



Inspiring Excellence

# Network Layer: IPv4 Static Routing

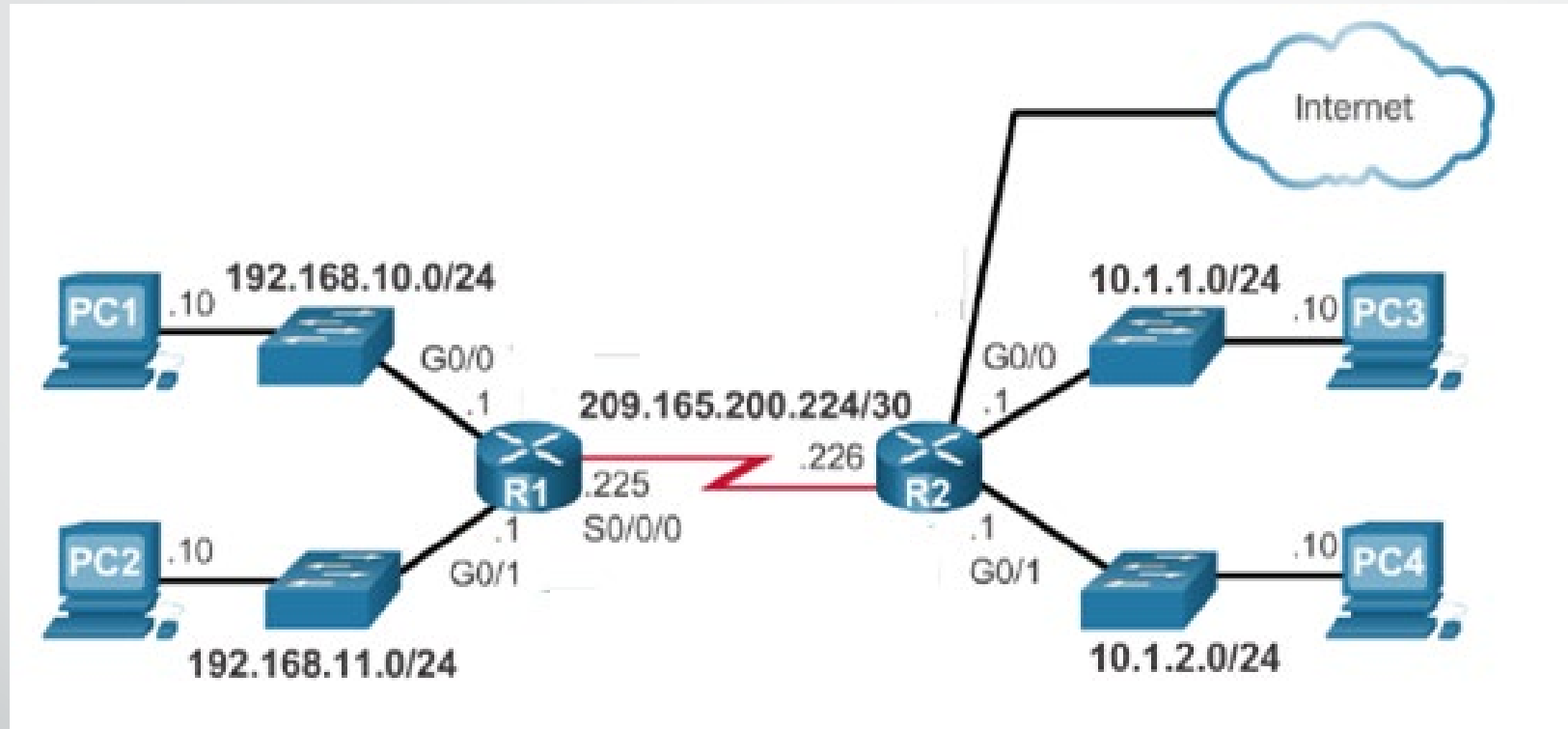
Lecture 12 | CSE421 – Computer Networks

Department of Computer Science and Engineering  
School of Data & Science

# Objectives

- Routing
  - Static Routing
    - Standard Static Routing
    - Summary Static Routing
    - Default Static Routing
    - Floating Static Routing
      - Directly attached/connected
      - Next Hop/Recursive
      - Fully Specified
    - Configuration and Verification
  - Dynamic Routing
    - RIP
    - OSPF

# Learning About Networks



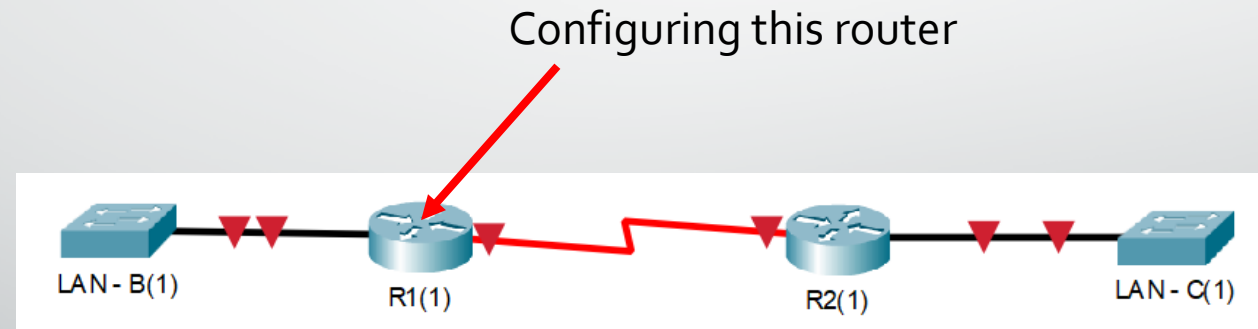
# Learning About Remote Networks

- A router can learn about remote networks in one of two ways:
  - **Manually** - Remote networks are manually entered into the route table using static routes.
  - **Dynamically** - Remote routes are automatically learned using a dynamic routing protocol.

	Dynamic Routing	Static Routing
<b>Configuration Complexity</b>	Generally independent of the network size	Increases with network size
<b>Topology Changes</b>	Automatically adapts to topology changes	Administrator intervention required
<b>Scaling</b>	Suitable for simple and complex topologies	Suitable for simple topologies
<b>Security</b>	Less secure	More secure
<b>Resource Usage</b>	Uses CPU, memory, link bandwidth	No extra resources needed
<b>Predictability</b>	Route depends on the current topology	Route to destination is always the same

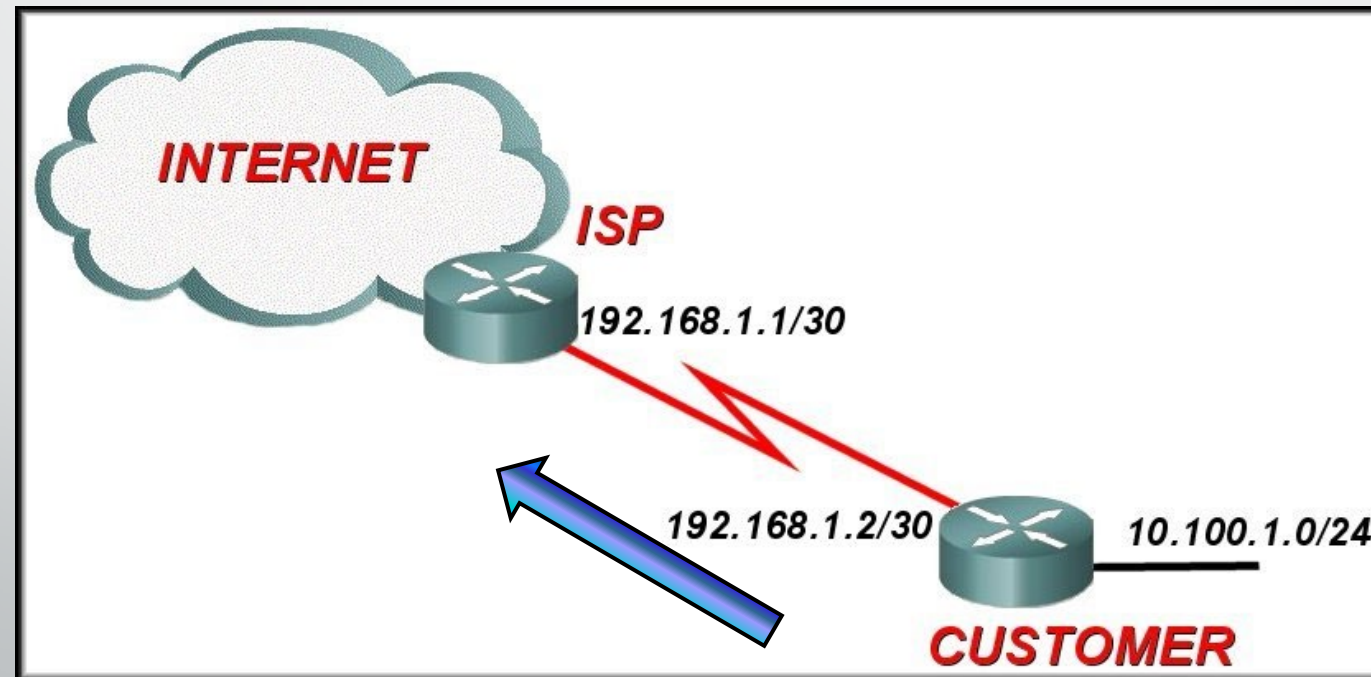
# Standard Static Routing

- Creating connections to specific **remote** networks.
- All static routes **have a cost of "0"** because we manually configure all routes. There's no need for the router to calculate/decide anything
- Has a **default Administrative Distance (AD) of "1"**
  - **Administrative Distance** is the measure of **trustworthiness** of a link
    - **Lower is better**
    - Used by the **Floating Static Route** and **Dynamic Routing Protocols**



# Default Static Routing

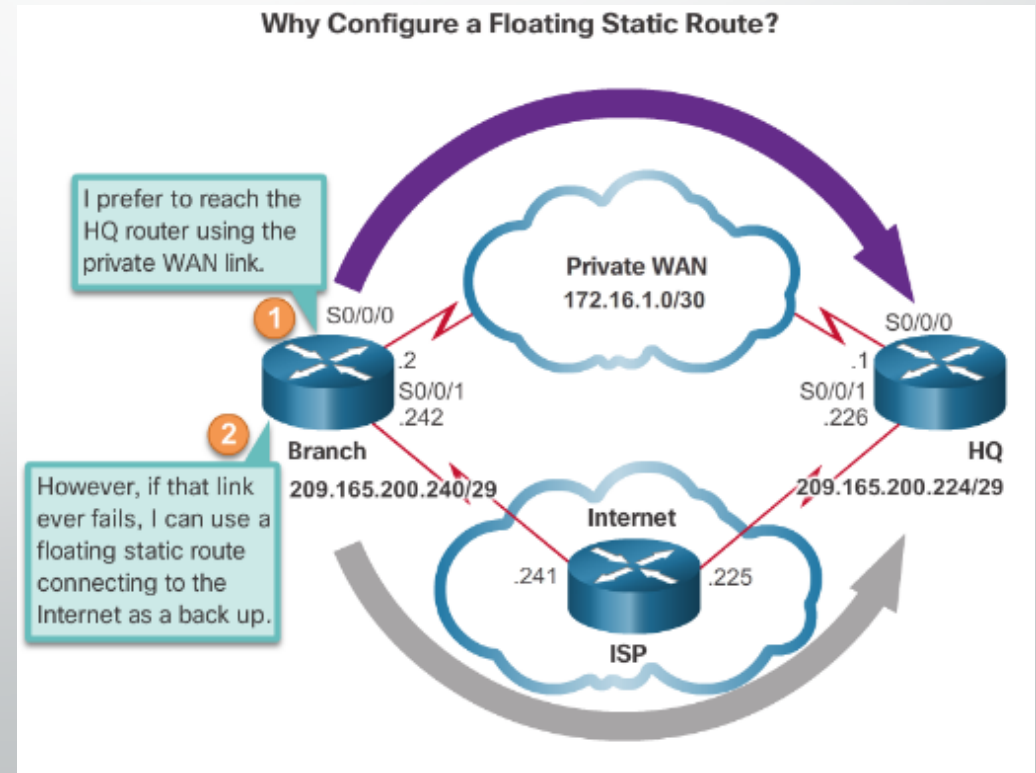
- A **default path** for all IP packets that the router **does not have a learned** or static route to send them
- Uses a **special network** address as destination: **0.0.0.0/0**
  - Has a subnet mask of 0. Meaning, it will check zero bits and hence it will **match all IPs!**
- Conventionally, **always points** towards the **border/ISP** Router.





# Floating Static Routing

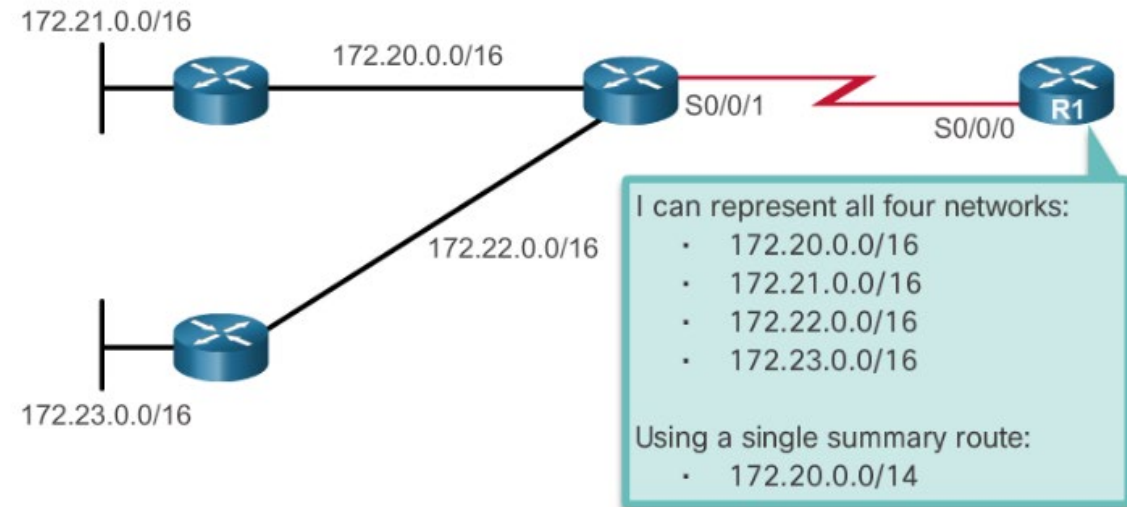
- Create a **backup route** in case a primary route link fails
- Uses **Administrative Distance (AD)**
  - The primary path has the **default AD of 1** (but, may be configured to have a higher value)
  - The value of AD of **back up path** is **greater** than the AD of **primary** path/route.
  - Since the AD of primary path is lower, it means that primary path is **more trustworthy** and hence ignore the back up path **unless** the primary path is down.
- The static route “floats” and is **not used** when the route with the **better** administrative distance is active.
- If the preferred route is lost the floating static route **can take over**



# Summary Static Routing

- A summary route is a single route that can be used to represent multiple routes.
  - Generally a set of contiguous networks.
  - Have the same exit interface or next-hop IP address.
  - Creates smaller routing tables
  - More efficient routing table lookup process.
  - Reduce the number of routes advertise

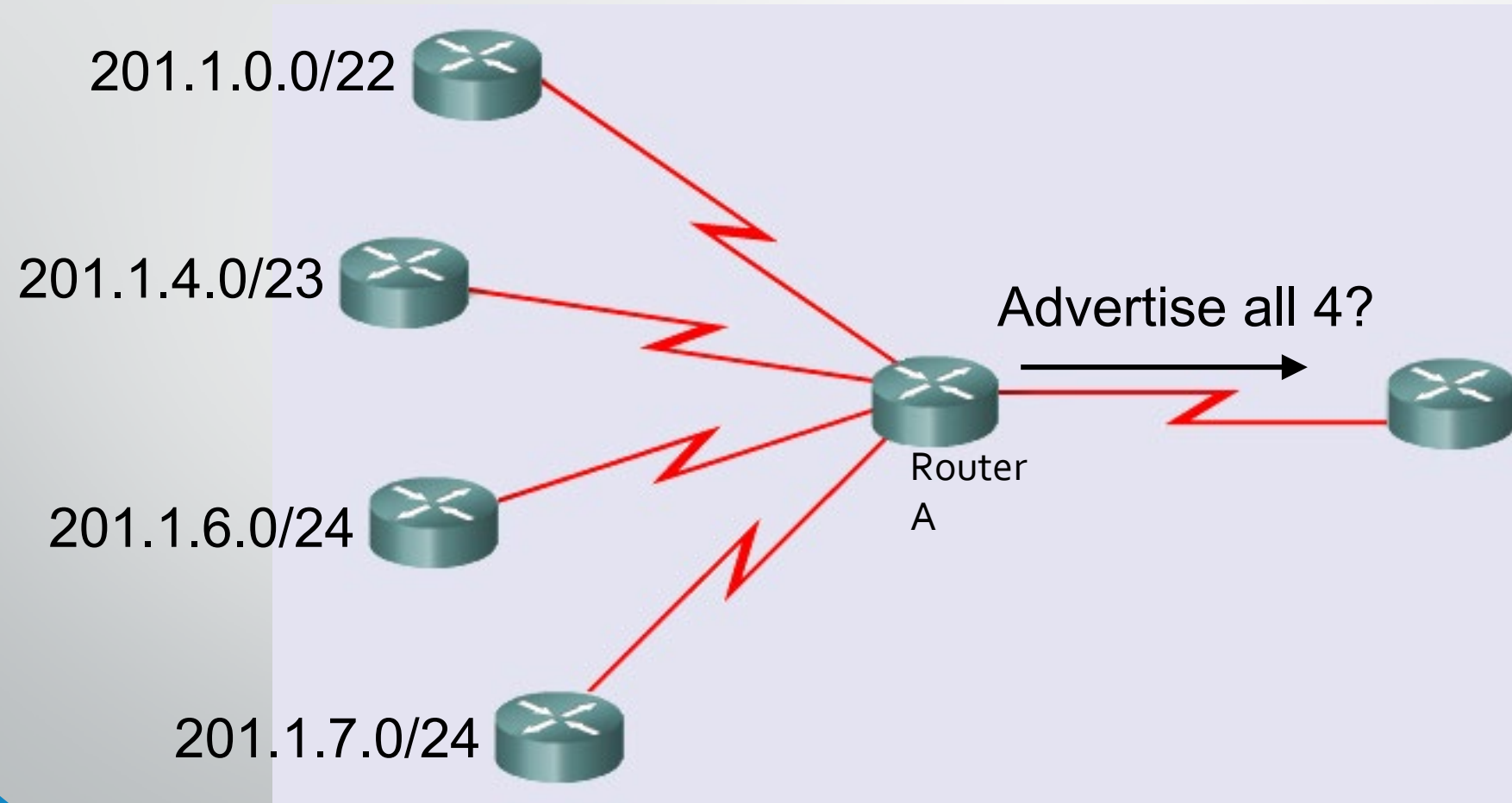
Using One Summary Static Route



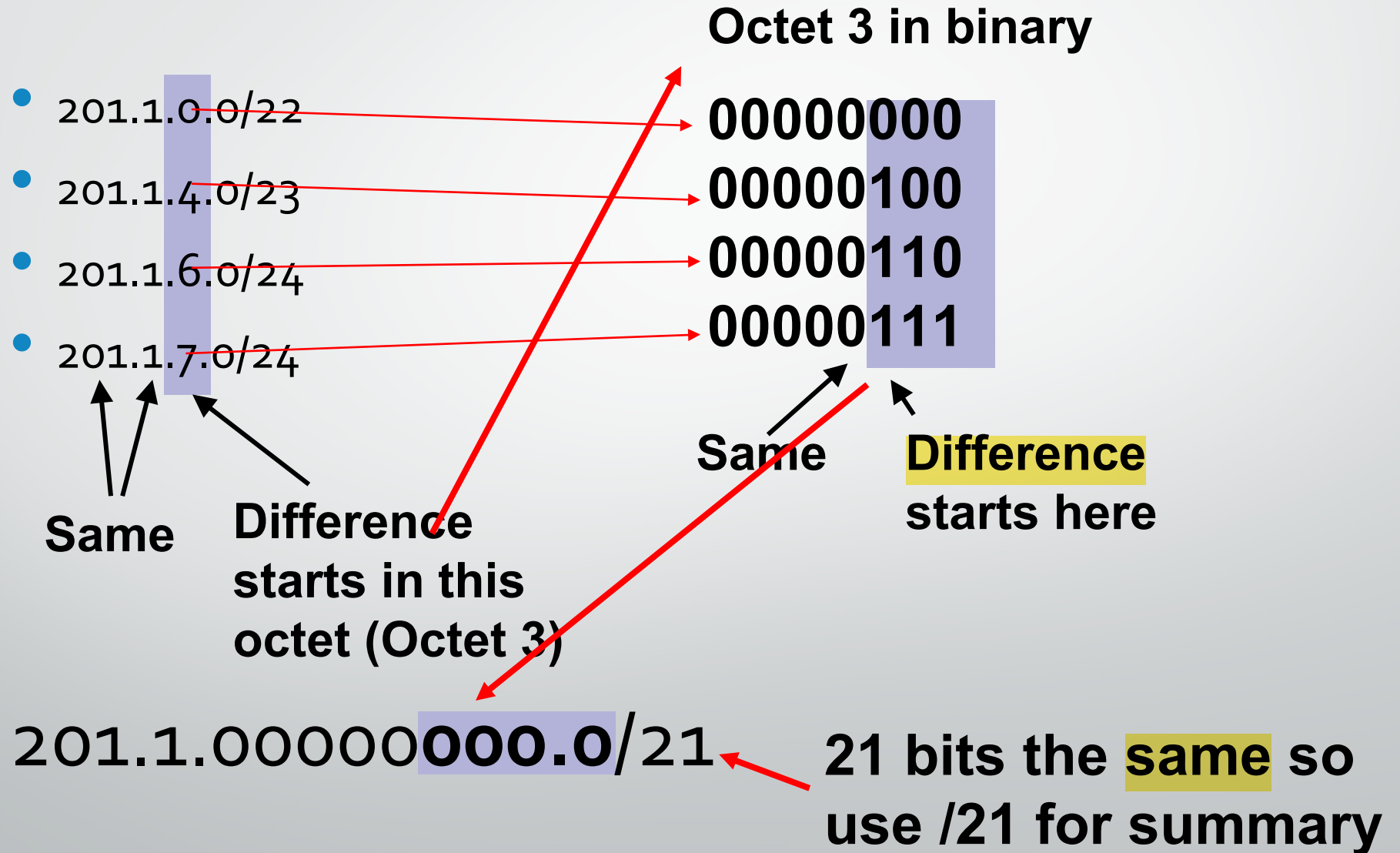


# Route Summarization

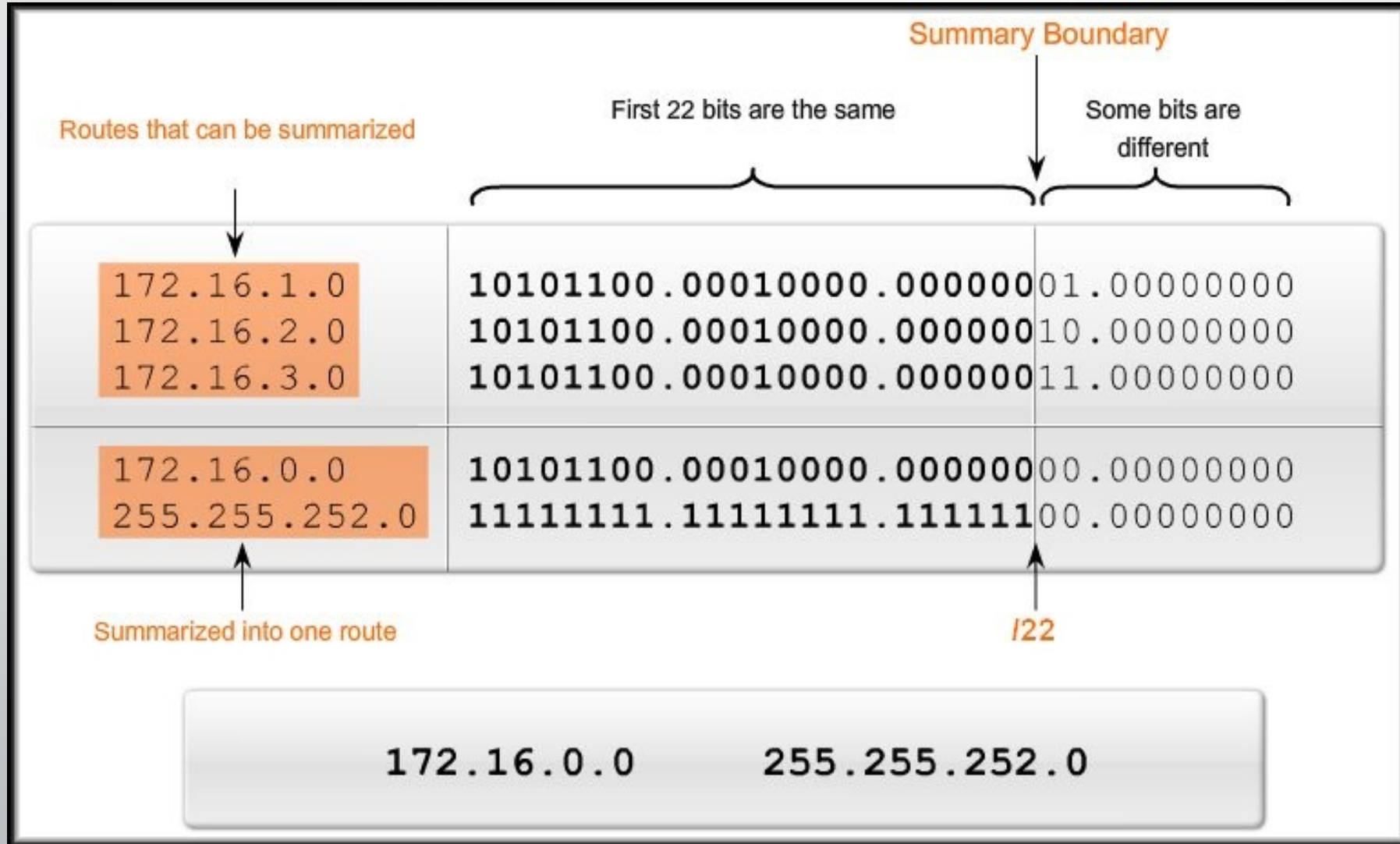
- How many entries does Router A have in its routing table?



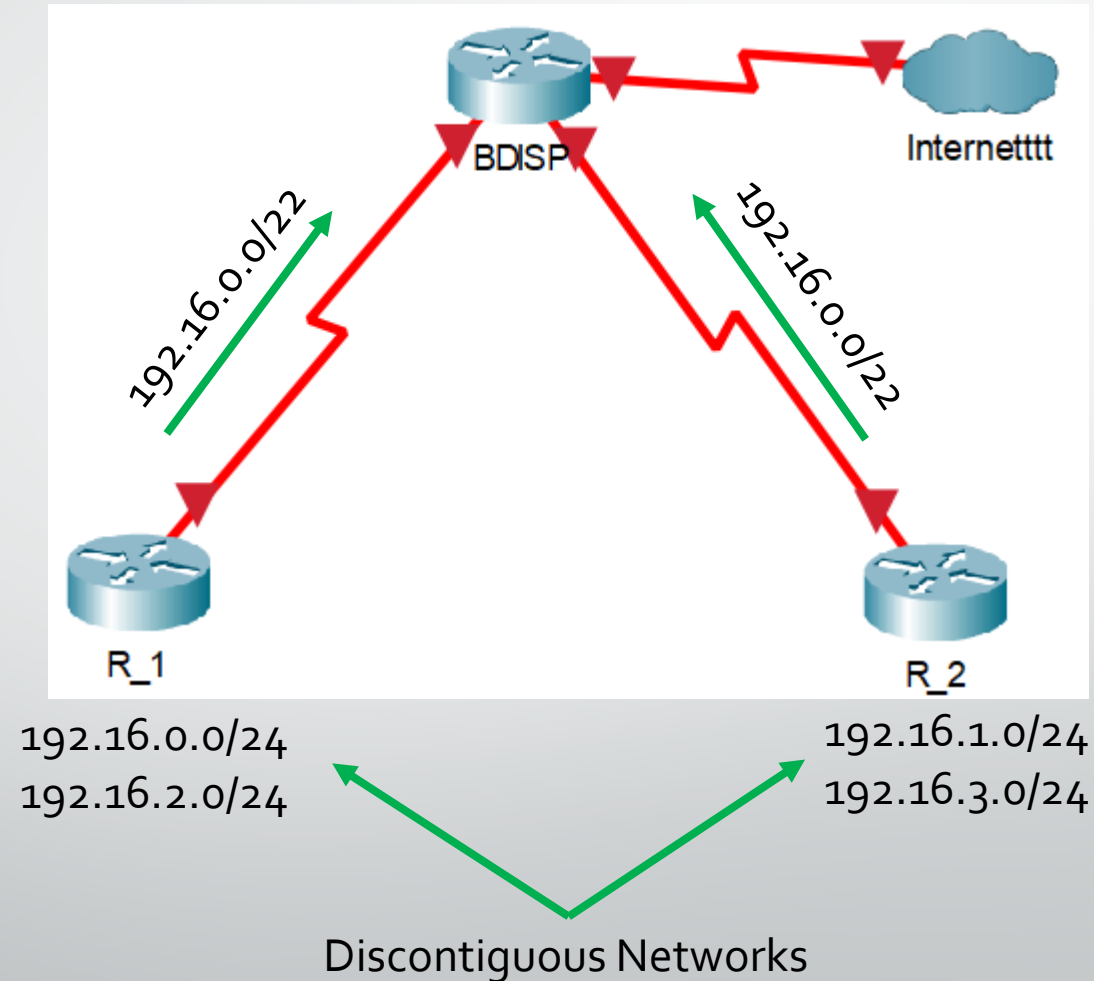
# Route Summarization



# Route Summarization Another Example

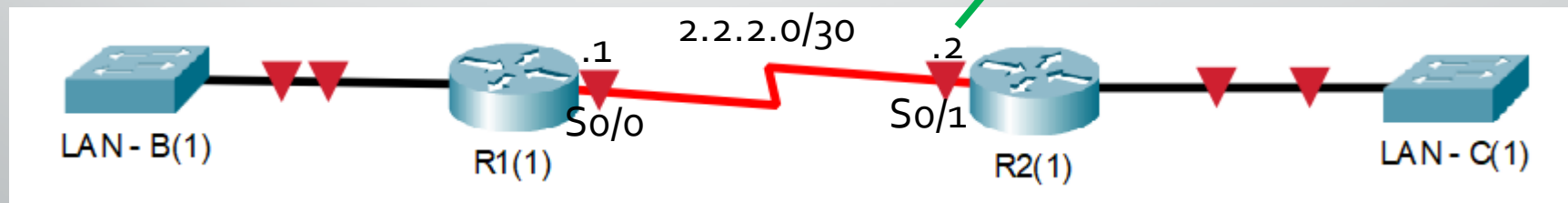


# Problem of Summary Static Routing



# Next Hop Options

- **Directly attached/connected static route**
  - Only the router **exit interface/port name** (i.e. so/o) is specified.
- **Next-hop/Recursive lookup static route**
  - Only the **next-hop IP** address (i.e. 2.2.2.2) is specified.
- **Fully specified static route**
  - The next-hop **IP** address and exit **interface** (i.e. so/o 2.2.2.2) are specified.
- **\*\*Note: Port labels:**
  - Each port has a name (so/o or fo/o or go/o or etc.) and an IP address (1.2.3.4 or etc.)



\*\*Configuring R1(1) towards LAN – C

\*\*\*All settings are done from R1(1)'s perspective

# Configuration

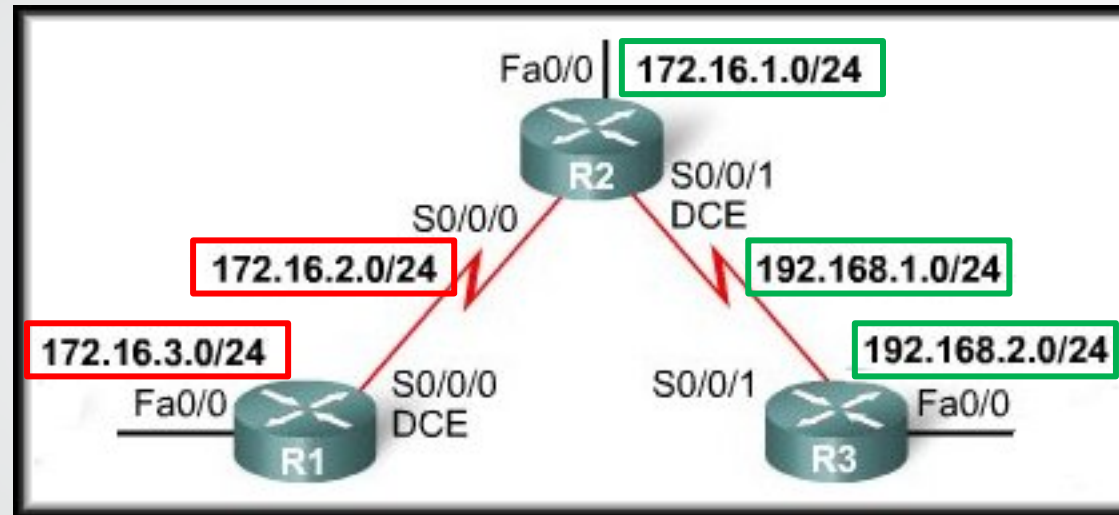


# Static Route Command

- `ip route [dest. net. add.] [dest. net. s/m] [exit option] [AD]`
  - **Destination Network Address:** Destination network address (can be summarized as well) of the remote network to be added to the routing table of the router
  - **Destination Network Subnet Mask:** Subnet mask of the remote network that is being added to the routing table. The subnet mask can be modified to summarize a group of networks
  - **Exit Options:** Directly attached; Next-hop; Fully specified
  - **AD (Administrative Distance):** Optional field; Default value is '1' if not set.
  - e.g. `ip route 1.1.3.0 255.255.255.0 s0/1`; Directly attached route (using exit-interface name)
  - To **delete** a route, just add the keyword "no" before the entire static route command.
    - e.g. `no ip route 1.1.3.0 255.255.255.0 s0/1`
    - **\*\*Note:** Most Cisco commands can be reversed like this

# Static Route Configuration

- A router, by default, knows of its directly connected networks only.



```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

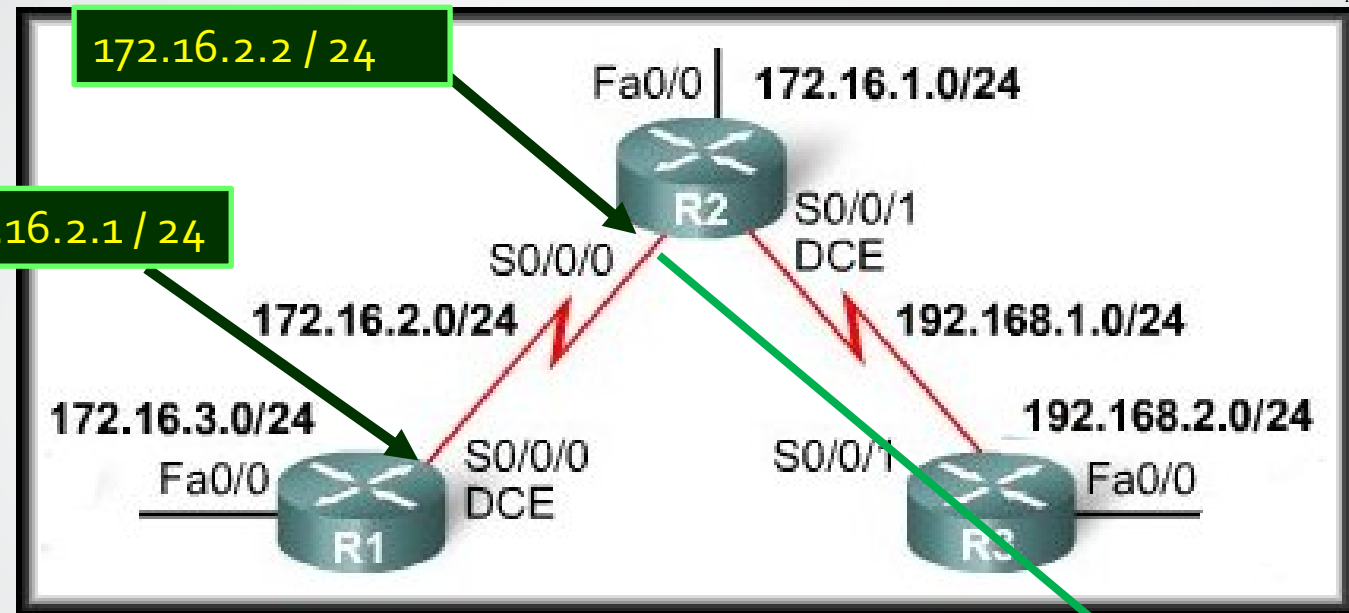
<output omitted>

Gateway of last resort is not set

    172.16.0.0/24 is subnetted, 3 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
```

# Adding a Static Route using Next Hop IP

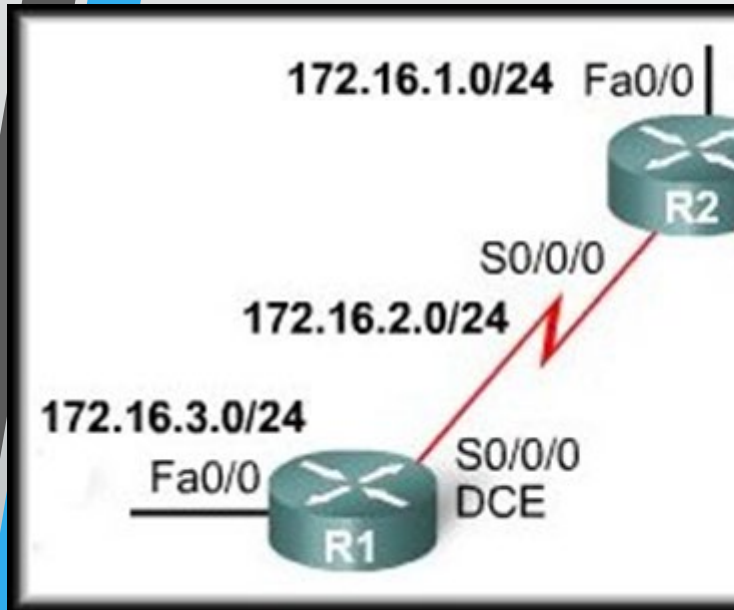
- The command to add a static route **on R1** towards **LAN of R2** using **Next-Hop IP**.



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

- Variants of the same command:
  - `ip route 172.16.1.0 255.255.255.0 s0/0/0` -> **Directly** attached
  - `ip route 172.16.1.0 255.255.255.0 s0/0/0 172.16.2.2` -> **Fully** Specified
    - The 2nd command is **not recommended** for **point-to-point** links/interfaces

# After adding the static route...



```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,
<output omitted>
Gateway of last resort is not set

172.16.0.0/24 is subnetted, 3 subnets
C      172.16.2.0 is directly connected, Serial0/0/0
C      172.16.3.0 is directly connected, FastEthernet0/0
```

**BEFORE**

```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,
<output omitted>
Gateway of last resort is not set

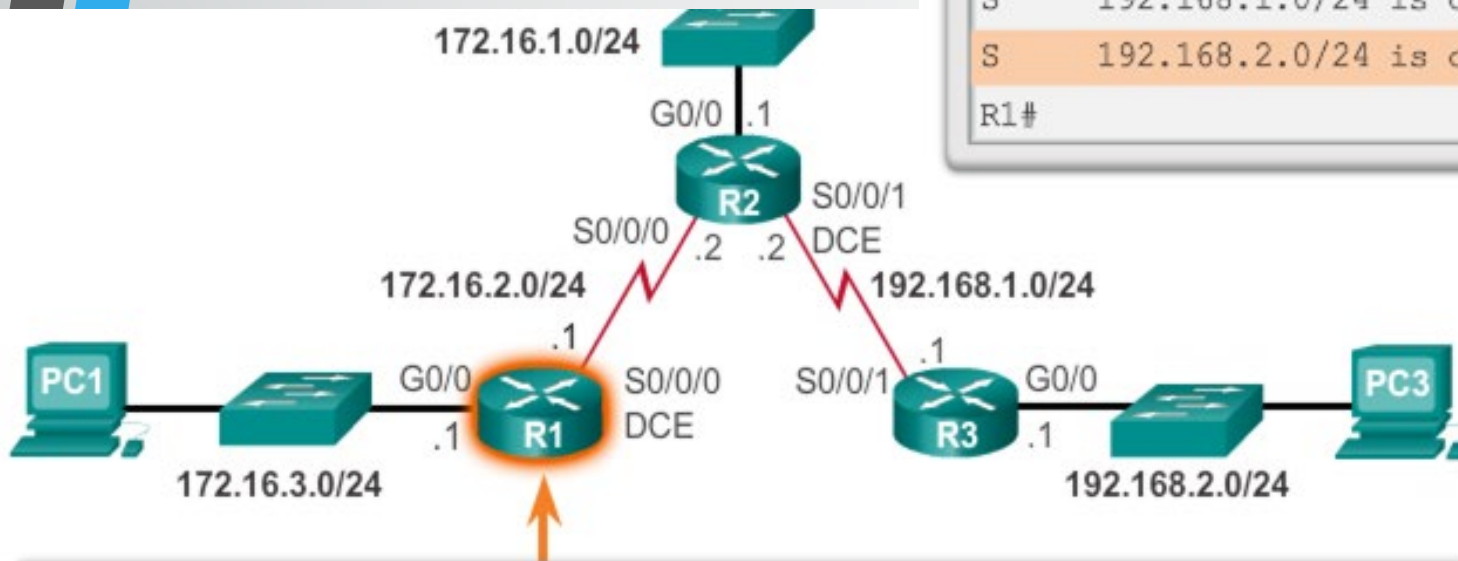
172.16.0.0/24 is subnetted, 3 subnets
S      172.16.1.0 [1/0] via 172.16.2.2
C      172.16.2.0 is directly connected, Serial0/0/0
C      172.16.3.0 is directly connected, FastEthernet0/0
```

**AFTER**

Would a 'ping' from a PC on the LAN on R1 to a PC on the LAN on R2 work?

# Example of Static Route using Exit Interface

```
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#
```



```
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) #
```



# Static Route : The line explained

```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,
<output omitted>

Gateway of last resort is not set

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
```

Type of route:  
S - Static

Destination  
Network

Administrative  
Distance

Cost of Path

Next Hop IP  
Or, Exit Interface  
Or, Fully Specified

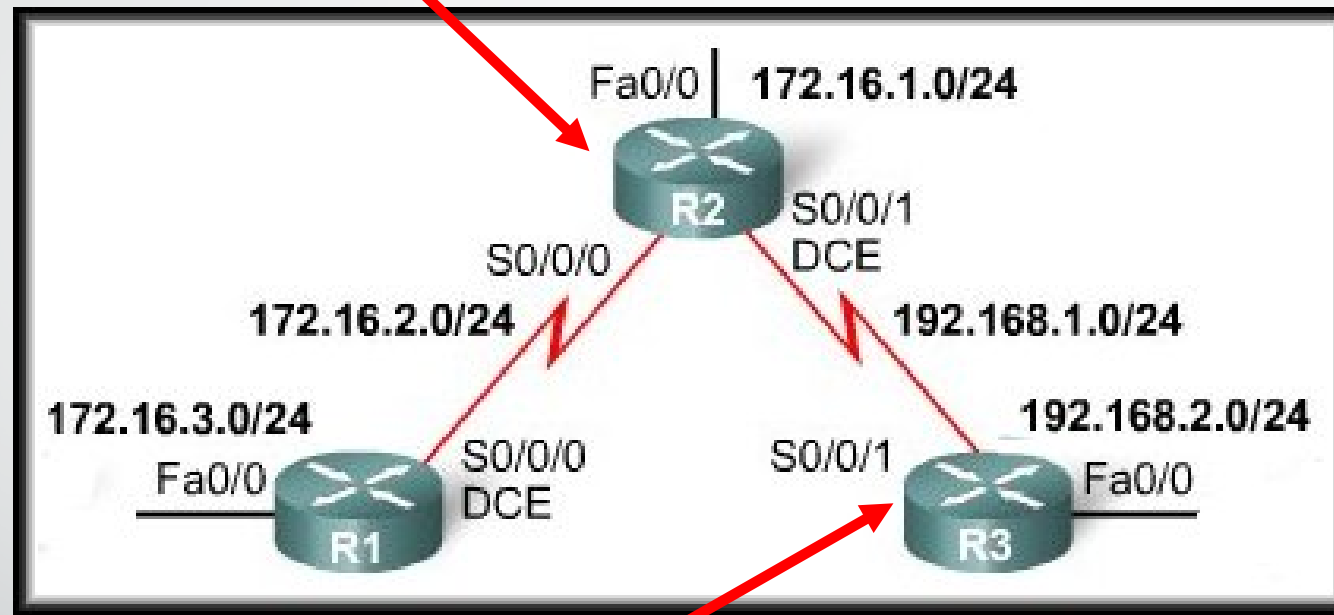
Static Routing table record if it was configured with Exit Interface

```
S    192.168.1.0/24 is directly connected, Serial0/0/0
S    192.168.2.0/24 is directly connected, Serial0/0/0
```



# Configuring R2 and R3

```
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
```

# Verifying Next Hop Static Routes

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

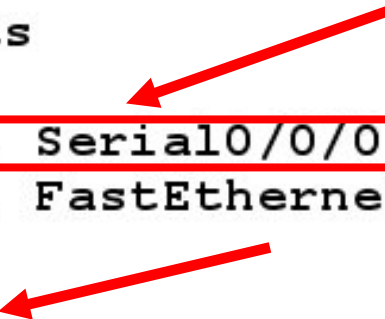
```
R2# show ip route
<output omitted>
    172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
S       172.16.3.0 [1/0] via 172.16.2.1
C       192.168.1.0/24 is directly connected, Serial0/0/1
S       192.168.2.0/24 [1/0] via 192.168.1.1
```

```
R3# show ip route
<output omitted>
    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
C       192.168.1.0/24 is directly connected, Serial0/0/1
C       192.168.2.0/24 is directly connected, FastEthernet0/0
```

# The Disadvantage of using Next Hop IP

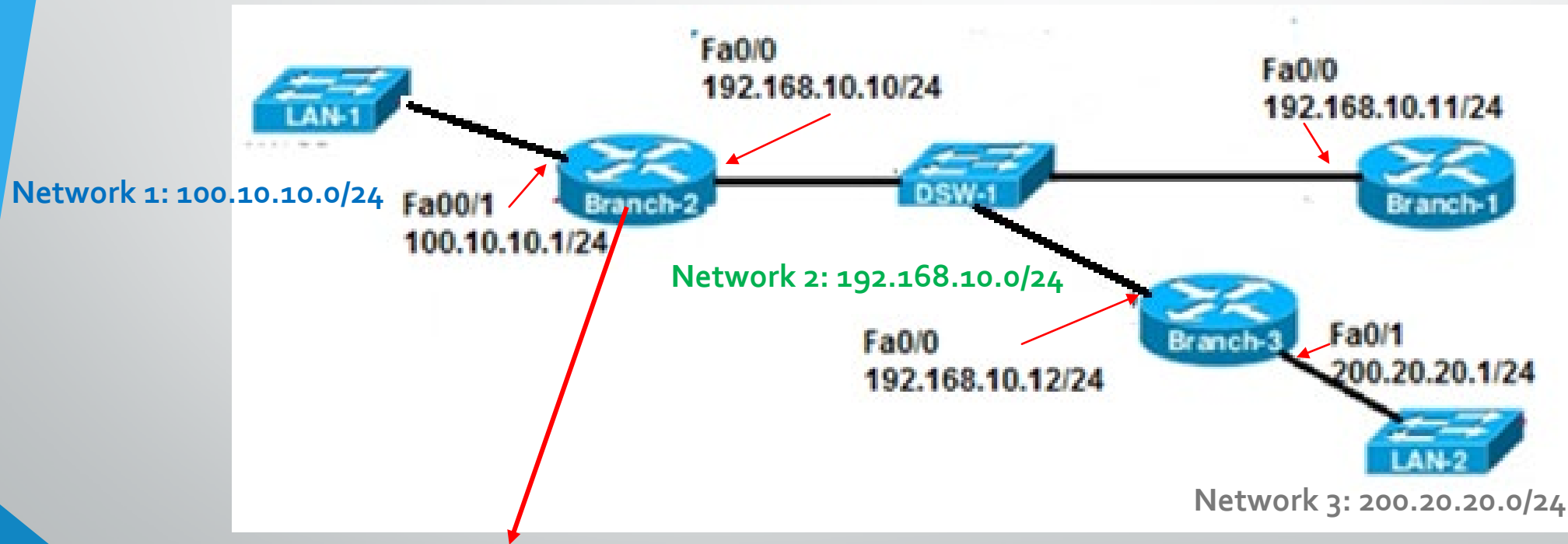
- Before any packet is forwarded by a router, the routing table process must determine the exit interface to use to forward the packet.
- When the router has to perform multiple lookups in the routing table before forwarding a packet, it is performing a process known as a **Recursive Route Lookup**.

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



# Configuring a Fully Specified Static Route

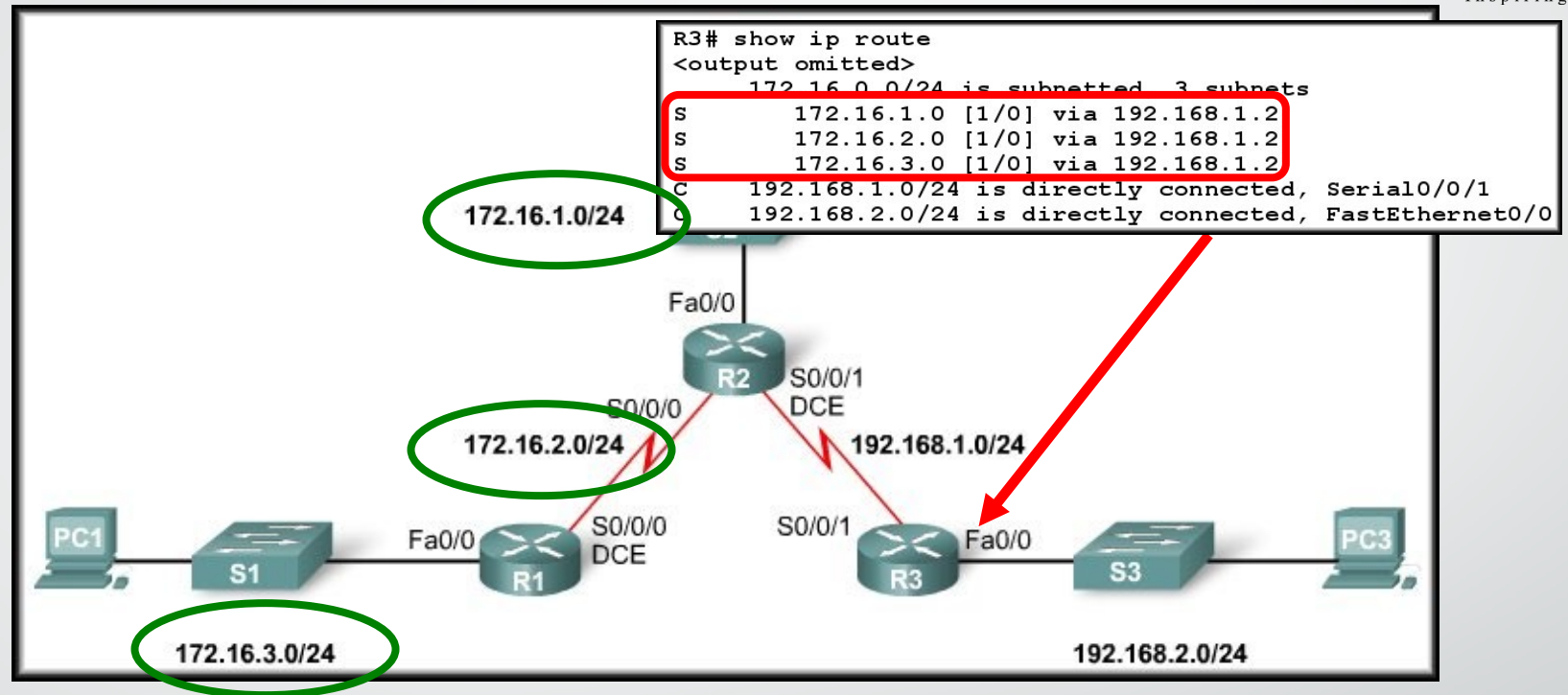
- Both the **output interface** and the **next-hop IP** address are specified.
- It's used when the output interface is a **multi-access interface** and it is necessary to explicitly identify the next hop else, the Router will have difficulty determining the destination MAC address.



```
Branch-2 (config)#ip route 200.20.20.0 255.255.255.0 fa0/0 192.168.10.12
```

**Recommended**

# Configuring a Summary Static Route



- R3 has three static routes configured.
- All three routes are forwarding traffic out the same Serial 0/0/1 interface.
- Can be summarized to **172.16.0.0 / 22 (255.255.252.0)**



# Verifying Summary Static Route

```

R3# show ip route
<output omitted>
    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
...
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

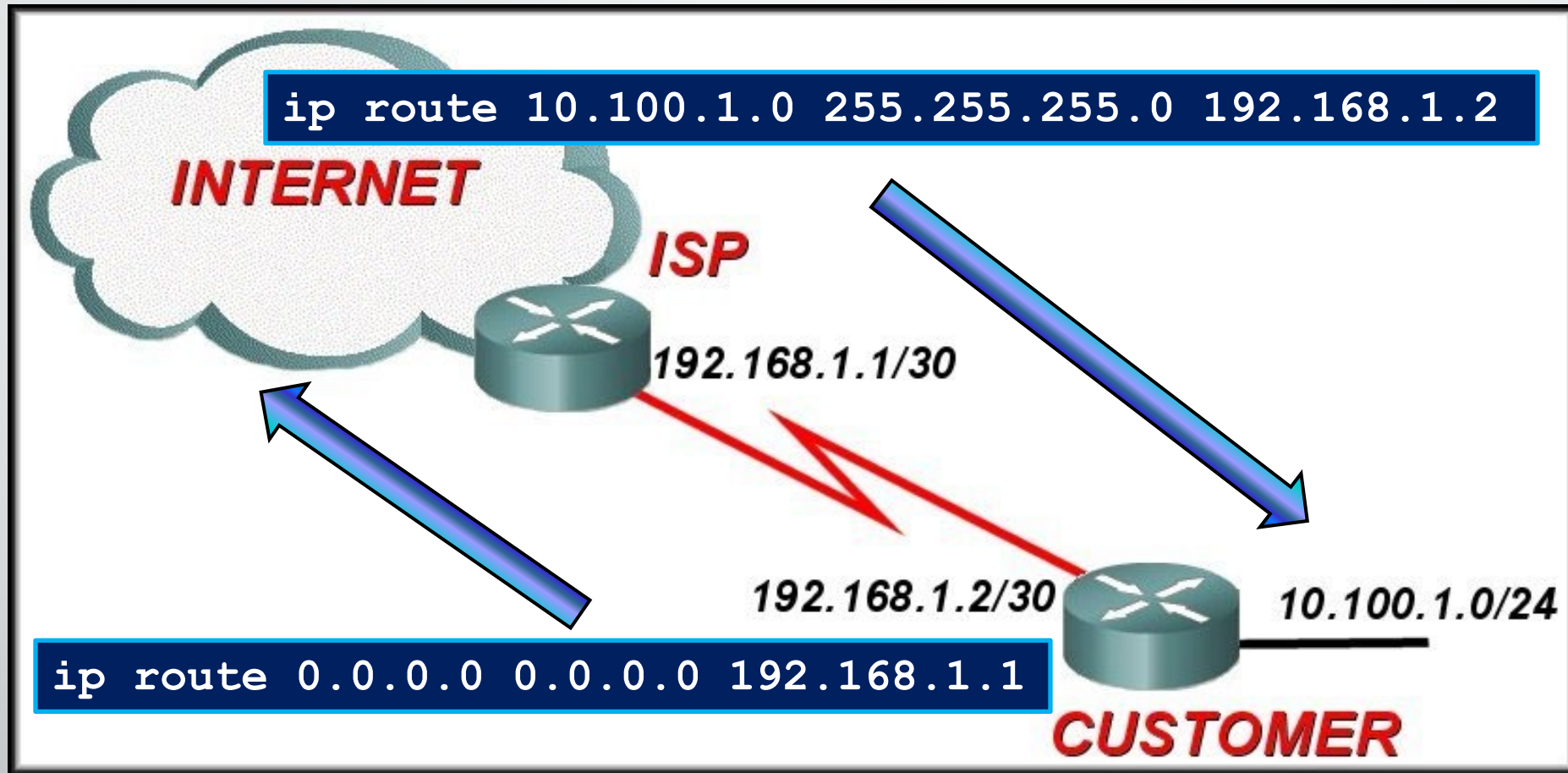
R3(config)# ip route 172.16.0.0 255.255.252.0 192.168.1.2

    172.16.0.0/22 is subnetted, 1 subnets
S       172.16.0.0 [1/0] via 192.168.1.2
C       192.168.1.0/24 is directly connected, Serial0/1
C       192.168.2.0/24 is directly connected, FastEthernet0/0
  
```

- Any packet with a destination IP address belonging to **the 172.16.1.0/24, 172.16.2.0/24, or 172.16.3.0/24** network matches this summarized route.



# Configuring Default Static Route



- **\*\*Note:** A static route usually always points towards the specific network, while default static route points towards outside the network where a border router is connected to the internet

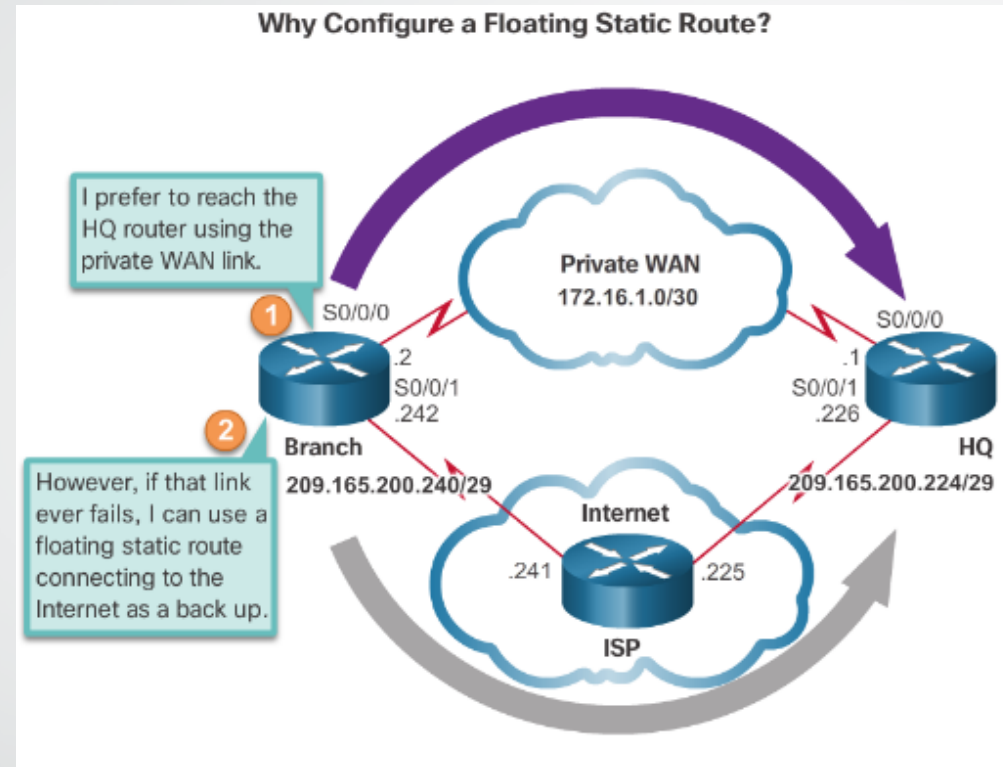
# Verifying Default Static Route

```
CUSTOMER#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
<output omitted>
      * - candidate default, U - per-user static route, o - ODR
      P - periodic downloaded static route

Gateway of last resort is 192.168.1.1 to network 0.0.0.0

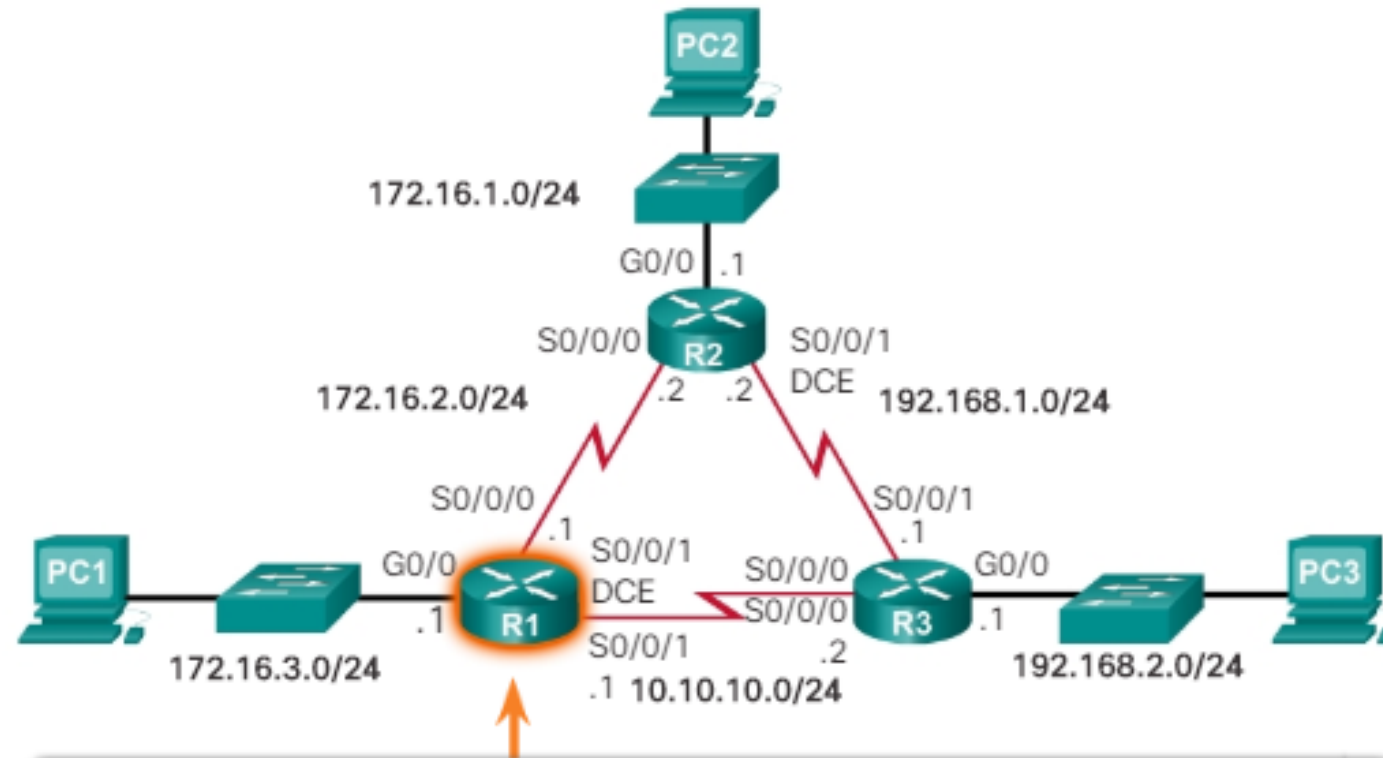
  10.0.0.0/8 is subnetted, 1 subnets
C    10.100.1.0/24 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
S*   0.0.0.0/0 [1/0] via 192.168.1.1
```

# Configuring a Floating Static Route



- **Branch(config)#ip route 209.165.200.224 255.255.255.240 S0/0/0**
- **Branch(config)#ip route 209.165.200.224 255.255.255.240 S0/0/1 5**  
AD > 1
  - \*In other words, the AD has to be **more than** the AD of sthe primary route.
  - \*\* A primary route may be set to have other AD values
  - \*\*There can be **more than one** back up route, or, a **back up** of the back up route.

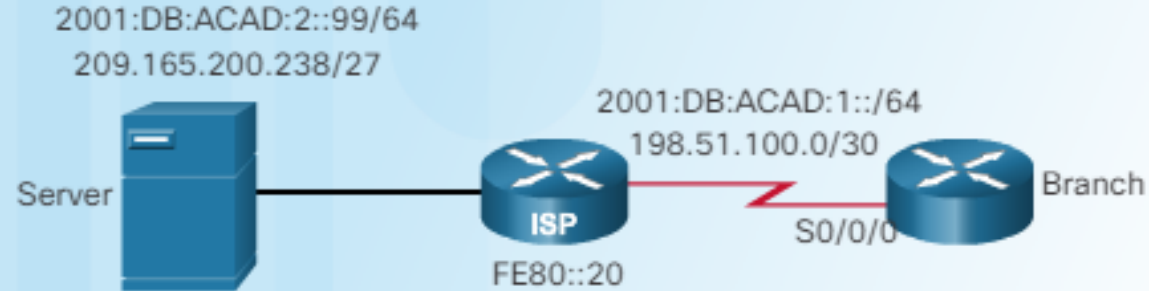
# Configuring Floating Default Static Route



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

# Automatically Installed Host Routes

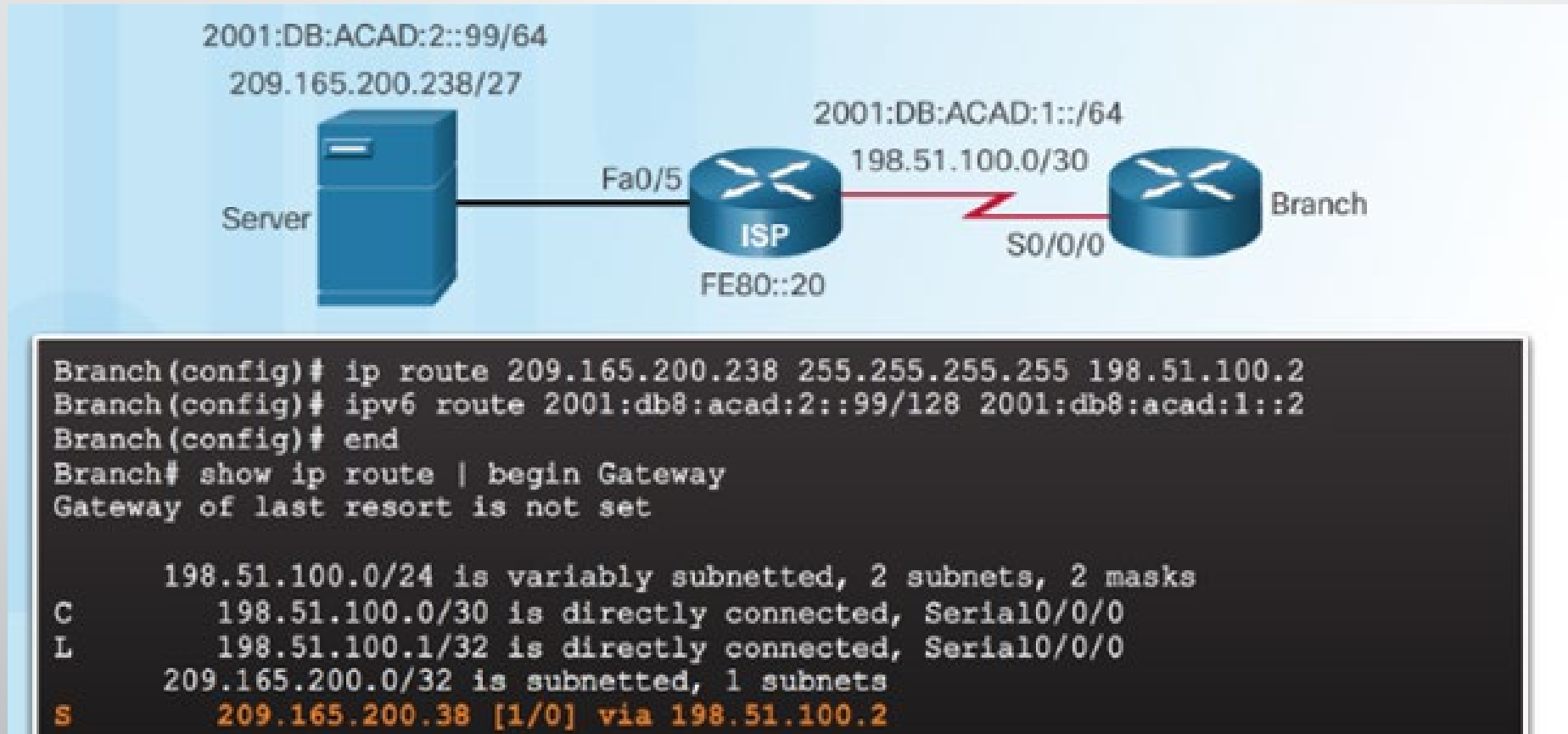
Branch IPv4 Routing Table



```
Branch# 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
       a - application route
       + - replicated route, % - next hop override
Gateway of last resort is not set

      198.51.100.0/24 is variably subnetted, 2 subnets, 2 masks
C       198.51.100.0/30 is directly connected, Serial0/0/0
L       198.51.100.1/32 is directly connected, Serial0/0/0
Branch#
```

# Configure IPv4 Static Host Routes



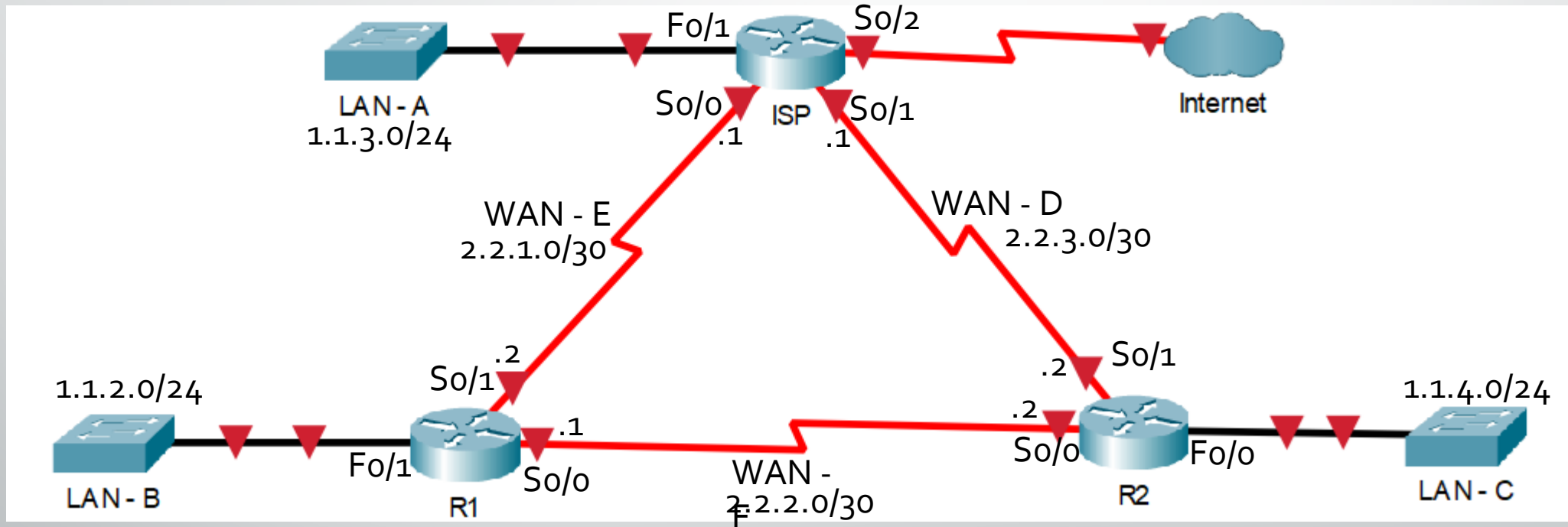


# Commands to Verify Static Routes

- Along with **ping** and **tracert**, useful commands to verify static routes include:
  - `show ip route`
  - `show ip route static`
  - `show ip route network`

# Example Network for routing

- Try to configure the following on Cisco Packet Tracer
  - \*\*Use the power of Google to search and find how to configure if you get stuck.



# The End