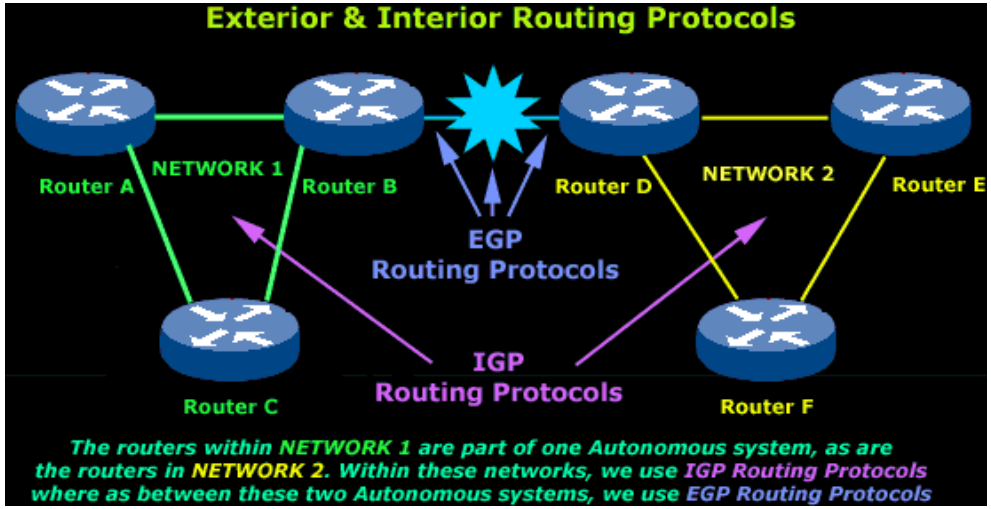
CIS 3210



Static Routing

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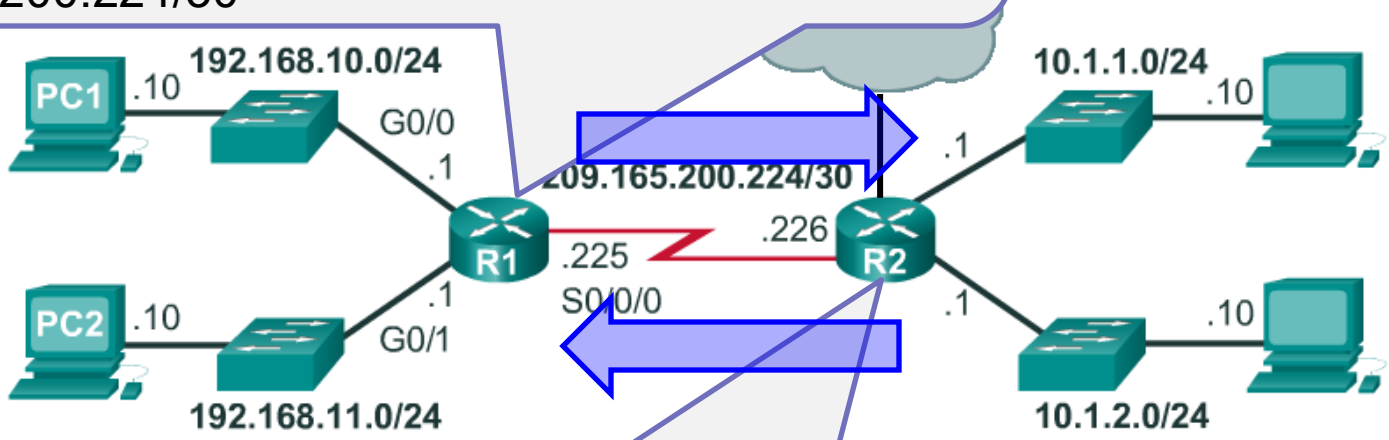
Reaching Remote Networks

Reaching Remote Networks Dynamically

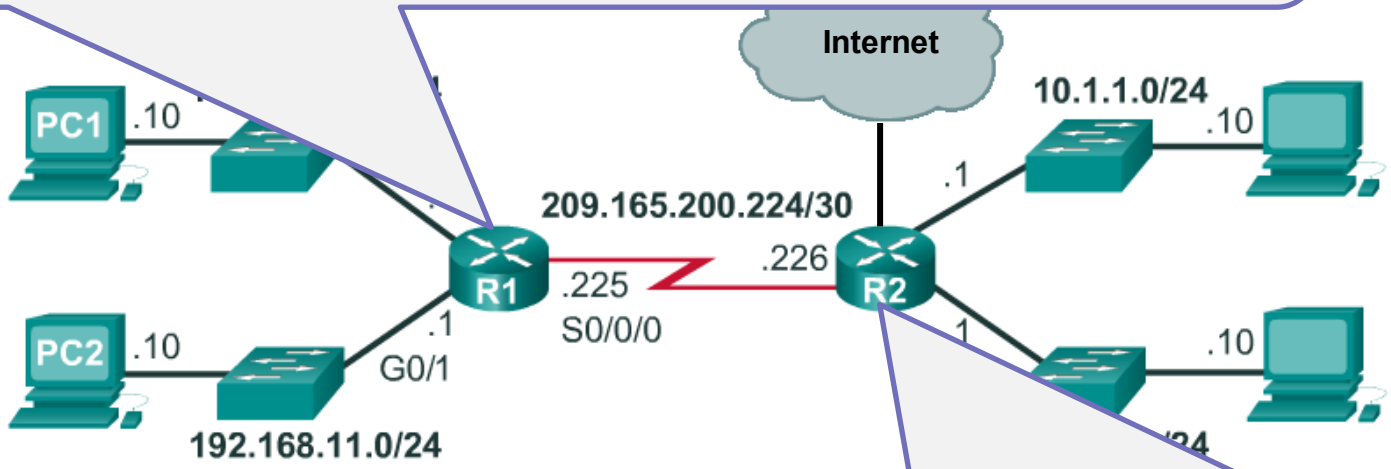
Hey I'm R1 and I'm using EIGRP to let my neighbors know that I'm directly connected to networks:
- 192.168.10.0/24
- 192.168.11.0/24
- 209.165.200.224/30



Hey I'm R2 and I'm using EIGRP to let my neighbors know that I'm the gateway to the Internet and that I'm directly connected to:
- 10.1.1.0/24
- 10.1.2.0/24
- 209.165.200.224/30

Reaching Remote Networks Statically

Hey I'm R1 and I know about my 3 directly connected networks. I'm also a stub router so to reach any network I do not know about I will use a ***default static route*** to R2



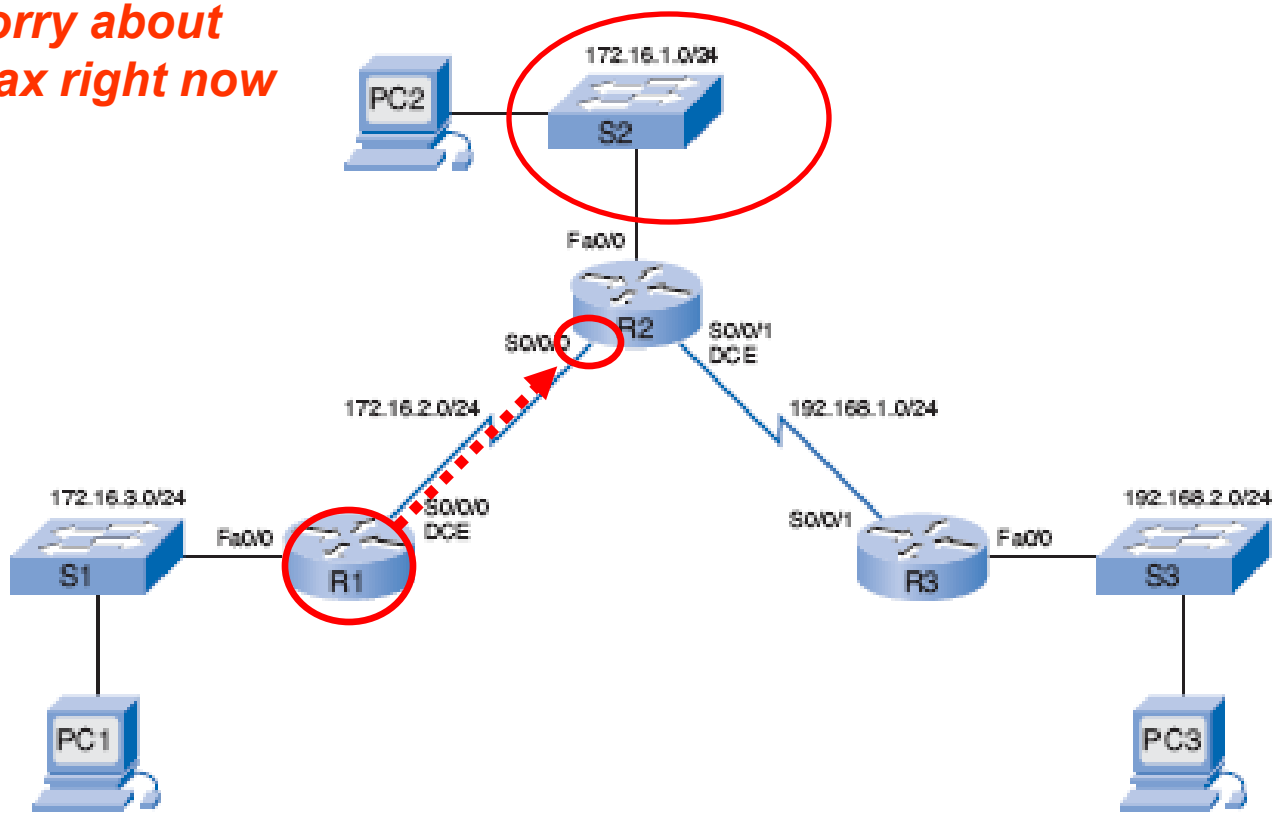
Hey I'm R2 and I know about my 3 directly connected networks and the Internet. I need to reach the two R1 LANs therefore I will use two ***static routes*** to R1. I will also use a ***default static route*** to connect to the ISP.

- A static route is a manually entered route into the routing table that specifies:
  - The remote network address/mask
  - The next hop router

Static Routing Advantages

```
R1(config)# ip route 172.16.1.0 255.255.255.0 172.16.2.2
```

Don't worry about the syntax right now



- More secure since they are not advertised over the network.
- More efficient since they use less bandwidth than dynamic routing protocols.
  - No CPU cycles are used to calculate and communicate routes.
- Predictable as the path a static route uses to send data always the same.

Static Routing Disadvantages

```
R1(config)# ip route 172.16.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.2.0 255.255.255.0 172.16.2.2
R2(config)# ip route 172.16.3.0 255.255.255.0 172.16.2.1
R2(config)# ip route 192.168.2.0 255.255.255.0 192.168.1.1
R3(config)# ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.3.0 255.255.255.0 192.168.1.2
```

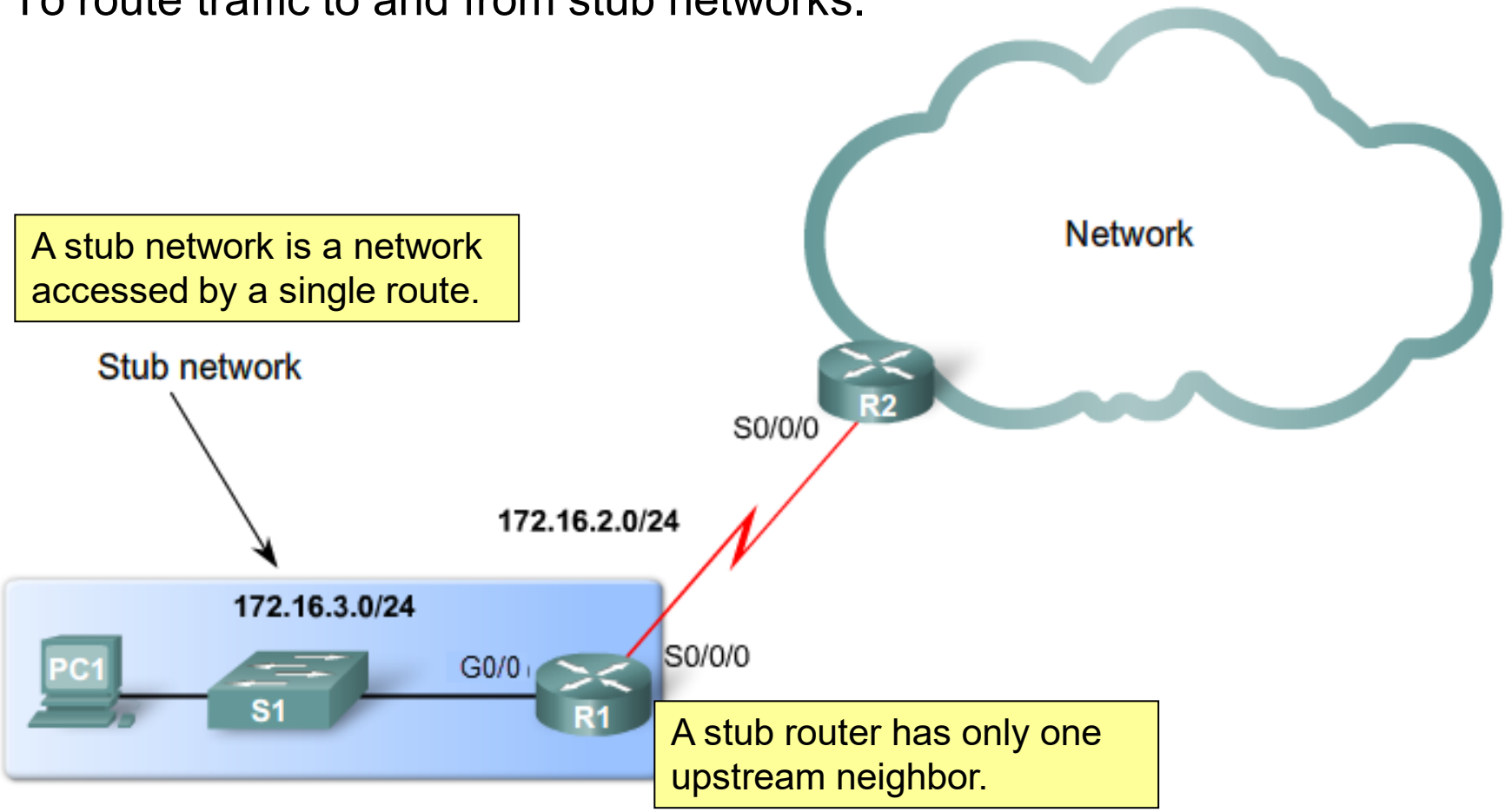
- Initial configuration and maintenance is time-consuming.
- Configuration is error-prone, especially in large networks.
- Administrator intervention is required to maintain changing route information.
- Does not scale well with growing networks; maintenance becomes cumbersome.
- Requires complete knowledge of the whole network for proper implementation.

Static Routing Versus Dynamic Routing

	Dynamic Routing	Static Routing
Configuration Complexity	Simple	Complicated in large networks
Topology Changes	Automatically reconfigures	Manual reconfiguration
Scaling	Scales well	Scales poorly
Security	Routing protocol traffic on the network	Routing information never visible on the network
Resource Usage	Resources for routing protocol	Very low
Predictability	Harder to predict routes in complicated cases	Completely determined by the administrator

When to Use Static Routes

- In small networks that are not expected to grow significantly.
- To route traffic to and from stub networks.



Types of Static Routes

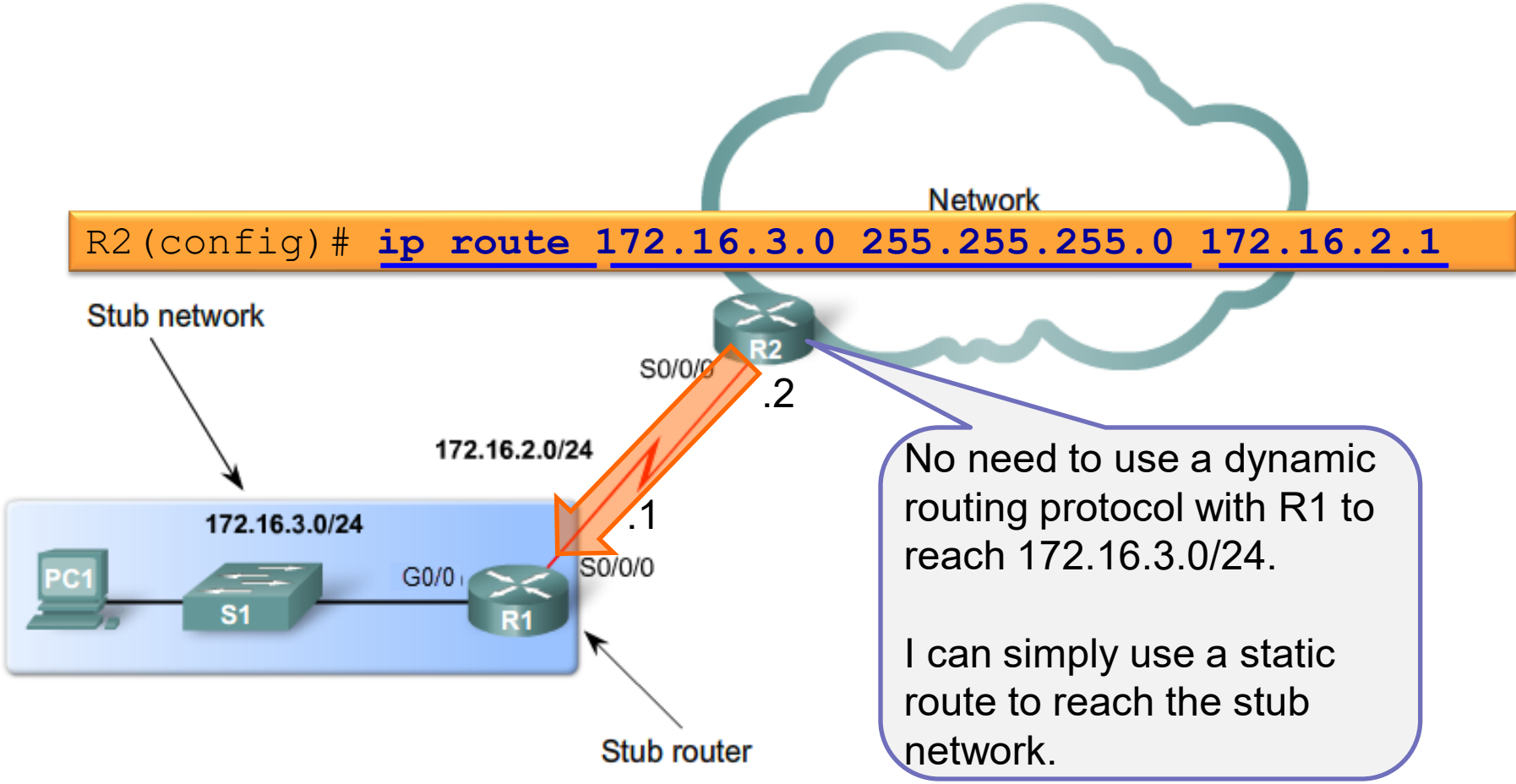
Types of Static Routes

- The following types of IPv4 and IPv6 static routes will be discussed:
  - **Standard static route**
  - **Default static route**
  - **Summary static route**
  - **Floating static route**

- Don’t worry about the terms and syntax until we get into the detail.

Standard Static Route

- Standard static routes are useful when connecting to a specific remote network.



Default Static Route

```
Router(config)# ip route 0.0.0.0 0.0.0.0 [exit-interface | ip-address ]
```

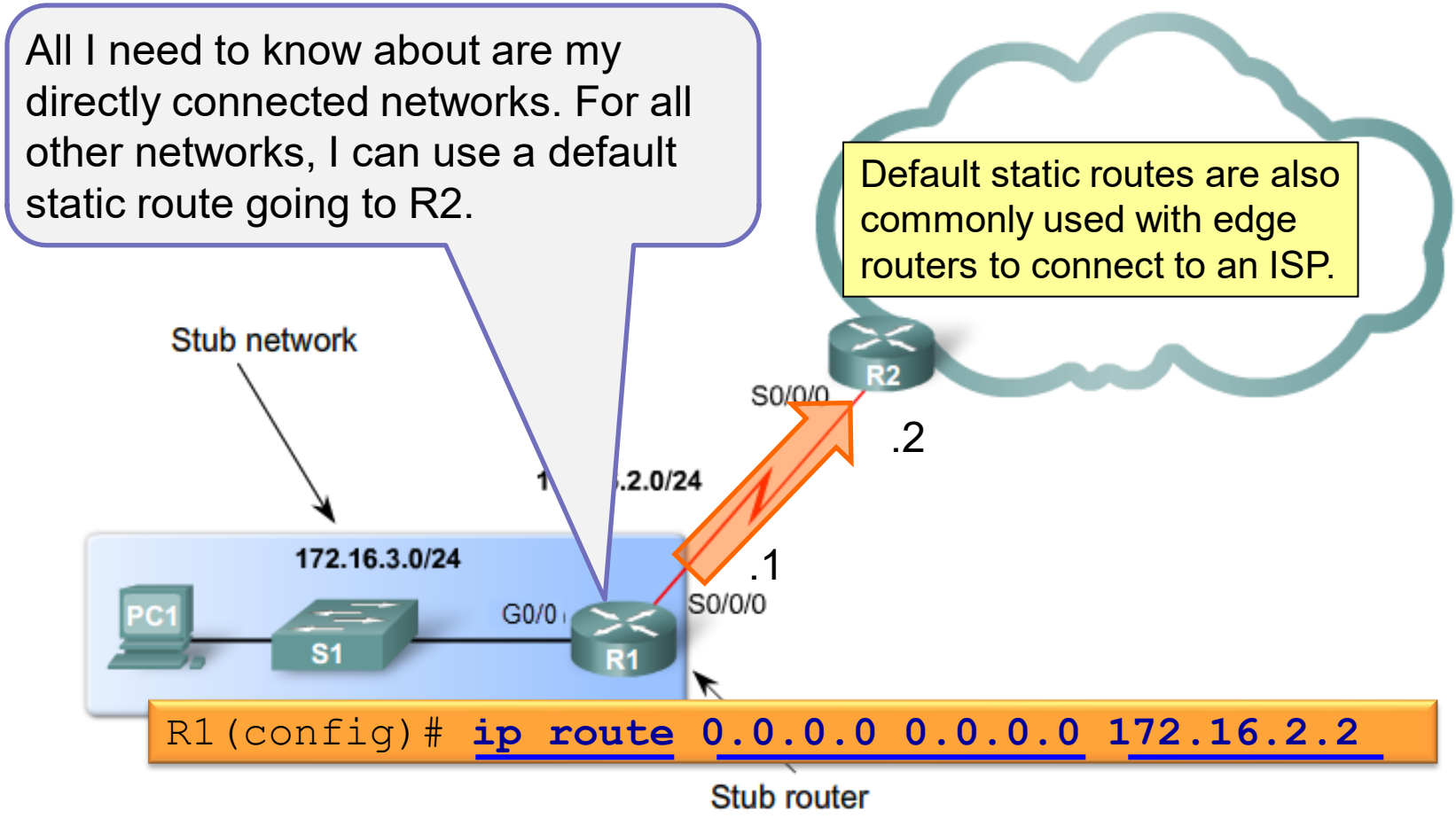
- A default static route is a “catch-all” route that matches all networks that is not in the routing table.
- The “exit-interface” is the name of the interface that faces the default route.
- The “ip-address” is the address of the gateway system (on the “far” end of the link).
- It is configured with a 0.0.0.0/0 “quad zero” destination address.
- It creates a “*Gateway of Last Resort*” in the routing table

Default Static Routes Are Used When …

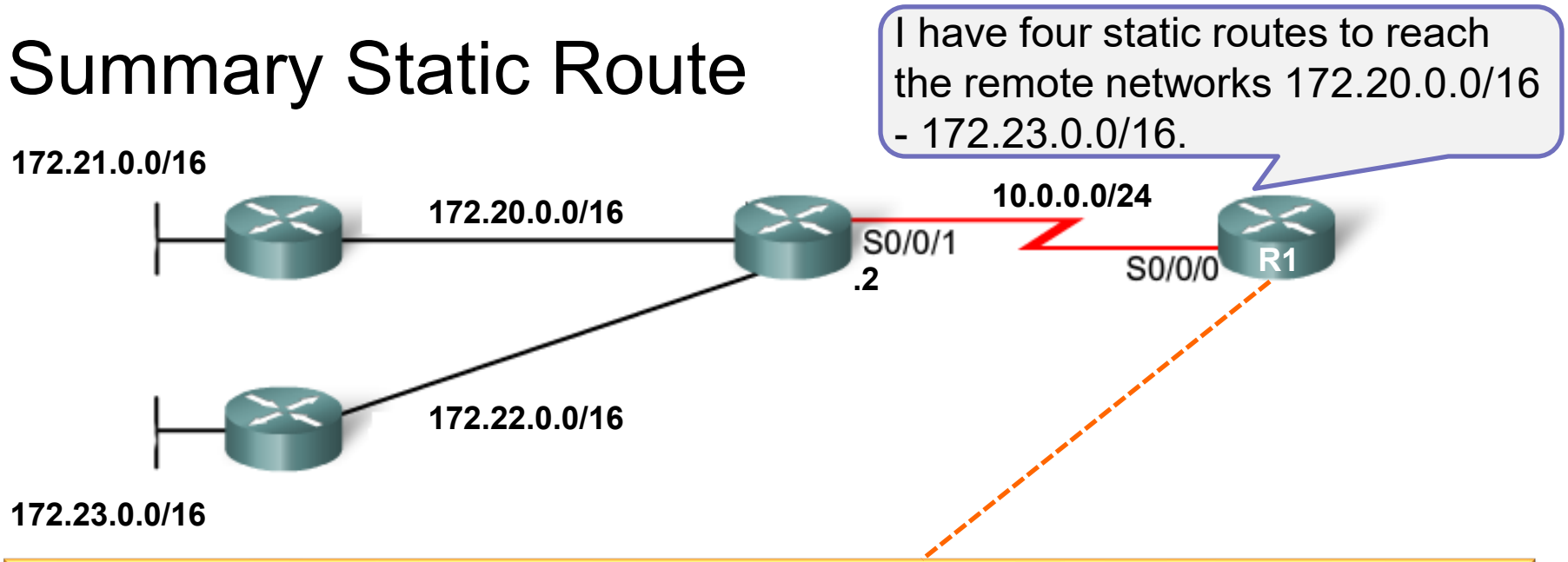
```
Router# show ip route
<some codes omitted>
* - candidate default, U - per-user static route, o - ODR

Gateway of last resort is 0.0.0.0 to network 0.0.0.0
List of directly connected networks and remote networks
C      172.16.2.0/24 is directly connected, Serial0/0/0
L      172.16.2.2/32 is directly connected, Serial0/0/0
S      192.168.1.0/24 [1/0] via 172.16.2.2
S      192.168.2.0/24 [1/0] via 172.16.2.2
. . .
S*     0.0.0.0/0 is directly connected, 172.16.2.1
```

- When no other routes in the routing table match the packet destination IP address.
  - In other words, when a "***more specific***" match does not exist.
  - A common use is when connecting a company's edge router to the ISP network.
- When a stub router connects to only one upstream router.

Default Static Route Example



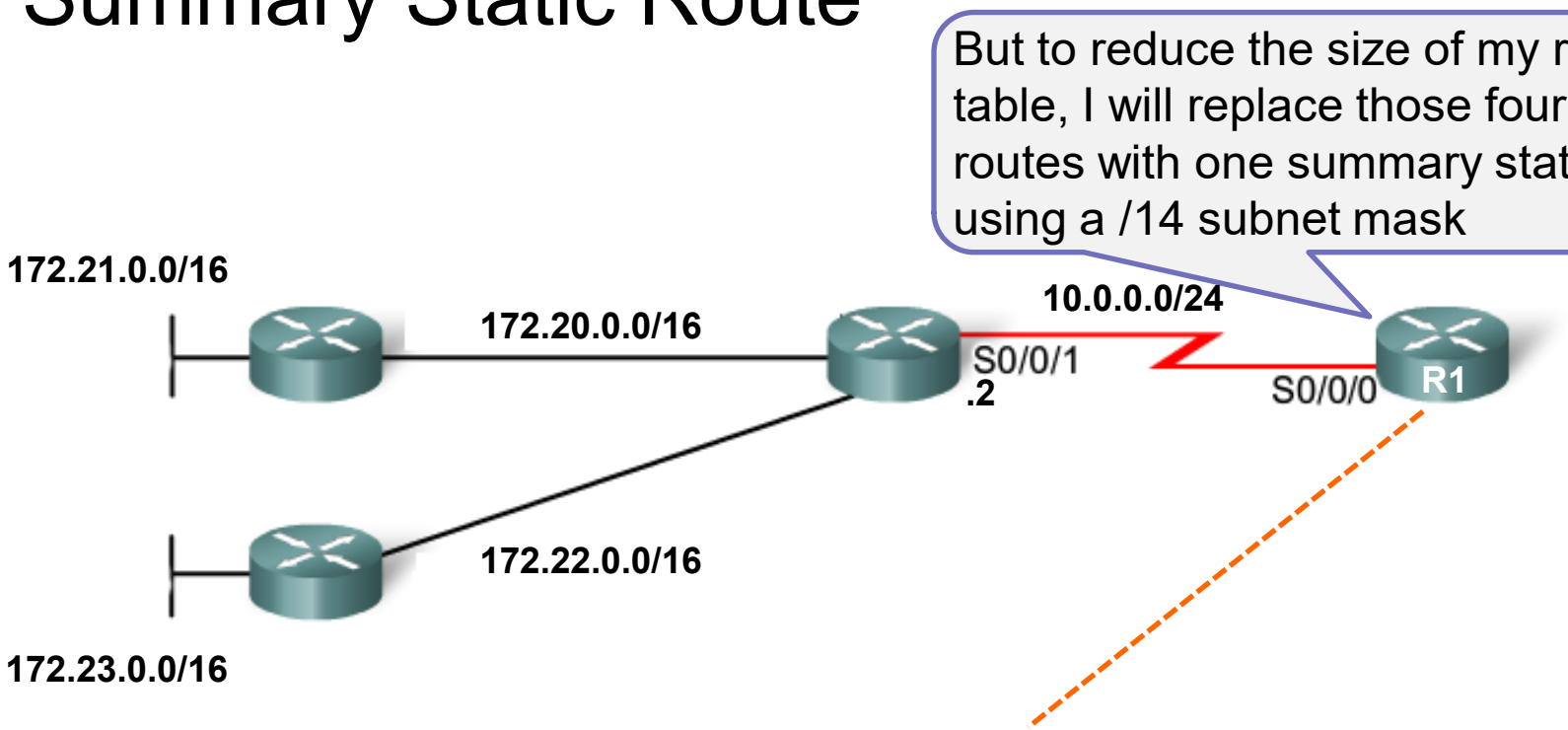
Summary Static Route




```
R1(config)# ip route 172.20.0.0 255.255.0.0 10.0.0.2
R1(config)# ip route 172.21.0.0 255.255.0.0 10.0.0.2
R1(config)# ip route 172.22.0.0 255.255.0.0 10.0.0.2
R1(config)# ip route 172.23.0.0 255.255.0.0 10.0.0.2
```

- Used to reduce the number of routing table entries.
- Multiple static routes can be summarized into a single static route if:
  - The destination networks are contiguous and can be summarized into a single network address.
  - The destination networks are all reachable using the same exit interface or next-hop IP address.

Summary Static Route

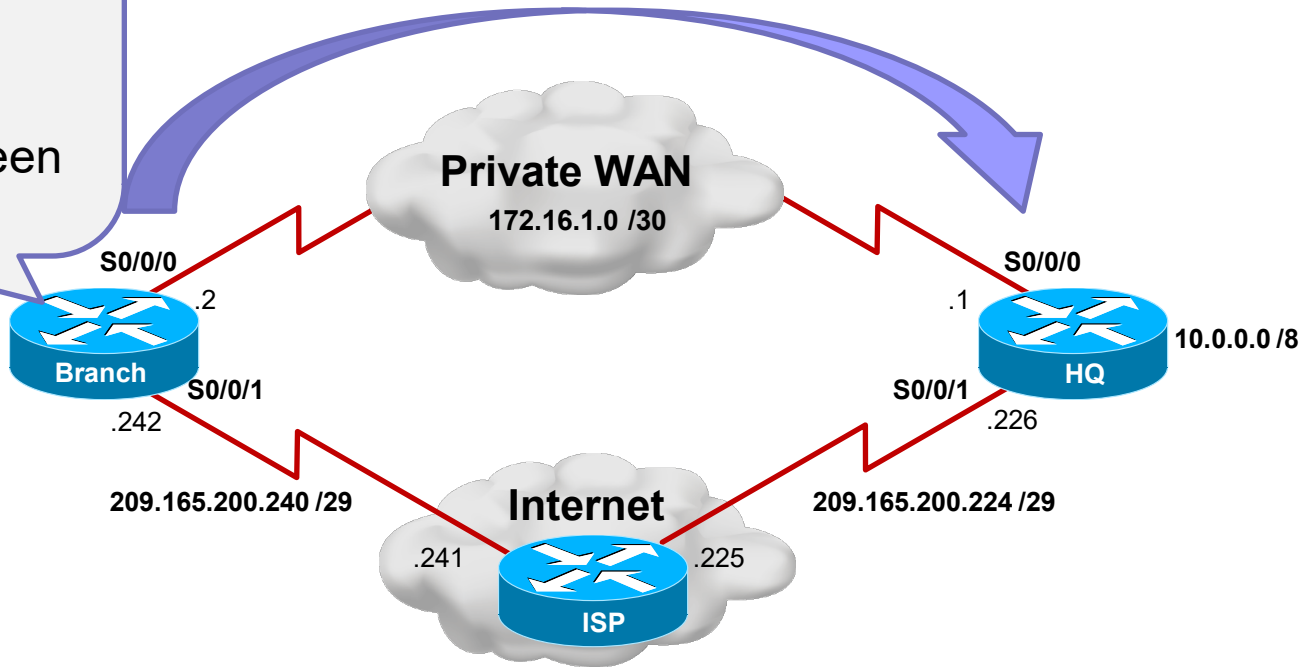



```
R1(config)# no ip route 172.20.0.0 255.255.0.0 10.0.0.2
R1(config)# no ip route 172.21.0.0 255.255.0.0 10.0.0.2
R1(config)# no ip route 172.22.0.0 255.255.0.0 10.0.0.2
R1(config)# no ip route 172.23.0.0 255.255.0.0 10.0.0.2
R1(config)#
R1(config)# ip route 172.20.0.0 255.252.0.0 10.0.0.20
```

Floating Static Route

I can reach the HQ router 10.0.0.0/8 LAN using the private WAN link.

I'm using EIGRP to exchange routes between sites.

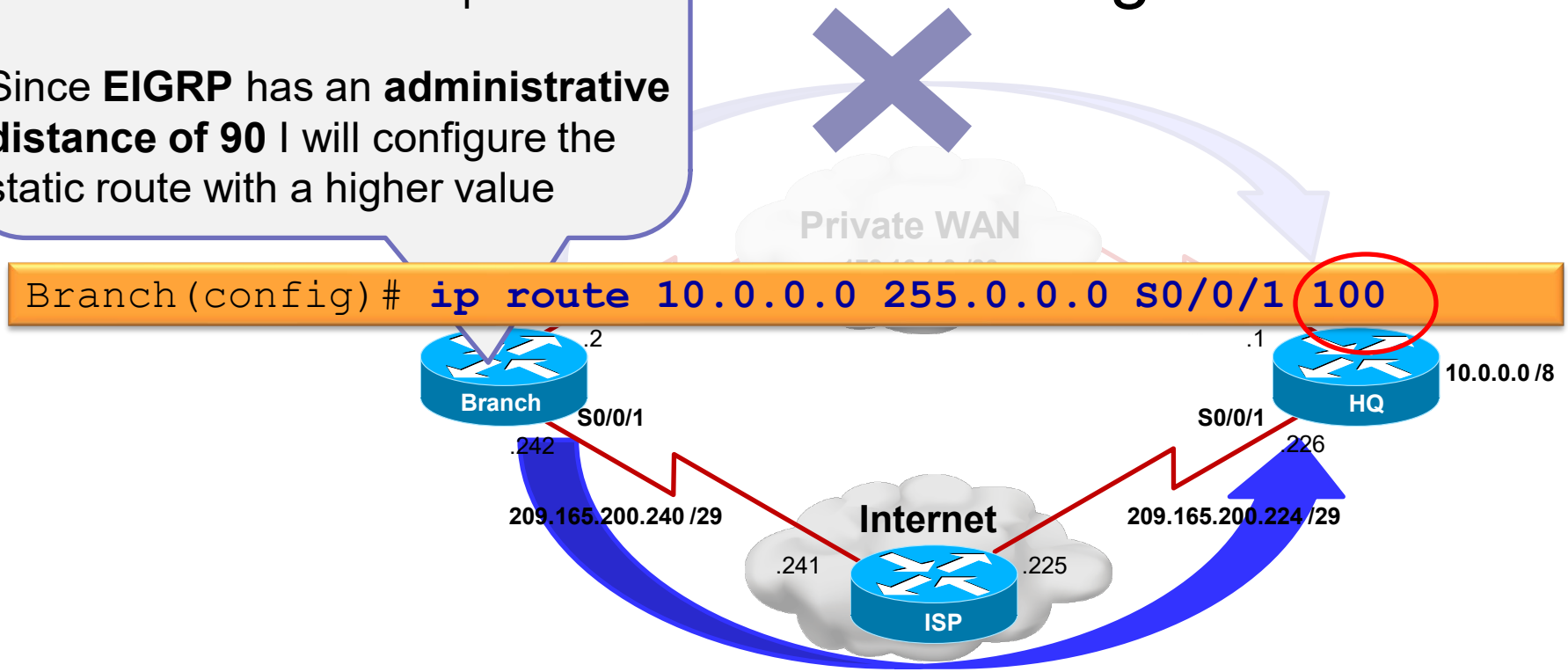


- **Floating static routes** are static routes used to provide a backup path to a primary static or dynamic route, in the event of a link failure.
  - The floating static route is only used when the primary route is not available.

Floating Static Route

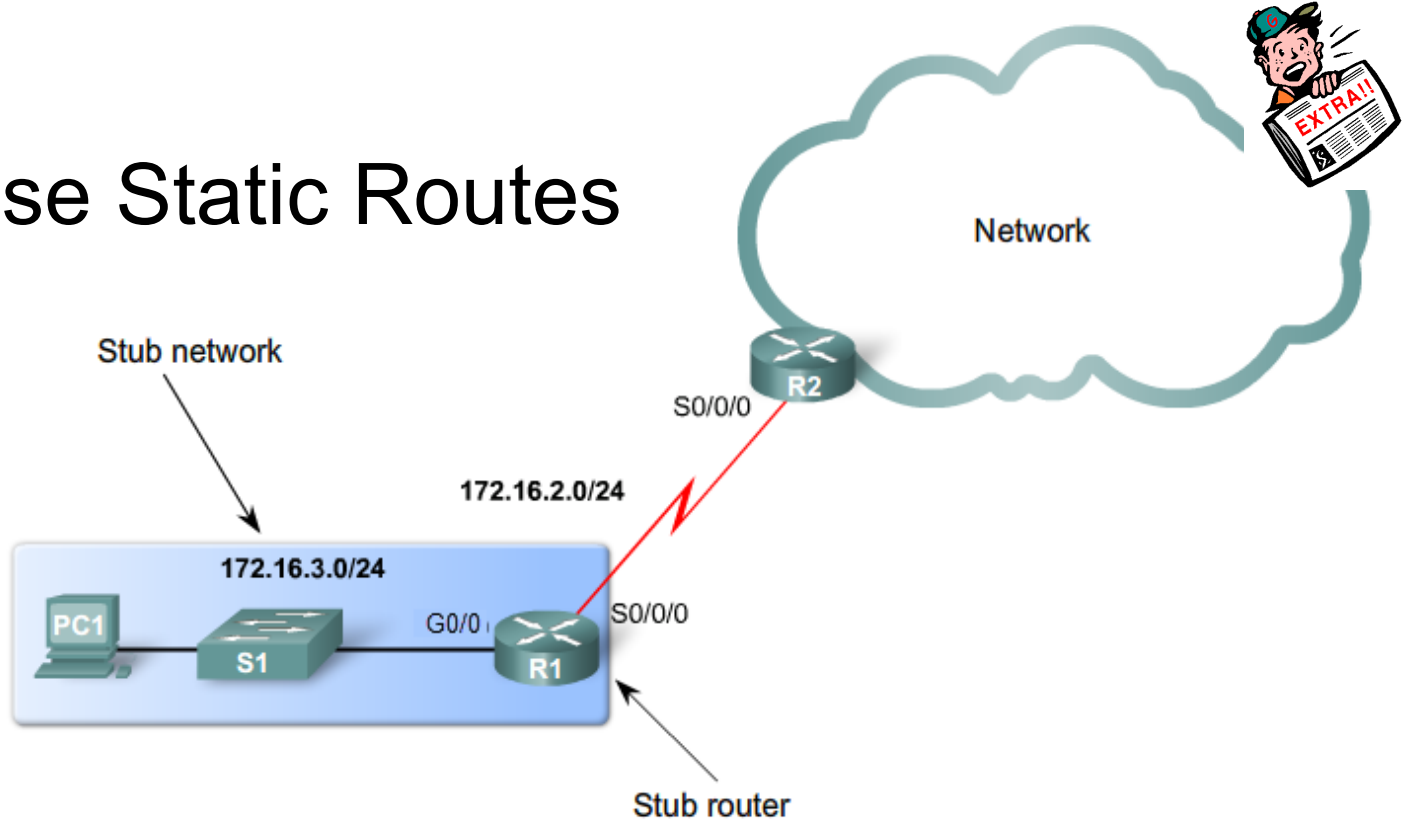
However, if that link ever fails, I will use a floating static route connecting to the Internet as a backup.

Since **EIGRP** has an **administrative distance of 90** I will configure the static route with a higher value



- Accomplished by configuring the static route with a higher administrative distance than the primary route.
- Administrative distance represents the trustworthiness of a route.
  - If multiple paths to the destination exist, the router will choose the path with the lowest administrative distance.

When to Use Static Routes



- In small networks that are not expected to grow significantly.
- To route traffic to and from stub networks.
- To configure a “catch-all” route (i.e., default route) when no other route in the routing table match.
- To summarize other routes in one route.
- To make a backup route for a dynamic routing protocol.

2.1.2.6

	Standard	Default	Summary	Floating
Backs up a route already discovered by a dynamic routing protocol.				✓
Uses a single network address to send multiple static routes to one destination address.			✓	
Matches all packets and sends them to a specific default gateway.		✓		
Useful when connecting to stub networks.	✓			
Configured with a higher administrative distance than the original dynamic routing protocol.				✓
Commonly used with edge routers to connect to the ISP network.		✓		

Configuring Standard Static Routes

TSHOOT Slide

Collecting and Filtering Using Cisco IOS

- To help find specific information, troubleshooters need to know how to use filtering techniques effectively.

- Filtering can be accomplished by using:
  - Additional options / keywords to make the command more specific.
  - Appending a pipe character (**|**) followed by one of the keywords **`include`**, **`exclude`**, or **`begin`**, and then a regular expression.
  - Use regular expressions for more granular filtering.
  - Adding **`redirect`**, **`tee`**, and **`append`** to **`show`** commands.

- NOTE: These may not work with Packet Tracer and may differ slightly with some IOS versions.

Filtering With Additional Options / Keywords

- To limit the output, enter a specific IP address, routing protocol or type of route as an option.

```
R1# show ip route ?
  Hostname or A.B.C.D  Network to display information about or hostname
  bgp                  Border Gateway Protocol (BGP)
  connected            Connected
  dhcp                 Show routes added by DHCP Server or Relay
  eigrp                Enhanced Interior Gateway Routing Protocol (EIGRP)
  isis                 ISO IS-IS
  list                 IP Access list
  mobile               Mobile routes
  odr                  On Demand stub Routes
  ospf                 Open Shortest Path First (OSPF)
  profile              IP routing table profile
  rip                  Routing Information Protocol (RIP)
  static               Static routes
  summary              Summary of all routes
  supernets-only       Show supernet entries only
  track-table          Tracked static table
  update-queue         Queue of RIB updates
  vrf                  Display routes from a VPN Routing/Forwarding...
  |                    Output modifiers
  <cr>

R1# show ip route
```

Filtering With Additional Options / Keywords

```
R1# show ip route 10.1.193.2
Routing entry for 10.1.193.0/30
  Known via "connected", distance 0, metric 0
   (connected, via interface)
  Redistributing via eigrp 1
  Routing Descriptor Blocks:
  * directly connected, via Serial0/0/1
      Route metric is 0, traffic share count is 1
 R1#
```

- To limit the output to a specific address

| *keyword*

```
R1# show running-config | ?
  append     Append redirected output to URL
  begin      Begin with the line that matches
  exclude    Exclude lines that match
  include    Include lines that match
  redirect   Redirect output to URL
  section    Filter a section of output
  tee        Copy output to URL

R1# show running-config |
```

| *keyword*

Using pipes with **`include`**, **`exclude`** and **`begin`** keywords.

```
R1# show processes cpu | include IP Input
  71      3149172    7922812         397  0.24%  0.15%  0.05%    0 IP Input

R1#
R1# show processes cpu| include IP Input
                      ^
% Invalid input detected at '^' marker.

R1#
```

There must always be at least one space preceding and following the pipe operator, otherwise it will not be accepted by the IOS CLI.

```
S1# show ip interface brief | exclude unassigned
Interface              IP-Address      OK? Method Status                Protocol
Vlan128                10.1.156.1      YES NVRAM  up                    up

S1#
S1# show running-config | begin line vty
line vty 0 4
 transport input telnet ssh
line vty 5 15
 transport input telnet ssh
!
```

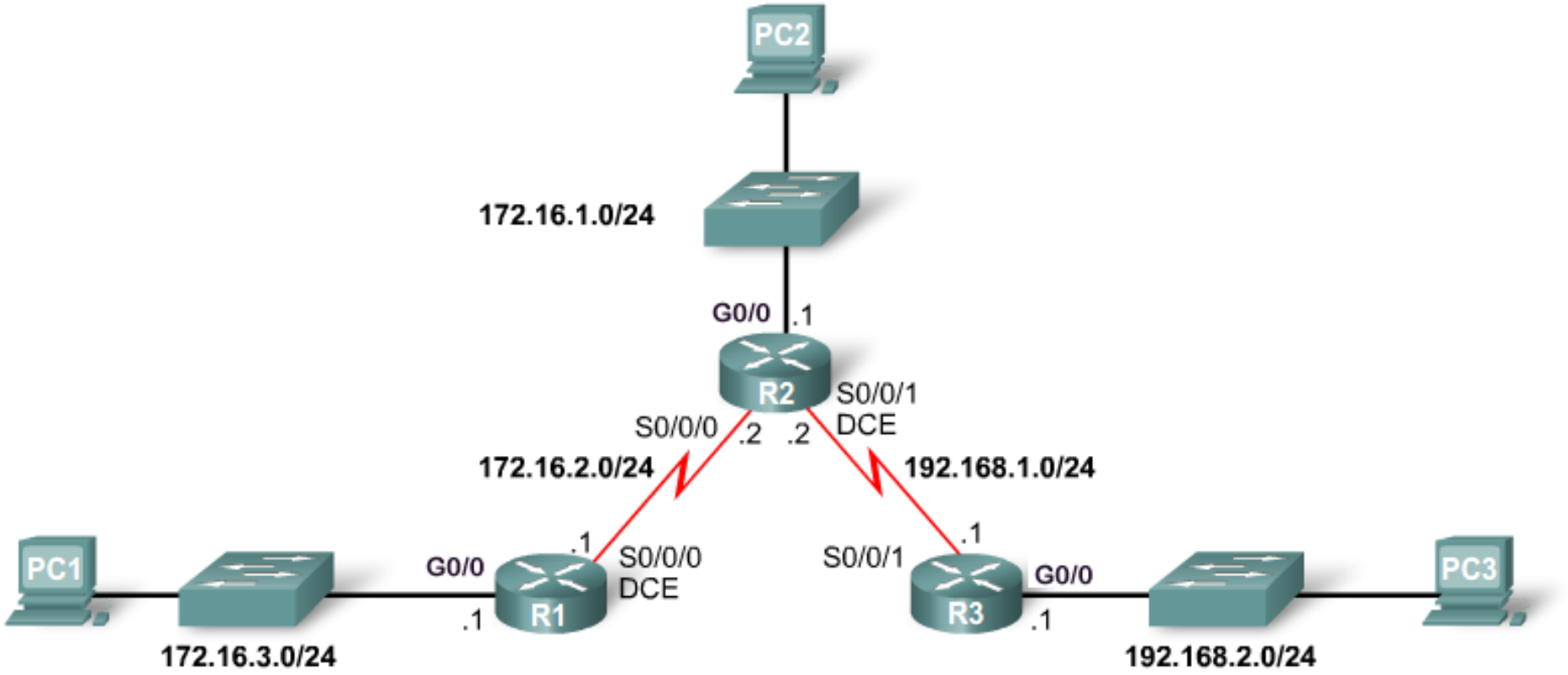
| *keyword* and Regular Expressions

Using pipes with **section** and **^**

```
R1# show running-config | section router eigrp
router eigrp 1
 network 10.1.192.2 0.0.0.0
 network 10.1.192.10 0.0.0.0
 network 10.1.193.1 0.0.0.0
 no auto-summary

R1#
R1# show processes cpu | include ^CPU|IP Input
CPU utilization for five seconds: 1%/0%; one minute: 1%; five minutes: 1%
  71    3149424    7923898     397  0.24%  0.04%  0.00%    0 IP Input
```

- The **^CPU** keyword only matches lines that start with the characters “CPU”.
  - Lines that do not start with the "CPU" characters do not match the ^CPU regular expression, even if they actually contain the string "CPU" somewhere else.
- The same line uses the pipe operator “|” as part of a regular expression to signify a logical “OR” to also include lines that contain the string “IP Input”.

Topology



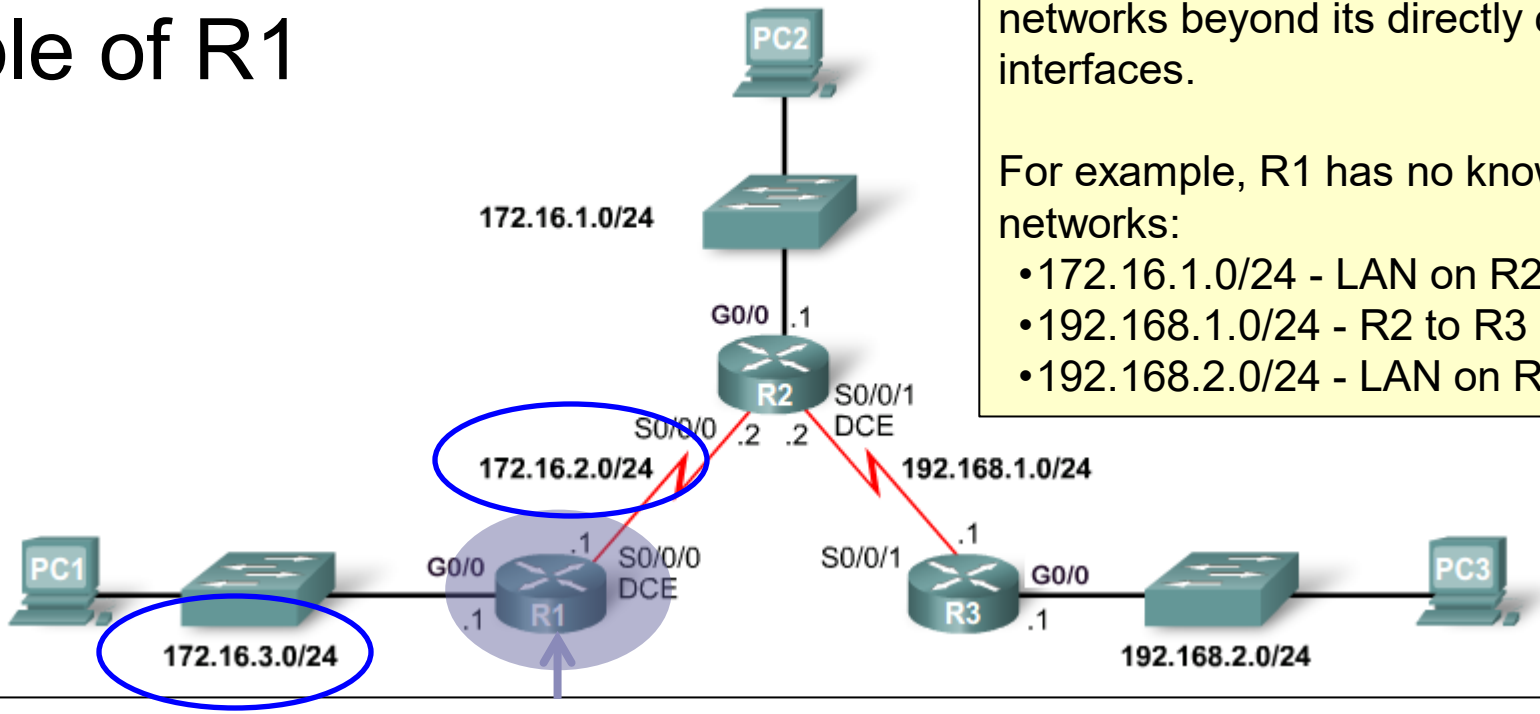
- We will assume all the interface have been configured with an IPv4 address and are in the up/up state.

Verify the Routing Table of R1

Notice how R1 only has entries for its directly connected networks. It does not have any knowledge of any networks beyond its directly connected interfaces.

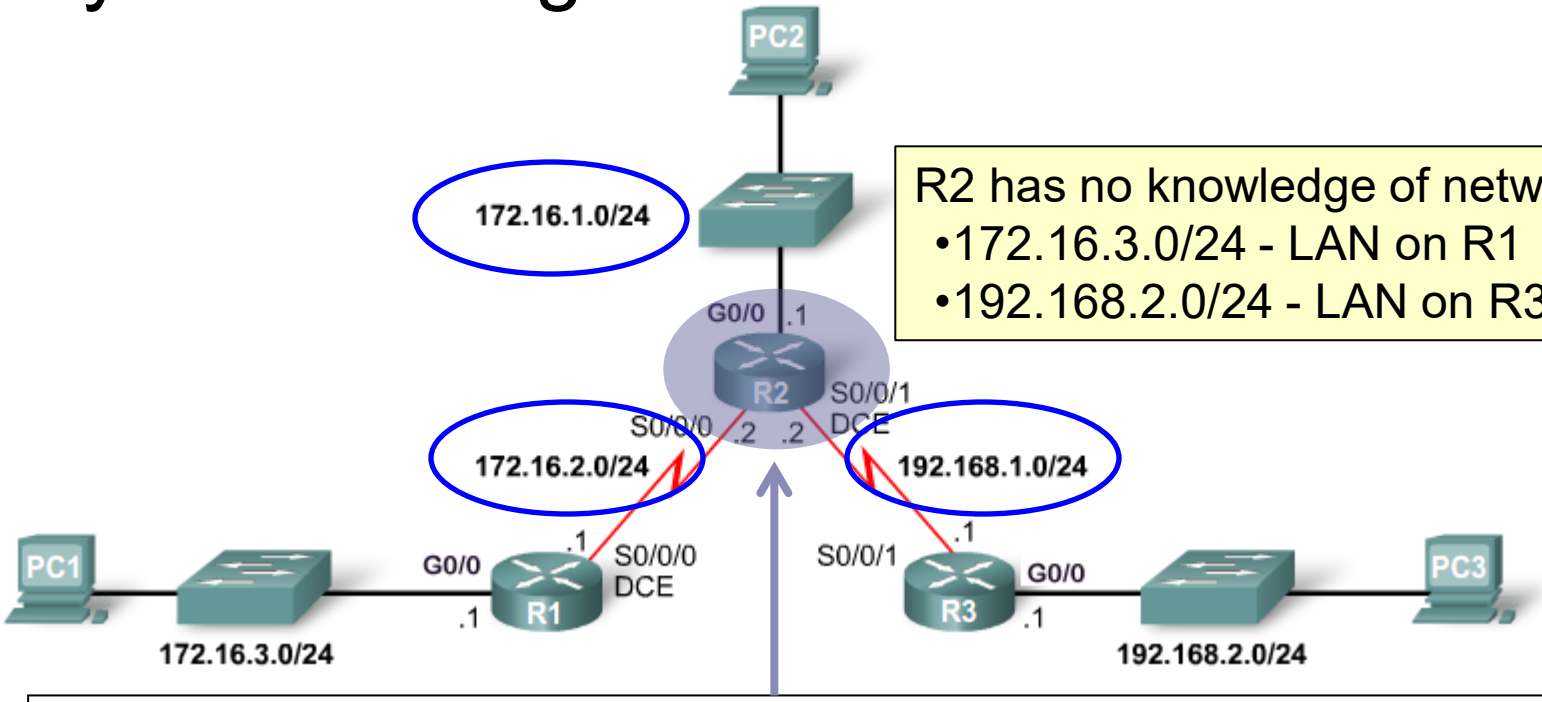
For example, R1 has no knowledge of networks:

- 172.16.1.0/24 - LAN on R2
- 192.168.1.0/24 - R2 to R3
- 192.168.2.0/24 - LAN on R3




```
R1# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.1/32 is directly connected, Serial0/0/0
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0
R1#
```

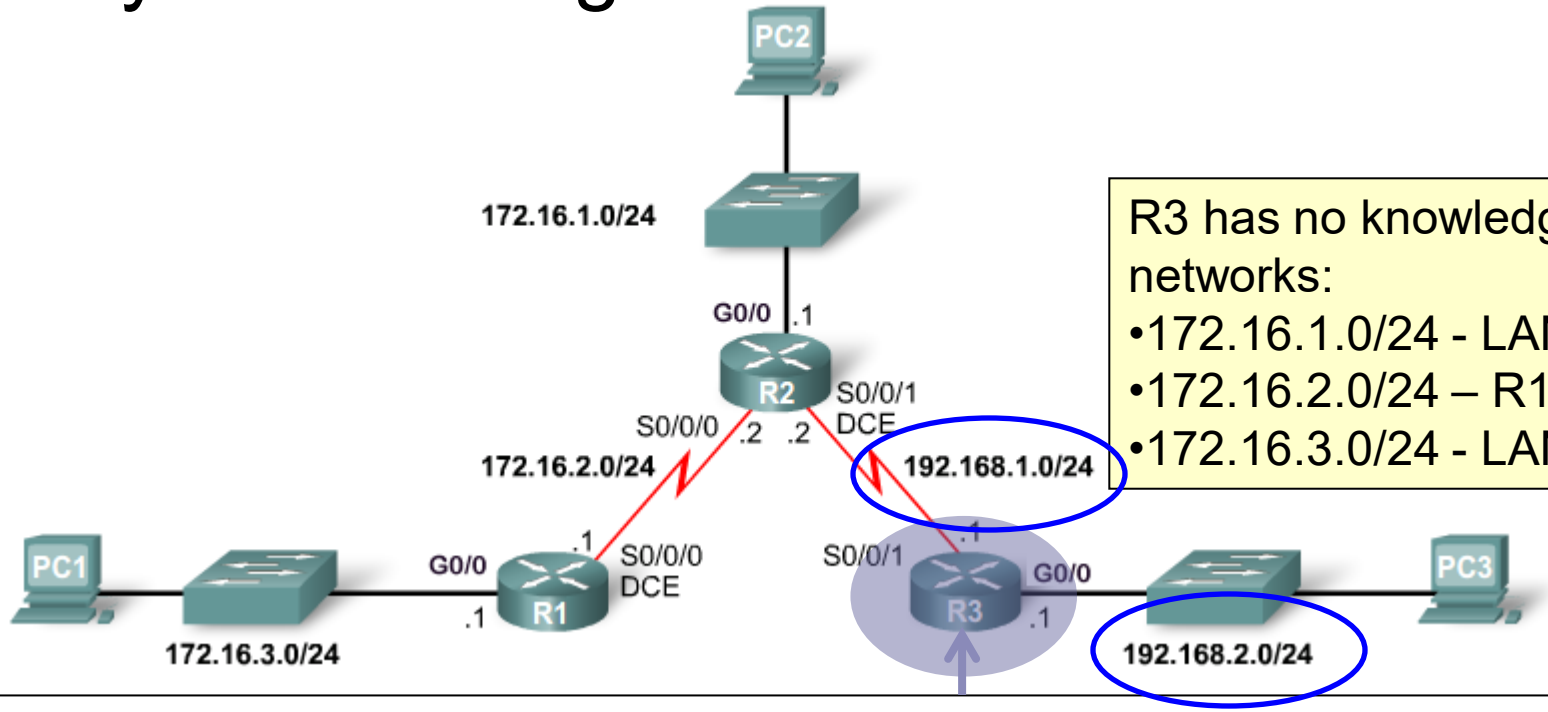
Verify the Routing Table of R2



R2 has no knowledge of networks:
- 172.16.3.0/24 - LAN on R1
- 192.168.2.0/24 - LAN on R3

```
R2# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks
C        172.16.1.0/24 is directly connected, GigabitEthernet0/0
L        172.16.1.1/32 is directly connected, GigabitEthernet0/0
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.2/32 is directly connected, Serial0/0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Serial0/0/1
L        192.168.1.2/32 is directly connected, Serial0/0/1
R2#
```

Verify the Routing Table of R3

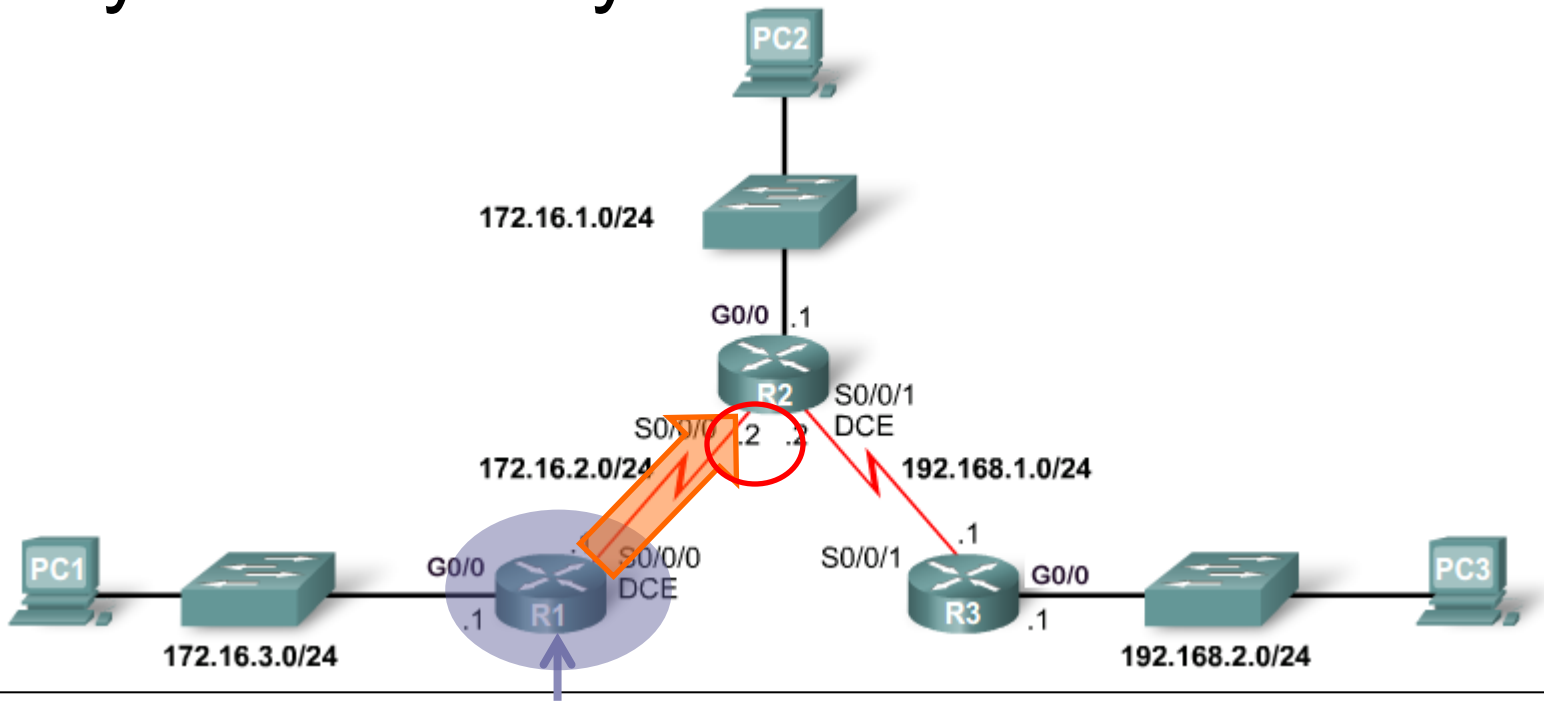


R3 has no knowledge of networks:

- 172.16.1.0/24 - LAN on R2
- 172.16.2.0/24 – R1 to R2
- 172.16.3.0/24 - LAN on R1

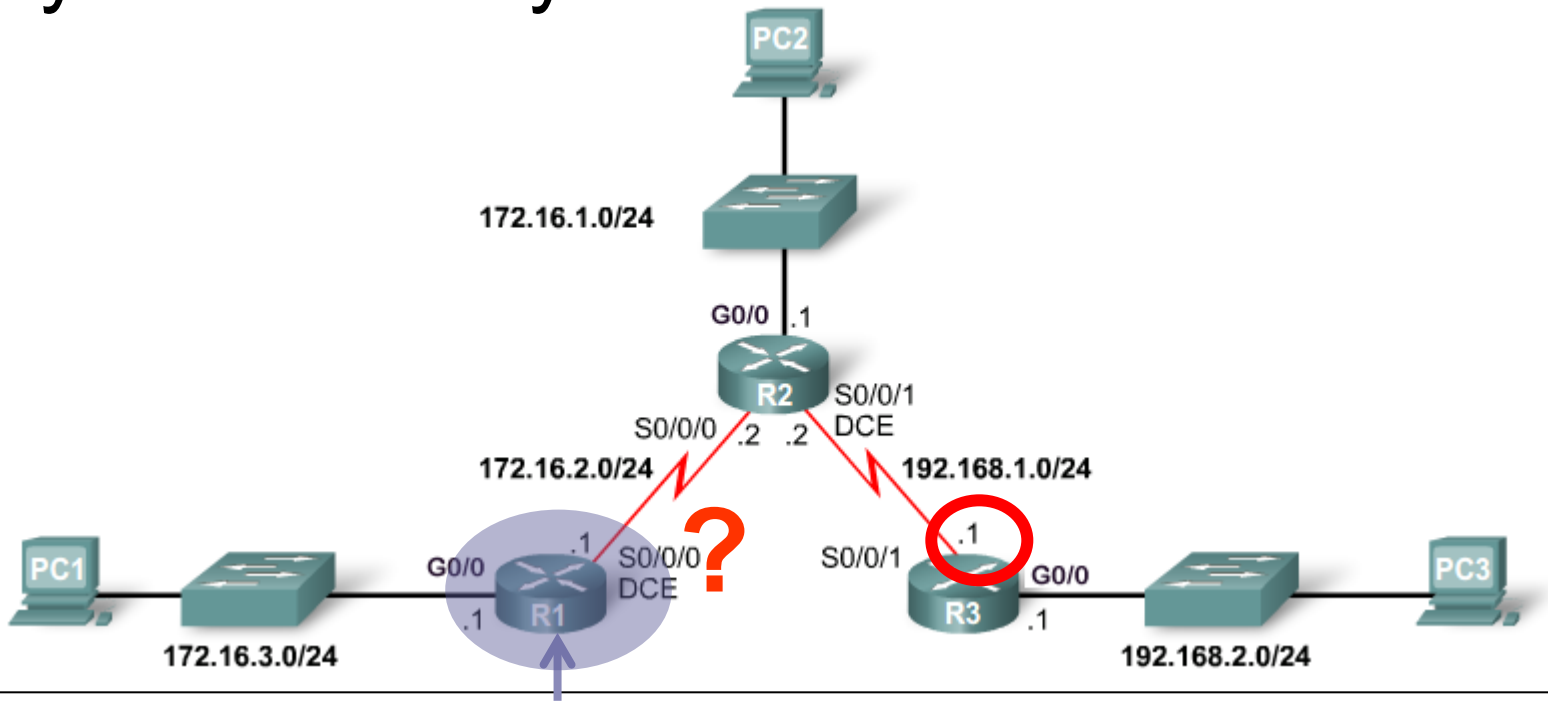
```
R3# show ip route | include C
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B
- BGP
C        192.168.1.0/24 is directly connected, Serial0/0/1
C        192.168.2.0/24 is directly connected, GigabitEthernet0/0
R3#
```

Verify Connectivity to R2




```
R1# ping 172.16.2.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.2.2, timeout is 2
seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max =
12/13/16 ms
R1#
```

Verify Connectivity to R3




```
R1# ping 192.168.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is
2 seconds:
.....
Success rate is 0 percent (0/5)
R1#
```

This network is not in the routing table and there is no IPv4 default route.

The `ip route` Command

`ip route` *`network-add subnet`* **`{`***`ip-address`* **`|`** *`exit-intf`* **`[`***`ip-address`***`]}`** **`[`***`distance`***`]`**

Parameter	Description
network-add	• Destination network address of the remote network to be added to the routing table.
subnet	• Subnet mask of the remote network to be added to the routing table. • Note: The subnet mask can be modified to summarize a group of networks
ip-address	• Commonly referred to as the next-hop router's IP address. • **Typically used when connecting to a broadcast media** (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**
distance	• Used to create a floating static route by setting an administrative distance that is higher than a dynamically learned route.

Types of Standard Static Routes

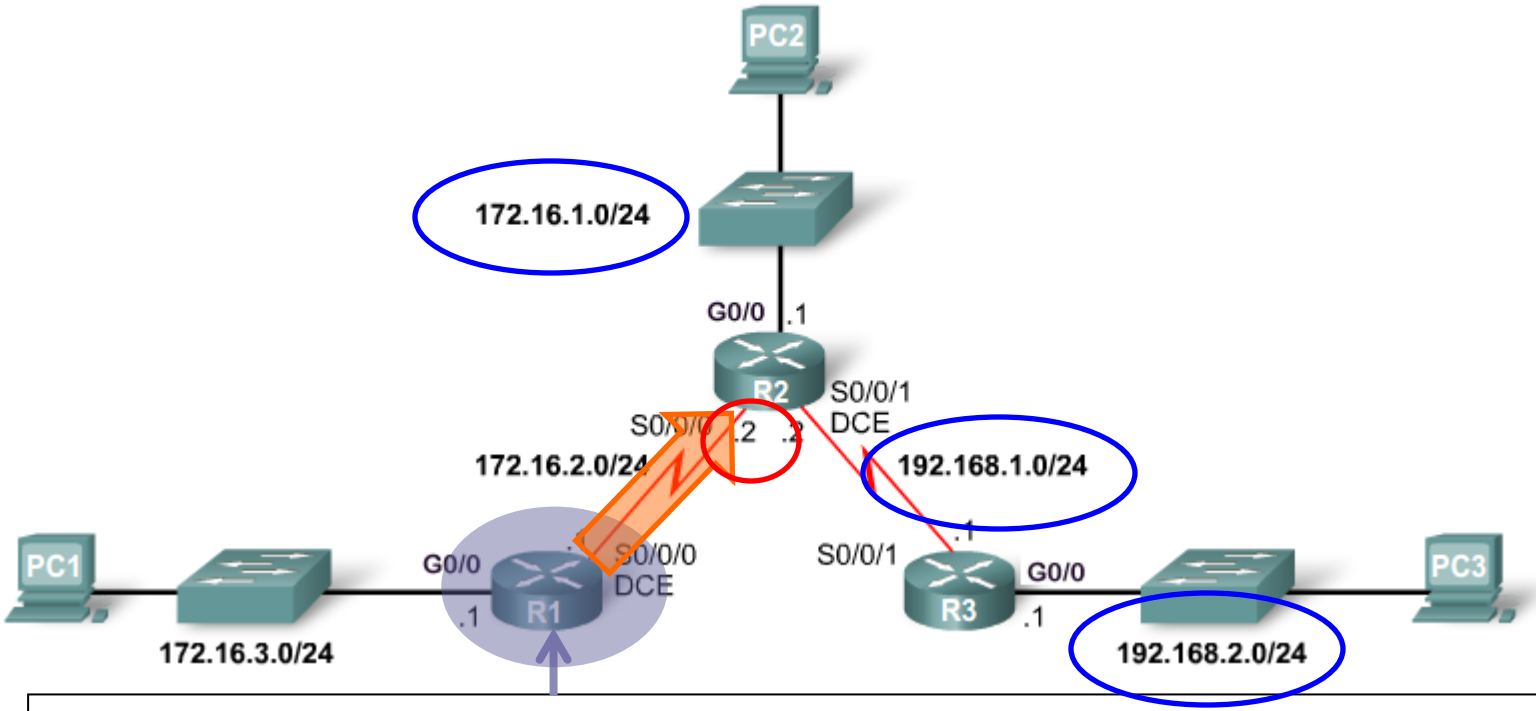
- **Next Hop Static Route (*With CEF….. Use this one*)**
  - **`ip route`** *`network-add subnet ip-address`*
- **Directly Attached Static Route**
  - **`ip route`** *`network-add subnet exit-intf`*
- **Fully Specified Static Route**
  - **`ip route`** *`network-add subnet exit-intf ip-address`*

Next Hop (IPv4) Static Routes

```
Router(config)# ip route network-address subnet-mask next-hop-ip-address
```

- A next hop static route uses an IPv4 address to in the **`ip route`** command to specify the next hop router.
- A next hop static route is recommended to be used over:
  - Directly attached routes
  - Fully specified static routes
- Directly attached and fully specified static routes should only be used when needed and CEF is disabled.
- CEF is enabled by default since IOS 12.2
- We will cover directly attached and fully specified static routes, but it is best to use the next hop static route when CEF is enabled.

Configure Next Hop Static Routes on R1

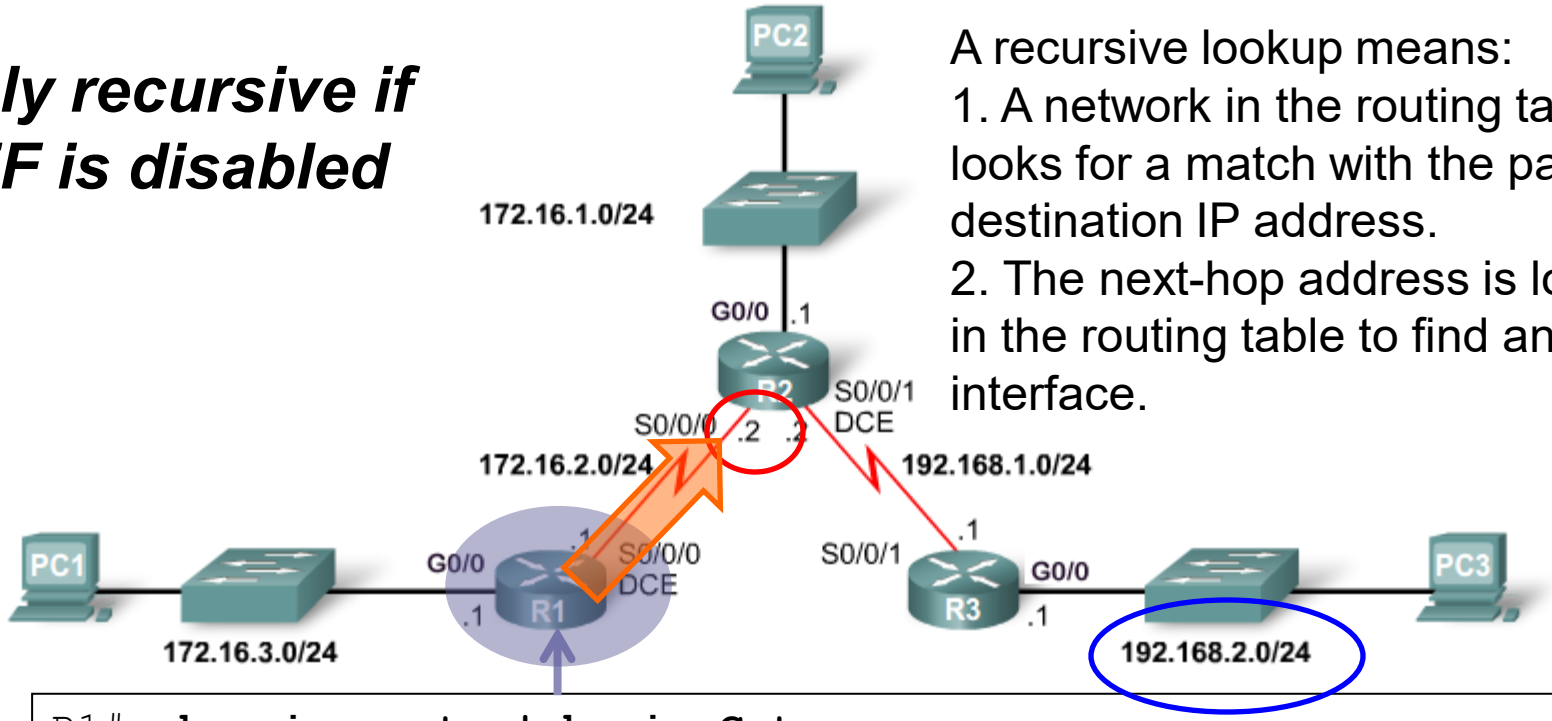



```
R1(config)# ip route 172.16.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.2.0 255.255.255.0 172.16.2.2
R1(config)#
```

Notice: R1 uses the same next-hop IPv4 address for all static routes.
It could have been configured to use a default route to 172.16.2.2

Next Hop Might be a Recursive Static Route

Only recursive if CEF is disabled



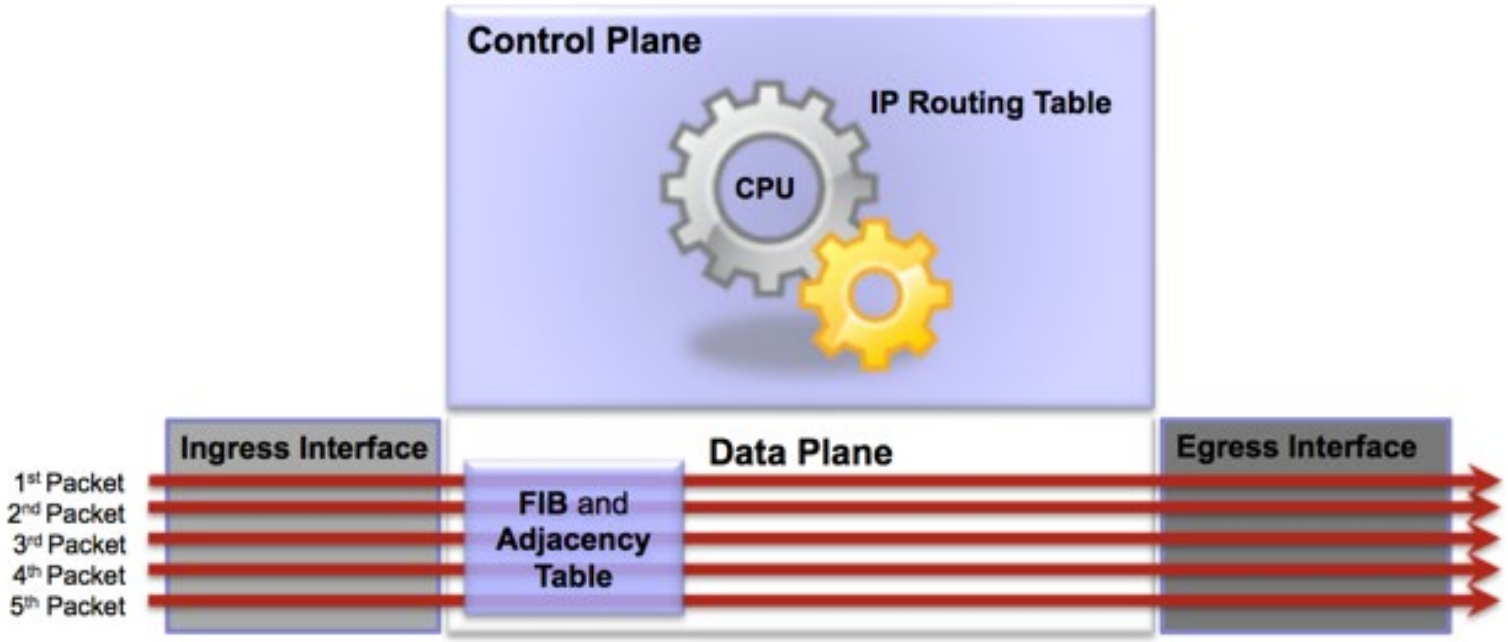
A recursive lookup means:
1. A network in the routing table looks for a match with the packet's destination IP address.
2. The next-hop address is looked up in the routing table to find an exit-interface.

```
R1# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.1.0/24 [1/0] via 172.16.2.2
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.1/32 is directly connected, Serial0/0/0
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0
S     192.168.1.0/24 [1/0] via 172.16.2.2
S     192.168.2.0/24 [1/0] via 172.16.2.2
R1#
```

2

1

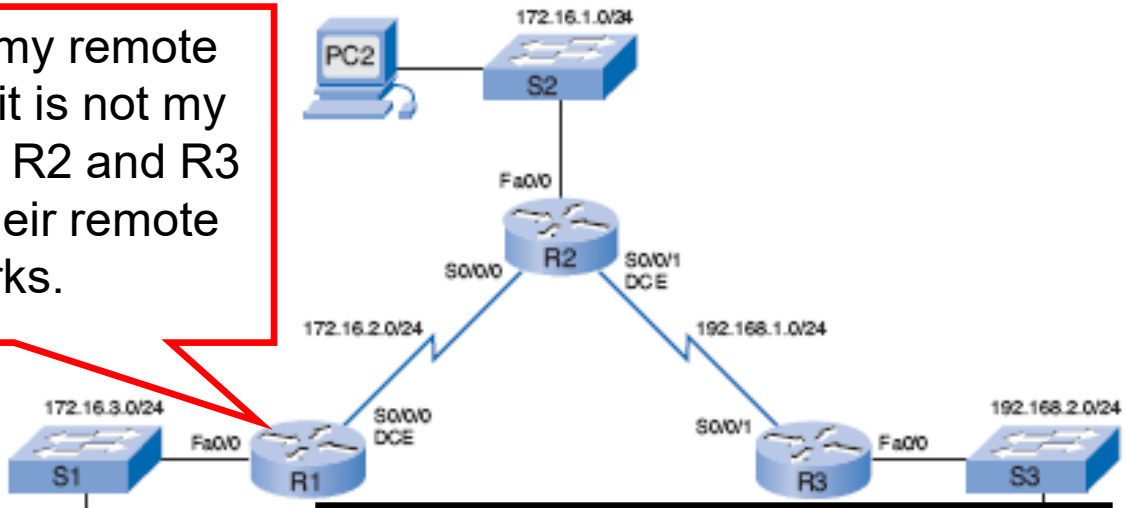
Cisco Express Forwarding (CEF)



- Recursive lookups are **not** a problem when **CEF is enabled**
- CEF is enabled by default beginning with IOS 12.2
- CEF provides optimized lookup for efficient packet forwarding by using the FIB and Adjacency tables.
- Therefore, a next hop static route is resolved in one single lookup when CEF is enabled.
- ***With CEF enabled, it is recommended that next-hop routes are used.***

Alex Zinin's Routing Table Principles

I know about my remote networks, but it is not my responsibility if R2 and R3 know about their remote networks.

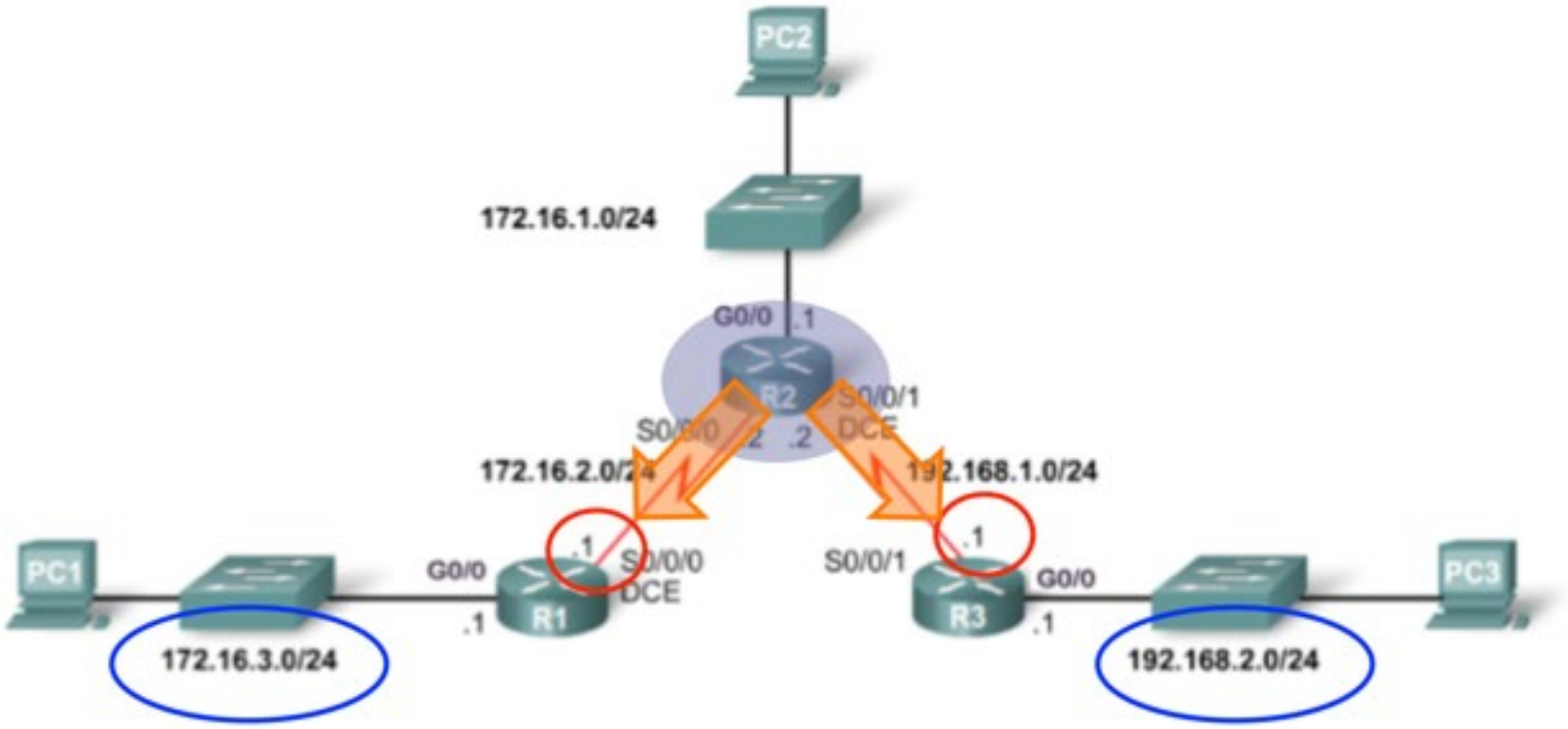



```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S 192.168.1.0/24 [1/0] via 172.16.2.2
S 192.168.2.0/24 [1/0] via 172.16.2.2
```

- **Principle 1: Every router makes its decision alone, based on the information it has in its own routing table.**
- **Principle 2: The fact that one router has certain information in its routing table does not mean that other routers have the same information.**
- **Principle 3: Routing information about a path from one network to another does not provide routing information about the reverse, or return, path.**

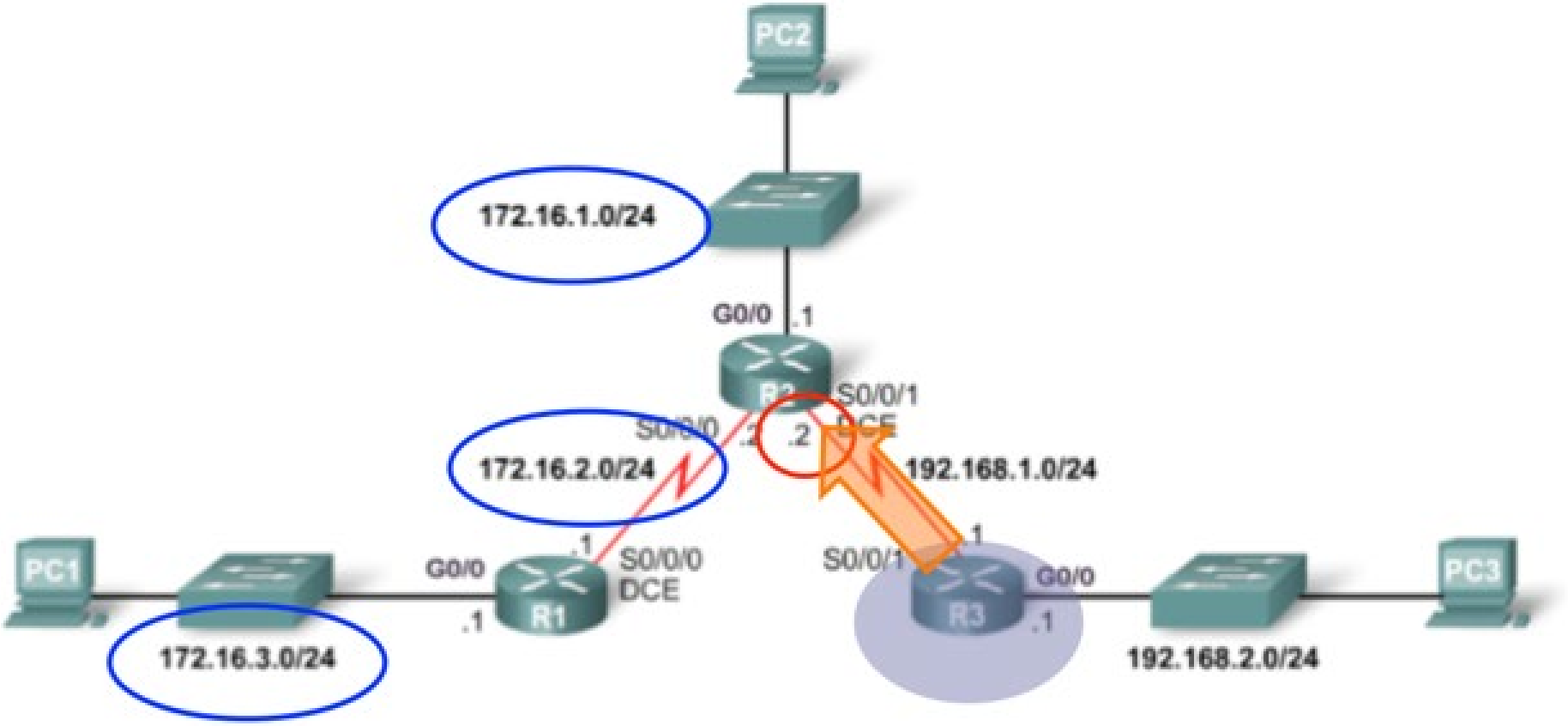
Configuring Next Hop Static Routes on R2

```
R2(config)# ip route 192.168.2.0 255.255.255.0 192.168.1.1
R2(config)# ip route 172.16.3.0 255.255.255.0 172.16.2.1
R2(config)# end
R2#
```



Configuring Next Hop Static Routes on R3

```
R3(config)# ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.3.0 255.255.255.0 192.168.1.2
R3(config)# end
```



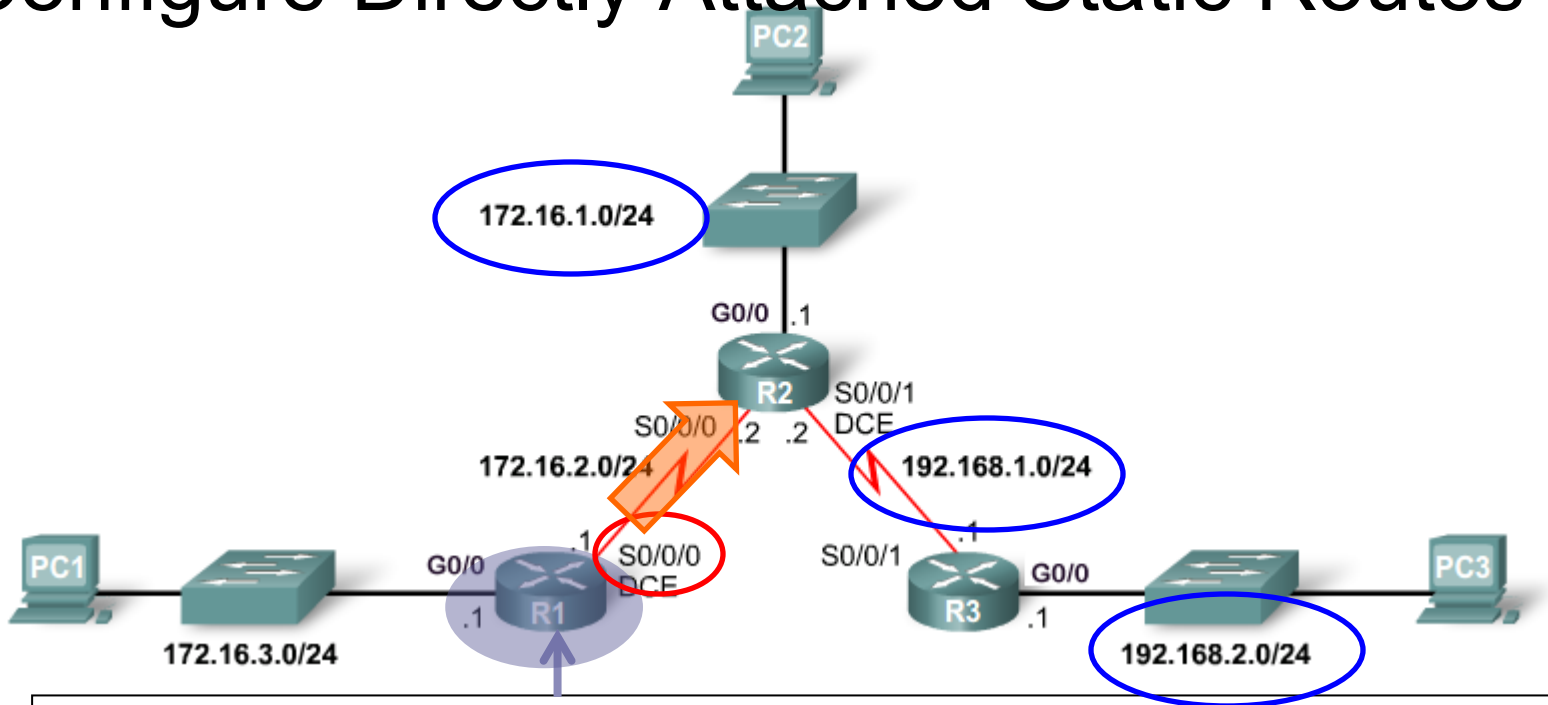
Directly Attached Static Routes

```
Router(config)# ip route network-address subnet-mask exit-interface
```

- ***When CEF is not enabled***, a directly attached static route avoids the recursive lookup problem on *point-to-point networks*.
  - It allows the routing table to resolve the exit interface in a single search, instead of two searches.
- Typically used with point-to-point serial interfaces.

Note: Next-hop static routes are recommended when CEF is enabled.

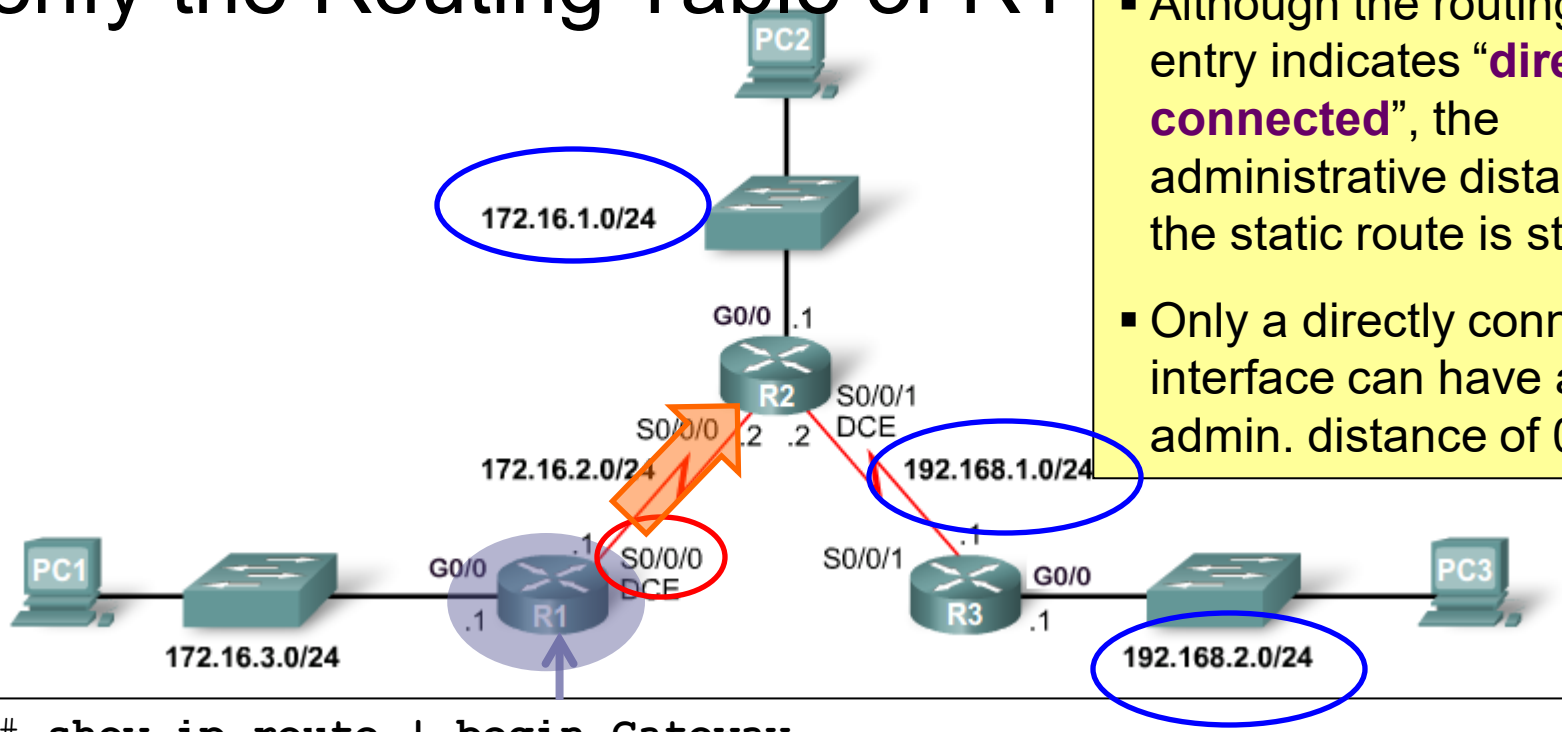
Configure Directly Attached Static Routes




```
R1(config)# ip route 172.16.1.0 255.255.255.0 s0/0/0
R1(config)# ip route 192.168.1.0 255.255.255.0 s0/0/0
R1(config)# ip route 192.168.2.0 255.255.255.0 s0/0/0
R1(config)#
```

- This is an alternative method for configuring static routes on a point-to-point network.
- Static routes with a next-hop address recommended when CEF is enabled.

Verify the Routing Table of R1



Note (covered more later):

- Although the routing table entry indicates "**directly connected**", the administrative distance of the static route is still 1.
- Only a directly connected interface can have an admin. distance of 0.

```
R1# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.1.0/24 is directly connected, Serial0/0/0
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.1/32 is directly connected, Serial0/0/0
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0
S     192.168.1.0/24 is directly connected, Serial0/0/0
S     192.168.2.0/24 is directly connected, Serial0/0/0
R1#
```

Directly Attached Static Routes on R2

```
R2(config)# ip route 172.16.3.0 255.255.255.0 s0/0/0
R2(config)# ip route 192.168.2.0 255.255.255.0 s0/0/1
R2(config)# ^Z
R2#
*Feb 21 18:04:37.207: %SYS-5-CONFIG_I: Configured from console by console
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
       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 not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
C        172.16.1.0/24 is directly connected, GigabitEthernet0/0
L        172.16.1.1/32 is directly connected, GigabitEthernet0/0
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.2/32 is directly connected, Serial0/0/0
S        172.16.3.0/24 is directly connected, Serial0/0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Serial0/0/1
L        192.168.1.2/32 is directly connected, Serial0/0/1
S     192.168.2.0/24 is directly connected, Serial0/0/1
R2#
```

Directly Attached Static Routes on R3

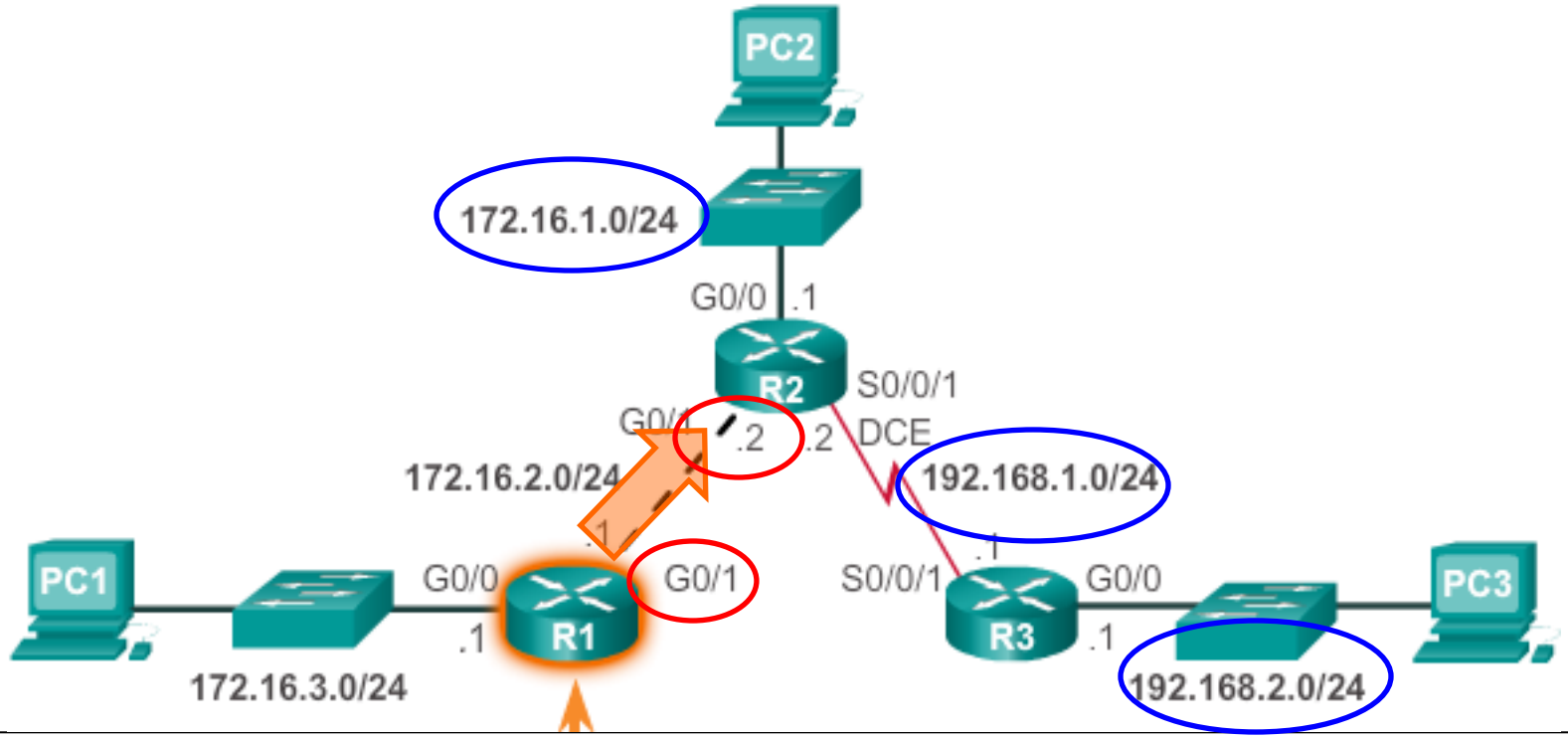
```
R3(config)# ip route 172.16.1.0 255.255.255.0 s0/0/1
R3(config)# ip route 172.16.2.0 255.255.255.0 s0/0/1
R3(config)# ip route 172.16.3.0 255.255.255.0 s0/0/1
R3(config)# ^Z
R3#
*Feb 21 18:01:14.055: %SYS-5-CONFIG_I: Configured from console by console
R3#
R3# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       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 not set

      172.16.0.0/24 is subnetted, 3 subnets
S        172.16.1.0 is directly connected, Serial0/0/1
S        172.16.2.0 is directly connected, Serial0/0/1
S        172.16.3.0 is directly connected, Serial0/0/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Serial0/0/1
L        192.168.1.1/32 is directly connected, Serial0/0/1
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, GigabitEthernet0/0
L        192.168.2.1/32 is directly connected, GigabitEthernet0/0
R3#
```

Fully Specified Static Routes

```
Router(config)# ip route network-address subnet-mask exit-interface
   next-hop-ip-address
```

- A static route with just an exit-interface will not work on multi-access networks such as Ethernet because there may be multiple next-hops.
- A fully specified static IPv4 route is can be used when:
  - CEF is disabled
  - The exit interface is a mutli-access network (Ethernet)
- Note: CEF is enabled by default beginning with IOS 12.2, so a static route with a next hop address is recommended.

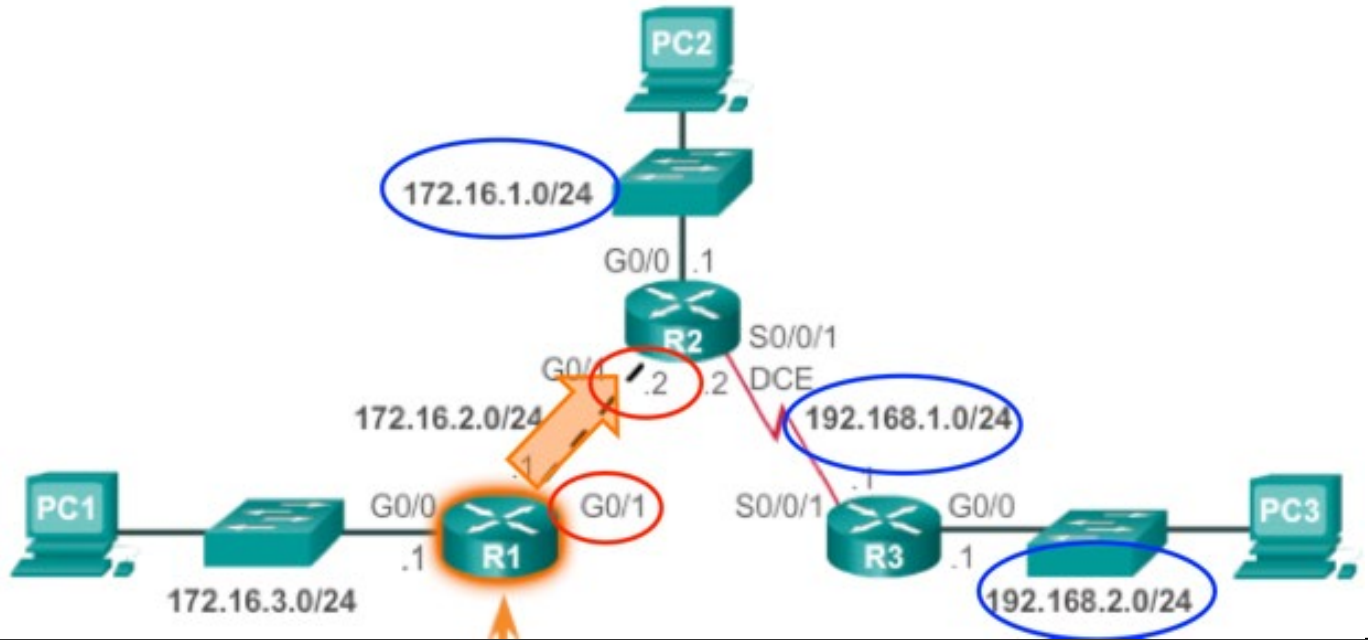
Fully Specified Static Routes on R1




```
R1(config)# ip route 172.16.1.0 255.255.255.0 G0/1 172.16.2.2
R1(config)# ip route 192.168.1.0 255.255.255.0 G0/1 172.16.2.2
R1(config)# ip route 192.168.2.0 255.255.255.0 G0/1 172.16.2.2
R1(config)#
```

- Required when CEF is disabled and on a multi-access network.

Verify the Routing Table of R1




```
R1# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.1.0/24 [1/0] via 172.16.2.2, Gigabitethernet0/1
C        172.16.2.0/24 is directly connected, Gigabitethernet0/1
L        172.16.2.1/32 is directly connected, Gigabitethernet0/1
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0
S     192.168.1.0/24 [1/0] via 172.16.2.2, Gigabitethernet0/1
S     192.168.2.0/24 [1/0] via 172.16.2.2, Gigabitethernet0/1
R1#
```

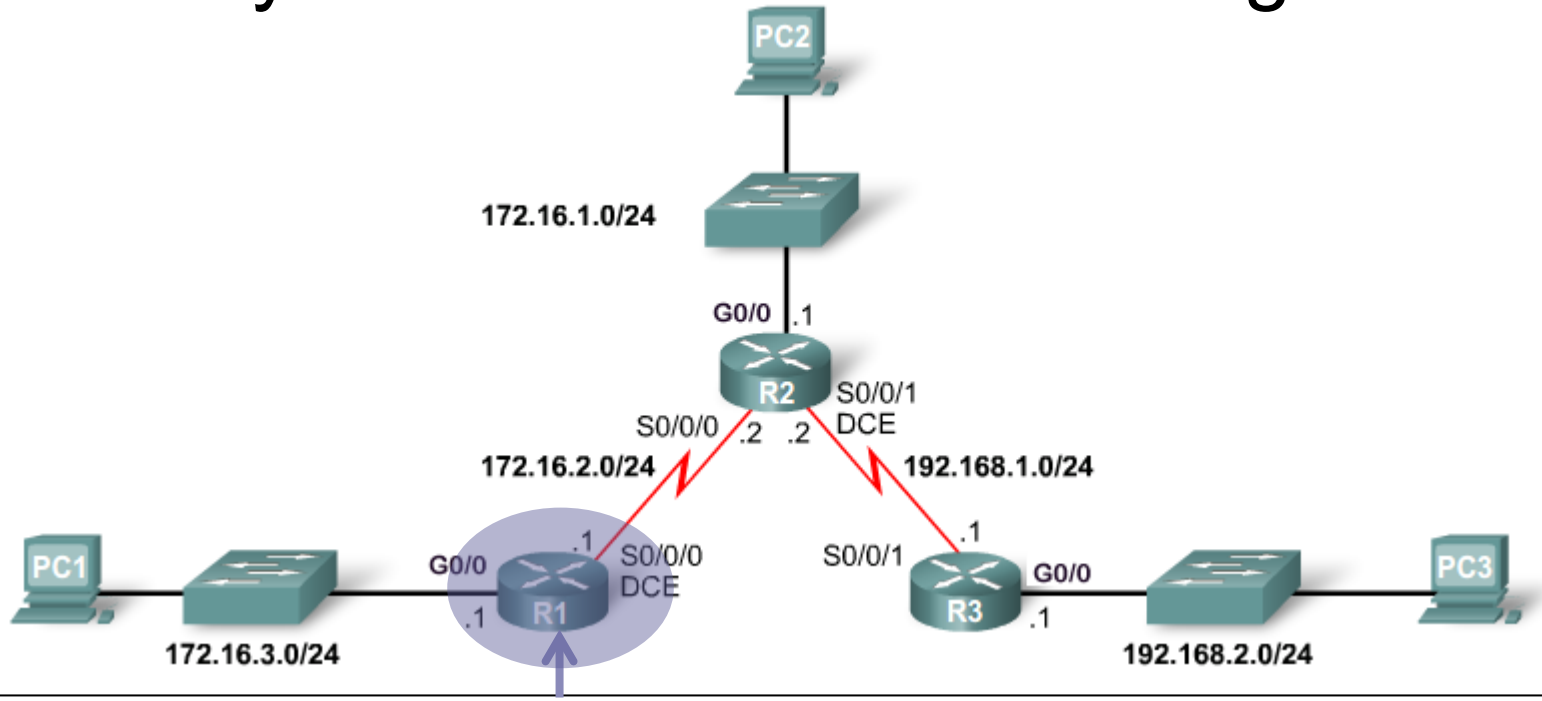
Fully Specified Static Routes on R2

```
R2(config)# ip route 172.16.3.0 255.255.255.0 s0/0/0 172.16.2.1
R2(config)# ip route 192.168.2.0 255.255.255.0 s0/0/1 192.168.1.1
R2(config)# ^Z
R2#
*Feb 21 18:07:06.915: %SYS-5-CONFIG_I: Configured from console by console
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
       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 not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
C        172.16.1.0/24 is directly connected, GigabitEthernet0/0
L        172.16.1.1/32 is directly connected, GigabitEthernet0/0
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.2/32 is directly connected, Serial0/0/0
S        172.16.3.0/24 [1/0] via 172.16.2.1, Serial0/0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Serial0/0/1
L        192.168.1.2/32 is directly connected, Serial0/0/1
S     192.168.2.0/24 [1/0] via 192.168.1.1, Serial0/0/1
R2#
```

Fully Specified Static Routes on R3

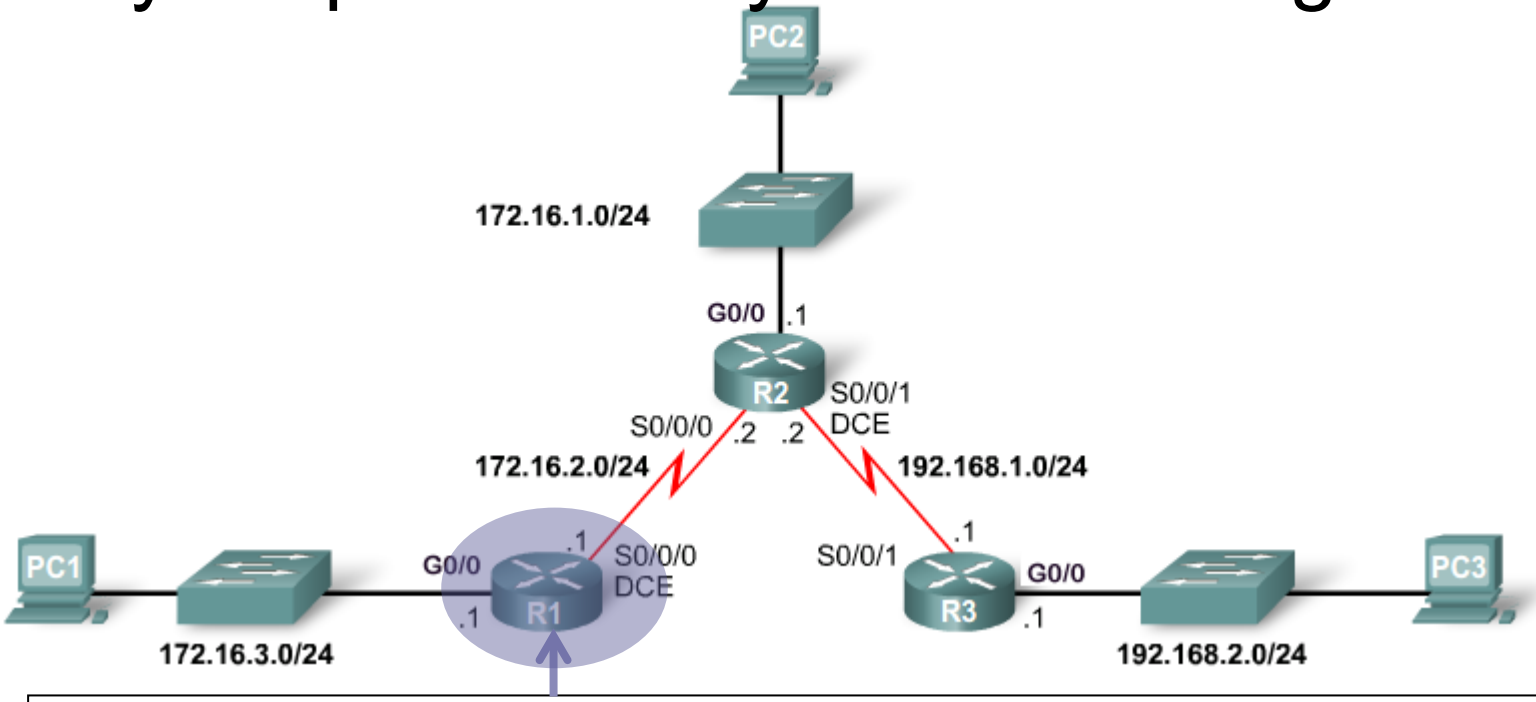
```
R3(config)# ip route 172.16.1.0 255.255.255.0 s0/0/1 192.168.1.2
R3(config)# ip route 172.16.2.0 255.255.255.0 s0/0/1 192.168.1.2
R3(config)# ip route 172.16.3.0 255.255.255.0 s0/0/1 192.168.1.2
R3(config)# ^Z
R3#
*Feb 21 18:07:51.319: %SYS-5-CONFIG_I: Configured from console by console
R3# show 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
       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 not set

      172.16.0.0/24 is subnetted, 3 subnets
S        172.16.1.0 [1/0] via 192.168.1.2, Serial0/0/1
S        172.16.2.0 [1/0] via 192.168.1.2, Serial0/0/1
S        172.16.3.0 [1/0] via 192.168.1.2, Serial0/0/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Serial0/0/1
L        192.168.1.1/32 is directly connected, Serial0/0/1
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, GigabitEthernet0/0
L        192.168.2.1/32 is directly connected, GigabitEthernet0/0
R3#
```

View only static routes in the routing table



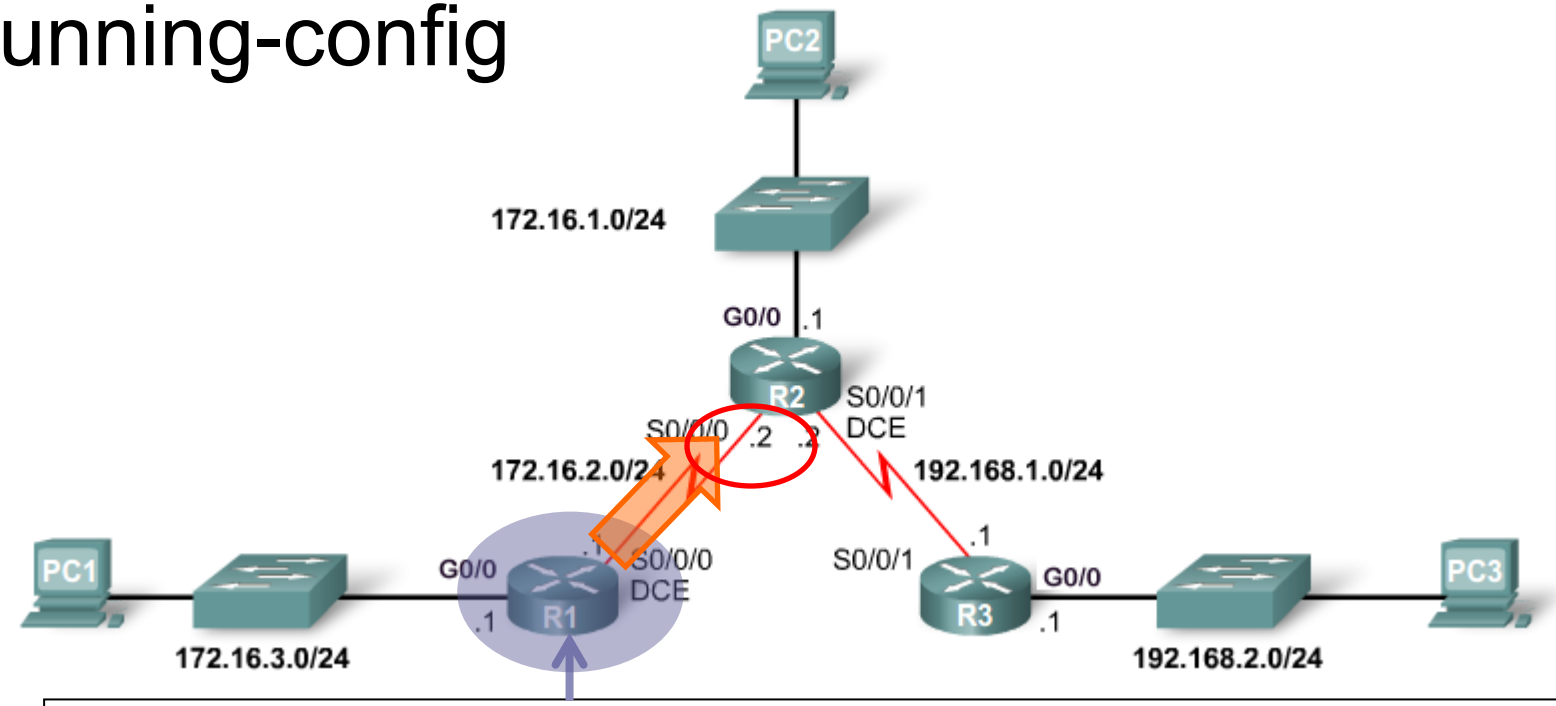

```
R1# show ip route static | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.1.0/24 [1/0] via 172.16.2.2
S     192.168.1.0/24 [1/0] via 172.16.2.2
S     192.168.2.0/24 [1/0] via 172.16.2.2
R1#
```

Verify a Specific Entry in the Routing Table




```
R1# show ip route 192.168.2.1
Routing entry for 192.168.2.0/24
  Known via "static", distance 1, metric 0
  Routing Descriptor Blocks:
  * 172.16.2.2
Route metric is 0, traffic share count is 1
R1#
```

Verify the Static Route Configuration in the running-config




```
R1# show running-config | section ip route
ip route 172.16.1.0 255.255.255.0 172.16.2.2
ip route 192.168.1.0 255.255.255.0 172.16.2.2
ip route 192.168.2.0 255.255.255.0 172.16.2.2
R1#
```

Verify the Static Routing Settings of R2

```
R2# show ip route static
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 not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.3.0/24 [1/0] via 172.16.2.1
S     192.168.2.0/24 [1/0] via 192.168.1.1
R2#
R2# show ip route 172.16.3.1
Routing entry for 172.16.3.0/24
  Known via "static", distance 1, metric 0
  Routing Descriptor Blocks:
  * 172.16.2.1
Route metric is 0, traffic share count is 1
R2#
R2# show running-config | section ip route
ip route 172.16.3.0 255.255.255.0 172.16.2.1
ip route 192.168.2.0 255.255.255.0 192.168.1.1
R2#
```

Verify the Static Routing Settings of R3

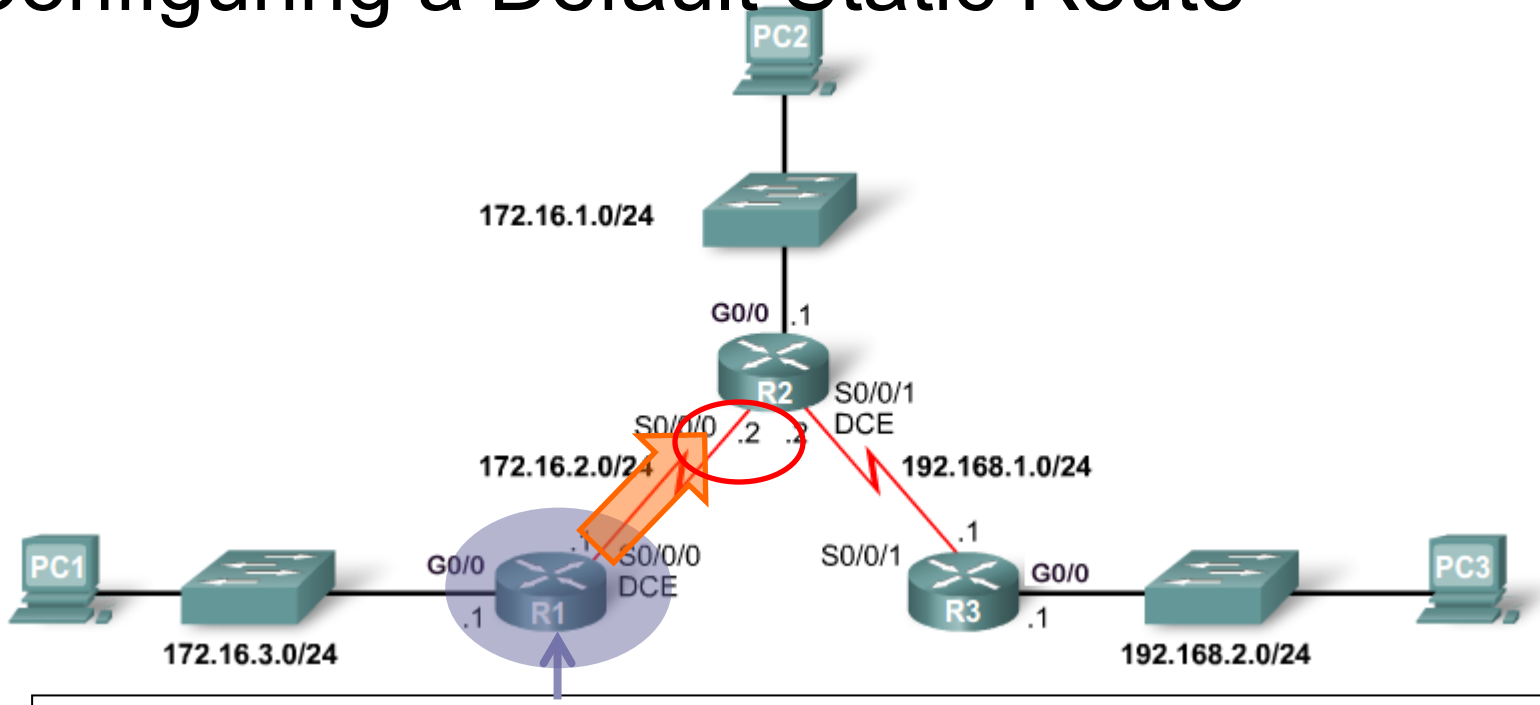
```
R3# show ip route static
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 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 not set

      172.16.0.0/24 is subnetted, 3 subnets
S        172.16.1.0 [1/0] via 192.168.1.2
S        172.16.2.0 [1/0] via 192.168.1.2
S        172.16.3.0 [1/0] via 192.168.1.2
R3#
R3# show ip route 172.16.3.1
Routing entry for 172.16.3.0/24
  Known via "static", distance 1, metric 0
  Routing Descriptor Blocks:
  * 192.168.1.2
Route metric is 0, traffic share count is 1
R3#
R3# show running-config | section ip route
ip route 172.16.1.0 255.255.255.0 192.168.1.2
ip route 172.16.2.0 255.255.255.0 192.168.1.2
ip route 172.16.3.0 255.255.255.0 192.168.1.2
R3#
```

Configuring a Default Static Route

```
ip route 0.0.0.0 0.0.0.0 {ip-address | exit-intf [ip-address]}
```

Parameter	Description
`0.0.0.0`	• Matches any network address.
`0.0.0.0`	• Matches any subnet mask.
ip-address	• Commonly referred to as the next-hop router's IP address. • **Typically used when connecting to a broadcast media** (e.g., 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**.

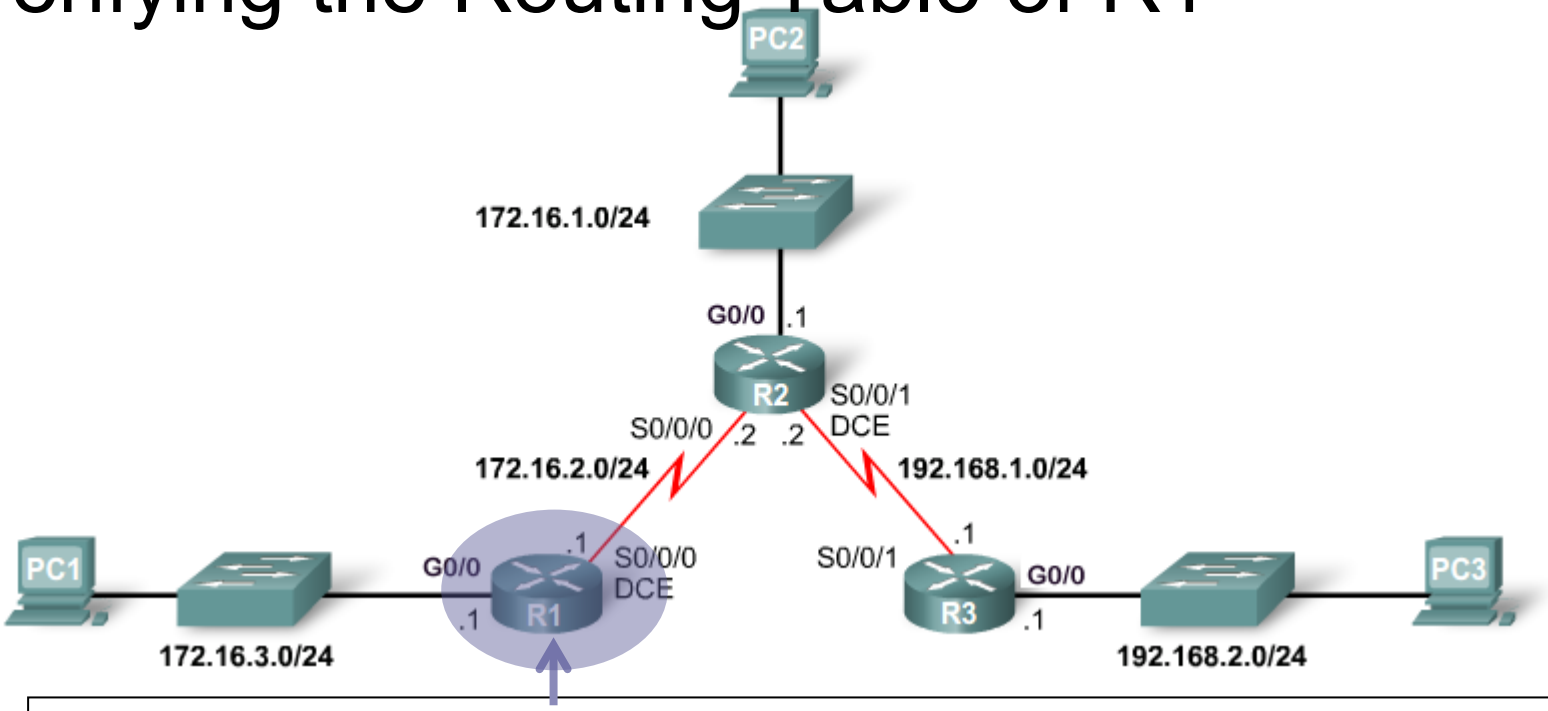
Configuring a Default Static Route




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

- Commonly used in every network to have at least one route to send packets when the destination IP address doesn't match a more specific route in the routing table.
- Used along with dynamic routing protocols (later)
- If a default route is not used and there is not a match in the routing table, then the packet is dropped.

Verifying the Routing Table of R1




```
R1# show ip route static
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 0.0.0.0 to network 0.0.0.0

S*    0.0.0.0/0 is via 172.16.2.2
R1#
```

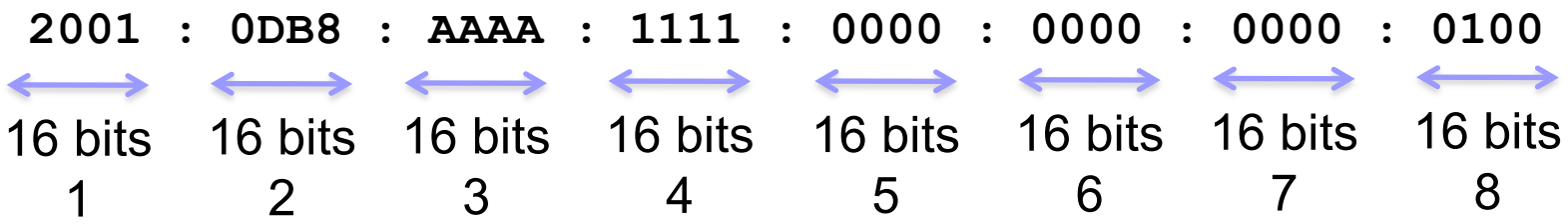
Configuring IPv6 Static Routes

IPv6 Address Notation

One Hex digit = 4 bits

Dec.	Hex.	Binary	Dec.	Hex.	Binary
0	0	0000	8	8	1000
1	1	0001	9	9	1001
2	2	0010	10	A	1010
3	3	0011	11	B	1011
4	4	0100	12	C	1100
5	5	0101	13	D	1101
6	6	0110	14	E	1110
7	7	0111	15	F	1111

2001:0DB8:AAAA:1111:0000:0000:0000:0100/64



- IPv6 addresses are 128-bit addresses represented in:
  - Eight 16-bit segments or “hextets” (not a formal term)
  - Hexadecimal (non-case sensitive) between 0000 and FFFF
  - Separated by colons
  - Reading and subnetting IPv6 is easier than IPv4!

Rule 1: Leading 0's

- Two rules for reducing the size of written IPv6 addresses.
- The first rule is: Leading zeroes in any 16-bit segment do not have to be written.

2001 : 0DB8 : 0001 : 1000 : 0000 : 0000 : 0ef0 : bc00

2001 : DB8 : 1 : 1000 : 0 : 0 : ef0 : bc00

2001 : 0DB8 : 010d : 000a : 00dd : c000 : e000 : 0001

2001 : DB8 : 10d : a : dd : c000 : e000 : 1

2001 : 0DB8 : 0000 : 0000 : 0000 : 0000 : 0000 : 0500

2001 : DB8 : 0 : 0 : 0 : 0 : 0 : 500

Rule 2: Double colon :: equals 0000…0000

- The second rule can reduce this address even further:
- Any single, contiguous string of one or more 16-bit segments consisting of all zeroes can be represented with a double colon.

FE80 : ~~0000 : 0000 : 0000 : 0000 : 0000 : 0000~~ : ~~000~~1

FE80 : : 1

Second Rule

First Rule

FE80::1

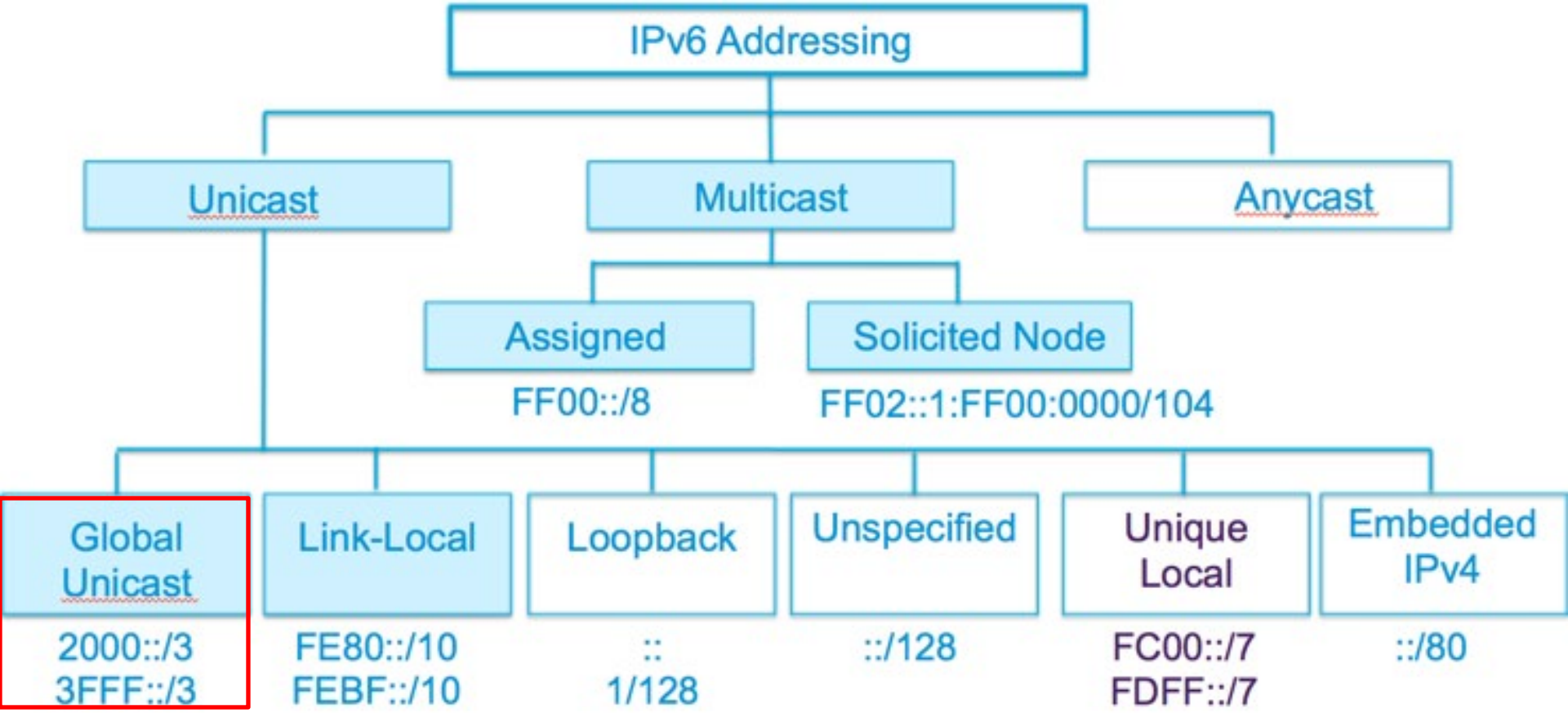
Network Prefixes

- IPv4, the prefix—the network portion of the address—can be identified by a dotted decimal netmask or bit count.

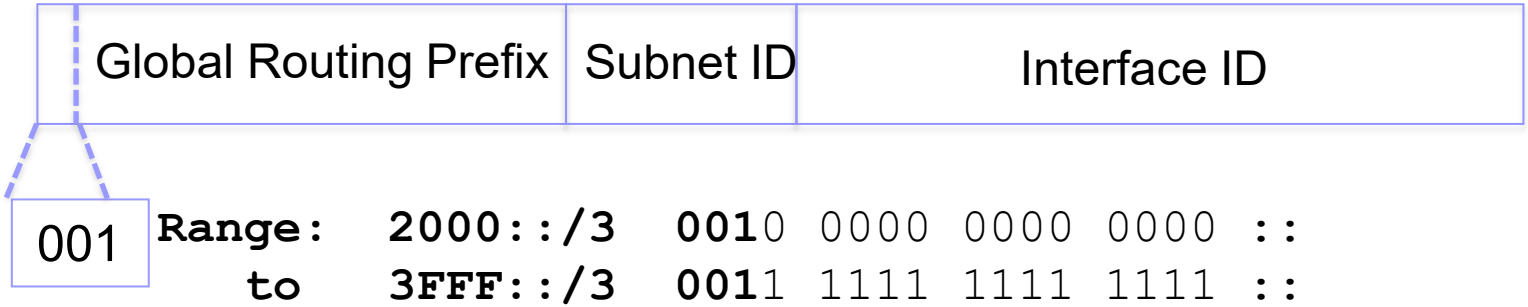
```
255.255.255.0   or /24
```

- IPv6 prefixes are always identified by bit count (prefix length).
- Prefix length notation:

```
3ffe:1944:100:a::/64
     ↑    ↑    ↑ ↑
    16   32   48 64 bits
```

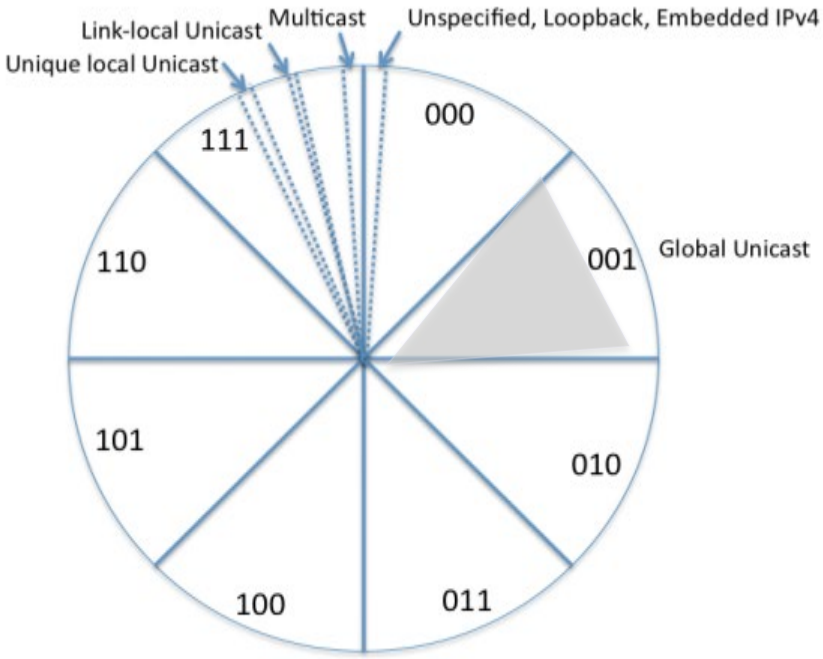

IPv6 Addressing
Unicast
Multicast
Anycast
Assigned
FF00::/8
Solicited Node
FF02::1:FF00:0000/104
Global Unicast
2000::/3
3FFF::/3
Link-Local
FE80::/10
FEBF::/10
Loopback
::
1/128
Unspecified
::/128
Unique Local
FC00::/7
FDFF::/7
Embedded IPv4
::/80

Global Unicast Address (GUA)



- Global unicast addresses are like IPv4 addresses
  - Routable
  - Unique

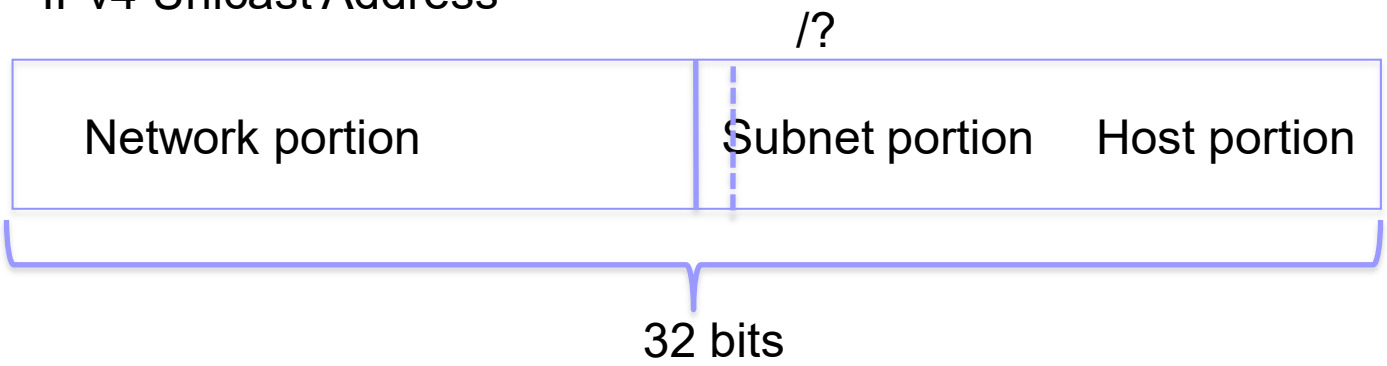
IANA's allocation of IPv6 address space in 1/8th sections



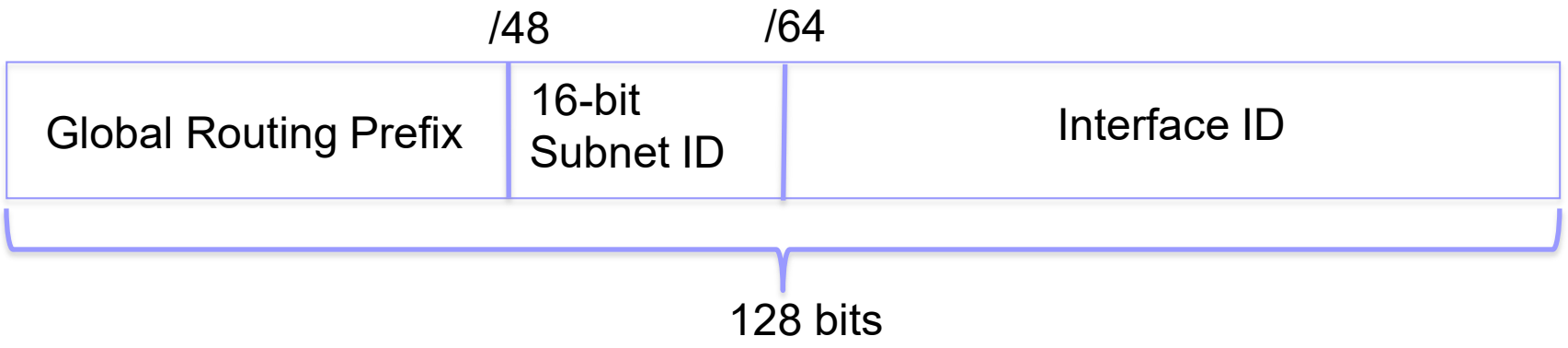
The remaining portion of IPv6 address space are reserved by IETF for future use.

Typical Global Unicast Address and Why We Love IPv6!

IPv4 Unicast Address

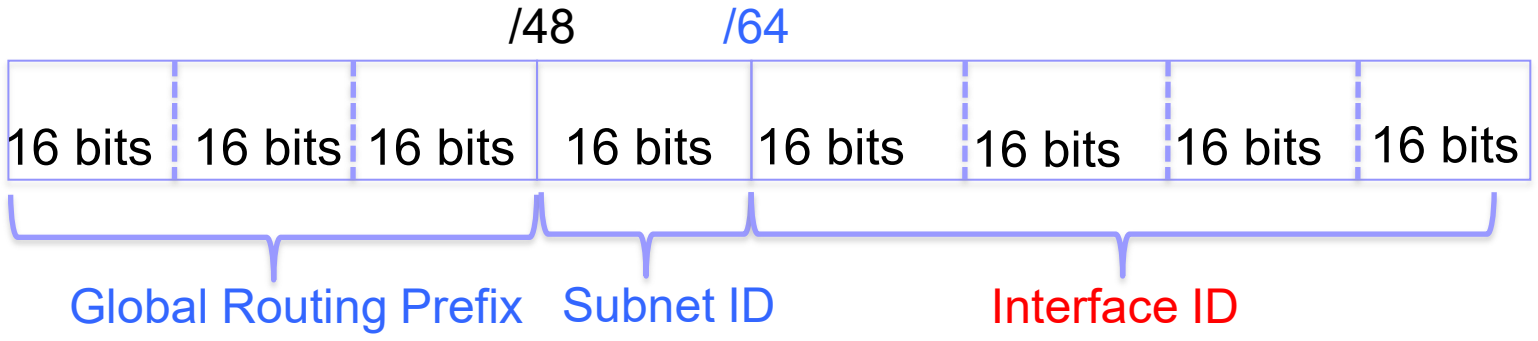


IPv6 Global Unicast Address



- 64-bit Interface ID = 18 quintillion (18,446,744,073,709,551,616) devices/subnet
- 16-bit Subnet ID = 65,536 subnets

/64 Global Unicast Addresses and the 3-1-4 rule



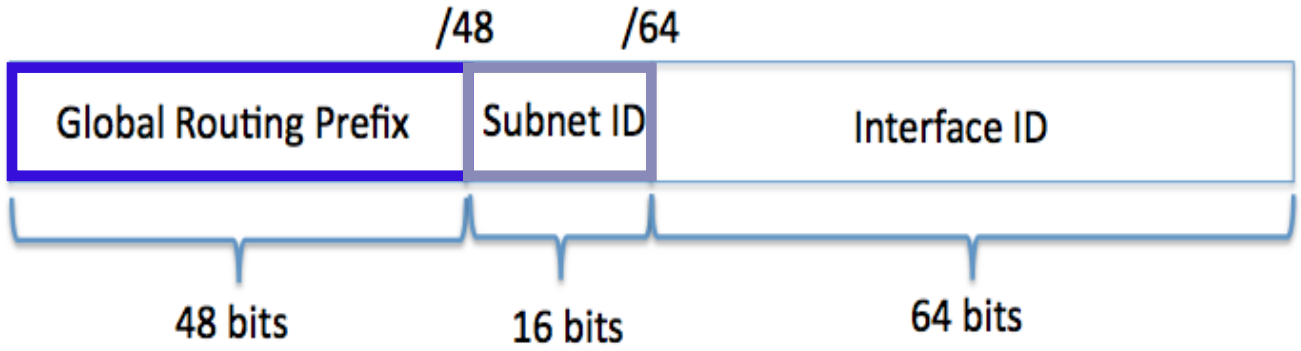
2001 : 0DB8 : AAAA : 1111 : 0000 : 0000 : 0000 : 0100

3 + 1 = 4 (/64) : 4

2001:0DB8:AAAA:1111:0000:0000:0000:0100/64

2001:0DB8:AAAA:1111::100/64

Subnetting IPv6 and Why We REALLY Love IPv6

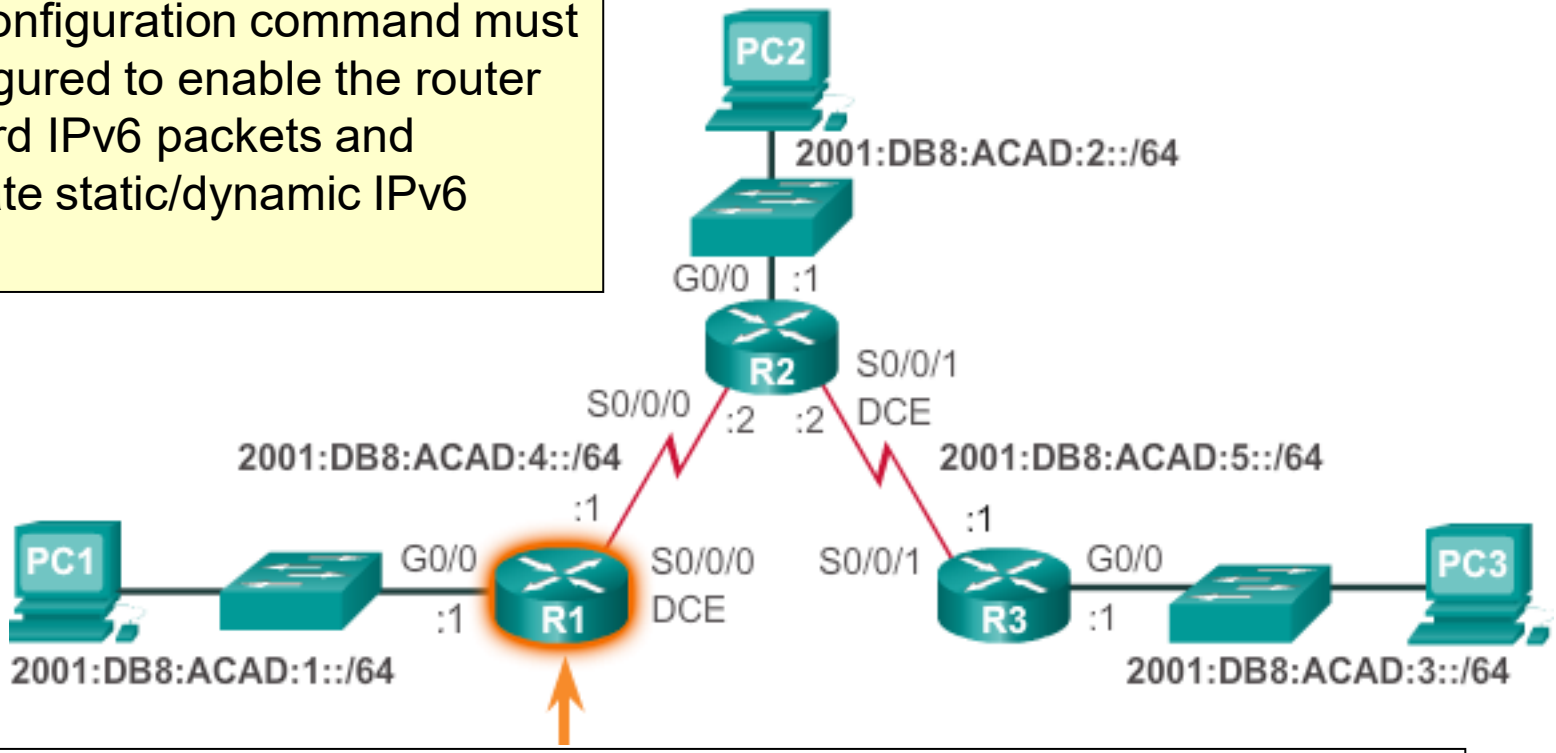


- Just increment by 1 in Hexadecimal:
  - **2001:0DB8:AAAA:0000::/64**
  - **2001:0DB8:AAAA:0001::/64**
  - **2001:0DB8:AAAA:0002::/64**
  - **2001:0DB8:AAAA:000A::/64**
- Valid abbreviation is to remove the 3 leading 0's from the first shown quartet
  - **2001:0DB8:AAAA:1::/64**

3-1-4 Rule

Enabling IPv6 Unicast Routing

The **ipv6 unicast-routing** global configuration command must be configured to enable the router to forward IPv6 packets and participate static/dynamic IPv6 routing.

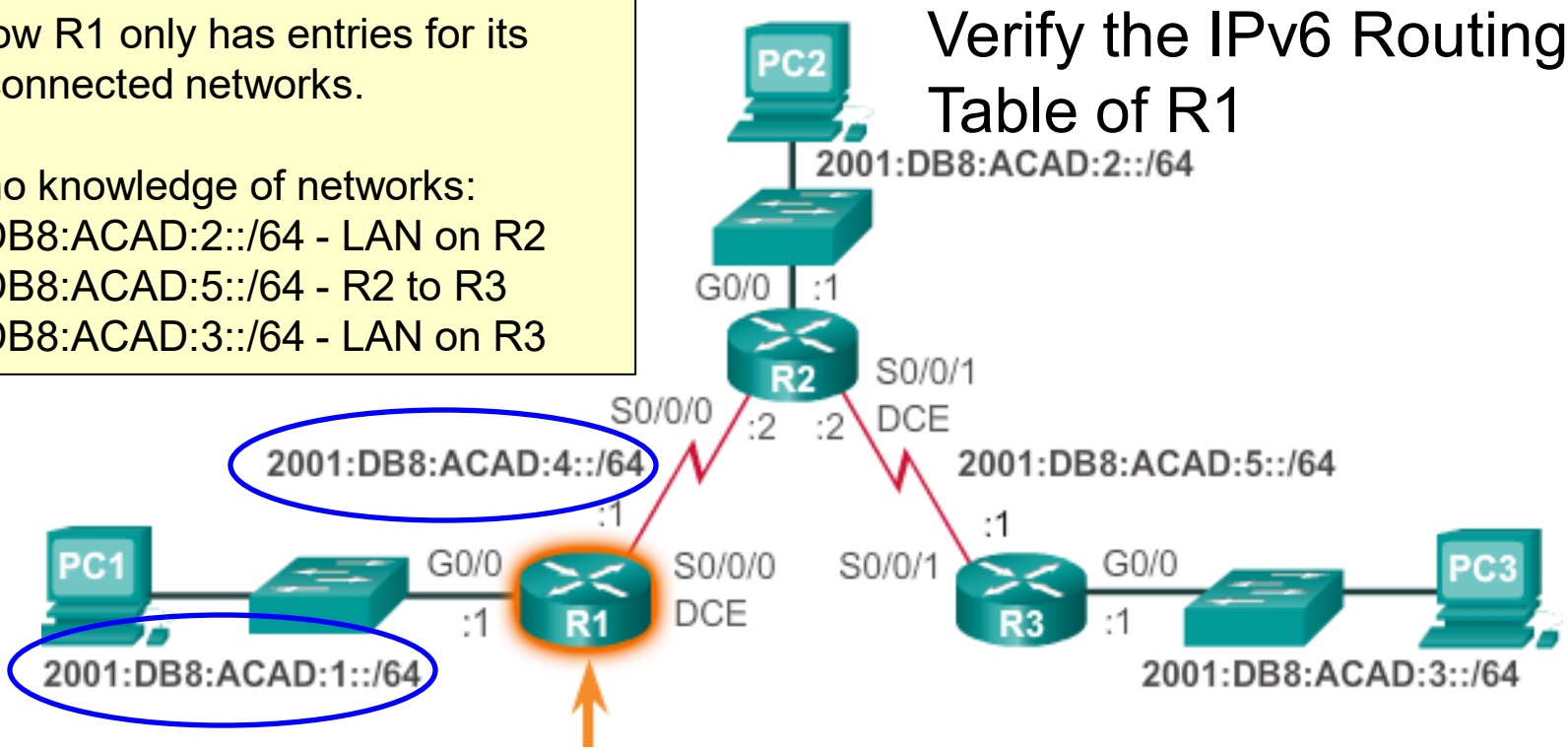



```
R1(config)# ipv6 unicast-routing
R1(config)#
```

Verify the IPv6 Routing Table of R1

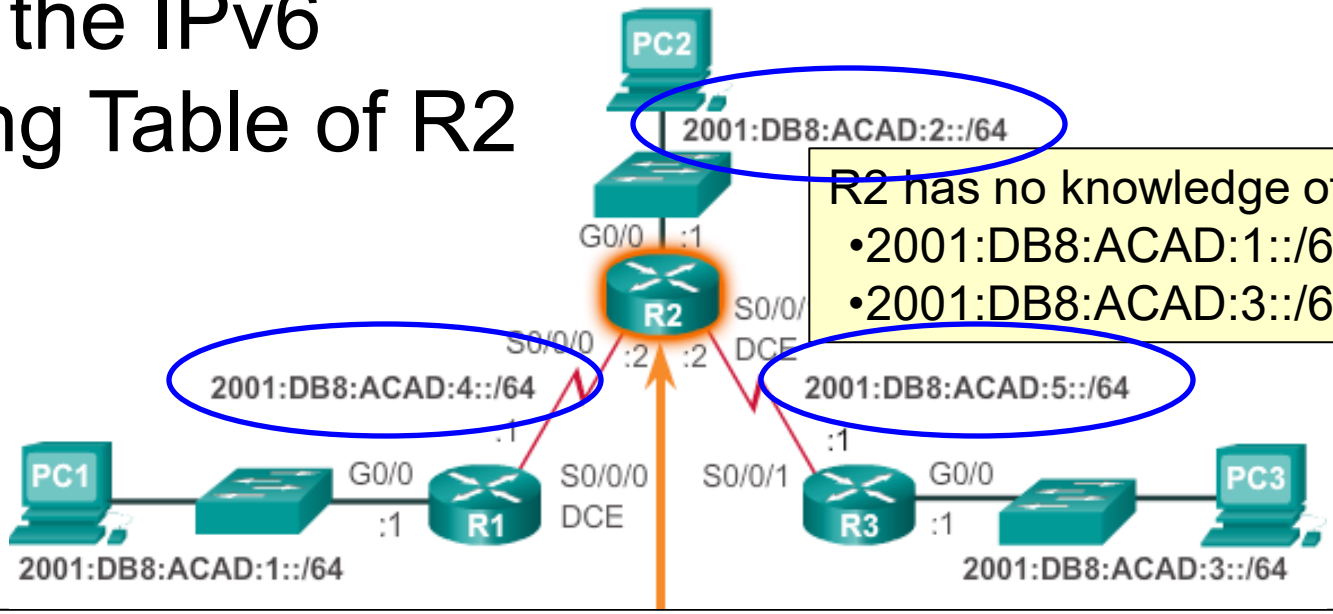
Notice how R1 only has entries for its directly connected networks.

R1 has no knowledge of networks:
- 2001:DB8:ACAD:2::/64 - LAN on R2
- 2001:DB8:ACAD:5::/64 - R2 to R3
- 2001:DB8:ACAD:3::/64 - LAN on R3




```
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#
```

Verify the IPv6 Routing Table of R2

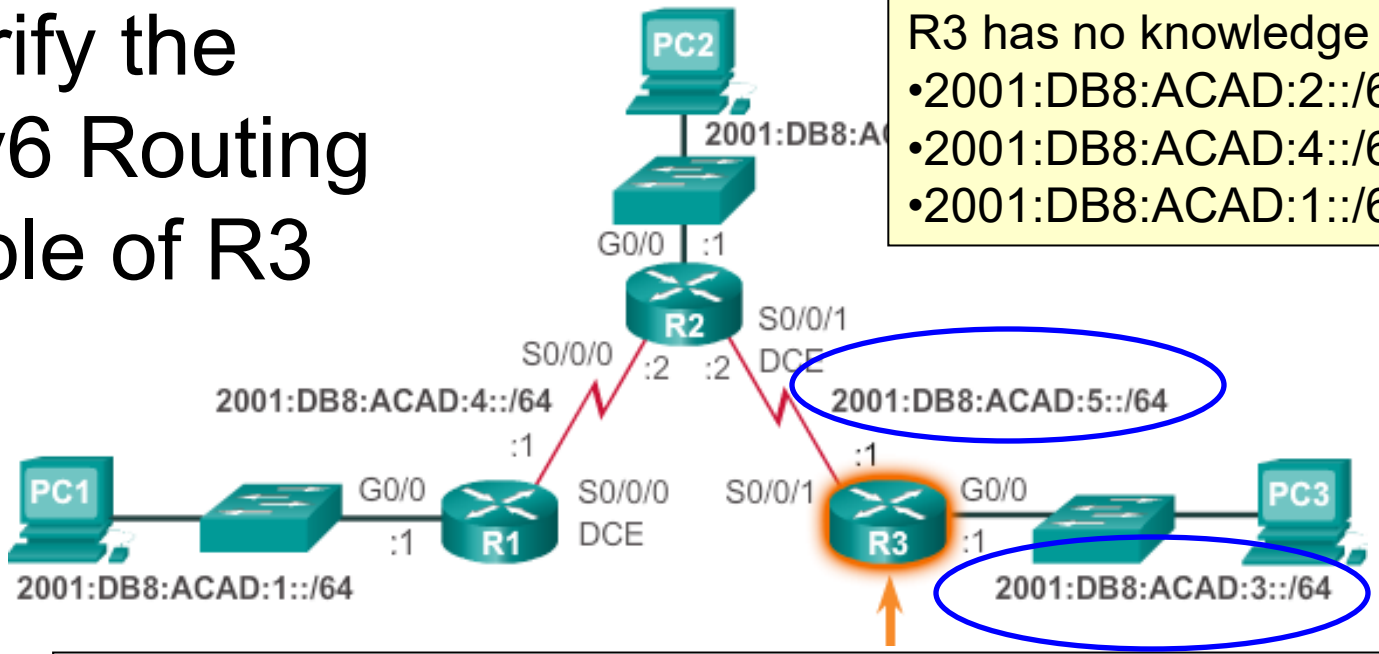


R2 has no knowledge of networks:
- 2001:DB8:ACAD:1::/64 - LAN on R1
- 2001:DB8:ACAD:3::/64 - LAN on R3

```
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
```

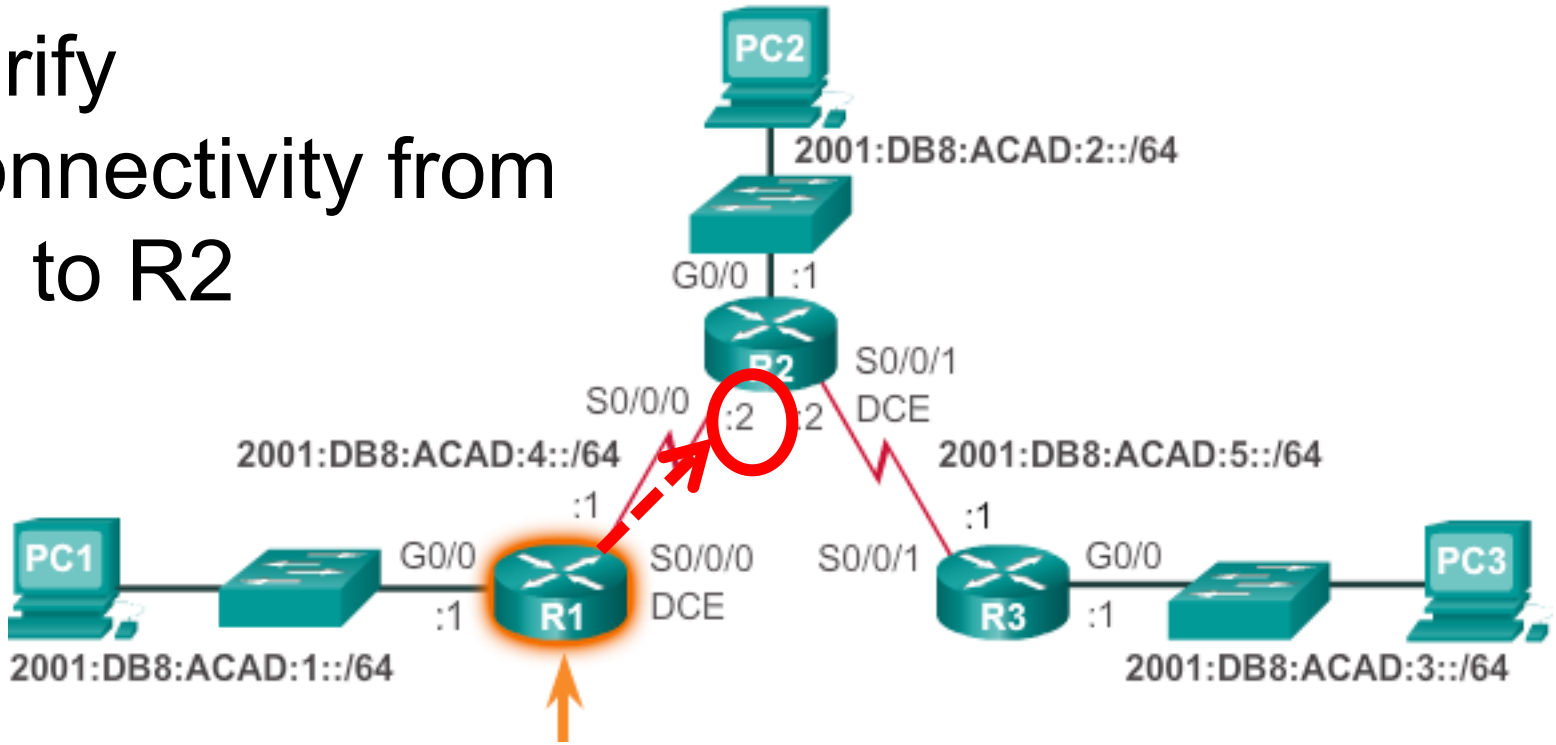
Verify the IPv6 Routing Table of R3

R3 has no knowledge of networks:
- 2001:DB8:ACAD:2::/64 - LAN on R2
- 2001:DB8:ACAD:4::/64 – R1 to R2
- 2001:DB8:ACAD:1::/64 - LAN on R1




```
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#
```

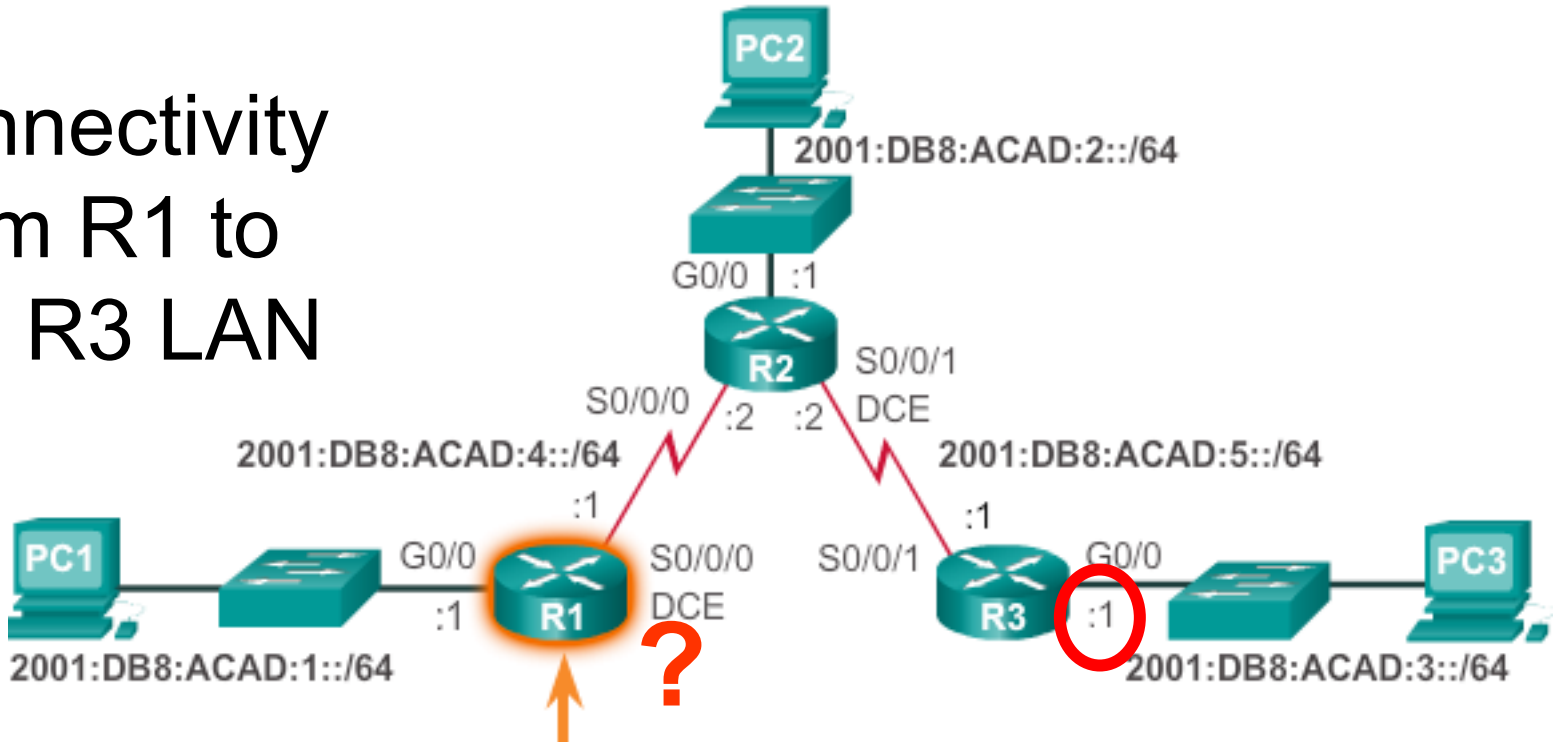
Verify Connectivity from R1 to R2




```
R1# ping 2001:DB8:ACAD:4::2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:4::2, timeout is 2
seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/30/96 ms
R1#
```

Note: The curriculum also uses the **`ping ipv6`** command. The **`ipv6`** is optional.

No connectivity from R1 to the R3 LAN




```
R1# ping 2001:DB8:ACAD:3::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:3::1, timeout is 2
seconds:

% No valid route for destination
Success rate is 0 percent (0/1)
R1#
```

This network is not in the routing table and there is no IPv6 default route.

Configuring an IPv6 Static Route

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

Parameter	Description
ipv6-prefix	• Destination IPv6 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. • Note: Can be modified to summarize a group of networks
exit-intf	• Use the outgoing interface to forward packets to the destination network.
ipv6-address	• Commonly referred to as the next-hop router's IPv6 address.

Types of IPv6 Static Routes

- Most of parameters are identical to the IPv4 version of the command.

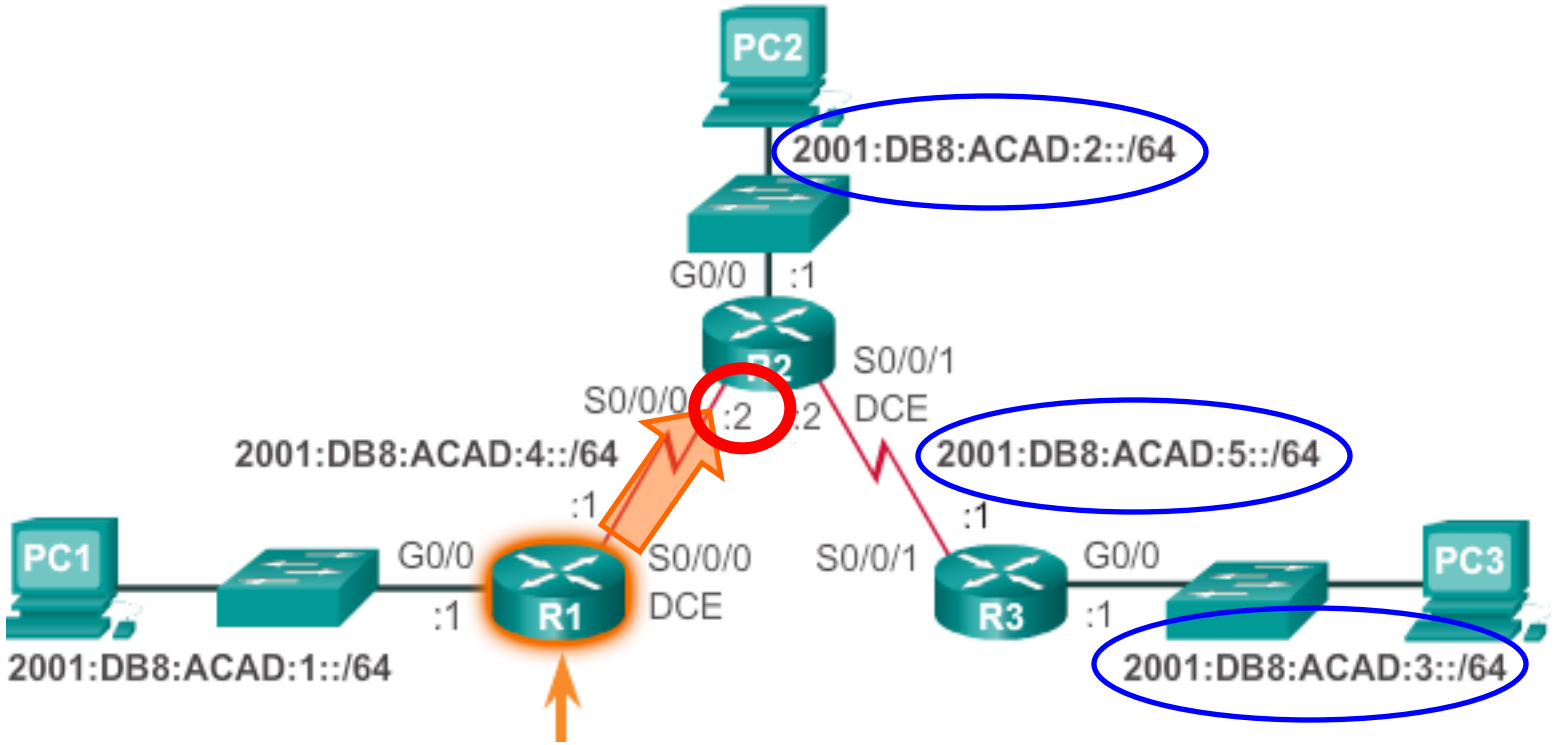
- **`ip`** = ipv4
- **`ipv6`** = ipv6

- IPv6 static routes can also be implemented as:
  - **Standard IPv6 static route**
  - **Default IPv6 static route**
  - **Summary IPv6 static route**
  - **Floating IPv6 static route**

Types of Standard IPv6 Static Routes

- **Next Hop Static Route**
  - **ipv6 route** *ipv6-prefix/prefix-length ipv6-address*
- **Directly Attached Static Route**
  - **ipv6 route** *ipv6-prefix/prefix-length exit-intf*
- **Fully Specified Static Route**
  - **ipv6 route** *ipv6-prefix/prefix-length exit-intf ipv6-address*

Configure Next Hop Static IPv6 Routes




```
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)#
```

Verifying an IPv6 Next Hop Route

```
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
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#
```

1

2

Only necessary if CEF is disabled

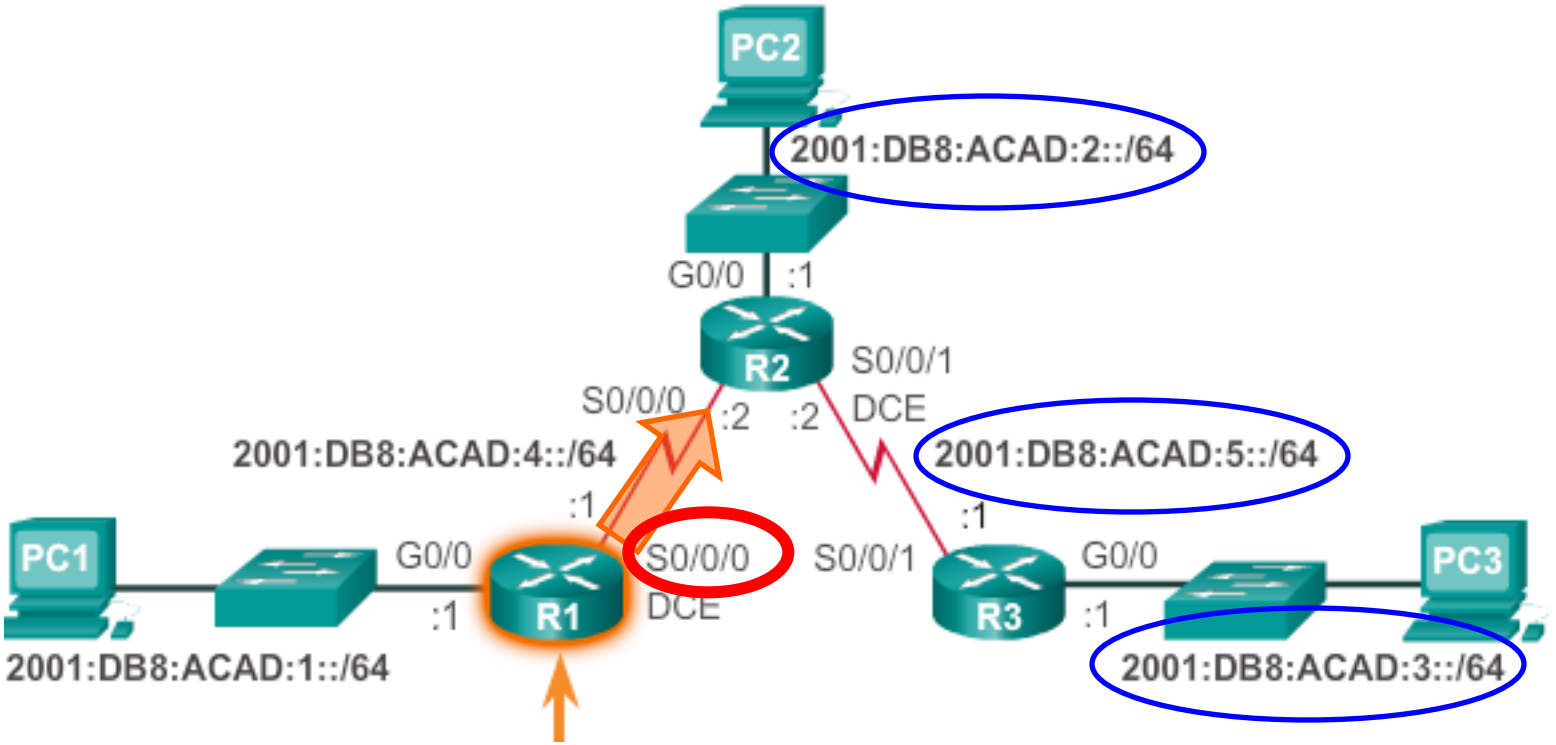
Configure Next Hop Static IPv6 Routes

```
R2(config)#ipv6 route 2001:DB8:ACAD:1::/64 2001:DB8:ACAD:4::1
R2(config)#ipv6 route 2001:DB8:ACAD:3::/64 2001:DB8:ACAD:5::1
R2(config)#exit
R2#
R2#show ipv6 route
<Output omitted>
S   2001:DB8:ACAD:1::/64 [1/0]
     via 2001:DB8:ACAD:4::1
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
S   2001:DB8:ACAD:3::/64 [1/0]
     via 2001:DB8:ACAD:5::1
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#
```

Configure Next Hop Static IPv6 Routes

```
R3(config)#ipv6 route 2001:DB8:ACAD:2::/64 2001:DB8:ACAD:5::2
R3(config)#ipv6 route 2001:DB8:ACAD:4::/64 2001:DB8:ACAD:5::2
R3(config)#ipv6 route 2001:DB8:ACAD:1::/64 2001:DB8:ACAD:5::2
R3(config)#exit
R3#show ipv6 route
<Output omitted>

S   2001:DB8:ACAD:1::/64 [1/0]
     via 2001:DB8:ACAD:5::2
S   2001:DB8:ACAD:2::/64 [1/0]
     via 2001:DB8:ACAD:5::2
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
S   2001:DB8:ACAD:4::/64 [1/0]
     via 2001:DB8:ACAD:5::2
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#
```

Directly Attached Static IPv6 Routes on R1




```
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)#
```

- This is an alternative method for configuring static routes on a point-to-point network.
- Next-hop address recommended when CEF is enabled.

Verify the Routing Table of R1

```
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
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#
```

Directly Attached Static IPv6 Routes

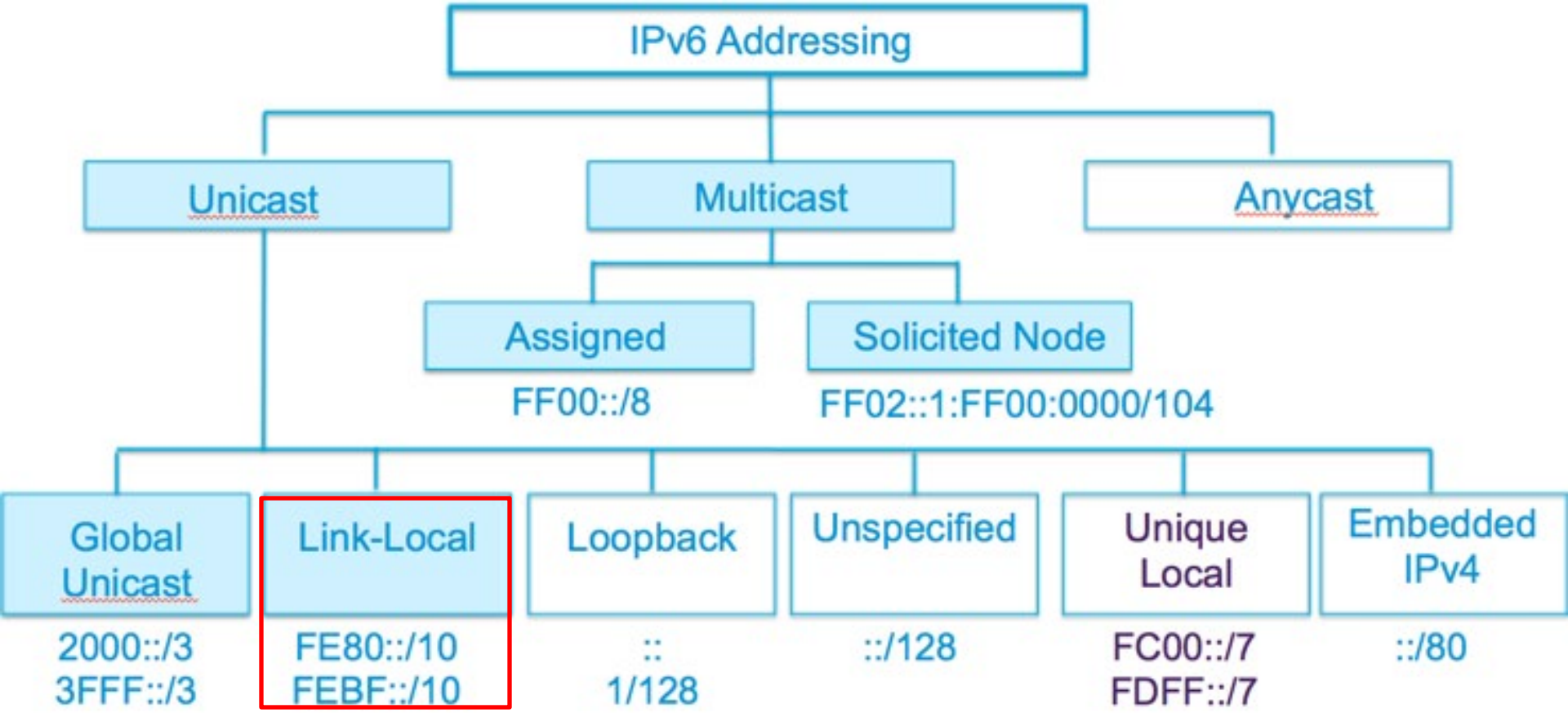
```
R2(config)#ipv6 route 2001:DB8:ACAD:1::/64 s0/0/0
R2(config)#ipv6 route 2001:DB8:ACAD:3::/64 s0/0/1
R2(config)#exit
R2#show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2
       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:1::/64 [1/0]
     via Serial0/0/0, directly connected
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
S   2001:DB8:ACAD:3::/64 [1/0]
     via Serial0/0/1, directly connected
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#
```

Directly Attached Static IPv6 Routes

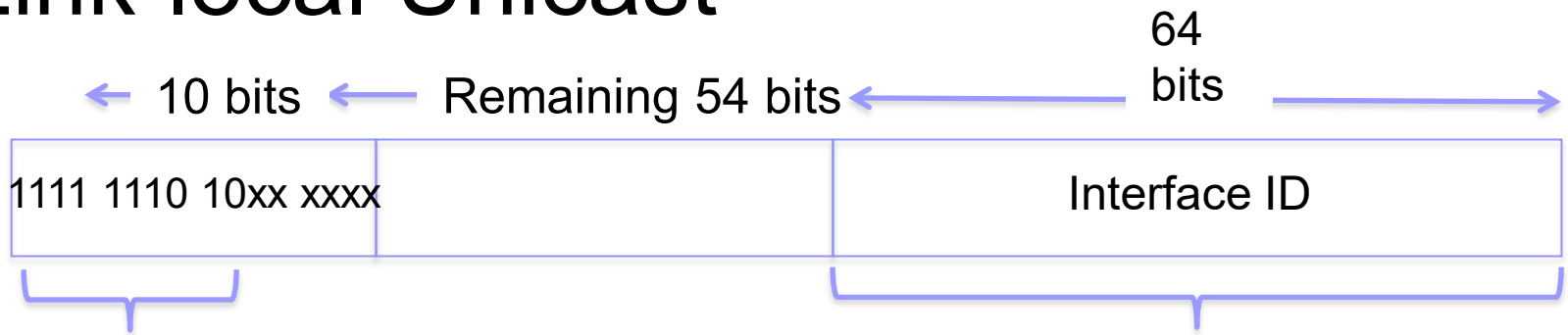
```
R3(config)#ipv6 route 2001:DB8:ACAD:2::/64 s0/0/1
R3(config)#ipv6 route 2001:DB8:ACAD:4::/64 s0/0/1
R3(config)#ipv6 route 2001:DB8:ACAD:1::/64 s0/0/1
R3(config)#exit
R3#show ipv6 route
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       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
S   2001:DB8:ACAD:1::/64 [1/0]
     via Serial0/0/1, directly connected
S   2001:DB8:ACAD:2::/64 [1/0]
     via Serial0/0/1, directly connected
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
S   2001:DB8:ACAD:4::/64 [1/0]
     via Serial0/0/1, directly connected
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#
```

Fully Specified Static IPv6 Routes on R1

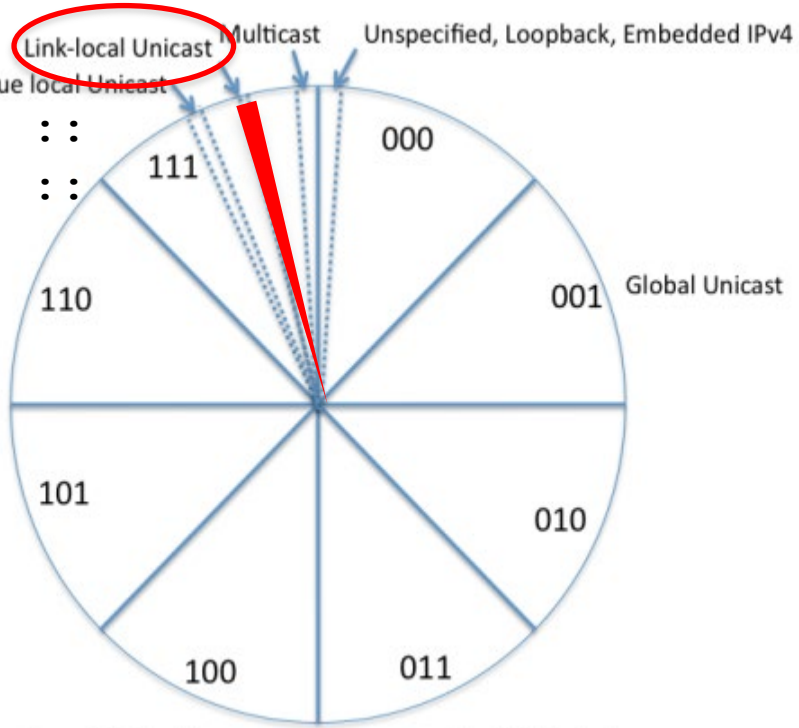
- Similar to IPv4 topology, a fully specified static IPv6 route is can be used when:
  - CEF is disabled
  - The exit interface is a mutli-access network (Ethernet)
- CEF is enabled by default beginning with IOS 12.2, so a static route with a next hop address is recommended.
- In IPv6, a fully specified route is required when the next-hop address is a link-local address.


IPv6 Addressing
Unicast
Multicast
Anycast
Assigned
FF00::/8
Solicited Node
FF02::1:FF00:0000/104
Global Unicast
2000::/3
3FFF::/3
Link-Local
FE80::/10
FEBF::/10
Loopback
::
1/128
Unspecified
::/128
Unique Local
FC00::/7
FDFF::/7
Embedded IPv4
::/80

Link-local Unicast

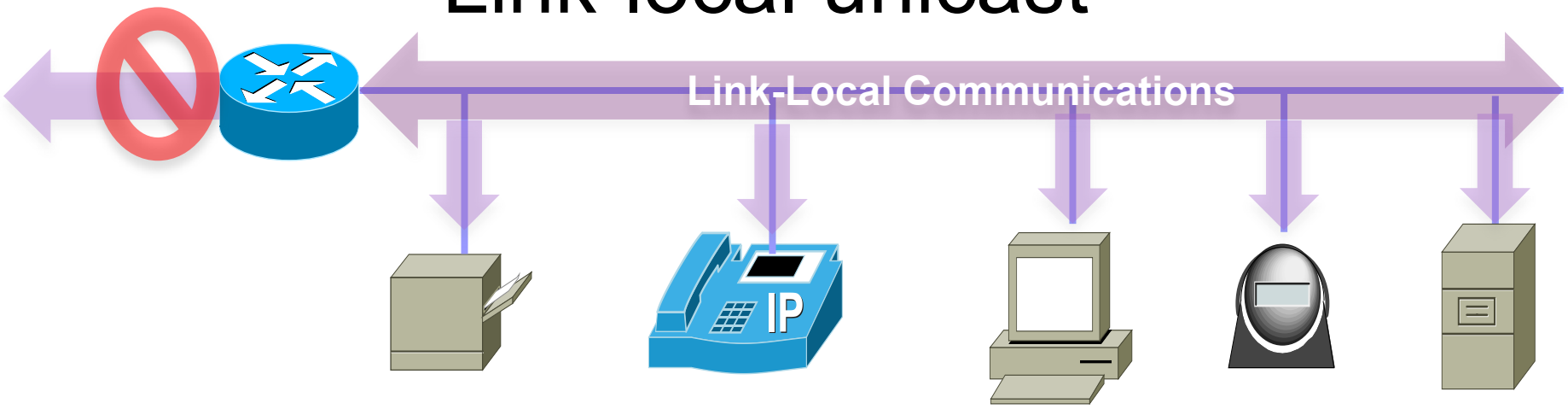


Range: FE80::/10 1111 1110 1000 0000 ::
to FEBF::/10 1111 1110 1011 1111 ::



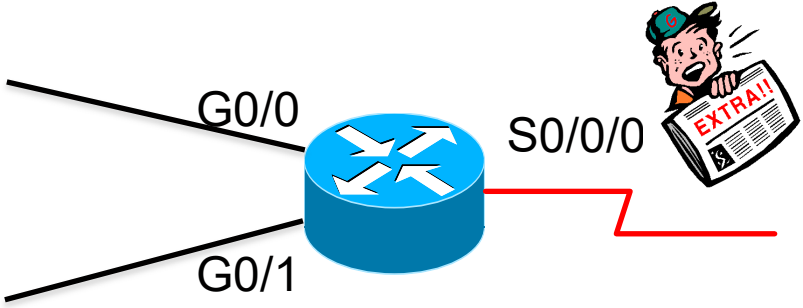
The remaining portion of IPv6 address space are reserved by IETF for future use.

Link-local unicast



- Used to communicate with other devices on the link.
- Are NOT routable off the link (network).
- Only have to be unique on the link.
- Are not included in the IPv6 routing table.
- An IPv6 device must have at least a link-local address.
- Used by:
  - Hosts to communicate to the IPv6 network before it has a global unicast address.
  - Router's link-local address is used by hosts as the default gateway address.
  - Adjacent routers to exchange routing updates

IOS uses EUI-64 to Create Link-Local Addresses




```
Router#show interface gigabitethernet 0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is CN Gigabit Ethernet, address is fc99.4775.c3e0
(bia fc99.4775.c3e0)
<Output Omitted>

Router#show ipv6 interface brief
GigabitEthernet0/0      [up/up]
    FE80::FE99:47FF:FE75:C3E0
    2001:DB8:ACAD:1::1
GigabitEthernet0/1      [up/up]
    FE80::FE99:47FF:FE75:C3E1
    2001:DB8:ACAD:2::1
Serial0/0/0             [up/up]
    FE80::FE99:47FF:FE75:C3E0
    2001:DB8:ACAD:3::1
R1#
```

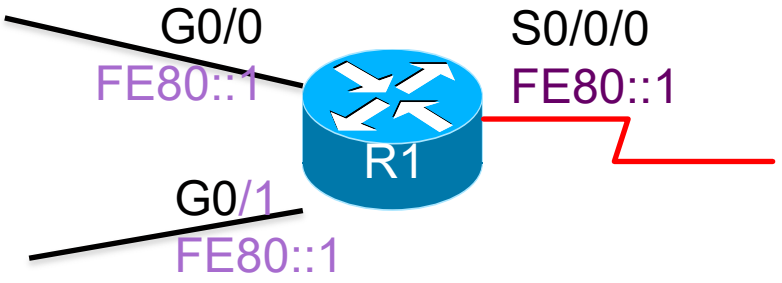
EUI-64

FF:FE = EUI-64 (most likely)

Serial interfaces will use a MAC address of an Ethernet interface.

Configuring Static Link-Local Addresses

Static addresses are more easily remembered and recognizable.




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

Router(config-if)#ipv6 address fe80::1 link-local
Router(config-if)#exit
Router(config)#interface gigabitethernet 0/1
Router(config-if)#ipv6 address fe80::1 link-local
Router(config-if)#exit
Router(config)#interface serial 0/0/0
Router(config-if)#ipv6 address fe80::1 link-local
Router(config-if)#
```

Link-Local Addresses only must be unique on the link!

Exit-interface required when link-local address is used as next-hop address

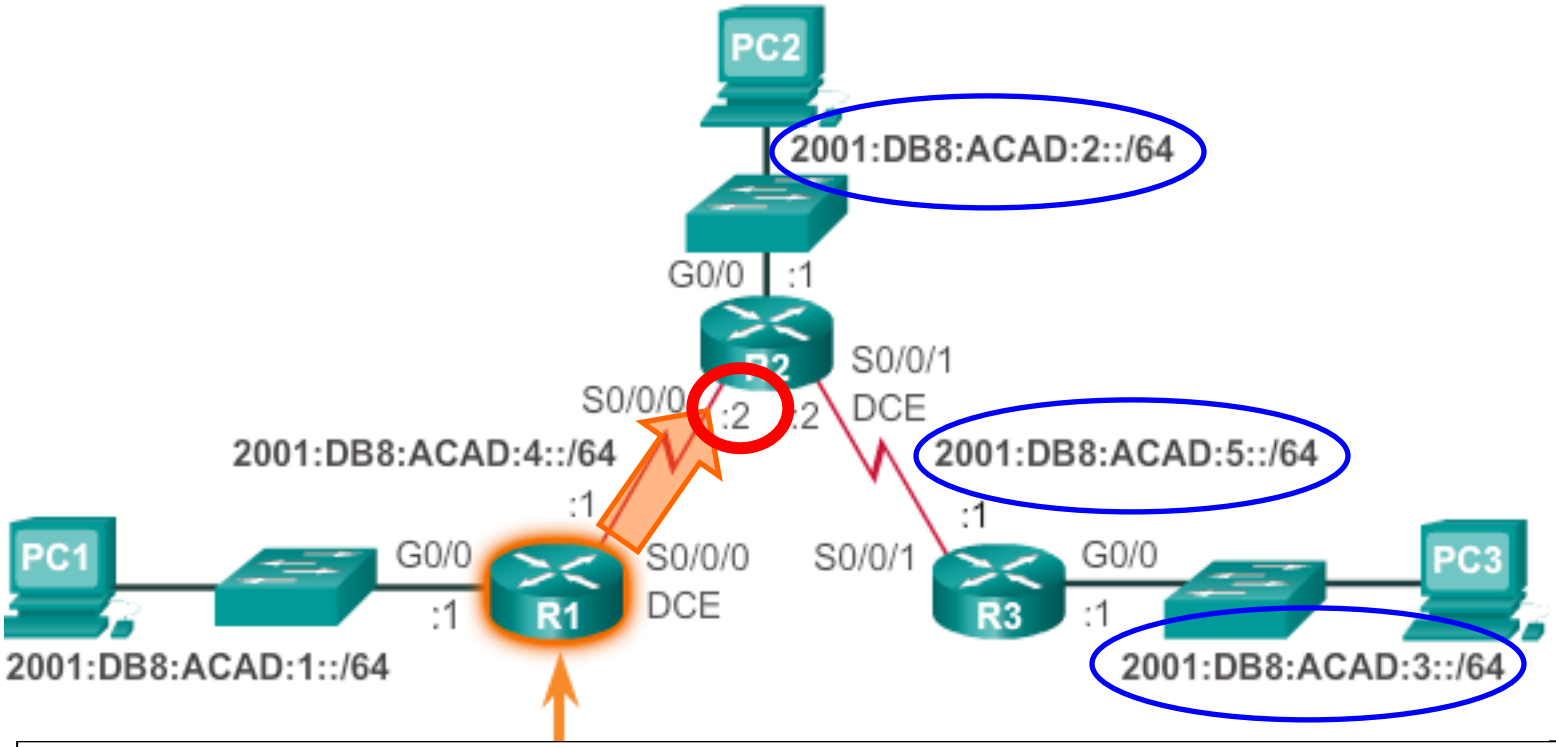

```
R1(config)# ipv6 route 2001:db8:acad:2::/64 fe80::2
% Interface must be specified for a link-local next hop
R1(config)# ipv6 route 2001:db8:acad:2::/64 s0/0/0 fe80::2
R1(config)#
```

- fe80::2 can uniquely exist on any interface
- fe80::2 must be on a directly connected interface (link local)
- The exit-interface is required to tell the router which exit-interface to use.

Verify the Static Route on R1

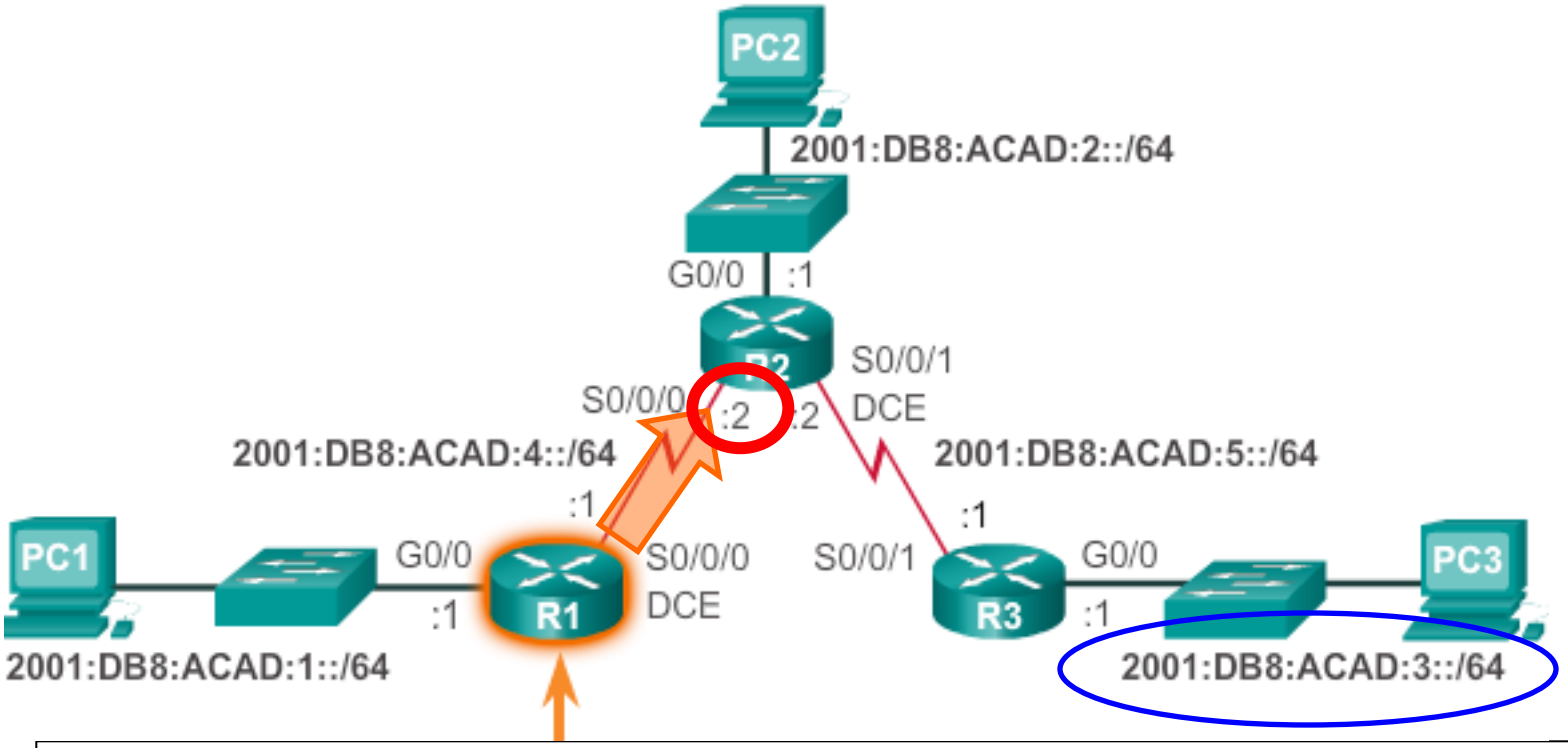

```
R1(config)# ipv6 route 2001:db8:acad:2::/64 s0/0/0 fe80::2
R1(config)# end

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
```

Verify the Routing Table of R1



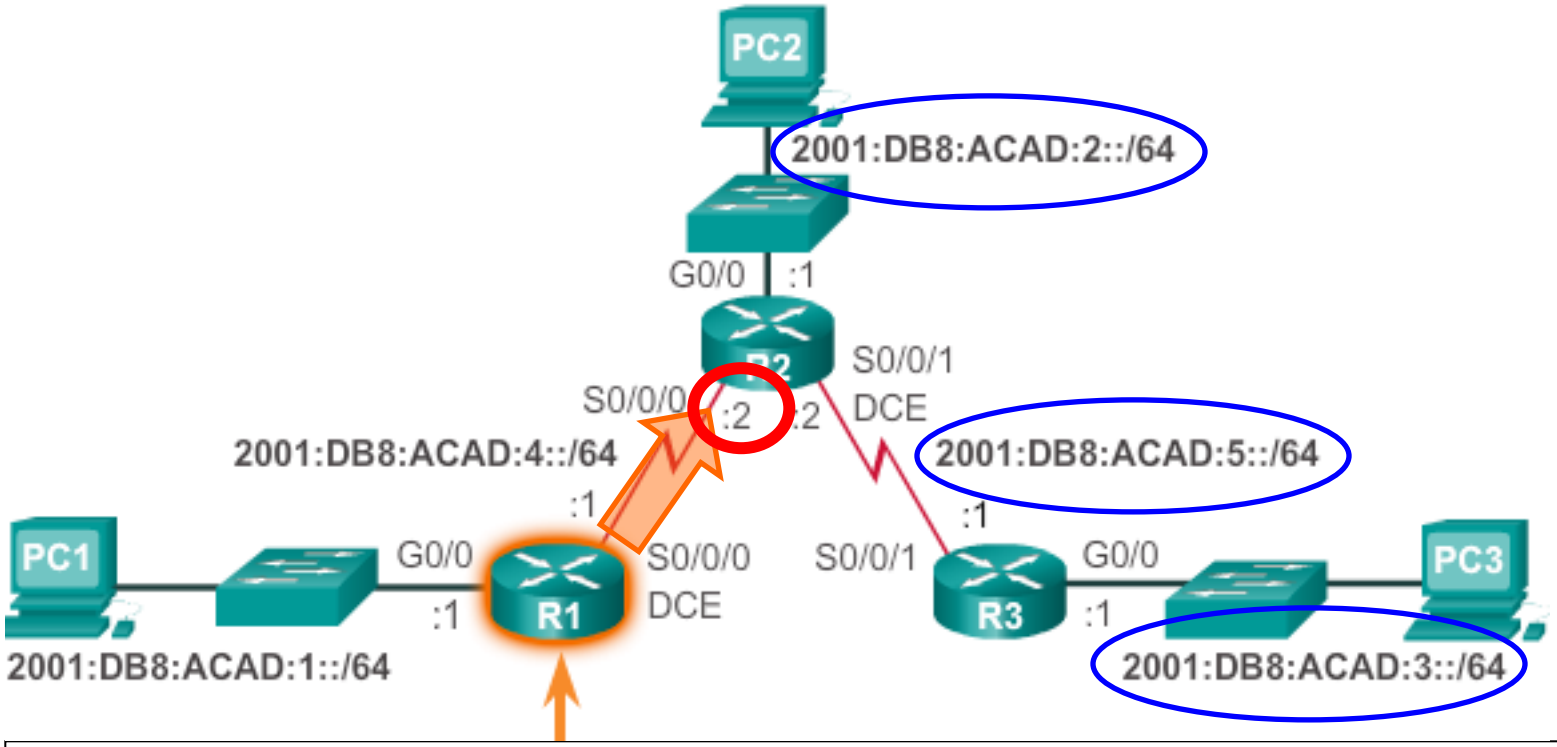

```
R1# show ipv6 route static
<Output omitted>

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#
```

Verify a Specific Entry in the Routing Table




```
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 15:28:05 ago

R1#
```

Verify the Static Route Configuration



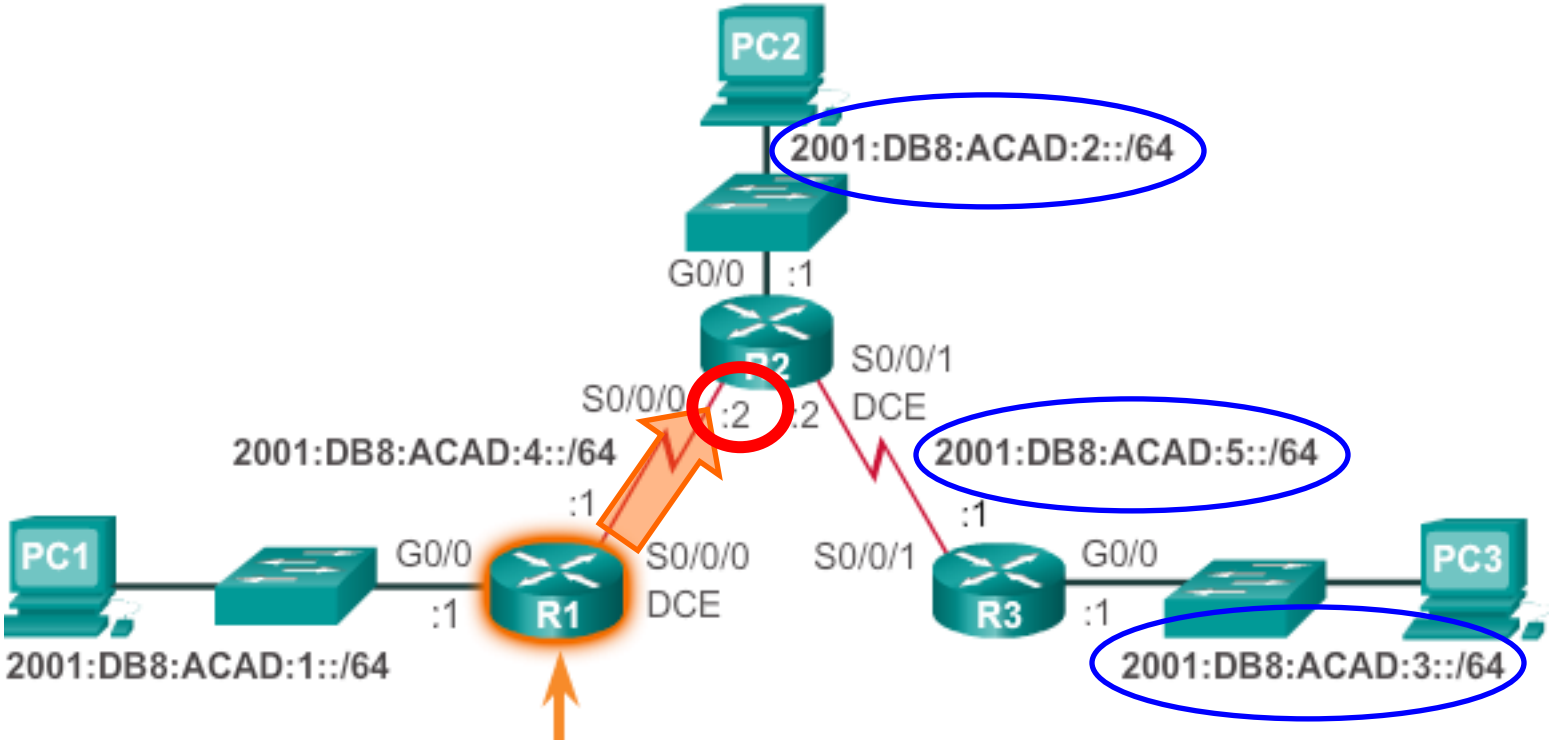

```
R1# show running-config | section ipv6 route
ipv6 route 2001:DB8:ACAD:2::/64 2001:DB8:ACAD:4::2
ipv6 route 2001:DB8:ACAD:3::/64 2001:DB8:ACAD:4::2
ipv6 route 2001:DB8:ACAD:5::/64 2001:DB8:ACAD:4::2
R1#
```

Configuring a Default IPv6 Static Route

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

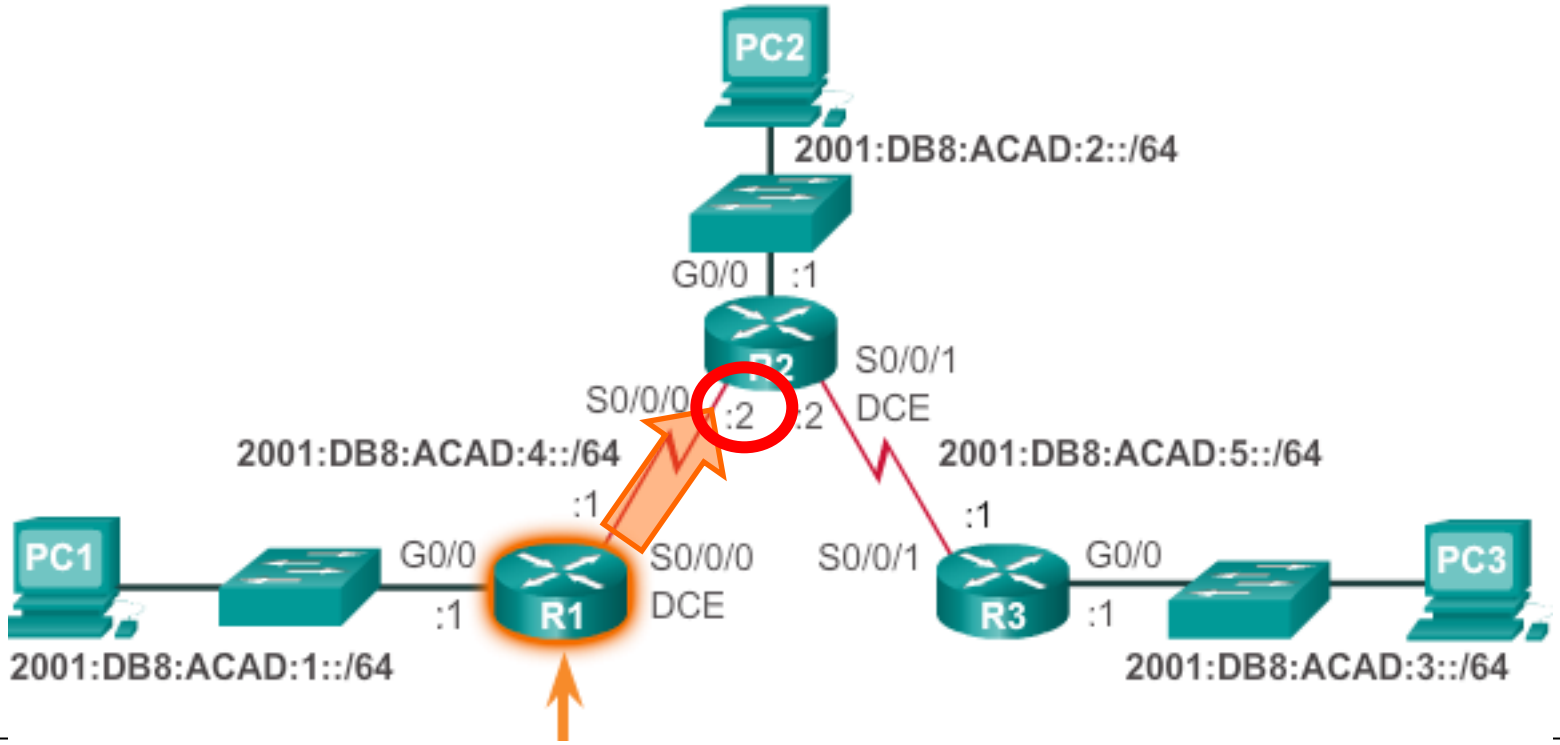
Parameter	Description
`::/0`	• Matches any IPv6 prefix regardless of IPv6 mask.
ipv6-address	• Commonly referred to as the next-hop router's IPv6 address. • Typically used when connecting to a broadcast media (i.e., Ethernet) . • Commonly creates a recursive lookup.
exit-intf	• Use the outgoing interface 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.

Configuring a Default Static IPv6 Route



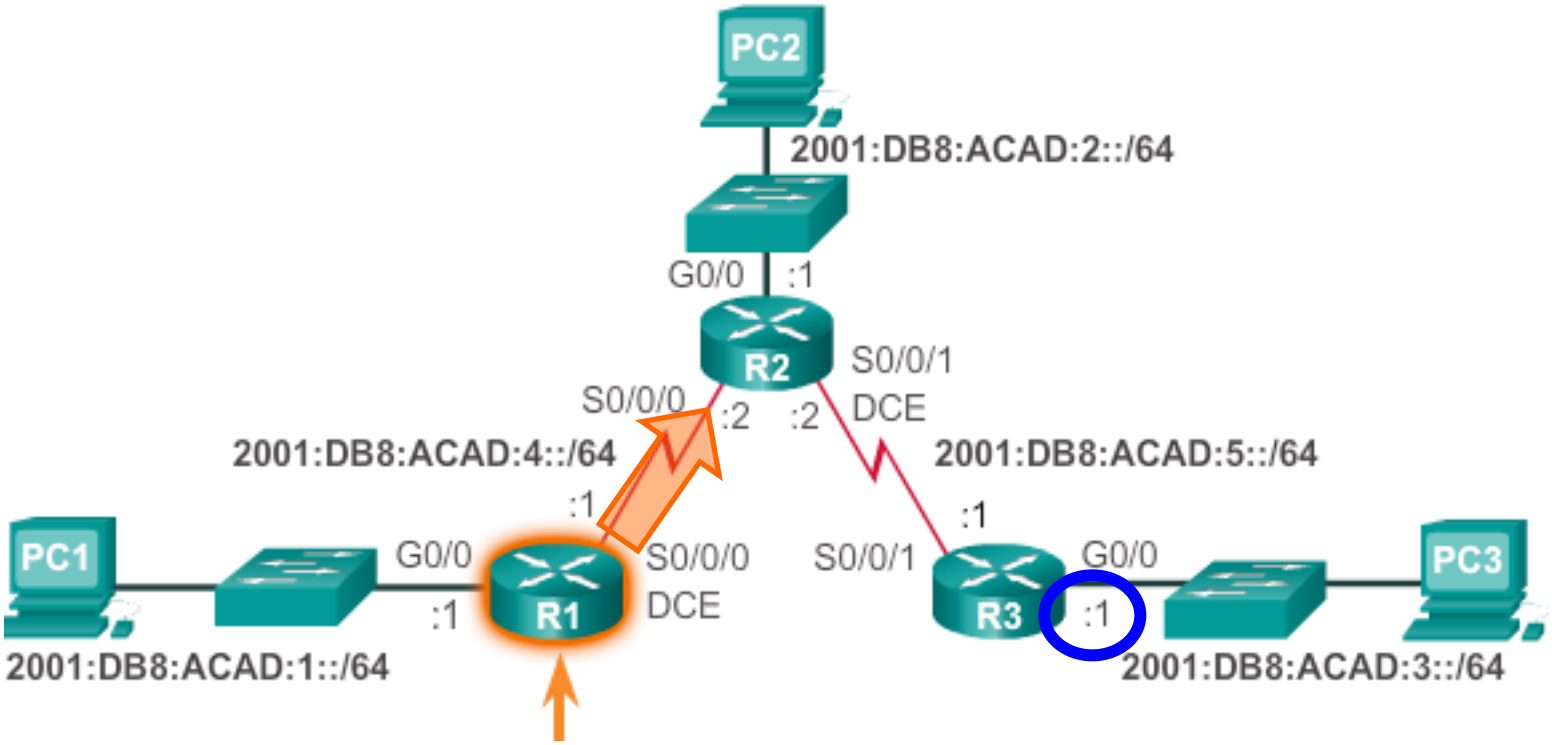

```
R1(config)# ipv6 route ::/0 2001:DB8:ACAD:4::2
R1(config)#
```

Verifying the Routing Table of R1



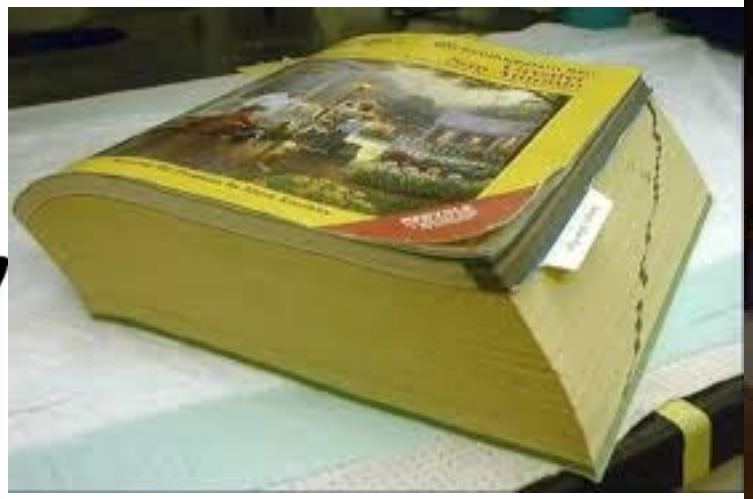

```
R1# show ipv6 route static
IPv6 Routing Table - default - 6 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user
Static route
<Output omitted>

S   ::/0 [1/0]
     via 2001:DB8:ACAD:4::2
R1#
```

Verifying Connectivity to the R3 LAN



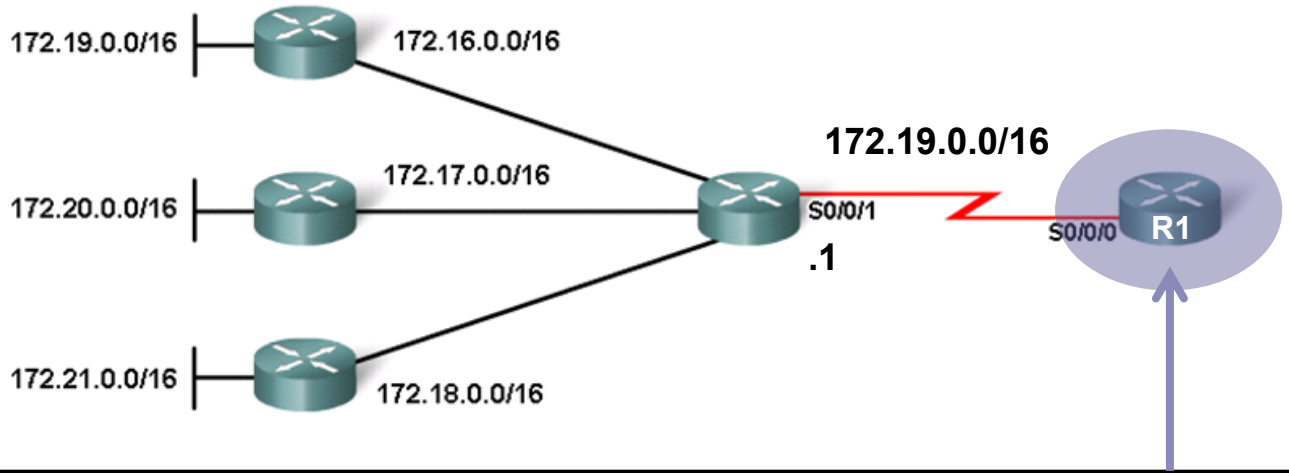

```
R1# ping 2001:0DB8:ACAD:3::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:3::1, timeout is 2
seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28
ms
R1#
```

Summarizing Routes



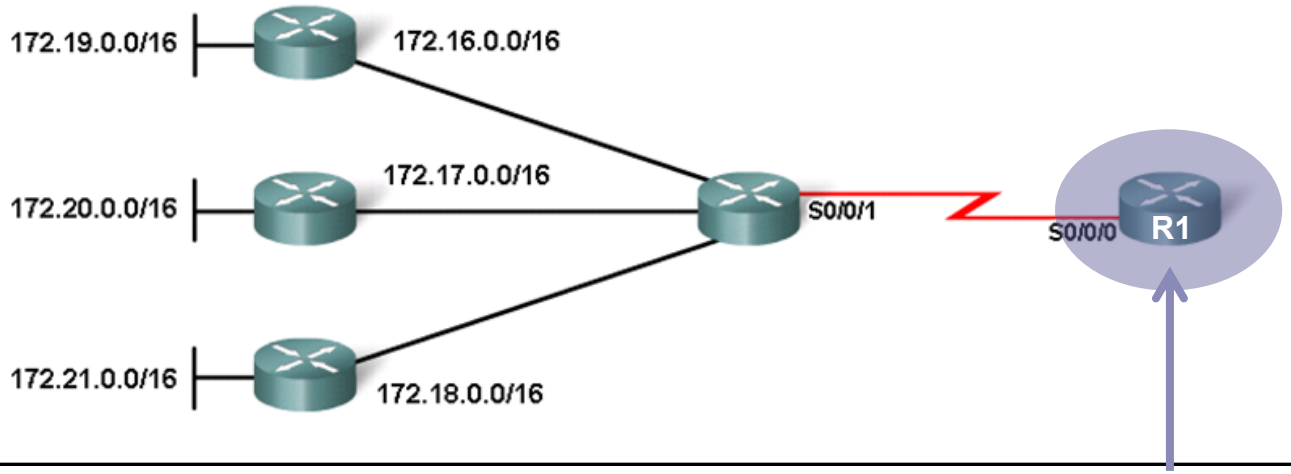
- Creating smaller routing tables makes the routing table lookup process more efficient.
  - Fewer routes to search.
  - If one static route can be used instead of multiple static routes, the size of the routing table is reduced.

For Example: Six Static Routes (more later)




```
R1(config)# ip route 172.16.0.0 255.255.0.0 172.19.0.2
R1(config)# ip route 172.17.0.0 255.255.0.0 172.19.0.2
R1(config)# ip route 172.18.0.0 255.255.0.0 172.19.0.2
R1(config)# ip route 172.19.0.0 255.255.0.0 172.19.0.2
R1(config)# ip route 172.20.0.0 255.255.0.0 172.19.0.2
R1(config)# ip route 172.21.0.0 255.255.0.0 172.19.0.2
R1(config)#
```

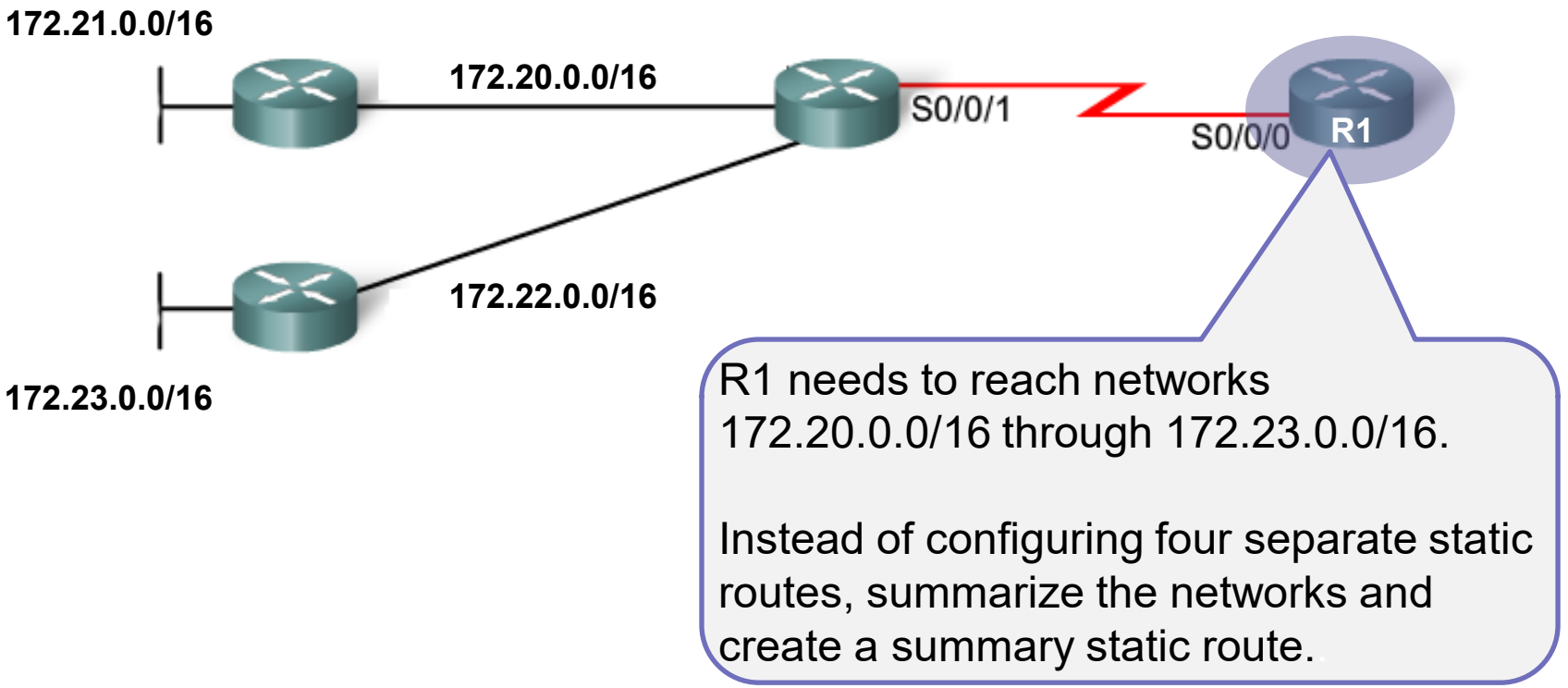
Replaced with One Summary Static Route




```
R1(config)# no ip route 172.16.0.0 255.255.0.0 172.19.0.2
R1(config)# no ip route 172.17.0.0 255.255.0.0 172.19.0.2
R1(config)# no ip route 172.18.0.0 255.255.0.0 172.19.0.2
R1(config)# no ip route 172.19.0.0 255.255.0.0 172.19.0.2
R1(config)# no ip route 172.20.0.0 255.255.0.0 172.19.0.2
R1(config)# no ip route 172.21.0.0 255.255.0.0 172.19.0.2
R1(config)#
R1(config)# ip route 172.16.0.0 255.248.0.0 172.19.0.2
R1(config)#
```

Route Summarization

Summary Static Route Example #1



Calculating a Route Summary

Step 1: List networks in binary format.

172.20.0.0	10101100 . 00010100 . 00000000 . 00000000
172.21.0.0	10101100 . 00010101 . 00000000 . 00000000
172.22.0.0	10101100 . 00010110 . 00000000 . 00000000
172.23.0.0	10101100 . 00010111 . 00000000 . 00000000

Calculating a Route Summary

Step 1: List networks in binary format.

172.20.0.0	10101100 . 00010100 . 00000000 . 00000000
172.21.0.0	10101100 . 00010101 . 00000000 . 00000000
172.22.0.0	10101100 . 00010110 . 00000000 . 00000000
172.23.0.0	10101100 . 00010111 . 00000000 . 00000000

Step 2: Count the number of left-most matching bits to determine the mask.

Answer: 14 matching bits = **/14** or **255.252.0.0**

Calculating a Route Summary

Step 1: List networks in binary format.

172.20.0.0	10101100 . 00010100 . 00000000 . 00000000
172.21.0.0	10101100 . 00010101 . 00000000 . 00000000
172.22.0.0	10101100 . 00010110 . 00000000 . 00000000
172.23.0.0	10101100 . 00010111 . 00000000 . 00000000

Step 2: Count the number of left-most matching bits to determine the mask.

Answer: 14 matching bits = **/14** or **255.252.0.0**

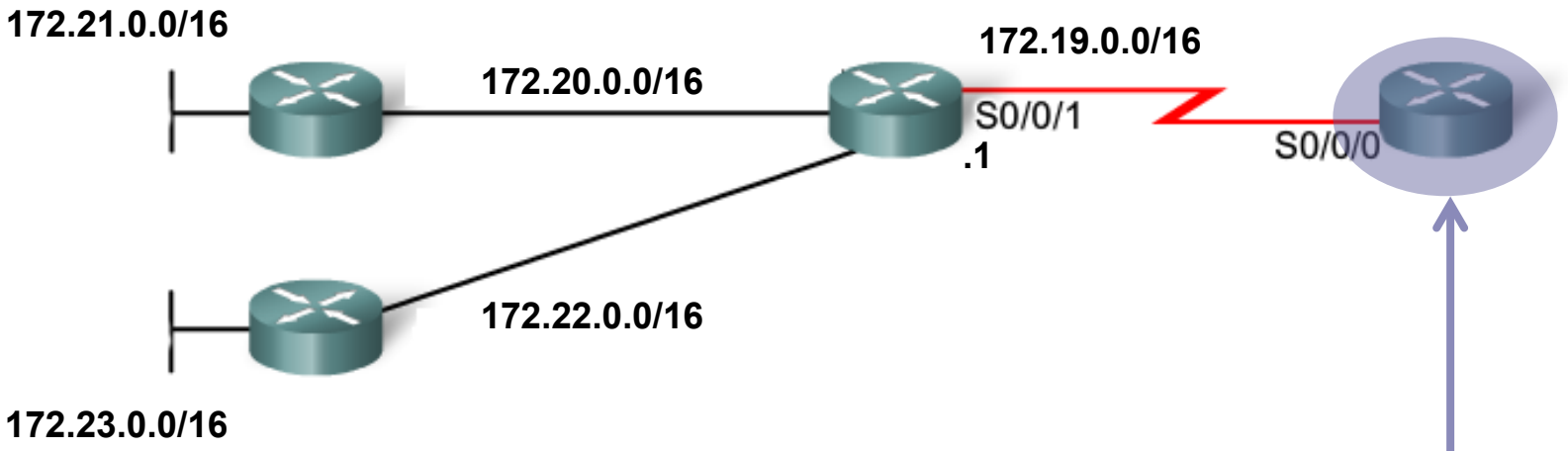
Step 3: Copy the matching bits and add zero bits to determine the network address.

10101100 . 00010100 . 00000000 . 00000000

Copy — Add zero bits

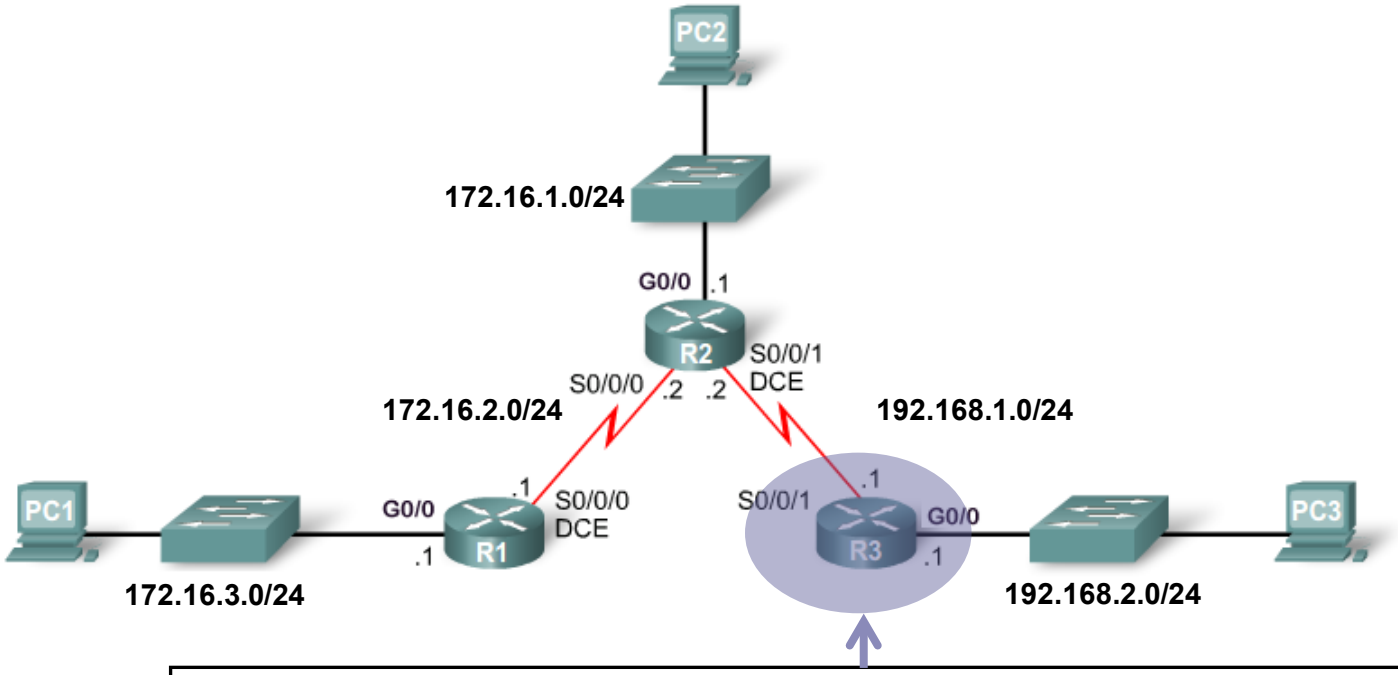
Answer: 172.20.0.0

One Summary Static Route



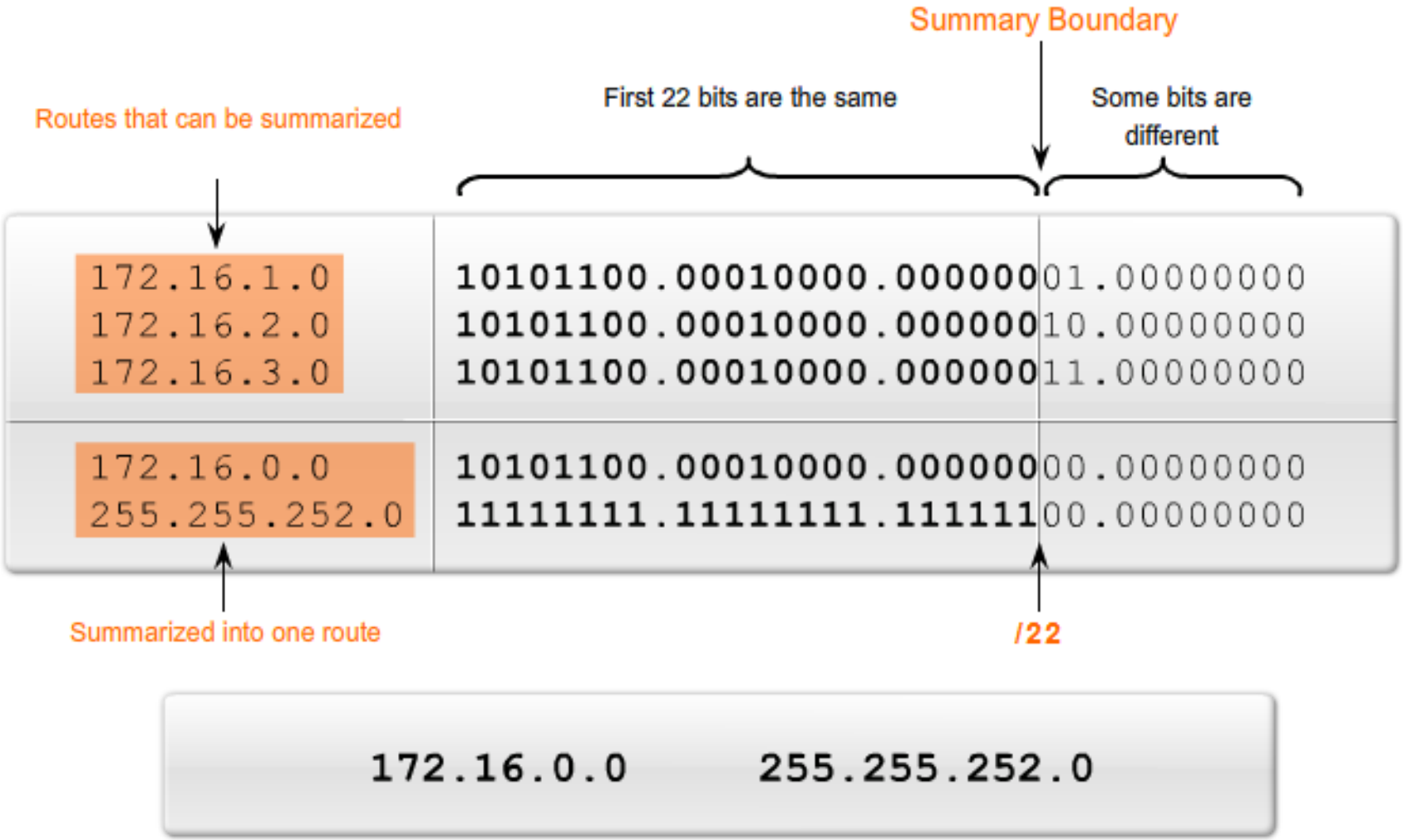

```
R1(config)# ip route 172.20.0.0 255.252.0.0 172.19.0.1
R1(config)#
```

Summary Static Route Example #2

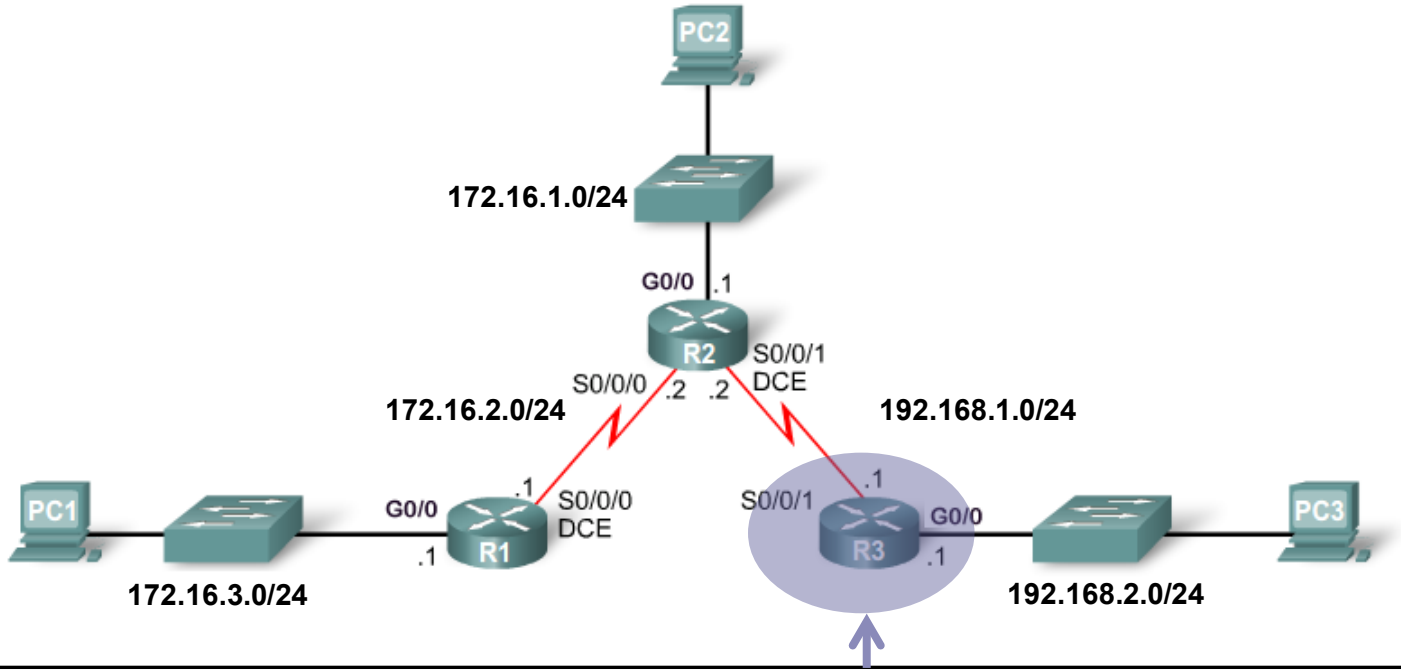



```
R3#show ip route static | begin Gateway
Gateway of last resort is not set

      172.16.0.0/24 is subnetted, 3 subnets
S        172.16.1.0 [1/0] via 192.168.1.2
S        172.16.2.0 [1/0] via 192.168.1.2
S        172.16.3.0 [1/0] via 192.168.1.2
R3#
```

Summarize the Networks

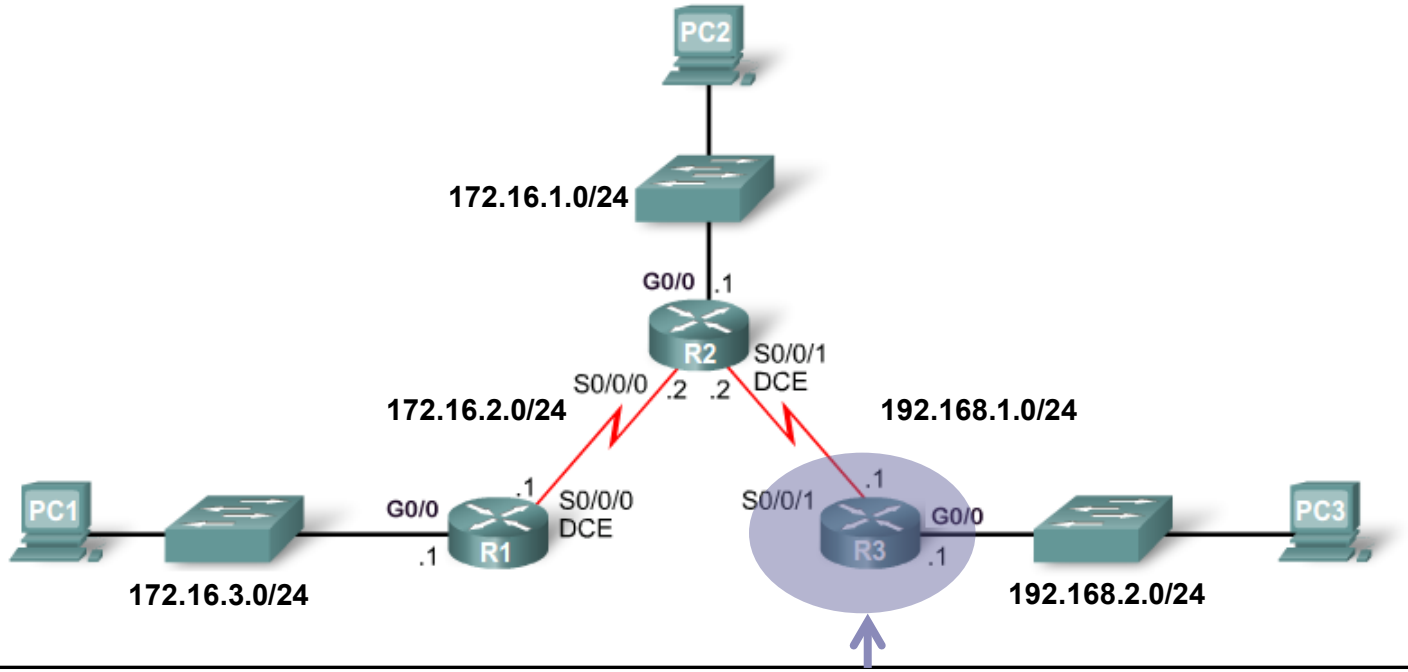


Configure Summary Static Route




```
R3(config)#no ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)#no ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)#no ip route 172.16.3.0 255.255.255.0 192.168.1.2
R3(config)#
R3(config)#ip route 172.16.0.0 255.255.252.0 192.168.1.2
R3(config)#
```

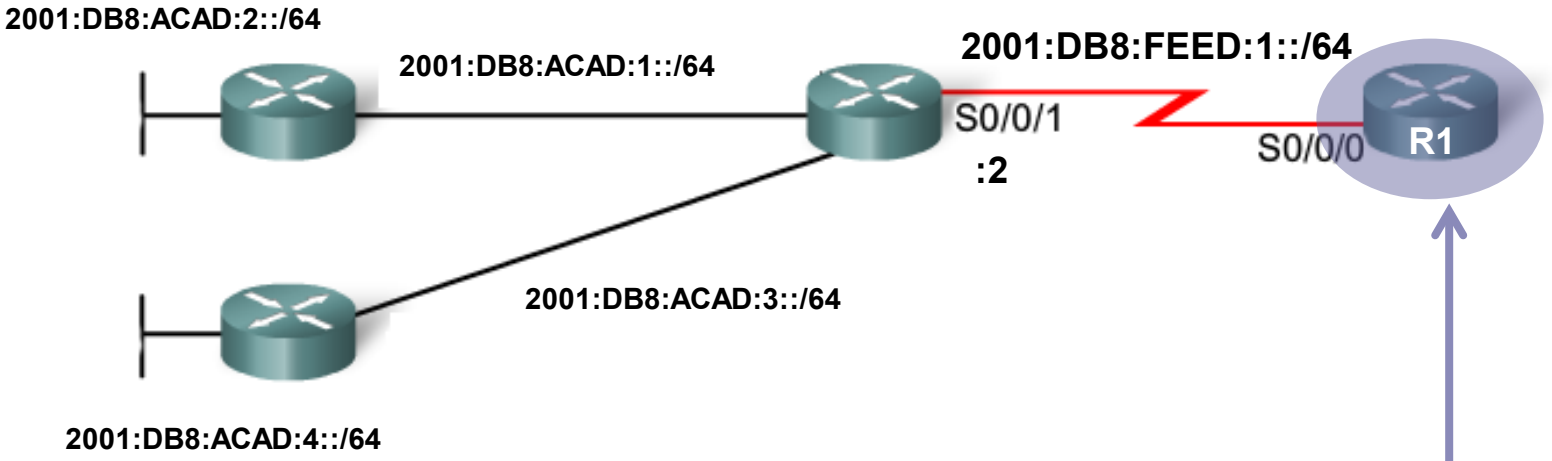
Verify the Summary Static Route




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

      172.16.0.0/22 is subnetted, 1 subnets
S        172.16.0.0 [1/0] via 192.168.1.2
R3#
```

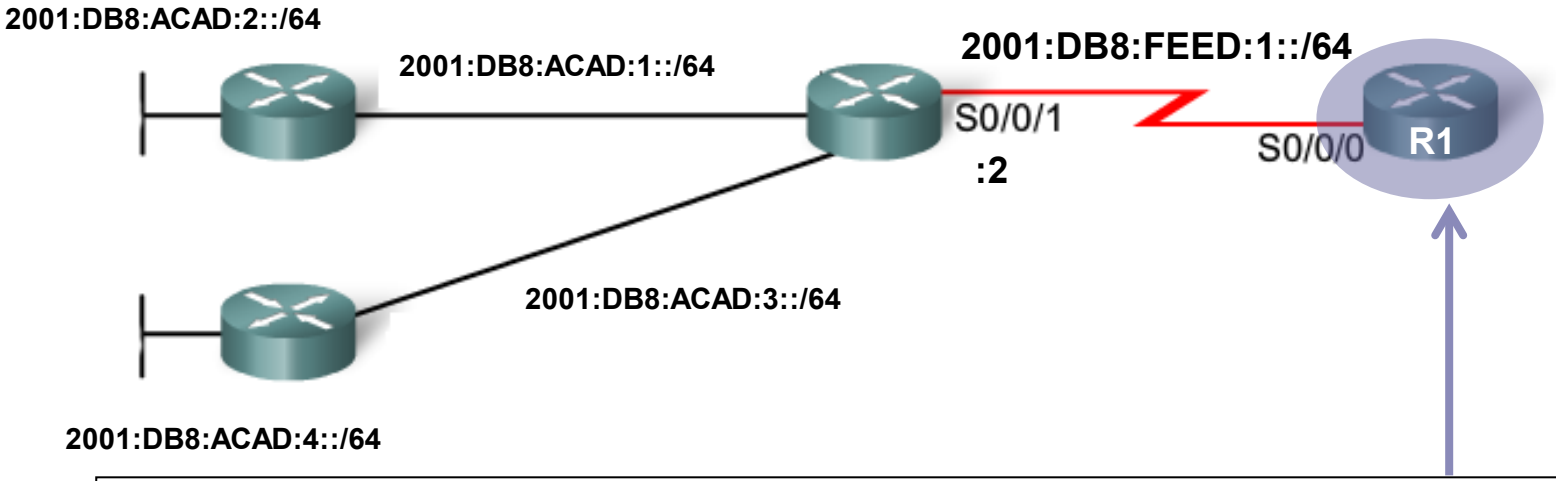
Configuring IPv6 Summary Routes

IPv6 Route Summarization




```
R1(config)#ipv6 route 2001:DB8:ACAD:1::/64 2001:db8:feed:1::2
R1(config)#ipv6 route 2001:DB8:ACAD:2::/64 2001:db8:feed:1::2
R1(config)#ipv6 route 2001:DB8:ACAD:3::/64 2001:db8:feed:1::2
R1(config)#ipv6 route 2001:DB8:ACAD:4::/64 2001:db8:feed:1::2
R1(config)#
```

Verify the Routing Table of R1




```
R1# show ipv6 route static
<Output omitted>

S   2001:DB8:ACAD:1::/64 [1/0]
     via 2001:DB8:FEED:1::2
S   2001:DB8:ACAD:2::/64 [1/0]
     via 2001:DB8:FEED:1::2
S   2001:DB8:ACAD:3::/64 [1/0]
     via 2001:DB8:FEED:1::2
S   2001:DB8:ACAD:4::/64 [1/0]
     via 2001:DB8:FEED:1::2
R1#
```

Identify Where the Addresses Differ

```
2001:0DB8:ACAD:1::/64
2001:0DB8:ACAD:2::/64
2001:0DB8:ACAD:3::/64
2001:0DB8:ACAD:4::/64
```

Identify Where the Addresses Differ

```
2001:0DB8:ACAD:0001::/64
2001:0DB8:ACAD:0002::/64
2001:0DB8:ACAD:0003::/64
2001:0DB8:ACAD:0004::/64
```

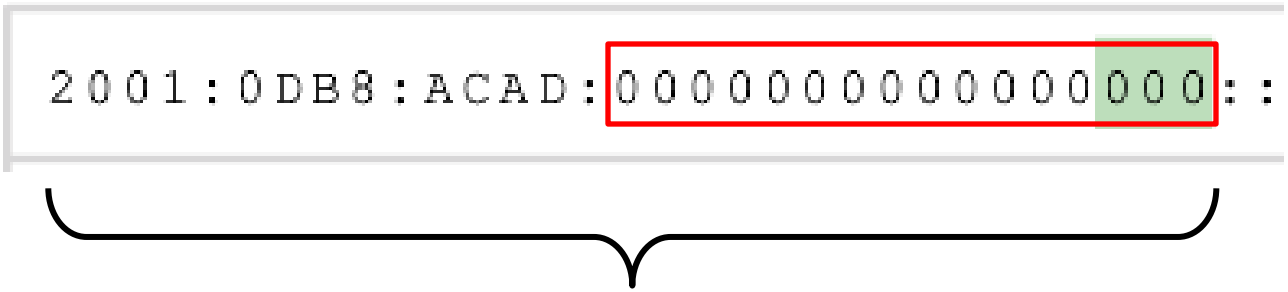
Convert the Section from Hex to Binary

Count the # of Left-Most Matching Bits

Add Zero Bits

```
2001:0DB8:ACAD:0000000000000000::
```

Convert the Binary Section Back to Hex



2001:0DB8:ACAD:0000::/61

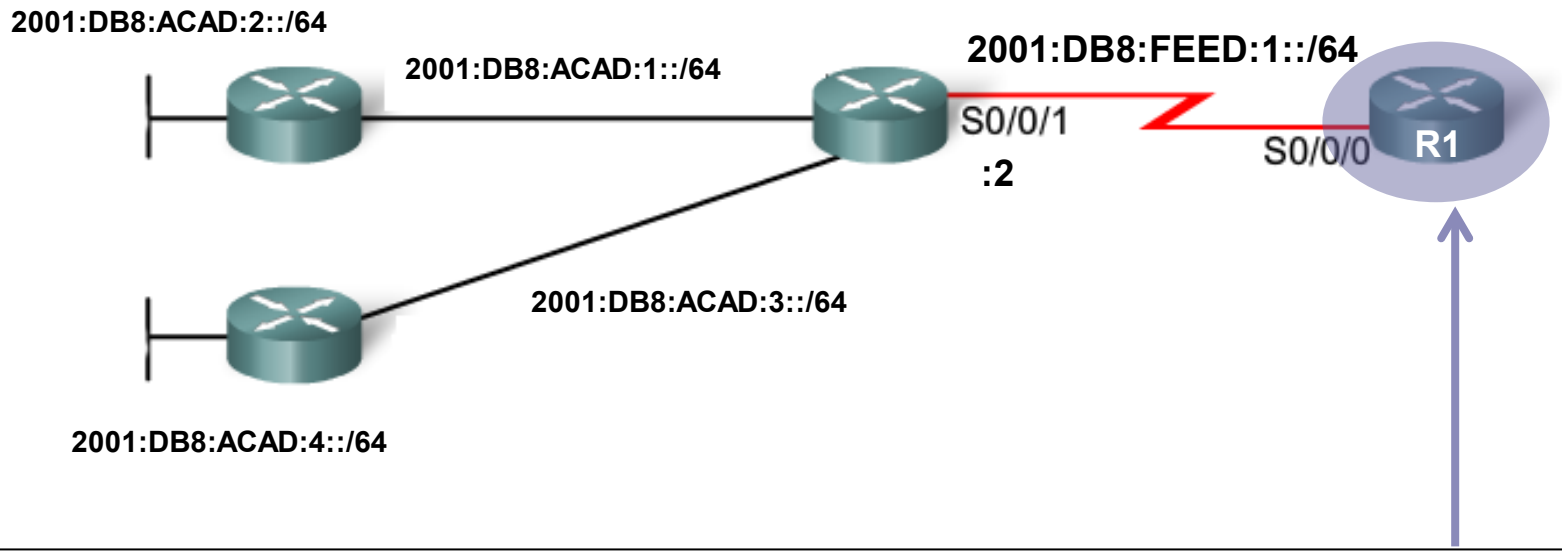
or

2001:0DB8:ACAD:0::/61

or

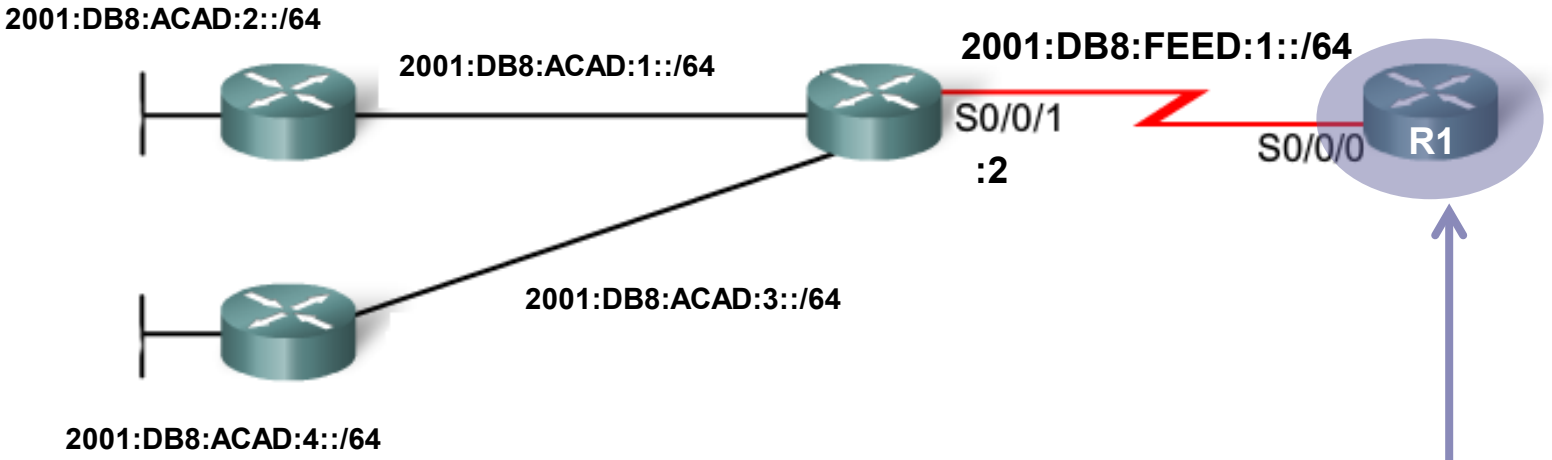
2001:0DB8:ACAD::/61

Configuring an IPv6 Summary Address




```
R1(config)#no ipv6 route 2001:DB8:ACAD:1::/64 2001:db8:feed:1::2
R1(config)#no ipv6 route 2001:DB8:ACAD:2::/64 2001:db8:feed:1::2
R1(config)#no ipv6 route 2001:DB8:ACAD:3::/64 2001:db8:feed:1::2
R1(config)#no ipv6 route 2001:DB8:ACAD:4::/64 2001:db8:feed:1::2
R1(config)#
R1(config)#
R1(config)#ipv6 route 2001:DB8:ACAD::/61 2001:db8:feed:1::2
R1(config)#
```

Verify the Summary IPv6 Route




```
R1# show ipv6 route static
<Output omitted>

S   2001:DB8:ACAD::/61 [1/0]
     via 2001:DB8:FEED:1::2
R1#
```

Troubleshooting Static Routes

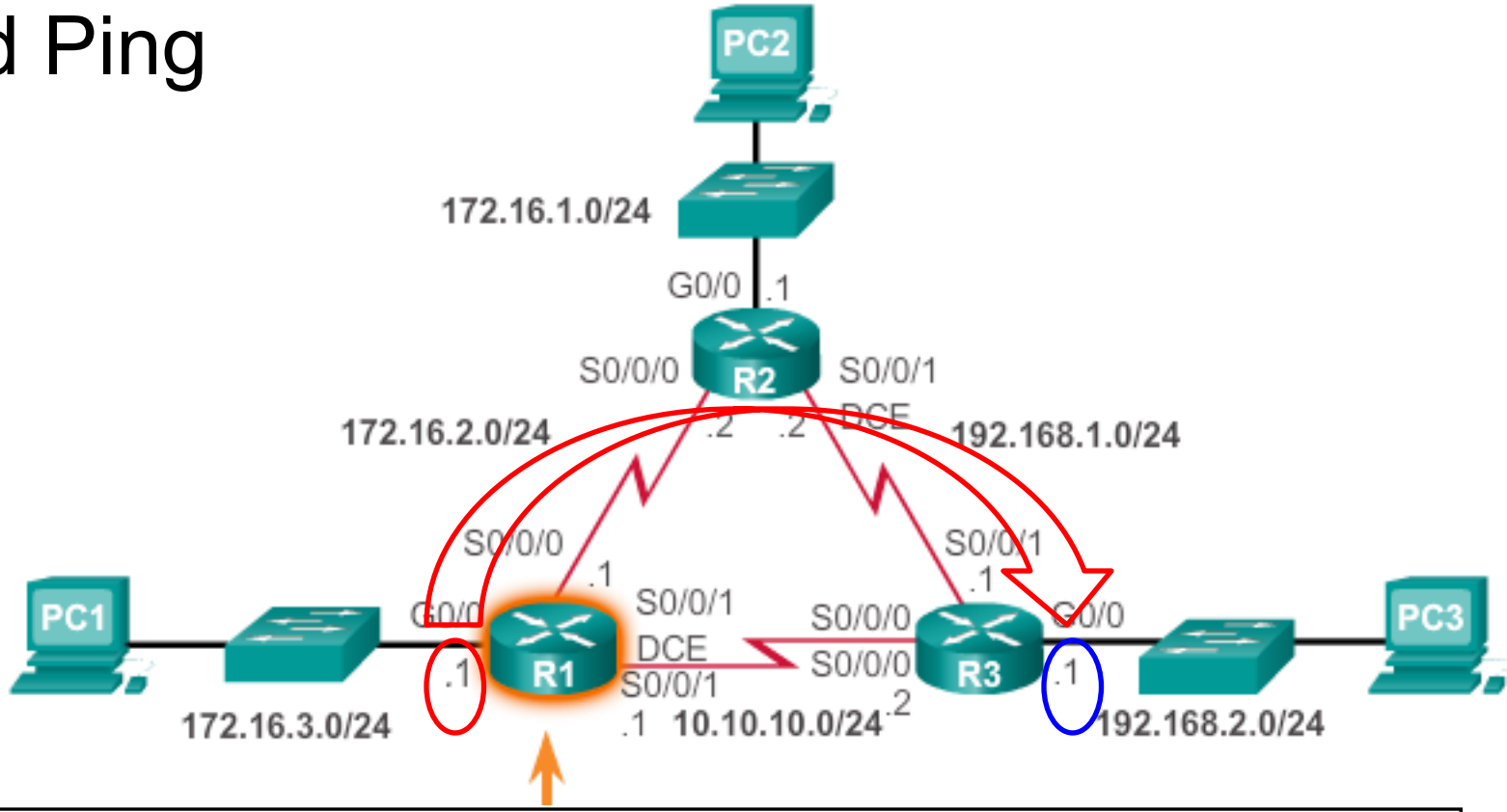
Networks Fail

- Due to a failed interface.
- A service provider drops a connection.
- Links become oversaturated.
- An administrator enters a wrong configuration.

Common IOS Troubleshooting Commands

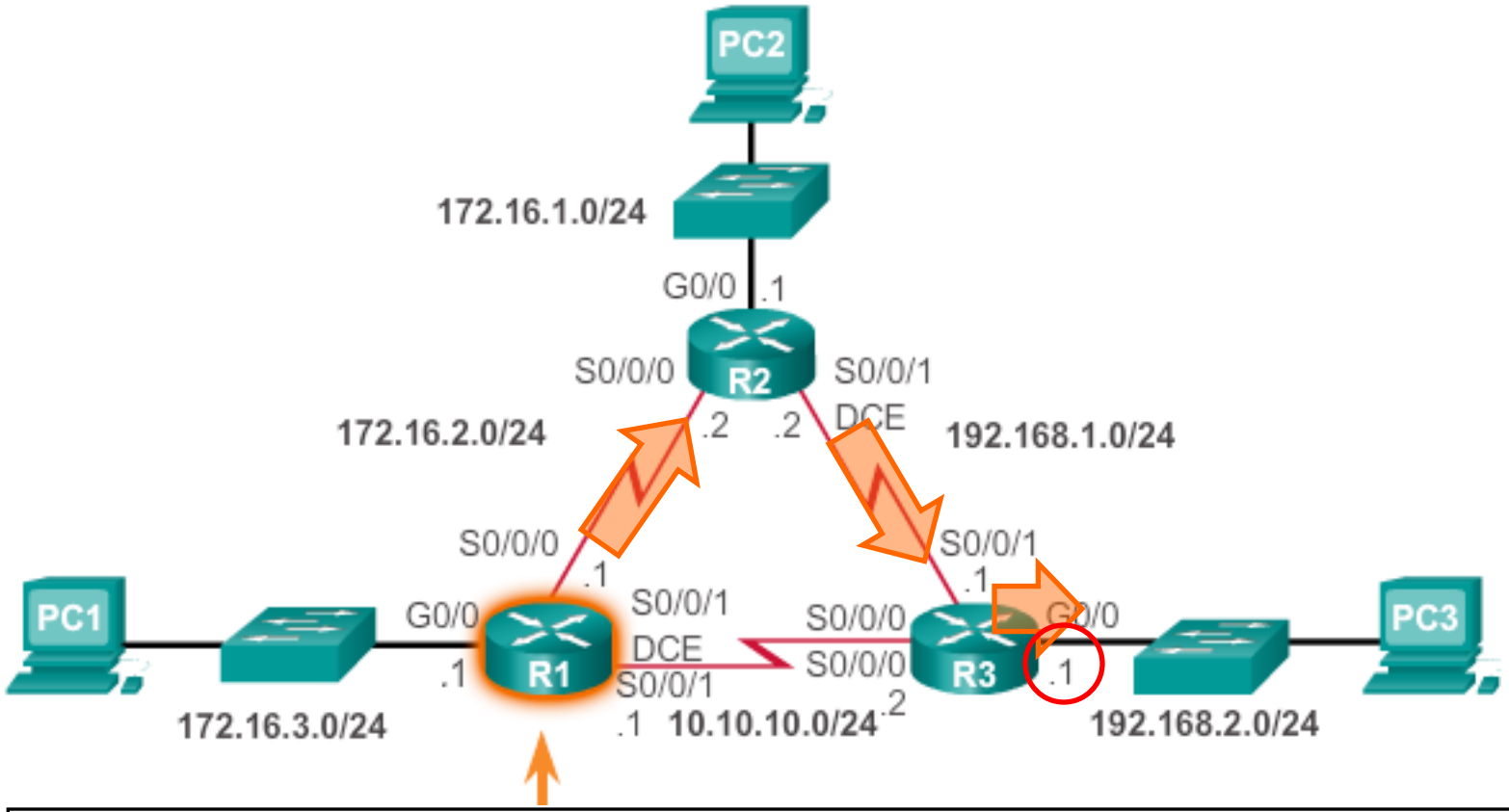
- **`ping`**
- **`traceroute`**
- **`show ip route`**
- **`show ip interface brief`**

Extended Ping



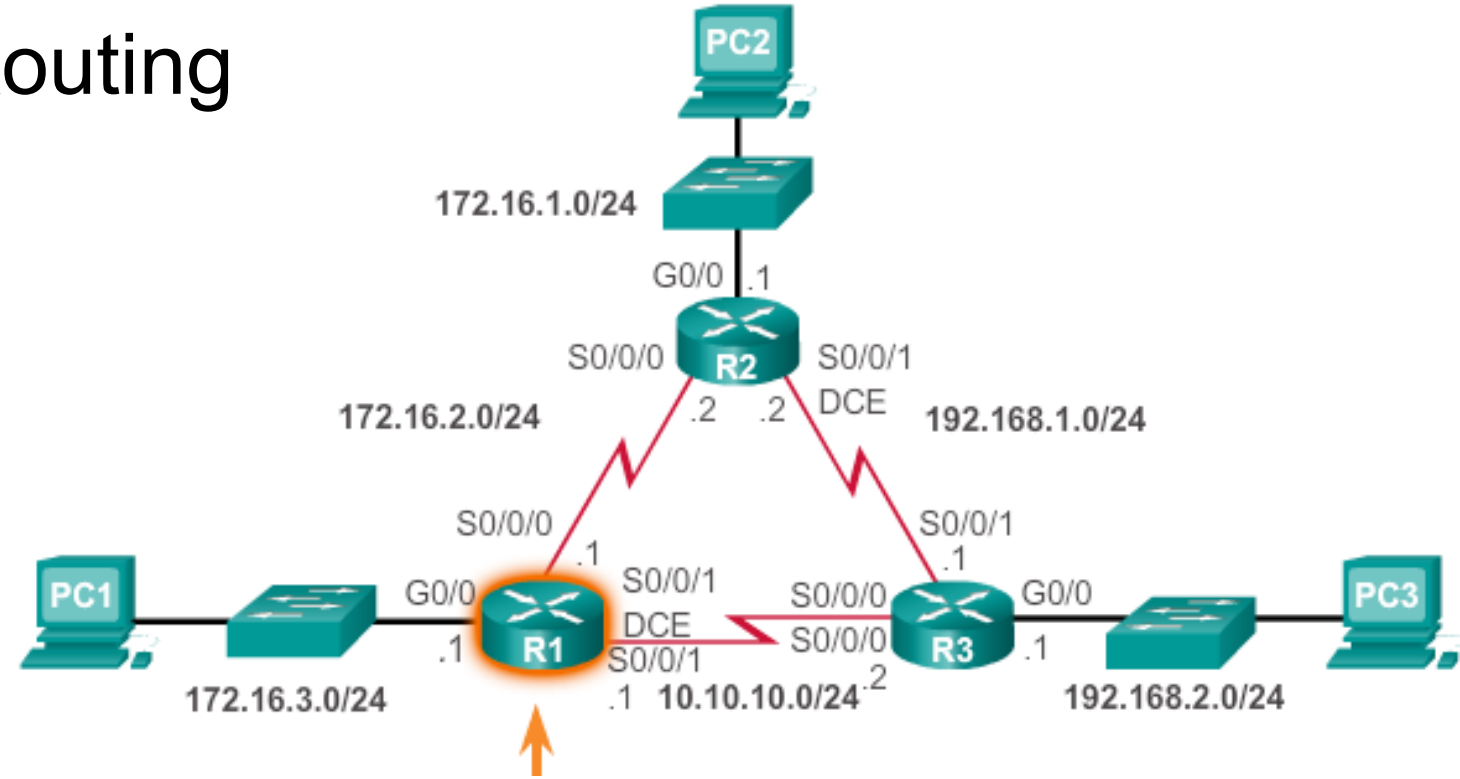

```
R1# ping 192.168.2.1 source 172.16.3.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2
seconds:
Packet sent with a source address of 172.16.3.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max =
28/28/28 ms
R1#
```

Traceroute



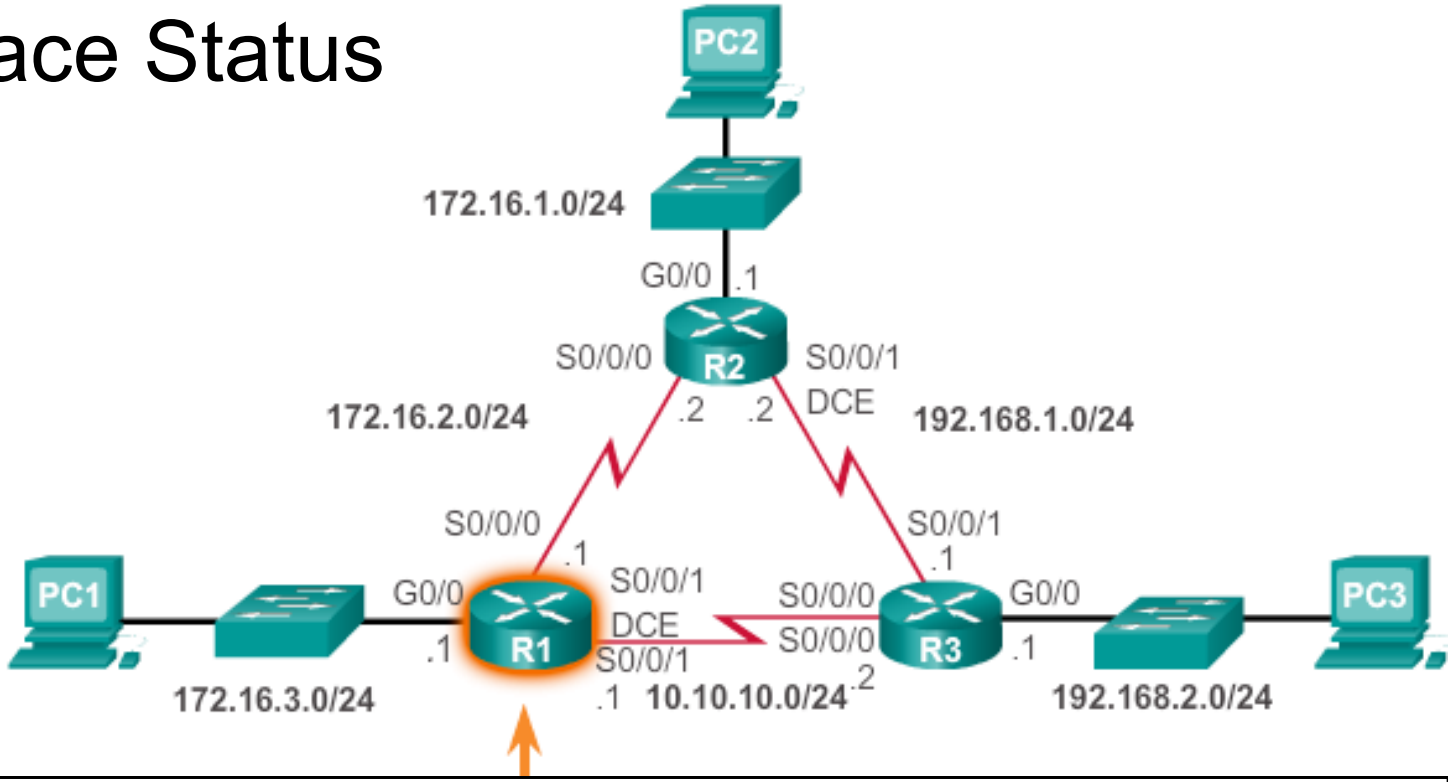

```
R1# traceroute 192.168.2.1
Type escape sequence to abort.
Tracing the route to 192.168.2.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.2.2 4 msec 4 msec 8 msec
  2 192.168.1.1 12 msec 12 msec *
R1#
```

Verify the Routing table



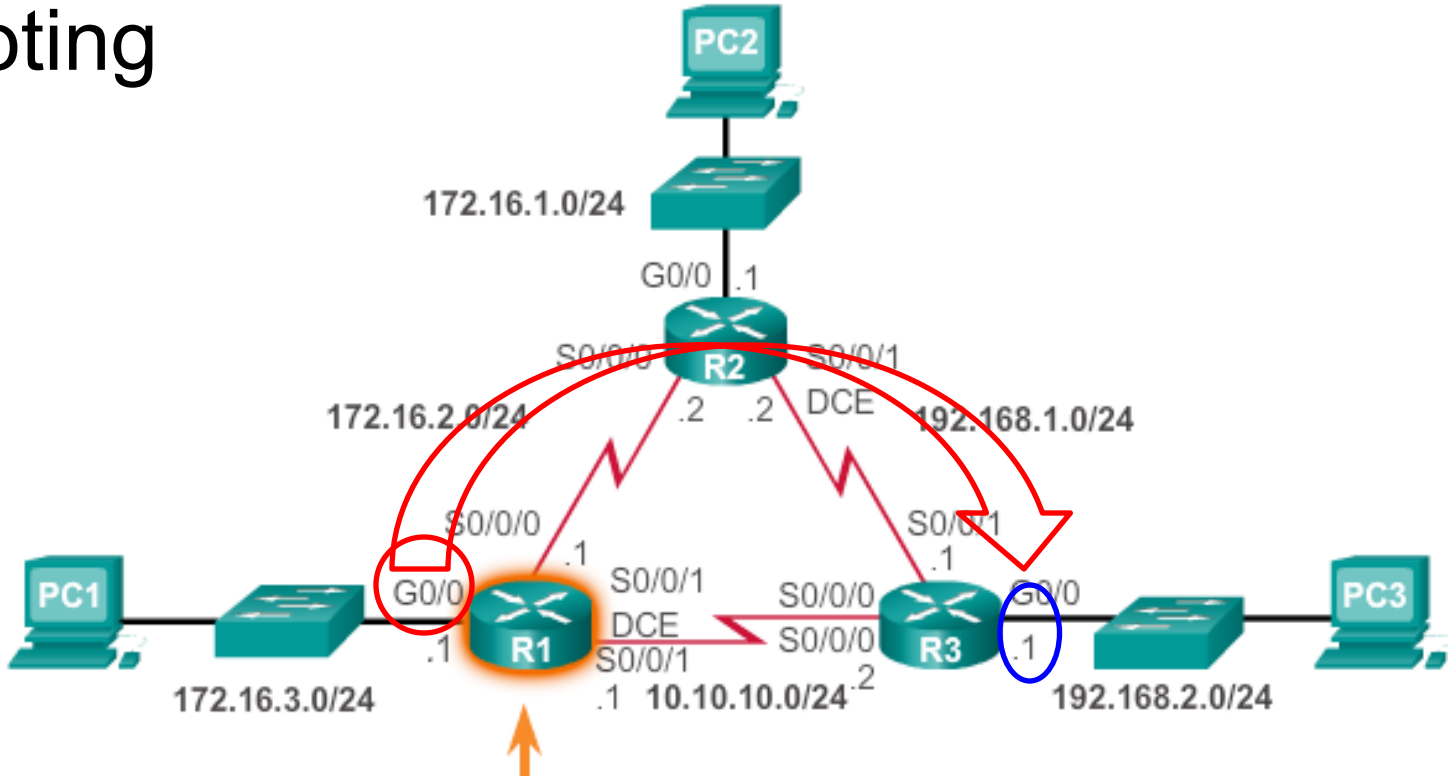

```
R1#show ip route | begin Gateway
Gateway of last resort is not set

 172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.1.0/24 [1/0] via 172.16.2.2
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.1/32 is directly connected, Serial0/0/0
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0
S     192.168.1.0/24 [1/0] via 172.16.2.2
S     192.168.2.0/24 [1/0] via 172.16.2.2
R1#
```

Verify Interface Status



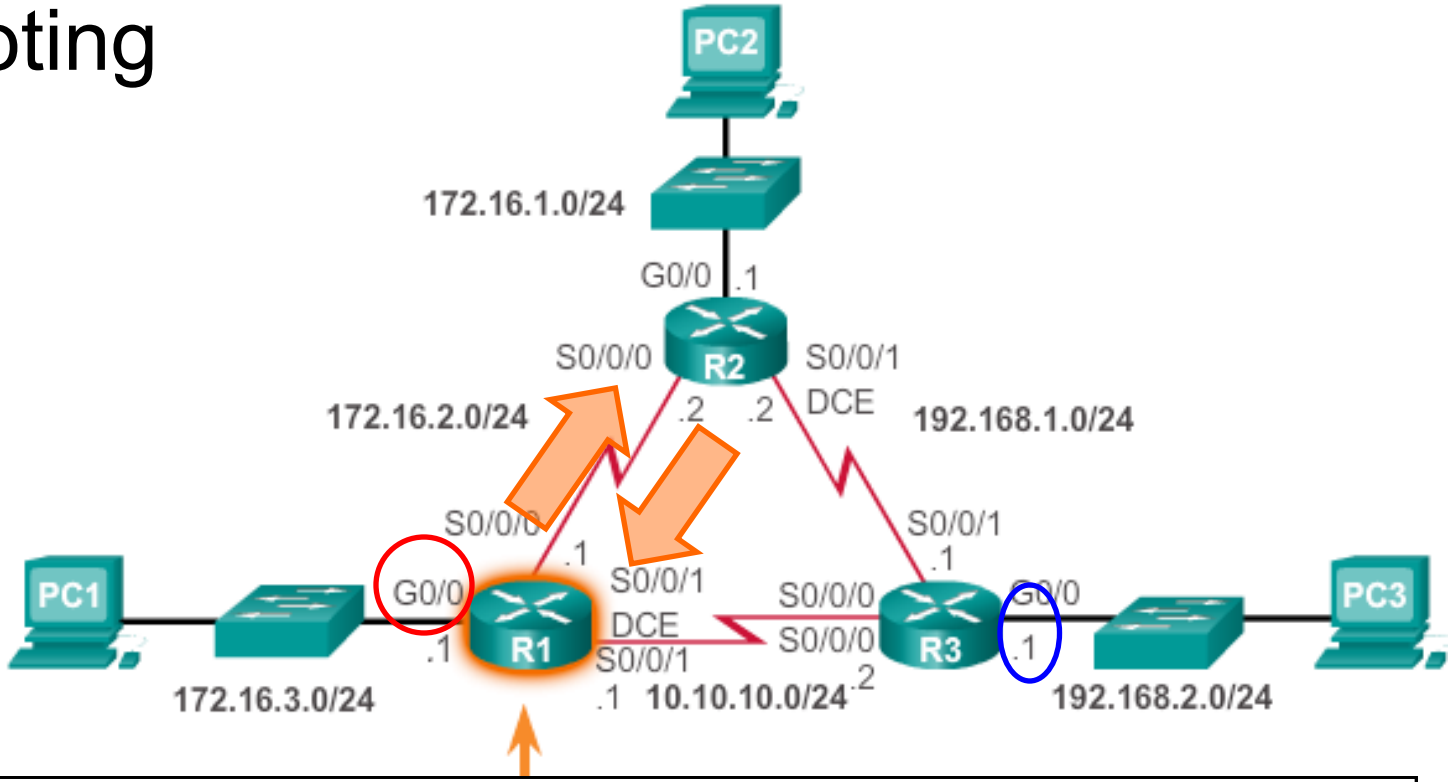

```
R1# show ip interface brief
Interface                  IP-Address      OK? Method Status                Protocol
Embedded-Service-Engine0/0 unassigned      YES unset  administratively down down
GigabitEthernet0/0         172.16.3.1      YES manual up                    up
GigabitEthernet0/1         unassigned      YES unset  administratively down down
Serial0/0/0                172.16.2.1      YES manual up                    up
Serial0/0/1                unassigned      YES unset  administratively down down
R1#
```

Troubleshooting Example #1




```
R1# ping 192.168.2.1 source g0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2
seconds:
Packet sent with a source address of 172.16.3.1
.....
Success rate is 0 percent (0/5)
R1#
```

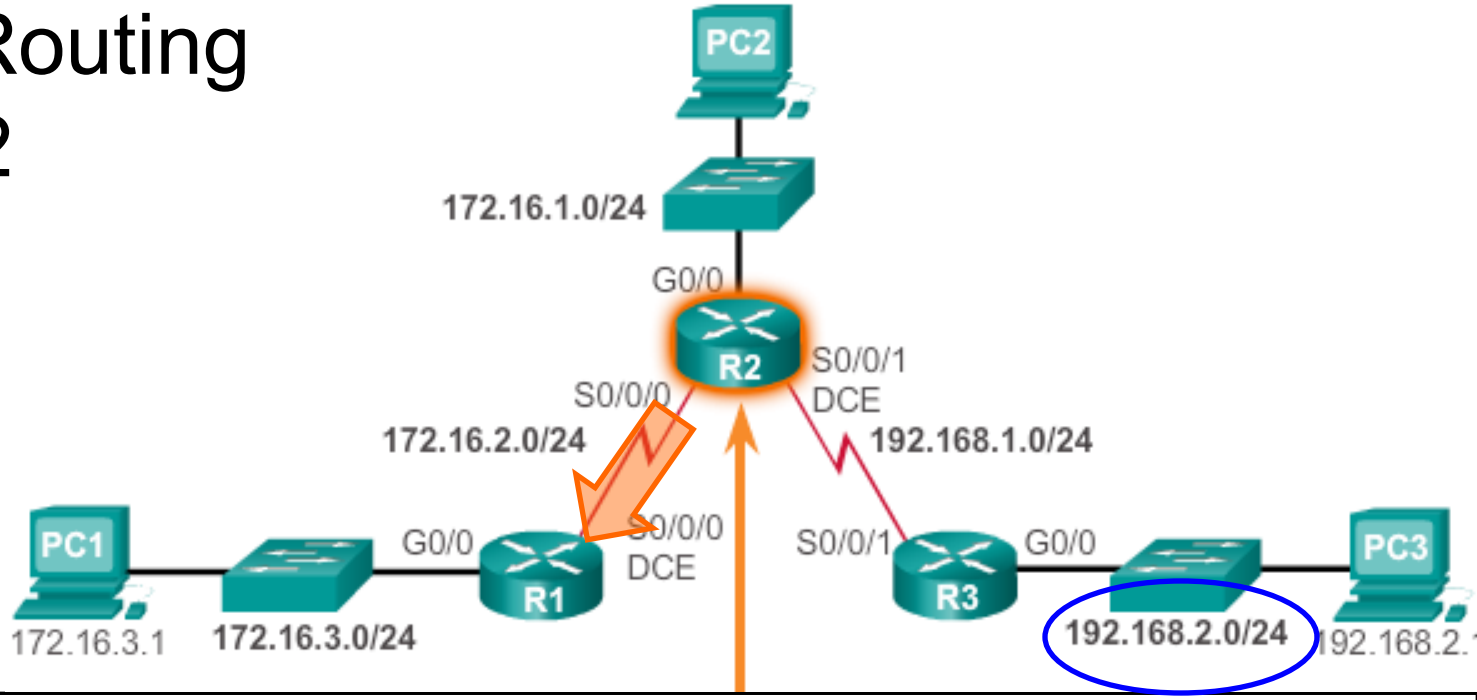
Troubleshooting Example #1




```
R1# traceroute 192.168.2.1
Type escape sequence to abort.
Tracing the route to 192.168.2.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.2.2 4 msec 4 msec 8 msec
  2 172.16.2.1 12 msec 12 msec 12 msec
  3 172.16.2.2 12 msec 8 msec 8 msec
  4 172.16.2.1 20 msec 16 msec 20 msec
  5 172.16.2.2 16 msec 16 msec 16 msec
  6 172.16.2.1 20 msec 20 msec 24 msec
```

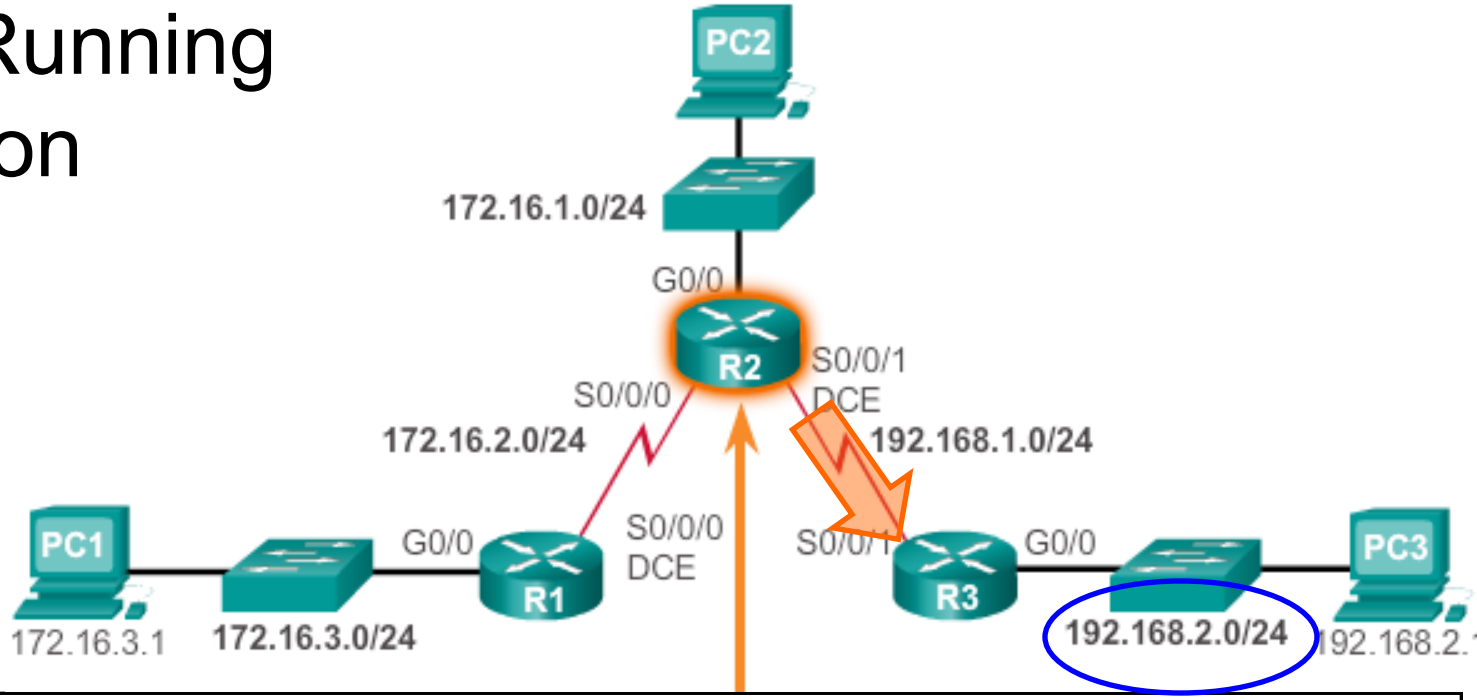
Routing Loop!

Verify the Routing Table of R2



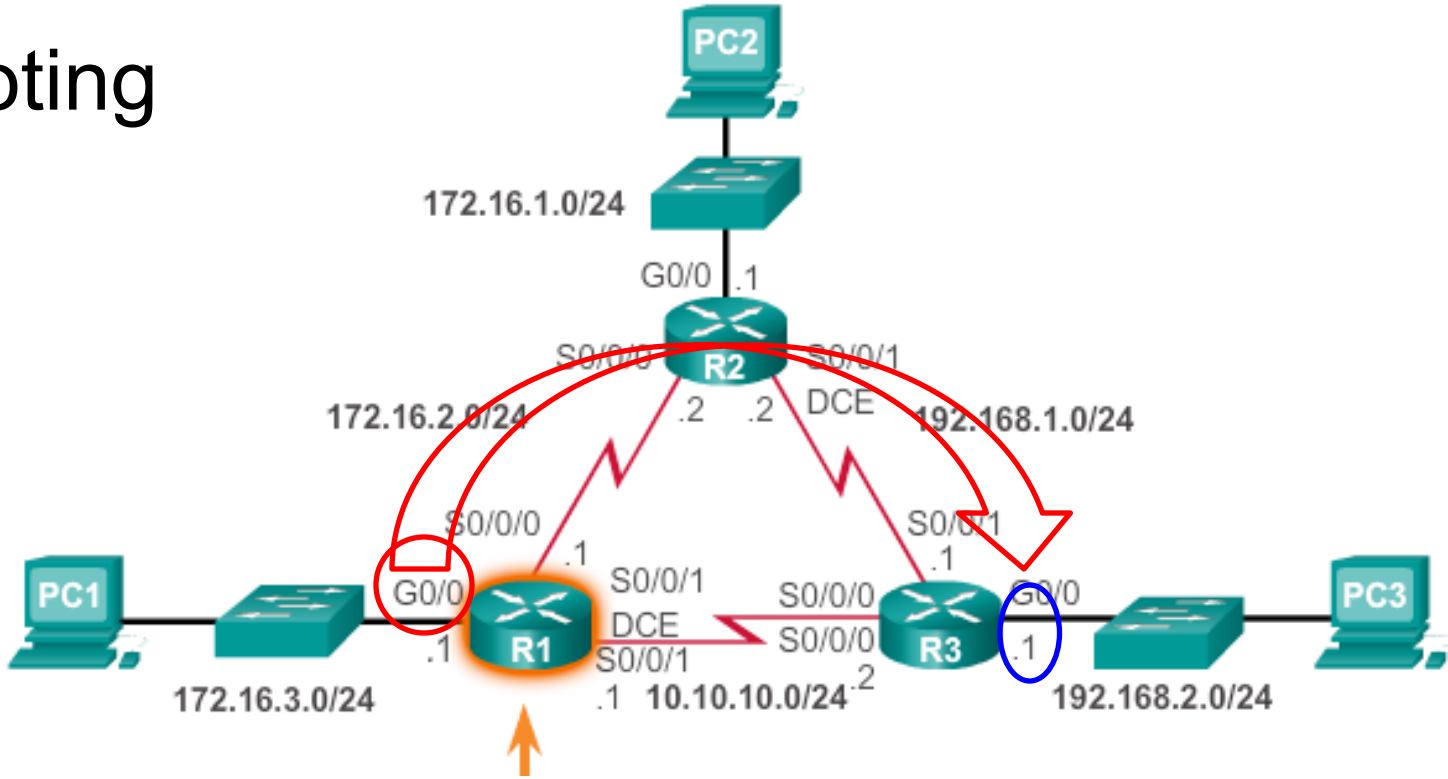

```
R2# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
C        172.16.1.0/24 is directly connected, GigabitEthernet0/0
L        172.16.1.1/32 is directly connected, GigabitEthernet0/0
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.2/32 is directly connected, Serial0/0/0
S        172.16.3.0/24 is directly connected, Serial0/0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Serial0/0/1
L        192.168.1.2/32 is directly connected, Serial0/0/1
S     192.168.2.0/24 [1/0] via 172.16.2.1
R2#
```

Verify the Running Configuration




```
R2# show running-config | section ip route
ip route 172.16.3.0 255.255.255.0 172.16.2.1
ip route 192.168.2.0 255.255.255.0 172.16.2.1
R2# conf t
R2(config)# no ip route 192.168.2.0 255.255.255.0 172.16.2.1
R2(config)# ip route 192.168.2.0 255.255.255.0 192.168.1.1
R2(config)#
```

Troubleshooting Example #1




```
R1# ping 192.168.2.1 source g0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2
seconds:
Packet sent with a source address of 172.16.3.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max =
28/28/28 ms
R1#
```