0/24		f0/0
10.0.2.0/24		f0/1
10.0.3.0/24	via	10.0.2.4

Routing Table (R2)

10.0.1.0/24	via	10.0.2.3
10.0.2.0/24		f0/1
10.0.3.0/24		f0/0

Echo Request	10.0.1.1	10.0.3.6

Destination Unreachable	10.0.2.4	10.0.1.1

```
C:\PC1> ping 10.0.3.6
Reply from 10.0.2.4: Destination host unreachable.
Reply from 10.0.2.4: Destination host unreachable.
Reply from 10.0.2.4: Destination host unreachable.
Reply from 10.0.2.4: Destination host unreachable.
```

```
R# U.U.U.U.U.
```

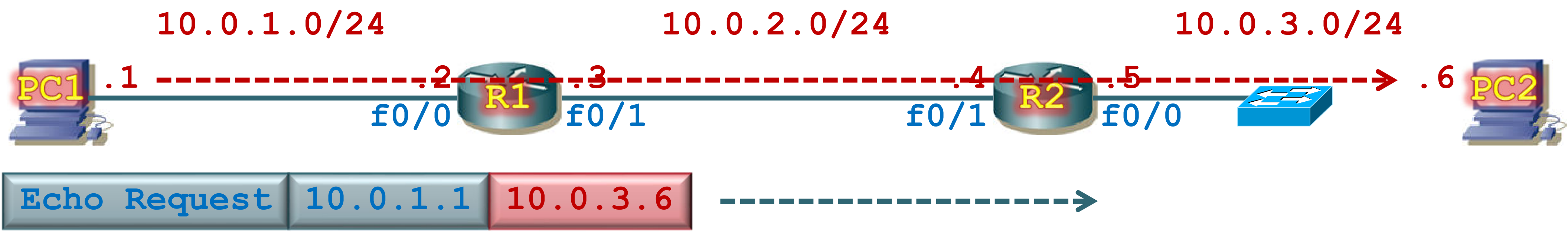
Request Timeout

Routing Table (R1)

10.0.1.0/24	f0/0
10.0.2.0/24	f0/1
10.0.3.0/24	via 10.0.2.4

Routing Table (R2)

10.0.1.0/24	via 10.0.2.3
10.0.2.0/24	f0/1
10.0.3.0/24	f0/0




```
C:\PC1> ping 10.0.3.6
Request timed out.
Request timed out.
Request timed out.
Request timed out.
```

```
R# .....
```

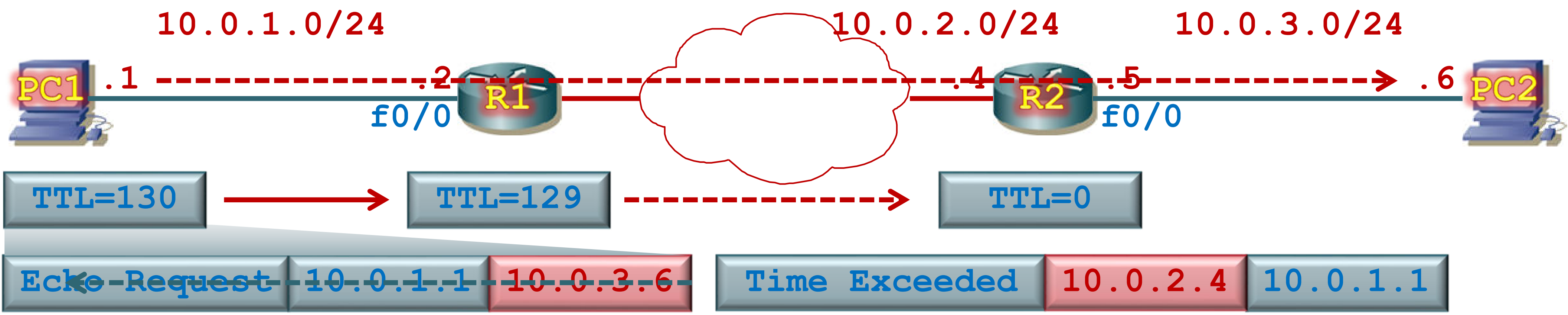
TTL expired in transit

Routing Table

10.0.1.0/24		f0/0
10.0.2.0/24		f0/1
10.0.3.0/24	via	10.0.2.4

Routing Table

10.0.1.0/24	via	10.0.2.3
10.0.2.0/24		f0/1
10.0.3.0/24		f0/0




```
C:\PC1> ping 10.0.3.6
Reply from 10.0.2.4 : TTL expired in transit.
Reply from 10.0.2.4 : TTL expired in transit.
Reply from 10.0.2.4 : TTL expired in transit.
Reply from 10.0.2.4 : TTL expired in transit.
```

R# .....

Host-Based Tools: tracert

C:\WINDOWS\system32\cmd.exe

```
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\pvancil>tracert yahoo.com

Tracing route to yahoo.com [66.94.234.13]
over a maximum of 30 hops:

  1     1 ms     1 ms     1 ms  rtp-pvancil-vpn.cisco.com [10.83.2.161]
  2    67 ms    59 ms    57 ms  rtp5-access-sdg1-t10.cisco.com [10.82.96.2]
  3    58 ms    58 ms    57 ms  rtp5-access-gw1-vlan100.cisco.com [10.83.100.9]

  4    58 ms    58 ms    57 ms  rtp7-bb-gw1-ge5-8.cisco.com [10.81.254.117]
  5    60 ms    59 ms    57 ms  rtp5-rbb-gw1-ge4-2.cisco.com [10.81.254.181]
  6    58 ms    59 ms    60 ms  rtp5-corp-gw1.cisco.com [10.81.254.194]
  7    59 ms    58 ms    58 ms  rtp7-dmzbb-gw1.cisco.com [64.102.241.135]
  8    60 ms    60 ms    58 ms  rtp1-isp-gw1-g1-2.cisco.com [64.102.254.193]
  9    59 ms    58 ms    58 ms  rtp5-isp-ssw1-v110.cisco.com [64.102.254.174]
 10    59 ms    59 ms    58 ms  rtp5-isp-ssw1-v151.cisco.com [64.102.254.249]
 11    60 ms    60 ms    59 ms  rtp1-isp-gw1-v100.cisco.com [64.102.254.165]
 12    64 ms    66 ms    65 ms  sl-gw20-rly-1-0.sprintlink.net [144.232.244.209]

 13    64 ms    66 ms    68 ms  sl-bb20-rly-3-2.sprintlink.net [144.232.14.29]
 14    66 ms    64 ms    65 ms  sl-bb24-rly-9-0.sprintlink.net [144.232.14.122]

 15    66 ms    66 ms    69 ms  sl-st22-ash-5-0.sprintlink.net [144.232.20.155]

 16    67 ms    68 ms    67 ms  te-4-2.car4.Washington1.Level3.net [4.68.111.169
]
 17    67 ms   127 ms    68 ms  ae-2-54.bbr2.Washington1.Level3.net [4.68.121.97
]
 18   136 ms     *      137 ms  as-1-0.bbr2.SanJose1.Level3.net [64.159.0.242]
 19   134 ms   136 ms   133 ms  ae-23-52.car3.SanJose1.Level3.net [4.68.123.45]

 20   142 ms   135 ms   135 ms  4.71.112.14
 21   133 ms   134 ms   134 ms  ge-3-0-0-p271.msr2.scd.yahoo.com [216.115.106.19
1]
 22   135 ms   135 ms   135 ms  ten-2-3-bas1.scd.yahoo.com [66.218.82.221]
 23   136 ms   136 ms   135 ms  w2.rc.vip.scd.yahoo.com [66.94.234.13]

Trace complete.
```

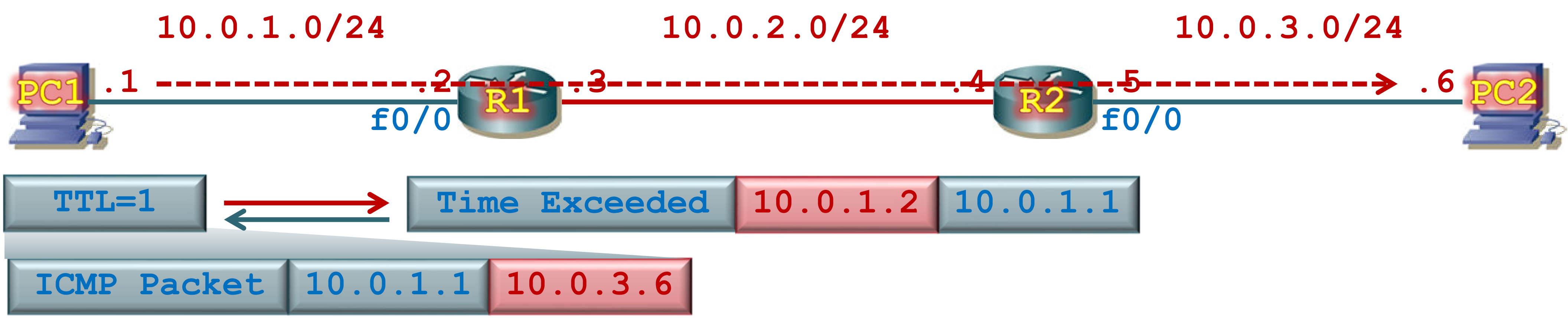
tracert

Routing Table (R1)

10.0.1.0/24	f0/0
10.0.2.0/24	f0/1
10.0.3.0/24 via 10.0.2.4	

Routing Table (R2)

10.0.1.0/24 via 10.0.2.3	
10.0.2.0/24	f0/1
10.0.3.0/24	f0/0




```
C:\PC1> tracert 10.0.3.6
1   35 ms   15 ms   1 ms          10.0.1.2
```

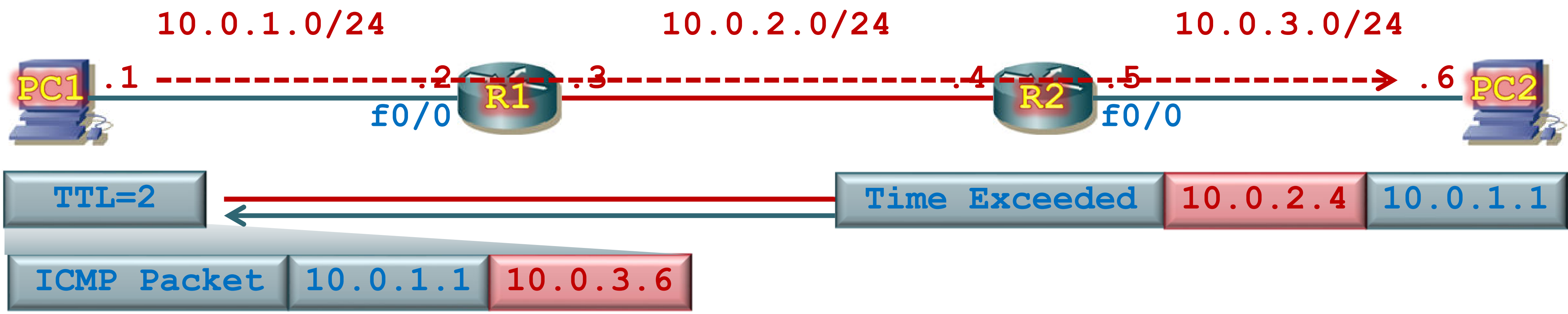
tracert

Routing Table

10.0.1.0/24		f0/0
10.0.2.0/24		f0/1
10.0.3.0/24	via	10.0.2.4

Routing Table

10.0.1.0/24	via	10.0.2.3
10.0.2.0/24		f0/1
10.0.3.0/24		f0/0




```
C:\PC1> tracert 10.0.3.6
1   35 ms   15 ms   1 ms         10.0.1.2
2   60 ms    7 ms   5 ms         10.0.2.4
```

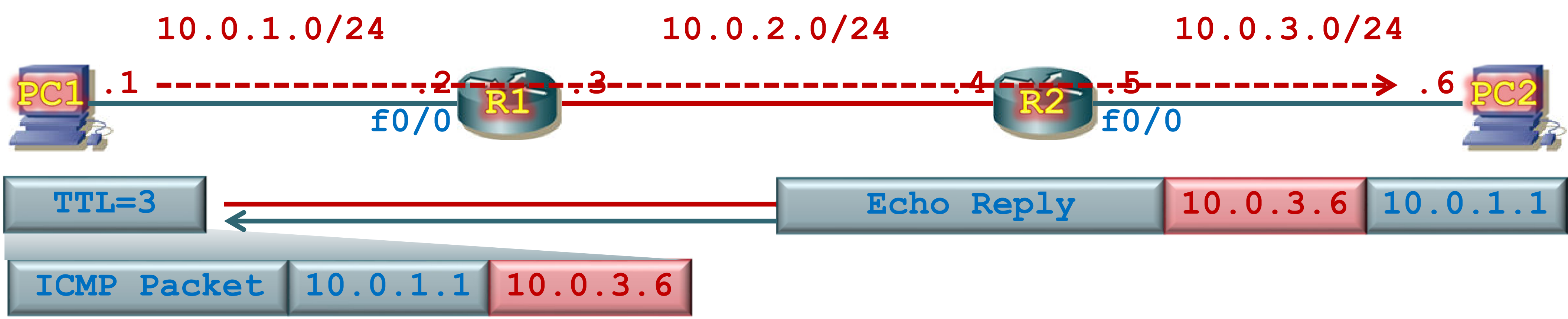
tracert

Routing Table

10.0.1.0/24		f0/0
10.0.2.0/24		f0/1
10.0.3.0/24	via	10.0.2.4

Routing Table

10.0.1.0/24	via	10.0.2.3
10.0.2.0/24		f0/1
10.0.3.0/24		f0/0




```
C:\PC1> tracert 10.0.3.6
1   35 ms   15 ms   1 ms       10.0.1.2
2   60 ms    7 ms   5 ms       10.0.2.4
3   44 ms   23 ms   9 ms       10.0.3.6
Trace complete.
```

R# traceroute

traceroute

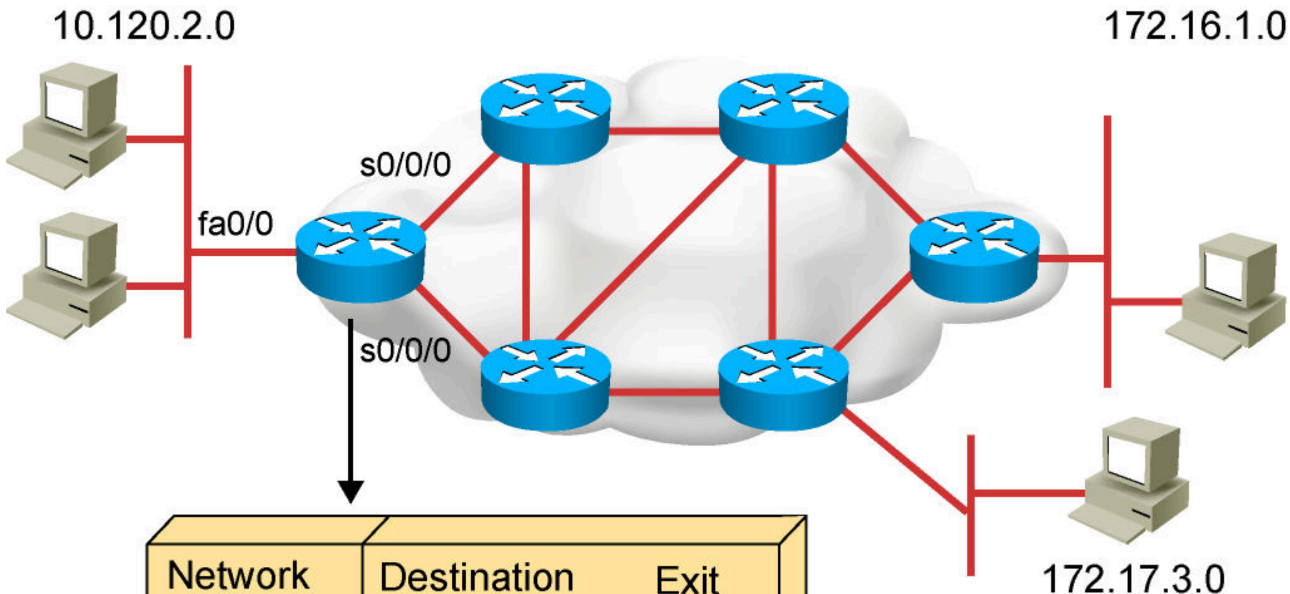
```
Router#
traceroute [protocol] destination
```

- **To discover the routes that packets will actually take when traveling to their destination address, use the traceroute command in user EXEC or privileged EXEC mode.**

Routing Overview
Enabling RIP

What Is a Routing Protocol?

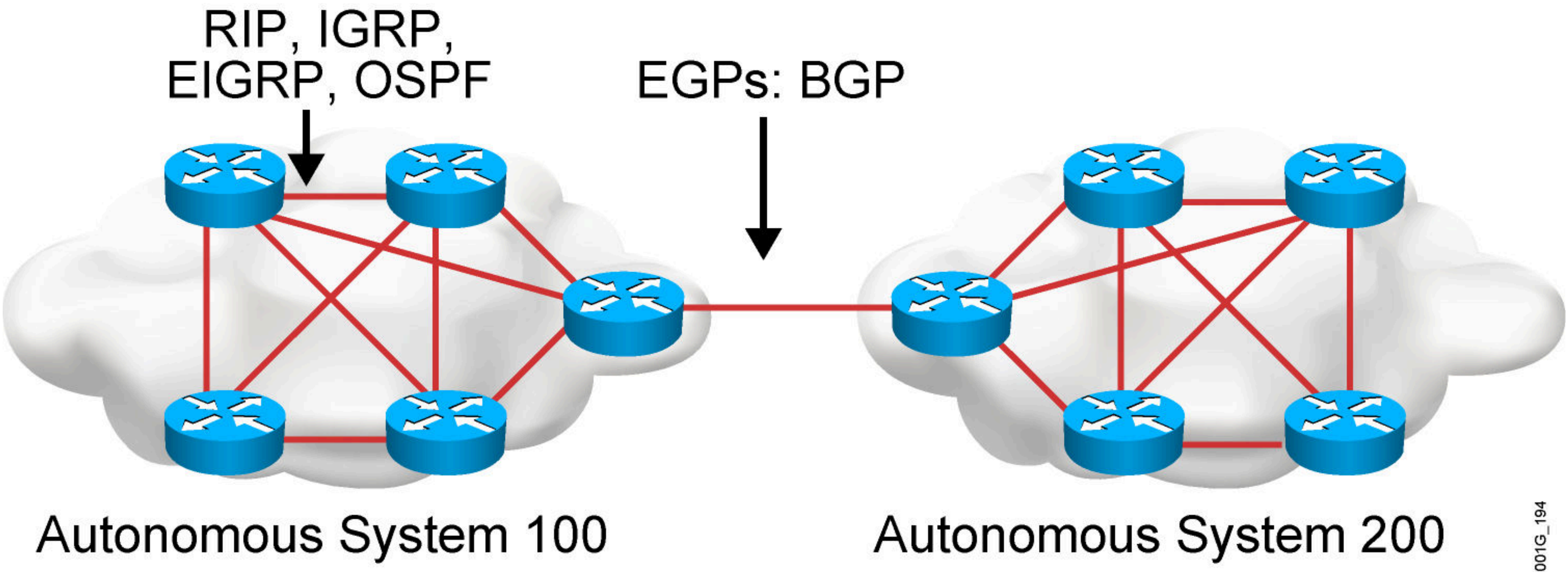
- **Routing protocols are used between routers to determine paths and maintain routing tables.**
- **After the path is determined, a router can route a routed protocol.**



Network Protocol	Destination Network	Exit Interface
Connected	10.120.2.0	fa0/0
RIP	172.16.1.0	s0/0/0
EIGRP	172.17.3.0	s0/0/0

Routed Protocol: IP
Routing Protocol: RIP, EIGRP

Autonomous Systems: Interior or Exterior Routing Protocols



- **An autonomous system is a collection of networks under a common administrative domain.**
- **IGPs operate within an autonomous system.**
- **EGPs connect different autonomous systems.**

Dynamic Routing Protocol Overview

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector		Link-State		Path Vector
IPv4	RIPv2	EIGRP	OSPFv2	IS-IS	BGP-4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGP-MP

RIP protocol was updated to RIPv2 to accommodate growth in the network environment

- **RIPv2 does not scale to current larger network implementations**

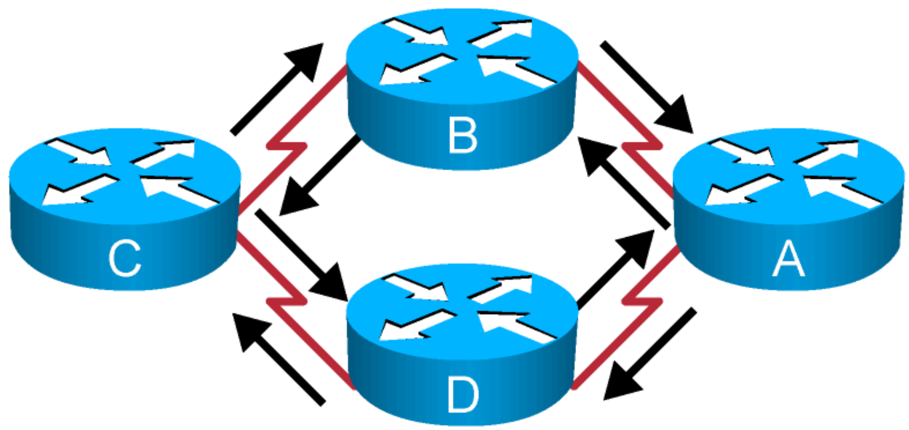
Routing Protocols developed to meet the need of larger networks include:

- **Open Shortest Path First (OSPF)**
- **Intermediate System-to-Intermediate System (IS-IS).**
- **Enhanced IGRP (EIGRP)**

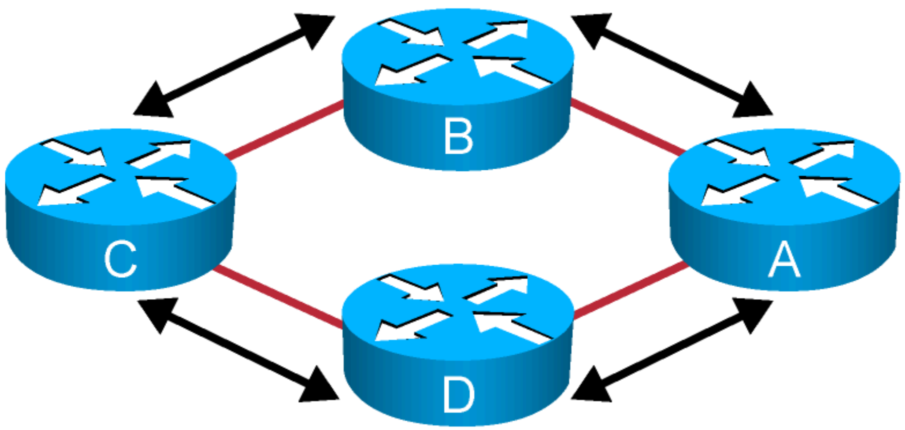
Border Gateway Protocol (BGP) is used between Internet service providers (ISPs)

Classes of Routing Protocols

Distance Vector



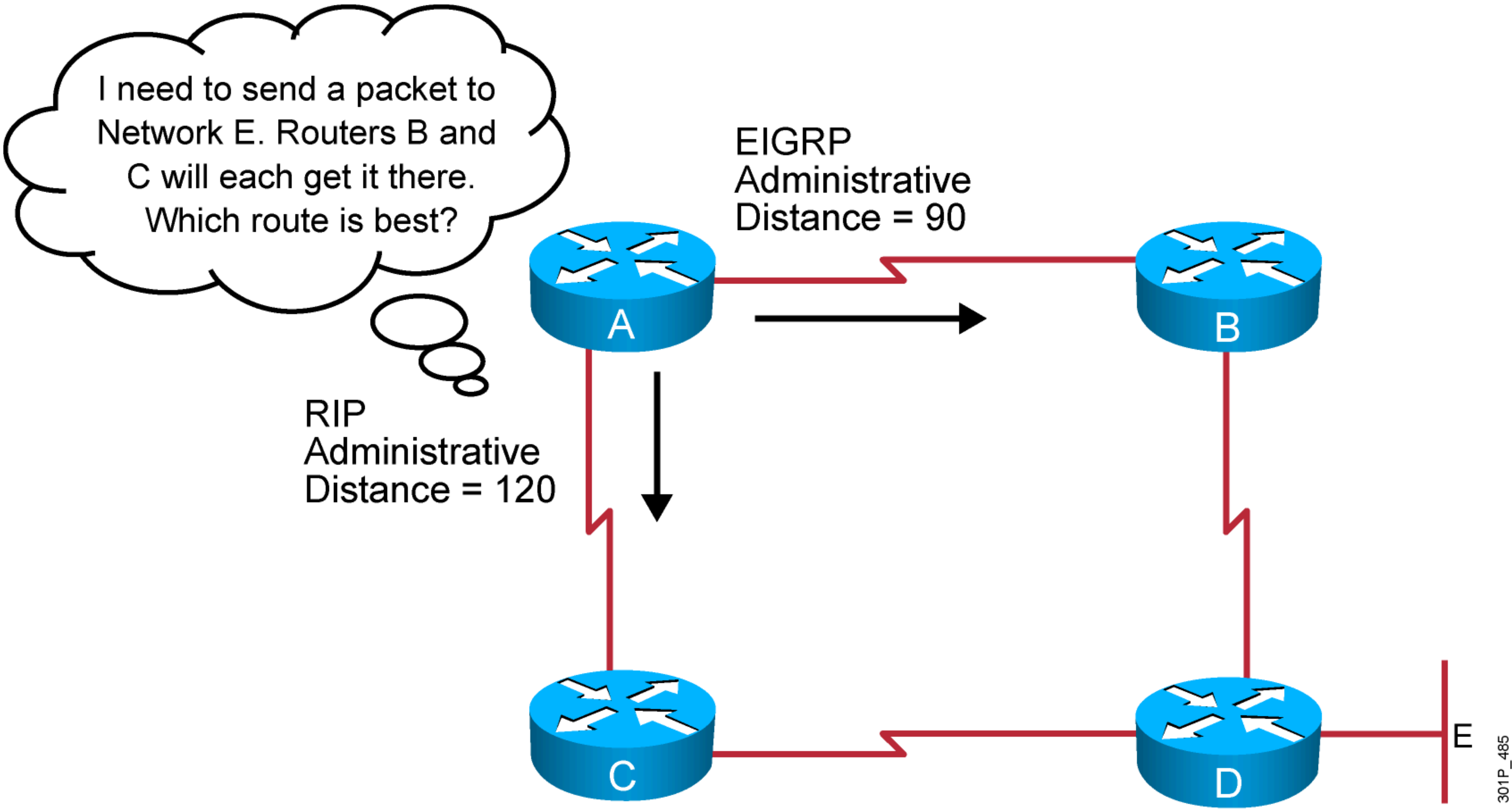
Hybrid Routing



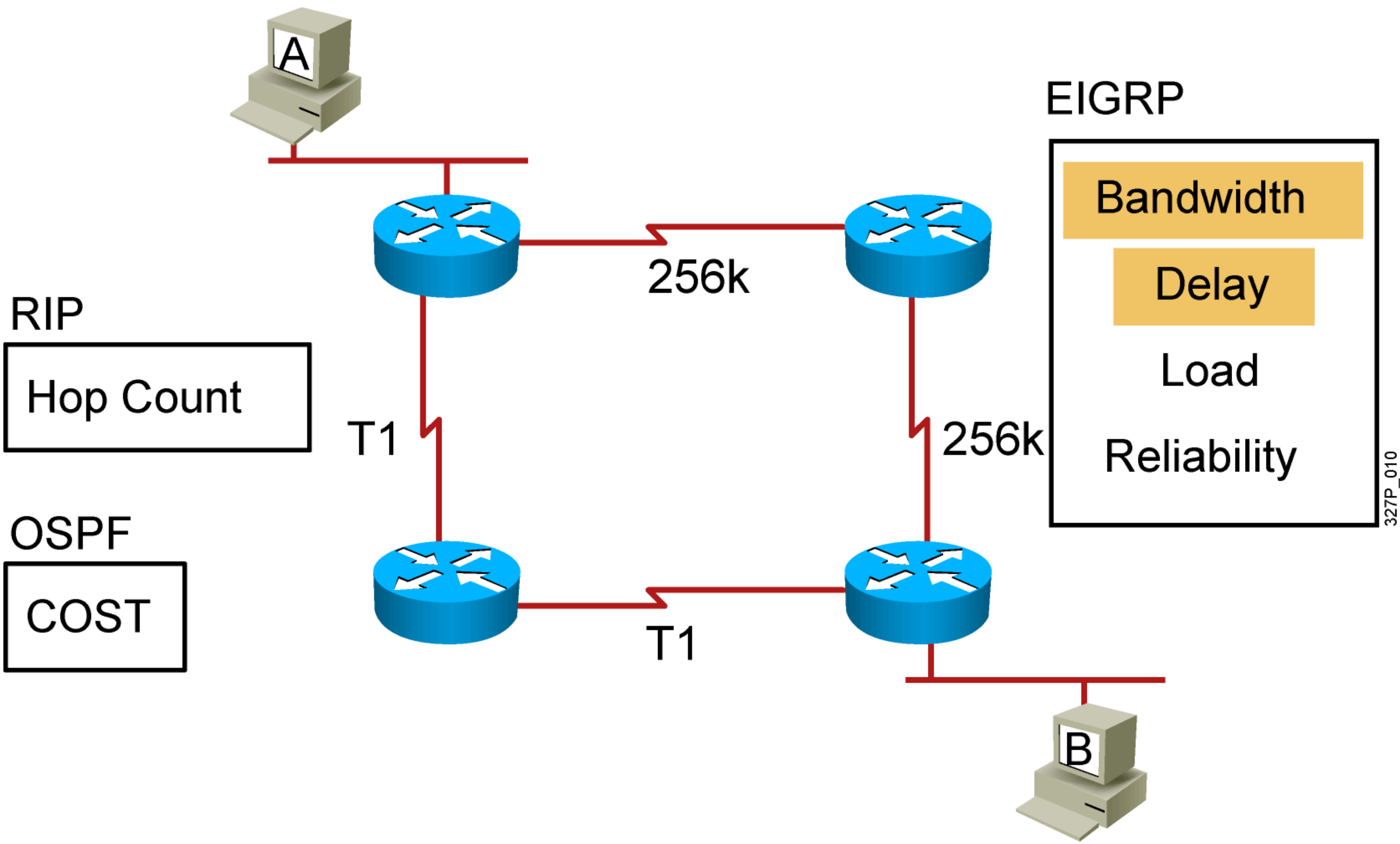
Link-State

301P_196

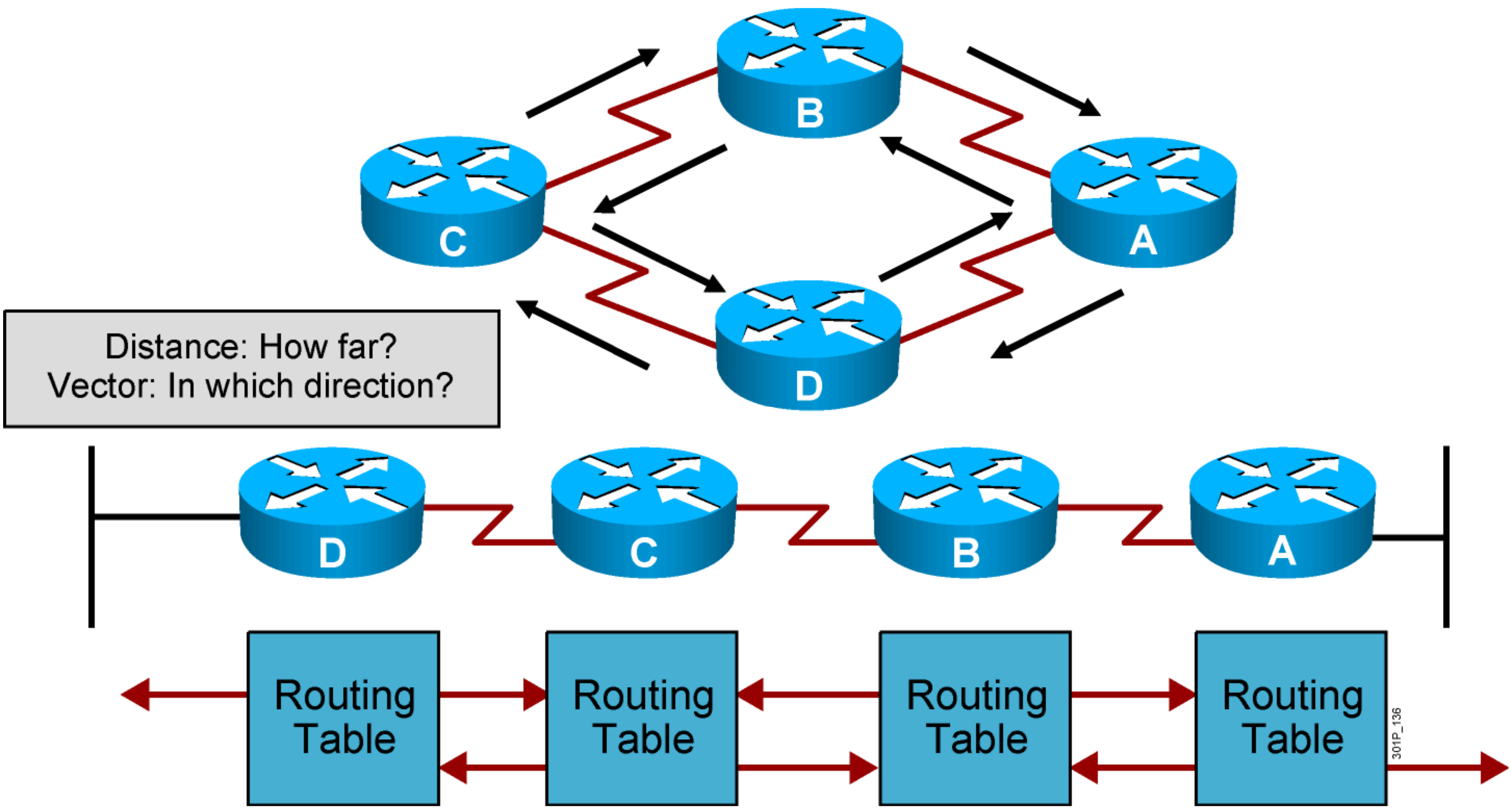
Administrative Distance: Ranking Routes



Selecting the Best Route Using Metrics

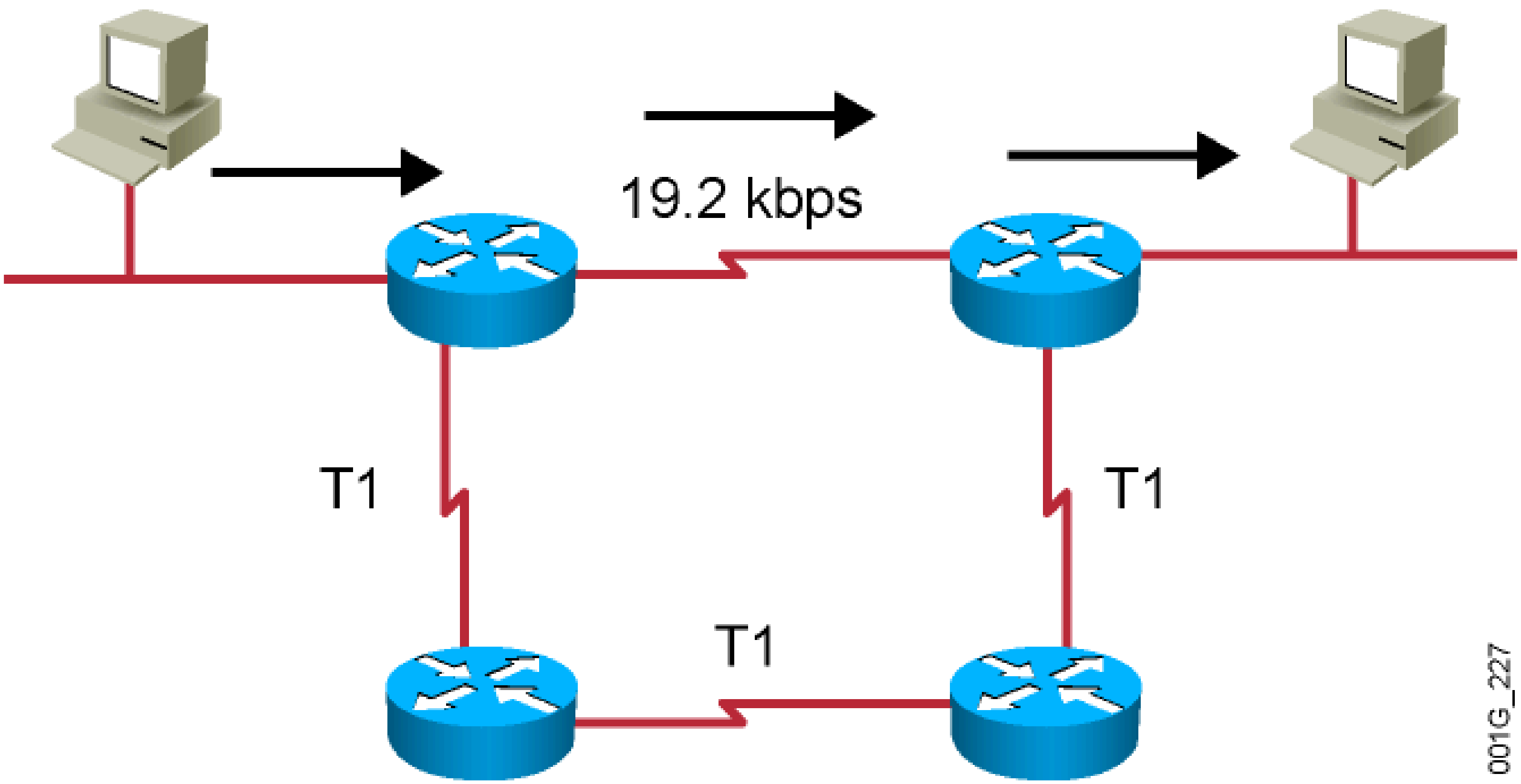


Distance Vector Routing Protocols



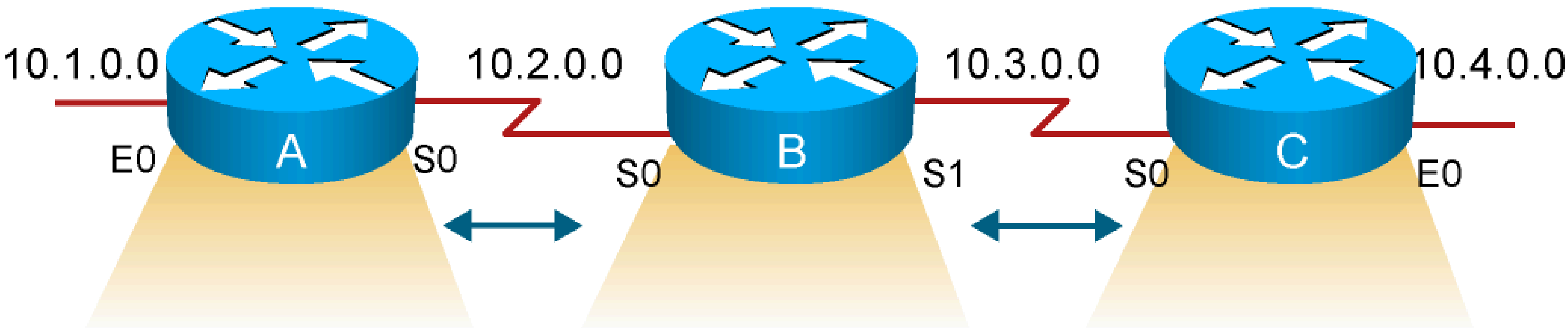
- **Routers pass periodic copies of their routing table to neighboring routers and accumulate distance vectors**

RIP Overview



- Maximum is 16 equal-cost paths (default = 4)
- Hop-count metric selects the path
- Routes update every 30 seconds

Sources of Information and Discovering Routes



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

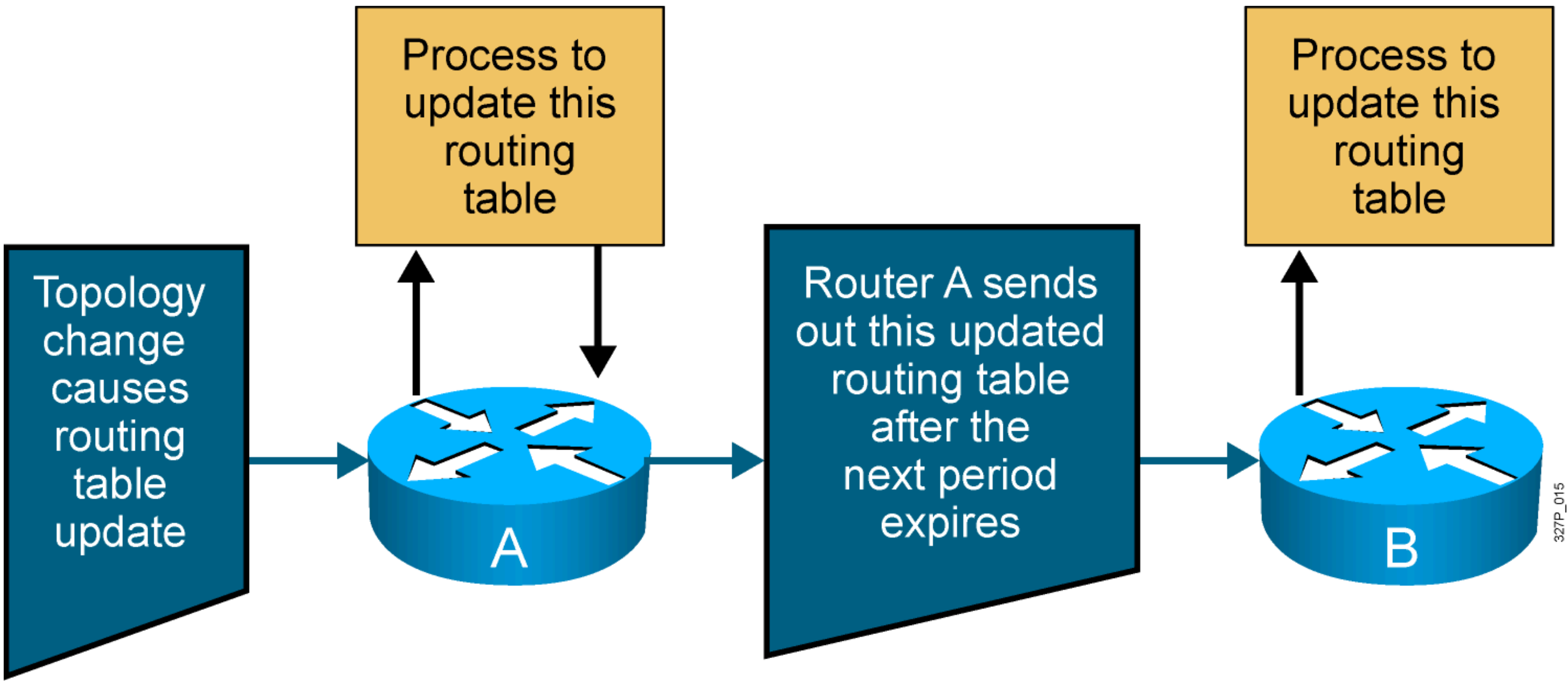
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	E0	0
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_014

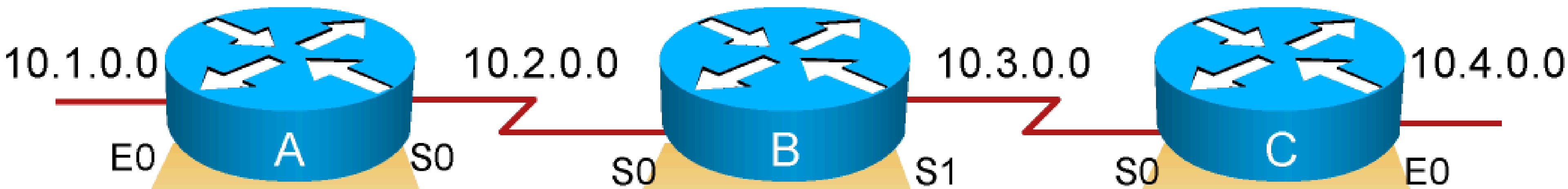
Routers discover the best path to destinations from each neighbor.

Maintaining Routing Information



Updates proceed step by step from router to router.

Inconsistent Routing Entries: Counting to Infinity and Routing Loops



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

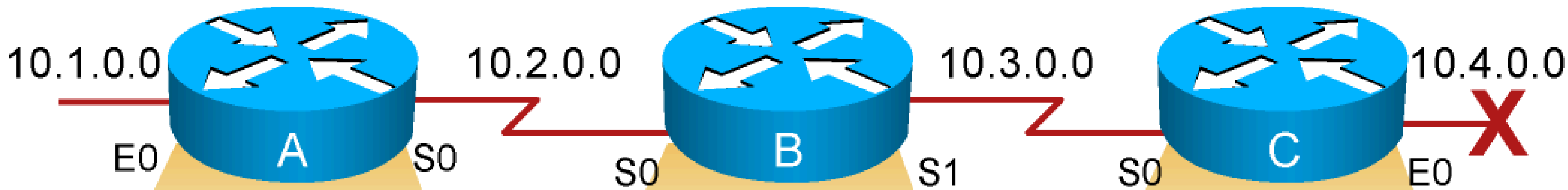
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	E0	0
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_017

Each node maintains the distance from itself to each possible destination network.

Counting to Infinity



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

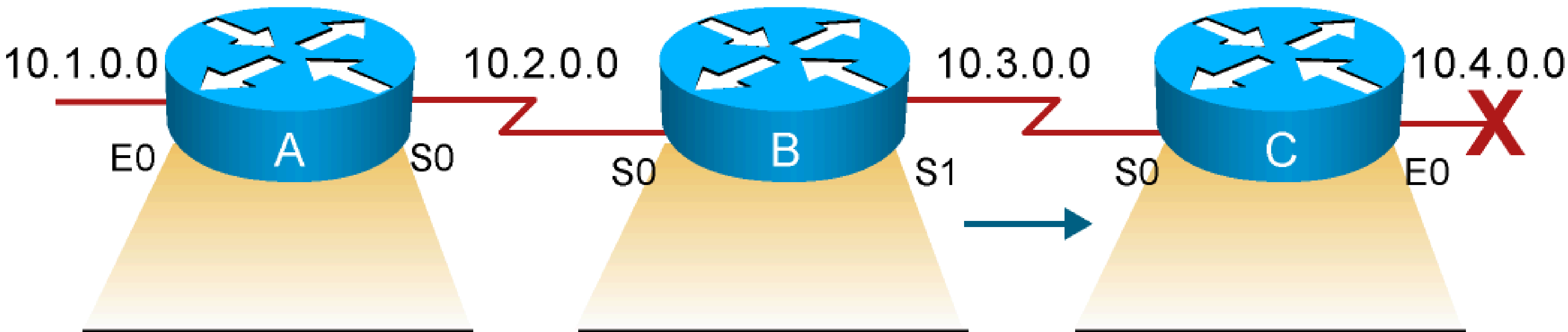
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	E0	Down
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_016

Slow convergence produces inconsistent routing.

Counting to Infinity (Cont.)



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

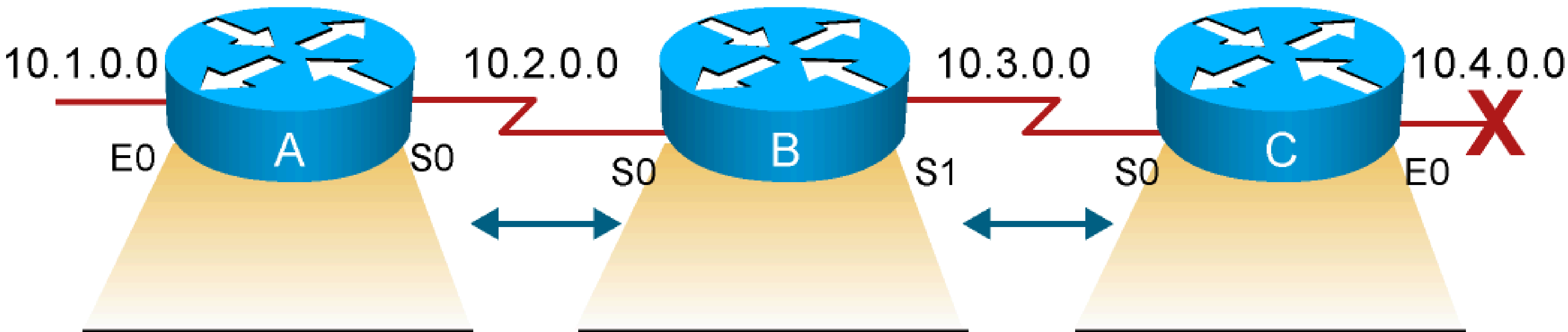
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	S0	2
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_018

Router C concludes that the best path to network 10.4.0.0 is through router B.

Solution to Counting to Infinity: Defining a Maximum



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	16

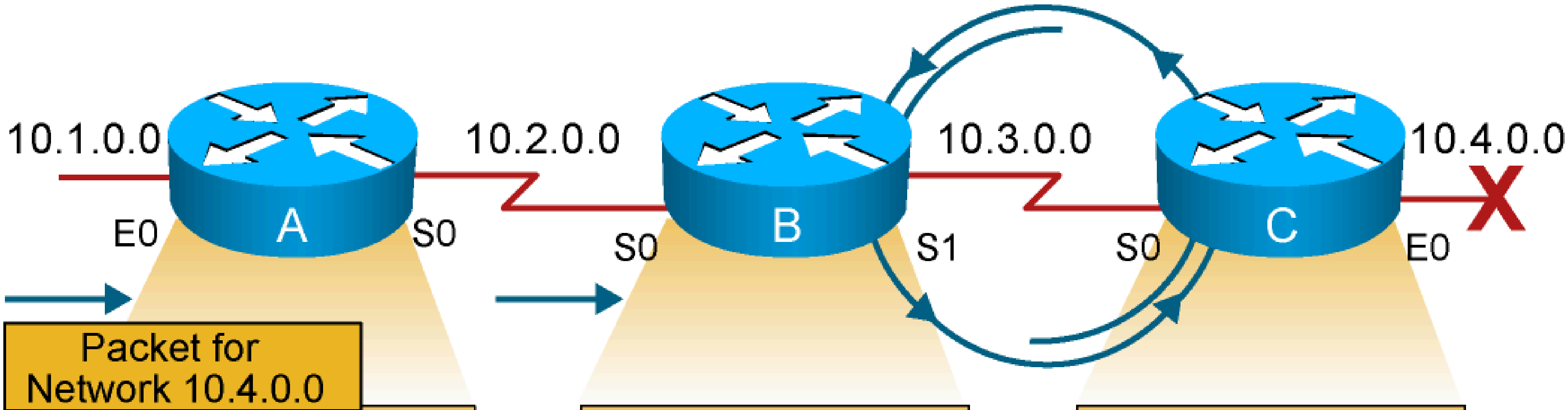
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	16
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	S0	16
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_021

A limit is set on the number of hops to prevent infinite loops.

Routing Loops



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	4

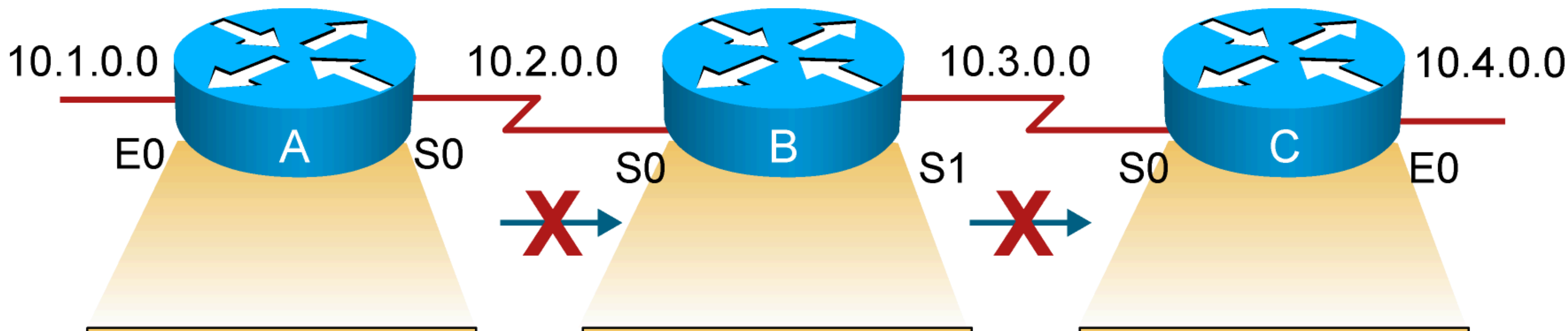
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	3
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	S0	2
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_022

Packets for network 10.4.0.0 bounce (loop) between routers B and C.

Solution to Routing Loops: Split Horizon



Router A

Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

Router B

Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

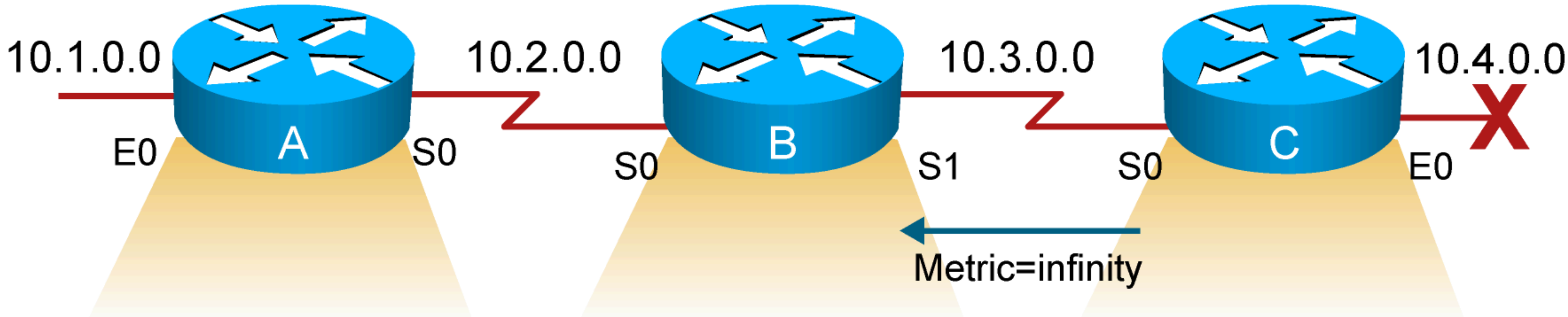
Router C

Routing Table		
10.3.0.0	S0	0
10.4.0.0	E0	0
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_023

It is never useful to send information about a route back in the direction from which the original information came.

Solution to Routing Loops: Route Poisoning and Poison Reverse



Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

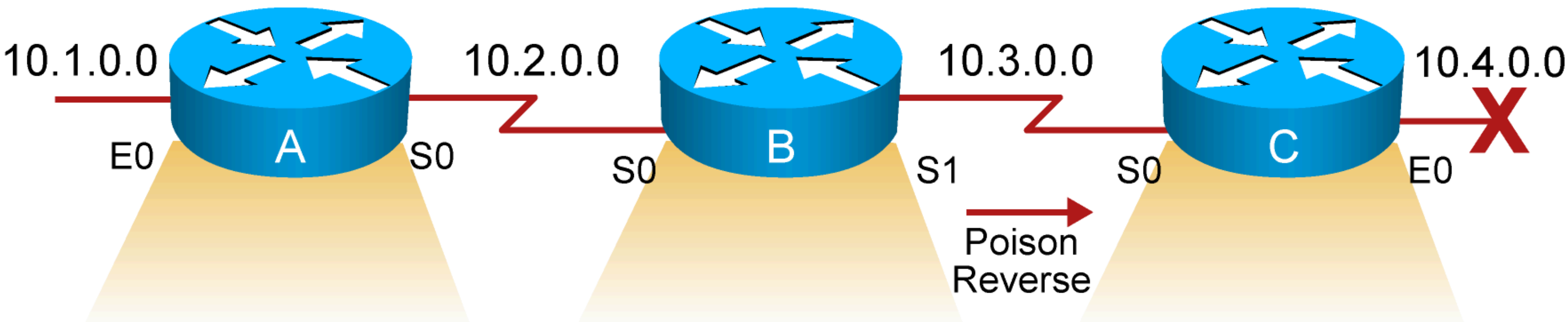
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	E0	Down
10.2.0.0	S0	1
10.1.0.0	S0	2

327P_024

Routers advertise the distance of routes that have gone down to infinity.

Solution to Routing Loops: Route Poisoning and Poison Reverse (Cont.)



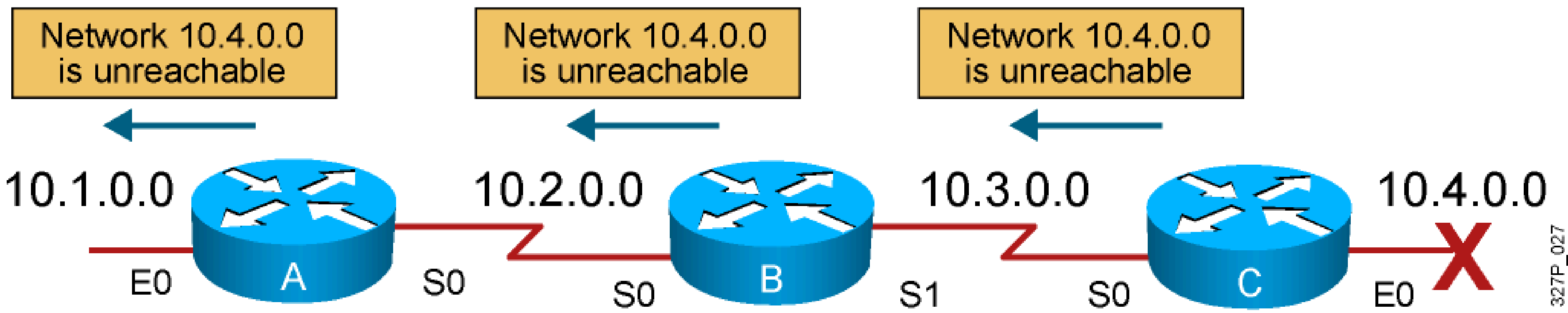
Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	Possibly Down
10.1.0.0	S0	1

Routing Table		
10.3.0.0	S0	0
10.4.0.0	S0	Infinity
10.2.0.0	S0	1
10.1.0.0	S0	2

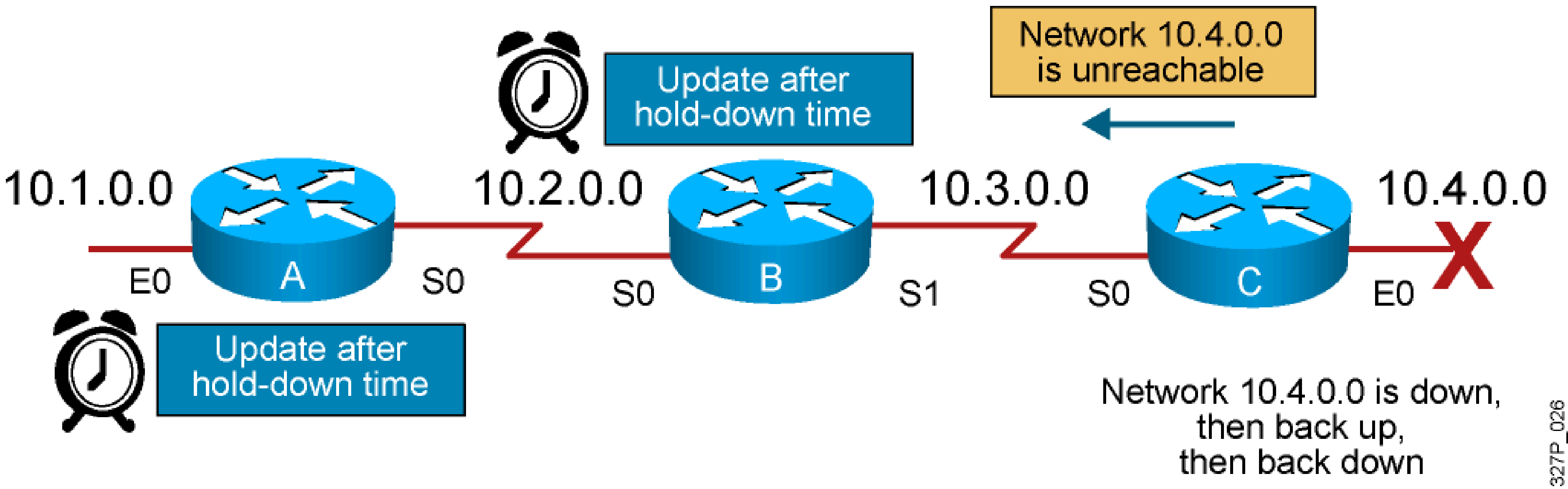
327P_025

Triggered Updates



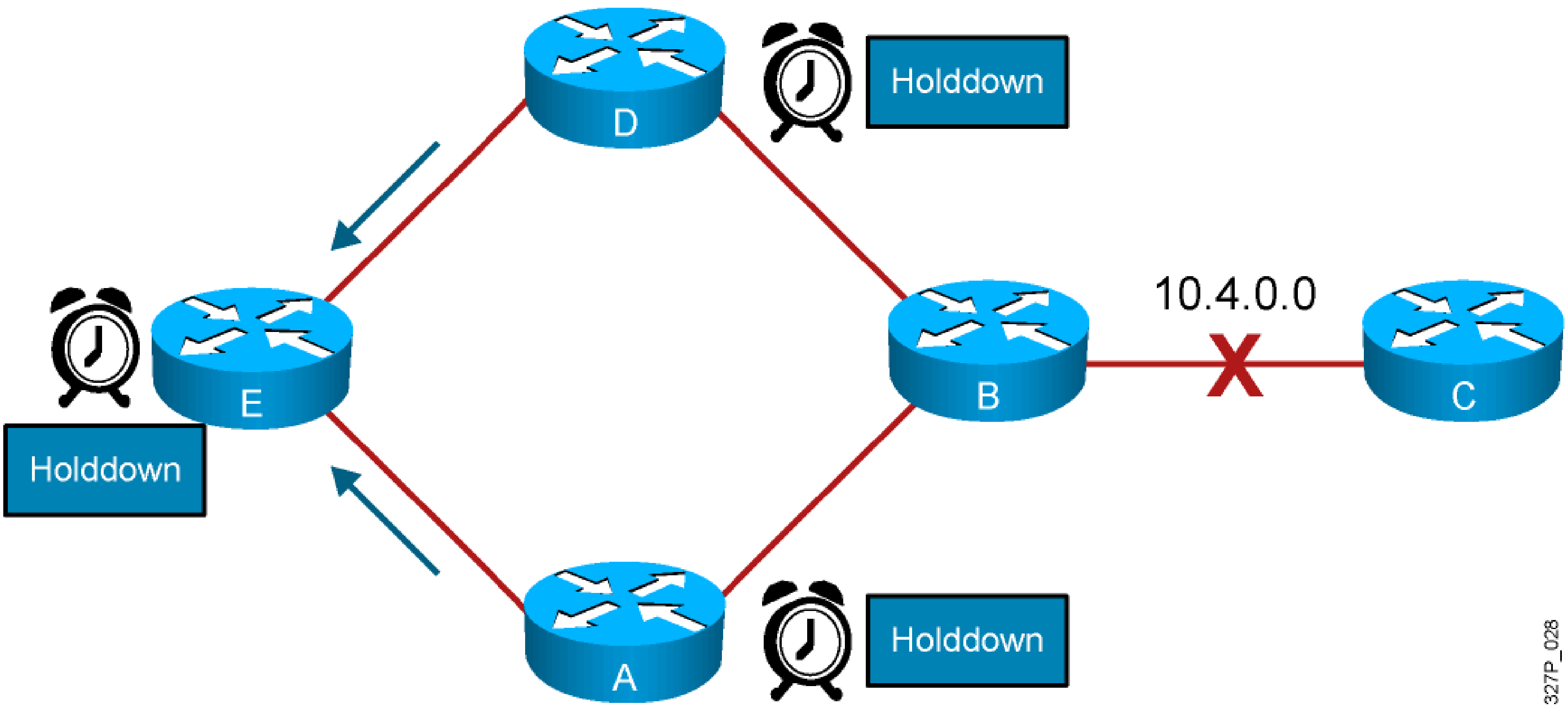
The router sends updates when a change in its routing table occurs.

Solution to Routing Loops: Hold-Down Timers (180s)

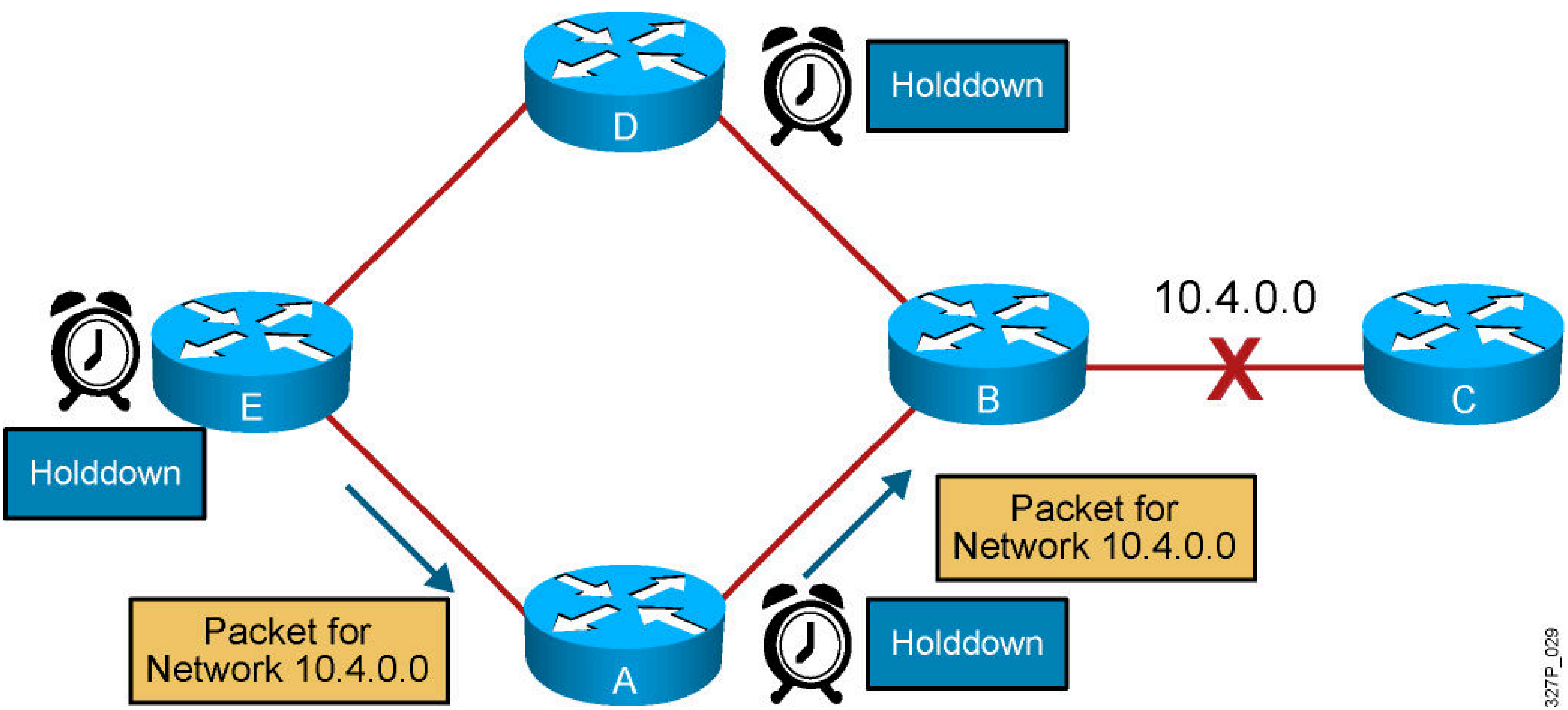


The router keeps an entry for the "possibly down" state in the network, allowing time for other routers to recompute for this topology change.

Eliminating Routing Loops



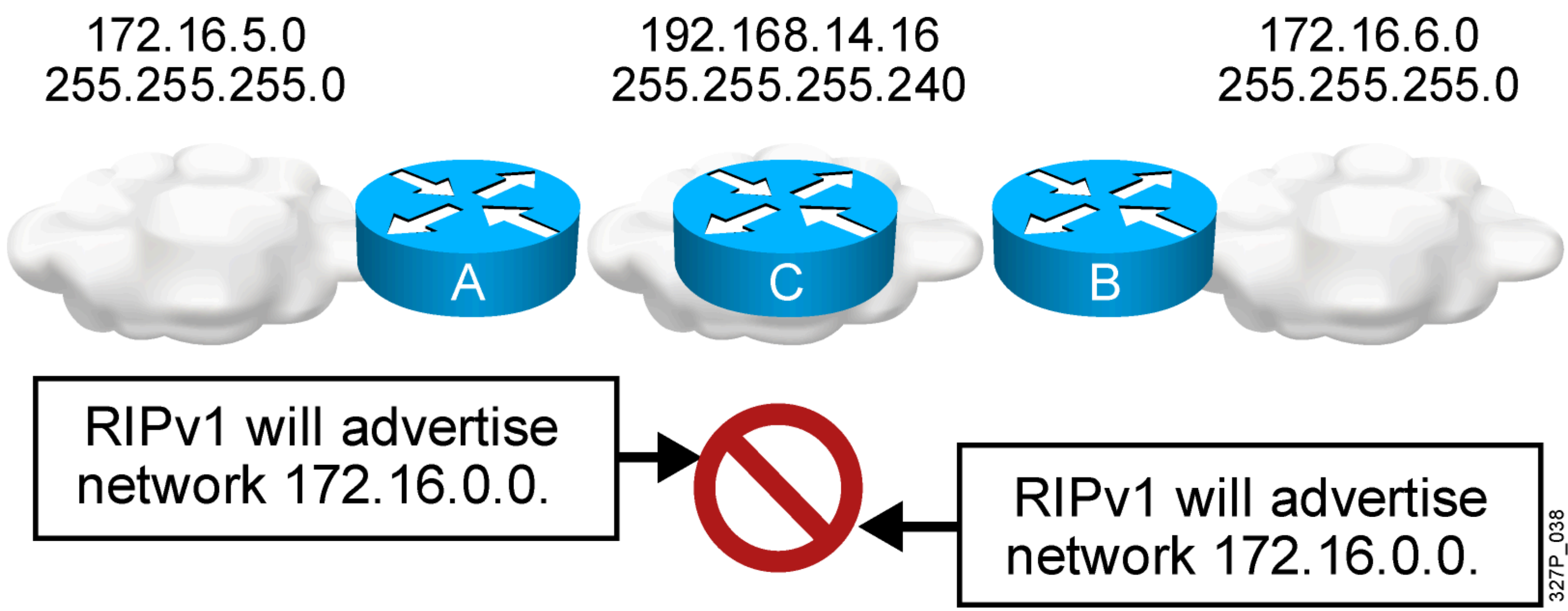
Eliminating Routing Loops (Cont.)



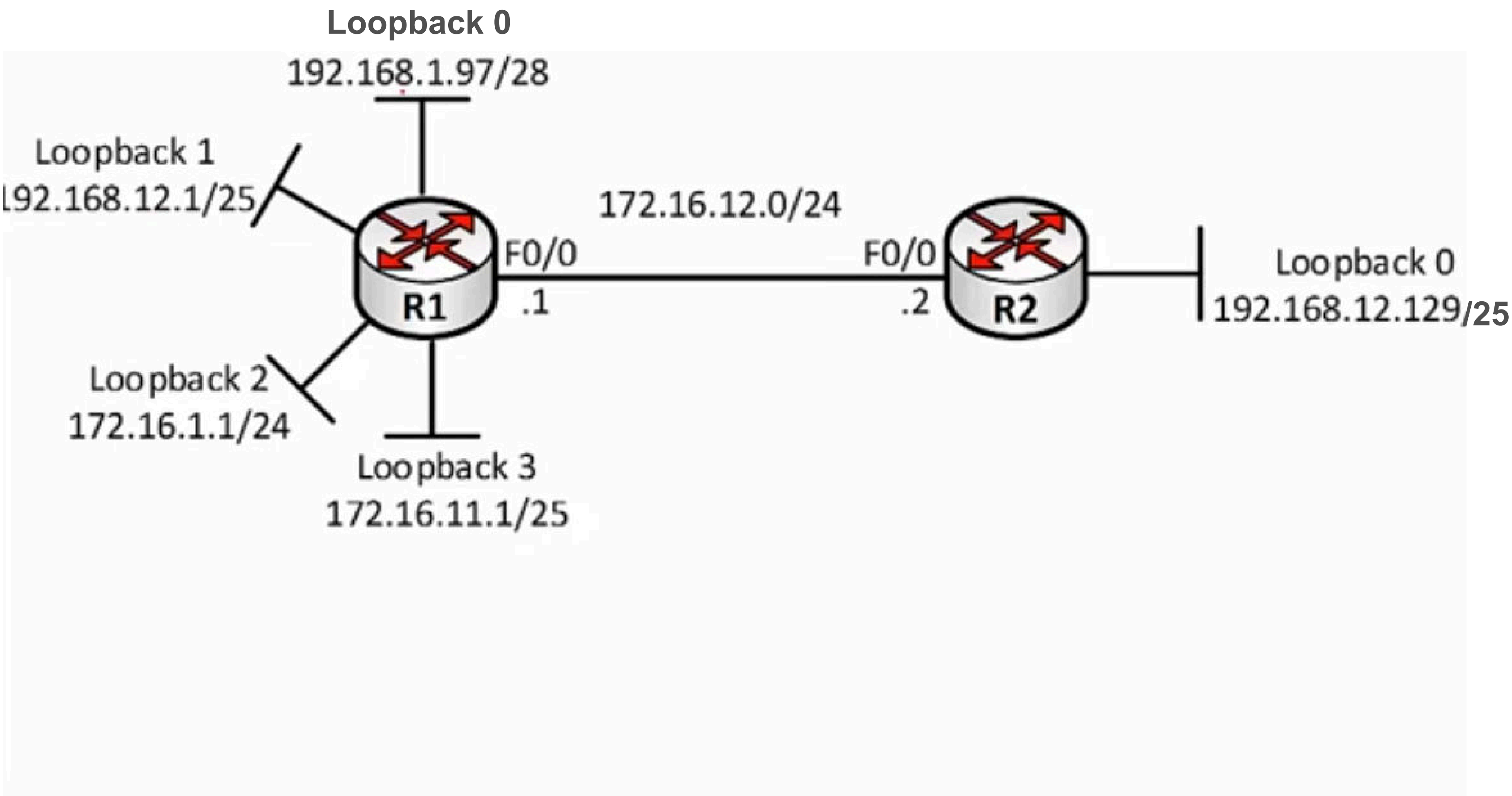
RIPv1 and RIPv2 Comparison

	RIPv1	RIPv2
Routing protocol	Classful	Classless
Supports variable-length subnet mask?	No	Yes
Sends the subnet mask along with the routing update?	No	Yes
Addressing type	Broadcast 255.255.255.255	Multicast 224.0.0.9
Defined in …	RFC 1058	RFCs 1721, 1722, and 2453
Supports manual route summarization?	No	Yes
Authentication support?	No	Yes

Summarizing Routes in a Discontiguous Network



- **Classful RIPv1 and IGRP do not advertise subnets, and therefore cannot support discontiguous subnets.**
- **Classless OSPF, EIGRP, and RIPv2 can advertise subnets, and therefore can support discontiguous subnets.**


Loopback 0
192.168.1.97/28
Loopback 1
192.168.12.1/25
172.16.12.0/24
F0/0
.1
R1
F0/0
.2
R2
Loopback 0
192.168.12.129/25
Loopback 2
172.16.1.1/24
Loopback 3
172.16.11.1/25

Classful Routing Protocol

- **Classful routing protocols do not include the subnet mask with the route advertisement.**
- **Within the same network, consistency of the subnet masks is assumed.**
- **Summary routes are exchanged between foreign networks.**
- **These are examples of classful routing protocols:**
  - **RIPv1**
  - **IGRP**

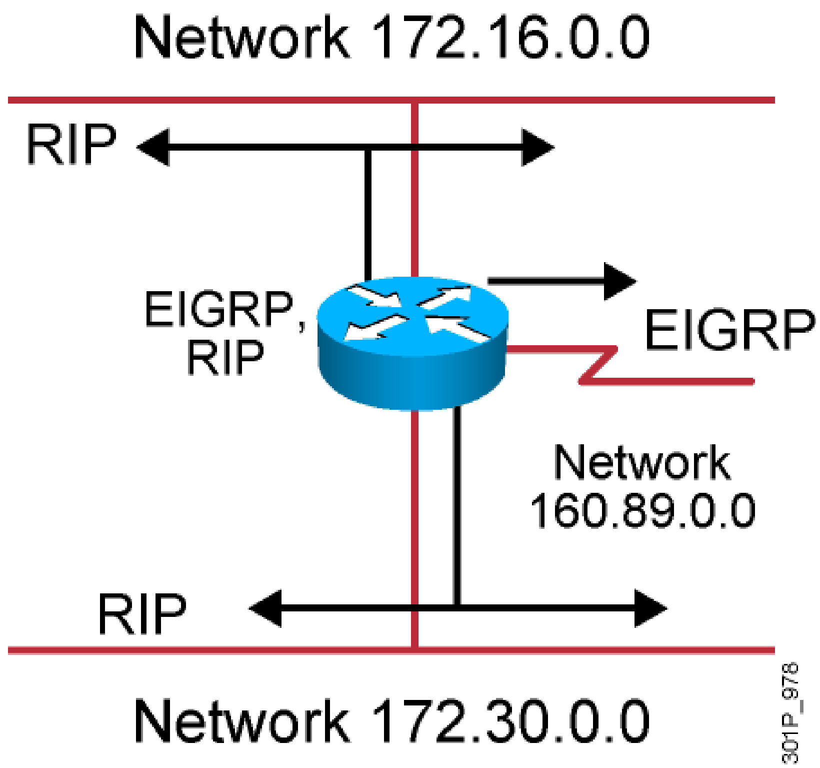
Classless Routing Protocol

- **Classless routing protocols include the subnet mask with the route advertisement.**
- **Classless routing protocols support a variable-length subnet mask (VLSM).**
- **Summary routes can be manually controlled within the network.**
- **These are examples of classless routing protocols:**
  - **RIPv2**
  - **EIGRP**
  - **OSPF**
  - **IS-IS**

Enabling RIP

IP Routing Configuration Tasks

- **Router configuration**
  - **Select routing protocols**
  - **Specify networks or interfaces**



RIP Configuration

```
RouterX(config)# router rip
```

- Starts the RIP routing process

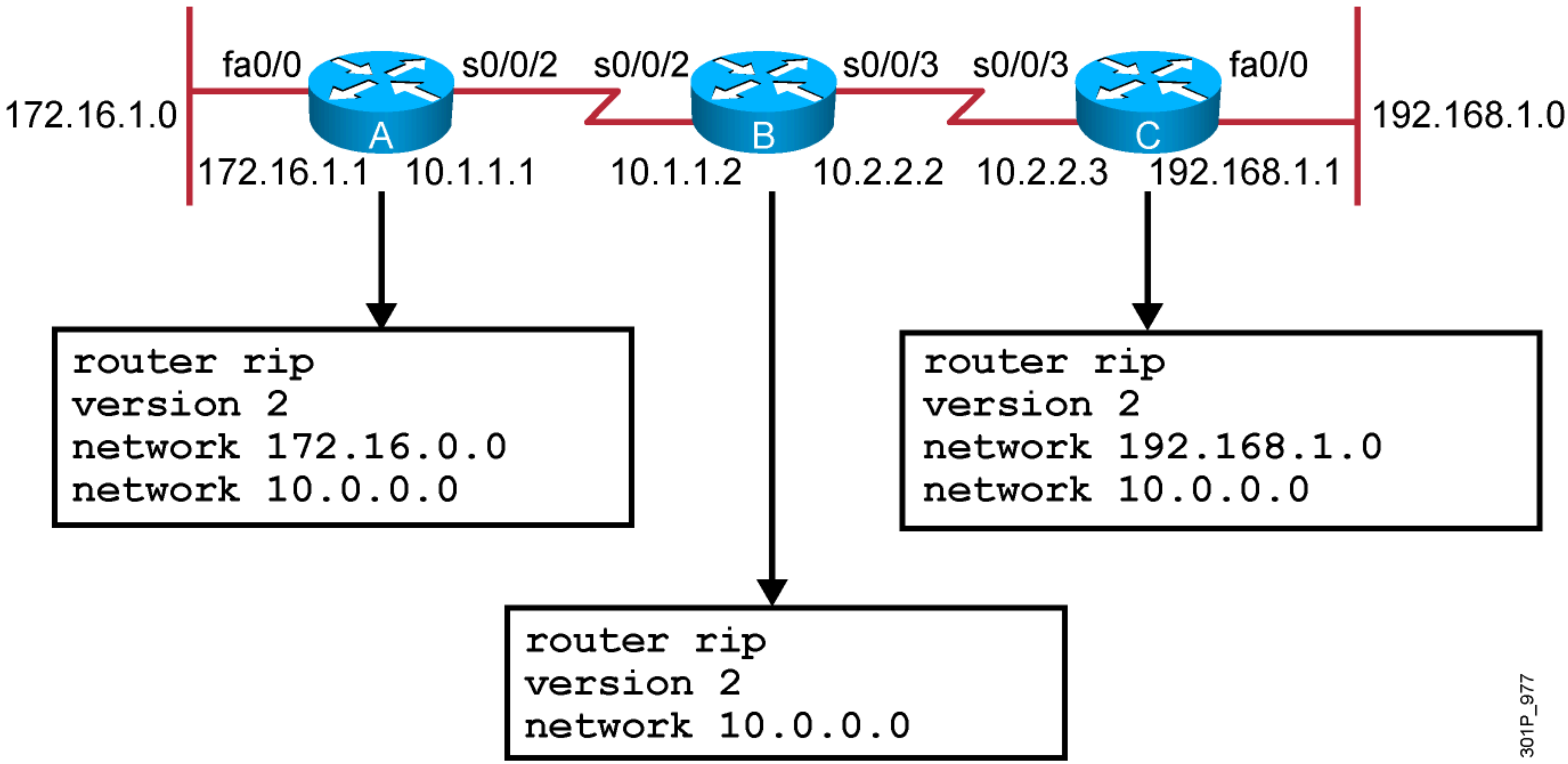
```
RouterX(config-router)# version 2
```

- Enables RIP version 2

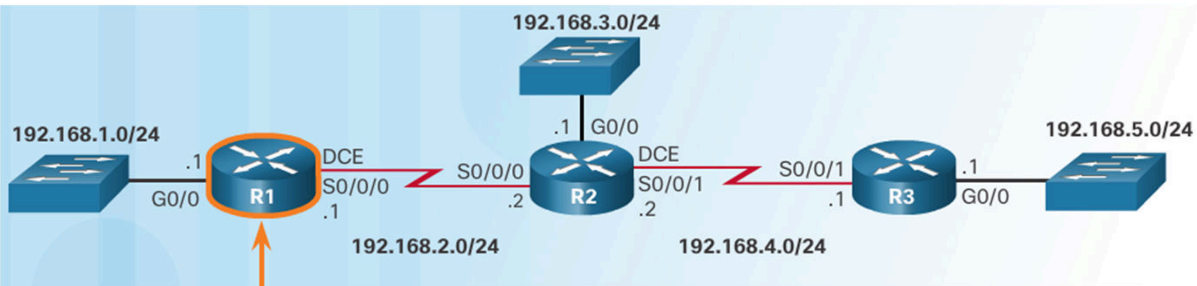
```
RouterX(config-router)# network network-number
```

- Selects participating attached networks
- Requires a major classful network number

RIP Configuration Example



Disable Auto Summarization




```
R1(config)# router rip
R1(config-router)# no auto-summary
R1(config-router)# end
R1#
*Mar 10 14:11:49.659: %SYS-5-CONFIG_I: Configured from
console by console
R1# show ip protocols | section Automatic
  Automatic network summarization is not in effect
R1#
```

RIPv2 automatically summarizes networks at major network boundaries.

Use the no auto-summary router configuration mode command to disable auto summarization.

Use the show ip protocols command to verify that auto summarization is off.

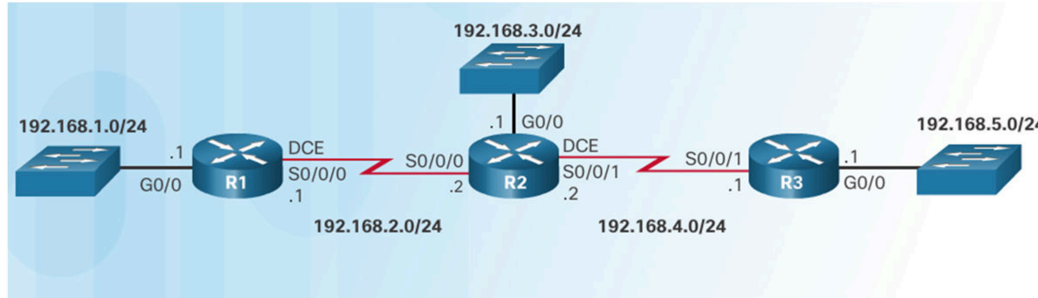
Configure Passive Interfaces

RIP updates:

- Are forwarded out all RIP-enabled interfaces by default.
- Only need to be sent out interfaces that are connected to other RIP-enabled routers.

Sending RIP updates to LANs wastes bandwidth, wastes resources, and is a security risk.

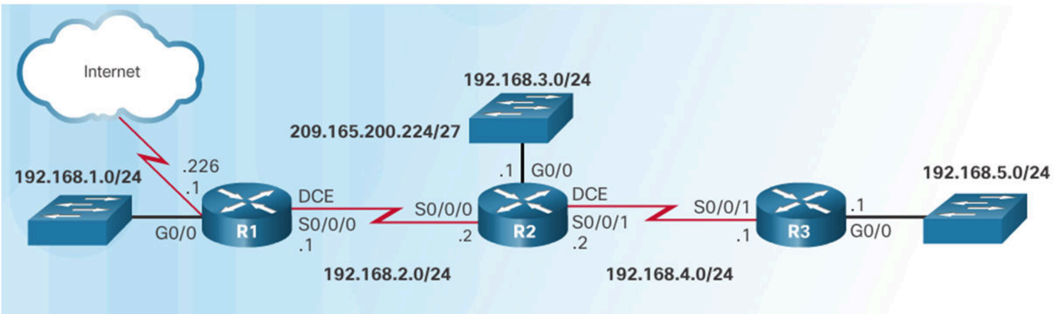
Use the passive-interface router configuration command to stop routing updates out the interface. Still allows that network to be advertised to other routers.




```
R1(config)# router rip
R1(config-router)# passive-interface g0/0
R1(config-router)# end
R1#
R1# show ip protocols | begin Default
  Default version control: send version 2, receive version 2
    Interface             Send  Recv  Triggered RIP  Key-
chain
    Serial0/0/0           2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    192.168.1.0
    192.168.2.0
  Passive Interface(s):
    GigabitEthernet0/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.2.2          120      00:00:06
  Distance: (default is 120)

R1#
```

Configuring the RIP Protocol

Propagate a Default Route

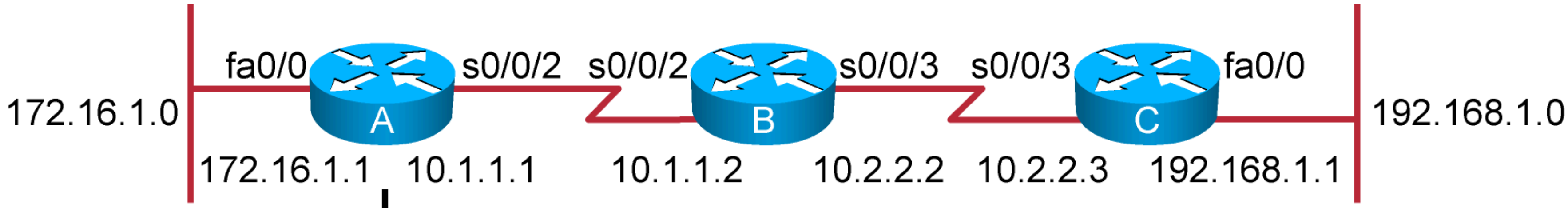



```
R1(config)# ip route 0.0.0.0 0.0.0.0 S0/0/1 209.165.200.226
R1(config)# router rip
R1(config-router)# default-information originate
R1(config-router)# ^Z
R1#
*Mar 10 23:33:51.801: %SYS-5-CONFIG_I: Configured from console by console
R1# show ip route | begin Gateway
Gateway of last resort is 209.165.200.226 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 209.165.200.226, Serial0/0/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/0
L        192.168.1.1/32 is directly connected, GigabitEthernet0/0
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, Serial0/0/0
L        192.168.2.1/32 is directly connected, Serial0/0/0
R     192.168.3.0/24 [120/1] via 192.168.2.2, 00:00:08, Serial0/0/0
R     192.168.4.0/24 [120/1] via 192.168.2.2, 00:00:08, Serial0/0/0
R     192.168.5.0/24 [120/2] via 192.168.2.2, 00:00:08, Serial0/0/0
      209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.200.0/24 is directly connected, Serial0/0/1
L        209.165.200.225/27 is directly connected, Serial0/0/1
R1#
```

In the diagram a default static route to the Internet is configured on R1.

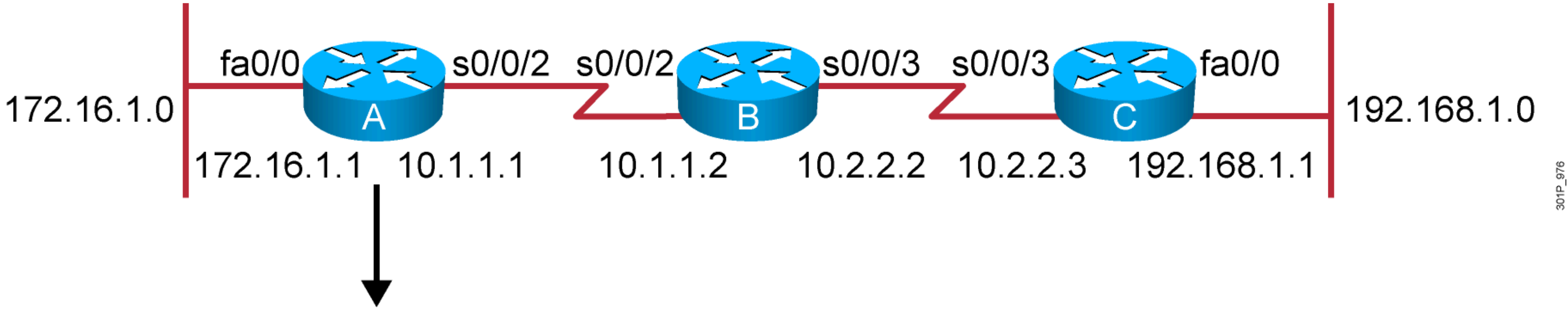
The default-information originate router configuration command instructs R1 to send the default static route information in the RIP updates.

Verifying the RIP Configuration



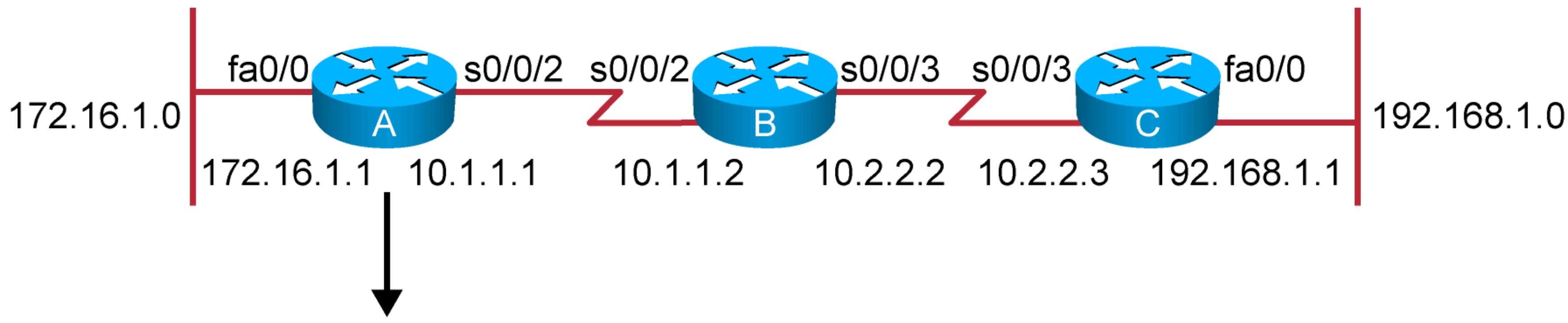

```
Routing Protocol is "rip"
  Sending updates every 30 seconds, next due in 6 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface             Send  Recv  Triggered RIP  Key-chain
    FastEthernet0/0        2     2
    Serial0/0/2            2     2
  Automatic network summarization is in effect
  Maximum path: 4
  Routing for Networks:
    10.0.0.0
    172.16.0.0
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.1.1.2             120      00:00:25
  Distance: (default is 120)

RouterA#
```

Displaying the IP Routing Table




```
RouterA# show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, * - candidate default
       U - per-user static route, o - ODR
       T - traffic engineered route

Gateway of last resort is not set


     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.1.0 is directly connected, fastethernet0/0
     10.0.0.0/24 is subnetted, 2 subnets
R       10.2.2.0 [120/1] via 10.1.1.2, 00:00:07, Serial0/0/2
C       10.1.1.0 is directly connected, Serial0/0/2
R    192.168.1.0/24 [120/2] via 10.1.1.2, 00:00:07, Serial0/0/2
```

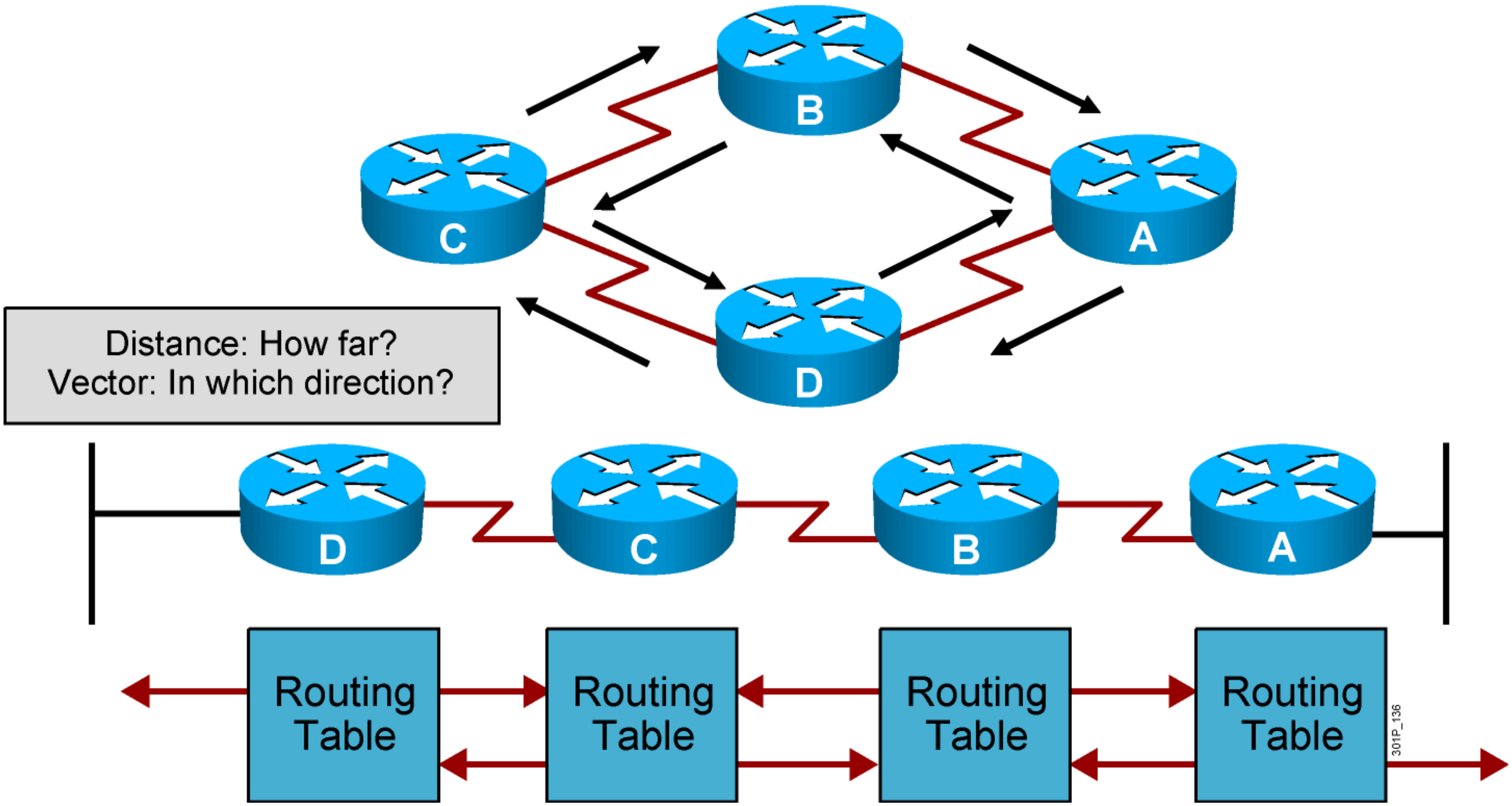
debug ip rip Command




```
RouterA# debug ip rip
RIP protocol debugging is on
RouterA#
00:06:24: RIP: received v1 update from 10.1.1.2 on Serial0/0/2
00:06:24:      10.2.2.0 in 1 hops
00:06:24:      192.168.1.0 in 2 hops
00:06:33: RIP: sending v1 update to 255.255.255.255 via FastEthernet0/0 (172.16.1.1)
00:06:34:      network 10.0.0.0, metric 1
00:06:34:      network 192.168.1.0, metric 3
00:06:34: RIP: sending v1 update to 255.255.255.255 via Serial0/0/2 (10.1.1.1)
00:06:34:      network 172.16.0.0, metric 1
```

OSPF
(Open Shortest Path First)

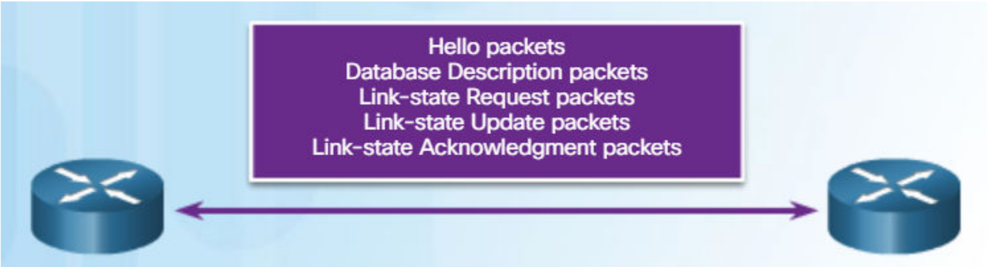
Distance Vector Routing Protocols



Passes periodic copies of routing table to neighbor routes and accumulates distance vectors

Open Shortest Path First

Components of OSPF

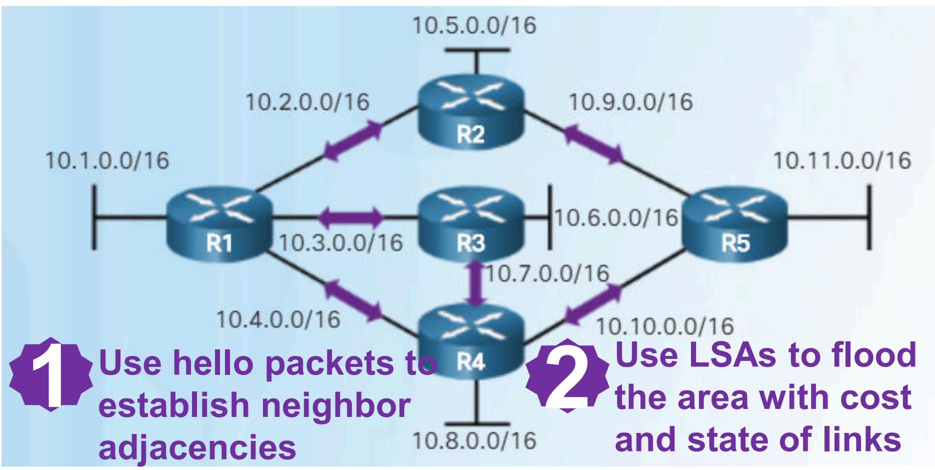


Database	Table	Description
Adjacency	Neighbor	• Lists all neighbor routers to which a router has established bidirectional communication • Unique for each router • View using the **show ip ospf neighbor** command
Link-state (LSDB)	Topology	• Lists information about all other routers • Represents the network topology • Contains the same LSDB as all other routers in the same area • View using the **show ip ospf database** command
Forwarding	Routing	• Lists routes generated when the SPF algorithm is run on the link-state database. • Unique to each router and contains information on how and where to send packets destined for remote networks • View using the **show ip route** command

OSPF packet types: hello, database description, link-state request, link-state update, link-state acknowledgment

Open Shortest Path First

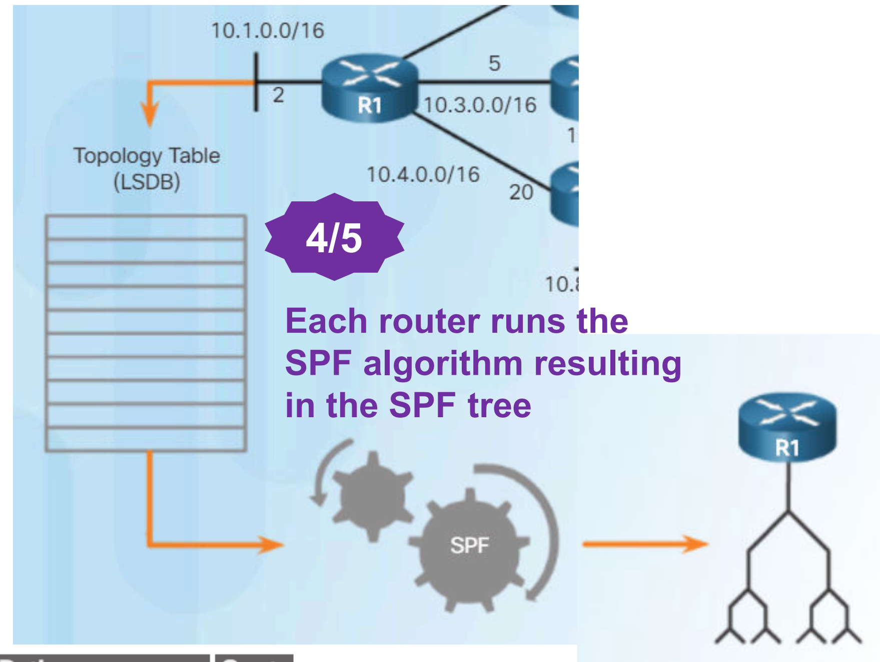
Link-State Operation



1 Use hello packets to establish neighbor adjacencies

2 Use LSAs to flood the area with cost and state of links

3 Each router builds a topology table



4/5 Each router runs the SPF algorithm resulting in the SPF tree

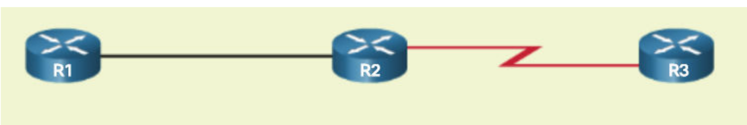
6 Each router builds a routing table that includes the path to get to the distant network and the cost to get there.

Destination	Shortest Path	Cost
10.5.0.0/16	R1→R2	22
10.6.0.0/16	R1→R3	7
10.7.0.0/16	R1→R3	15
10.8.0.0/16	R1→R3→R4	17
10.9.0.0/16	R1→R2	30
10.10.0.0/16	R1→R3→R4	25
10.11.0.0/16	R1→R3→R4→R5	27
10.5.0.0/16	R1→R2	22

Open Shortest Path First

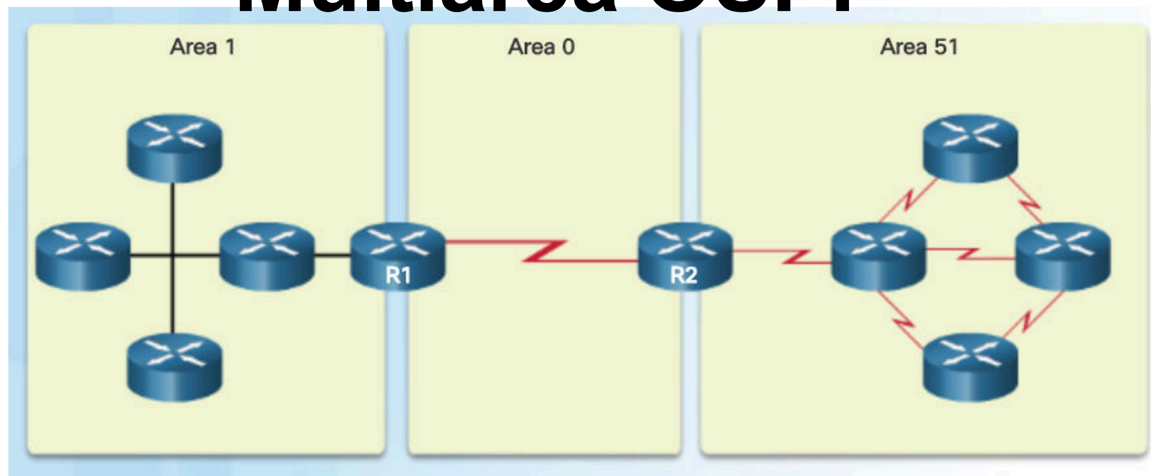
Single-Area and Multiarea OSPF

Single-Area OSPF



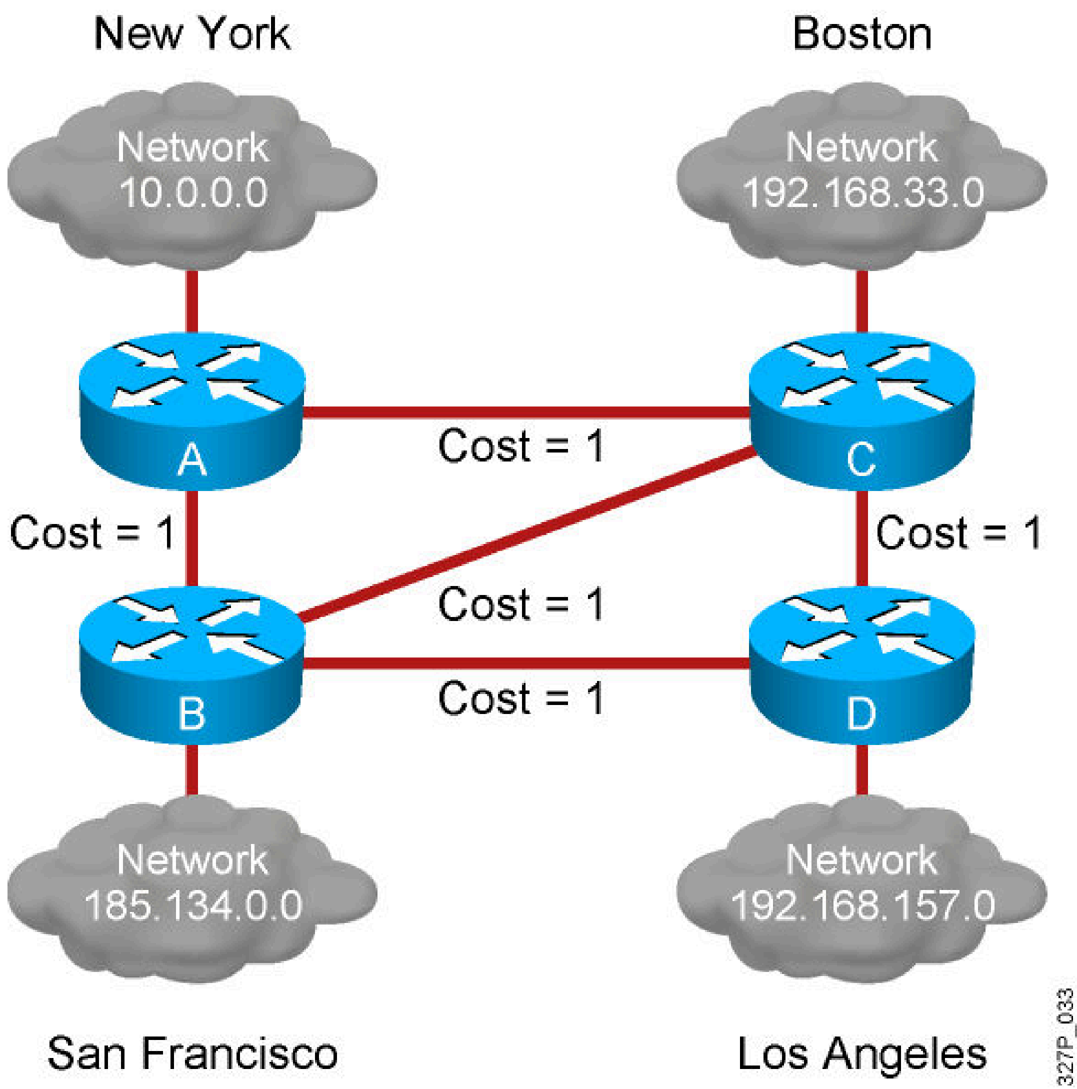
- All routers contained in one area
- Called the backbone area
- Known as Area 0
- Used in smaller networks with few routers

Multiarea OSPF



- Designed using a hierarchical scheme
- All areas connect to area 0
- More commonly seen with numerous areas around area 0 (like a daisy or aster)
- Routers that connect area 0 to another area is known as an Area Border Router (ABR)
- Used in large networks
- Multiple areas reduces processing and memory overhead
- A failure in one area does not affect other areas

Link-State Routing Protocol Algorithms



Benefits and Drawbacks of Link-State Routing

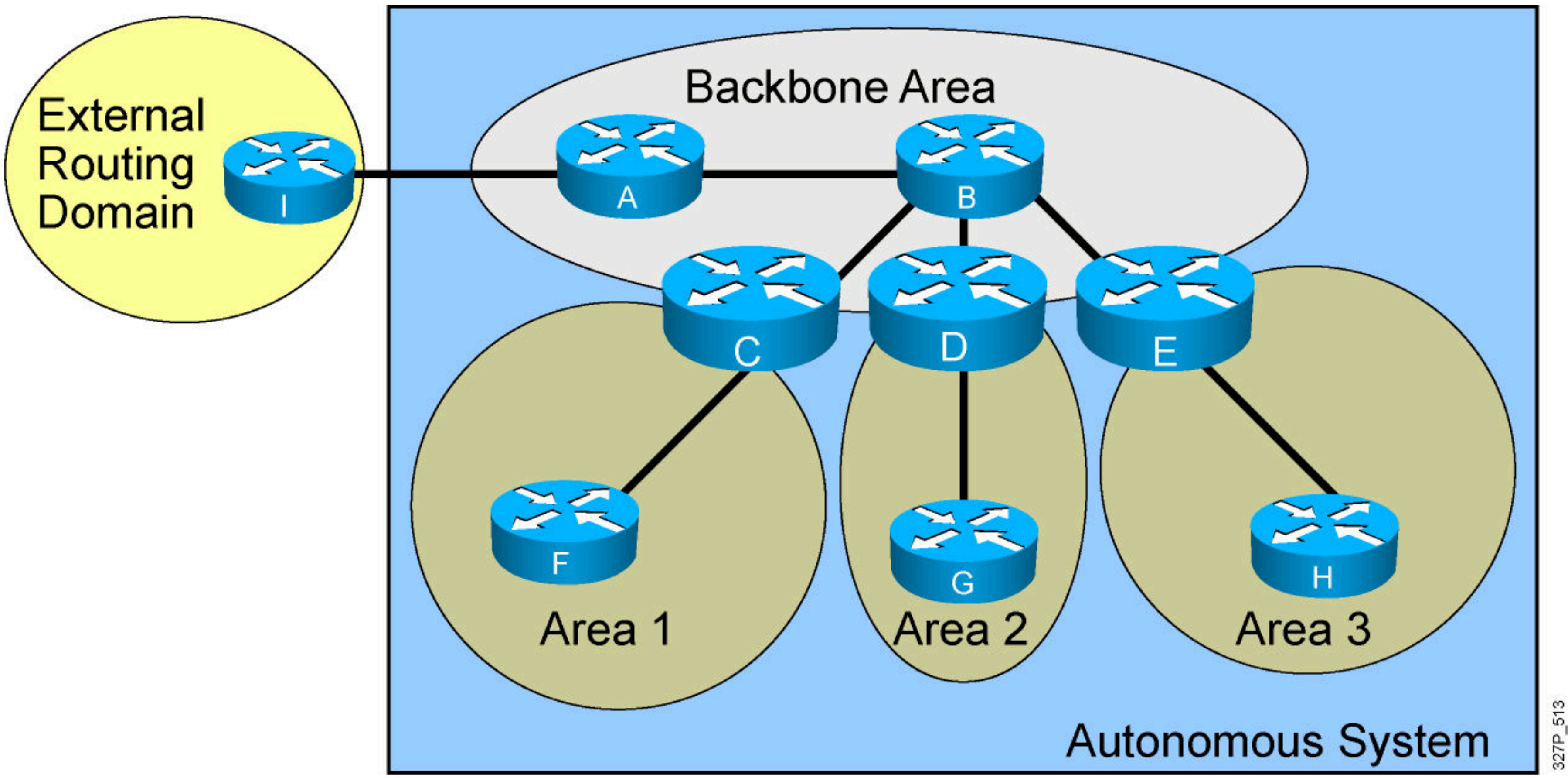
- **Benefits of link-state routing:**
  - **Fast convergence:**
    - **Changes are reported immediately by the affected source**
  - **Robustness against routing loops:**
    - **Routers know the topology**
    - **Link-state packets are sequenced and acknowledged**
  - **Hierarchical network design enables optimization of resources.**

- **Drawbacks of link-state routing:**
  - **Significant demands for resources:**
    - **Memory (three tables: adjacency, topology, forwarding)**
    - **CPU (Dijkstra’s algorithm can be intensive, especially when there are many instabilities)**
  - **Requires very strict network design**
  - **Configuration can be complex when tuning various parameters and when design is complex**

OSPF Overview

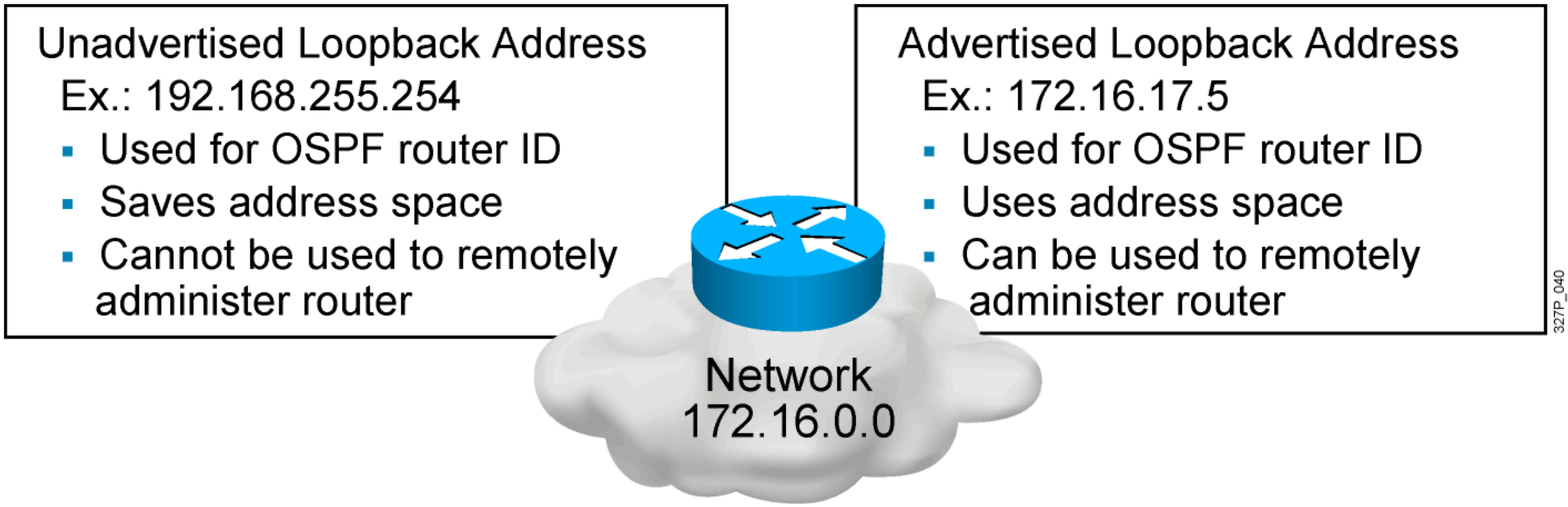
- Creates a neighbor relationship by exchanging hello packets
- Propagates LSAs rather than routing table updates
  - Link: Router interface
  - State: Description of an interface and its relationship to neighboring routers
- Floods LSAs to all OSPF routers in the area, not just directly connected routers
- Pieces together all the LSAs generated by the OSPF routers to create the OSPF link-state database
- Uses the SPF algorithm to calculate the shortest path to each destination and places it in the routing table

OSPF Hierarchy Example



- Minimizes routing table entries
- Localizes the impact of a topology change within an area

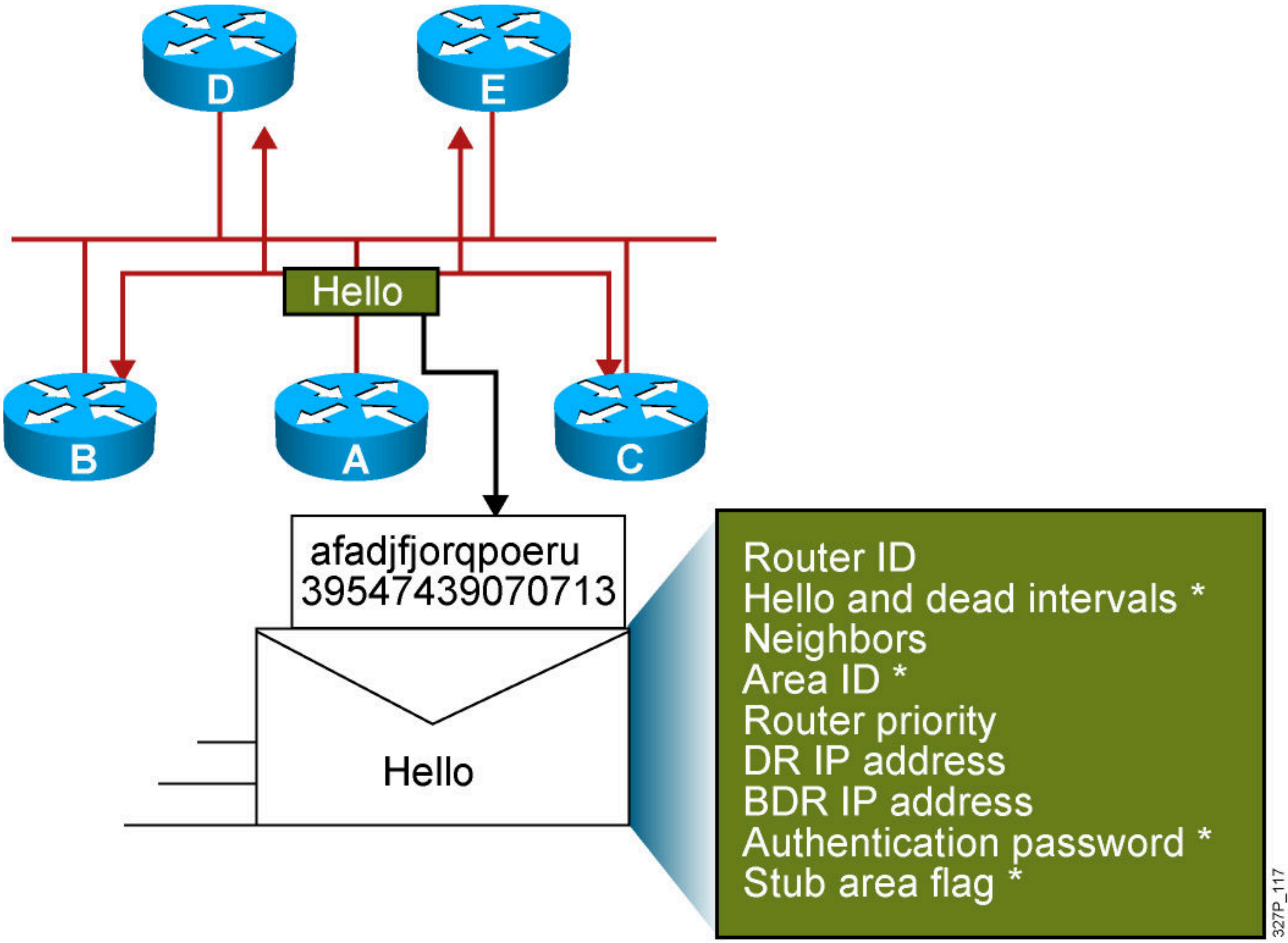
Configuring Loopback Interfaces



Router ID:

- Number by which the router is known to OSPF
- Default: The highest IP address on an active interface at the moment of OSPF process startup
- Can be overridden by a loopback interface: Highest IP address of any active loopback interface
- Can be set manually using the **router-id** command

Neighbor Adjacencies: The Hello Packet

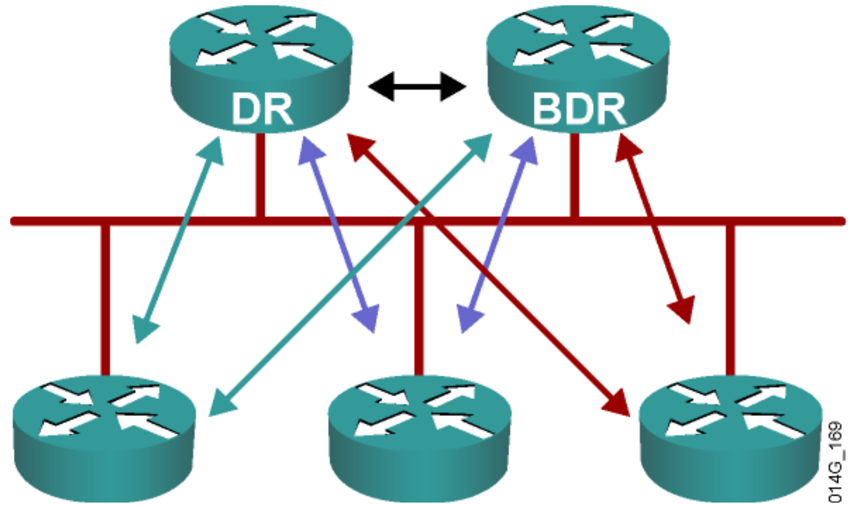


* Entry must match on neighboring routers

Point-to-Point Links

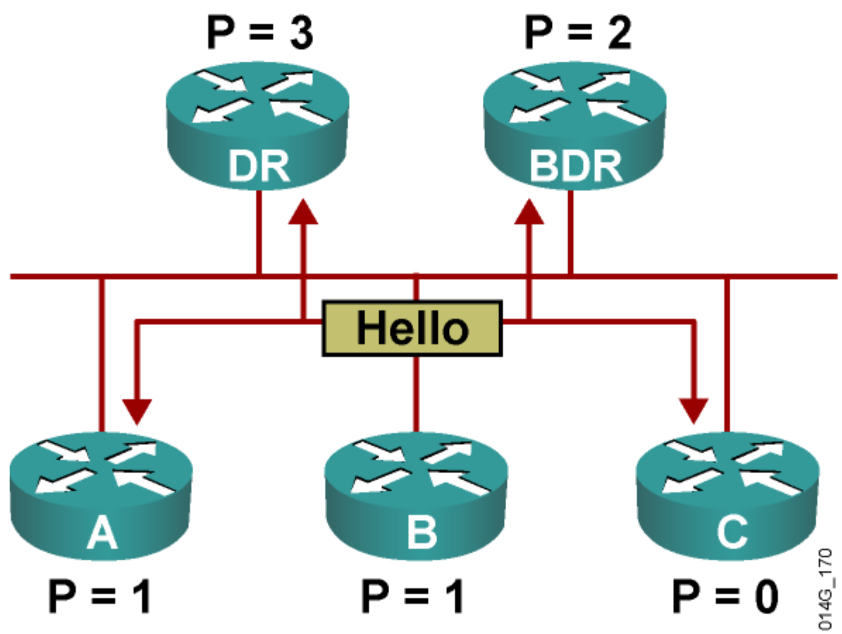
- Usually a serial interface running either PPP or HDLC.
- May also be a point-to-point subinterface running Frame Relay or ATM.
- No DR or BDR election required.
- OSPF autodetects this interface type.
- OSPF packets are sent using multicast 224.0.0.5.

Multiaccess Broadcast Network



- Generally these are, LAN technologies like Ethernet and Token Ring.
- DR and BDR selection are required.
- All neighbor routers form full adjacencies with the DR and BDR only.
- Packets to the DR and the BDR use 224.0.0.6.
- Packets from DR to all other routers use 224.0.0.5.

Electing the DR and BDR



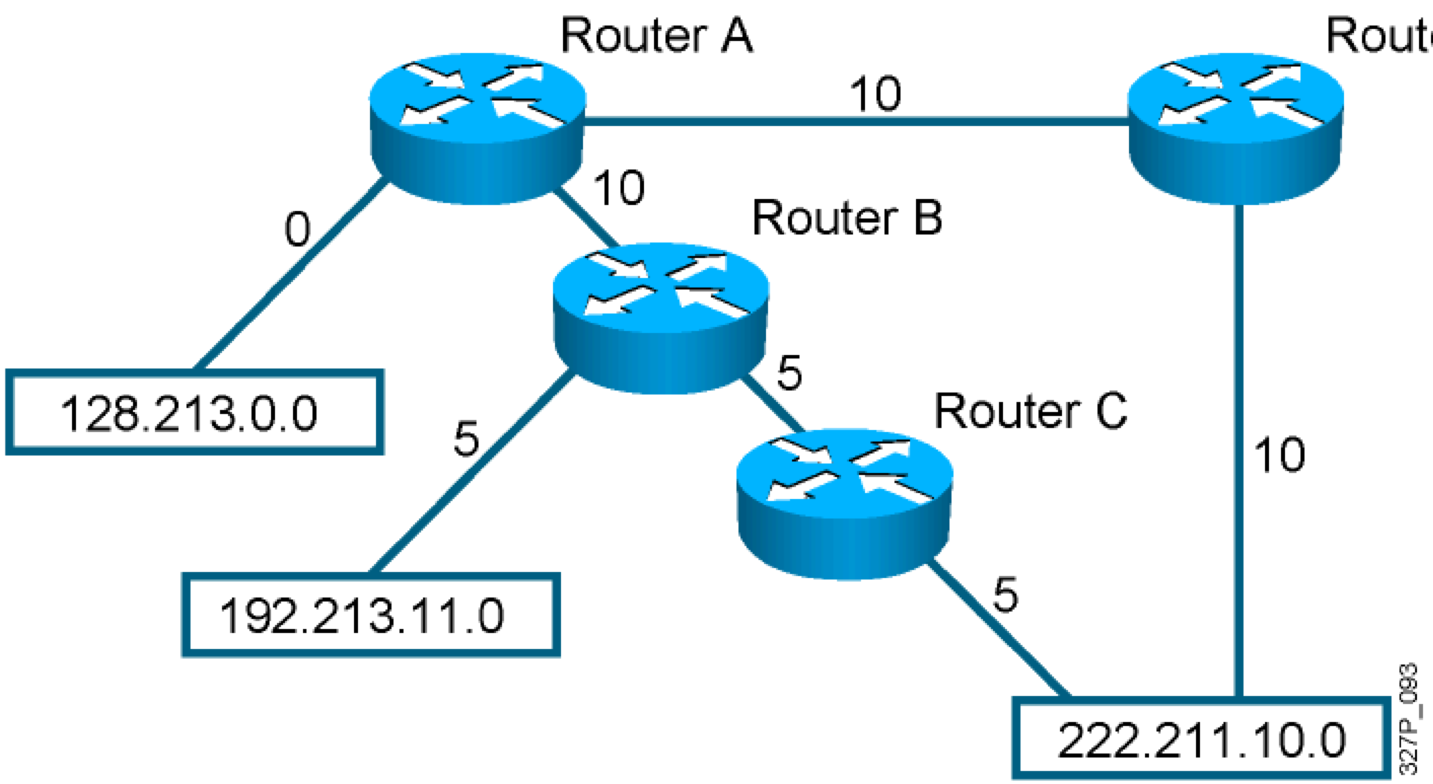
- Hello packets are exchanged via IP multicast.
- The router with the highest OSPF priority is selected as the DR. The router with the second-highest priority value is the BDR.
- Use the OSPF router ID as the tiebreaker.
- The DR election is nonpreemptive.

Setting Priority for DR Election

```
Router(config-if)#
ip ospf priority number
```

- This interface configuration command assigns the OSPF priority to an interface.
- Different interfaces on a router may be assigned different values.
- The default priority is 1. The range is from 0 to 255.
- 0 means the router cannot be the DR or BDR.
- A router that is not the DR or BDR is DROTHER.

SPF Algorithm



- Places each router at the root of a tree and calculates the shortest path to each destination based on the cumulative cost

Configuring Single-Area OSPF

```
RouterX(config)#
```

```
router ospf process-id
```

- Defines OSPF as the IP routing protocol

```
RouterX(config-router)#
```

```
network address wildcard-mask area area-id
```

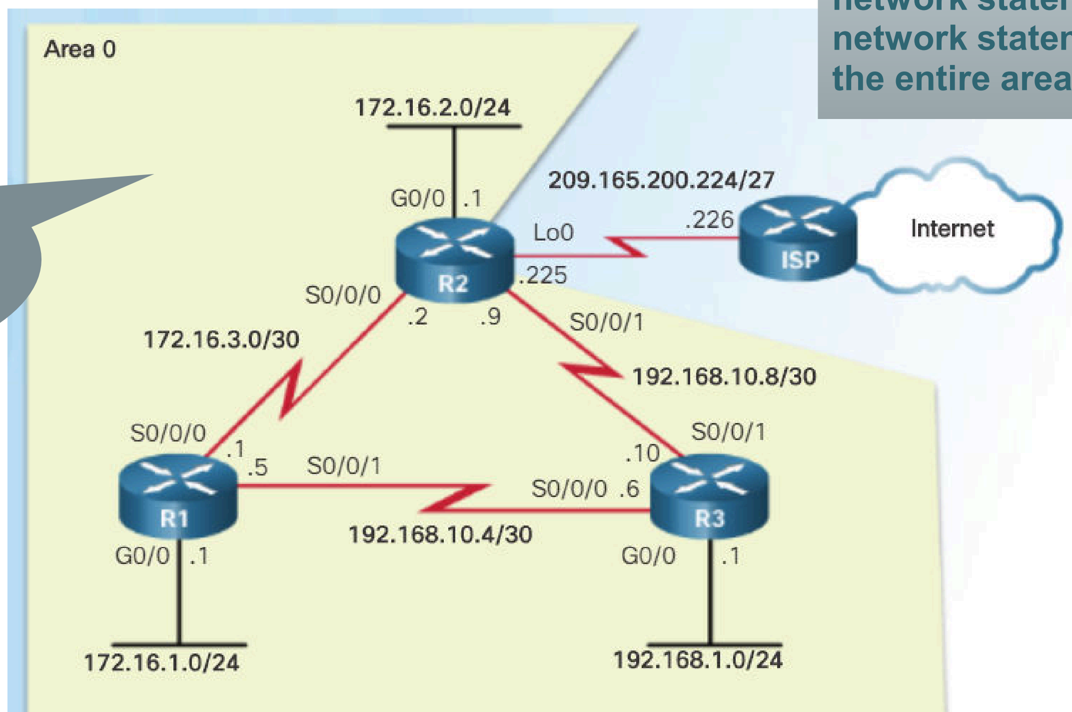
- Assigns networks to a specific OSPF area

Configuring Single-Area OSPF

Common misconception!

R2 has 3 interfaces in Area 0 so three network statements are used (not 6 network statements for all 6 networks in the entire area)

If a single-area topology is used, it is best to use Area 0




```
R1(config)# router ospf 10
R1(config-router)# network 172.16.1.0 0.0.0.255 area 0
R1(config-router)# network 172.16.3.0 0.0.0.3 area 0
R1(config-router)# network 192.168.10.4 0.0.0.3 area 0
```

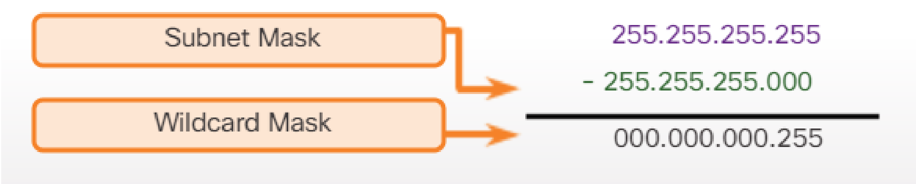
Wildcard Mask

To determine the wildcard mask, subtract the normal mask from 255.255.255.255

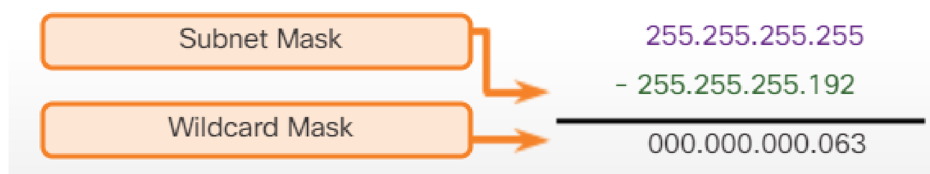
A wildcard mask bit of 0 – match the bit

A wildcard mask bit of 1 – ignore the bit

A wildcard mask is a series of 0s with the rest 1s (the 0s and 1s are not alternating like an IP address)



/24 mask



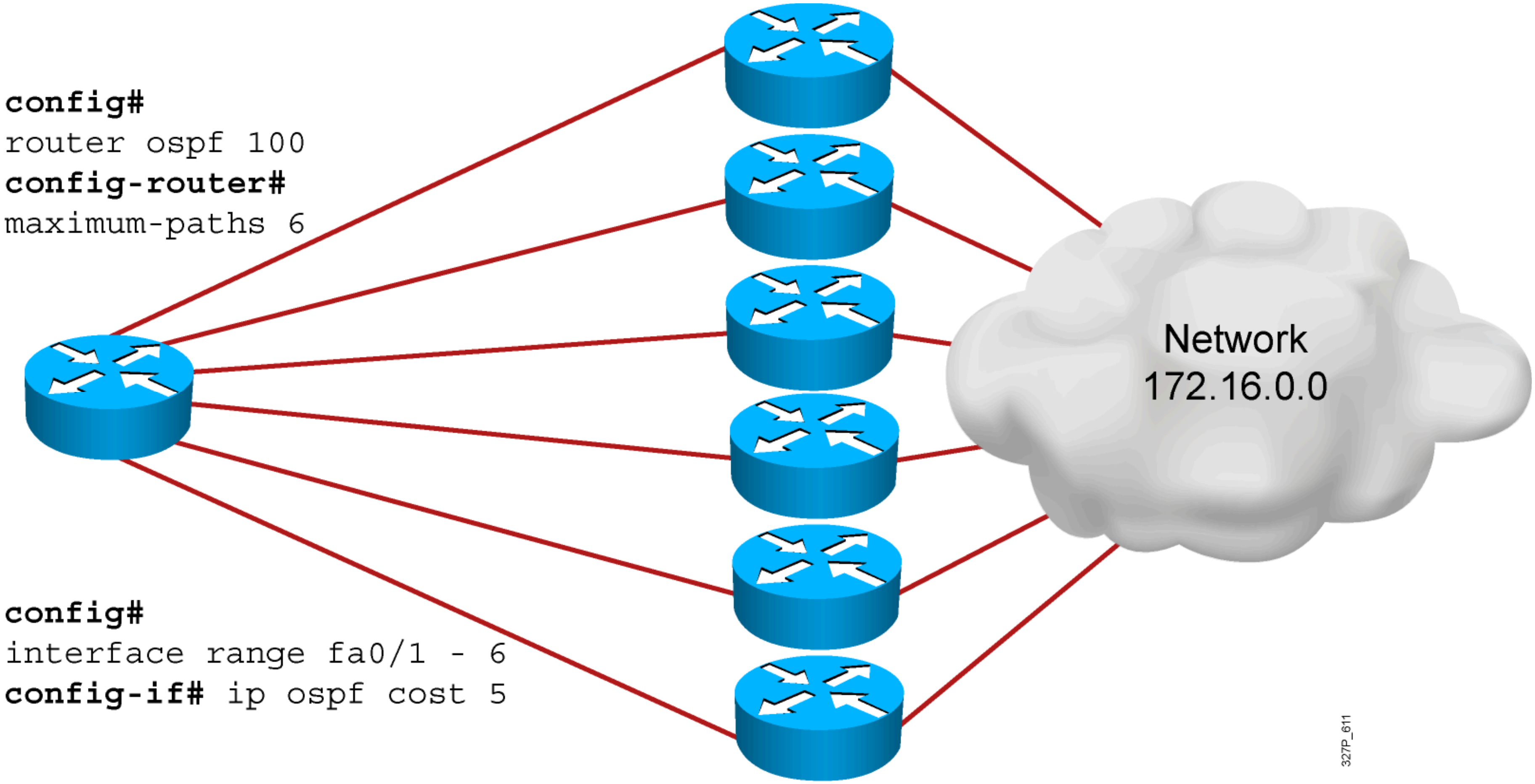
/26 mask

Load Balancing with OSPF

OSPF load balancing:

- Paths must be equal cost
- By default, up to four equal-cost paths can be placed into the routing table
- With a configuration change, up to a maximum of 16 paths can be configured:
  - `(config-router)# maximum-paths <value>`
- To ensure paths are equal cost for load balancing, you can change the cost of a particular link:
  - `(config-if)# ip ospf cost <value>`

Load Balancing with OSPF



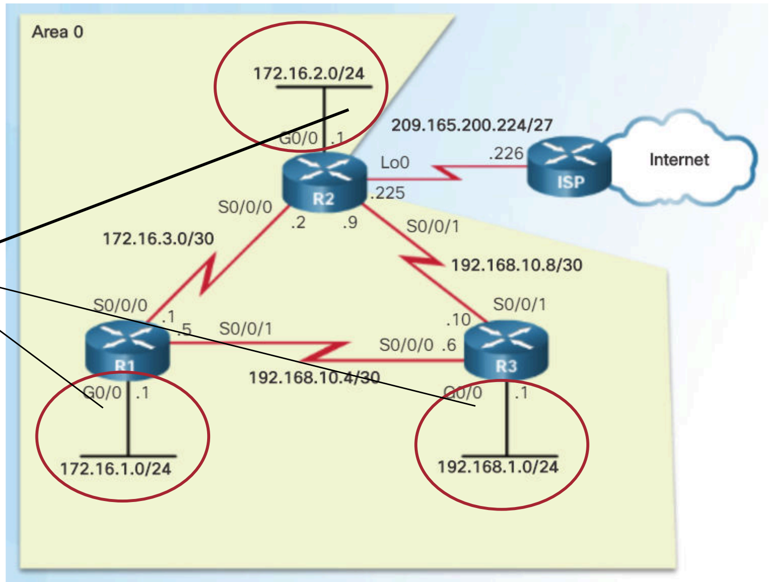
Passive Interface

An interface configured as a passive interface does not SEND OSPF messages.

Best practice for interfaces that have users attached (security)

Doesn't waste bandwidth sending messages out OSPF-enabled interfaces that don't have another router attached.

Interfaces to configure as a passive interface



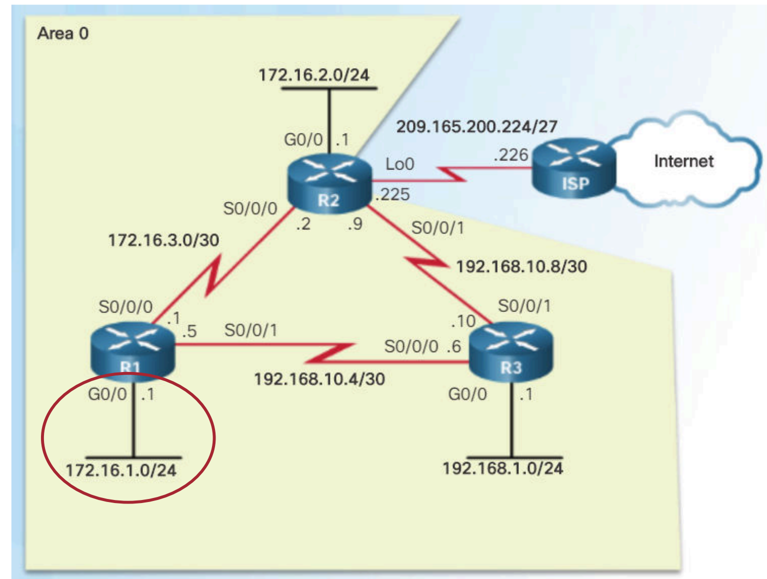
Configuring Passive Interfaces

Use the passive-interface command to configure

Use the show ip protocols to verify

```
R1(config)# router ospf 10
R1(config-router)# passive-interface GigabitEthernet 0/0
```

```
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
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    172.16.1.1 0.0.0.0 area 0
    172.16.3.1 0.0.0.0 area 0
    192.168.10.5 0.0.0.0 area 0
  Passive Interface(s):
    GigabitEthernet0/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      00:08:35
    2.2.2.2              110      00:08:35
  Distance: (default is 110)
```

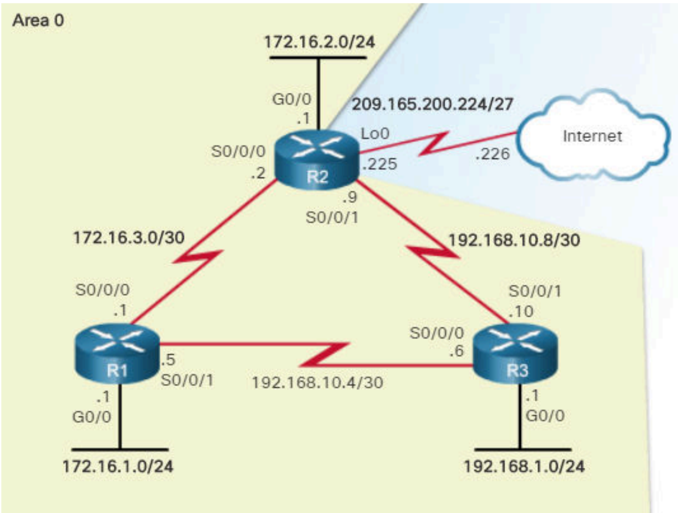


Default Route Propagation

An OSPF ASBR router (aka, edge, entrance, or the gateway router) connects to the Internet and can be configured to propagate a default route to other routers in the OSPF routing domain.

```
R2(config)# ip route 0.0.0.0 0.0.0.0 209.165.200.226
R2(config)#
R2(config)# router ospf 10
R2(config-router)# default-information originate
R2(config-router)# end
R2#
```

- **To propagate a default route, R2 is configured with:**
  - **A default static route.**
  - **ip route 0.0.0.0 0.0.0.0 {*ip-address* | *exit-intf*} command.**
  - **The default-information originate router config mode command to propagate the default route in OSPF updates.**



Verifying the OSPF Configuration

```
RouterX# show ip protocols
```

- Verifies that OSPF is configured

```
RouterX# show ip route
```

- Displays all the routes learned by the router

```
RouterX# show ip route

Codes: I - IGRP derived, R - RIP derived, O - OSPF derived,
C - connected, S - static, E - EGP derived, B - BGP derived,
E2 - OSPF external type 2 route, N1 - OSPF NSSA external type 1 route,
N2 - OSPF NSSA external type 2 route

Gateway of last resort is 10.119.254.240 to network 10.140.0.0

O 10.110.0.0 [110/5] via 10.119.254.6, 0:01:00, Ethernet2
O IA 10.67.10.0 [110/10] via 10.119.254.244, 0:02:22, Ethernet2
O 10.68.132.0 [110/5] via 10.119.254.6, 0:00:59, Ethernet2
O 10.130.0.0 [110/5] via 10.119.254.6, 0:00:59, Ethernet2
O E2 10.128.0.0 [170/10] via 10.119.254.244, 0:02:22, Ethernet2
```

Verifying the OSPF Configuration (Cont.)

```
RouterX# show ip ospf
```

- Displays the OSPF router ID, timers, and statistics

```
RouterX# show ip ospf
 Routing Process "ospf 50" with ID 10.64.0.2
<output omitted>

 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 Number of areas transit capable is 0
 External flood list length 0
    Area BACKBONE(0)
    Area BACKBONE(0)
        Area has no authentication
        SPF algorithm last executed 00:01:25.028 ago
        SPF algorithm executed 7 times
<output omitted>
```

Verifying the OSPF Configuration (Cont.)

```
RouterX# show ip ospf interface
```

- Displays the area ID and adjacency information

```
RouterX# show ip ospf interface ethernet 0

Ethernet 0 is up, line protocol is up
Internet Address 192.168.254.202, Mask 255.255.255.0, Area 0.0.0.0
AS 201, Router ID 192.168.99.1, Network Type BROADCAST, Cost: 10
Transmit Delay is 1 sec, State OTHER, Priority 1
Designated Router id 192.168.254.10, Interface address 192.168.254.10
Backup Designated router id 192.168.254.28, Interface addr 192.168.254.28
Timer intervals configured, Hello 10, Dead 60, Wait 40, Retransmit 5
Hello due in 0:00:05
Neighbor Count is 8, Adjacent neighbor count is 2
  Adjacent with neighbor 192.168.254.28 (Backup Designated Router)
  Adjacent with neighbor 192.168.254.10 (Designated Router)
```

Verifying the OSPF Configuration (Cont.)

```
RouterX# show ip ospf neighbor
```

- Displays the OSPF neighbor information on a per-interface basis

```
RouterX# show ip ospf neighbor

ID              Pri  State          Dead Time   Address          Interface
10.199.199.137  1    FULL/DR         0:00:31    192.168.80.37    FastEthernet0/0
172.16.48.1     1    FULL/DROTHER    0:00:33    172.16.48.1      FastEthernet0/1
172.16.48.200   1    FULL/DROTHER    0:00:33    172.16.48.200    FastEthernet0/1
10.199.199.137  5    FULL/DR         0:00:33    172.16.48.189    FastEthernet0/1
```

Verifying the OSPF Configuration (Cont.)

```
RouterX# show ip ospf neighbor 10.199.199.137
Neighbor 10.199.199.137, interface address 192.168.80.37
In the area 0.0.0.0 via interface Ethernet0
Neighbor priority is 1, State is FULL
Options 2
Dead timer due in 0:00:32
Link State retransmission due in 0:00:04
Neighbor 10.199.199.137, interface address 172.16.48.189
In the area 0.0.0.0 via interface Fddi0
Neighbor priority is 5, State is FULL
Options 2
Dead timer due in 0:00:32
Link State retransmission due in 0:00:03
```

OSPF debug Commands

```
RouterX# debug ip ospf events

OSPF:hello with invalid timers on interface Ethernet0
hello interval received 10 configured 10
net mask received 255.255.255.0 configured 255.255.255.0
dead interval received 40 configured 30

OSPF: rcv. v:2 t:1 l:48 rid:200.0.0.117
      aid:0.0.0.0 chk:6AB2 aut:0 auk:

RouterX# debug ip ospf packet

OSPF: rcv. v:2 t:1 l:48 rid:200.0.0.116
      aid:0.0.0.0 chk:0 aut:2 keyid:1 seq:0x0
```

OSPF Metric = Cost

OSPF uses the metric of cost to determine the best path used to reach a destination network

Cost = Reference Bandwidth / Interface Bandwidth (b/s) = 10^8/BW

Lowest cost is a better path

The interface bandwidth influences the cost assigned

- **A lower bandwidth interface has a higher cost**

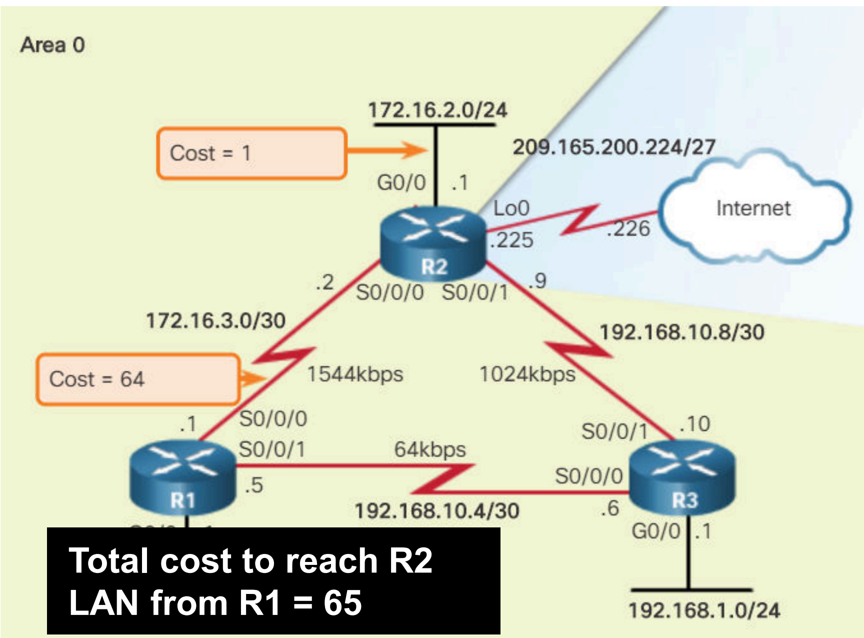
Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gbps Ethernet	100,000,000	÷	10,000,000,000	1
1 Gbps Ethernet	100,000,000	÷	1,000,000,000	1
100 Mbps Ethernet	100,000,000	÷	100,000,000	1
10 Mbps Ethernet	100,000,000	÷	10,000,000	10
1.544 Mbps Serial	100,000,000	÷	1,544,000	64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

This is an issue because it is the same cost due to the default reference bandwidth. Needs to be adjusted!

OSPF Accumulates Costs

The "cost" for a destination network is an accumulation of all cost values from source to destination.

The cost metric can be seen in the routing table as the second number within the brackets.

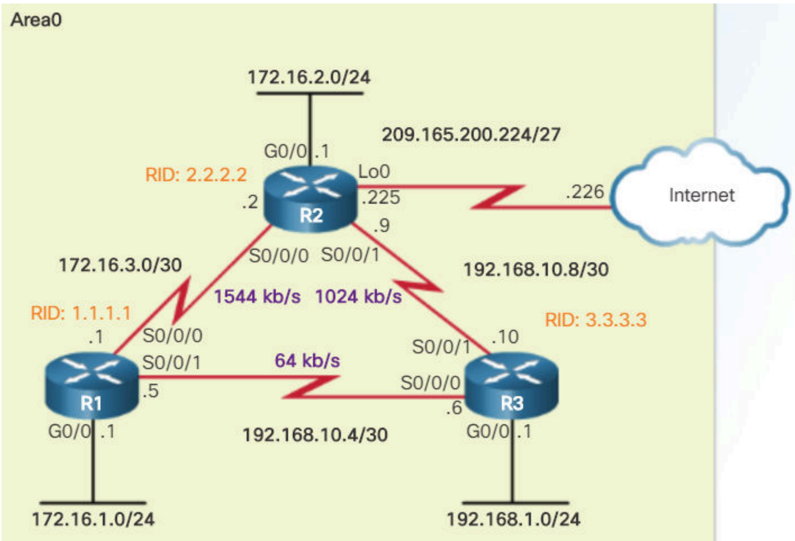


Cost metric to destination network 172.16.2.0 from R1

```
R1# show ip route | include 172.16.2.0
O        172.16.2.0/24 [110/65] via 172.16.3.2, 03:39:07,
         Serial0/0/0
R1#
R1# show ip route 172.16.2.0
Routing entry for 172.16.2.0/24
  Known via "ospf 10", distance 110, metric 65, type intra
  area
  Last update from 172.16.3.2 on Serial0/0/0, 03:39:15 ago
  Routing Descriptor Blocks:
  * 172.16.3.2, from 2.2.2.2, 03:39:15 ago, via Serial0/0/0
      Route metric is 65, traffic share count is 1
```

OSPF Cost

Adjusting the Interface Bandwidth




```
R1(config)# int s0/0/1
R1(config-if)# bandwidth 64
R1(config-if)# end
R1#
*Mar 27 10:10:07.735: %SYS-5-CONFIG_I: Configured from console by c
R1#
R1# show interfaces serial 0/0/1 | include BW
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
R1#
R1# show ip ospf interface serial 0/0/1 | include Cost:
  Process ID 10, Router ID 1.1.1.1, Network Type
  POINT_TO_POINT, Cost: 15625
R1#
```

- The bandwidth must be adjusted at each end of the serial links, therefore:
  - R2 requires its S0/0/1 interface to be adjusted to 1,024 kb/s.
  - R3 requires its serial 0/0/0 to be adjusted to 64 kb/s and its serial 0/0/1 to be adjusted to 1,024 kb/s.
- Note: Command only modifies OSPF bandwidth metric. Does not modify the actual link bandwidth.

Manually Setting the OSPF Cost

Instead of manually setting the interface bandwidth, the OSPF cost can be manually configured using the ip ospf cost *value* interface configuration mode command.

The no bandwidth 64 is used to remove the command that was previously applied and reset the bandwidth back to the default.

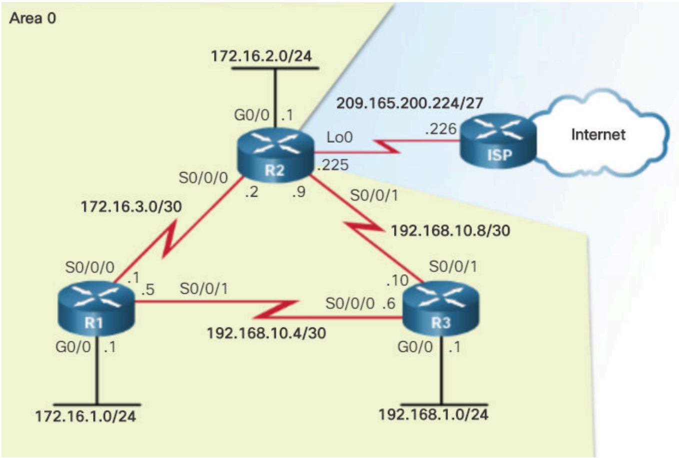
```
R1(config)# int s0/0/1
R1(config-if)# no bandwidth 64
R1(config-if)# ip ospf cost 15625
R1(config-if)# end
R1#
R1# show interface serial 0/0/1 | include BW
    MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
R1#
R1# show ip ospf interface serial 0/0/1 | include Cost:
    Process ID 10, Router ID 1.1.1.1, Network Type POINT_TO_POINT,
    Cost: 15625
```

Adjusting the Interface Bandwidth	=	Manually Setting the OSPF Cost
R1(config)# **interface S0/0/1** R1(config-if)# **bandwidth 64**	=	R1(config)# **interface S0/0/1** R1(config-if)# **ip ospf cost 15625**
R2(config)# **interface S0/0/1** R2(config-if)# **bandwidth 1024**	=	R2(config)# **interface S0/0/1** R2(config-if)# **ip ospf cost 976**
R3(config)# **interface S0/0/0** R3(config-if)# **bandwidth 64**	=	R3(config)# **interface S0/0/0** R3(config-if)# **ip ospf cost 15625**
R3(config)# **interface S0/0/1** R3(config-if)# **bandwidth 1024**	=	R3(config)# **interface S0/0/1** R3(config-if)# **ip ospf cost 976**

Verify OSPF Neighbors

Use the show ip ospf neighbor to verify the router has formed an adjacency with a directly-connected router.

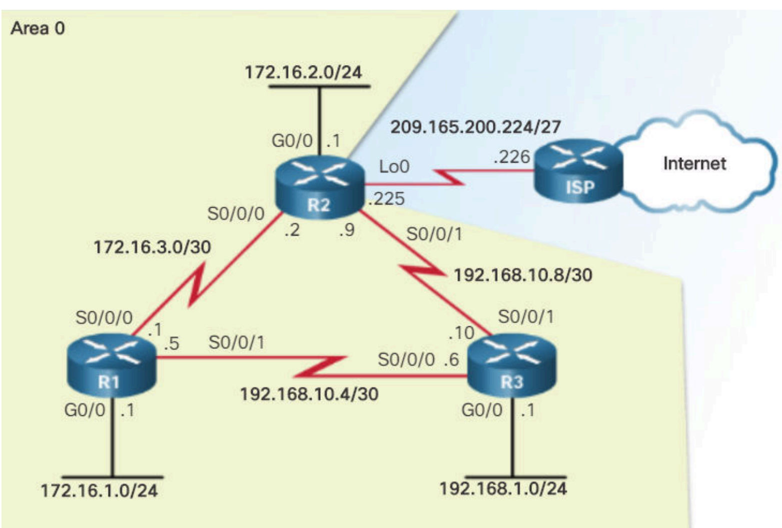
```
R1# show ip ospf neighbor

Neighbor ID  Pri State  Dead Time  Address        Interface
3.3.3.3       0  FULL/- 00:00:37  192.168.10.6   Serial0/0/1
2.2.2.2       0  FULL/- 00:00:30  172.16.3.2     Serial0/0/0
```



Output	Description
Neighbor ID	The router ID of the neighbor router
Pri	The OSPFv2 priority of the interface used in the DR/BDR election process
State	The OSPFv2 state – Full means that the link-state database has had the algorithm executed and the neighbor router and R1 have identical LSDBs. Ethernet multi-access interfaces may show as 2WAY. The dash indicates that no DR/BDR is required.
Dead time	Amount of time remaining before expecting to receive a hello packet from the neighbor before declaring the neighbor down. This value is reset when a hello packet is received.
Address	The address of the neighbor's directly-connected interface
Interface	The interface on R1 used to form an adjacency with the neighbor router

Verify OSPF Protocol Settings

The show ip protocols command is used to verify the OSPFv2 process ID, router ID, networks being advertised by the router, neighbors that are sending OSPF updates, and the administrative distance (110 by default).




```
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
  Number of areas in this router is 1. 1 normal 0 stub 0
  nssa
  Maximum path: 4
  Routing for Networks:
    172.16.1.0 0.0.0.255 area 0
    172.16.3.0 0.0.0.3 area 0
    192.168.10.4 0.0.0.3 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    2.2.2.2              110      00:17:18
    3.3.3.3              110      00:14:49
  Distance: (default is 110)
```

Verify OSPF Interface Settings

Use the show ip ospf interface command to see details for every OSPFv2-enabled interface especially to see if the network statements were correctly composed.

Use the show ip ospf interface brief command to see key information about OSPFv2-enabled interfaces on a particular router.

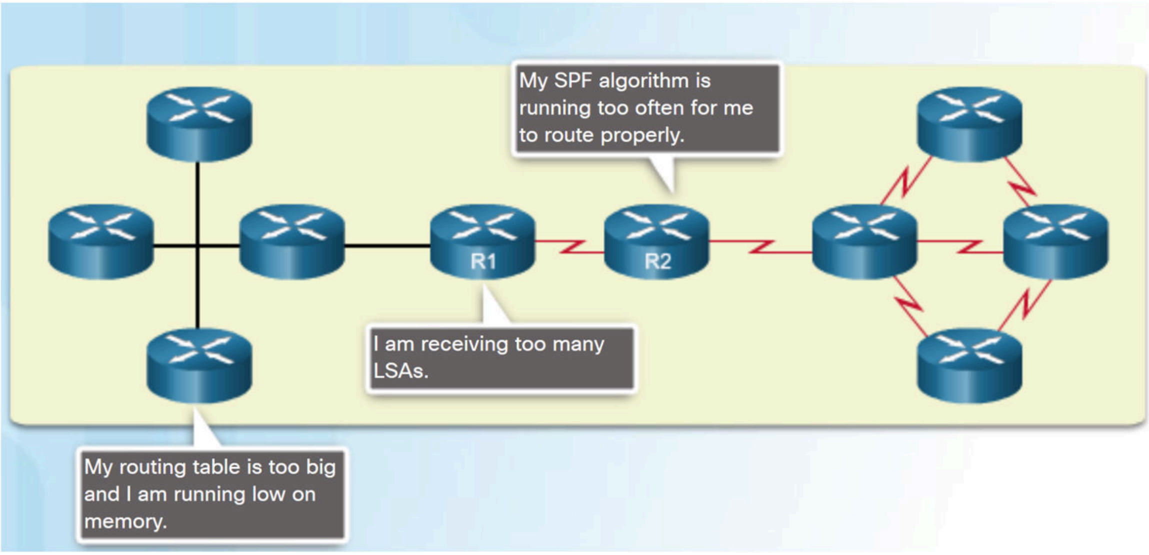
```
R1# show ip ospf interface brief
Interface  PID  Area  IP Address/Mask   Cost  State  Nbrs F/C
Se0/0/1    10   0     192.168.10.5/30   15625 P2P    1/1
Se0/0/0    10   0     172.16.3.1/30     647   P2P    1/1
Gi0/0      10   0     172.16.1.1/24     1     DR     0/0
```

Multiarea OSPF - Why Multiarea OSPF?

Issues in a large single area OSPF:

- **Large routing table**
- **Large link-state database (LSDB)**
- **Frequent SPF algorithm calculations**

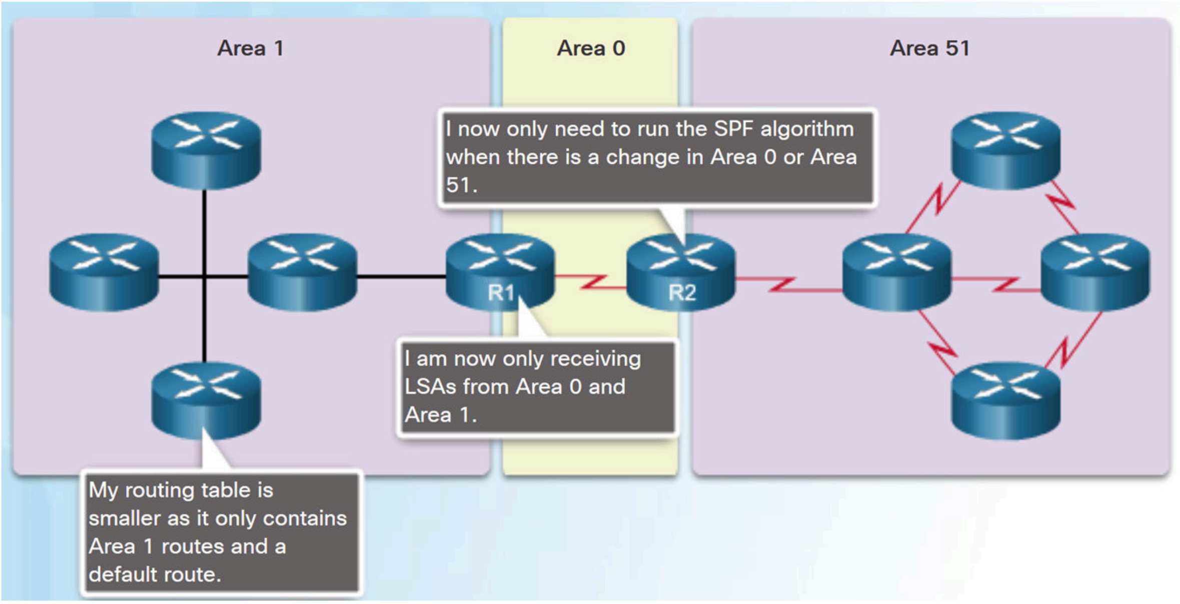
To make OSPF more efficient and scalable, OSPF supports hierarchical routing using areas.



Multiarea OSPF

Multiarea OSPF:

- Large OSPF area is divided into smaller areas.
- Reduces processing and memory overhead.
- Requires a hierarchical network design.
- The main area is the backbone area (area 0) and all other areas connect to it.



Advantages of Multiarea OSPF:

- Smaller routing tables - Fewer routing table entries as network addresses can be summarized between areas.
- Reduced link-state update overhead.
- Reduced frequency of SPF calculations.

OSPF 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 routes in an IPv4 routing table are identified using the following descriptors:

- O - The routing table reflects the link-state information with a designation of O, meaning that the route is intra-area
- O IA - Summary LSAs appear in the routing table as IA (interarea routes).
- O E1 or O E2 - External LSAs appear in the routing table marked as external type 1 (E1) or external type 2 (E2) routes.

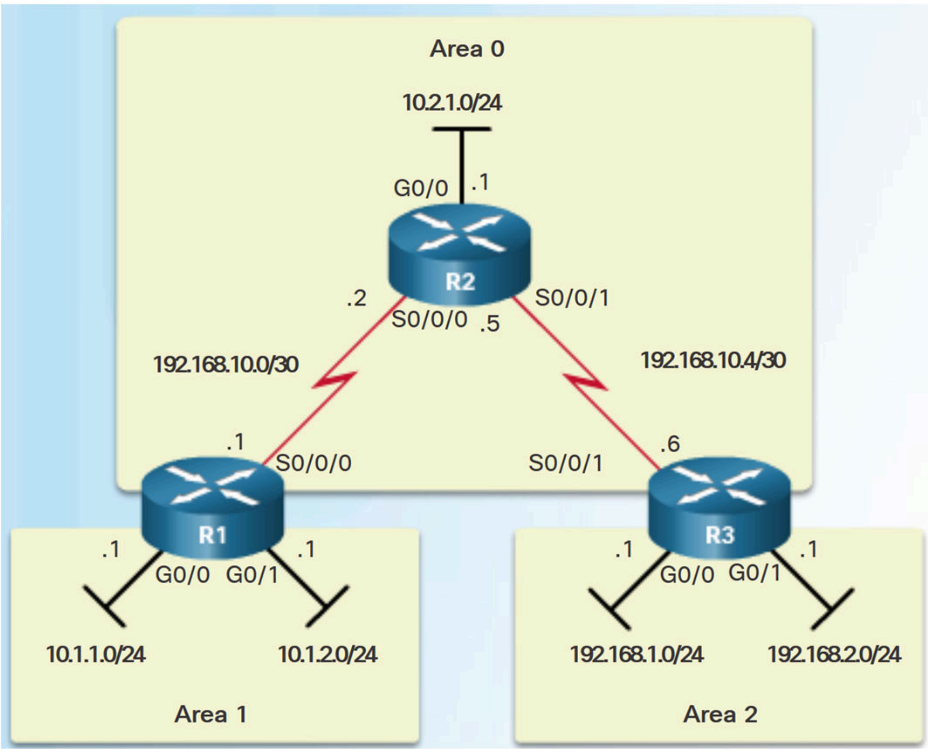
Configuring Multiarea OSPF

Implementing Multiarea OSPF

There are 4 steps to implementing multiarea OSPF:

- Step 1. Gather the network requirements and parameters
- Step 2. Define the OSPF parameters
  - Single area or multiarea OSPF?
  - IP addressing plan
  - OSPF areas
  - Network topology
- Step 3. Configure the multiarea OSPF implementation based on the parameters.
- Step 4. Verify the multiarea OSPF implementation

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#
```

There are no special commands to implement multiarea OSPFv2.

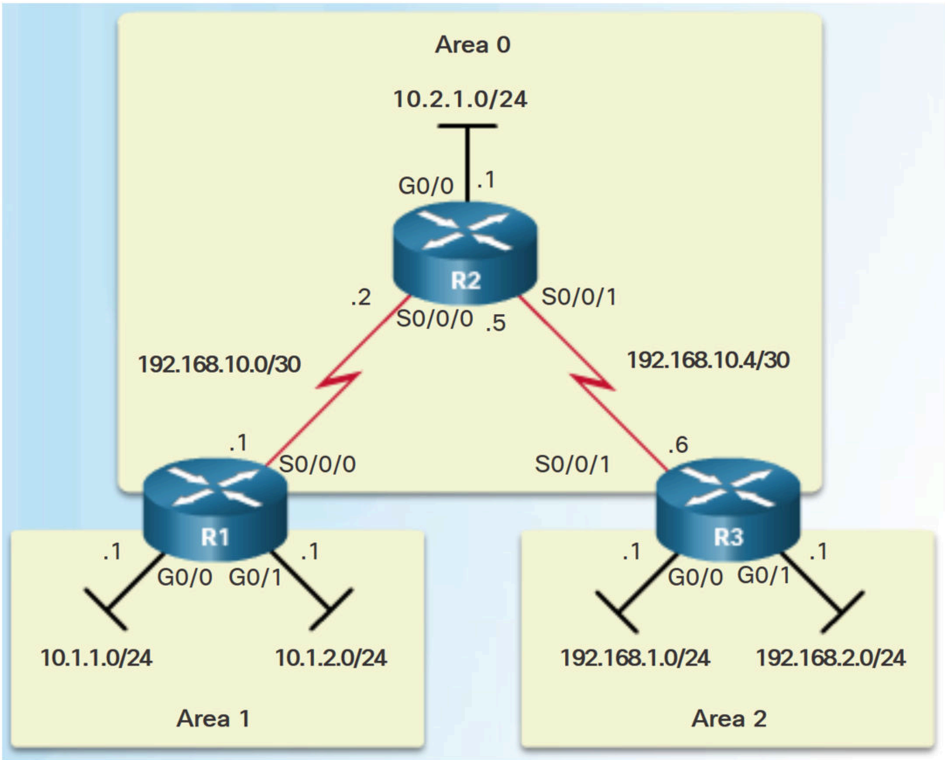
A router becomes an ABR when it has two network statements in different areas.

R1 is an ABR because it has interfaces in area 1 and an interface in area 0.

Verifying Multiarea OSPFv2

Commands to verify multiarea OSPFv2

- 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



Verify General Multiarea OSPFv2 Settings

Use the show ip protocols command to verify the OSPFv2 status.

- Lists routing protocols configured on router, number of areas, router ID and networks included in routing protocol.

Use the show ip ospf interface brief command to display OSPFv2-related information for OSPFv2-enabled interfaces.

- Lists the OSPFv2 process ID, area that the interfaces are in, and interface cost.

```
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# 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 OSPFv2 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#
```

Use the show ip route ospf command to verify the muliarea OSPFv2 configuration..

- **O represents OSPFv2 routes and IA represents interarea, which means that the route originated from another area.**

EIGRP

EIGRP Basic Features

Enhanced IGRP is a Cisco-proprietary distance-vector routing protocol released in 1992.

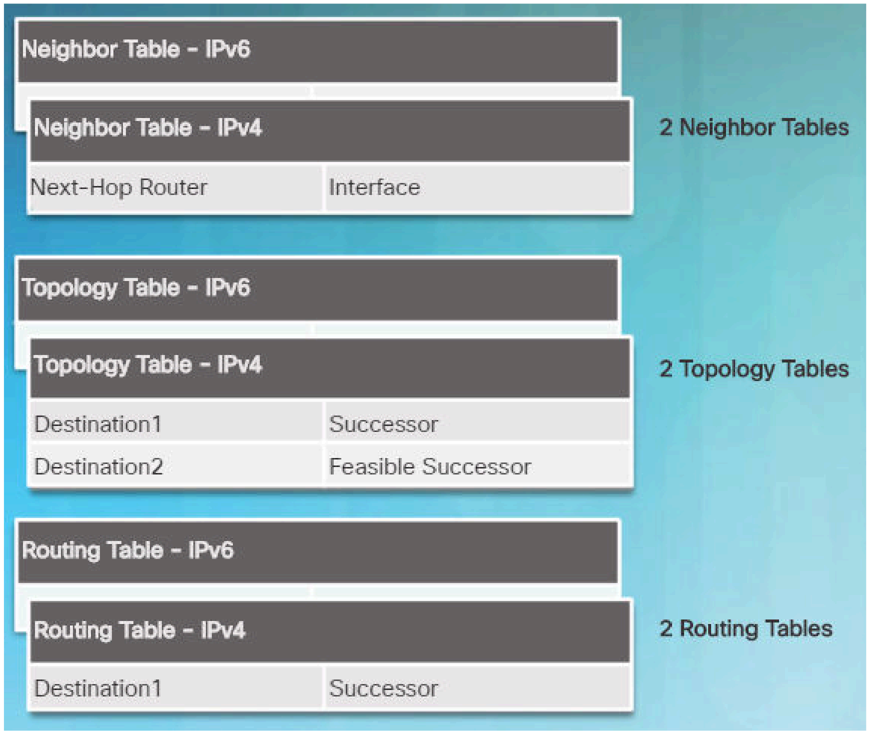
- **EIGRP was created as a classless version of IGRP.**
- **Ideal choice for large, multiprotocol networks built primarily on Cisco routers.**

EIGRP Feature	Description
Diffusing Update Algorithm (DUAL)	• EIGRP uses DUAL as its routing algorithm. • DUAL guarantees loop-free and backup paths throughout the routing domain.
Establishing Neighbor Adjacencies	• EIGRP establishes relationships with directly connected EIGRP routers. • Adjacencies are used to track the status of these neighbors.
Reliable Transport Protocol	• EIGRP RTP provides delivery of EIGRP packets to neighbors. • RTP and neighbor adjacencies are used by DUAL.
Partial and Bounded updates	• Instead of periodic updates, EIGRP sends partial triggered updates when a path or metric changes. • Only those routers that require the information are updated minimizing bandwidth use.
Equal and Unequal Cost Load Balancing	• EIGRP supports equal cost load balancing and unequal cost load balancing, which allows administrators to better distribute traffic flow in their networks.

EIGRP Basic Features

EIGRP uses protocol-dependent modules (PDMs) to support different protocols such as IPv4, IPv6, and legacy protocols IPX and AppleTalk.

EIGRP maintains individual tables for each routed protocol.

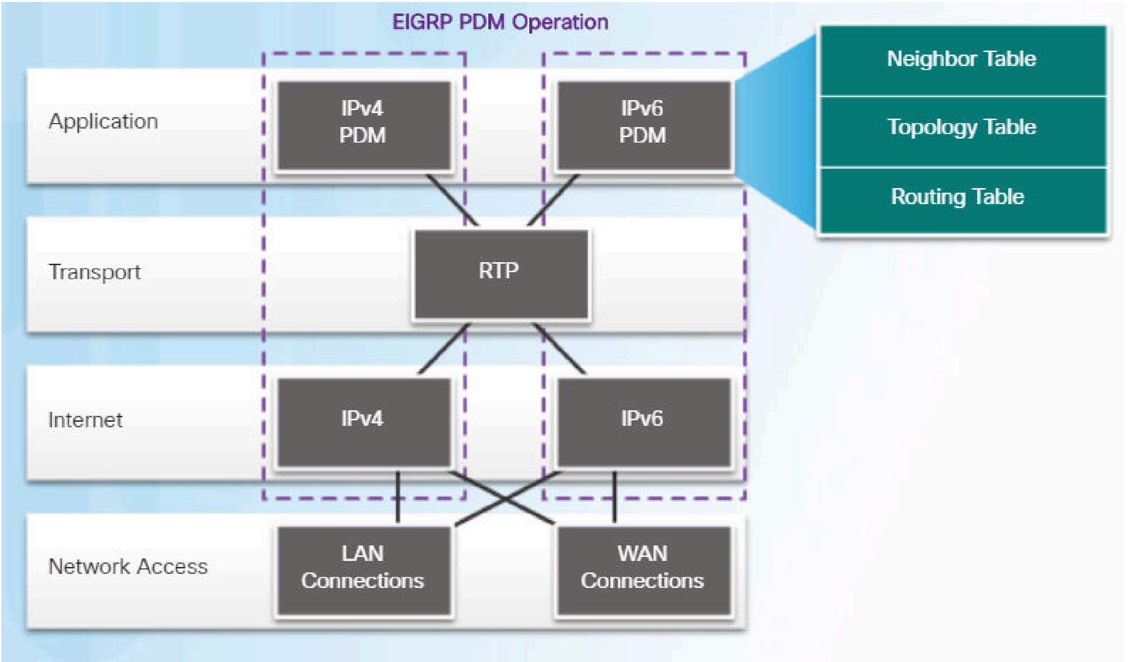


- PDMs are responsible for:
  - Maintaining EIGRP neighbor and topology tables
  - Computing the metric using DUAL
  - Interfacing DUAL and routing table
  - Implementing filtering and access lists
  - Performing redistribution with other routing protocols

EIGRP Basic Features

RTP is the EIGRP Transport layer protocol used for the delivery and reception of EIGRP packets.

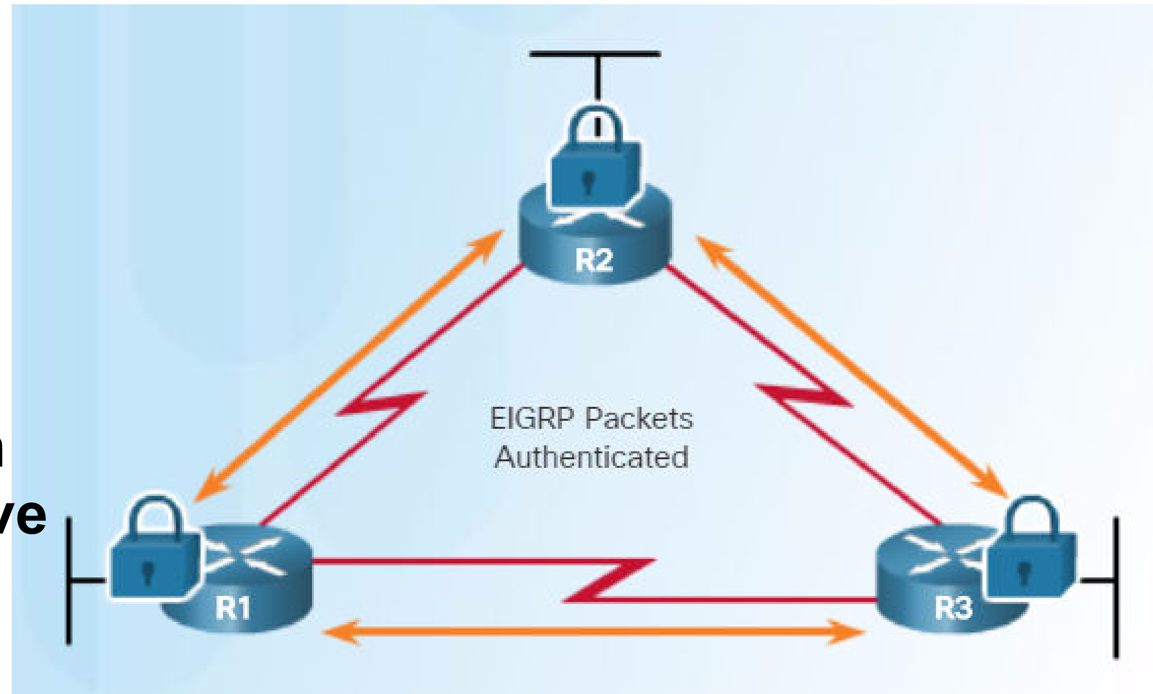
- Not all RTP packets are sent reliably.
  - Reliable packets require explicit acknowledgement from destination
  - Update, Query, Reply
  - Unreliable packets do not require acknowledgement from destination
  - Hello, ACK



EIGRP Basic Features

EIGRP supports authentication and is recommended.

- EIGRP authentication ensures that routers only accept routing information from other routers that have been configured with the same password or authentication information.



Note:

- Authentication does not encrypt the EIGRP routing updates.

EIGRP Packet Types

IP EIGRP relies on 5 types of packets to maintain its various tables and establish complex relationships with neighbor routers.

EIGRP Packet Types

Packet Type	Used to...
Hello	Discover other EIGRP routers in the network.
Update	Convey routing information to known destinations.
Acknowledgement	Acknowledge the receipt of any EIGRP packet.
Query	Request specific information from a neighbor router.
Reply	Respond to a query.

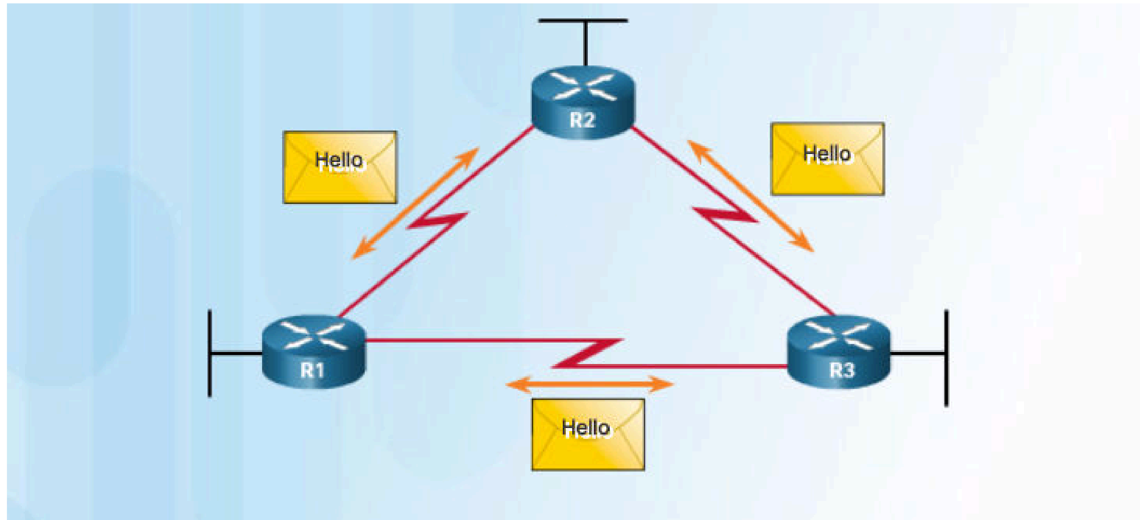
EIGRP Packet Types

Hello packets are used to discover & form adjacencies with neighbors.

- On hearing Hellos, a router creates a neighbor table and the continued receipt of Hellos maintains the table.

Hello packets are always sent unreliably.

- Therefore Hello packets do not require acknowledgment.



Bandwidth	Example Link	Default Hello Interval	Default Hold Time
1.544 Mb/s	Multipoint Frame Relay	60 seconds	180 seconds
Greater than 1.544 Mb/s	T1, Ethernet	5 seconds	15 seconds

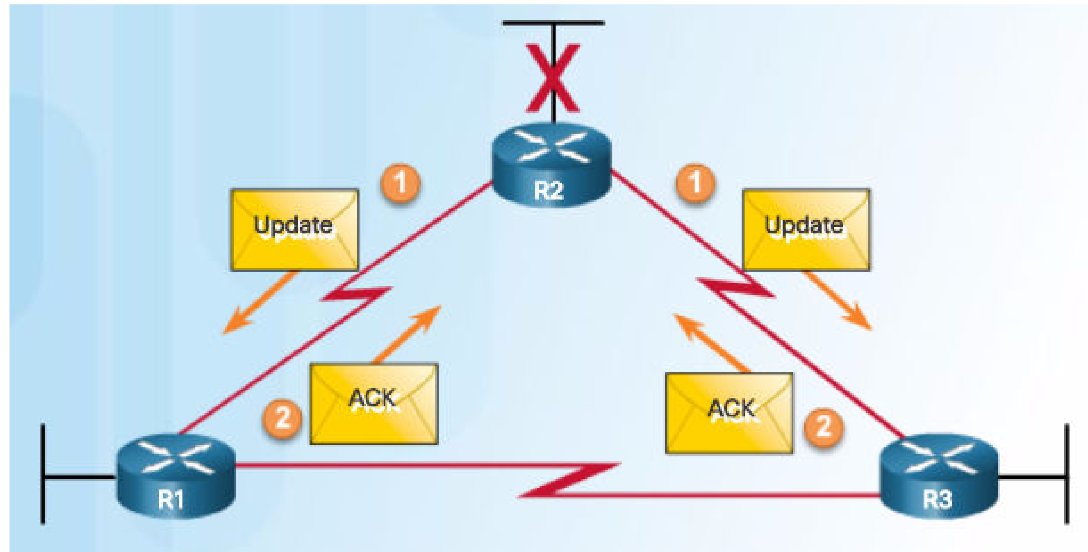
EIGRP uses multicast and unicast rather than broadcast.

- **As a result, end stations are unaffected by routing updates or queries.**
- **The EIGRP multicast IPv4 address is 224.0.0.10**
- **The EIGRP multicast IPv6 address is FF02::A.**

EIGRP Packet Types

EIGRP Update packets are used to propagate routing information.

- Sent to initially exchange topology information or topology change.
- EIGRP updates only contain needed routing information and are unicast to routers that require it.
- Update packets are sent reliably and therefore requires acknowledgements.



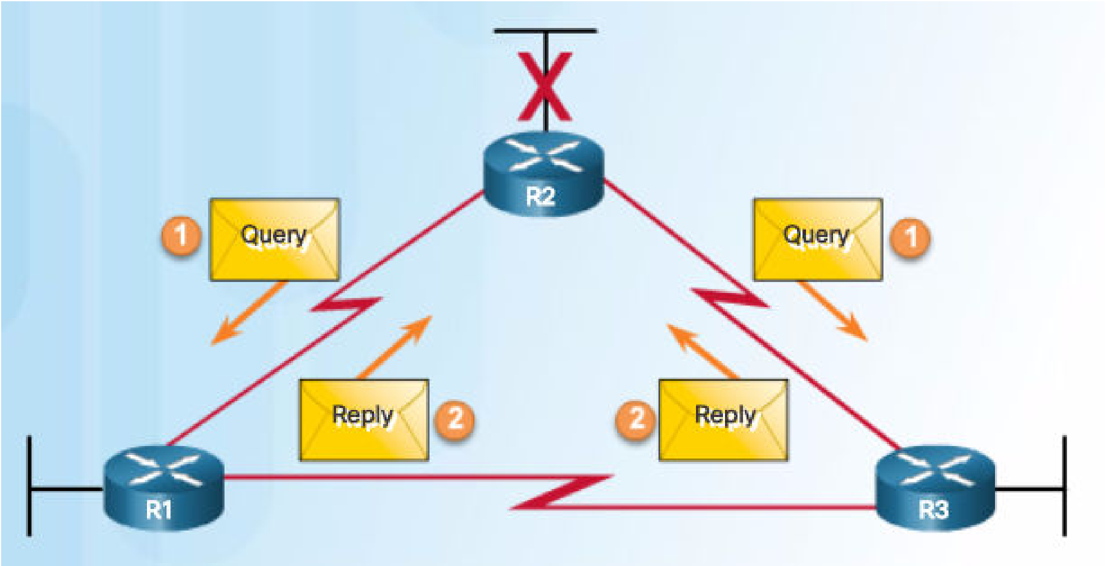
- Acknowledgements packets are “dataless” Hello packets used to indicate receipt of any EIGRP packet during a "reliable" (i.e., RTP) exchange.
  - Used to acknowledge the receipt of Update packets, Query packets, and Reply packets.

EIGRP Packet Types

Query and reply packets are used by DUAL when searching for networks.

They both use reliable delivery and therefore require acknowledgement.

Queries can use multicast or unicast, whereas Replies are always sent as unicast.



EIGRP Messages

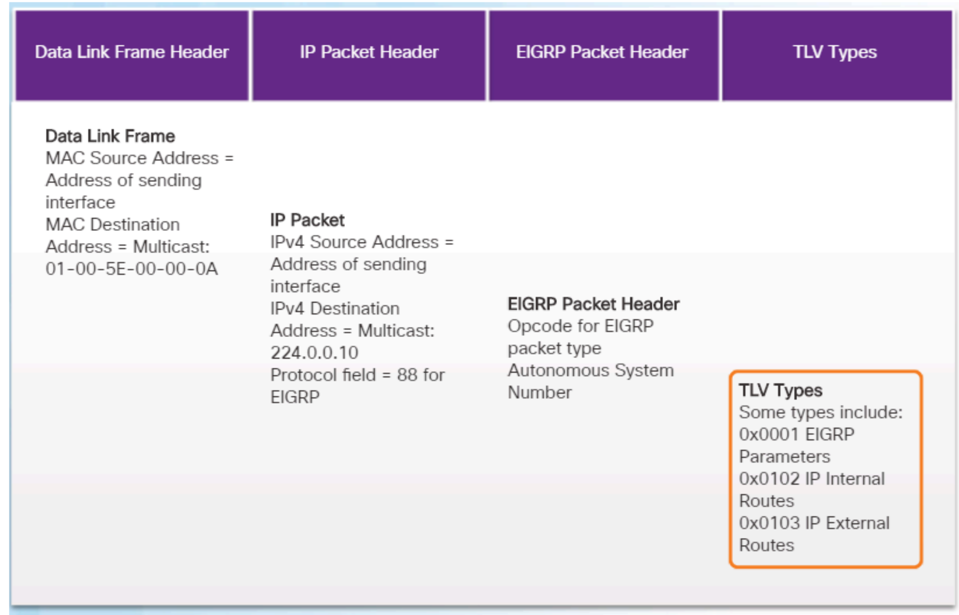
EIGRP frame contains destination multicast address 01-00-5E-00-00-0A.

The IP packet header contains destination IP address 224.0.0.10 and identifies this packet as an EIGRP packet (protocol 88).

The data portion of the EIGRP message includes:

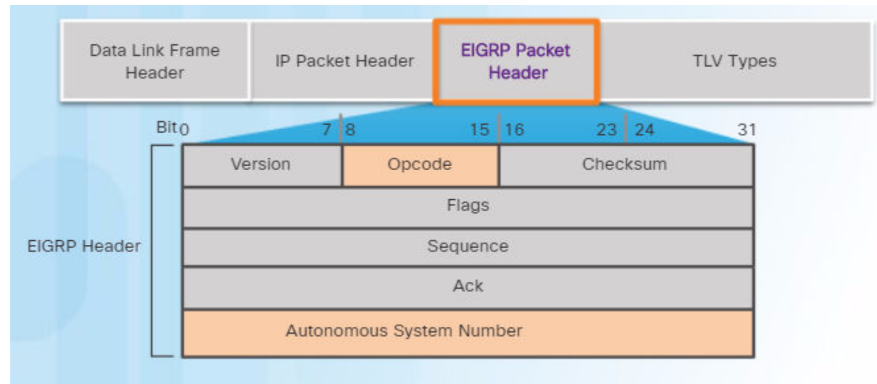
- Packet header - The EIGRP packet header identifies the type of EIGRP message.
- Type/Length/Value (TLV) - The TLV field contains EIGRP parameters, IP internal and external routes.

EIGRP for IPv6 is encapsulated using an IPv6 header with multicast address FF02::A and the next header field set to protocol 88.

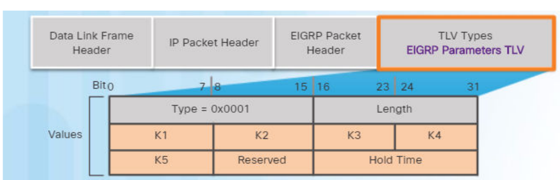


EIGRP Messages

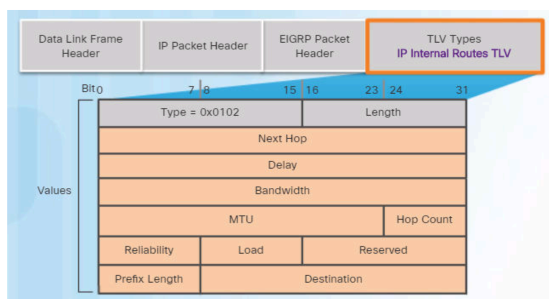
EIGRP messages include the header with an Opcode field that specifies the type of EIGRP packet (Hello, Ack, Update, Query, and Reply) and the AS number field.



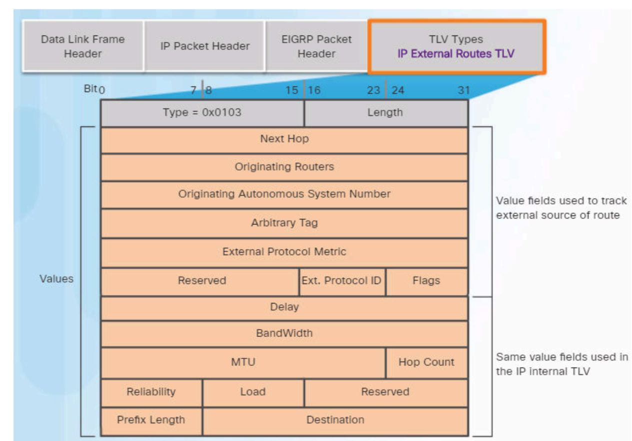
EIGRP TLV: EIGRP Parameters



EIGRP TLV: Internal Routes

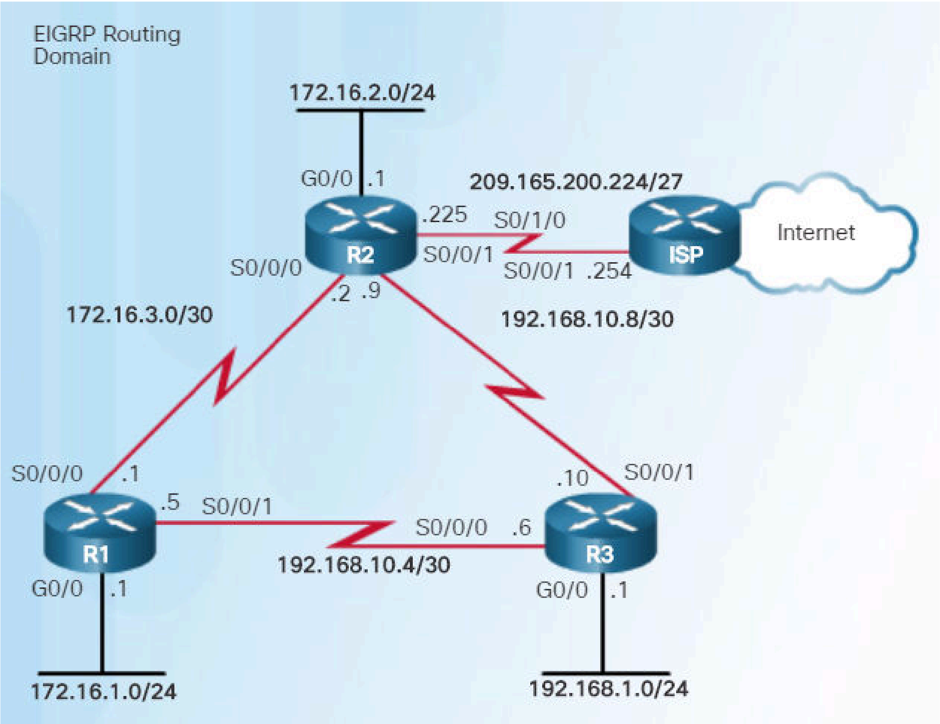


EIGRP TLV: External Routes



Configure EIGRP with IPv4

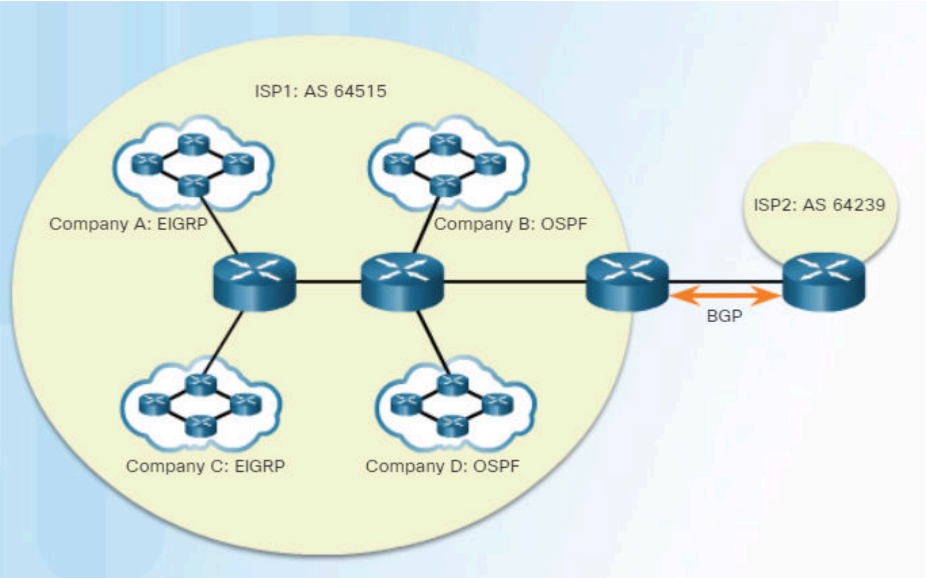
The routers in the topology have a starting configuration that includes addresses on the interfaces. There is currently no static routing or dynamic routing configured on any of the routers.



Configure EIGRP with IPv4

An Autonomous System (AS) is a collection of networks under the control of a single authority (reference RFC 1930).

- **AS numbers are needed to exchange routes between AS.**
- **AS numbers are managed by IANA and assigned by RIRs to ISPs, Internet Backbone providers, and institutions connecting to other institutions using AS numbers.**



- **AS numbers are usually 16-bit numbers, ranging from 0 to 65535.**
  - **Since 2007, AS numbers can now be 32 bits, therefore increasing the number of AS numbers to over 4 billion.**

Configure EIGRP with IPv4

To configure EIGRP, use the router eigrp *AS-#* command.

- **The *AS-#* functions as a process ID.**
- **The AS number used for EIGRP configuration is only significant to the EIGRP routing domain.**
- **All routers in the EIGRP routing domain must use the same AS number (process ID number).**

Note:

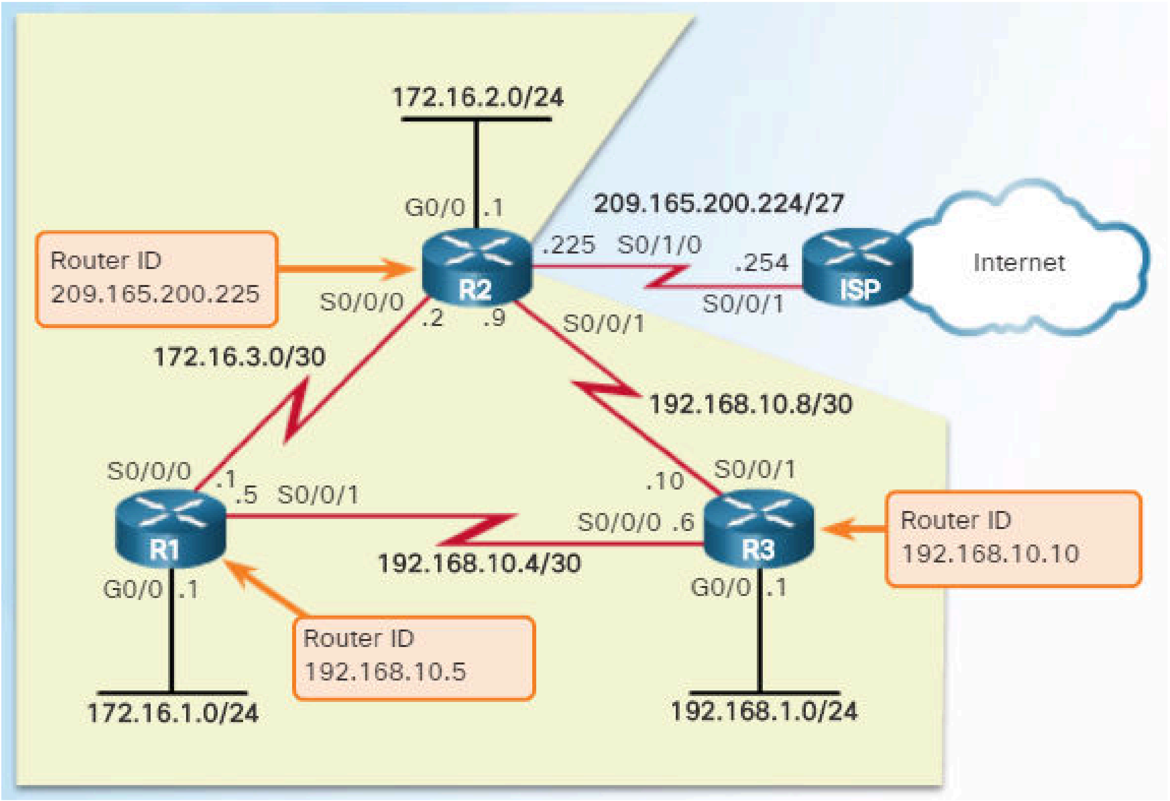
- **Do NOT configure multiple instances of EIGRP on the same router.**

Configure EIGRP with IPv4

The EIGRP router ID is used to uniquely identify each router in the EIGRP routing domain.

Routers use the following three criteria to determine its router ID:

1. Use the address configured with the eigrp router-id *ipv4-address* router config command.
2. If the router ID is not configured, choose the highest IPv4 address of any of its loopback interfaces.
3. If no loopback interfaces are configured, choose the highest active IPv4 address of any of its physical interfaces.

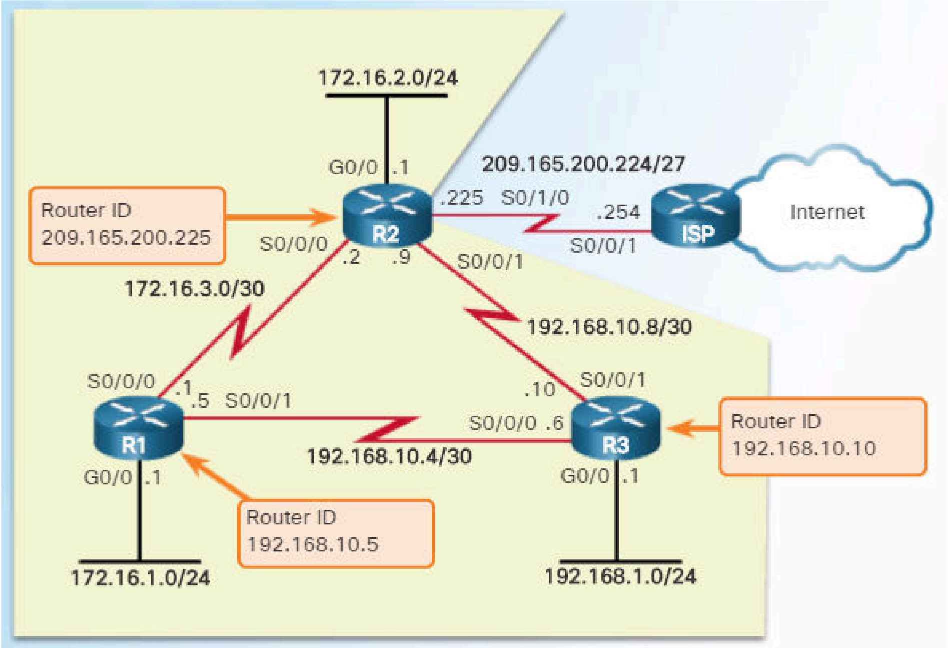


Configure EIGRP with IPv4

```
R1(config)# router eigrp 1
R1(config-router)# eigrp router-id 1.1.1.1
R1(config-router)#
```

```
R2(config)# router eigrp 1
R2(config-router)# eigrp router-id 2.2.2.2
R2(config-router)#
```

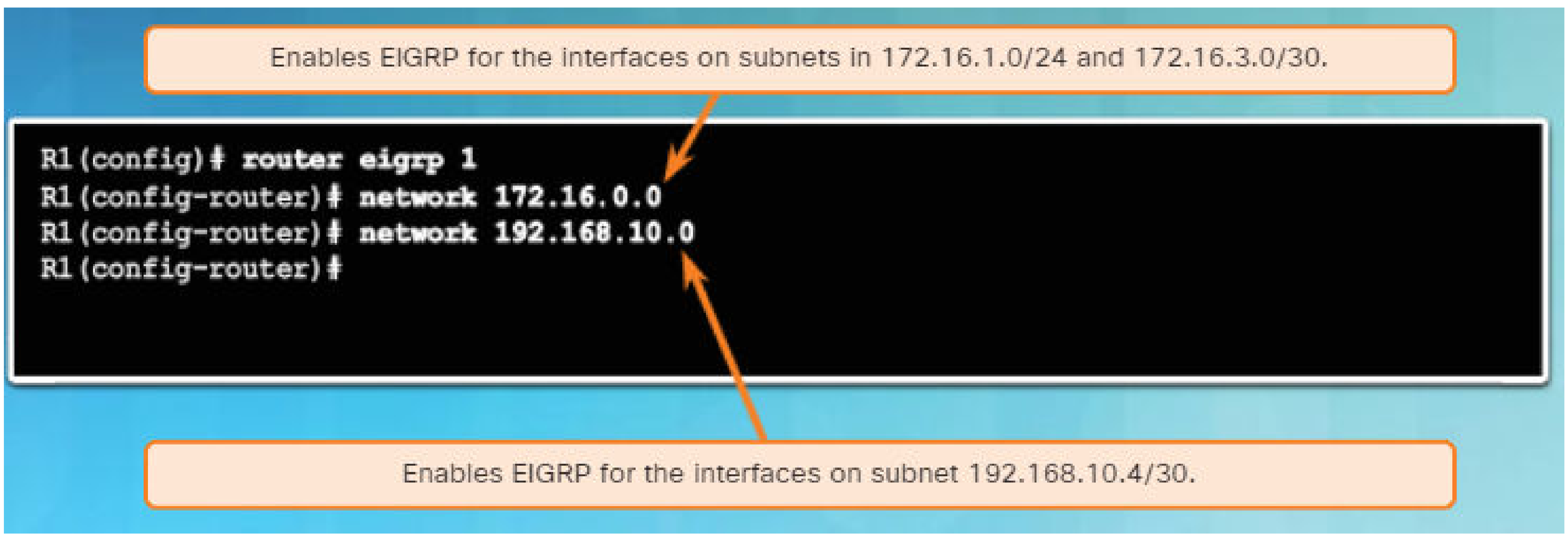
```
R1# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "eigrp 1"
  Outgoing update filter list for all interfaces is not
  set
  Incoming update filter list for all interfaces is not
  set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 Protocol for AS(1)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
    NSF-aware route hold timer is 240
    Router-ID: 1.1.1.1
    Topology : 0 (base)
      Active Timer: 3 min
      Distance: internal 90 external 170
      Maximum path: 4
      Maximum hopcount 100
      Maximum metric variance 1

  Automatic Summarization: disabled
  Maximum path: 4
  Routing for Networks:
  Routing Information Sources:
    Gateway         Distance      Last Update
  Distance: internal 90 external 170
```



Configure EIGRP with IPv4

Use the network *network-number* [*wildcard-mask*] router config command to enable and advertise a network in EIGRP.

- It enables the interfaces configured for that network address to begin transmitting & receiving EIGRP updates
- Includes network or subnet in EIGRP updates



Configure EIGRP with IPv4

A wildcard mask is similar to a subnet mask but is calculated by subtracting a SNM from 255.255.255.255.

```
R2(config)# router eigrp 1
R2(config-router)# network 192.168.10.8 0.0.0.3
R2(config-router)
```

- **For example, if the SNM is 255.255.255.252:**

```
  255.255.255.255
- 255.255.255.252
      0.  0.  0.  3
```

Wildcard mask

- **EIGRP also automatically converts a subnet mask to its wildcard mask equivalent.**
  - **E.g., entering 192.168.10.8 255.255.255.252 automatically converts to 192.168.10.8 0.0.0.3**

```
R2(config)# router eigrp 1
R2(config-router)# network 192.168.10.8 255.255.255.252
R2(config-router)# end
R2# show running-config | section eigrp 1
router eigrp 1
 network 172.16.0.0
 network 192.168.10.8 0.0.0.3
 eigrp router-id 2.2.2.2
R2#
```

Configure EIGRP with IPv4

Passive interfaces prevent EIGRP updates out a specified router interface.

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

```
passive-interface type number [default]
```

```
R3(config)# router eigrp 1
R3(config-router)# passive-interface gigabitethernet 0/0
```

```
R3# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "eigrp 1"
<output omitted>
Routing for Networks:
    192.168.1.0
    192.168.10.4/30
    192.168.10.8/30
 Passive Interface(s):
   GigabitEthernet0/0
 Routing Information Sources:
    Gateway          Distance      Last Update
    192.168.10.5           90      01:37:57
    192.168.10.9           90      01:37:57
  Distance: internal 90 external 170
R3#
```

Set a particular interface or all router interfaces to passive.

- The default option sets all router interfaces to passive.
- Prevents neighbor relationships from being established.
- Routing updates from a neighbor are ignored.

Verify EIGRP with IPv4

The show ip protocols command is useful to identify the parameters and other information about the current state of any active IPv4 routing protocol processes configured on the router.

For example, in the command output in the figure:

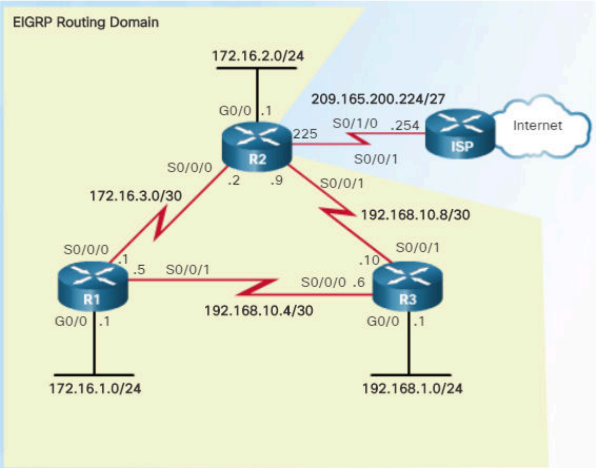
1. EIGRP is an active dynamic routing protocol on R1 configured with the autonomous system number 1.
2. The EIGRP router ID of R1 is 1.1.1.1.
3. The EIGRP administrative distances on R1 are internal AD of 90 and external of 170 (default values).
4. By default, EIGRP does not automatically summarize networks. Subnets are included in the routing updates.
5. The EIGRP neighbor adjacencies R1 has with other routers used to receive EIGRP routing updates.

```
R1# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "eigrp 1" (1) Routing protocol and Process ID (AS
                                  Number)
 Outgoing update filter clist for all interfaces is not set
 Incoming update filter list for all interfaces is not set
 Default networks flagged in outgoing updates
 Default networks accepted from incoming updates
 EIGRP-IPv4 Protocol for AS(1)
   Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
   NSF-aware route hold timer is 240
   Router-ID: 1.1.1.1 (2)    EIGRP Router ID

   Topology : 0 (base)
     Active Timer: 3 min
Distance: internal 90 external 170  (3)   EIGRP Administrative
                                          Distances

     Maximum path: 4
     Maximum hopcount 100
     Maximum metric variance 1

  Automatic Summarization: disabled  (4)   EIGRP Automatic Summarization
                                           is disabled.
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.10.0
  Routing Information Sources:           (5)   EIGRP Routing
                                               Information Sources
    Gateway         Distance    Last Update    lists all the EIGRP
    192.168.10.6          90    00:40:20       routing sources the
    172.16.3.2            90    00:40:20       IOS uses to build its
                                               IPv4 routing table.

  Distance: internal 90 external 170

 R1#
```

Implement EIGRP for IPv4

Verify EIGRP with IPv4

```
R2# 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
<output omitted>
Gateway of last resort is not set

 172.16.0.0/16 is variably subnetted, 5 subnets, 3 masks
D    172.16.1.0/24 [90/2170112] via 172.16.3.1, 00:11:05, Serial0/0/0
C    172.16.2.0/24 is directly connected, GigabitEthernet0/0
L    172.16.2.1/32 is directly connected, GigabitEthernet0/0
C    172.16.3.0/30 is directly connected, Serial0/0/0
L    172.16.3.2/32 is directly connected, Serial0/0/0
D   192.168.1.0/24 [90/2170112] via 192.168.10.10, 00:15:16,Serial0/0/1
  192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
D    192.168.10.4/30 [90/2681856] via 192.168.10.10, 00:52:00,Serial0/0/1
                     [90/2681856] via 172.16.3.1, 00:52:00,Serial0/0/0
C    192.168.10.8/30 is directly connected, Serial0/0/1
L    192.168.10.9/32 is directly connected, Serial0/0/1
  209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C    209.165.200.224/27 is directly connected, Loopback209
L    209.165.200.225/32 is directly connected, Loopback209
R2#
```

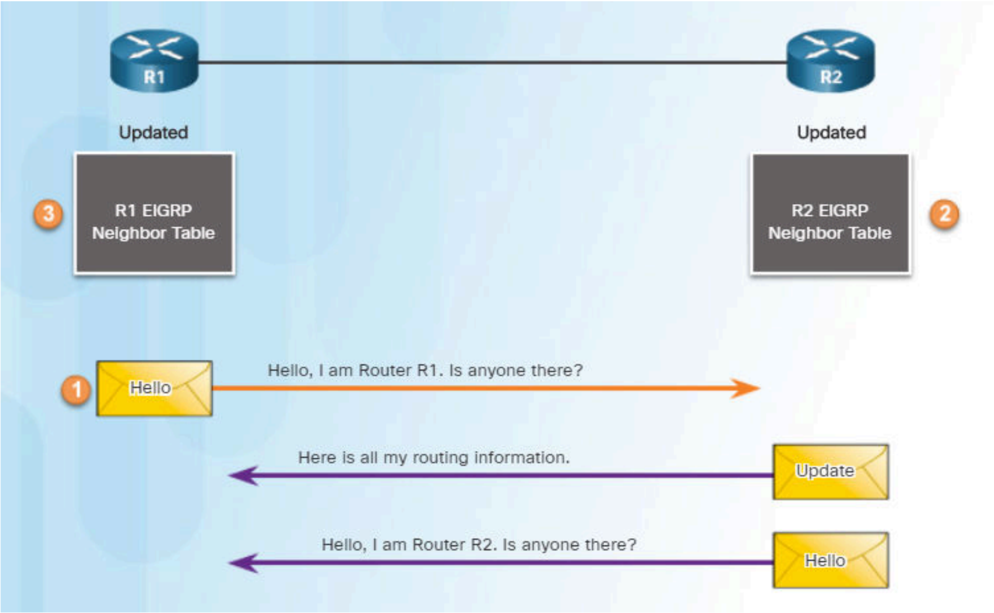



```
R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
<output omitted>
Gateway of last resort is not set

     172.16.0.0/16 is variably subnetted, 5 subnets, 3 masks
C      172.16.1.0/24 is directly connected,GigabitEthernet0/0
L      172.16.1.1/32 is directly connected,GigabitEthernet0/0
D      172.16.2.0/24 [90/2170112] via 172.16.3.2,00:14:35, Serial0/0/0
C      172.16.3.0/30 is directly connected, Serial0/0/0
L      172.16.3.1/32 is directly connected, Serial0/0/0
D 192.168.1.0/24 [90/2170112] via 192.168.10.6,00:13:57, Serial0/0/1
  192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C      192.168.10.4/30 is directly connected, Serial0/0/1
L      192.168.10.5/32 is directly connected, Serial0/0/1
D      192.168.10.8/30 [90/2681856] via 192.168.10.6,00:50:42, Serial0/0/1
                       [90/2681856] via 172.16.3.2,00:50:42, Serial0/0/0
R1#
```

```
R3# 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
<output omitted>
Gateway of last resort is not set

 172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks
D     172.16.1.0/24 [90/2170112] via 192.168.10.5, 00:12:00, Serial0/0/0
D     172.16.2.0/24 [90/2170112] via 192.168.10.9, 00:16:49, Serial0/0/1
D     172.16.3.0/30 [90/2681856] via 192.168.10.9, 00:52:55, Serial0/0/1
                    [90/2681856] via 192.168.10.5, 00:52:55, Serial0/0/0
  192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C     192.168.1.0/24 is directly connected, GigabitEthernet0/0
L     192.168.1.1/32 is directly connected, GigabitEthernet0/0
  192.168.10.0/24 is variably subnetted, 4 subnets, 2 masks
C     192.168.10.4/30 is directly connected, Serial0/0/0
L     192.168.10.6/32 is directly connected, Serial0/0/0
C     192.168.10.8/30 is directly connected, Serial0/0/1
L     192.168.10.10/32 is directly connected, Serial0/0/1
R3#
```

EIGRP Initial Route Discovery

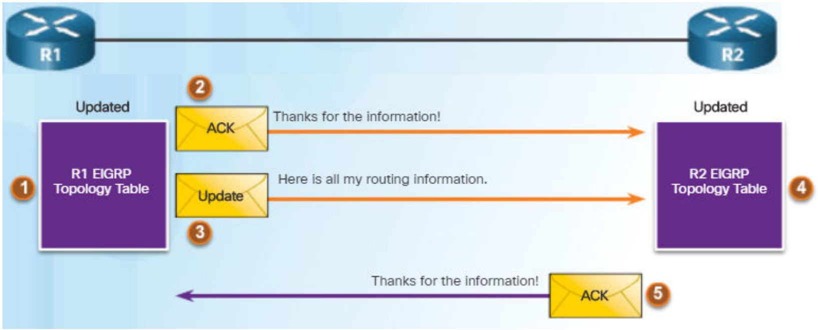
1. Router R1 starts has joined the EIGRP routing domain and sends an EIGRP Hello packet out all EIGRP enabled interfaces.
2. Router R2 receives the Hello packet and adds R1 to its neighbor table.
   - R2 sends an Update packet that contains all the routes it knows.
   - R2 also sends an EIGRP Hello packet to R1.
3. R1 updates its neighbor table with R2.



EIGRP Operation

EIGRP Initial Route Discovery

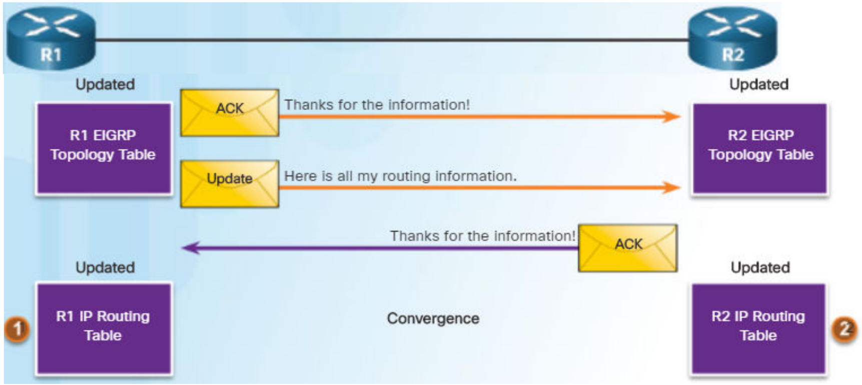
1. R1 adds all update entries from R1 to its topology table.
   - The topology table includes all destinations advertised by neighboring (adjacent) routers and the cost (metric) to reach each network.



2. EIGRP update packets use reliable delivery; therefore, R1 replies with an EIGRP acknowledgment packet informing R2 that it has received the update.
3. R1 sends an EIGRP update to R2 advertising the routes that it is aware of, except those learned from R2 (split horizon).
4. R2 receives the EIGRP update from R1 and adds this information to its own topology table.
5. R2 responds to R1’s EIGRP update packet with an EIGRP acknowledgment.

EIGRP Initial Route Discovery

1. R1 uses DUAL to calculate the best routes to each destination, including the metric and the next-hop router and updates its routing table with the best routes.
2. Similarly, R2 uses DUAL and updates its routing table with the best newly discovered routes.



EIGRP Metrics

EIGRP uses a composite metric which can be based on the following metrics:

- Bandwidth: The lowest bandwidth between source and destination.
- Delay: The cumulative interface delay along the path
- Reliability: (Optional) Worst reliability between source and destination.
- Load: (Optional) Worst load on a link between source and destination.

- The EIGRP composite metric formula consists metric weights with values K1 to K5.
  - K1 represents bandwidth, K3 delay, K4 load, and K5 reliability.

Default Values:
K1 (bandwidth) = 1
K2 (load) = 0
K3 (delay) = 1
K4 (reliability) = 0
K5 (reliability) = 0

Default Composite Formula:

metric = [K1*bandwidth + K3*delay] * 256

Complete Composite Formula:

metric = [K1*bandwidth + (K2*bandwidth) / (256 - load) + K3*delay] * 256*[K5/(reliability+K4)]

(Not used if " K" values are 0)

Note: This is a conditional formula. If K5 = 0, the last term is replaced by 1 and the formula becomes: Metric = [K1*bandwidth + (K2*bandwidth) / (256-load) + K3*delay] * 256

EIGRP Metrics

Use the following interface configuration mode command to modify the bandwidth metric:

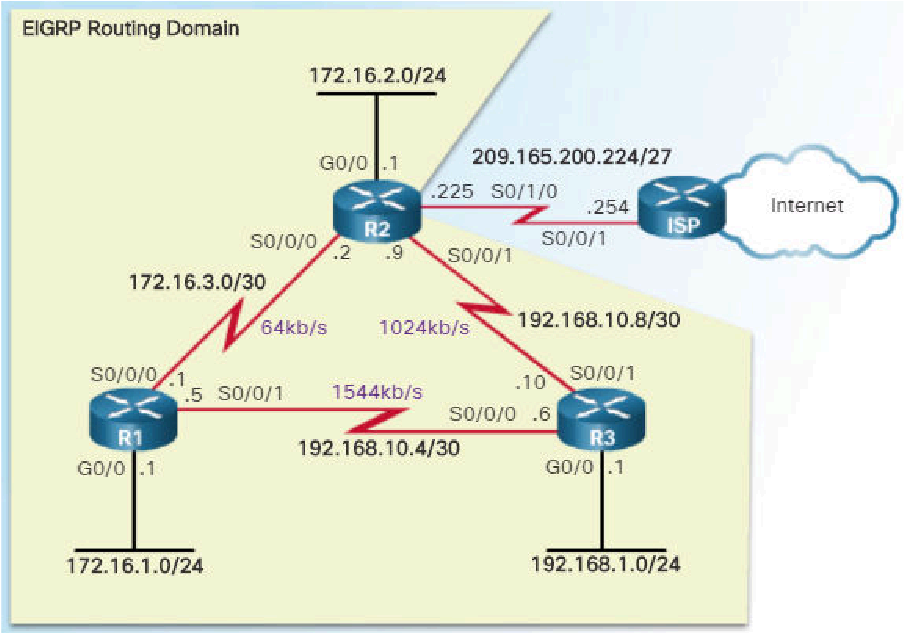
- Router(config-if)# bandwidth *kilobits-bandwidth-value*

```
R1# show interface s 0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is WIC MBRD Serial
  Internet address is 172.16.3.1/30
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<output omitted>
R1#
```

Use the show interfaces command to verify the new bandwidth parameters.

```
R2# show interface s 0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is WIC MBRD Serial
  Internet address is 172.16.3.2/30
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<output omitted>
R2#
```

```
R2(config)# interface s 0/0/0
R2(config-if)# bandwidth 64
R2(config-if)# exit
R2(config)# interface s 0/0/1
R2(config-if)# bandwidth 1024
```




```
R1(config)# interface s 0/0/0
R1(config-if)# bandwidth 64
```

```
R3(config)# interface s 0/0/1
R3(config-if)# bandwidth 1024
```

EIGRP Metrics

Delay is a measure of the time it takes for a packet to traverse a route.

The delay (DLY) metric is not measured dynamically.

- **It is a static value measured in microseconds (μs or usec) based on the type of link to which the interface is connected.**

The delay value is calculated using the cumulative (sum) of all interface delays along the path, divided by 10.

Media	Delay In usec
Gigabit Ethernet	10
Fast Ethernet	100
FDDI	100
16M Token Ring	630
Ethernet	1,000
T1 (Serial Default)	20,000
DS0 (64 Kbps)	20,000
1024 Kbps	20,000
56 Kbps	20,000

EIGRP Operation

EIGRP Metrics

We can determine the EIGRP metric as follows:

1. **Determine the link with the slowest bandwidth and use that value to calculate bandwidth (10,000,000/bandwidth).**
2. **Determine the delay value for each outgoing interface on the way to the destination and add the delay values and divide by 10 (sum of delay/10).**
3. **This composite metric produces a 24-bit value which EIGRP multiplies with 256.**

[K1 * bandwidth + K3 * delay] * 256 = Metric

Because K1 and K3 both equal 1, the formula becomes:

(Bandwidth + Delay) * 256 = Metric

((10,000,000 / bandwidth) + (sum of delay / 10)) * 256 = Metric

EIGRP Metrics

```
R2# show ip route
<output omitted>
D 192.168.1.0/24 [90/3012096] via 192.168.10.10, 00:12:32, Serial0/0/1
```

How does EIGRP determine the following metric?

- EIGRP Composite Metric = (Bandwidth + Delay) x 256

- Bandwidth = 10,000,000 / slowest bandwidth

```
R2# show interface s 0/0/1
Serial0/0/1 is up, line protocol is up
  Hardware is WIC MBRD Serial
  Internet address is 192.168.10.9/30
  MTU 1500 bytes, BW 1024 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<output omitted>
R2#
```

```
R3# show interface g 0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is CN Gigabit Ethernet, address is fc99.4771.7a20 (bia fc99.4771.7a20)
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<output omitted>
R3#
```

- Bandwidth = 10,000,000 / 1024 = 9765

- Delay = (Sum of all delays) / 10

```
R2# show interface s 0/0/1
Serial0/0/1 is up, line protocol is up
  Hardware is WIC MBRD Serial
  Internet address is 192.168.10.9/30
  MTU 1500 bytes, BW 1024 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<output omitted>
R2#
```

```
R3# show interface g 0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is CN Gigabit Ethernet, address is fc99.4771.7a20 (bia fc99.4771.7a20)
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<output omitted>
  R3#
```

- Delay = (20,000 + 10) / 10 = 2001

- EIGRP Composite Metric = (9765 + 2001) x 256 = 3,012.096

DUAL and the Topology Table

EIGRP uses the Diffusing Update Algorithm (DUAL) to provide the best and backup loop-free paths.

DUAL uses several terms, which are discussed in more detail throughout this section:

Term	Description
Successor	• Is a neighboring router that is used for packet forwarding and is the least-cost route to the destination network. • The IP address of a successor is shown in a routing table entry right after the word "via".
Feasible Successors (FS)	• These are the "Backup paths" that are a loop-free. • Must comply to a feasibility condition.
Reported Distance (RD)	• Also called "advertised distance", this is the reported metric from the neighbor advertising the route. • If the RD metric is less than the FD, then the next-hop router is downstream and there is no loop.
Feasible Distance (FD)	• This is the actual metric of a route from the current router. • Is the lowest calculated metric to reach the destination network. • FD is the metric listed in the routing table entry as the second number inside the brackets.

EIGRP Operation

DUAL and the Topology Table

Routing loops, even temporary ones, can be detrimental to network performance and EIGRP prevents routing loops with the DUAL algorithm.

- The DUAL algorithm is used to obtain loop-freedom at every instance throughout a route computation.

The decision process for all route computations is done by the DUAL Finite State Machine (FSM). An FSM is a workflow model, similar to a flow chart, which is composed of the following:

- A finite number of stages (states)
- Transitions between those stages
- Operations

The DUAL FSM tracks all routes and uses EIGRP metrics to select efficient, loop-free paths, and to identify the routes with the least-cost path to be inserted into the routing table.

EIGRP Operation

DUAL and the Topology Table

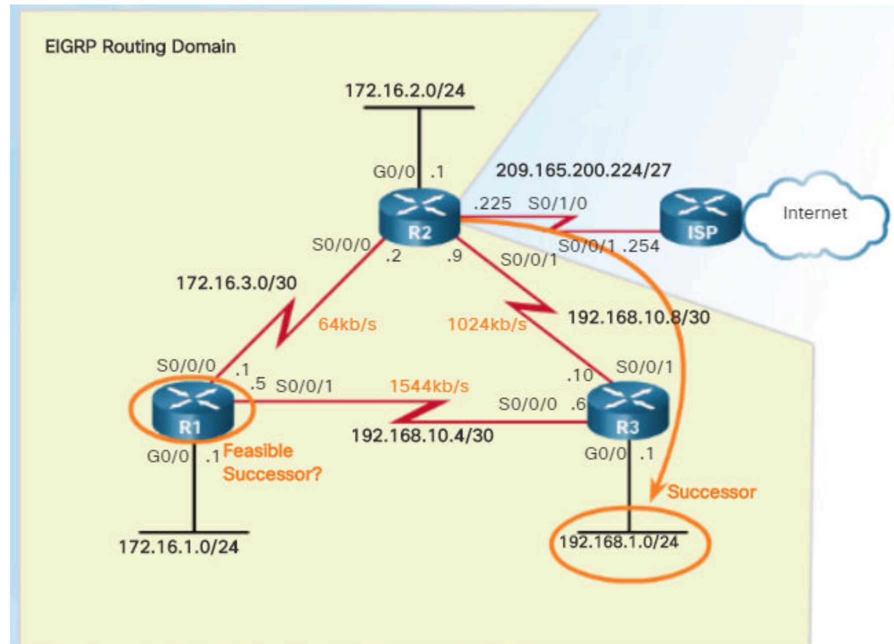
A successor is a neighboring router with the least-cost route to the destination network.

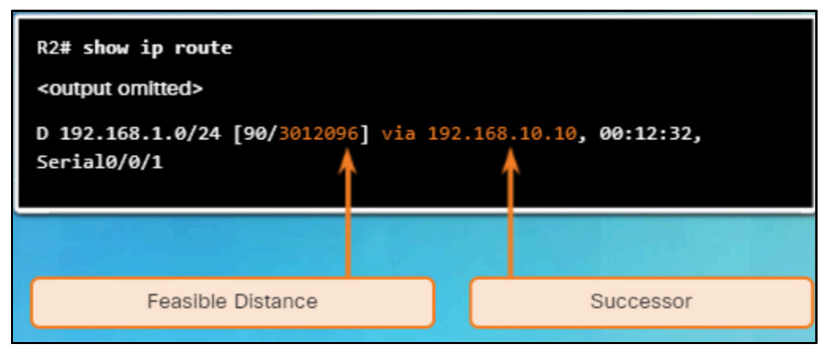
- **The successor IP address is shown right after “via”.**

FD is the lowest calculated metric to reach the destination network.

- **FD is the second number inside the brackets.**
- **Also known as the “*metric*” for the route.**

Notice that EIGRP’s best path for the 192.168.1.0/24 network is through router R3, and that the feasible distance is 3,012,096.





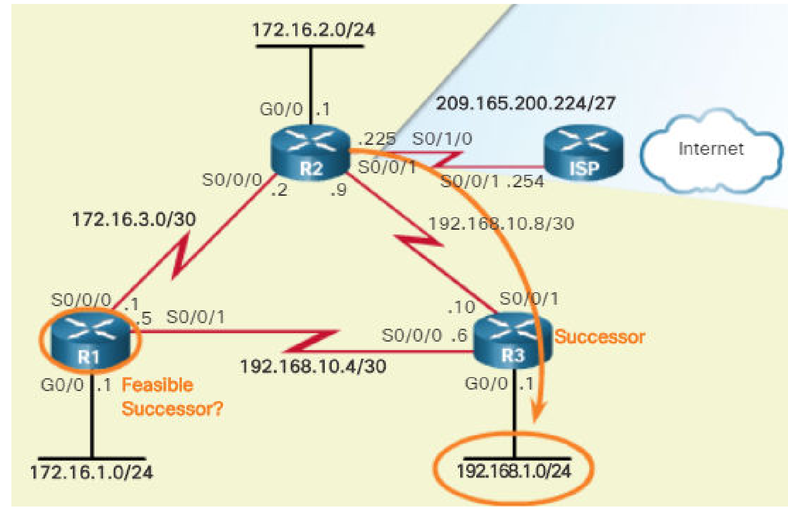
EIGRP Operation
DUAL and the Topology Table

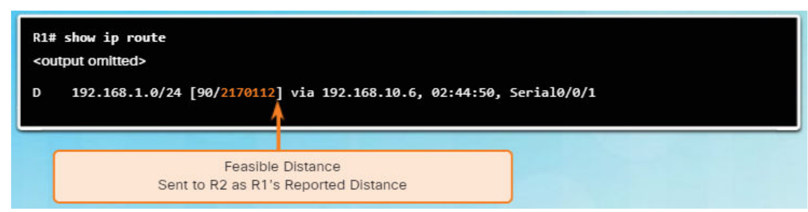
DUAL converges quickly because it can use backup paths known as Feasible Successors (FSs).

A FS is a neighbor with a loop-free backup path to the same network as the successor.

- A FS must satisfy the Feasibility Condition (FC).
- The FC is met when a neighbor's Reported Distance (RD) is less than the local router's feasible distance.
- If the reported distance is less, it represents a loop-free path.

E.g., the RD of R1 (2,170,112) is less than R2's own FD (3,012,096) and therefore, R1 meets the FC and becomes the FS for R2 to the 192.168.1.0/24 network.





EIGRP Operation

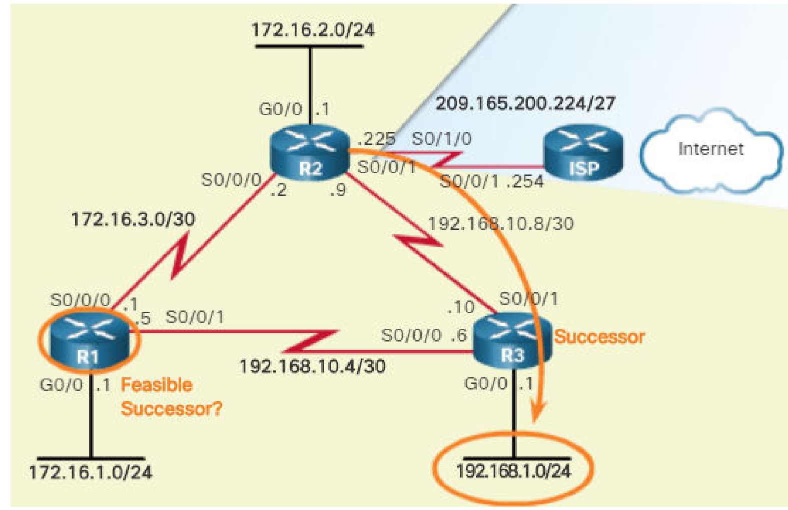
DUAL and the Topology Table

Topology table stores the following information required by DUAL to calculate distances and vectors to destinations.

- **The reported distance (RD) that each neighbor advertises for each destination**
- **The feasible distance (FD) that this router would use to reach the destination via that neighbor.**

Use the show ip eigrp topology command to list all successors and FSs to destination networks.

- **Only the successor is installed into the IP routing table.**
- **Passive State - Route is in stable state and available for use.**
- **Active State - Route is being recomputed by DUAL.**

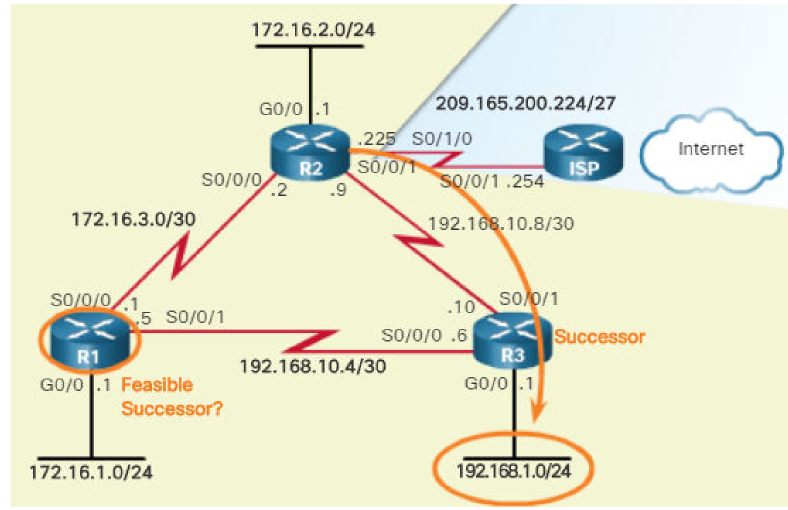



```
R2# show ip eigrp topology
EIGRP-IPv4 Topology Table for AS(1)/ID(2.2.2.2)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 172.16.2.0/24, 1 successors, FD is 2816
        via Connected, GigabitEthernet0/0
P 192.168.10.4/30, 1 successors, FD is 3523840
        via 192.168.10.10 (3523840/2169856), Serial0/0/1
        via 172.16.3.1 (41024000/2169856), Serial0/0/0
P 192.168.1.0/24, 1 successors, FD is 3012096
        via 192.168.10.10 (3012096/2816), Serial0/0/1
        via 172.16.3.1 (41024256/2170112), Serial0/0/0
P 172.16.3.0/30, 1 successors, FD is 40512000
        via Connected, Serial0/0/0
P 172.16.1.0/24, 1 successors, FD is 3524096
        via 192.168.10.10 (3524096/2170112), Serial0/0/1
        via 172.16.3.1 (40512256/2816), Serial0/0/0
P 192.168.10.8/30, 1 successors, FD is 3011840
        via Connected, Serial0/0/1

R2#
```

DUAL and the Topology Table

The first line in the topology table displays:

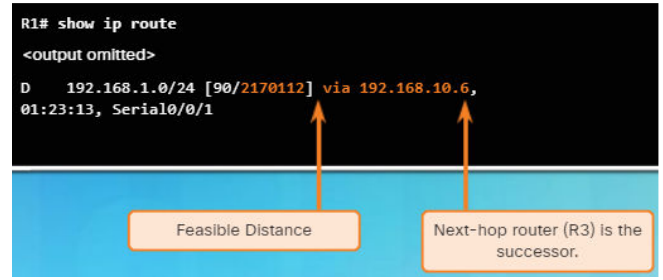
- **P - Route in the passive state (the route is in a stable mode). If DUAL recalculates or searches for a new path, the route is in an active state and displays an A.**
- **192.168.1.0/24 - Destination network is also found in the routing table.**
- **1 successors - Displays the number of successors for this network. If there are multiple equal cost paths to this network, there are multiple successors.**
- **FD is 3012096 - FD, the EIGRP metric to reach the destination network. This is the metric displayed in the IP routing table.**




```
R2# show ip eigrp topology
EIGRP-IPv4 Topology Table for AS(1)/ID(2.2.2.2)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 172.16.2.0/24, 1 successors, FD is 2816
        via Connected, GigabitEthernet0/0
P 192.168.10.4/30, 1 successors, FD is 3523840
        via 192.168.10.10 (3523840/2169856), Serial0/0/1
        via 172.16.3.1 (41024000/2169856), Serial0/0/0
P 192.168.1.0/24, 1 successors, FD is 3012096
        via 192.168.10.10 (3012096/2816), Serial0/0/1
        via 172.16.3.1 (41024256/2170112), Serial0/0/0
P 172.16.3.0/30, 1 successors, FD is 40512000
        via Connected, Serial0/0/0
P 172.16.1.0/24, 1 successors, FD is 3524096
        via 192.168.10.10 (3524096/2170112), Serial0/0/1
        via 172.16.3.1 (40512256/2816), Serial0/0/0
P 192.168.10.8/30, 1 successors, FD is 3011840
        via Connected, Serial0/0/1

R2#
```

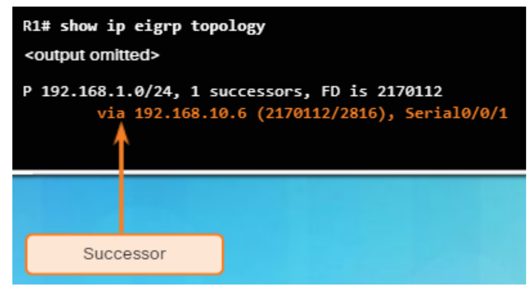
DUAL and the Topology Table

The partial output of the show ip route command displays the 192.168.1.0/24 route with the successor is R3 via 192.168.10.6 with an FD of 2,170,112.

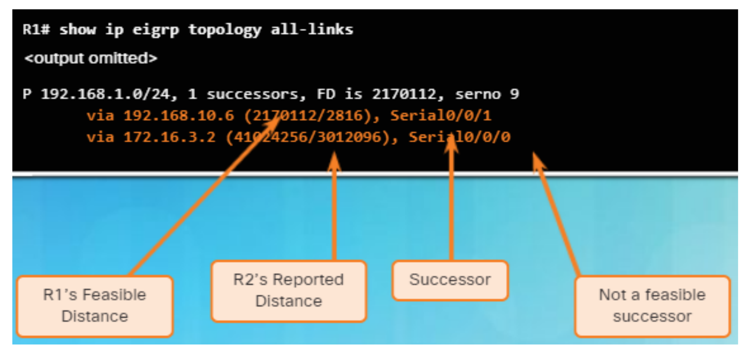


The show ip eigrp topology command only shows the successor 192.168.10.6, which is R3.

- **Notice there are no FSs.**



The show ip eigrp topology all-links command shows all possible paths to a network, including successors, FSs, and even those routes that are not FSs.

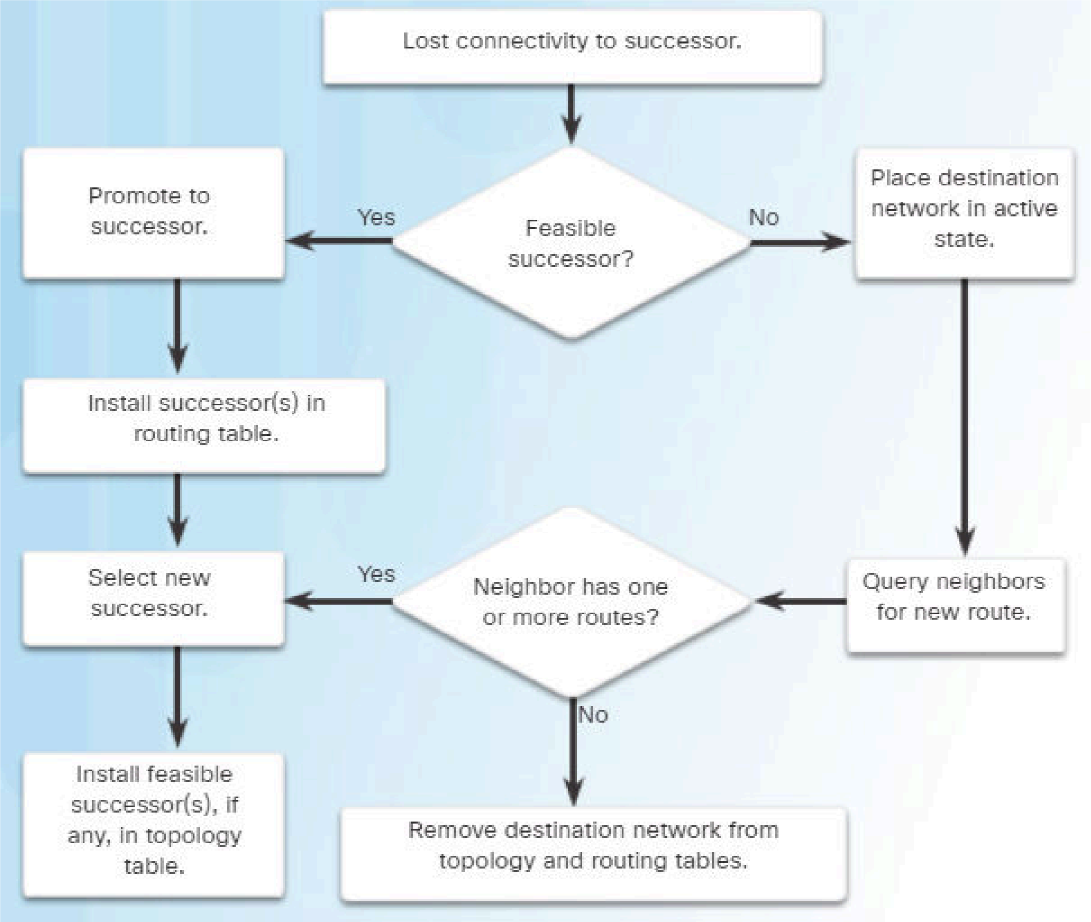


DUAL and Convergence

The DUAL Finite State Machine (FSM) contains all of the logic used to calculate and compare routes in an EIGRP network.

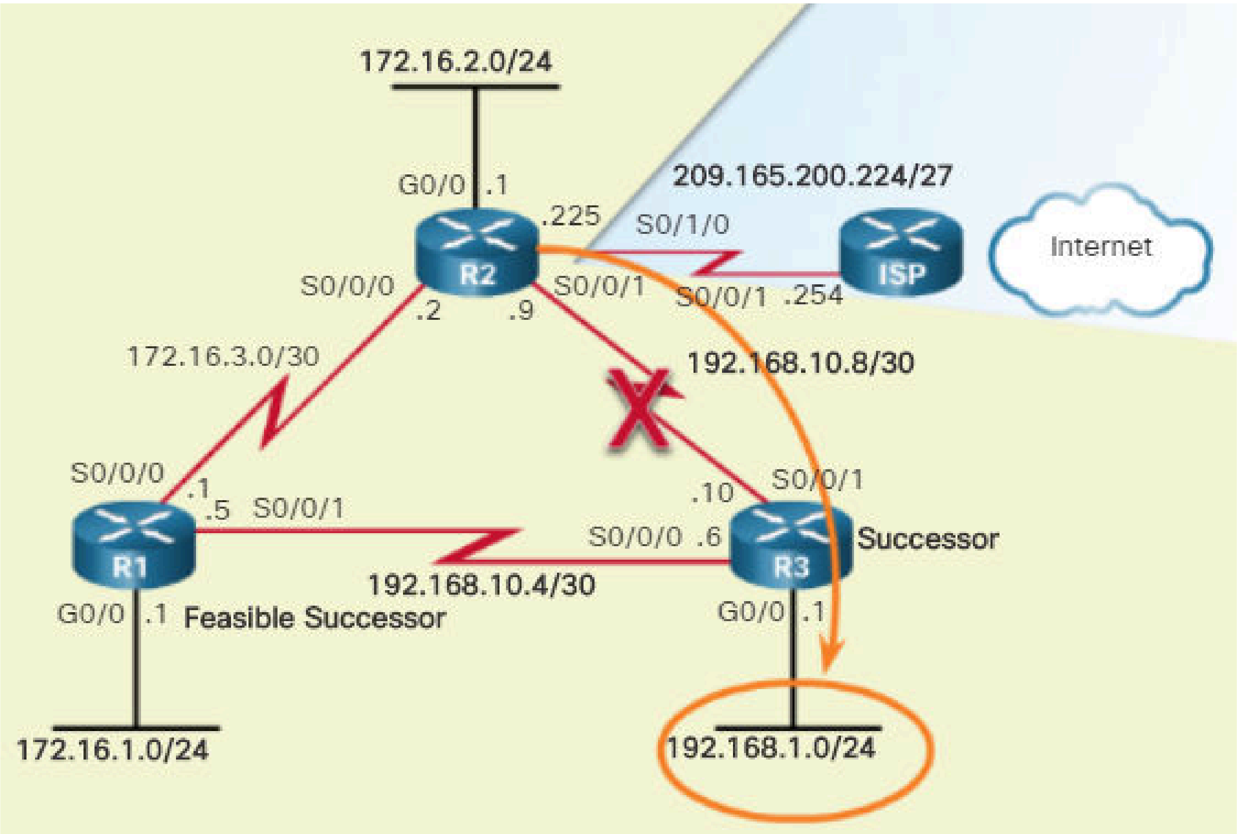
An FSM is an abstract machine, that defines a set of possible states that something can go through, what events cause those states, and what events result from those states.

- **Designers use FSMs to describe how a device, computer program, or routing algorithm reacts to a set of input events.**



DUAL and Convergence

IP EIGRP



EIGRP Operation

DUAL and Convergence

If the path to the successor fails and there are no FSs, DUAL puts the network into the active state and actively queries its neighbors for a new successor.

- DUAL sends EIGRP queries asking other routers for a path to the network.
- Other routers return EIGRP replies, letting the sender of the EIGRP query know that they have a path to the requested network. If there is no reply, the sender of the query does not have a route to this network.
- If the sender receives EIGRP replies with a path to the requested network, the preferred path is added as the new successor and also added to the routing table.

EIGRP Load Balancing

- By default, EIGRP does equal-metric load balancing:
  - By default, up to four routes with a metric equal to the minimum metric are installed in the routing table.
- There can be up to 16 entries in the routing table for the same destination:
  - The number of entries is configurable with the maximum-paths command.

EIGRP Unequal-Cost Load Balancing

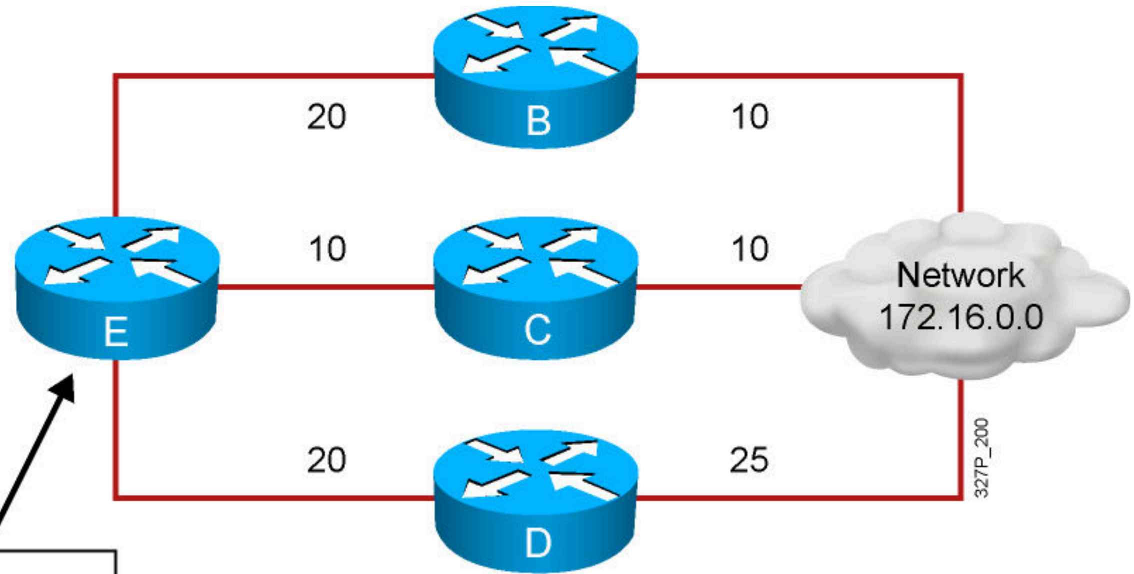
```
RouterX(config-router)#
```

```
variance multiplier
```

- **Allows the router to load-balance across routes with a metric smaller than the *multiplier* value times the minimum metric route to that destination.**
- **The default variance is 1, which means equal-cost load balancing.**

Variance Example

Network	Neighbor	FD	AD
172.16.0.0	B	30	10
	C	20	10
	D	45	25




```
(config)#router eigrp 200
(config-router)#variance 2
```

FD = feasible distance
AD = advertised distance

- Router E chooses router C to route to network 172.16.0.0 because it has the lowest feasible distance of 20.
- With a variance of 2, router E also chooses router B to route to network 172.16.0.0 (20 + 10 = 30) < [2 * (FD) = 40].
- Router D is not considered to route to network 172.16.0.0 (because 25 > 20).

Verifying the EIGRP Configuration

```
RouterX# show ip route eigrp
```

- Displays the current EIGRP entries in the routing table

```
RouterX# show ip protocols
```

- Displays the parameters and current state of the active process

```
RouterX# show ip eigrp interfaces
```

- Displays information about interfaces configured for EIGRP

```
RouterX# show ip eigrp interfaces
IP EIGRP interfaces for process 109

                        Xmit Queue   Mean   Pacing Time   Multicast    Pending
Interface        Peers  Un/Reliable  SRTT   Un/Reliable   Flow Timer   Routes
Di0                0        0/0         0      11/434           0           0
Et0                1        0/0       337       0/10            0           0
SE0:1.16           1        0/0        10       1/63          103           0
Tu0                1        0/0       330       0/16            0           0
```

Verifying the EIGRP Configuration (Cont.)

```
RouterX# show ip eigrp neighbors [detail]
```

- **Displays the neighbors discovered by IP EIGRP**

```
RouterX# show ip eigrp neighbors
IP-EIGRP Neighbors for process 77
Address                  Interface     Holdtime Uptime    Q      Seq  SRTT  RTO
                                       (secs)   (h:m:s)   Count  Num  (ms)  (ms)
172.16.81.28             Ethernet1     13       0:00:41   0      11   4     20
172.16.80.28             Ethernet0     14       0:02:01   0      10   12    24
172.16.80.31             Ethernet0     12       0:02:02   0      4    5     20
```

Verifying the EIGRP Configuration (Cont.)

```
RouterX# show ip eigrp topology [all]
```

- Displays the IP EIGRP topology table
- Without the [all] parameter, shows successors and feasible successor

```
RouterX# show ip eigrp topology
IP-EIGRP Topology Table for process 77
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - Reply status
P 172.16.90.0 255.255.255.0, 2 successors, FD is 46251776
          via 172.16.80.28 (46251776/46226176), Ethernet0
          via 172.16.81.28 (46251776/46226176), Ethernet1
          via 172.16.80.31 (46277376/46251776), Serial0
P 172.16.81.0 255.255.255.0, 2 successors, FD is 307200
          via Connected, Ethernet1
          via 172.16.81.28 (307200/281600), Ethernet1
          via 172.16.80.28 (307200/281600), Ethernet0
          via 172.16.80.31 (332800/307200), Serial0
```

Verifying the EIGRP Configuration (Cont.)

```
RouterX# show ip eigrp traffic
```

- Displays the number of IP EIGRP packets sent and received

```
RouterX# show ip eigrp traffic
IP-EIGRP Traffic Statistics for process 77
  Hellos sent/received: 218/205
  Updates sent/received: 7/23
  Queries sent/received: 2/0
  Replies sent/received: 0/2
  Acks sent/received: 21/14
```

IPv6 Routing

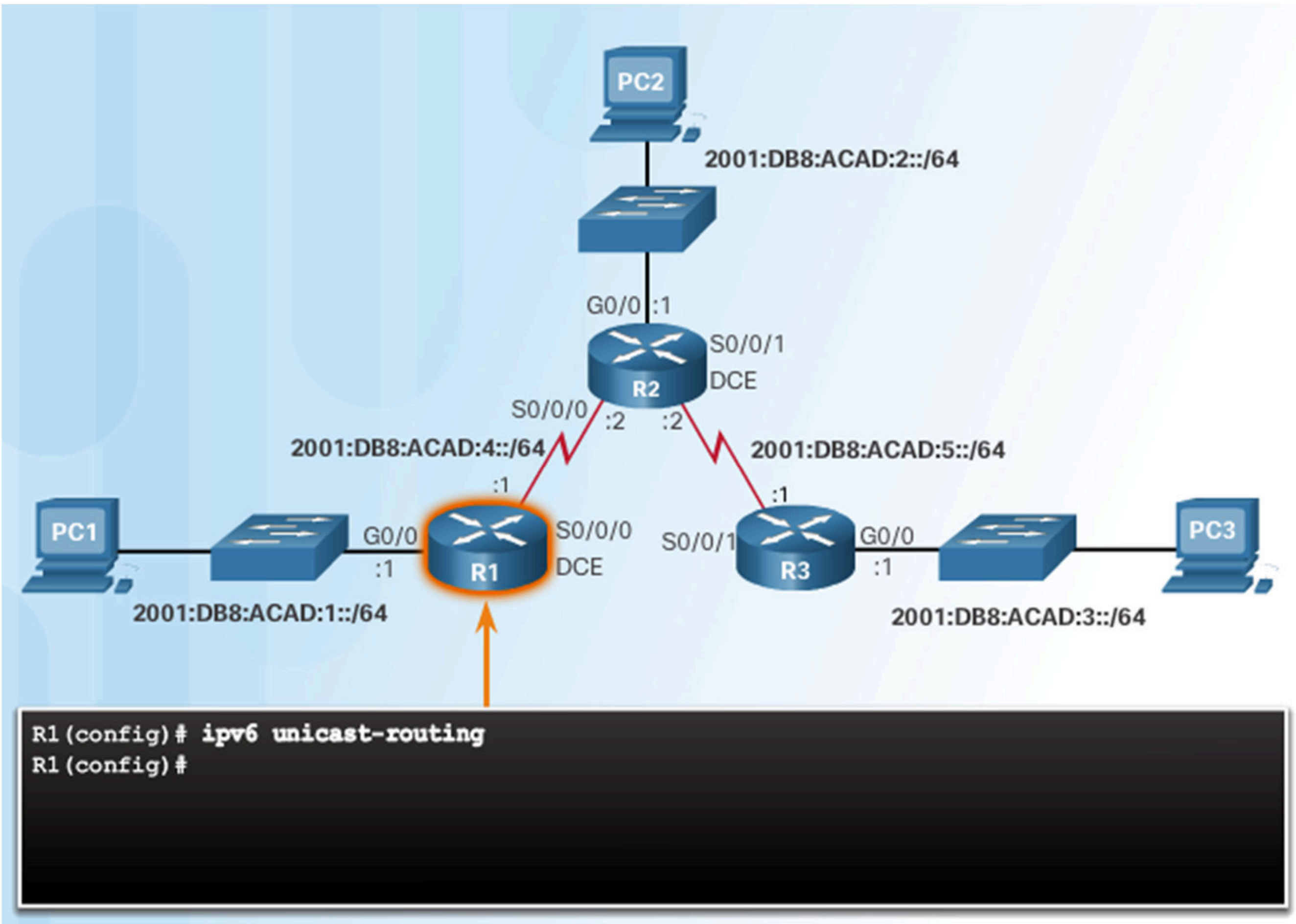
IPv6 Static Routes

```
Router(config)# ipv6 route ipv6-prefix/prefix-length {ipv6-address | exit-intf}
```

Parameter	Description
`ipv6-prefix`	Destination network address of the remote network to be added to the routing table.
`prefix-length`	Prefix length of the remote network to be added to the routing table.
`ipv6-address`	• Commonly referred to as the next-hop router's IP address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
`exit-intf`	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

The ipv6 route Command (Cont.)

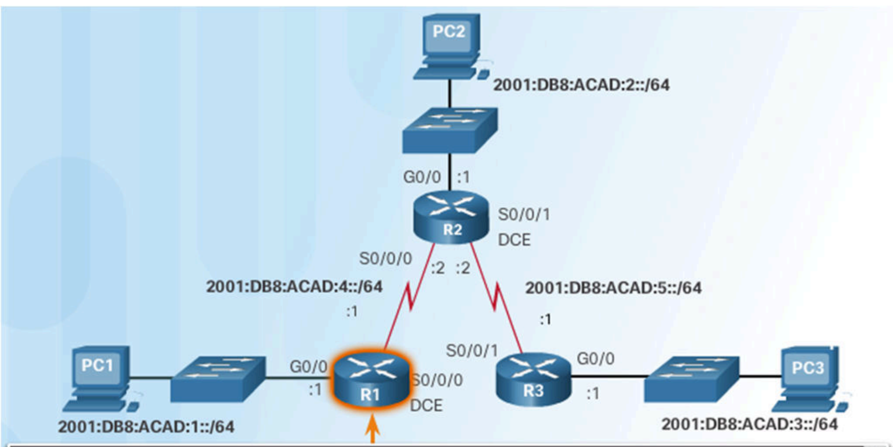
- **ipv6 unicast-routing** enables the router to forward IPv6 packets



Next-Hop Options

Each router only knows about directly connected networks

- **R1 can ping R2 (ipv6 2001:DB8:ACAD:4::2) but cannot ping R3 (ipv6 2001:DB8:ACAD:3::2)**




```
R1#show ipv6 route
<output omitted>
C   2001:DB8:ACAD:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
C   2001:DB8:ACAD:4::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:ACAD:4::1/128 [0/0]
     via Serial0/0/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```

```
R2#show ipv6 route
<output omitted>
C   2001:DB8:ACAD:2::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:2::1/128 [0/0]
     via GigabitEthernet0/0, receive
C   2001:DB8:ACAD:4::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:ACAD:4::2/128 [0/0]
     via Serial0/0/0, receive
C   2001:DB8:ACAD:5::/64 [0/0]
     via Serial0/0/1, directly connected
L   2001:DB8:ACAD:5::2/128 [0/0]
     via Serial0/0/1, receive
L   FF00::/8 [0/0]
     via Null0, receive
R2#
```

```
R3#show ipv6 route
<output omitted>
C   2001:DB8:ACAD:3::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:3::1/128 [0/0]
     via GigabitEthernet0/0, receive
C   2001:DB8:ACAD:5::/64 [0/0]
     via Serial0/0/1, directly connected
L   2001:DB8:ACAD:5::1/128 [0/0]
     via Serial0/0/1, receive
L   FF00::/8 [0/0]
     via Null0, receive
R3#
```

Next-Hop Options (Cont.)

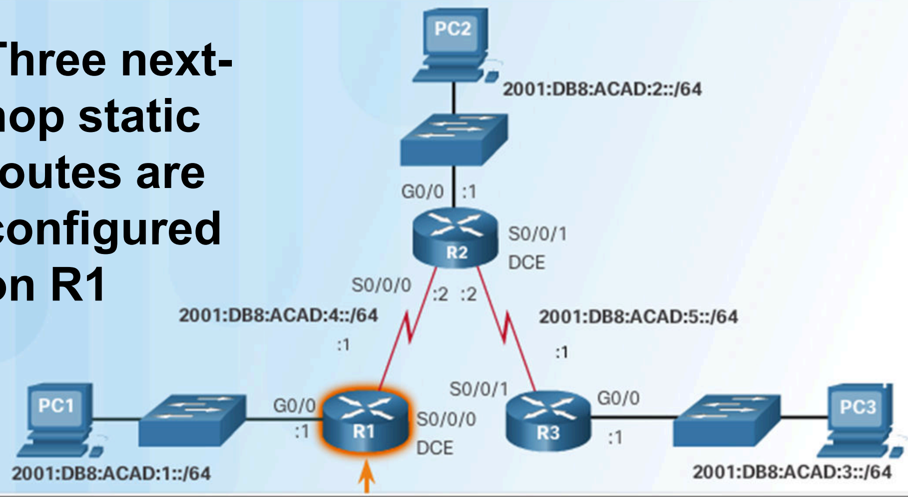
Next hop can be identified by an IPv6 address, exit interface, or both.

Destination is specified by one of three route types:

- Next-hop static IPv6 route - Only the next-hop IPv6 address is specified
- Directly connected static IPv6 route - Only the router exit interface is specified
- Fully specified static IPv6 route - The next-hop IPv6 address and exit interface are specified

Configure a Next Hop Static IPv6 Route

Three next-hop static routes are configured on R1




```
R1(config)# ipv6 route 2001:DB8:ACAD:2::/64   2001:DB8:ACAD:4::2
R1(config)# ipv6 route 2001:DB8:ACAD:5::/64   2001:DB8:ACAD:4::2
R1(config)# ipv6 route 2001:DB8:ACAD:3::/64   2001:DB8:ACAD:4::2
R1(config)#
```

As with IPv4, must resolve the route to determine the exit interface to use to forward the packet

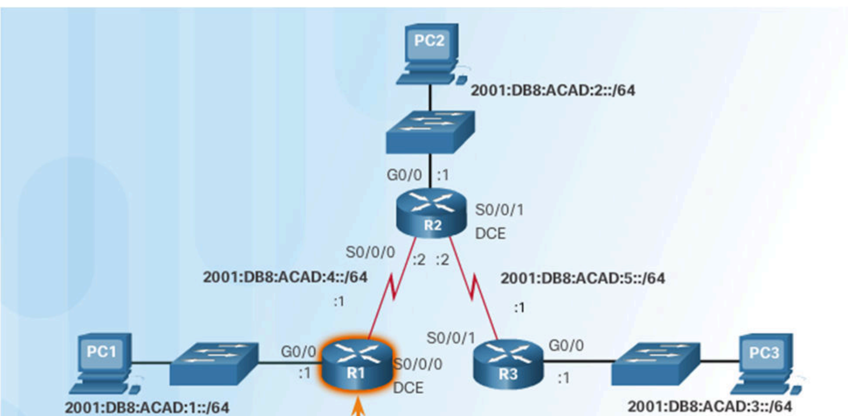
```
R1# show ipv6 route
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route, B - BGP,
       R - RIP, H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea,
       IS - ISIS summary, D - EIGRP, EX - EIGRP external, ND - ND Default,
       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

C    2001:DB8:ACAD:1::/64 [0/0]
      via GigabitEthernet0/0, directly connected
L    2001:DB8:ACAD:1::1/128 [0/0]
      via GigabitEthernet0/0, receive
S    2001:DB8:ACAD:2::/64 [1/0]
      via 2001:DB8:ACAD:4::2
S    2001:DB8:ACAD:3::/64 [1/0]
      via 2001:DB8:ACAD:4::2
C    2001:DB8:ACAD:4::/64 [0/0]
      via Serial0/0/0, directly connected
L    2001:DB8:ACAD:4::1/128 [0/0]
      via Serial0/0/0, receive
S    2001:DB8:ACAD:5::/64 [1/0]
      via 2001:DB8:ACAD:4::2
L    FF00::/8 [0/0]
      via Null0, receive
R1#
```

The IPv6 address matches the route for the directly connected network 2001:DB8:ACAD:4::/64 with the exit interface Serial 0/0/0.

Configure a Directly Connected Static IPv6 Route

Alternative to next hop is to specify the exit interface

Packet destined for 2001:DB8:ACAD:3::/64 network, forwarded out Serial 0/0/0 – no other lookups needed

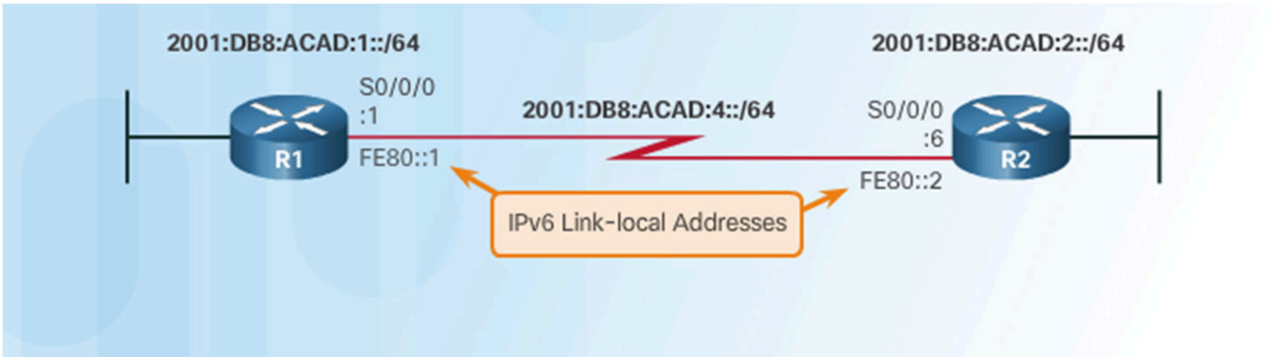



```
R1(config)# ipv6 route 2001:DB8:ACAD:2::/64 s0/0/0
R1(config)# ipv6 route 2001:DB8:ACAD:5::/64 s0/0/0
R1(config)# ipv6 route 2001:DB8:ACAD:3::/64 s0/0/0
R1(config)#
R1#
```

```
R1# show ipv6 route
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, 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
C   2001:DB8:ACAD:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
S   2001:DB8:ACAD:2::/64 [1/0]
     via Serial0/0/0, directly connected
S   2001:DB8:ACAD:3::/64 [1/0]
     via Serial0/0/0, directly connected
C   2001:DB8:ACAD:4::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:ACAD:4::1/128 [0/0]
     via Serial0/0/0, receive
S   2001:DB8:ACAD:5::/64 [1/0]
     via Serial0/0/0, directly connected
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```

Configure a Fully Specified Static IPv6 Route

Fully specified static route must be used if IPv6 link-local address is used as next-hop

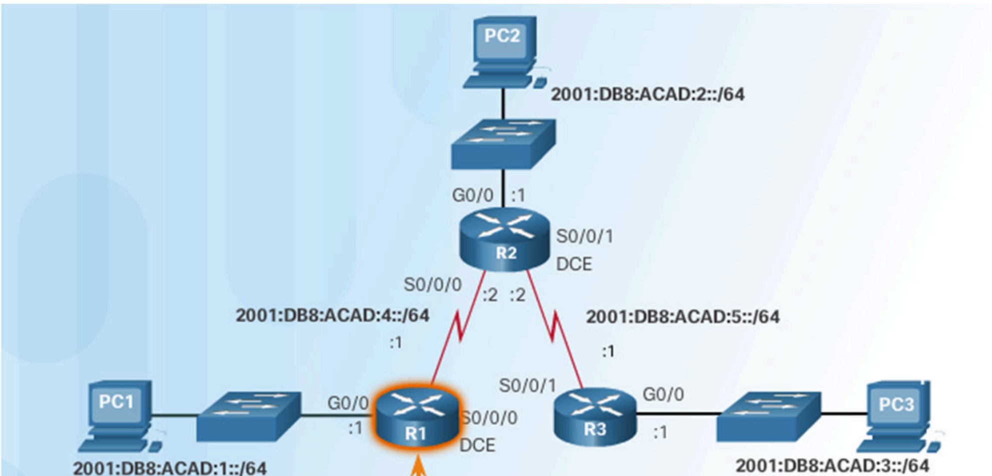



```
R1(config)# ipv6 route 2001:db8:acad:2::/64 fe80::2
% Interface has to be specified for a link-local nexthop
R1(config)# ipv6 route 2001:db8:acad:2::/64 s0/0/0 fe80::2
R1(config)#
```

```
R1# show ipv6 route static | begin 2001:DB8:ACAD:2::/64
S   2001:DB8:ACAD:2::/64 [1/0]
     via FE80::2, Serial0/0/0
```

Configure IPv6 Static Routes

Verify IPv6 Static Routes




```
R1# show ipv6 route static
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route, B - BGP,
       R - RIP, 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
S   2001:DB8:ACAD:2::/64 [1/0]
     via 2001:DB8:ACAD:4::2
S   2001:DB8:ACAD:3::/64 [1/0]
     via 2001:DB8:ACAD:4::2
S   2001:DB8:ACAD:5::/64 [1/0]
     via 2001:DB8:ACAD:4::2
R1#
```

```
R1# show ipv6 route 2001:db8:acad:3::
Routing entry for 2001:DB8:ACAD:3::/64
  Known via "static", distance 1, metric 0
  Route count is 1/1, share count 0
  Routing paths:
    2001:DB8:ACAD:4::2
      Last updated 00:19:11 ago
R1#
```

```
R1# show running-config | section ipv6 route
ipv6 route 2001:DB8:ACAD:2::/64 2001:DB8:ACAD:4::2
ipv6 route 2001:DB8:ACAD:3::/64 2001:DB8:ACAD:4::2
ipv6 route 2001:DB8:ACAD:5::/64 2001:DB8:ACAD:4::2
R1#
```

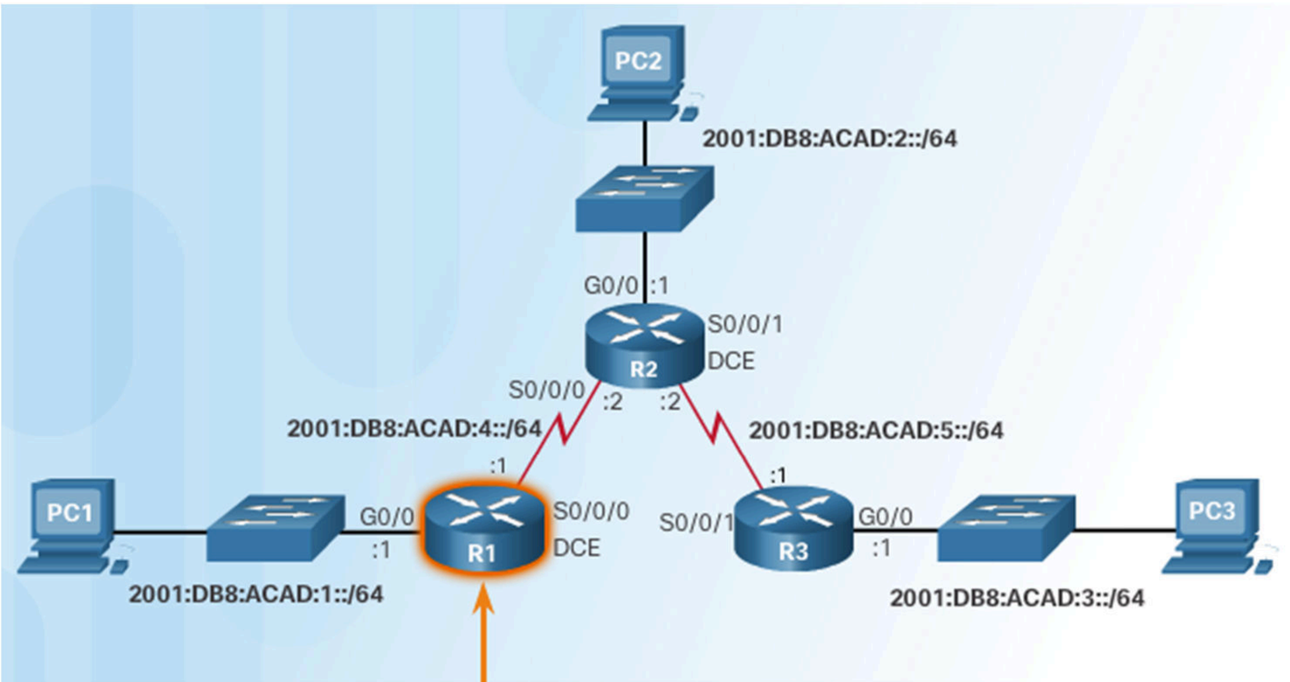
Default Static IPv6 Route

Default static route matches all packets not specified in routing table

```
Router(config)# ipv6 route ::/0 {ipv6-address | exit-intf}
```

Parameter	Description
::/0	Matches any IPv6 prefix regardless of prefix length.
ipv6-address	• Commonly referred to as the next-hop router's IPv6 address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
exit-intf	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

Configure a Default Static IPv6 Route

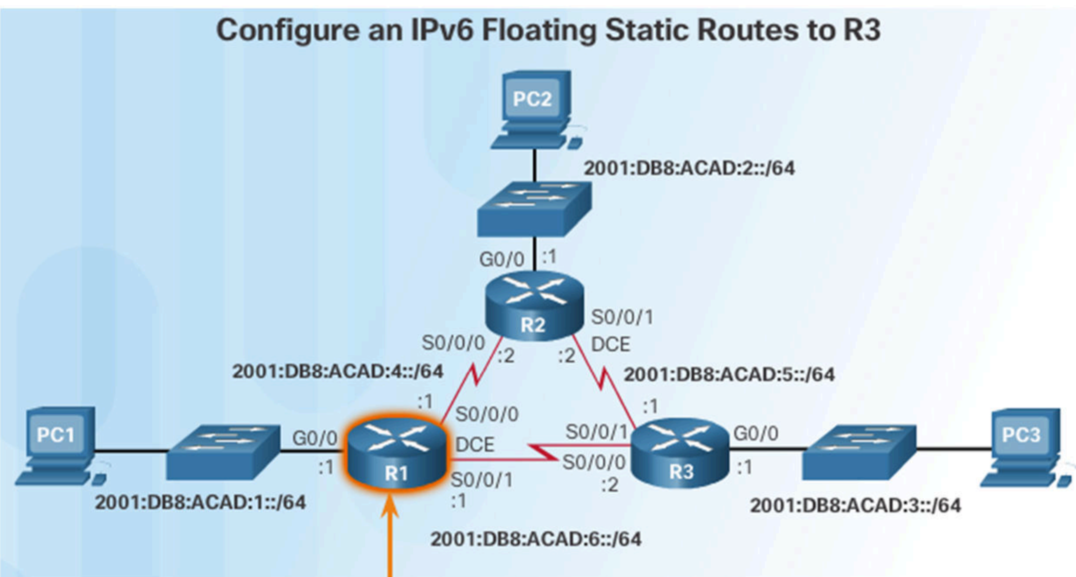



```
R1(config)# ipv6 route ::/0 2001:DB8:ACAD:4::2
R1(config)#
```

- **R1 is a stub router because it is only connected to R2**
- **More efficient to configure a default static IPv6 route in this topology**

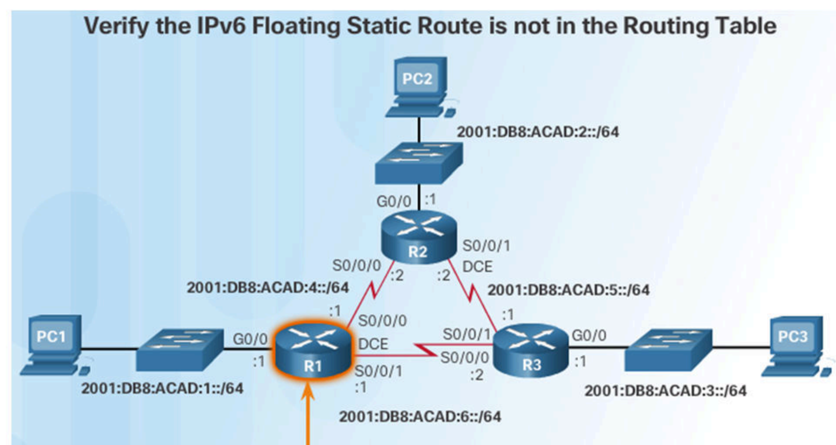
Configure an IPv6 Floating Static Route

Similar to IPv4 floating static routes




```
R1(config)# ipv6 route ::/0 2001:db8:acad:4::2
R1(config)# ipv6 route ::/0 2001:db8:acad:6::2 5
R1(config)#
```

```
R1# show run | include ipv6 route
ipv6 route ::/0 2001:DB8:ACAD:6::2 5
ipv6 route ::/0 2001:DB8:ACAD:4::2
R1#
```

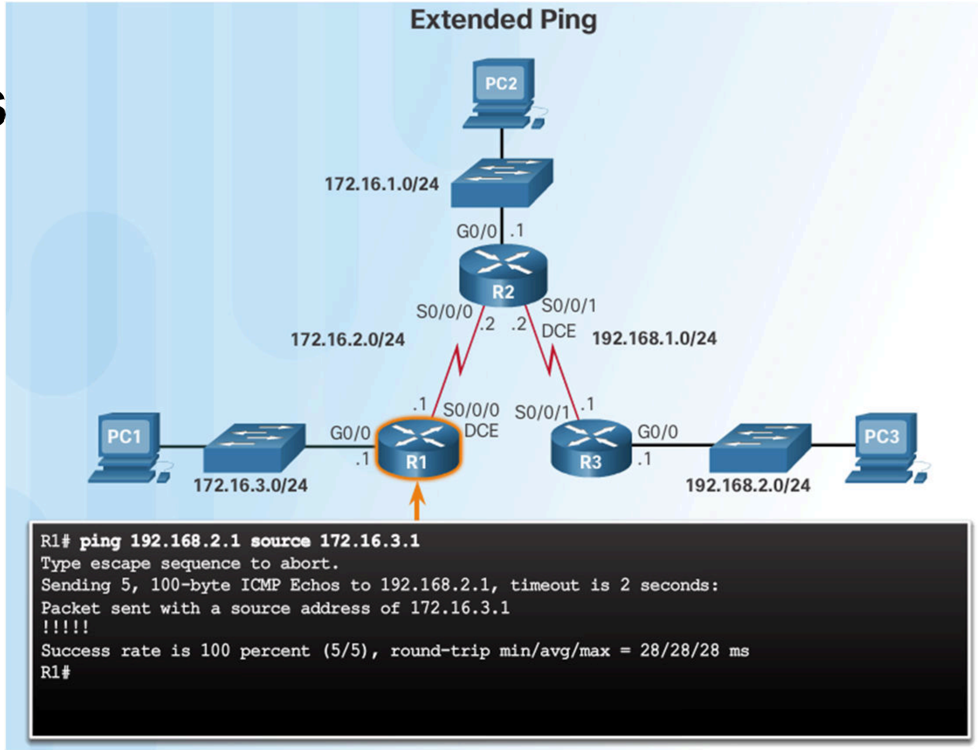



```
R1# show ipv6 route static | begin S    :
S    ::/0 [1/0]
     via 2001:DB8:ACAD:4::2
R1#
```

Troubleshoot a Missing Route

Common IOS troubleshooting commands include:

- ping
- traceroute
- show ip route
- show ip interface brief
- show cdp neighbors detail

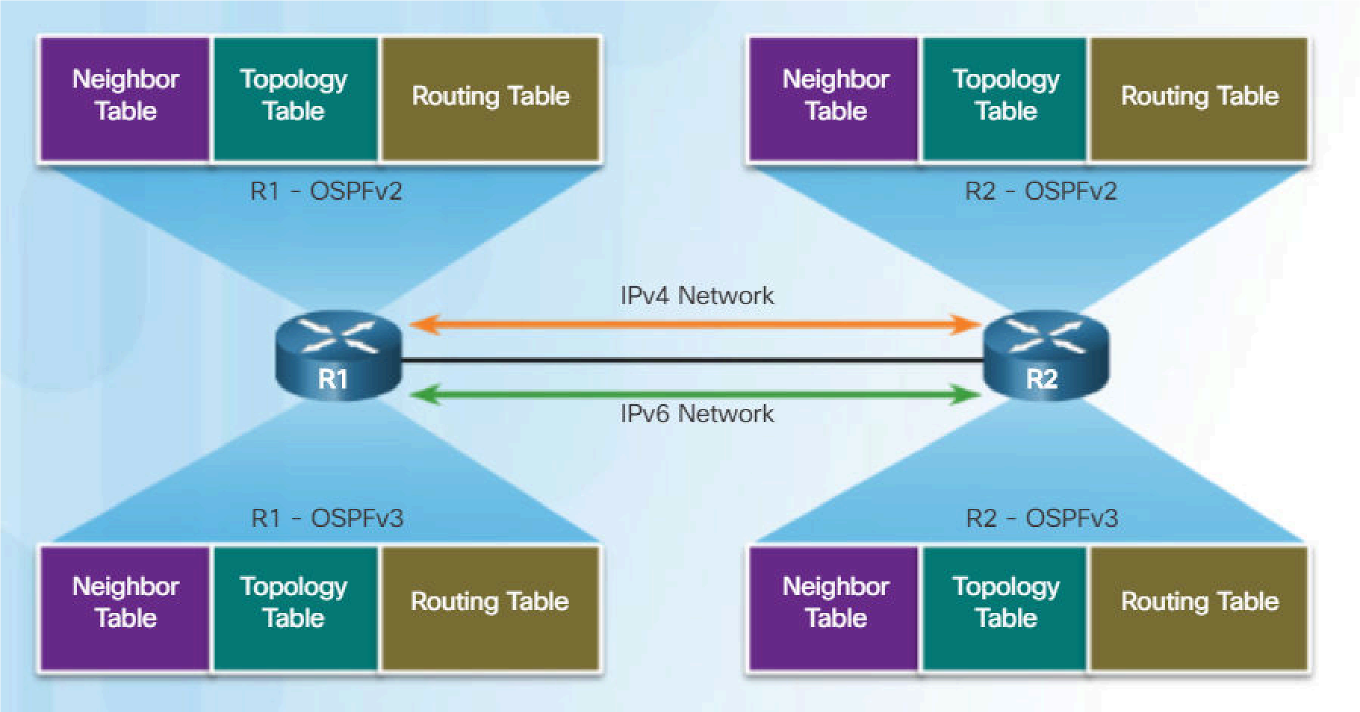


Dynamic Route with IPv6

OSPFv3

OSPFv3 is used to exchange IPv6 prefixes and build an IPv6 routing table.

OSPFv3 builds three OSPF tables – neighbor table, topology table, and routing table.



Similarities Between OSPFv2 and OSPFv3

Feature	Comments
Link-State	Both are this type of routing protocol
Routing algorithm	Shortest Path First (SPF)
Metric	Cost
Areas	Both use and support a two-level hierarchy with areas connecting to Area 0
Packet types	Both use the same Hello, DBD, LSR, LSU, and LSAck packets
Neighbor discovery	Transitions through the same states using Hello packets
DR/BDR	Function and election process is the same
Router ID	Both use a 32-bit router ID; determined by the same process

Differences Between OSPFv2 and OSPFv3

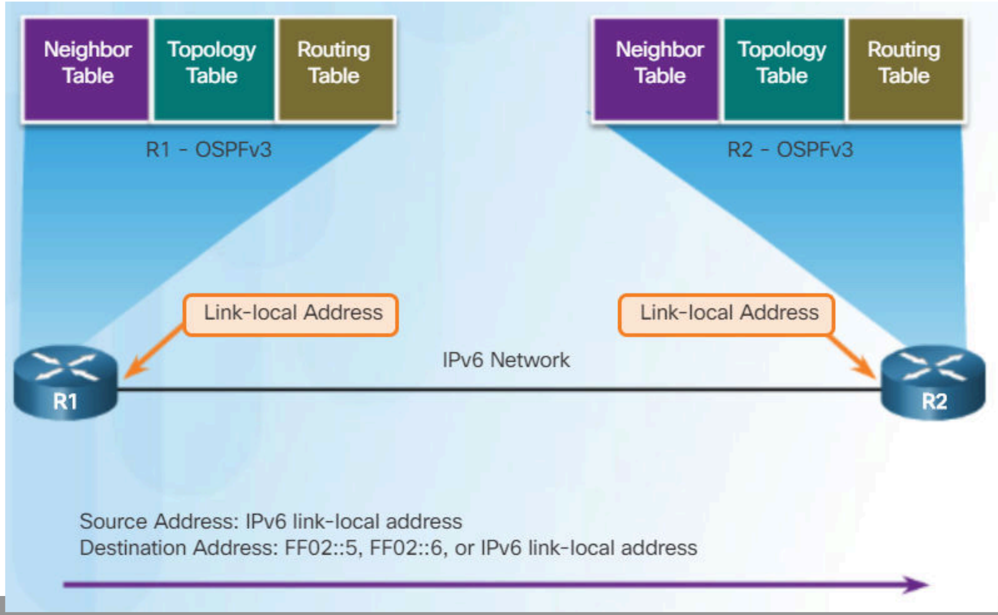
Feature	OSPFv2	OSPFv3
Advertisements	IPv4 networks	IPv6 prefixes
Source address	IPv4 source address	IPv6 link-local address
Destination address	Choice of: • Neighbor IPv4 unicast address • 224.0.0.5 all-OSPF-routers multicast address • 224.0.0.6 DR/BDR multicast address	Choice of: • Neighbor IPv6 link-local address • FF02::5 all-OSPF-routers multicast address • FF02::6 DR/BDR multicast address
Advertise networks	Configured using the **network** router configuration command	Configured using the **ipv6 ospf** *process-id* **area** *area-id* interface configuration command
IP unicast routing	IPv4 unicast routing is enabled by default	IPv6 unicast forwarding is not enabled by default. Use the **ipv6 unicast-routing** global configuration command to enable.
Authentication	Plain text and MD5	IPv6 authentication (IPsec)

Link-Local Addresses

An IPv6-link-local address enables a device to communicate with other IPv6-enabled devices on the same link and only on that link (subnet).

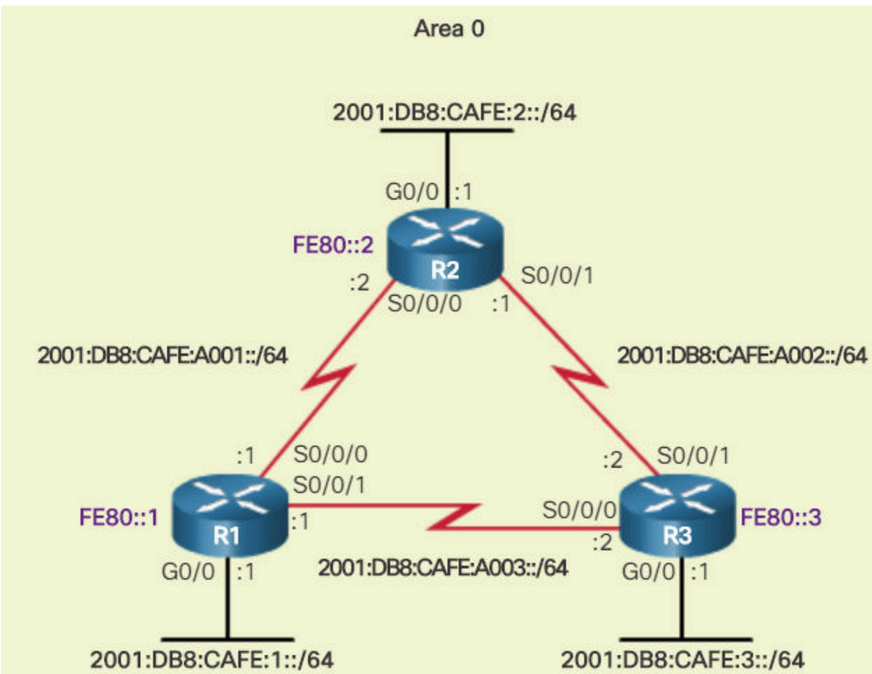
- Packets with a source or destination link-local address cannot be routed beyond the link from where the packet originated.

IPv6 link-local address are used to exchange OSPFv3 messages



OSPFv3 Network Topology

Be sure to turn on IPv6 routing and assign IPv6 addresses to interfaces before enabling OSPFv3.




```
R1(config)# ipv6 unicast-routing
R1(config)#
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# description R1 LAN
R1(config-if)# ipv6 address 2001:DB8:CAFE:1::1/64
R1(config-if)# no shut
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# description Link to R2
R1(config-if)# ipv6 address 2001:DB8:CAFE:A001::1/64
R1(config-if)# clock rate 128000
R1(config-if)# no shut
R1(config-if)#
R1(config-if)# interface Serial0/0/1
R1(config-if)# description Link to R3
R1(config-if)# ipv6 address 2001:DB8:CAFE:A003::1/64
R1(config-if)# no shut
```

The FE80 address on each router represents the link-local address assigned to each router.

OSPFv3 Network Topology (Cont.)

Steps to Configure OSPFv3

1. Enable IPv6 unicast routing in global configuration mode – ipv6 unicast-routing
2. (Optional) Configure link-local addresses.
3. Configure a 32-bit router ID in OSPFv3 router configuration mode – router-id *rid*
4. Configure optional routing specifics such as adjusting the reference bandwidth.
5. (Optional, but optimum) Configure OSPFv3 interface specific settings such as setting the interface bandwidth on serial links.
6. Enable OSPFv3 routing in interface configuration mode – ipv6 ospf area

Configuring the OSPFv3 Router ID

Use the ipv6 router ospf *process-id* global configuration command to enter router configuration mode.

Use the router-id *rid* command in router configuration mode to assign a router ID and use the show ipv6 protocols command to verify.

```
R1(config)# ipv6 router ospf 10
R1(config-rtr)#
*Mar 29 11:21:53.739: %OSPFv3-4-NORTRID: Process OSPFv3-1-
IPv6 could not pick a router-id, please configure manually
R1(config-rtr)#
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)#
R1(config-rtr)# auto-cost reference-bandwidth 1000
% OSPFv3-1-IPv6:  Reference bandwidth is changed. Please
ensure reference bandwidth is consistent across all routers.
R1(config-rtr)#
R1(config-rtr)# end
R1#
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
  Number of areas: 0 normal, 0 stub, 0 nssa
  Redistribution:
    None
```

Modifying an OSPFv3 Router ID

Use the clear ipv6 ospf process privileged EXEC mode command after changing the router ID to complete the router ID change and force a router to renegotiate neighbor adjacencies using the new router ID.

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 10.1.1.1
  Number of areas: 0 normal, 0 stub, 0 nssa
  Redistribution:
   None
```

Original router ID

```
R1(config)# ipv6 router ospf 10
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)# end
R1#
```

Change the router ID.

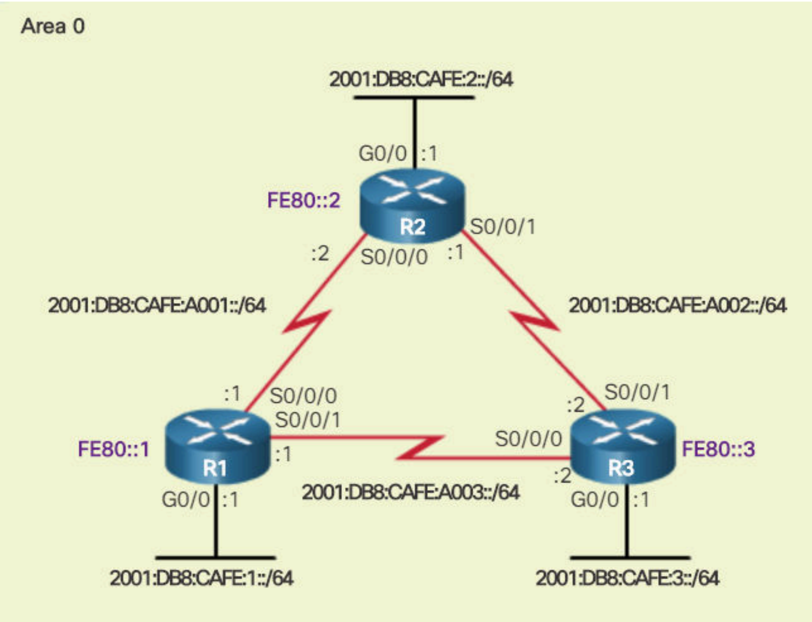
```
R1# clear ipv6 ospf process
Reset selected OSPFv3 processes? [no]: y
R1#
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Number of areas: 0 normal, 0 stub, 0 nssa
  Redistribution:
    None
```

Complete the router ID change.

Enabling OSPFv3 on Interfaces

Use the ipv6 ospf area interface configuration mode command to enable OSPFv3 on a specific interface. Ensure the interface is within an OSPF area.

Use the show ipv6 ospf interfaces brief command to verify.




```
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)#
R1(config-if)# interface Serial0/0/1
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)#
R1(config-if)# end
R1#
R1# show ipv6 ospf interfaces brief
Interface  PID   Area     Intf ID  Cost   State  Nbrs F/C
Se0/0/1    10     0          7     15625  P2P    0/0
Se0/0/0    10     0          6     647    P2P    0/0
Gi0/0      10     0          3       1    WAIT   0/0
R1#
```

Verify OSPFv3

Verifying OSPFv3 Neighbors

Use the show ipv6 ospf neighbor command to verify neighbor connectivity with directly-connected routers.

```
R1# show ipv6 ospf neighbor

OSPFv3 Router with ID (1.1.1.1) (Process ID 10)

Neighbor ID   Pri  State     Dead Time   Interface ID Interface
3.3.3.3        0   FULL/  -   00:00:39   6            Serial0/0/1
2.2.2.2        0   FULL/  -   00:00:36   6            Serial0/0/0
```

Output	Description
Neighbor ID	The router ID of the neighbor router
Pri	The OSPFv3 priority of the interface used in the DR/BDR election process
State	The OSPFv3 state – Full means that the link-state database has had the algorithm executed and the neighbor router and R1 have identical LSDBs. Ethernet multi-access interfaces may show as 2WAY. The dash indicates that no DR/BDR is required.
Dead time	Amount of time remaining before expecting to receive an OSPFv3 Hello packet from the neighbor before declaring the neighbor down. This value is reset when a hello packet is received.
Address	The address of the neighbor’s directly-connected interface
Interface	The interface on R1 used to form an adjacency with the neighbor router

Verifying OSPFv3 Protocol Settings

Use the show ipv6 protocols command to verify vital OSPFv3 configuration information.

```
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
 Number of areas: 1 normal, 0 stub, 0 nssa
 Interfaces (Area 0):
   Serial0/0/1
   Serial0/0/0
   GigabitEthernet0/0
```

Verify OSPFv3 Interfaces

Use the show ipv6 ospf interface command to display a detailed list for every OSPFv3-enabled interface.

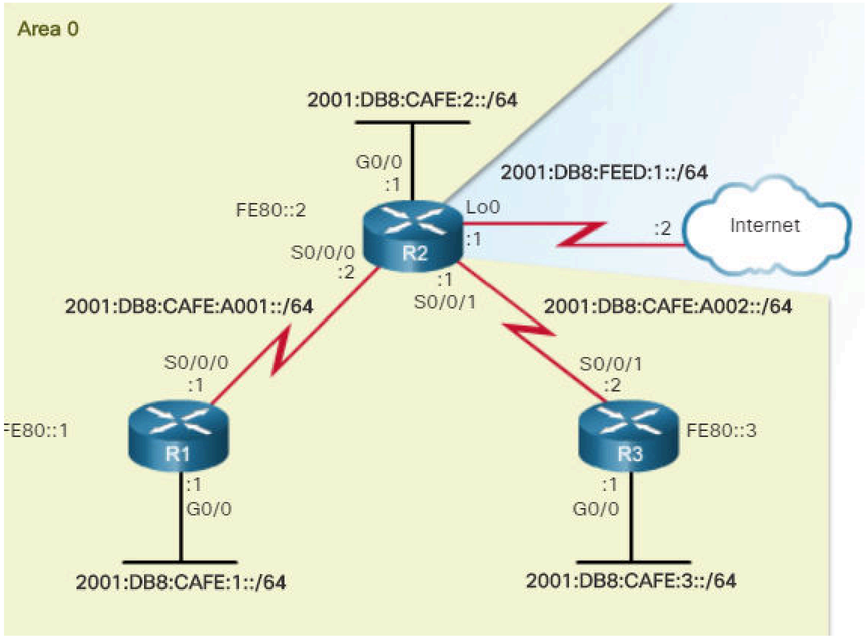
The show ipv6 ospf interface brief command is an easier output to verify which interfaces are being used with OSPFv3.

```
R1# show ipv6 ospf interface brief
Interface    PID   Area            Intf ID    Cost  State Nbrs F/C
Se0/0/1      10    0               7          15625 P2P   1/1
Se0/0/0      10    0               6          647   P2P   1/1
Gi0/0        10    0               3          1     DR    0/0
```

Propagating a Default Static Route in OSPFv3

To propagate a default route, the edge router (R2) must be configured with:

- **A default static route using the ipv6 route ::/0 {*ipv6-address* | *exit-intf*} command.**
- **The default-information originate router configuration mode command.**




```
R2(config)# ipv6 route ::/0 2001:DB8:FEED:1::2
R2(config)#
R2(config)# ipv6 router ospf 10
R2(config-rtr)# default-information originate
R2(config-rtr)# end
R2#
*Apr 10 11:36:21.995: %SYS-5-CONFIG_I: Configured from console by console
R2#
```

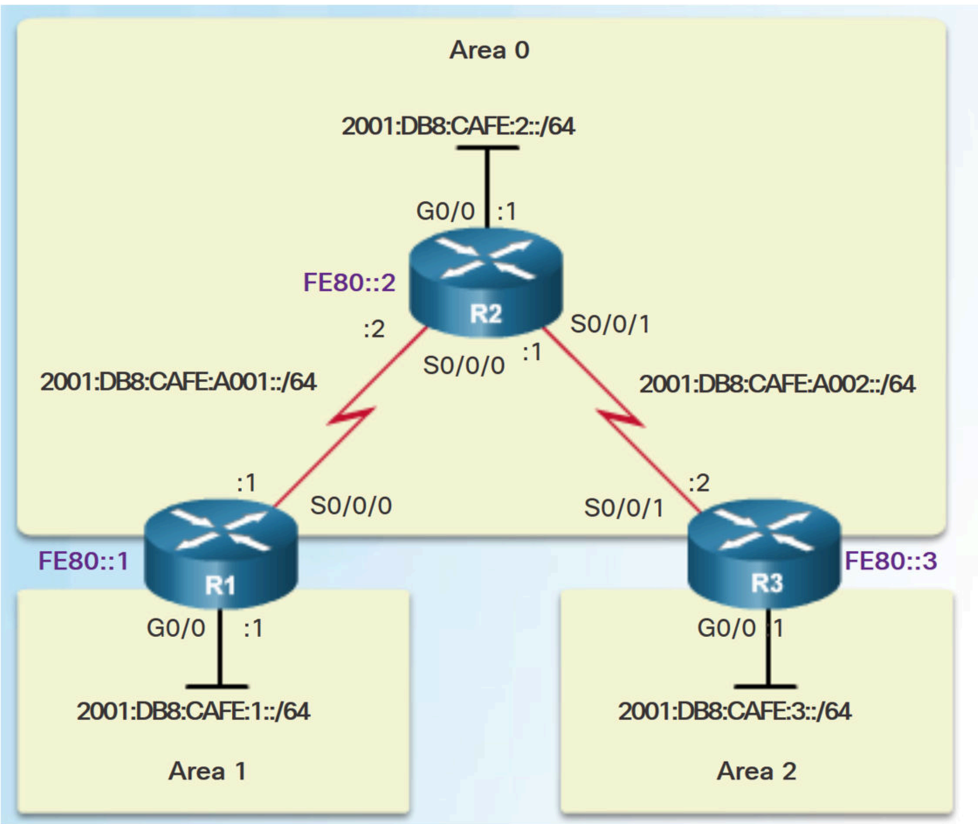
Verify The IPv6 Routing Table

Use the show ipv6 route command to see an IPv6 routing table.

Use the show ipv6 route ospf command to see just the OSPFv3 routes.

```
R1# show ipv6 route ospf
IPv6 Routing Table - default - 10 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 [110/657]
     via FE80::2, Serial0/0/0
 O   2001:DB8:CAFE:3::/64 [110/1304]
     via FE80::2, Serial0/0/0
 O   2001:DB8:CAFE:A002::/64 [110/1294]
     via FE80::2, Serial0/0/0
```

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#
```

There are no special commands required to implement multiarea OSPFv3.

A router becomes an ABR when it has two interfaces in different areas.

Verify 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#
```

Use the show ipv6 protocols command to verifyOSPFv3.

Use the show ipv6 interface brief to verify the OSPFv3-enabled interfaces and the area to which they belong.

Use show ipv6 route ospf to display the routing table.

Use show ipv6 ospf database to display the contents of the LSDB.

```
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
```

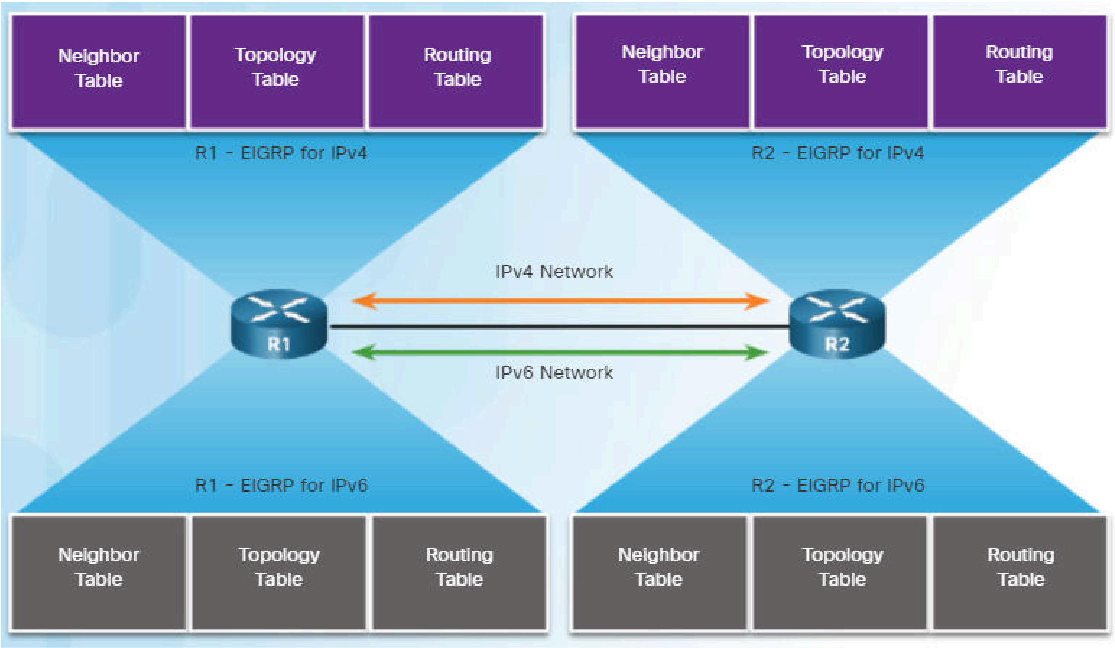
EIGRP for IPv6

EIGRP for IPv6 is a distance-vector routing protocol.

- The configuration and operation is similar to EIGRP for IPv4.

The following remained the same as EIGRP for IPv4:

- Uses the same protocol number (88)
- Maintains a topology table and queries if no feasible successors are available.
- Uses DUAL to calculate the successor routes



EIGRP for IPv6

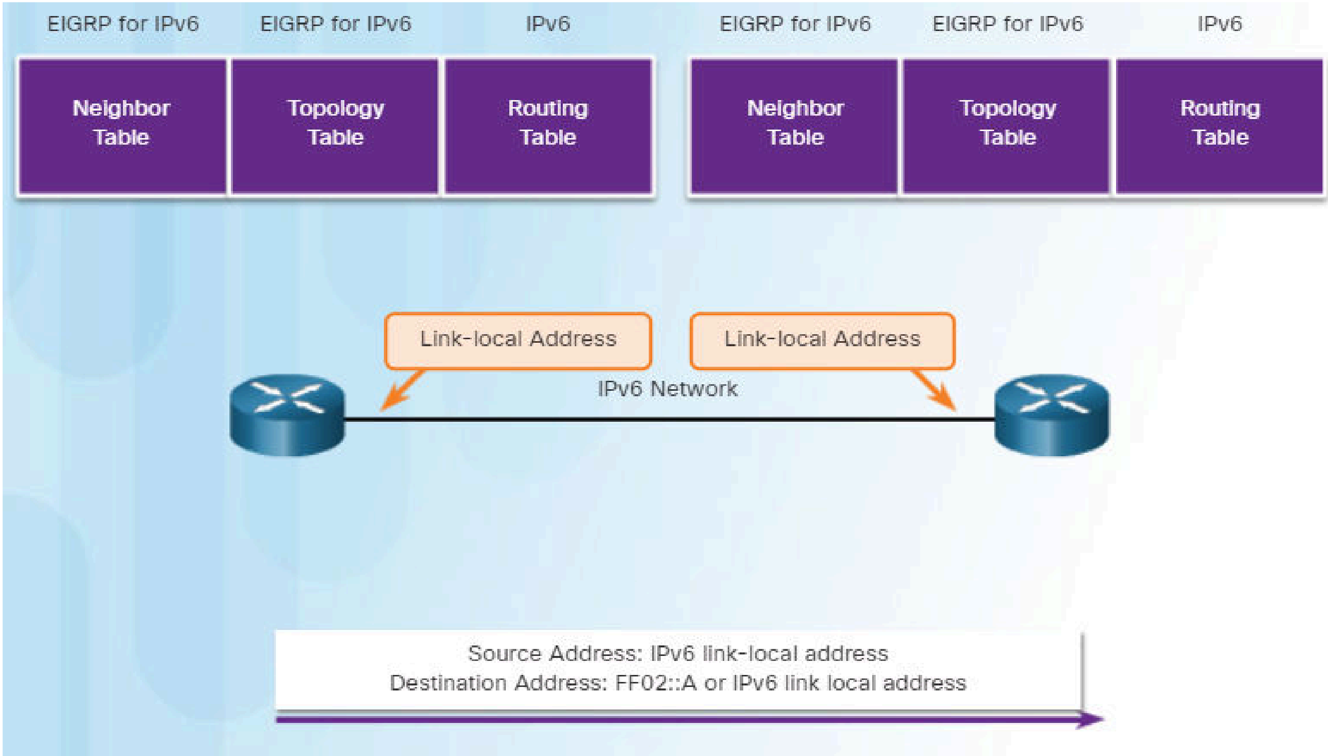
The following compares EIGRP for IPv4 and IPv6

	EIGRP for IPv4	EIGRP for IPv6
Advertised Routes	IPv4 networks	IPv6 prefixes
Distance Vector	Yes	Yes
Convergence Technology	DUAL	DUAL
Metric	Bandwidth and delay by default, reliability and load are optional	Bandwidth and delay by default, reliability and load are optional
Transport Protocol	RTP	RTP
Update Messages	Incremental, partial, and bounded updates	Incremental, partial, and bounded updates
Neighbor Discovery	Hello packets	Hello packets
Source and Destination Addresses	IPv4 source address and 224.0.0.10 IPv4 multicast destination address	IPv6 link-local source address and FF02::A IPv6 multicast destination address
Authentication	MD5, SHA256	MD5, SHA256
Router ID	32-bit router ID	32-bit router ID

EIGRP for IPv6

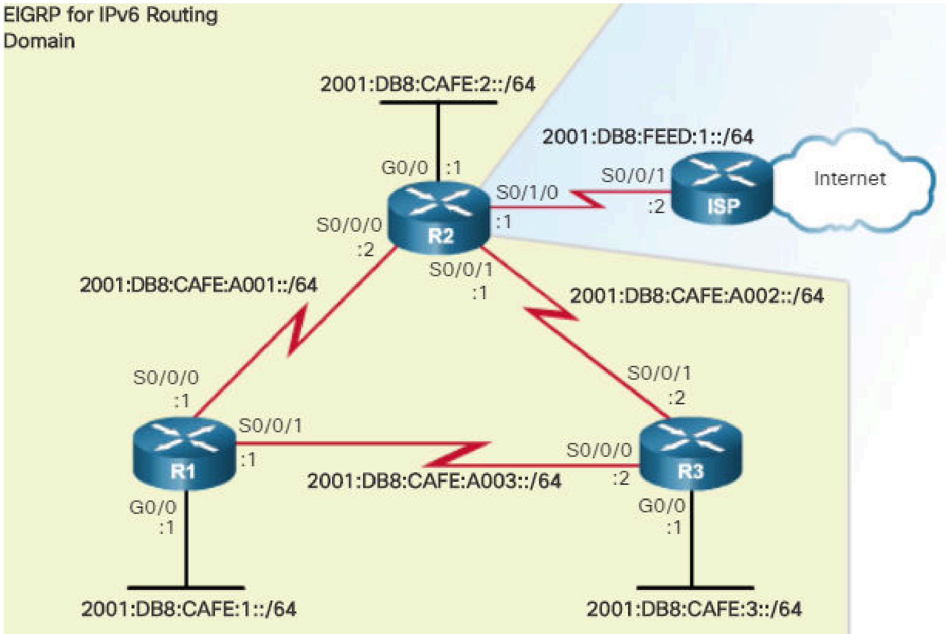
EIGRP for IPv6 messages are sent using:

- **Source IPv6 address - This is the IPv6 link-local address of the exit interface.**
- **Destination IPv6 address - When the packet needs to be sent to a multicast address, it is sent to the IPv6 multicast address FF02::A, the all-EIGRP-routers with link-local scope. If the packet can be sent as a unicast address, it is sent to the link-local address of the neighboring router.**



Configure EIGRP for IPv6

```
R2# show running-config
<output omitted>
!
interface GigabitEthernet0/0
 ipv6 address 2001:DB8:CAFE:2::1/64
!
interface Serial0/0/0
 ipv6 address 2001:DB8:CAFE:A001::2/64
!
interface Serial0/0/1
 ipv6 address 2001:DB8:CAFE:A002::1/64
 clock rate 64000
!
interface Serial0/1/0
 ipv6 address 2001:DB8:FEED:1::1/64
```




```
R1# show running-config
<output omitted>
!
interface GigabitEthernet0/0
 ipv6 address 2001:DB8:CAFE:1::1/64
!
interface Serial0/0/0
 ipv6 address 2001:DB8:CAFE:A001::1/64
 clock rate 64000
!
interface Serial0/0/1
 ipv6 address 2001:DB8:CAFE:A003::1/64
```

```
R3# show running-config
<output omitted>
!
interface GigabitEthernet0/0
 ipv6 address 2001:DB8:CAFE:3::1/64
!
interface Serial0/0/0
 ipv6 address 2001:DB8:CAFE:A003::2/64
 clock rate 64000
!
interface Serial0/0/1
 ipv6 address 2001:DB8:CAFE:A002::2/64
```

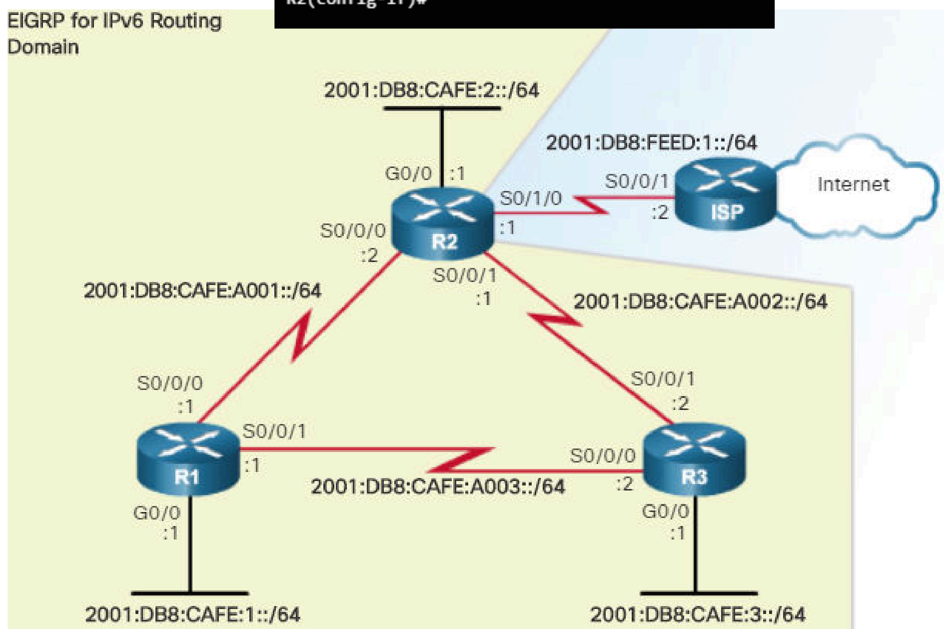
Configure EIGRP for IPv6

```
R1(config)# interface s 0/0/0
R1(config-if)# ipv6 address fe80::1 ?
  link-local  Use link-local address

R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# exit
R1(config)# interface s 0/0/1
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# exit
R1(config)# interface g 0/0
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)#
```

```
R1# show ipv6 interface brief
GigabitEthernet0/0     [up/up]
    FE80::1
    2001:DB8:CAFE:1::1
Serial0/0/0            [up/up]
    FE80::1
    2001:DB8:CAFE:A001::1
Serial0/0/1            [up/up]
    FE80::1
    2001:DB8:CAFE:A003::1
R1#
```

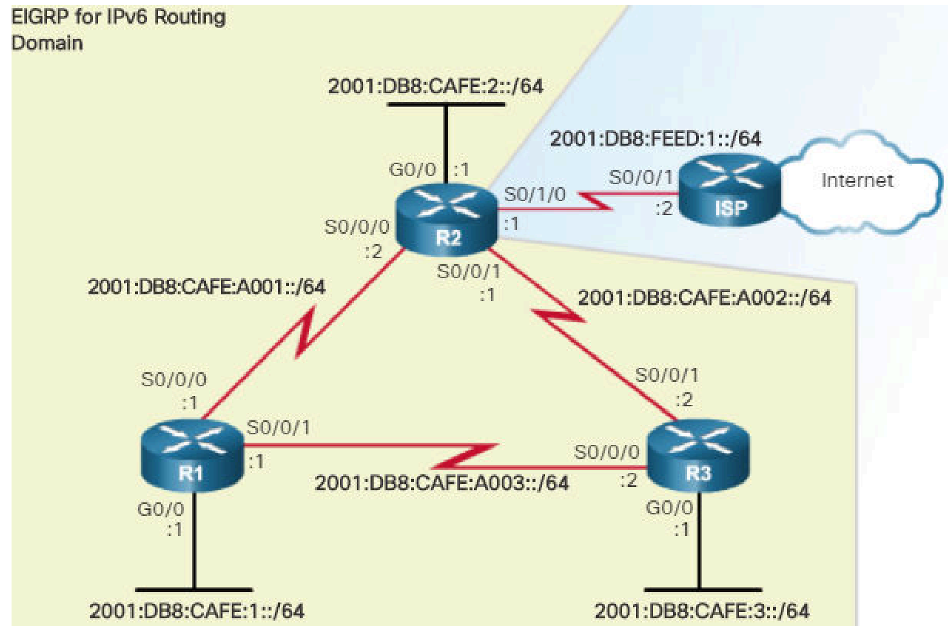
Same IPv6 link-local address is configured on all interfaces.

```
R2(config)# interface s 0/0/0
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)# exit
R2(config)# interface s 0/0/1
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)# exit
R2(config)# interface s 0/1/0
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)# exit
R2(config)# interface g 0/0
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)#
```



Configure EIGRP for IPv6

```
R2(config)# ipv6 unicast-routing
R2(config)# ipv6 router eigrp 2
R2(config-rtr)# eigrp router-id 2.0.0.0
R2(config-rtr)# no shutdown
R2(config-rtr)#
```



The ipv6 unicast-routing global config mode command enables IPv6 routing on the router.

Use the ipv6 router eigrp *autonomous-system* to enter EIGRP for IPv6 router configuration mode.

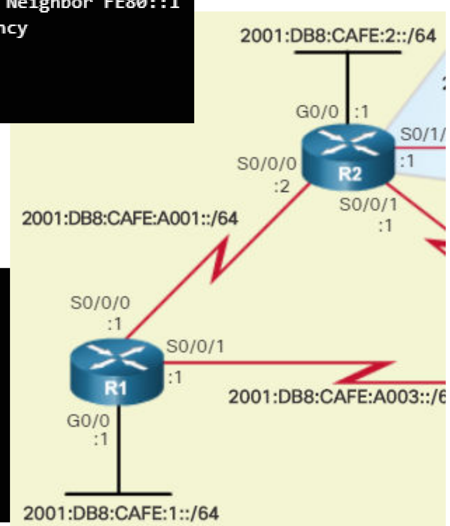
Use the eigrp router-id *router-id* command is used to configure the router ID.

By default, the EIGRP for IPv6 process is in a shutdown state and the no shutdown command is required to activate the EIGRP for IPv6 process.

Configure EIGRP for IPv6

Unlike EIGRP for IPv4 which uses the network command, EIGRP for IPv6 is configured directly on the interface using the ipv6 eigrp *autonomous-system* interface configuration command.

```
R2(config)# interface g 0/0
R2(config-if)# ipv6 eigrp 2
R2(config-if)# exit
R2(config)# interface s 0/0/0
R2(config-if)# ipv6 eigrp 2
R2(config-if)# exit
%DUAL-5-NBRCHANGE: EIGRP-IPv6 2: Neighbor FE80::1
 (Serial0/0/0) is up: new adjacency
R2(config)# interface s 0/0/1
R2(config-if)# ipv6 eigrp 2
R2(config-if)#
```




```
R1(config)# interface g0/0
R1(config-if)# ipv6 eigrp 2
R1(config-if)# exit
R1(config)# interface s 0/0/0
R1(config-if)# ipv6 eigrp 2
R1(config-if)# exit
R1(config)# interface s 0/0/1
R1(config-if)# ipv6 eigrp 2
R1(config-if)#
```

The same passive-interface command used for IPv4 is used with EIGRP for IPv6.

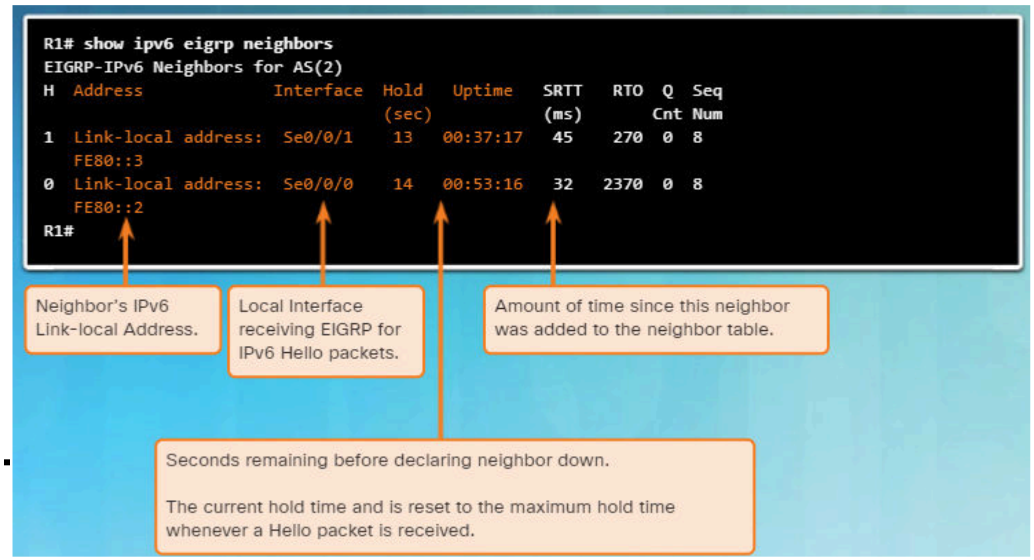
```
R1(config)# ipv6 router eigrp 2
R1(config-rtr)# passive-interface gigabitethernet 0/0
R1(config-rtr)# end

R1# show ipv6 protocols

IPv6 Routing Protocol is "eigrp 2"
EIGRP-IPv6 Protocol for AS(2)
<output omitted>

  Interfaces:
    Serial0/0/0
    Serial0/0/1
    GigabitEthernet0/0 (passive)
 Redistribution:
    None
R1#
```

Implement EIGRP for IPv6

Verifying EIGRP for IPv6

Use the show ipv6 eigrp neighbors command to view the neighbor table and verify that EIGRP for IPv6 has established an adjacency with its neighbors.

- **H - Lists the neighbors in order they were learned.**
- **Address - IPv6 link-local address of the neighbor.**
- **Interface - Local interface that received the Hello.**
- **Hold - Current hold time.**
- **Uptime - Time since this neighbor was added.**
- **SRTT and RTO - Used by RTP.**
- **Queue Count - Should always be zero.**
- **Sequence Number - Used to track updates, queries, and reply packets.**



Verifying EIGRP for IPv6

The show ipv6 protocols command displays the parameters and other information about the state of any active IPv6 routing protocol processes currently configured on the router.

1. EIGRP for IPv6 is an active dynamic routing protocol on R1.
2. These are the *k* values used to calculate the EIGRP composite metric.
3. The EIGRP for IPv6 router ID of R1 is 1.0.0.0.
4. Same as EIGRP for IPv4, EIGRP for IPv6 administrative distances have internal AD of 90 and external of 170 (default values).
5. The interfaces enabled for EIGRP for IPv6.

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "eigrp 2"
EIGRP-IPv6 Protocol for AS(2)                1 Routing protocol and Process ID (AS Number)


  Metric weight K1=1, K2=0, K3=1, K4=0, K5=0      2 K values used in composite metric

  NSF-aware route hold timer is 240
  Router-ID: 1.0.0.0                         3 EIGRP Router ID
  Topology : 0 (base)
    Active Timer: 3 min
    Distance: internal 90 external 170        4 EIGRP Administrative Distances
    Maximum path: 16
    Maximum hopcount 100
    Maximum metric variance 1

  Interfaces:                                5 Interfaces enabled for EIGRP for IPv6
    GigabitEthernet0/0
    Serial0/0/0
    Serial0/0/1
  Redistribution:
    None
R1#
```

Verifying EIGRP for IPv6

Use the show ipv6 route command to examine the IPv6 routing table.

- EIGRP for IPv6 routes are denoted with a D.

The figure shows that R1 has installed three EIGRP routes to remote IPv6 networks in its IPv6 routing table:

- 2001:DB8:CAFE:2::/64 via R3 (FE80::3) using its Serial 0/0/1 interface
- 2001:DB8:CAFE:3::/64 via R3 (FE80::3) using its Serial 0/0/1 interface
- 2001:DB8:CAFE:A002::/64 via R3 (FE80::3) using its Serial 0/0/1 interface

```
R1# show ipv6 route
<output omitted>

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
D   2001:DB8:CAFE:2::/64 [90/3524096]
     via FE80::3, Serial0/0/1
D   2001:DB8:CAFE:3::/64 [90/2170112]
     via FE80::3, Serial0/0/1
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
D   2001:DB8:CAFE:A002::/64 [90/3523840]
     via FE80::3, Serial0/0/1
C   2001:DB8:CAFE:A003::/64 [0/0]
     via Serial0/0/1, directly connected
L   2001:DB8:CAFE:A003::1/128 [0/0]
     via Serial0/0/1, receive
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```