Network Layer: IPv4 Static Routing

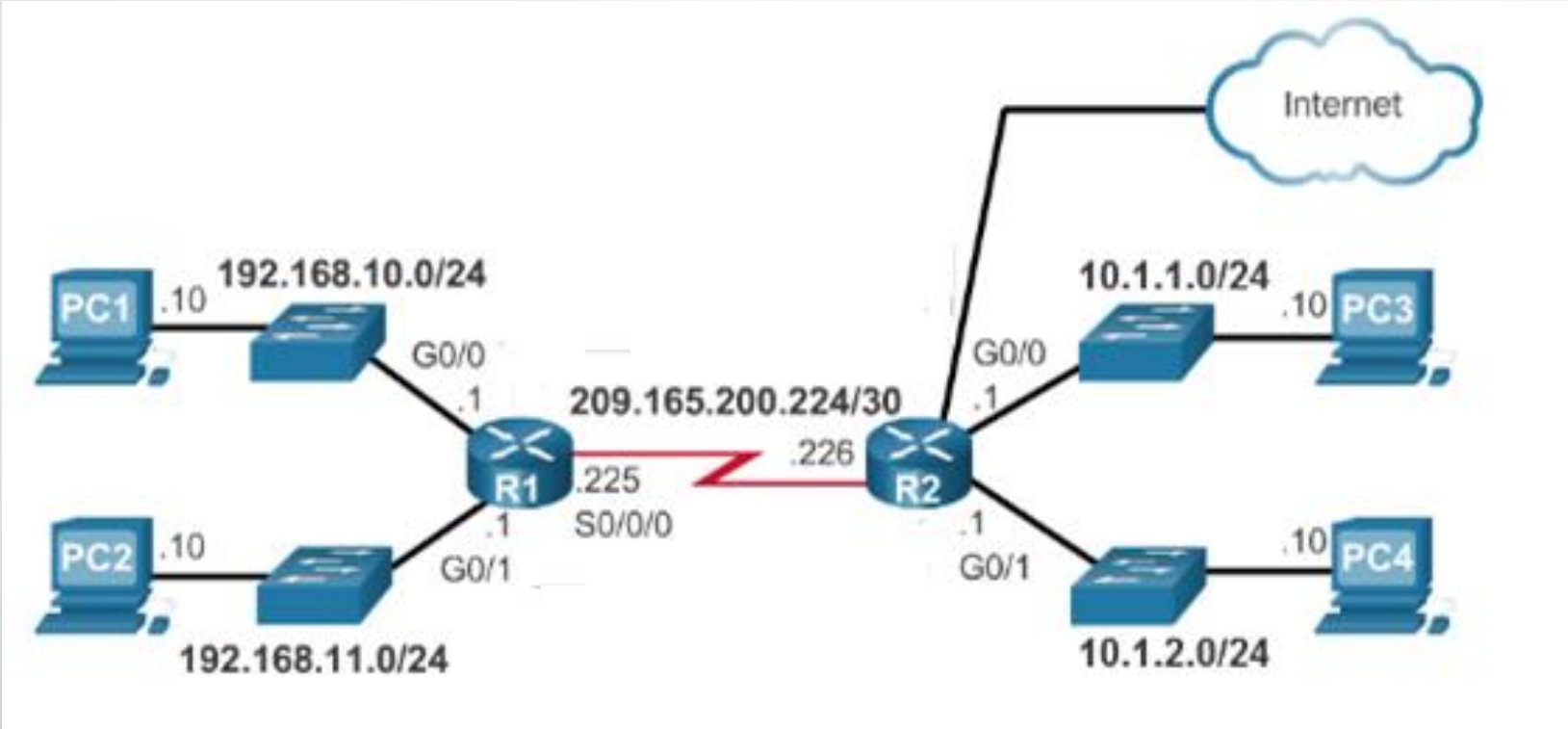
Lecture 12 | CSE421 – Computer Networks

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



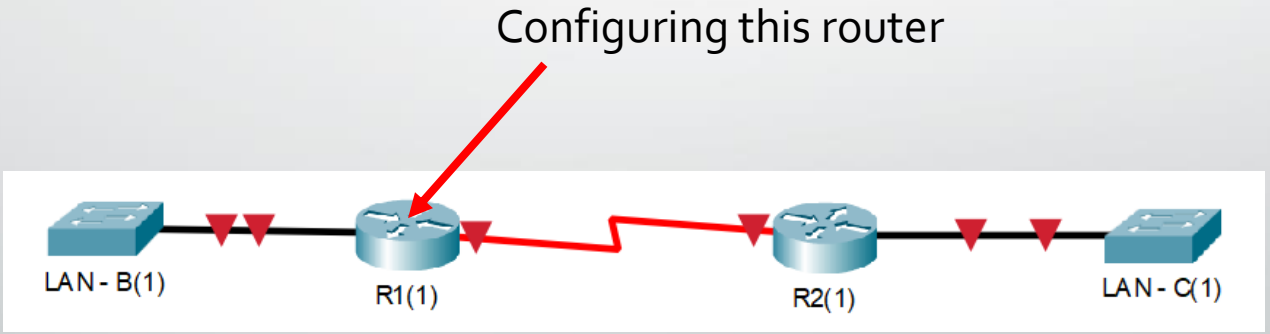
Learning About Remote Networks

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

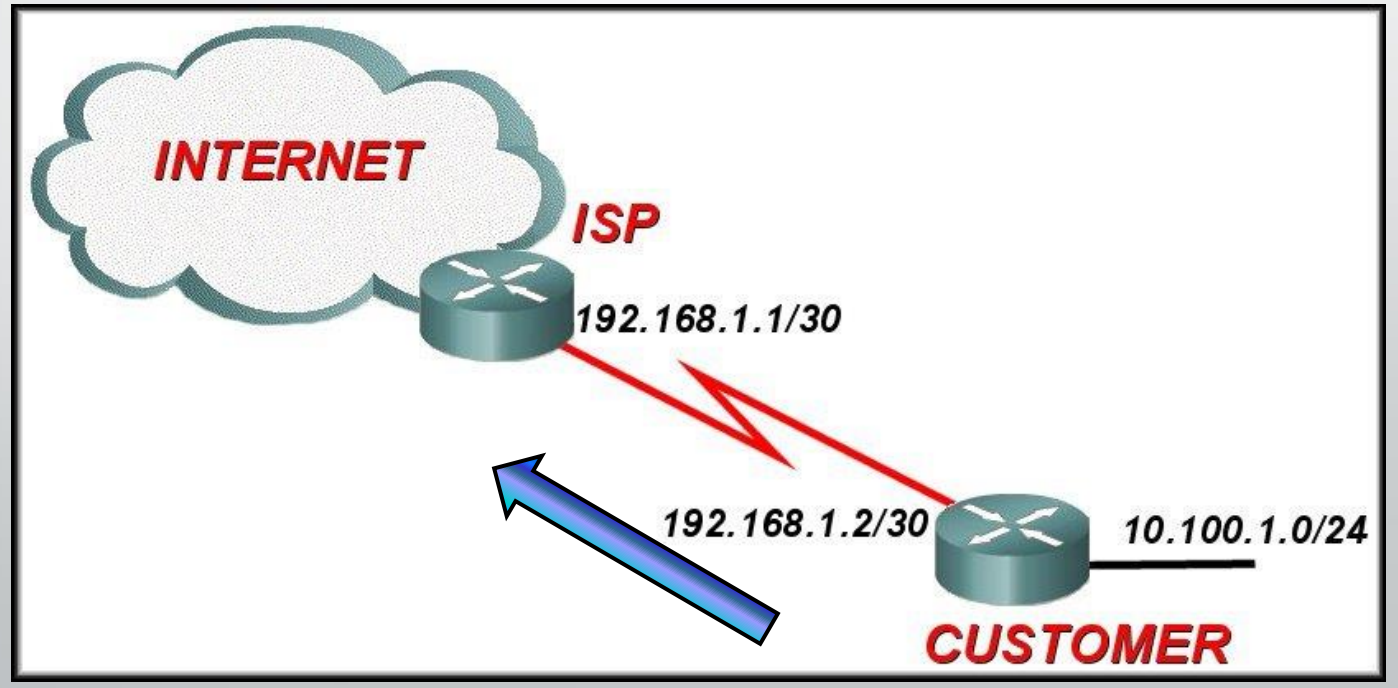
Standard Static Routing

- 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**



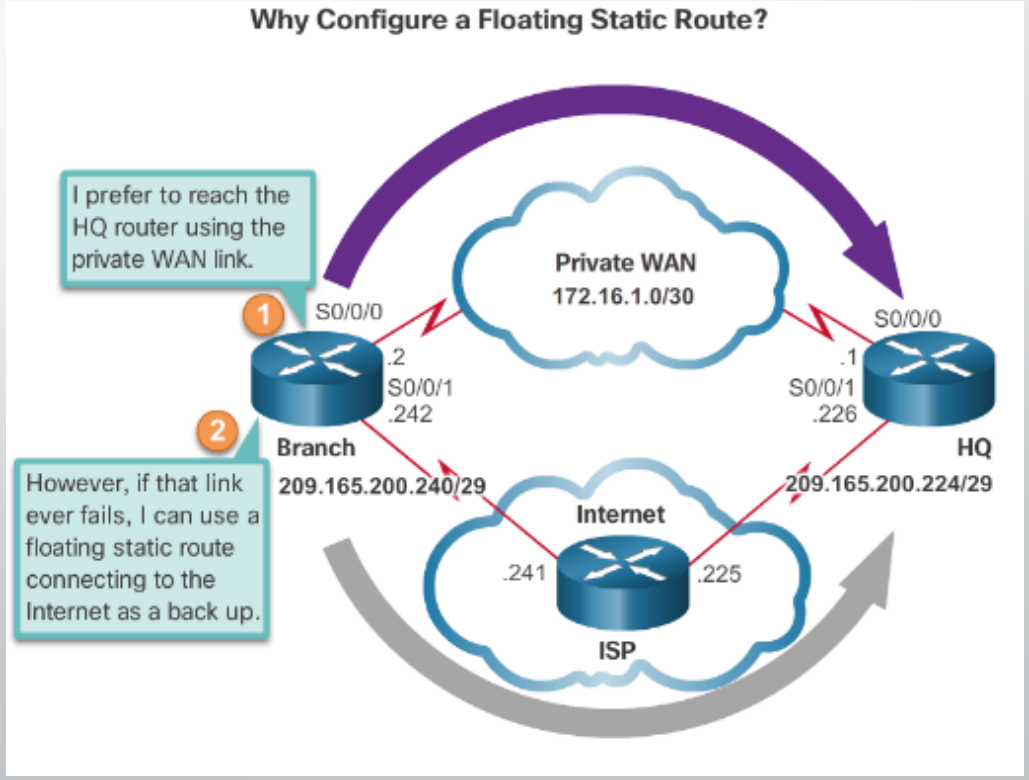
Default Static Routing

- 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.



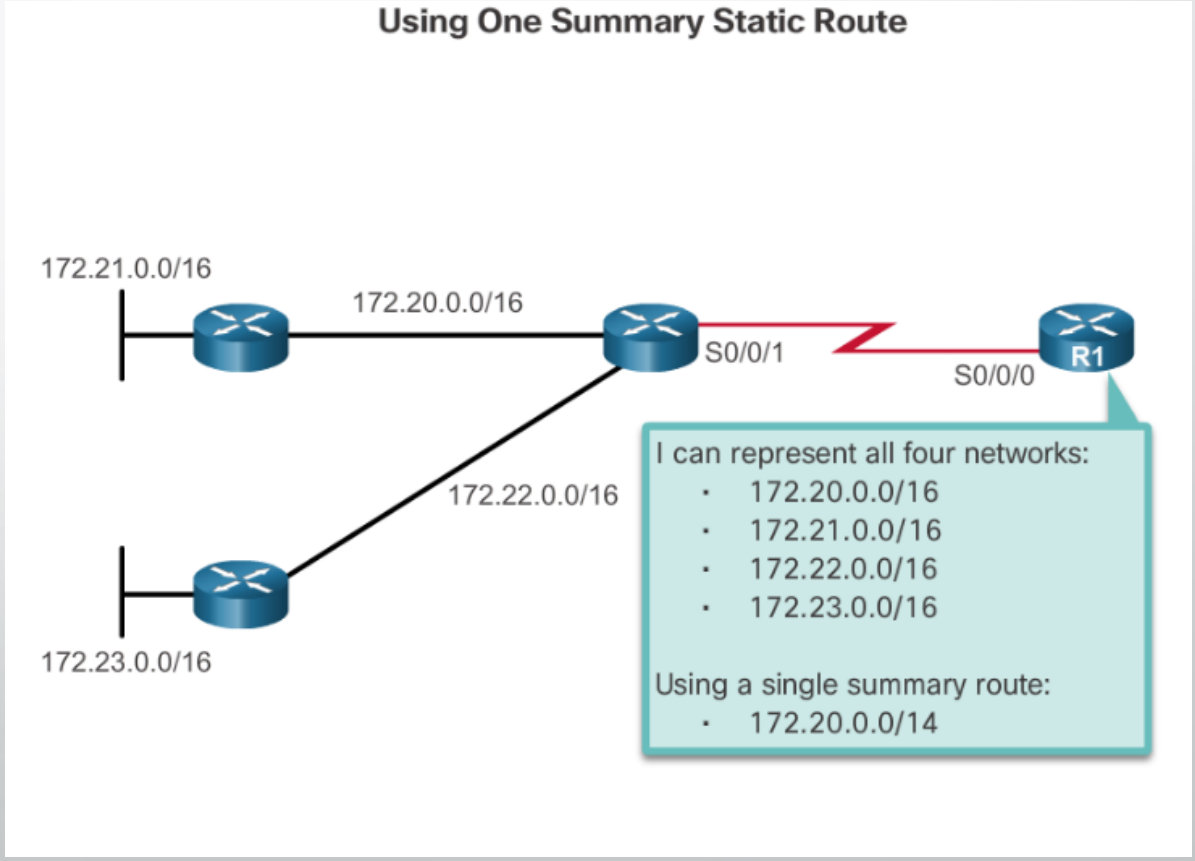
Floating Static Routing

- 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



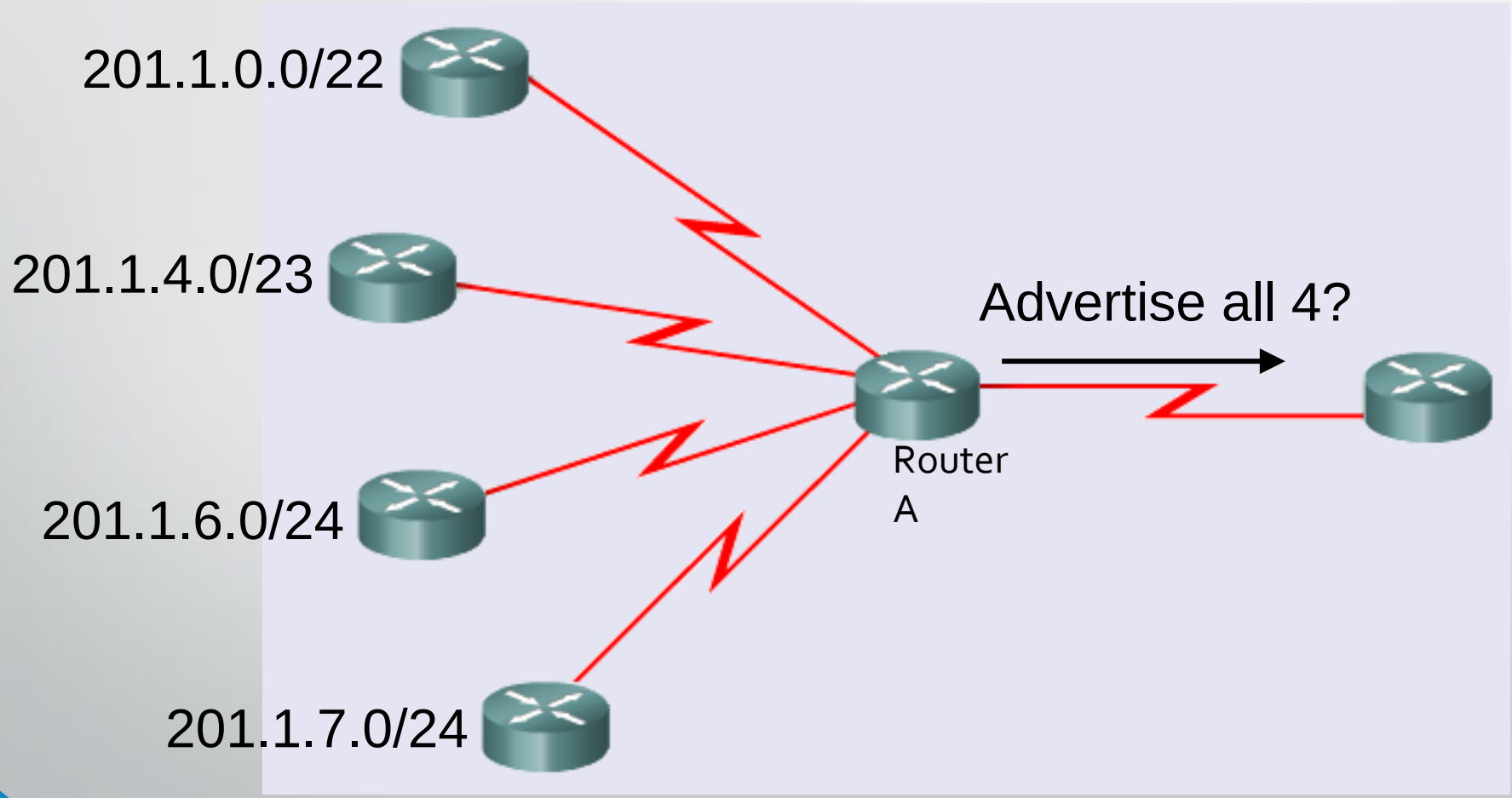
Summary Static Routing

- 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

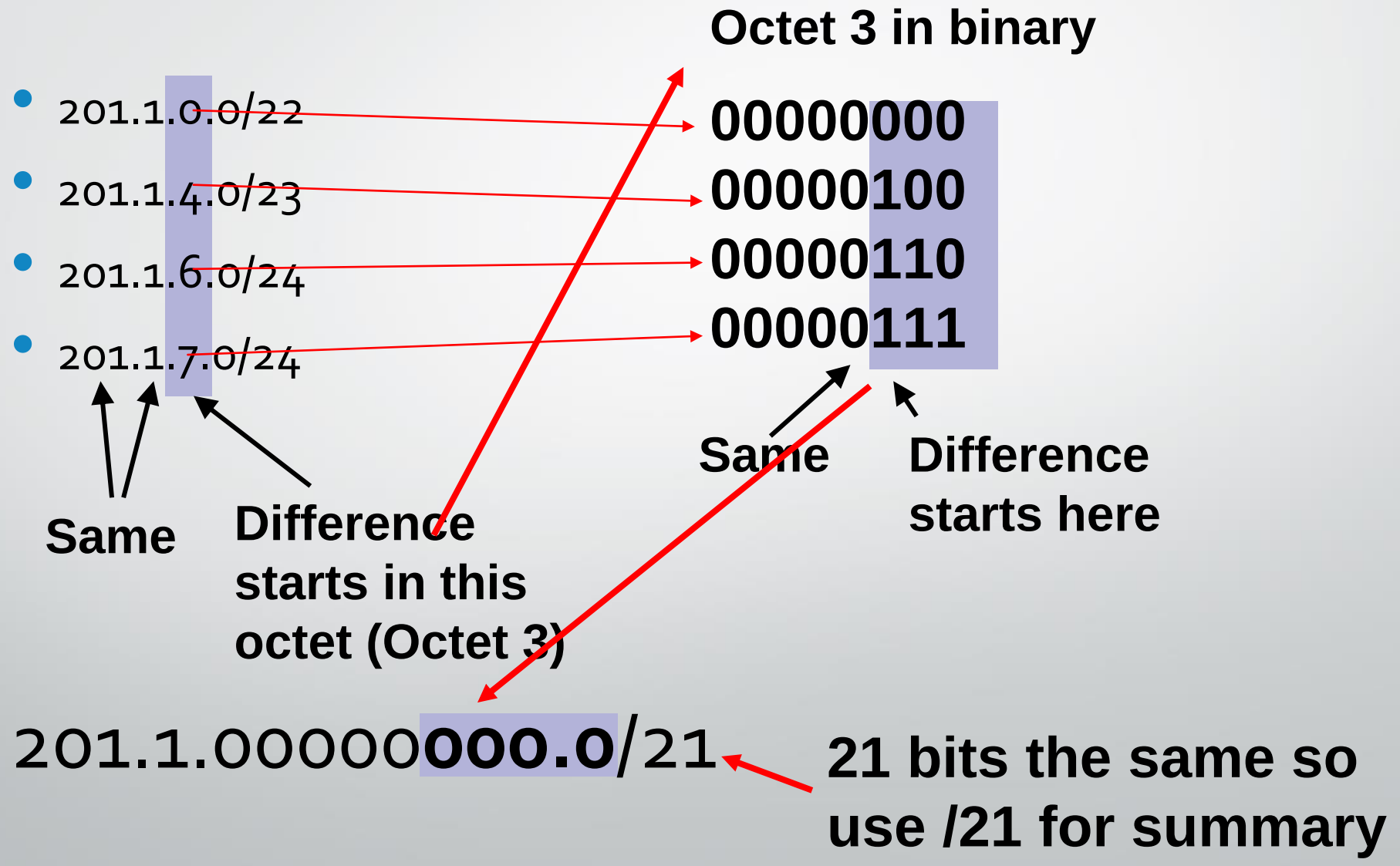


Route Summarization

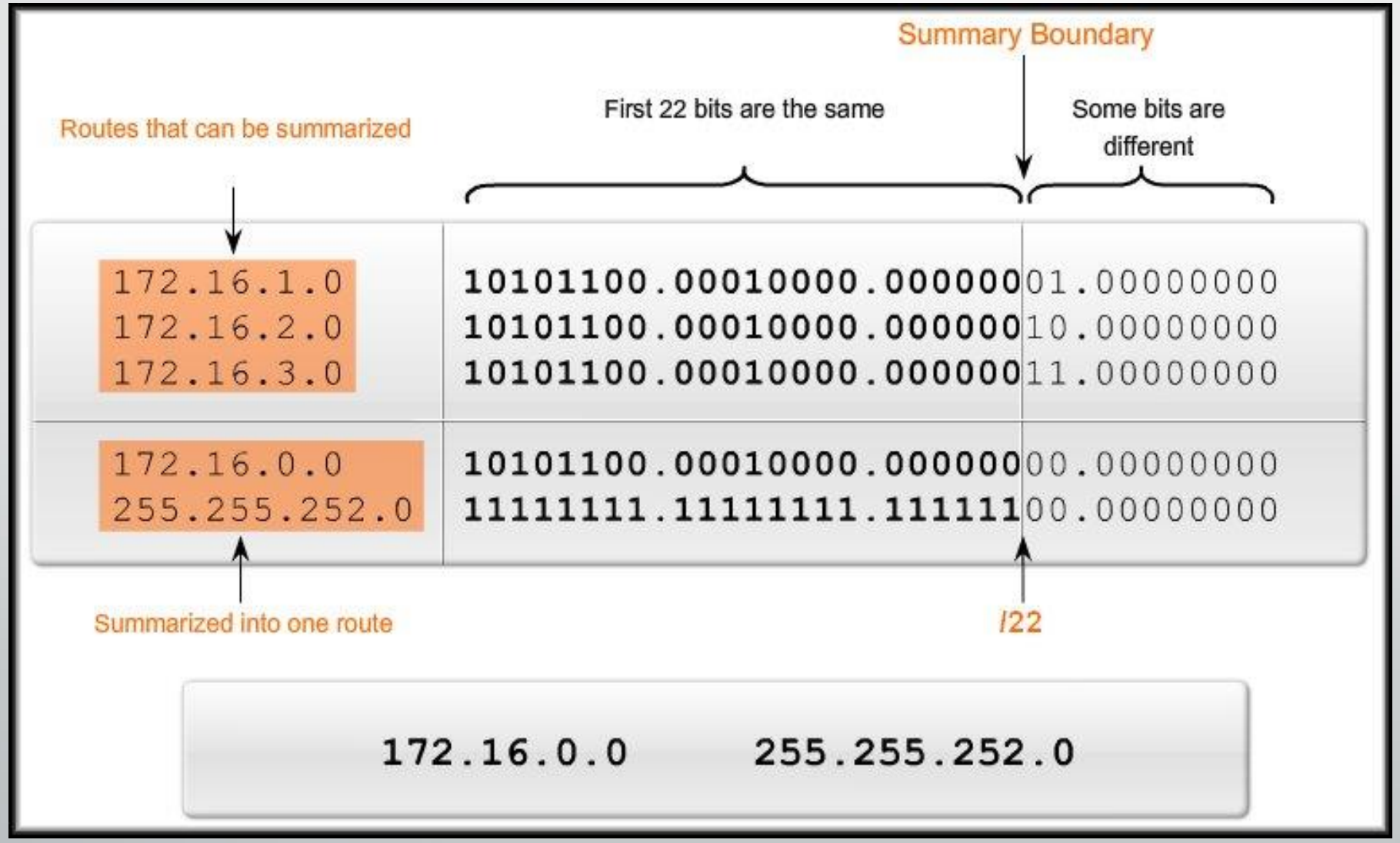
- How many entries does Router A have in it's routing table?



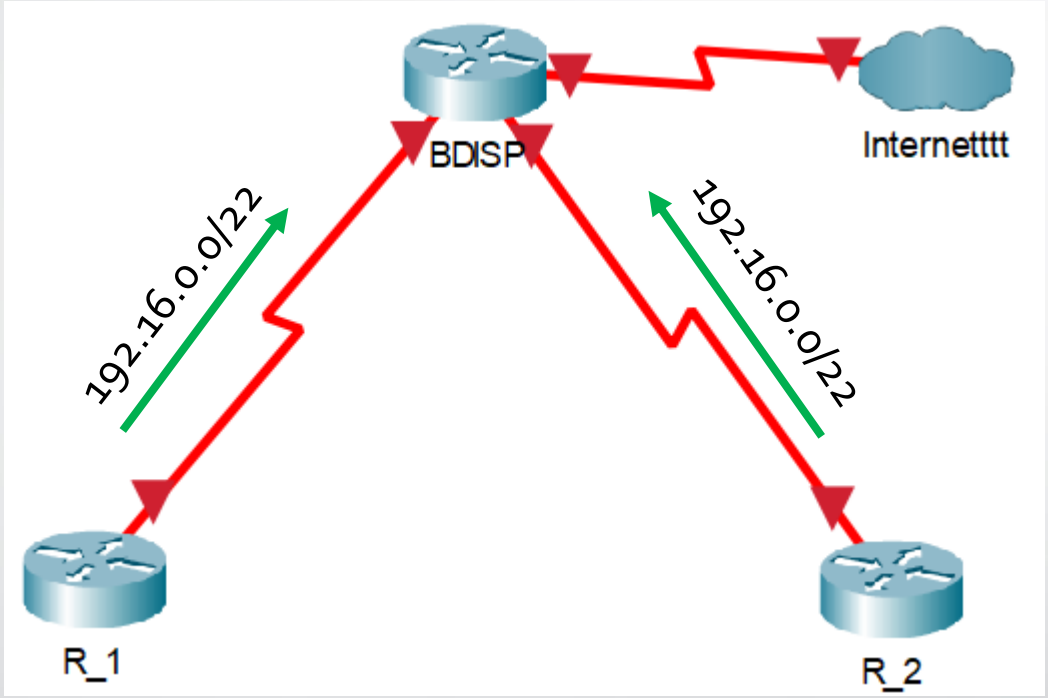
Route Summarization



Route Summarization Another Example



Problem of Summary Static Routing



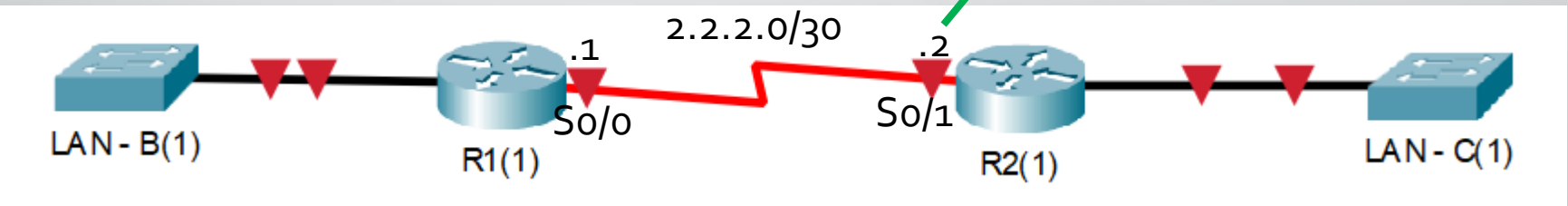
192.16.0.0/24
192.16.2.0/24

192.16.1.0/24
192.16.3.0/24

Discontiguous Networks

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

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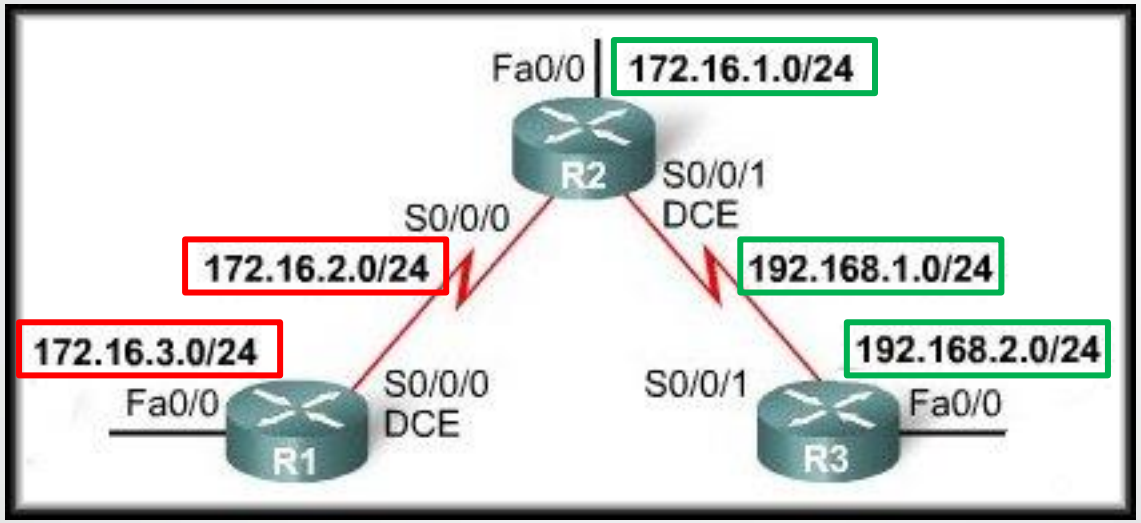
Configuration

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 they **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

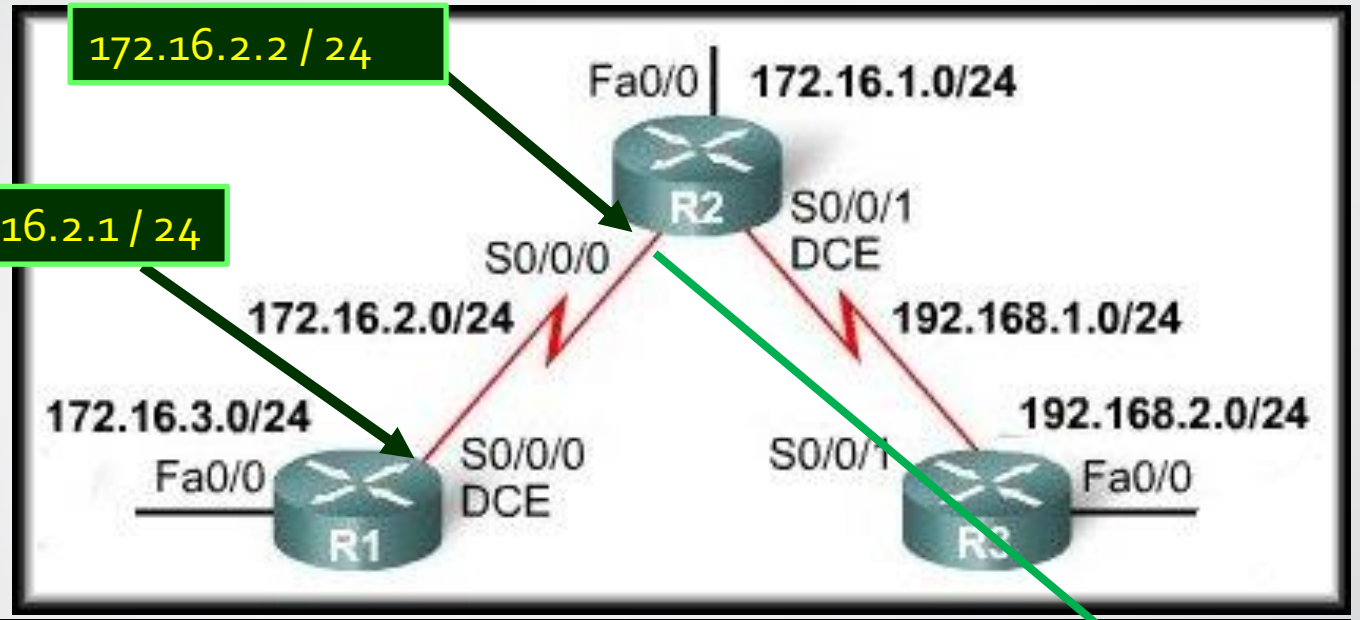
- A router, by default, knows of its directly connected networks only.




```
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

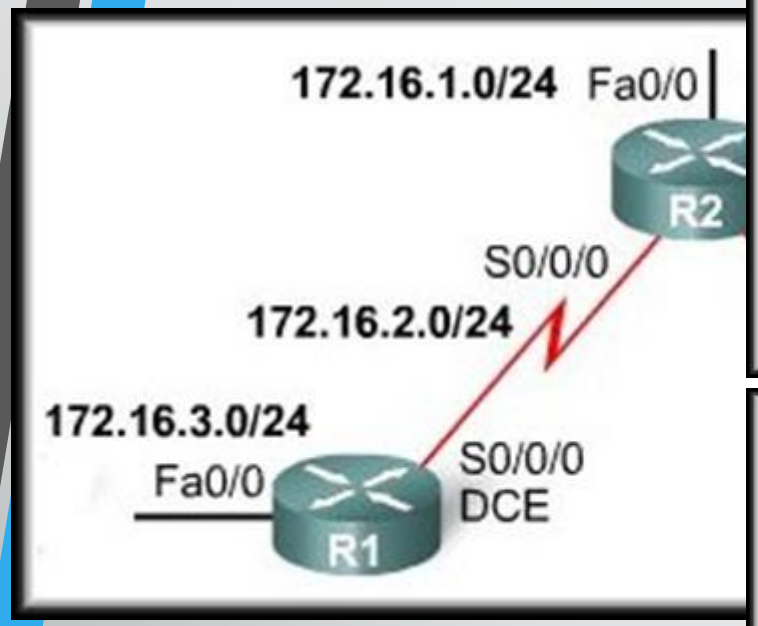
- The command to add a static route **on R1** towards **LAN of R2** using **Next-Hop IP.**




```
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

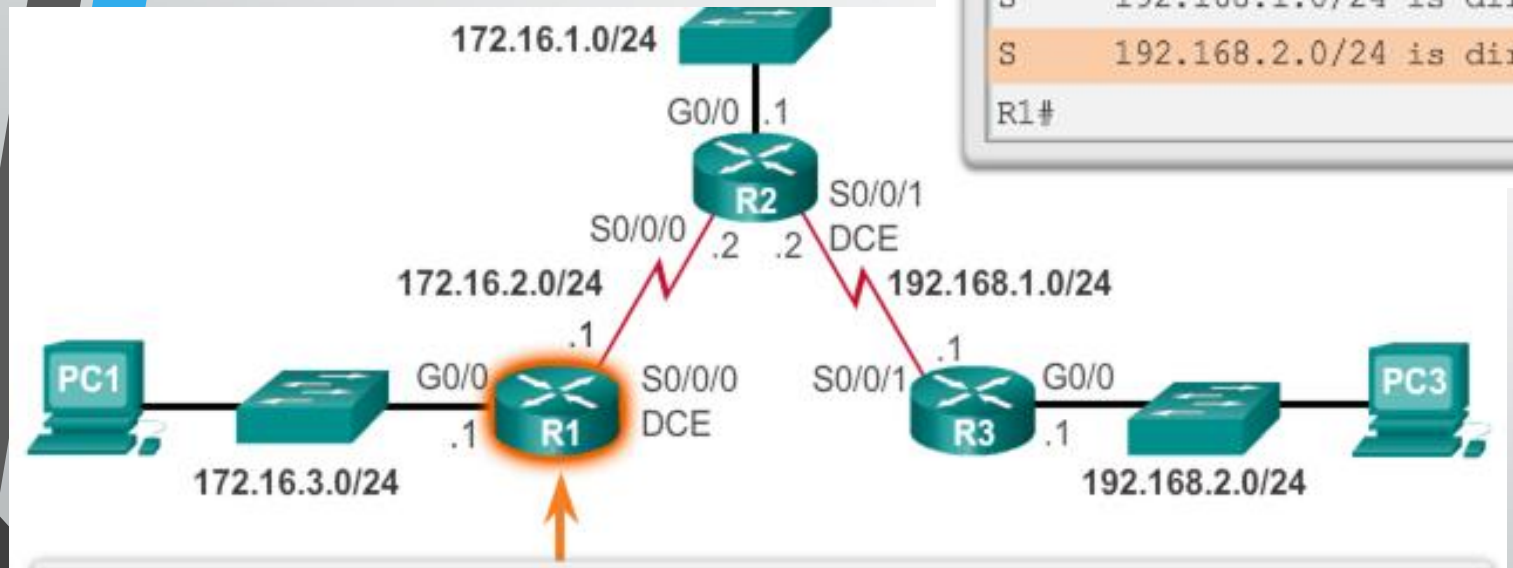
```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

<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

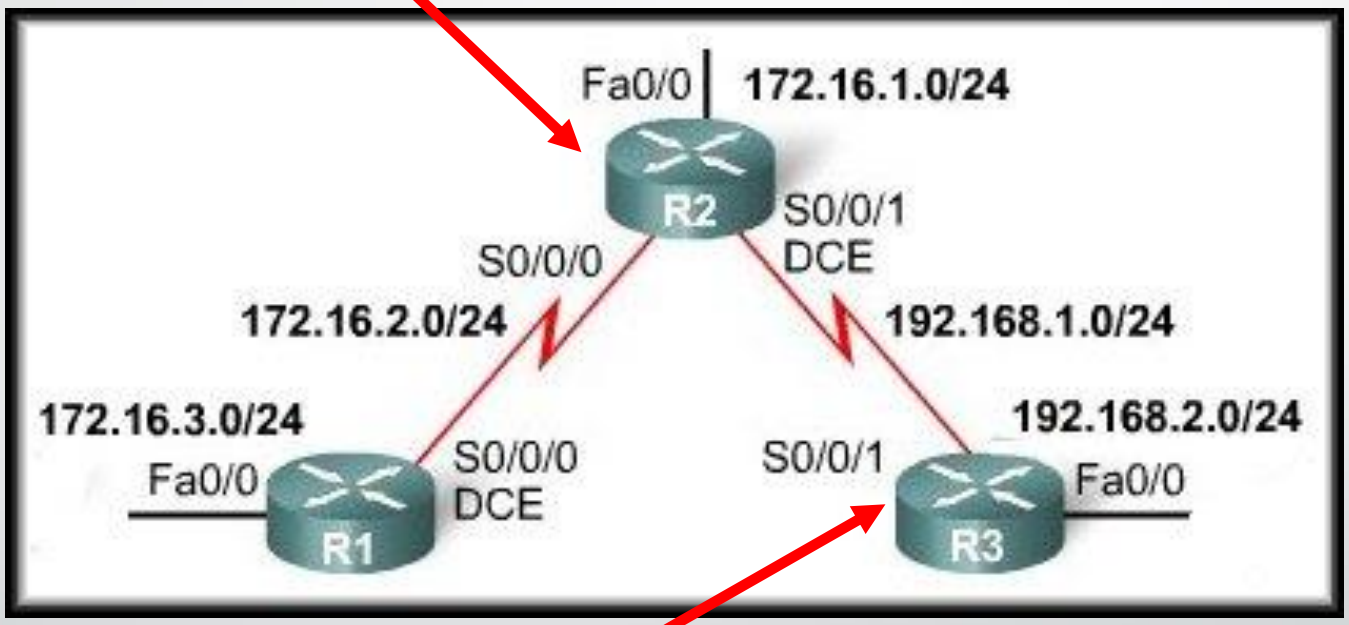
Next Hop IP
Or, Exit Interface
Or, Fully Specified

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

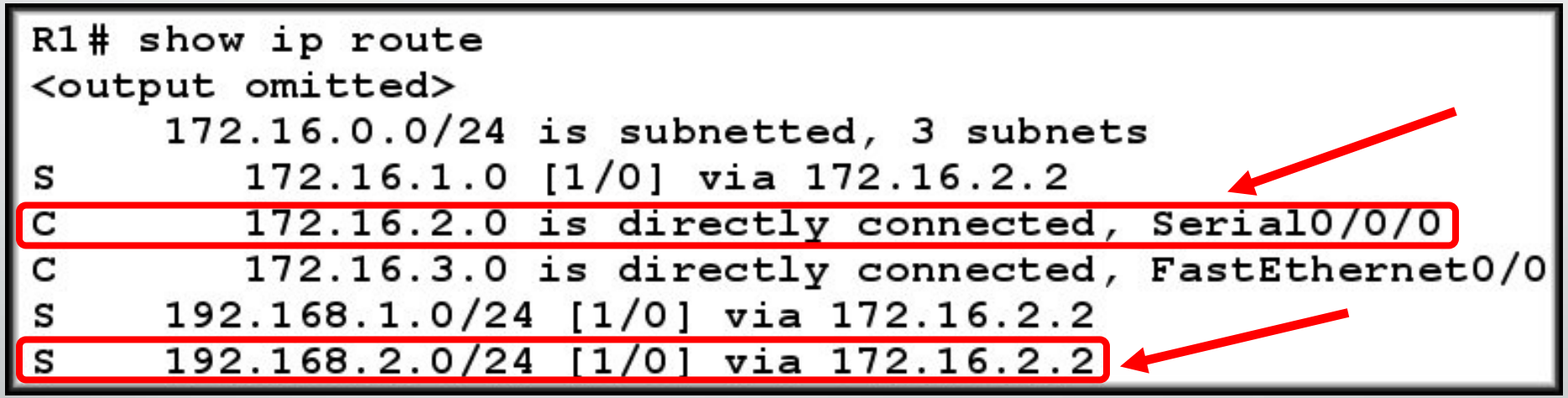
```
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0/24 [1/0] via 172.16.2.2
S    192.168.2.0/24 [1/0]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

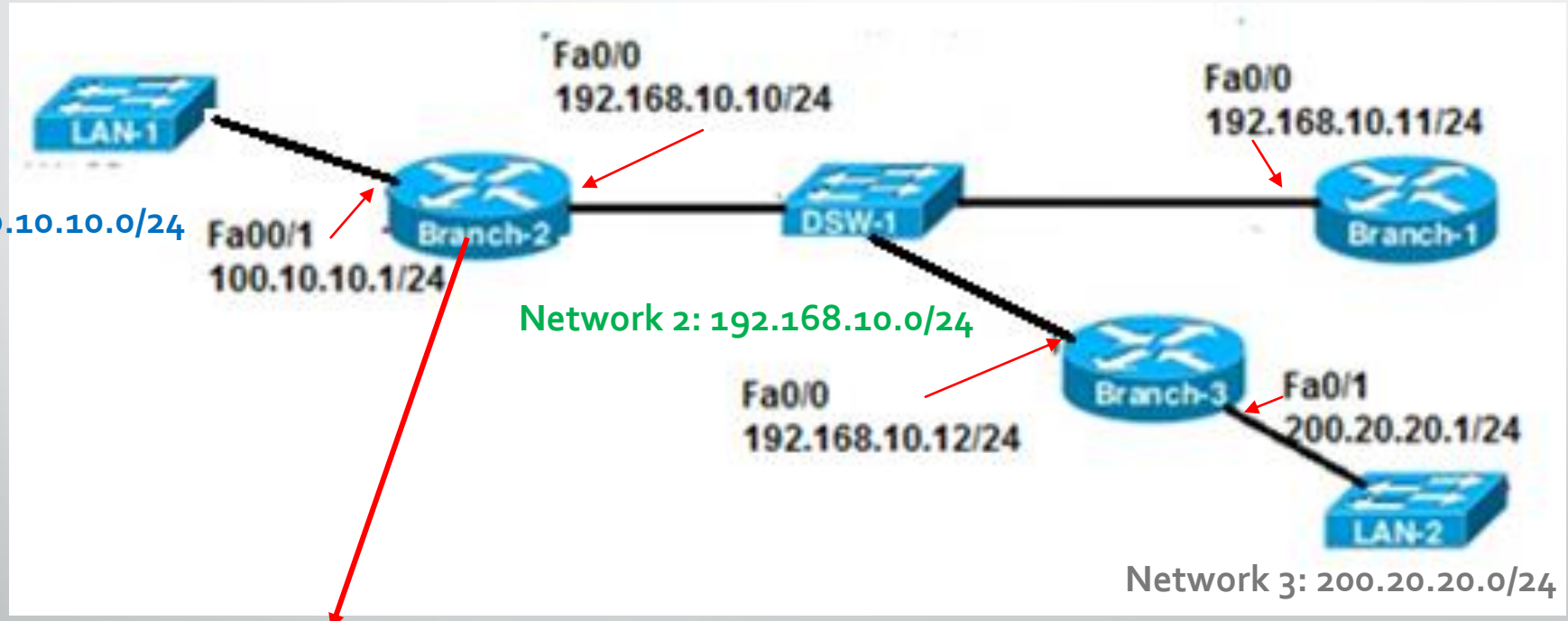
The Disadvantage of using Next Hop IP

- 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**.



Configuring a Fully Specified Static Route

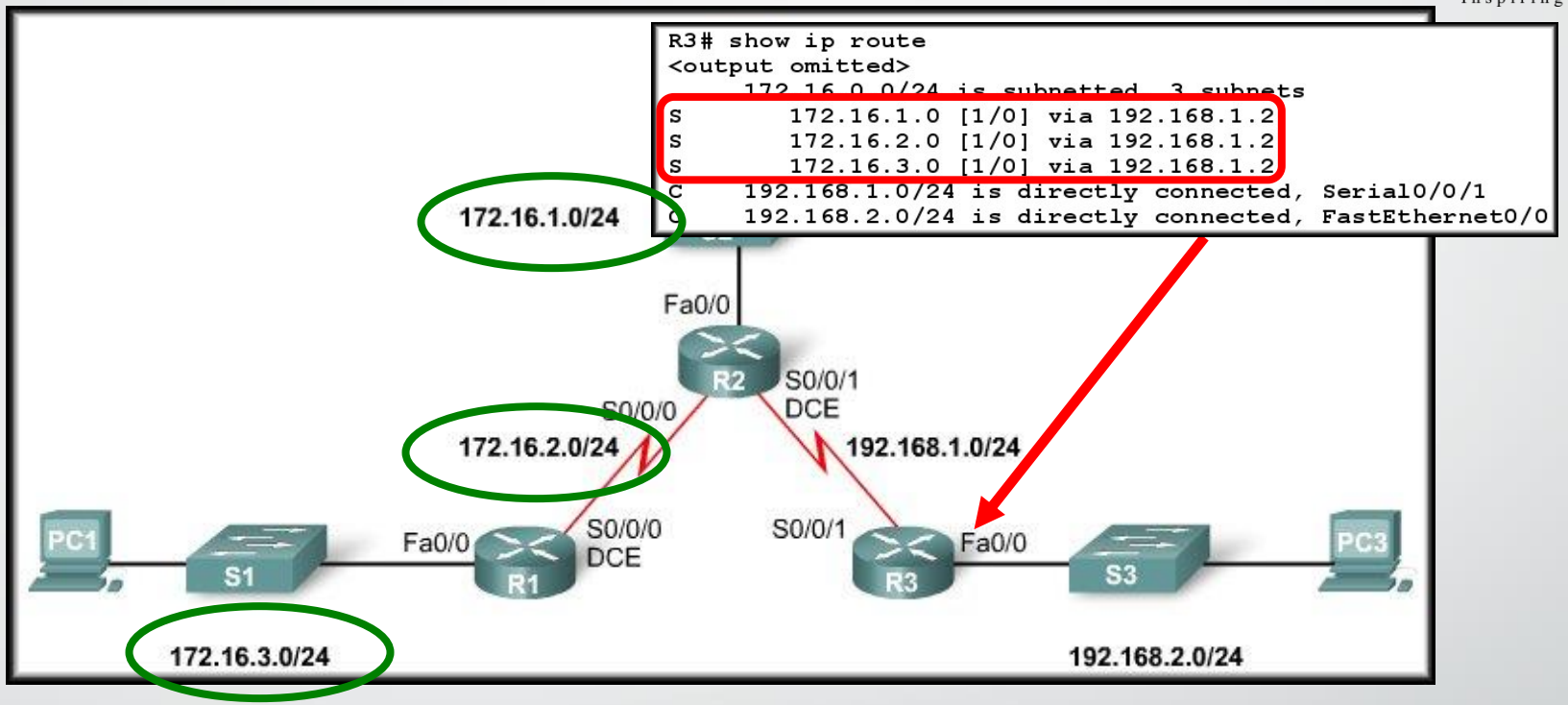
- Both the **output interface** and the **next-hop IP** address are specified.
- It's used when the output interface is a **multi-access interface** and it is necessary to explicitly identify the next hop else, the Router will have difficulty determining the destination MAC address.




```
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
```

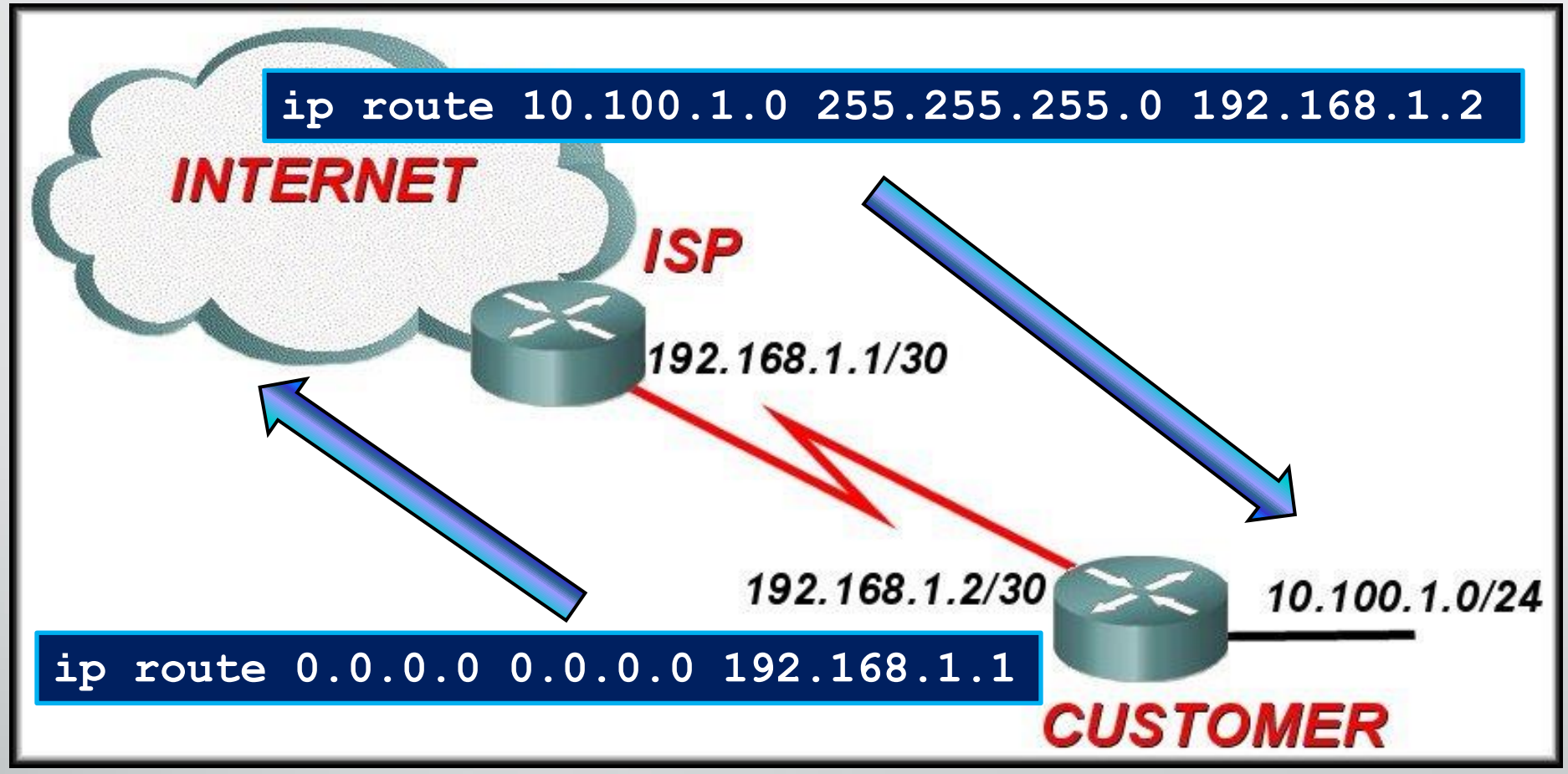
BEFORE

```
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

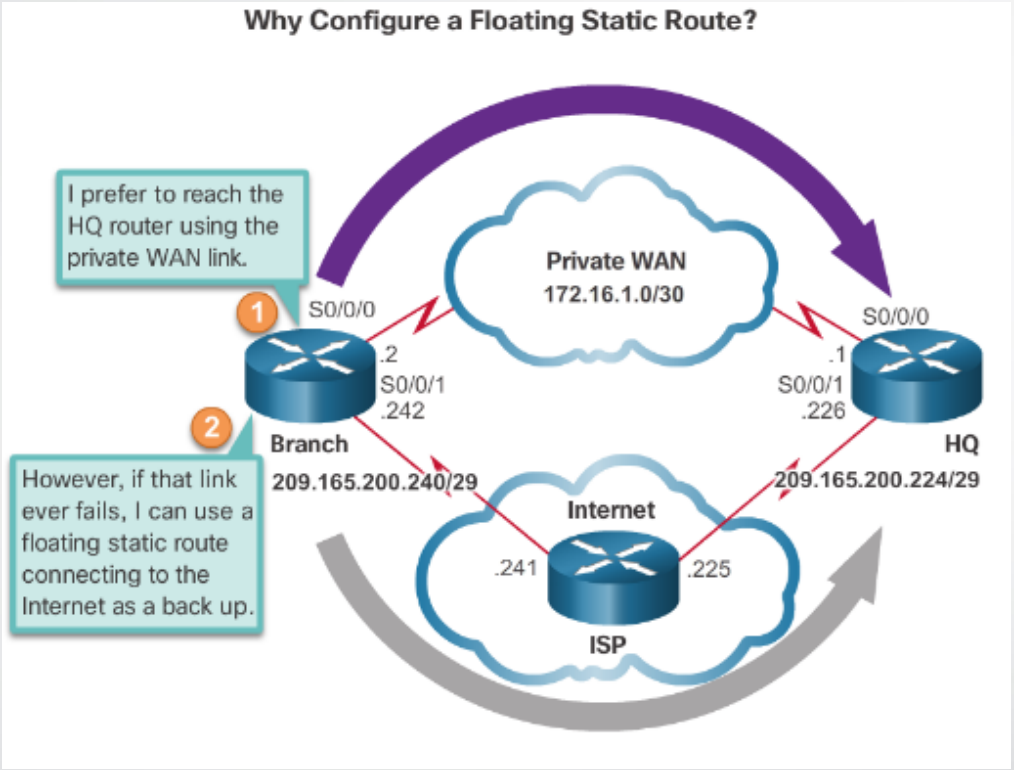


- **Note: A static route usually always points towards the specific network, while default static route points towards outside the network where a border router is connected to the internet

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

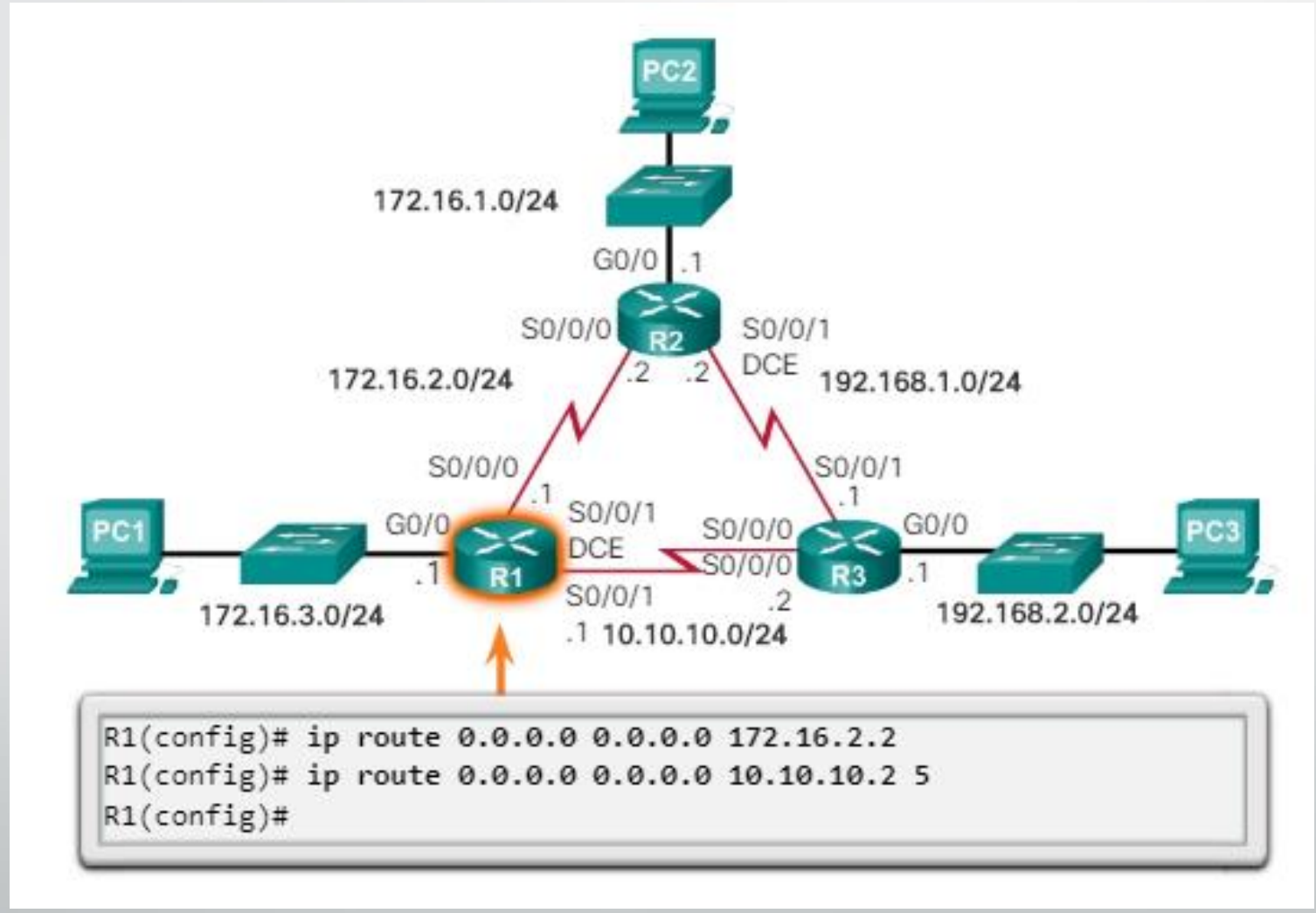


- `Branch(config)#ip route 209.165.200.224 255.255.255.240 S0/0/0`
- `Branch(config)#ip route 209.165.200.224 255.255.255.240 S0/0/1 5`

  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

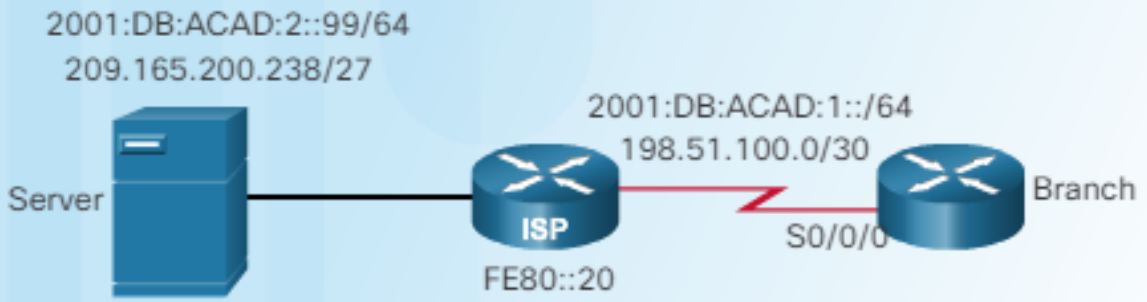
  There can be **more than one back up route, or, **a back up** of the back up route.

Configuring Floating Default Static Route



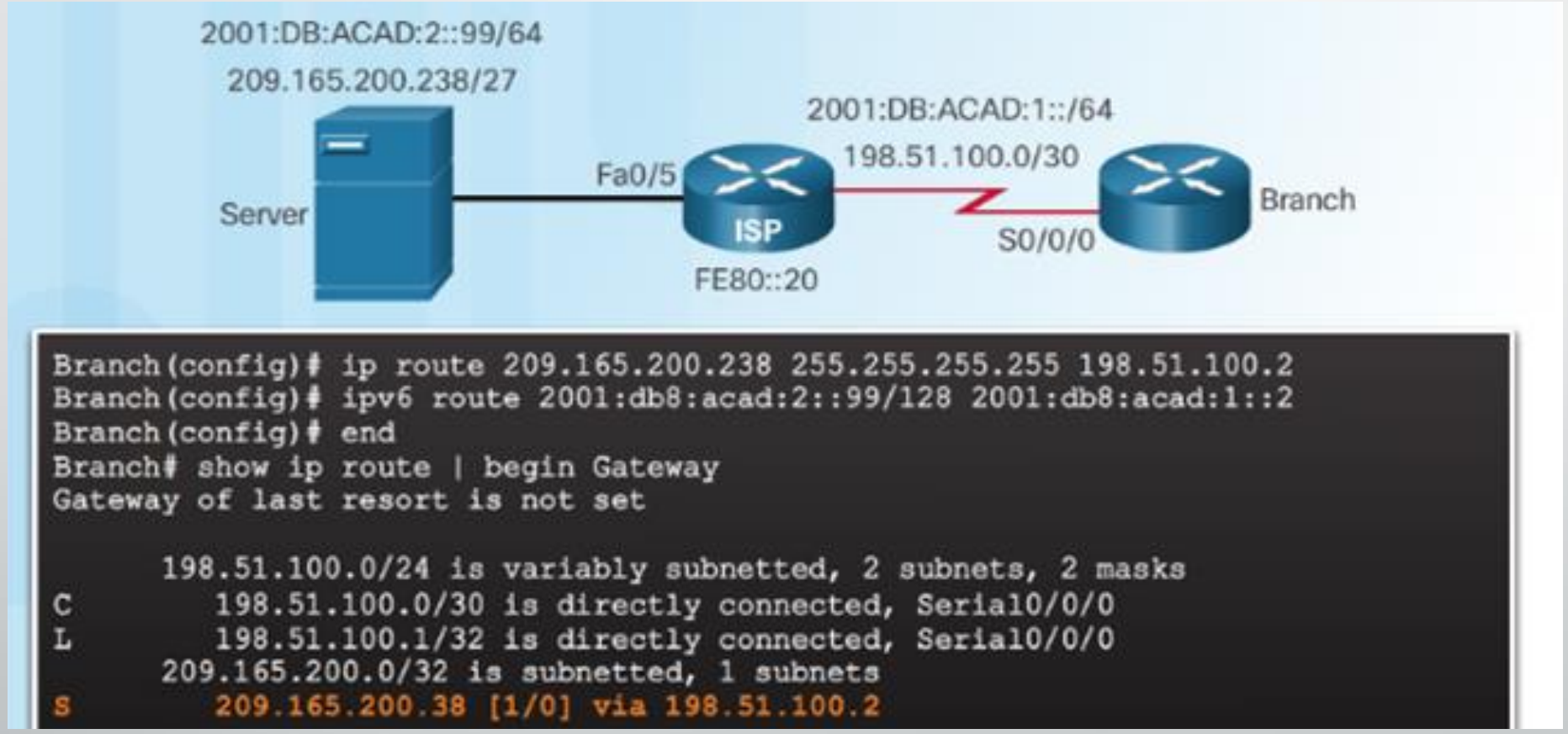
Automatically Installed Host Routes

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

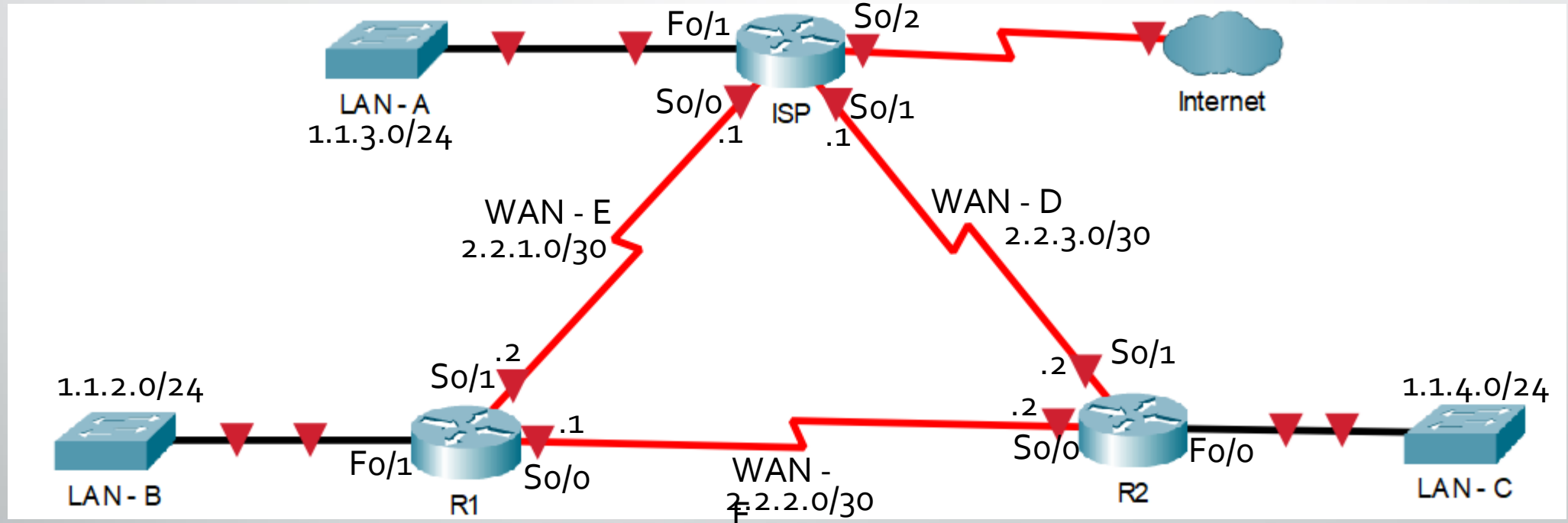


Commands to Verify Static Routes

- Along with **ping** and **traceroute**, 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