Medium-Sized Routed Network Construction

Implementing VLSM

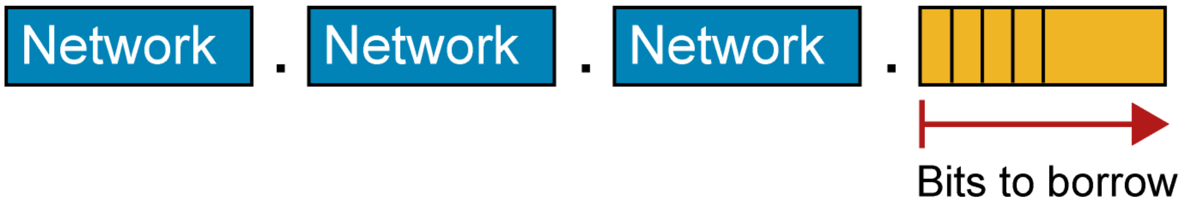
Subnetting Review

Network.Host

To identify subnets, you will “borrow” bits from the host ID portion of the IP address:

- **The number of subnets available depends on the number of bits borrowed.**
  - The available number of subnets = 2^s, I which *s* is the number of bits borrowed.
- **The number of hosts per subnet available depends upon the number of host ID bits *not* borrowed.**
  - The available number of hosts per subnet = 2^h -2, in which *h* is the number of host bits not borrowed.
  - One address is reserved as the network address.
  - One address is reserved as the broadcast address.

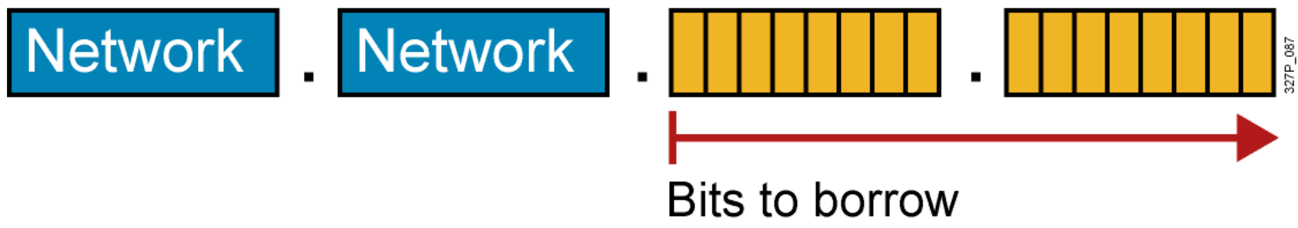
Possible Subnets and Hosts for a Class C Network



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($8 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	7	126
2	4	6	62
3	8	5	30
4	16	4	14
5	32	3	6
6	64	2	2
7	128	1	0

327P_034

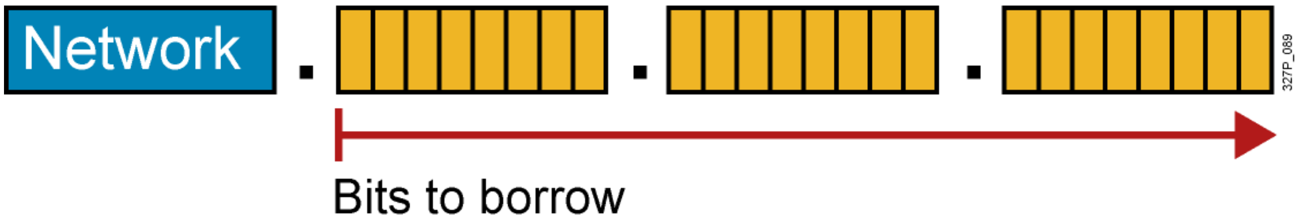
Possible Subnets and Hosts for a Class B Network



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($16 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	15	32,766
2	4	14	16,382
3	8	13	8,190
4	16	12	4,094
5	32	11	2,046
6	64	10	1,022
7	128	9	510
...	...	...	...

327P_088

Possible Subnets and Hosts for a Class A Network



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($24 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	23	8,388,606
2	4	22	4,194,302
3	8	21	2,097,150
4	16	20	1,048,574
5	32	19	524,286
6	64	18	262,142
7	128	17	131,070
...	...	...	...

327P_090

Subnetting Review Exercise

Từ lớp mạng 172.16.0.0/16 hãy chia subnet để được 100 mạng con. Xác định địa chỉ subnet, địa chỉ broadcast và dãy địa chỉ host hợp lệ của từng subnet.

- Cần mượn bao nhiêu bit? $2^s \geq 100 \rightarrow$ **s = 7**

→ Địa chỉ IP tổng quát sau khi chia? **172.16.abcdefgx.xxxxxxxx /23**

→ Subnet Mask mới: **255.255.254.0**

→ Bước nhảy = **2**

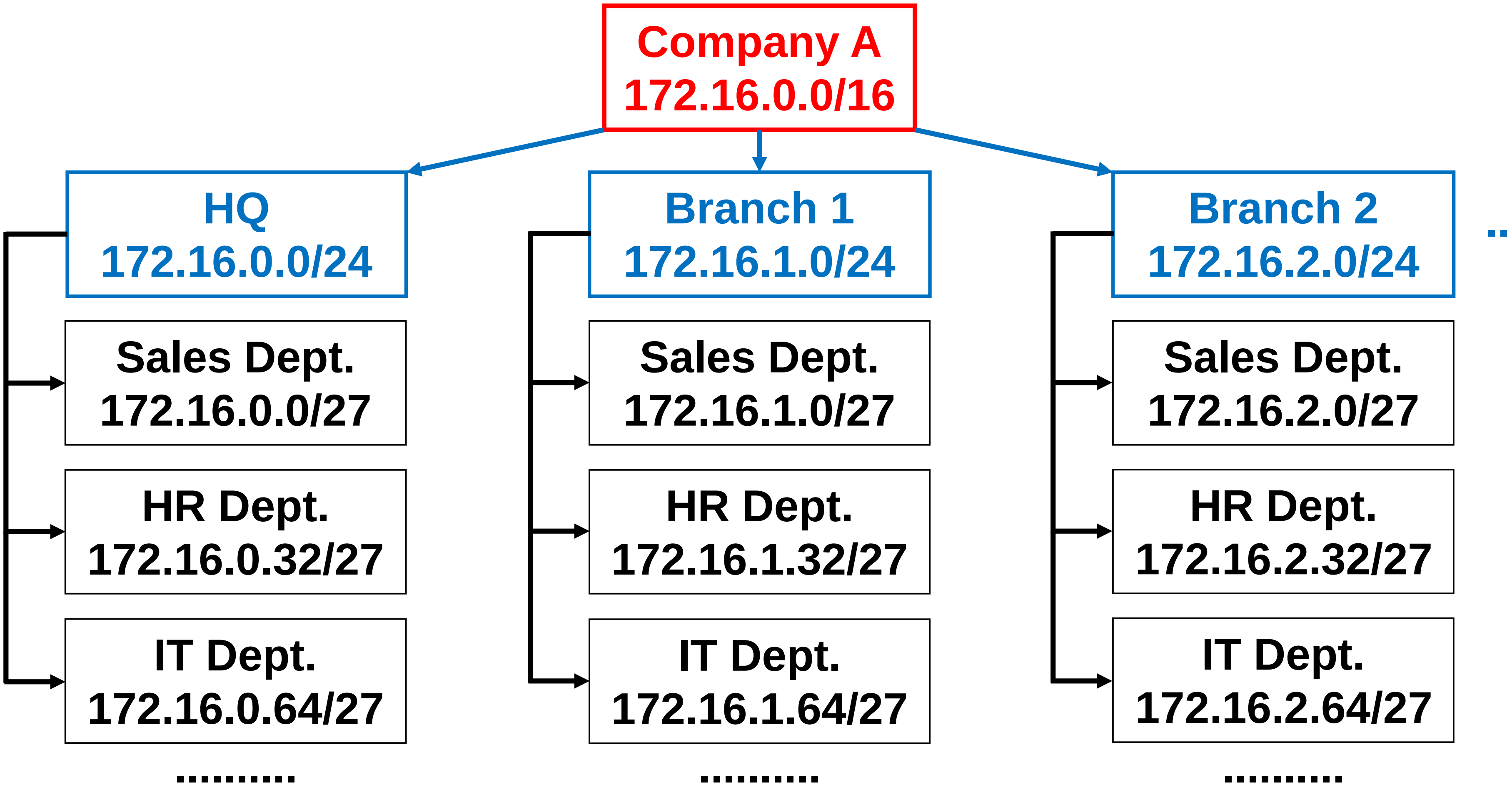
FLSM (**F**ixed-**L**ength **S**ubnet **M**ask)

- Liệt kê danh sách tất cả các subnet dựa trên bước nhảy, thêm vào địa chỉ broadcast và dãy địa chỉ host:

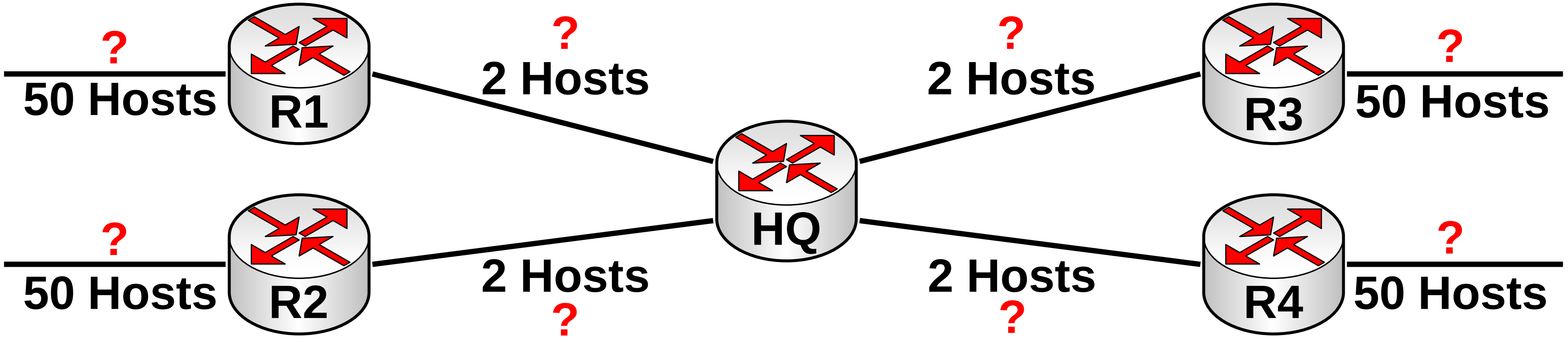
172.16.0.0	[172.16.0.1 - 172.16.1.254]	172.16.1.255	/23
172.16.2.0	[172.16.2.1 - 172.16.3.254]	172.16.3.255	/23
172.16.4.0	[172.16.4.1 - 172.16.5.254]	172.16.5.255	/23
172.16.6.0	[172.16.6.1 - 172.16.7.254]	172.16.7.255	/23
....			
172.16.254.0	[172.16.254.1 - 172.16.255.254]	172.16.255.255	/23

What Is a Variable-Length Subnet Mask?

VLSM simply means that the subnet design uses more than one mask in the same classful network.



VLSM Example 1



Từ lớp mạng 172.16.32.0/20 được hoạch định dành cho HQ, hãy đem chia subnet để đáp ứng cho mô hình mạng trên

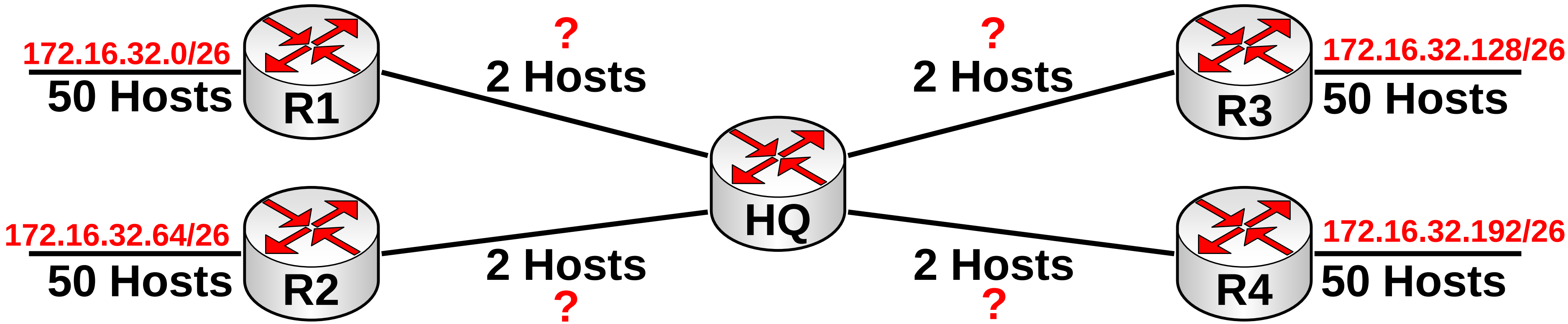
Mạng ban đầu là 172.16.32.0/20 = 172.16.0010xxxx.xxxxxxxx

Số host lớn nhất cần cho 1 mạng con là 50 → cần bao nhiêu bit host? $\rightarrow 2^h - 2 \geq 50 \rightarrow$ **h = 6**

→ Subnet mới sau khi chia sẽ là? → 172.16.0010abcd.efxxxxxx /26

- **172.16.00100000.00xxxxxx → 172.16.32.0 /26 → dùng cho R1**
- **172.16.00100000.01xxxxxx → 172.16.32.64 /26 → dùng cho R2**
- **172.16.00100000.10xxxxxx → 172.16.32.128 /26 → dùng cho R3**
- **172.16.00100000.11xxxxxx → 172.16.32.192 /26 → dùng cho R4**
- **172.16.00100001.00xxxxxx → 172.16.33.0 /26 → dùng cho các đoạn link kết nối**

VLSM Example 1 (Cont.)



Từ lớp mạng 172.16.32.0/20 được hoạch định dành cho HQ, hãy đem chia subnet để đáp ứng cho mô hình mạng trên

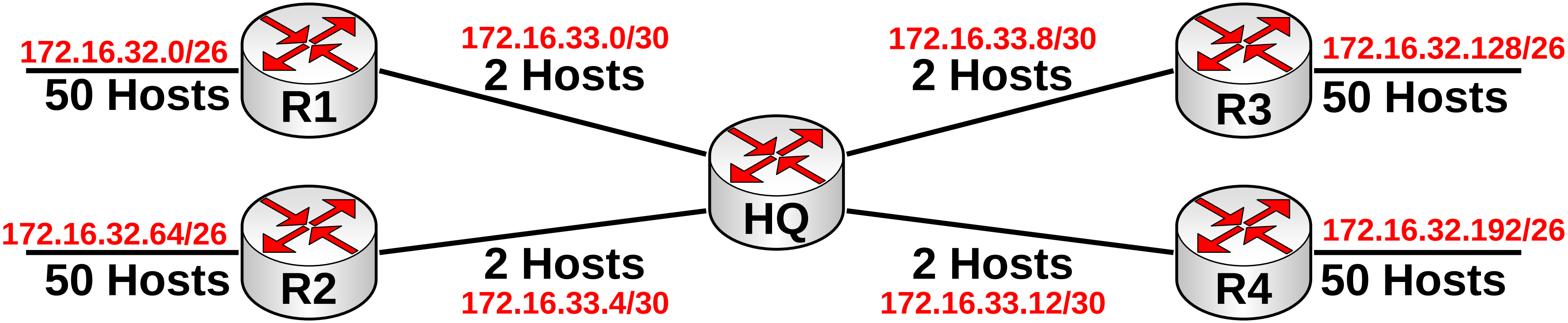
Tiếp tục chia subnet cho mạng 172.16.33.0 /26 = 172.16.33.00xxxxxx → dùng cho các đoạn link kết nối

Số host cần cho 1 link kết nối là 2 → cần bao nhiêu bit host? → $2^h - 2 \geq 2$ → h = 2

→ Subnet mới sau khi chia sẽ là? → 172.16.33.00abcdxx /30

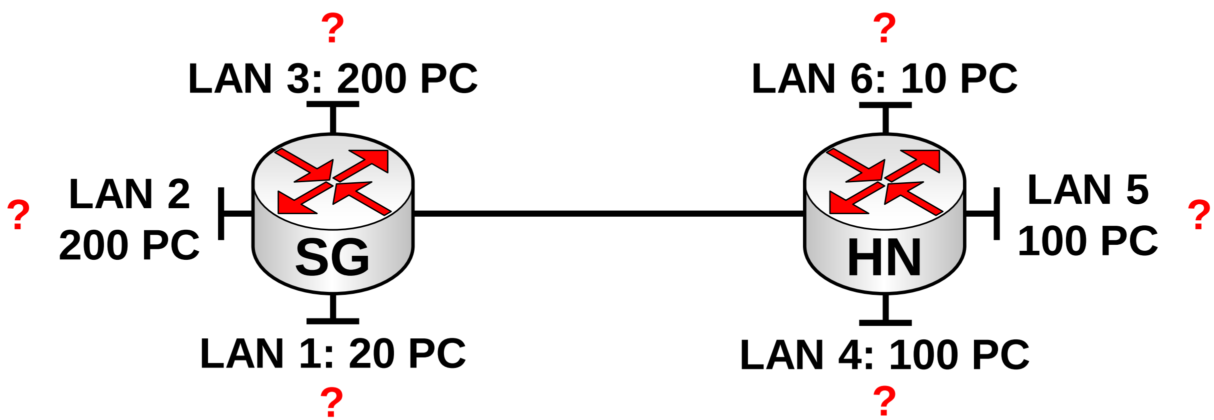
- **172.16.33.000000xx → 172.16.33.0 /30 → dùng cho link R1-HQ**
- **172.16.33.000001xx → 172.16.33.4 /30 → dùng cho link R2-HQ**
- **172.16.33.000010xx → 172.16.33.8 /30 → dùng cho link R3-HQ**
- **172.16.33.000011xx → 172.16.33.12 /30 → dùng cho link R4-HQ**
- **Các subnet còn lại → dự phòng**

VLSM Example 1 (Cont.)



Từ lớp mạng 172.16.32.0/20 được hoạch định dành cho HQ, hãy đem chia subnet để đáp ứng cho mô hình mạng trên

VLSM Example 2



Công ty có lớp mạng 155.55.0.0/16 còn trống, có thể sử dụng được. Hãy tiến hành chia subnet để có thể sử dụng cho mô hình mạng trên.

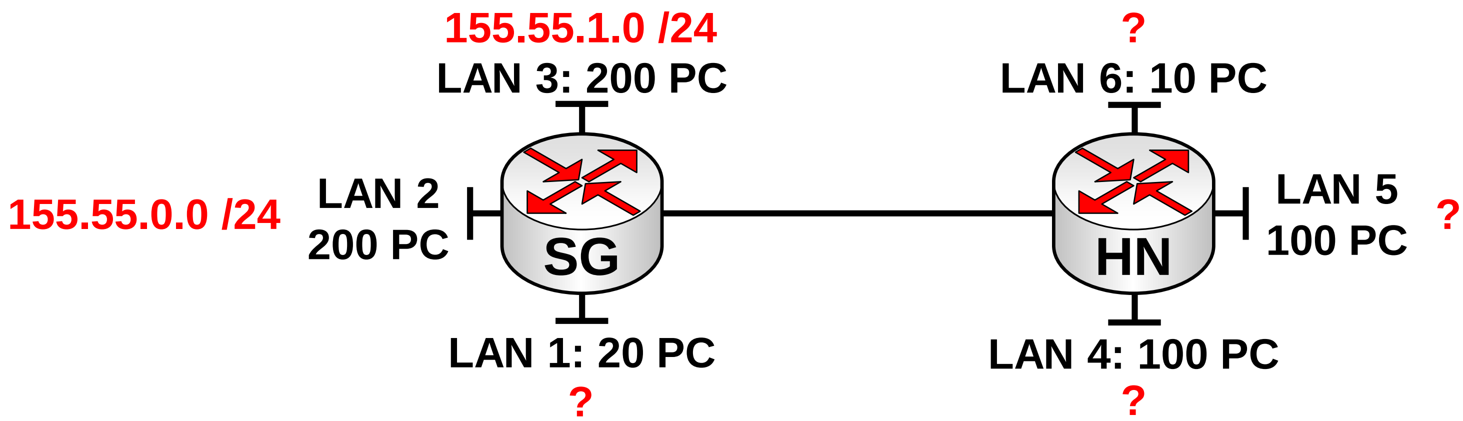
Mạng ban đầu là 155.55.0.0/16 = 155.55.xxxxxxxx.xxxxxxxx

Số host lớn nhất cần cho 1 mạng con là 200 → cần bao nhiêu bit host? $\rightarrow 2^h - 2 \geq 200 \rightarrow$ **h = 8**

→ Subnet mới sau khi chia sẽ là? → 155.55.abcdefgh.xxxxxxxx /24

- **155.55.00000000.xxxxxxxx → 155.55.0.0 /24 → dùng cho LAN 2**
- **155.55.00000001.xxxxxxxx → 155.55.1.0 /24 → dùng cho LAN 3**
- **155.55.00000010.xxxxxxxx → 155.55.2.0 /24 → đem chia tiếp**
- **155.55.00000011.xxxxxxxx → 155.55.3.0 /24 → dự phòng**
- **..........**

VLSM Example 2 (Cont.)



Công ty có lớp mạng 155.55.0.0/16 còn trống, có thể sử dụng được. Hãy tiến hành chia subnet để có thể sử dụng cho mô hình mạng trên.

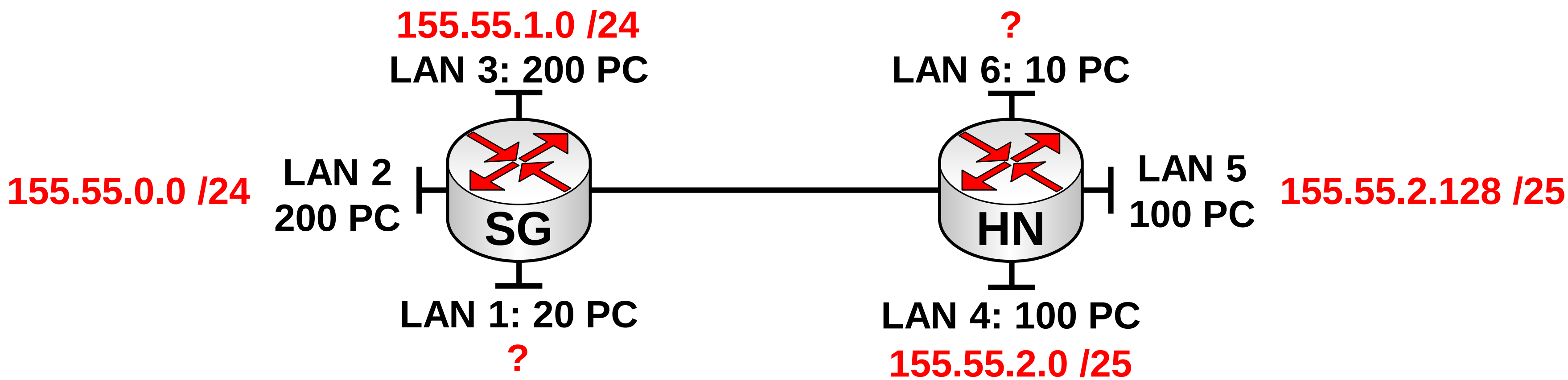
Tiếp tục đem subnet 155.55.2.0 /24 đi chia tiếp

Số lượng host lớn nhất tiếp theo là 100 → cần bao nhiêu bit host? $\rightarrow 2^h - 2 \geq 100 \rightarrow$ **h = 7**

→ Subnet mới sau khi chia sẽ là? → 155.55.2.axxxxxxx /25

- **155.55.2.0xxxxxxx → 155.55.2.0 /25 → dùng cho LAN 4**
- **155.55.2.1xxxxxxx → 155.55.2.128 /25 → dùng cho LAN 5**

VLSM Example 2 (Cont.)



Công ty có lớp mạng 155.55.0.0/16 còn trống, có thể sử dụng được. Hãy tiến hành chia subnet để có thể sử dụng cho mô hình mạng trên.

Tiếp tục đem subnet 155.55.3.0 /24 đi chia tiếp

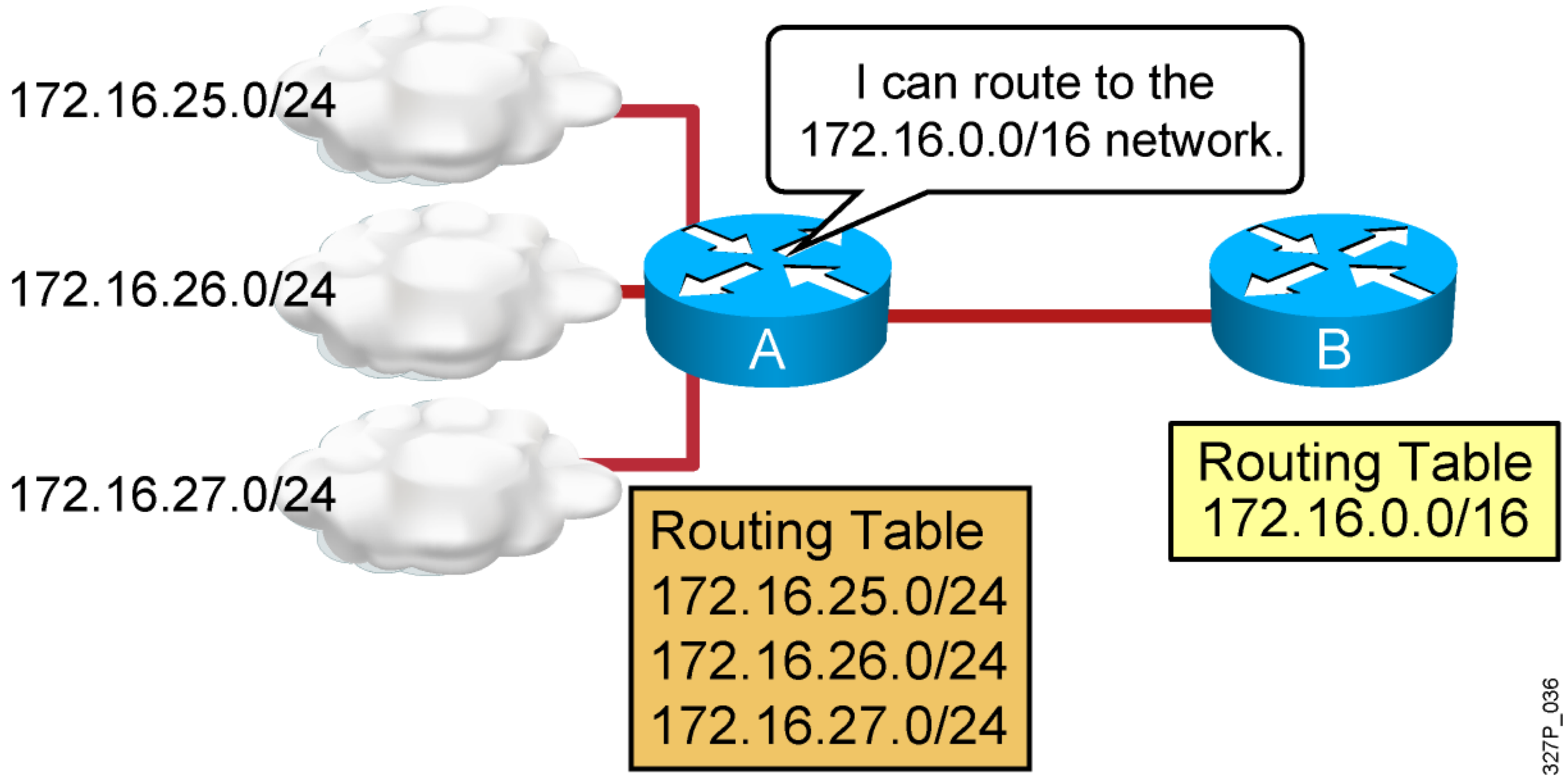
Số lượng host lớn nhất tiếp theo là 20 → cần bao nhiêu bit host? $\rightarrow 2^h - 2 \geq 20 \rightarrow$ **h = 5**

→ Subnet mới sau khi chia sẽ là? → 155.55.3.abcxxxxx /27

- **155.55.3.000xxxxx → 155.55.3.0 /27 → dùng cho LAN 1**
- **155.55.3.001xxxxx → 155.55.3.32 /27** $\xrightarrow{\text{chia tiếp}}$ **10 host → được subnet 155.55.3.001axxxx /28**
  - **155.55.3.0010xxxx /28 → 155.55.3.32 /28 → dùng cho LAN 6**
  - **155.55.3.0011xxxx /28 → dùng cho đoạn link kết nối** $\xrightarrow{\text{chia tiếp}}$ **/30 → 155.55.3.0011abxx /30**
    → 155.55.3.001100xx /30 → 155.55.3.48 /30 → dùng cho đoạn link kết nối SG-HN
    → .... $\}$ **Dự phòng**
- **..........**

Understanding Route Summarization

Route Summarization can be called Route Aggregation (or Supernetting)



Routing protocols can summarize addresses of several networks into one address.

Summarizing Within an Octet

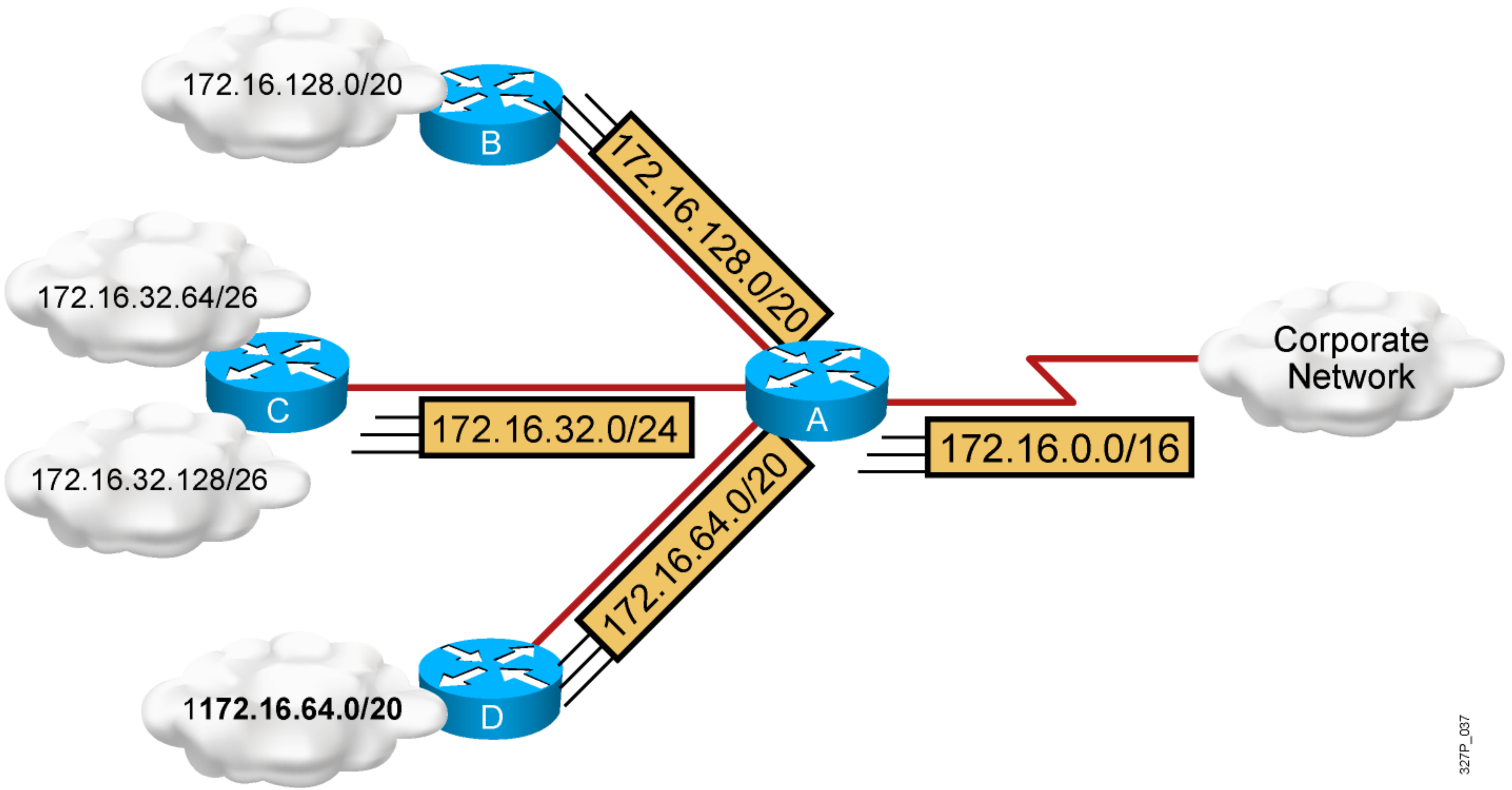
172.16.168.0/24 =	10101100	.	00010000	.	10101	000	.	00000000
172.16.169.0/24 =	172	.	16	.	10101	001	.	0
172.16.170.0/24 =	172	.	16	.	10101	010	.	0
172.16.171.0/24 =	172	.	16	.	10101	011	.	0
172.16.172.0/24 =	172	.	16	.	10101	100	.	0
172.16.173.0/24 =	172	.	16	.	10101	101	.	0
172.16.174.0/24 =	172	.	16	.	10101	110	.	0
172.16.175.0/24 =	172	.	16	.	10101	111	.	0

327P_092

Number of common bits = 21
Summary: 172.16.168.0/21

Noncommon bits = 11

Summarizing Addresses in a VLSM-Designed Network



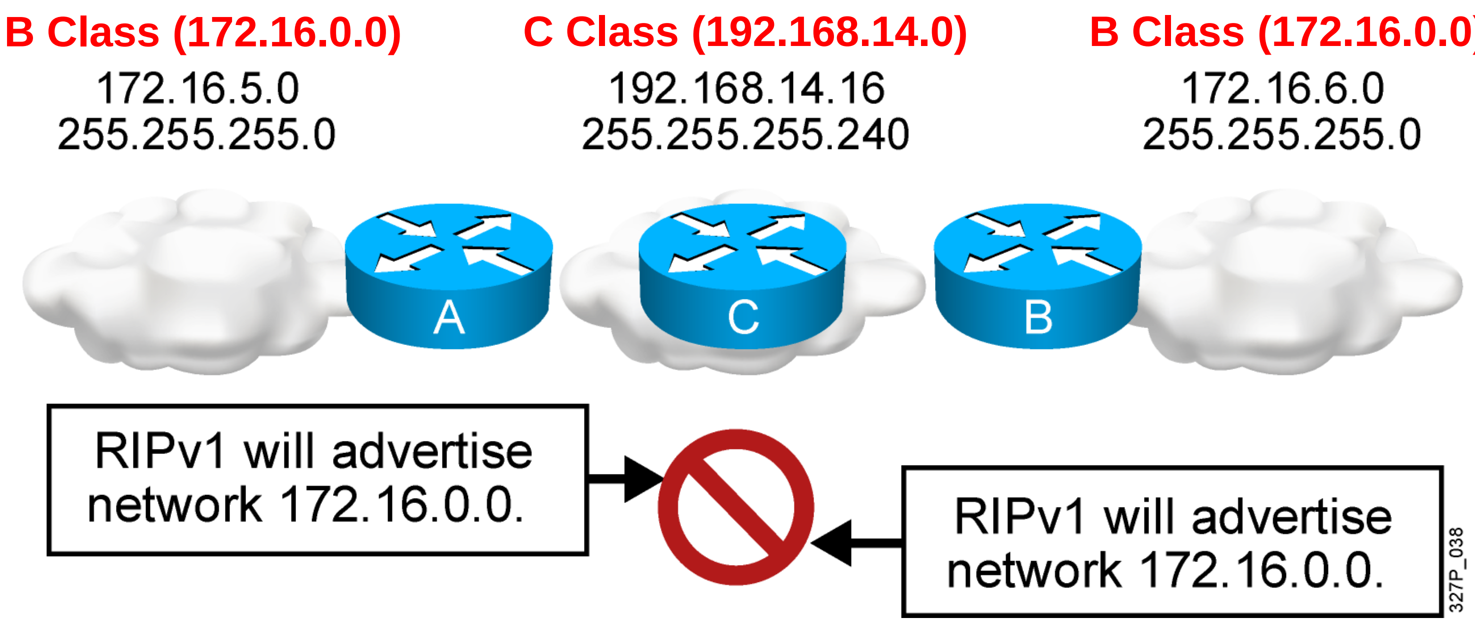
Route Summarization Operation in Cisco Routers

192.16.5.33	**/32**	**Host**
192.16.5.32	**/27**	**Subnet**
192.16.5.0	**/24**	**Network**
192.16.0.0	**/16**	**Block of Networks**
0.0.0.0	**/0**	**Default**

- Supports host-specific routes, blocks of networks, and default routes
- Routers use longest prefix match

Summarizing Routes in a Discontiguous Network

- Two networks of the same classful network are separated by a different classful network

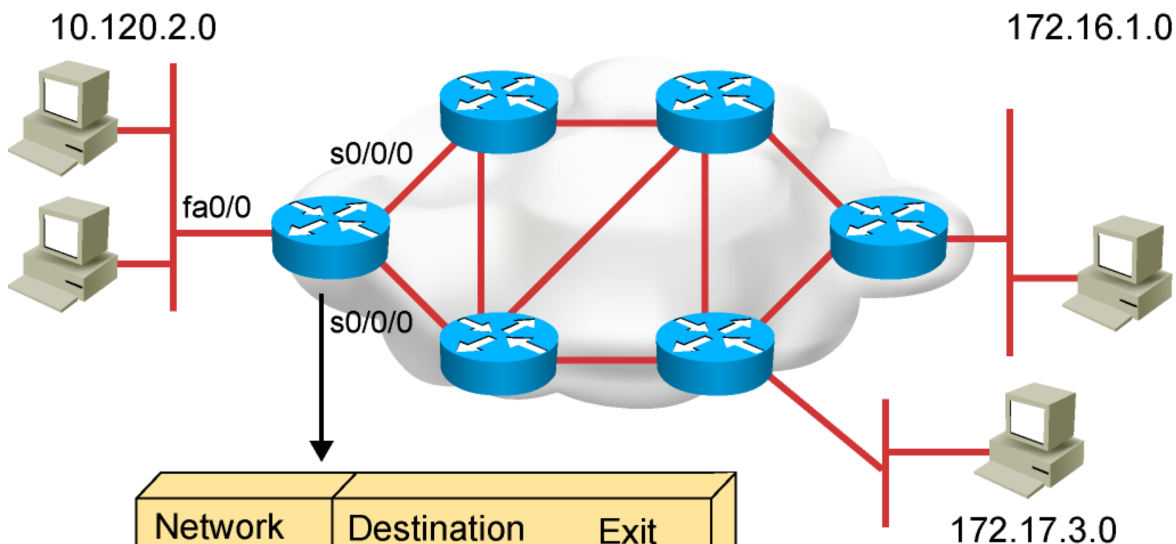


- Classful Routing Protocol (RIPv1 and IGRP) do not advertise subnets, and therefore cannot support discontiguous subnets.
- Classless Routing Protocol (OSPF, EIGRP, and RIPv2) can advertise subnets, and therefore can support discontiguous subnets.

Enabling RIP
(Routing Information Protocol)

What Is a Routing Protocol?

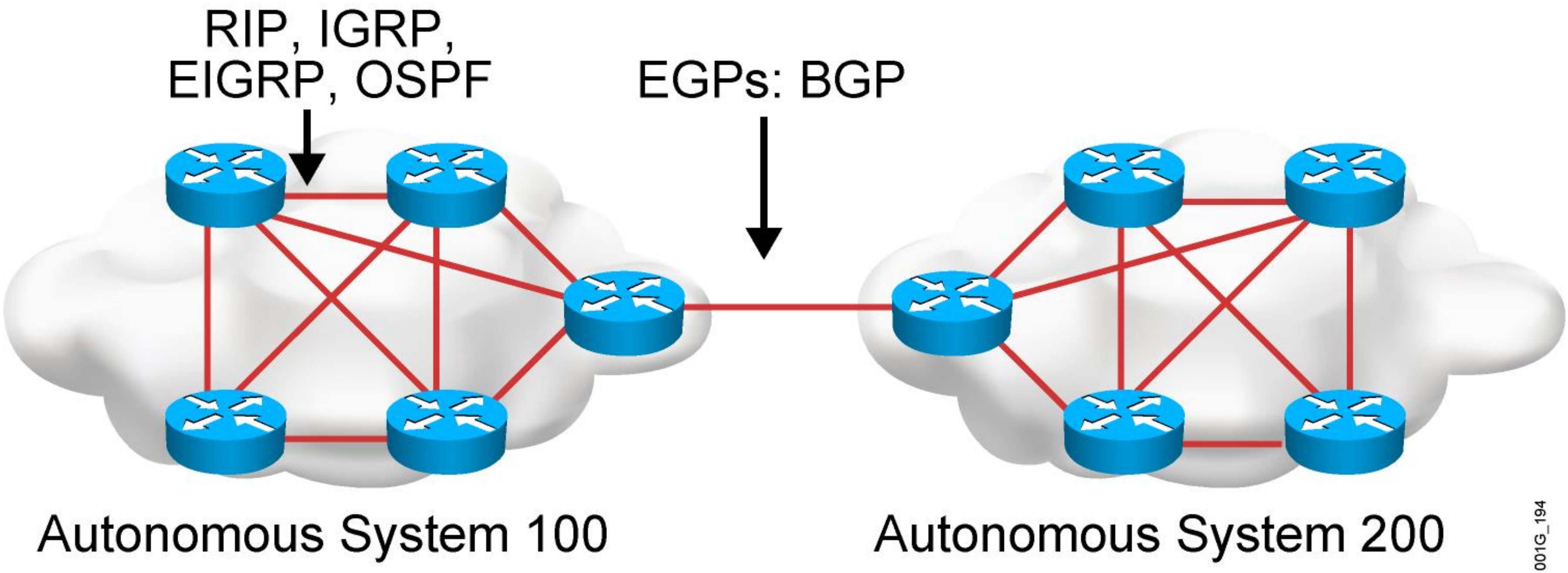
- Routing protocols are used between routers to determine paths and maintain routing tables.
- After the path is determined, a router can route a routed protocol.



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.

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 (auto-summary).
- These are examples of classful routing protocols:
  - RIPv1
  - IGRP

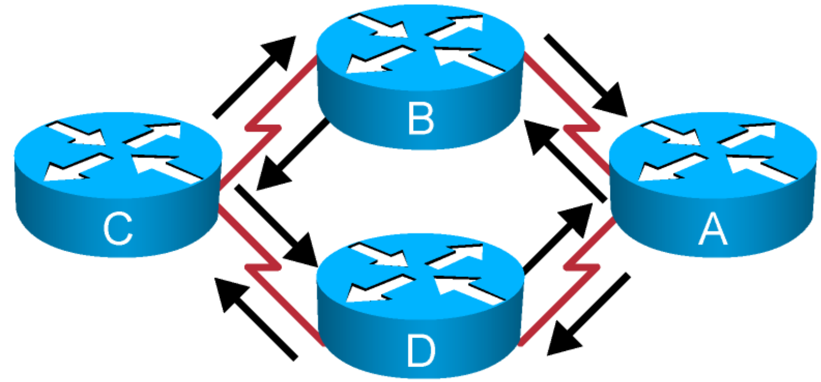
Classless Routing Protocol

- 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

Classes of Routing Protocols

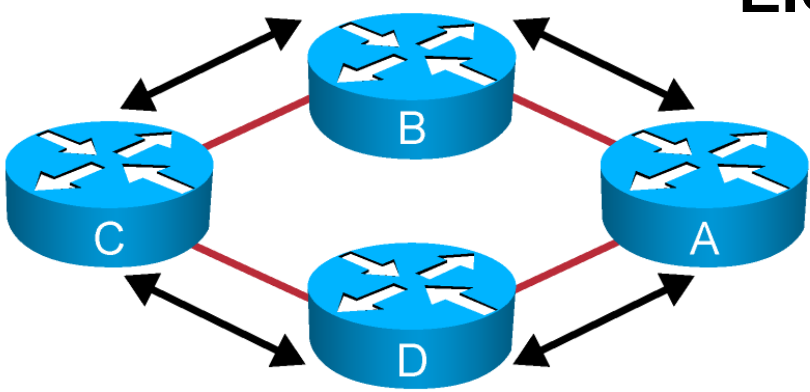
Distance Vector

RIP



Hybrid Routing

EIGRP

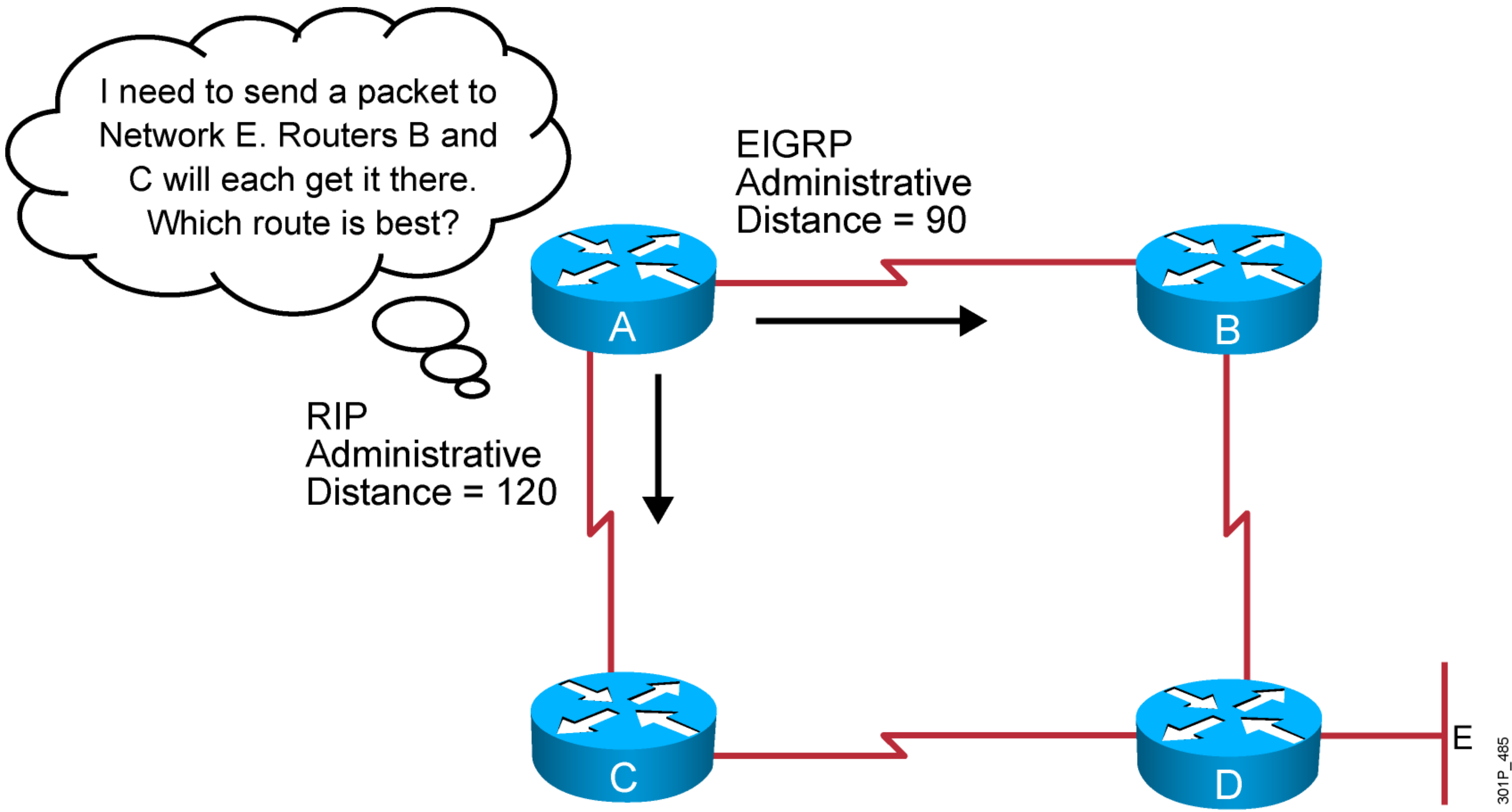


Link-State

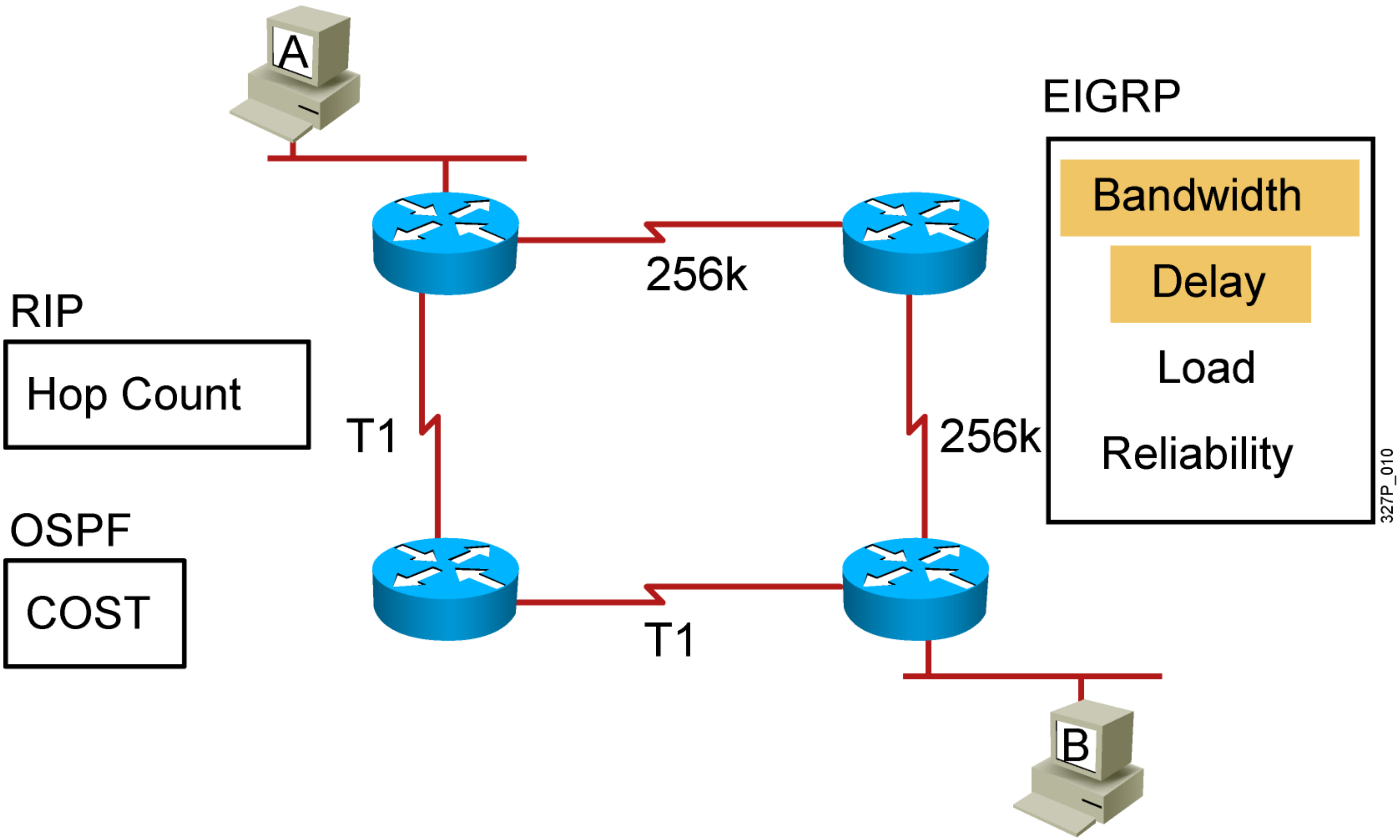
OSPF

301P_196

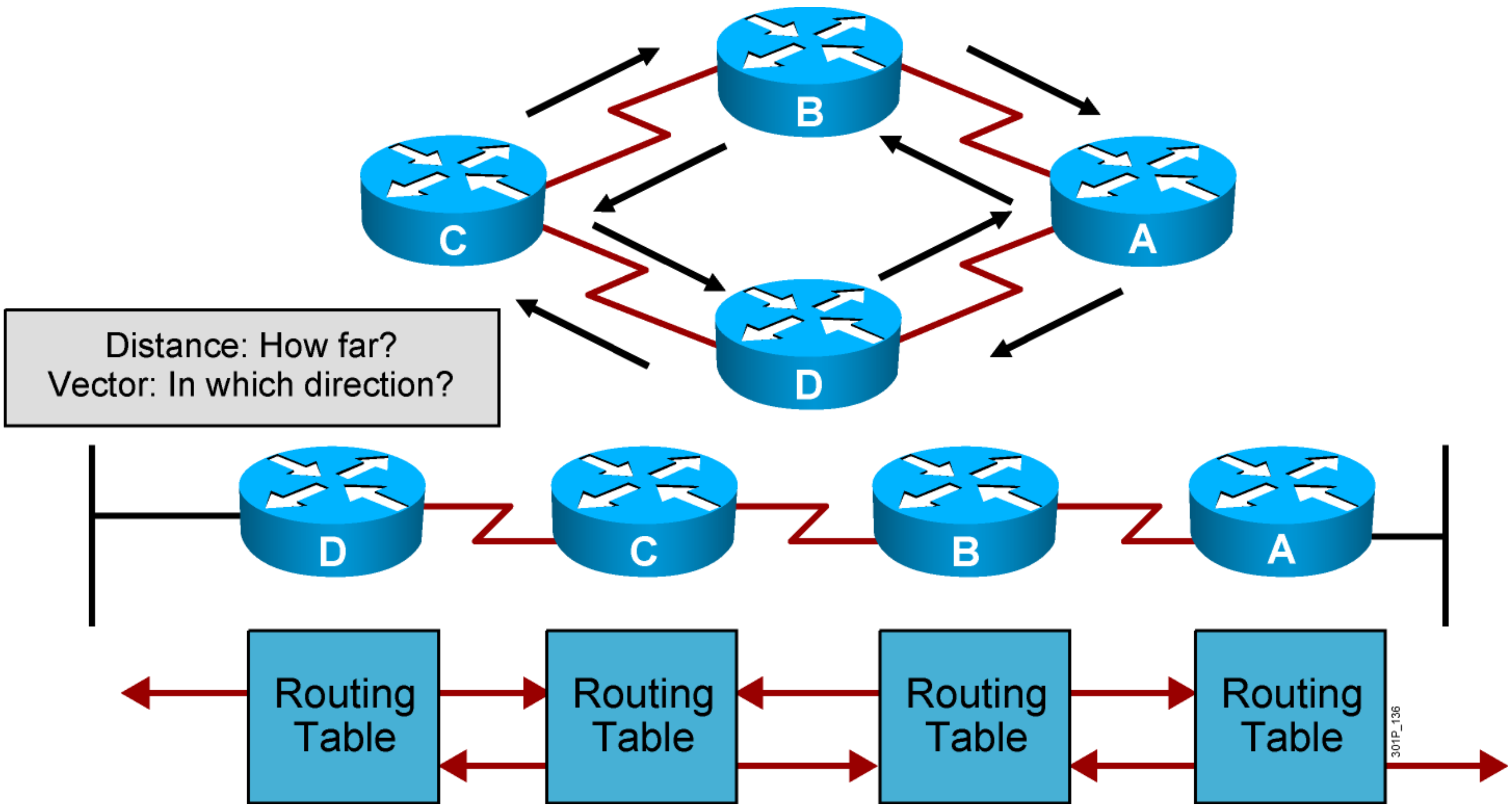
Administrative Distance: Ranking Routes



Selecting the Best Route Using Metrics

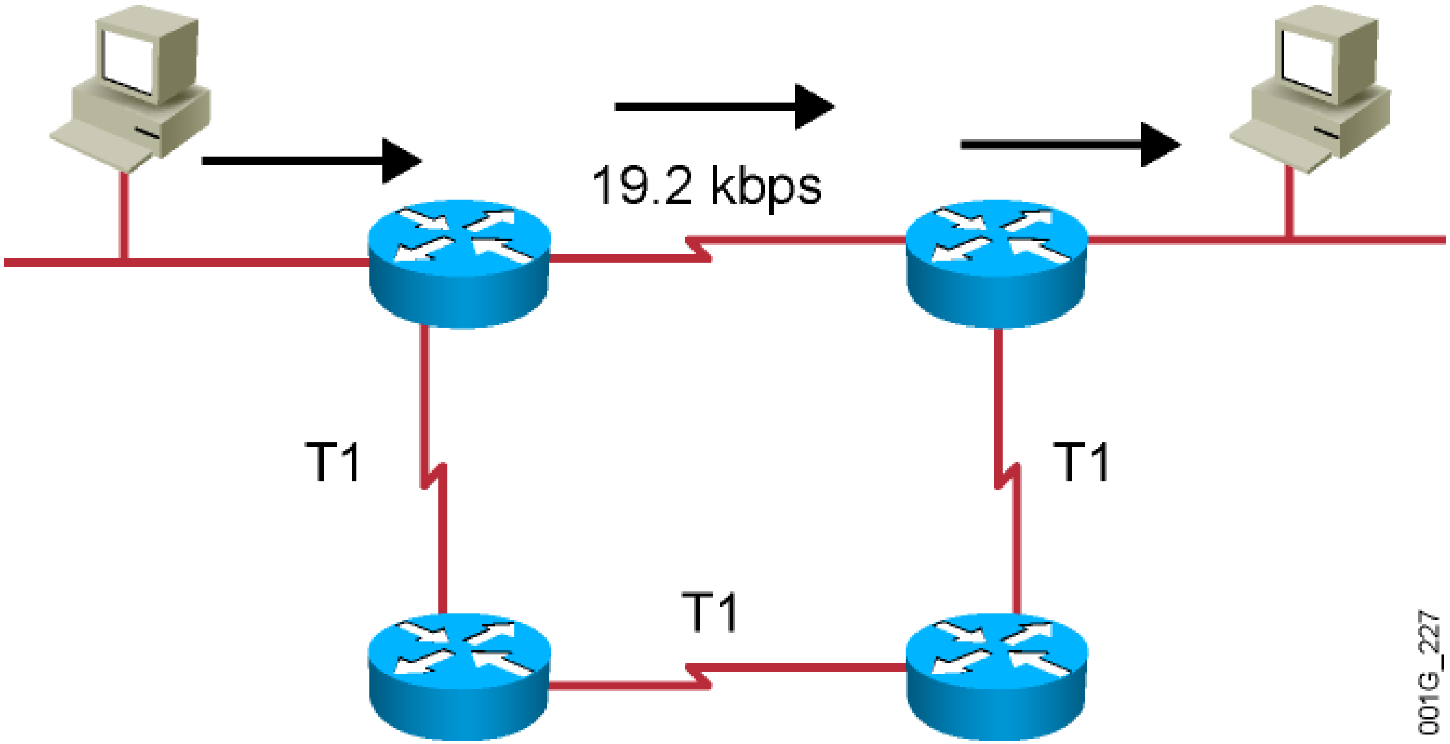


Distance Vector Routing Protocols



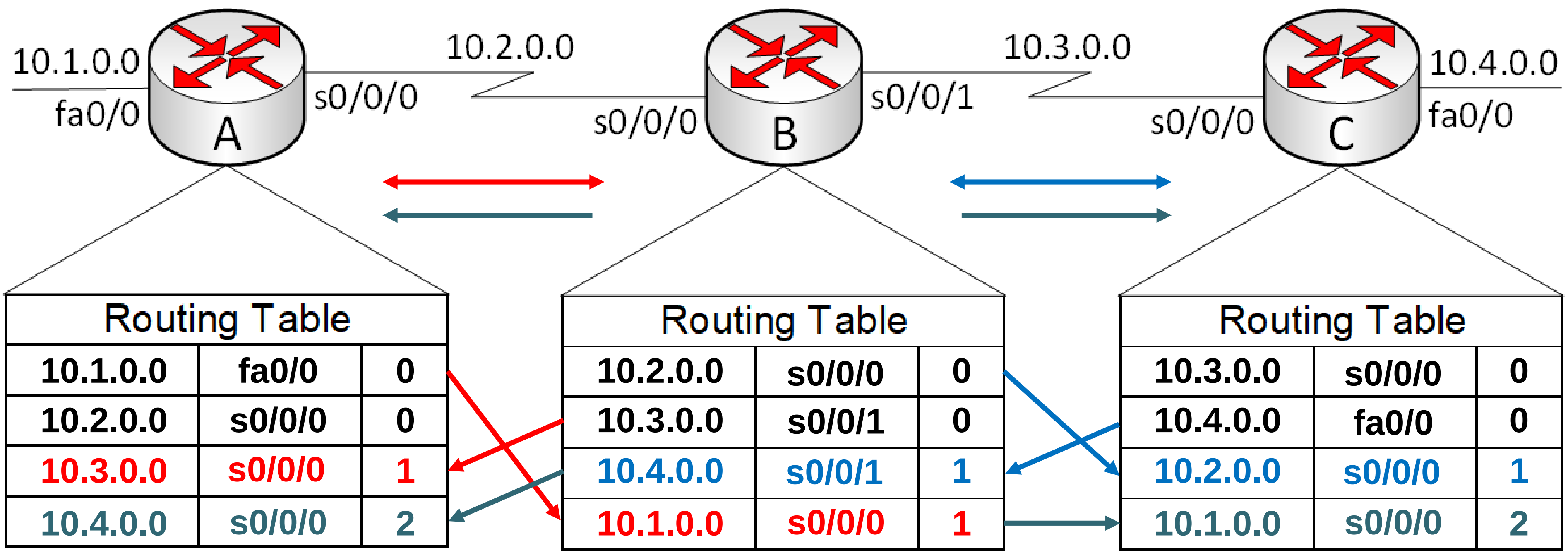
- Routers pass periodic copies of their routing table to neighboring routers and accumulate distance vectors (every 30 seconds by default)

RIP Overview



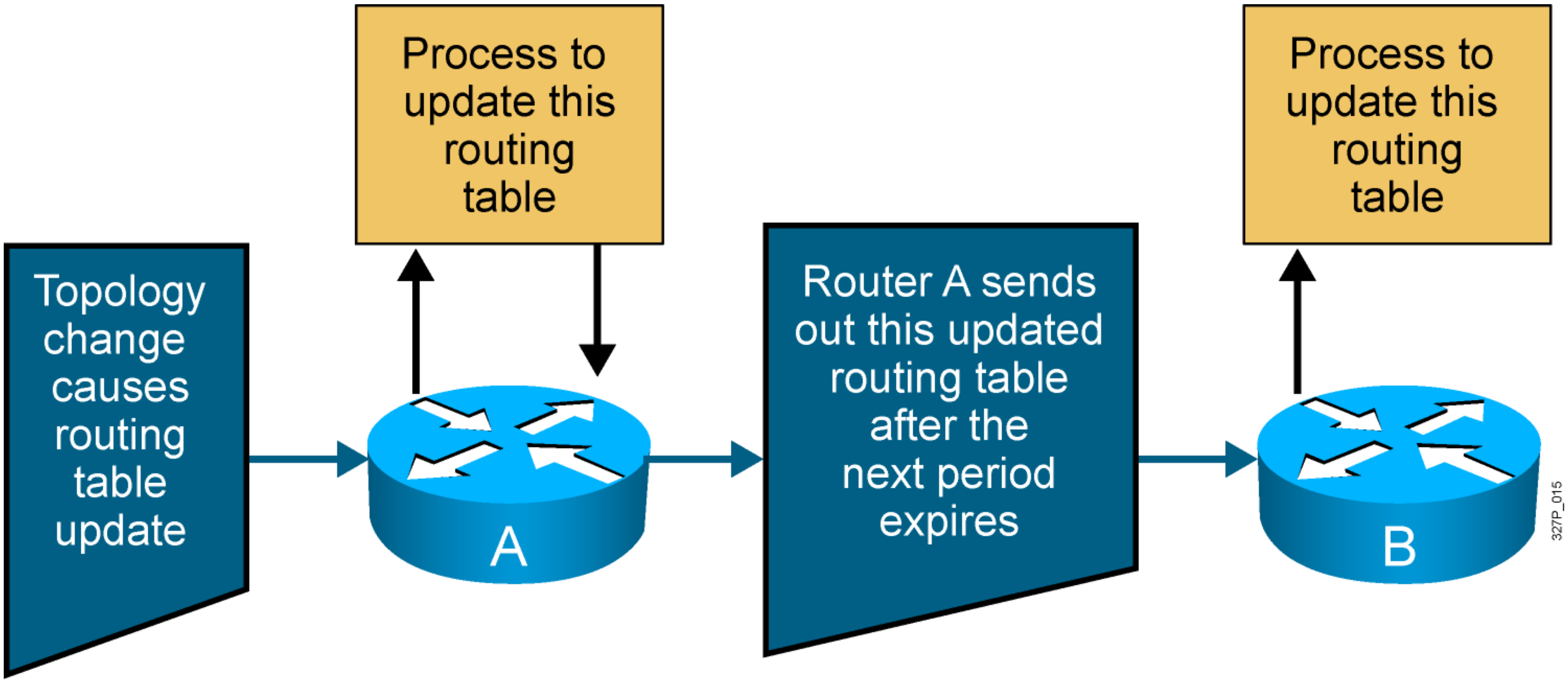
- Hop-count metric selects the path
- Maximum number of hops allowed = 15
- Routes update every 30 seconds
- Maximum is 16 equal-cost paths (default = 4)

Sources of Information and Discovering Routes



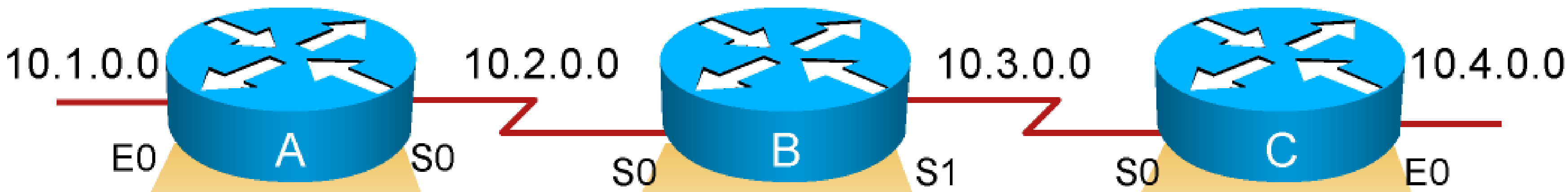
Routers discover the best path to destinations from each neighbor

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

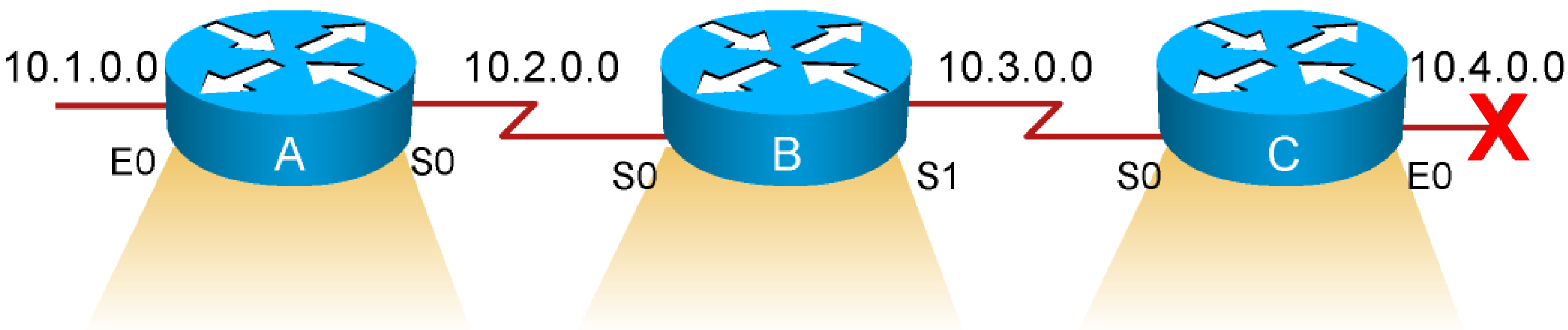
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

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

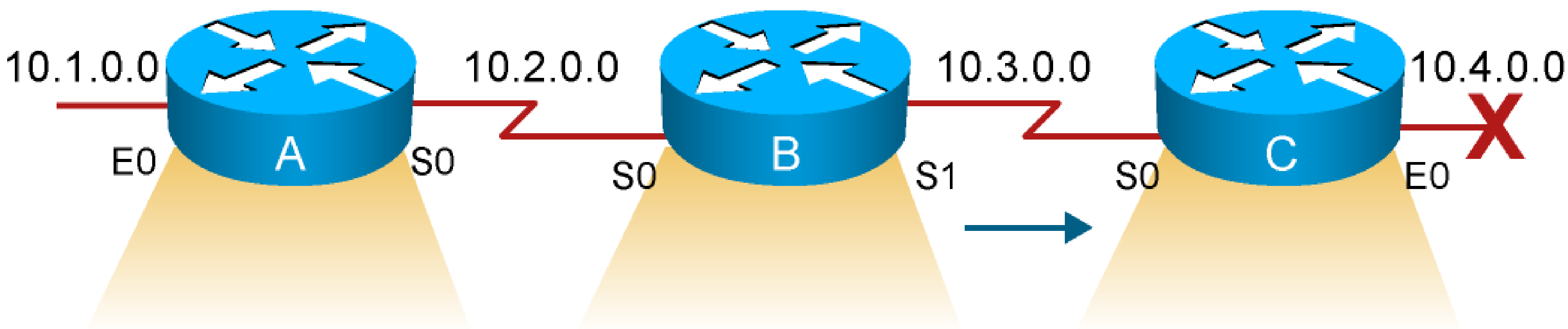
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

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

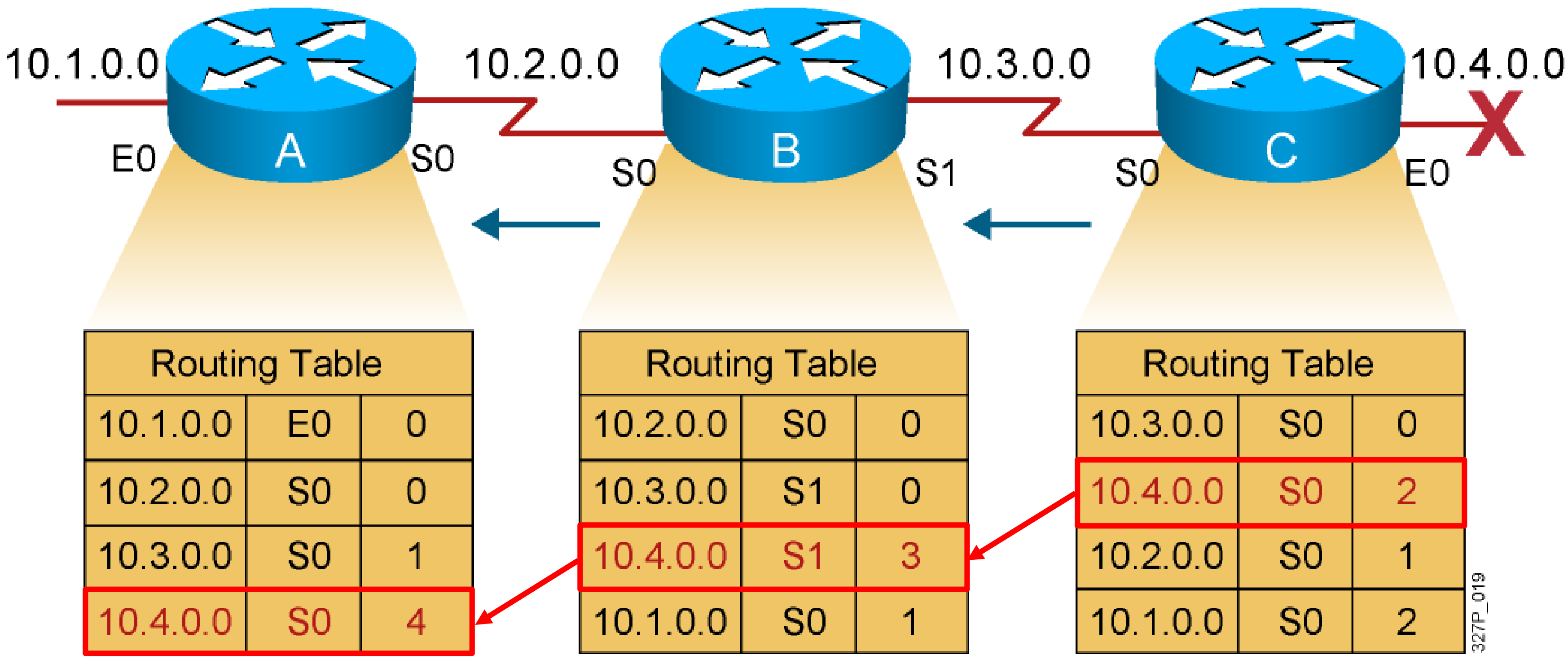
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

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.

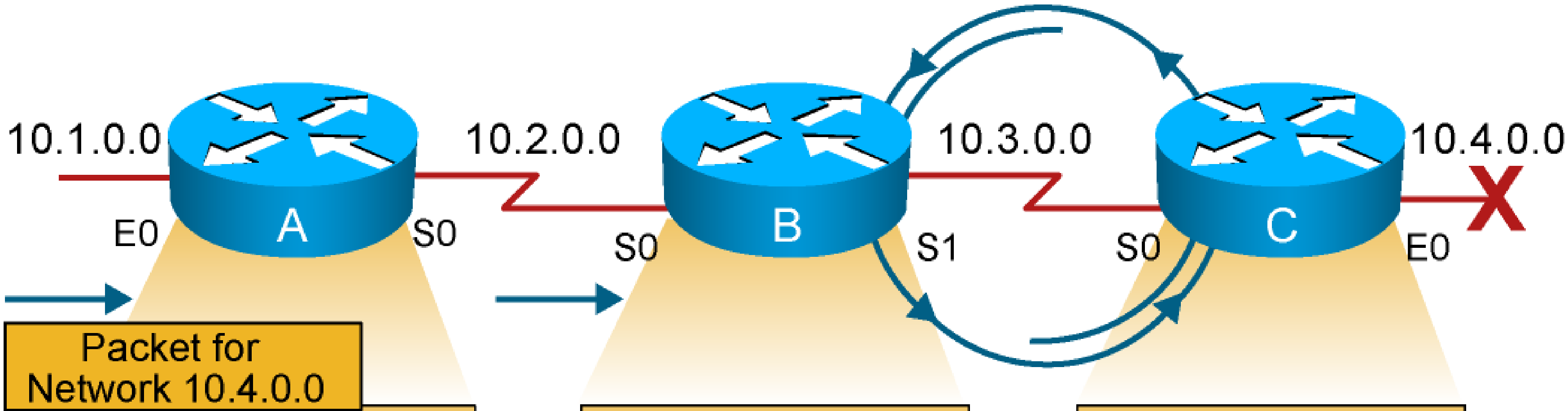
Counting to Infinity (Cont.)



Router A updates its table to reflect the new but erroneous hop count.

The hop count for network 10.4.0.0 counts to infinity.

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

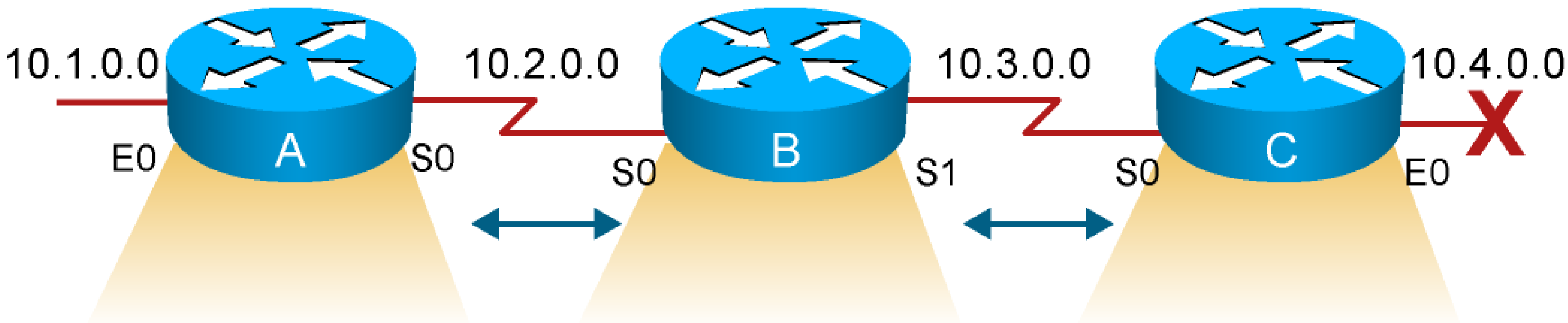
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	3
10.1.0.0	S0	1

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 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

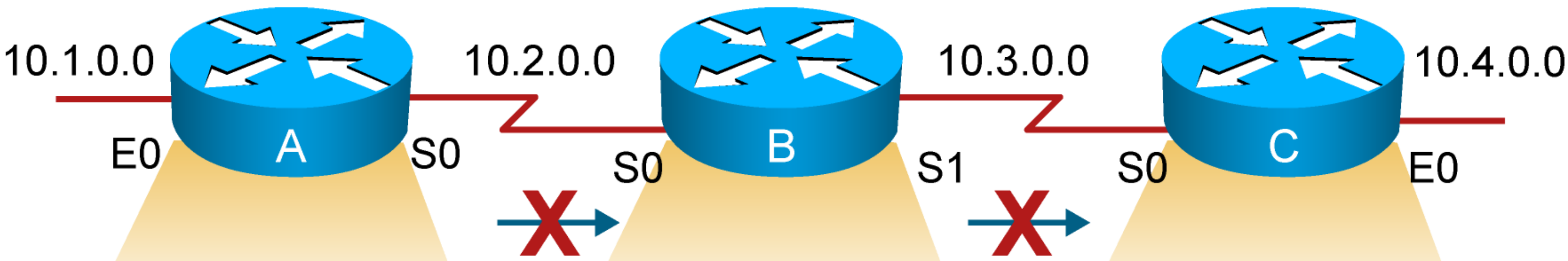
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	16
10.1.0.0	S0	1

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 (maximum = 15 hops).

Solution to Routing Loops: Split Horizon



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

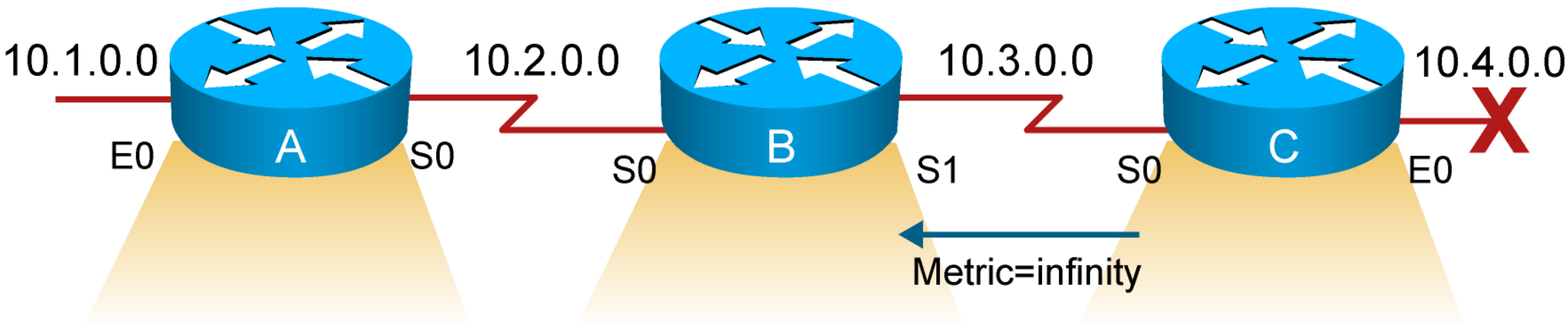
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

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_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



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

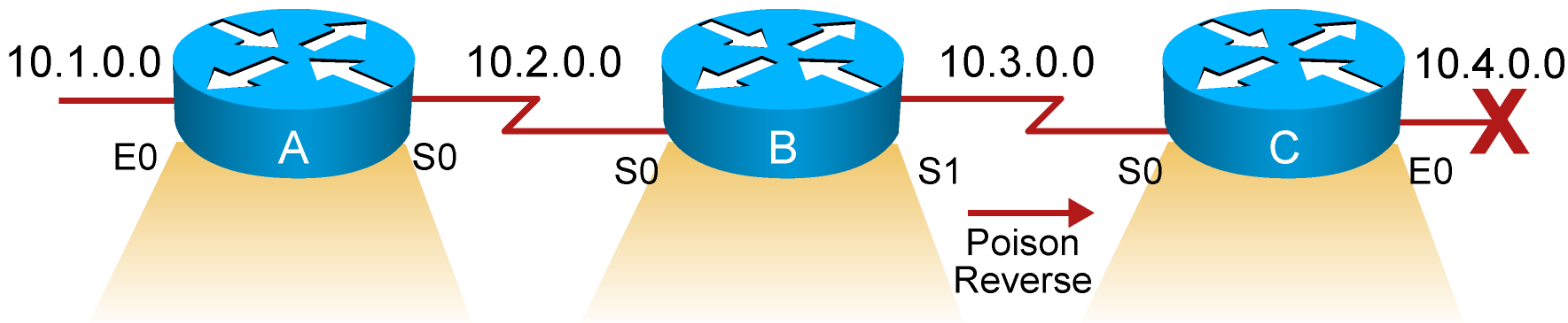
Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	1
10.1.0.0	S0	1

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 (metric = 16).

Solution to Routing Loops: Poison Reverse



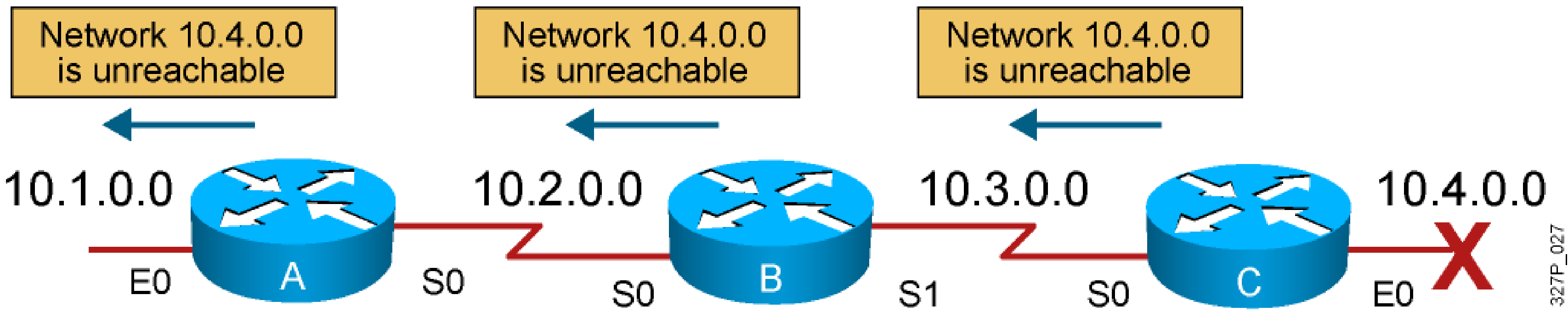
Routing Table		
10.1.0.0	E0	0
10.2.0.0	S0	0
10.3.0.0	S0	1
10.4.0.0	S0	2

Routing Table		
10.2.0.0	S0	0
10.3.0.0	S1	0
10.4.0.0	S1	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

- The poison reverse rule overwrites split horizon rule.
- This ensures all the routers in the domain receive the poisoned route update.
- Notice that every router performs poison reverse when learning about a downed network.

Triggered Updates

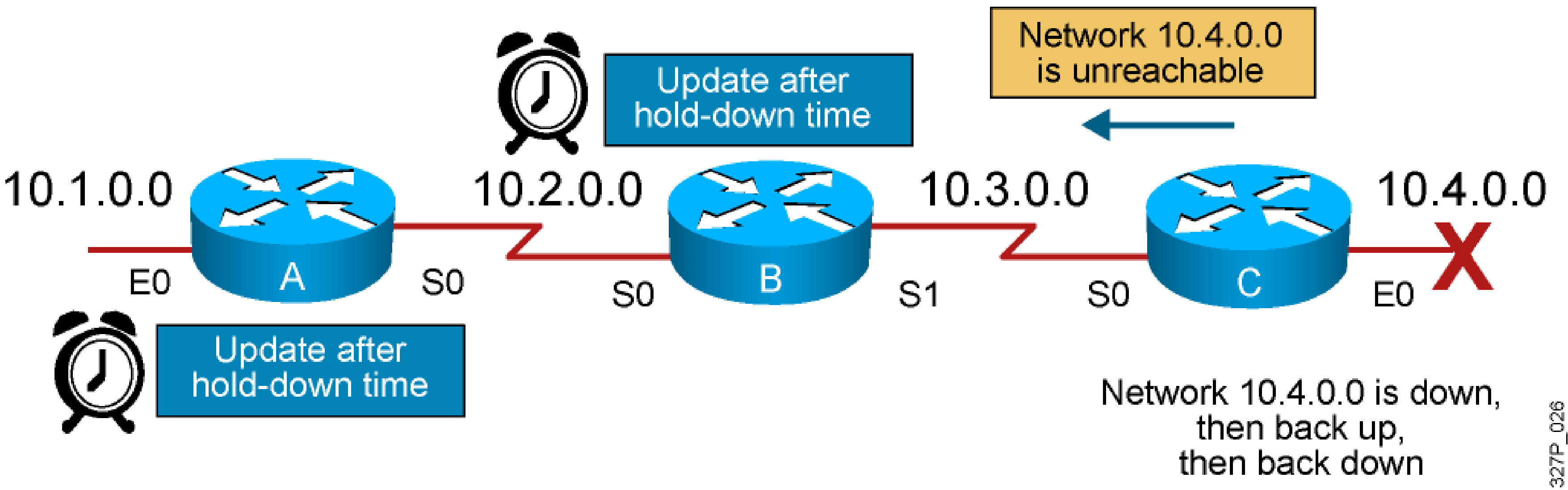


The router sends updates when a change in its routing table occurs.

Solution to Routing Loops: Hold-Down Timers

After hearing a route poisoning, router starts a hold-down timer for that route.

The default hold-down timer value = 180 seconds.

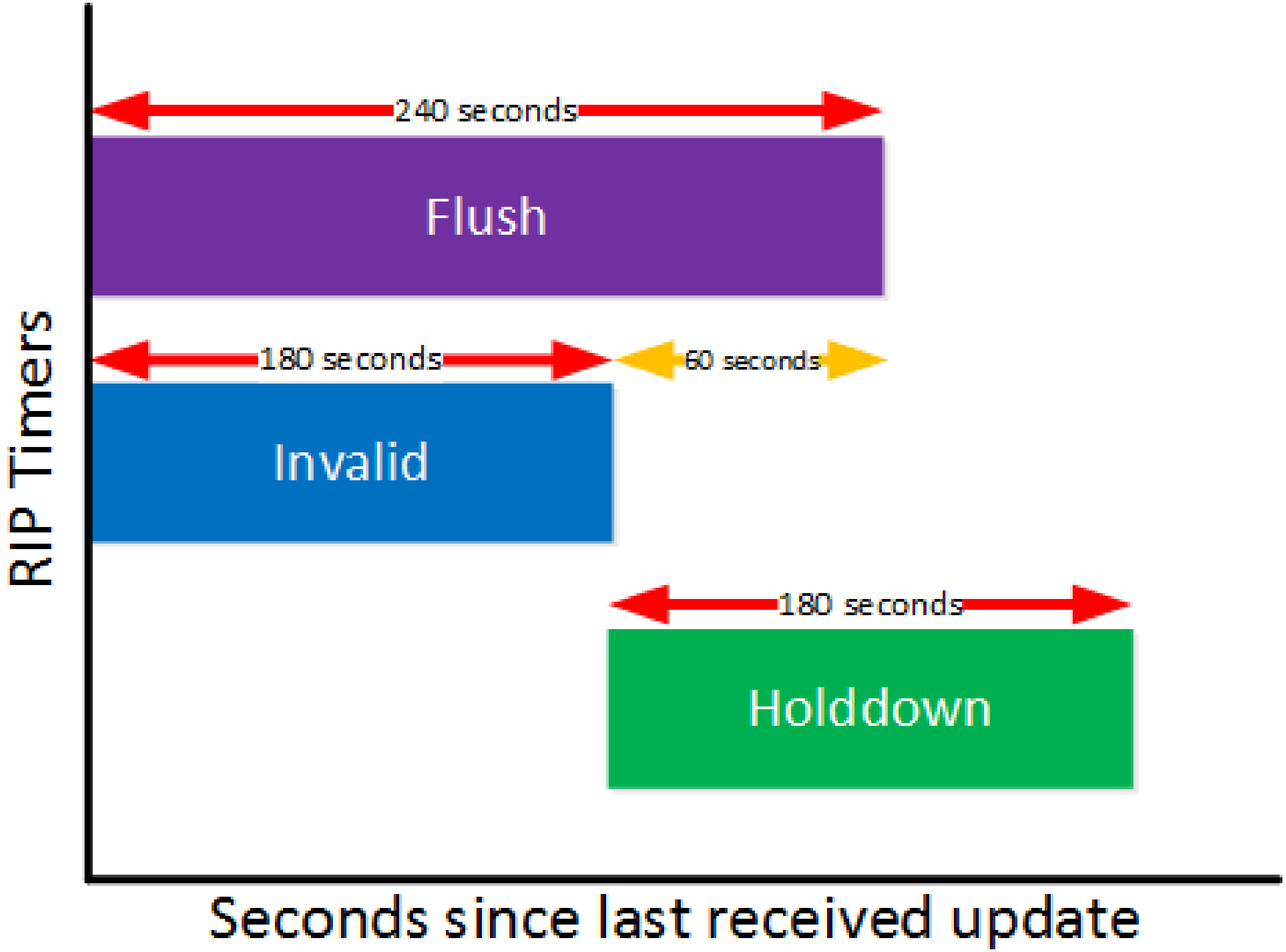


The router keeps an entry for the “possibly down” state in the network, allowing time for other routers to recompute for this topology change.

RIP Timers

- **Update timer**: how often the router sends update.
  Default update timer is 30 seconds.
- **Invalid timer**: how much time must expire before a route becomes invalid since seeing a valid update; and place the route into holddown.
  Default invalid timer is 180 seconds.
- **Flush timer:** how much time since the last valid update, until RIP deletes that route in its routing table.
  Default Flush timer is 240 seconds
- **Holddown timer:** the router will not believe any new updates with a hop count equal to or higher (poorer) than the hop count recording in the routing table.
  Default holddown timer is 180 seconds

RIP Timers (Cont.)

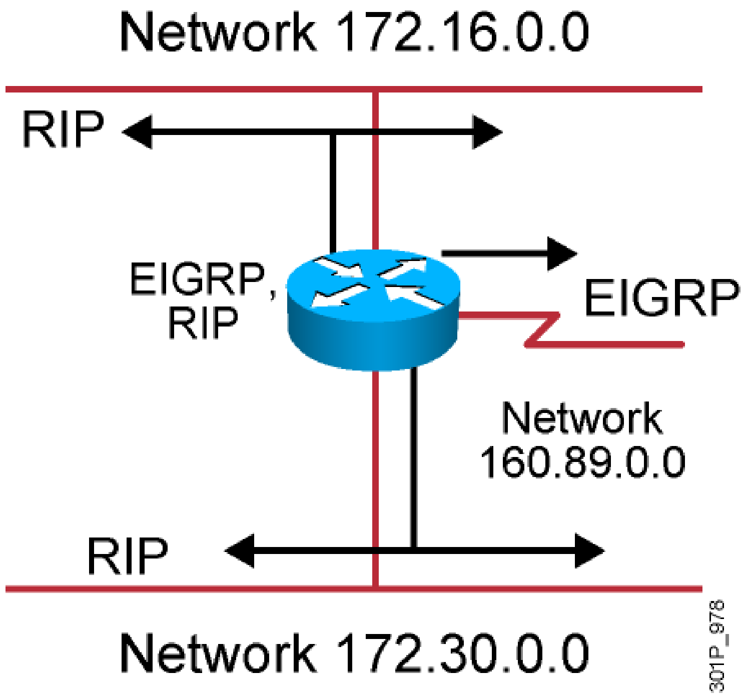


RIPv1 and RIPv2 Comparison

	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	Multicast (224.0.0.9)
Defined in …	RFC 1058	RFCs 1721, 1722, and 2453
Supports manual route summarization?	No	Yes
Authentication support?	No	Yes

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

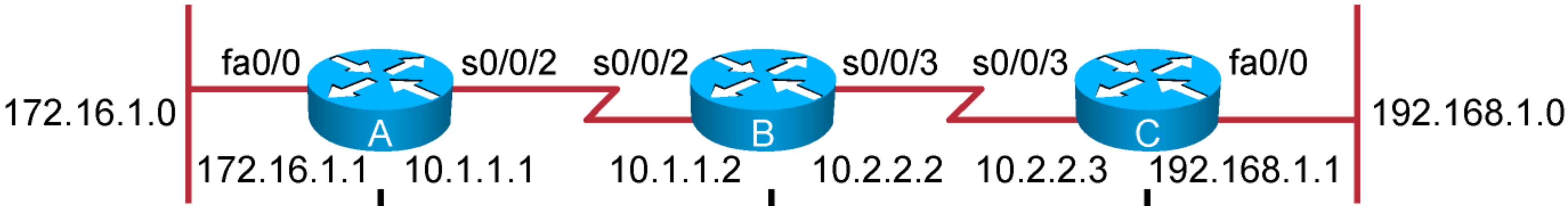
```
RouterX(config-router)# network network-number
```

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

```
RouterX(config-router)# no auto-summary
```

- Disable auto-summarization (Optional)

RIP Configuration Example



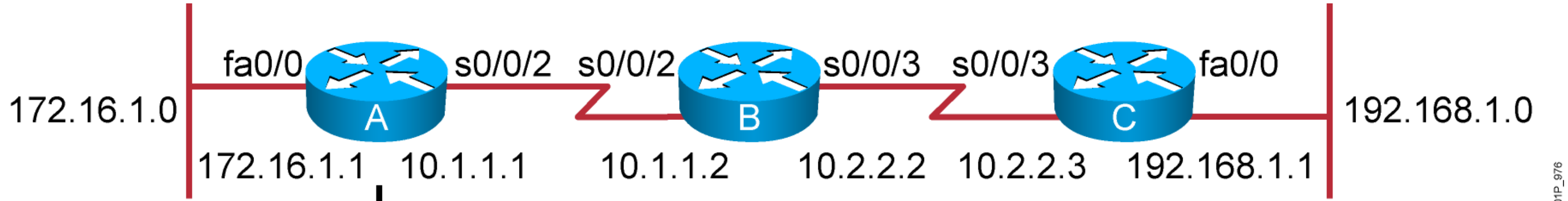

```
router rip
version 2
network 172.16.0.0
network 10.0.0.0
```

```
router rip
version 2
network 10.0.0.0
```

```
router rip
version 2
network 192.168.1.0
network 10.0.0.0
```

301P_977

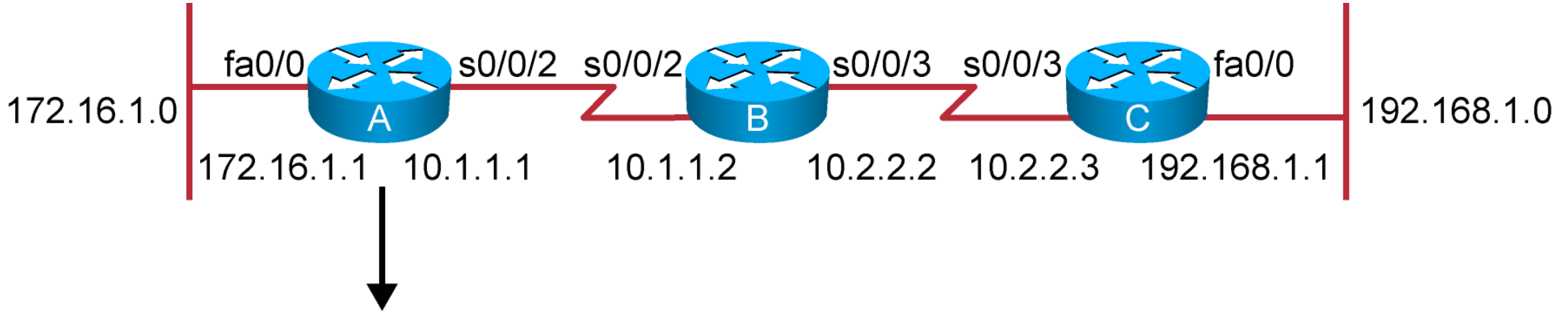
Verifying the RIP Configuration




```
RouterA# show ip protocols

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)
```

Displaying the IP Routing Table



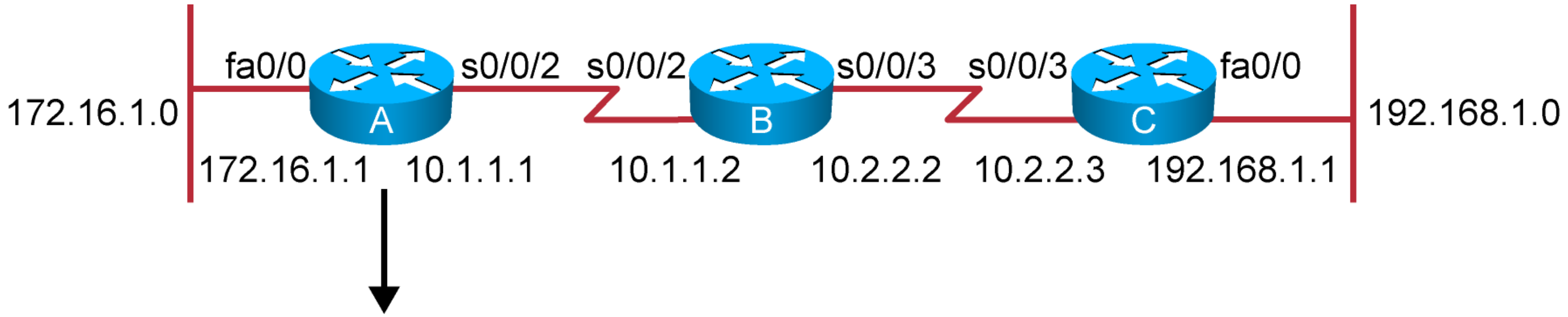

```
RouterA# show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, 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
```

AD   Metric

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


RouterA# undebug all
```

CISCO