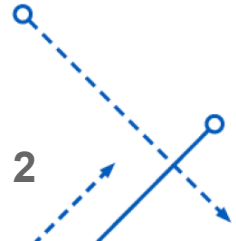
The University of Danang
University of Science and Technology

STATIC ROUTING

FACULTY OF INFORMATION TECHNOLOGY
PhD. LE TRAN DUC

OUTLINE

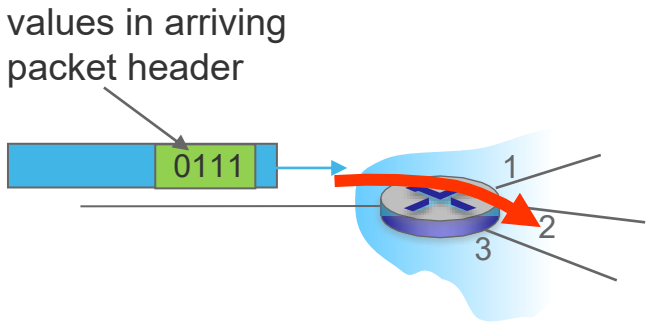
1. Data plane & Control plane
2. IP Routing process
3. The routing table on a cisco router
4. Configuring static route



NETWORK LAYER: DATA PLANE, CONTROL PLANE

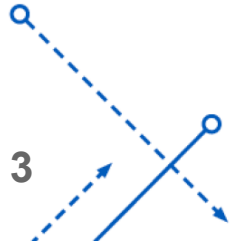
Data plane

- Local, per-router function
- Determines how packet arriving on router-input-port is forwarded to router-output-port
- Forwarding function



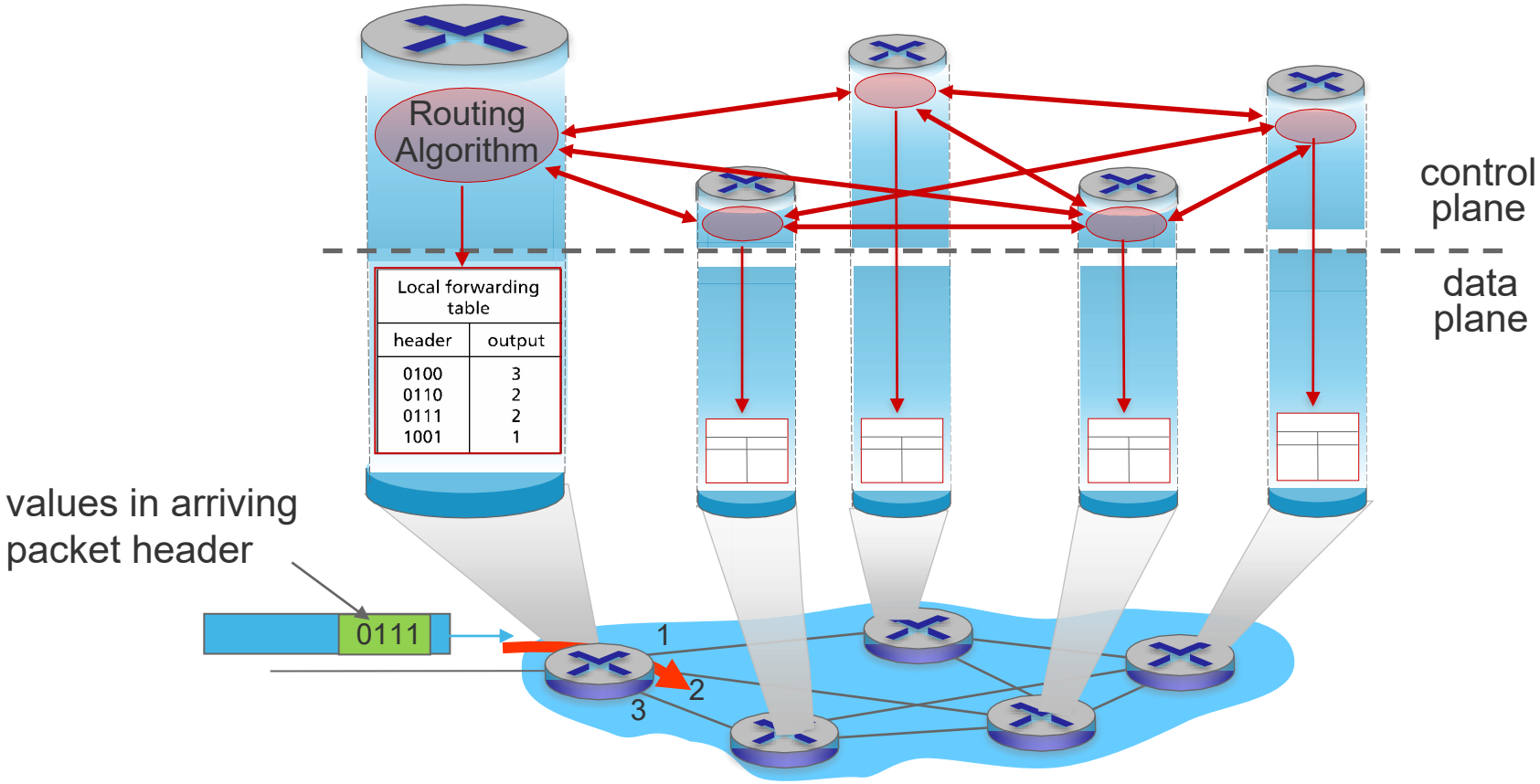
Control plane

- Network-wide logic
- Determines how packet is routed among routers along end-to-end path from source host to destination host
- Two control-plane approaches:
  - ***Traditional routing algorithms***: implemented in routers
  - ***Software-defined networking (SDN)***: implemented in (remote) servers



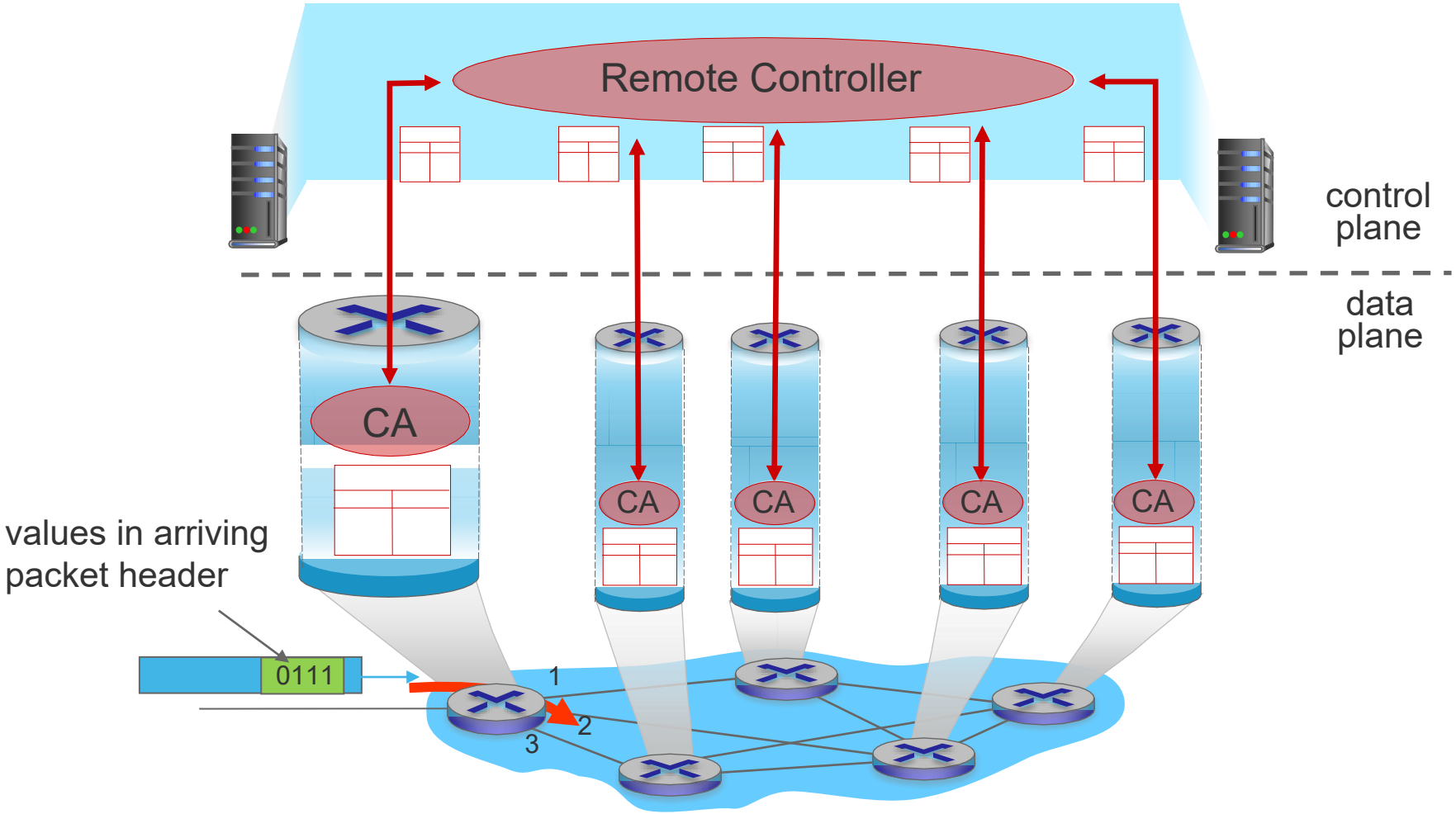
PER-ROUTER CONTROL PLANE

Individual **routing algorithm** components ***in each and every router*** interact in the control plane



LOGICALLY CENTRALIZED CONTROL PLANE

A **distinct** (typically remote) **controller** interacts with local control agents (CAs)



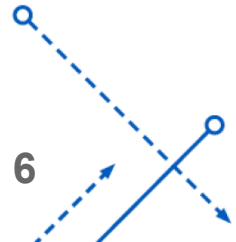
RECALL NETWORK-LAYER FUNCTIONS

***Recall**: two network-layer functions:*

- ***Forwarding**:* move packets from router's input to appropriate router output — ***data plane***
- ***Routing**:* determine route taken by packets from source to destination — ***control plane***

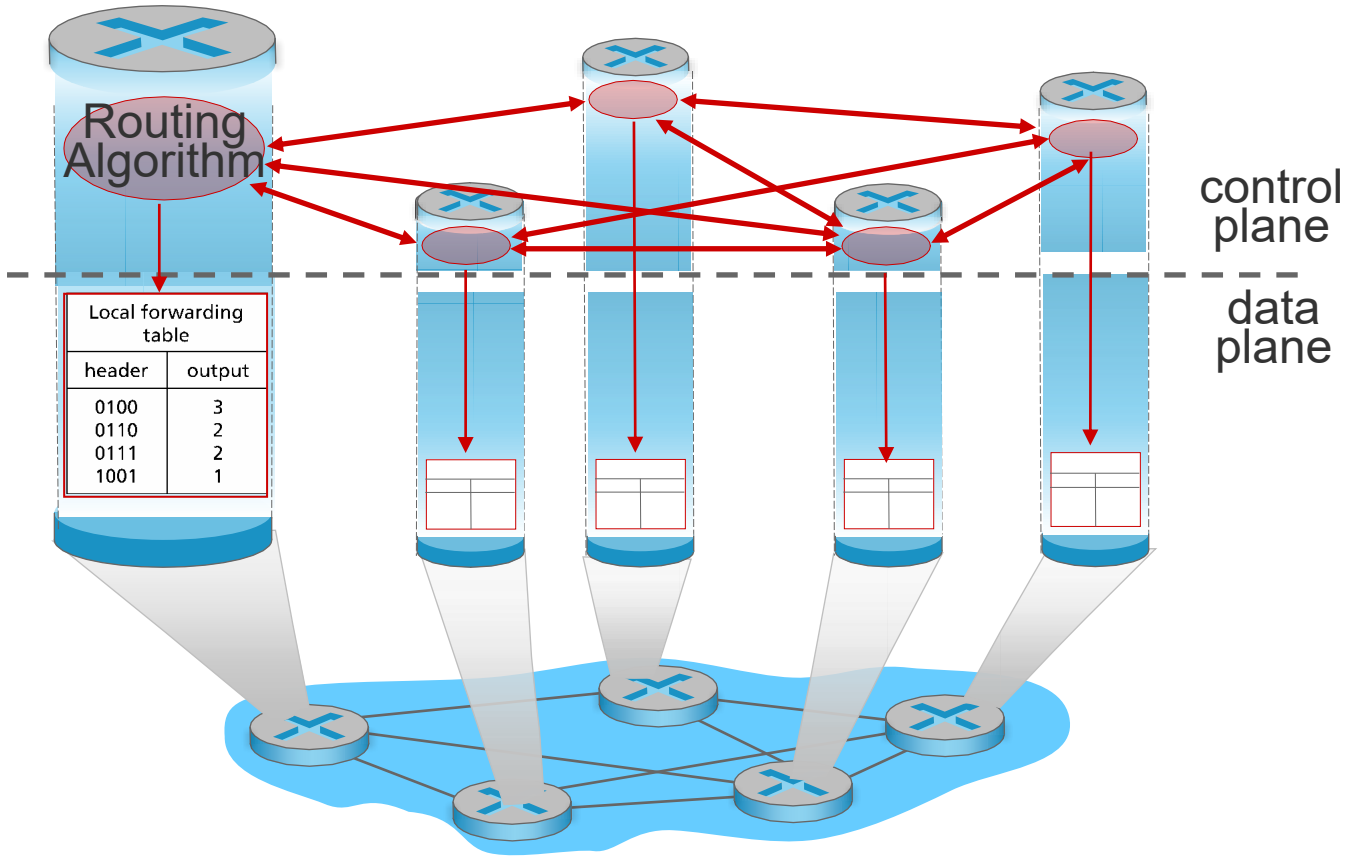
Two approaches to structuring network control plane:

- Per-router control (traditional)
- Logically centralized control (software defined networking)



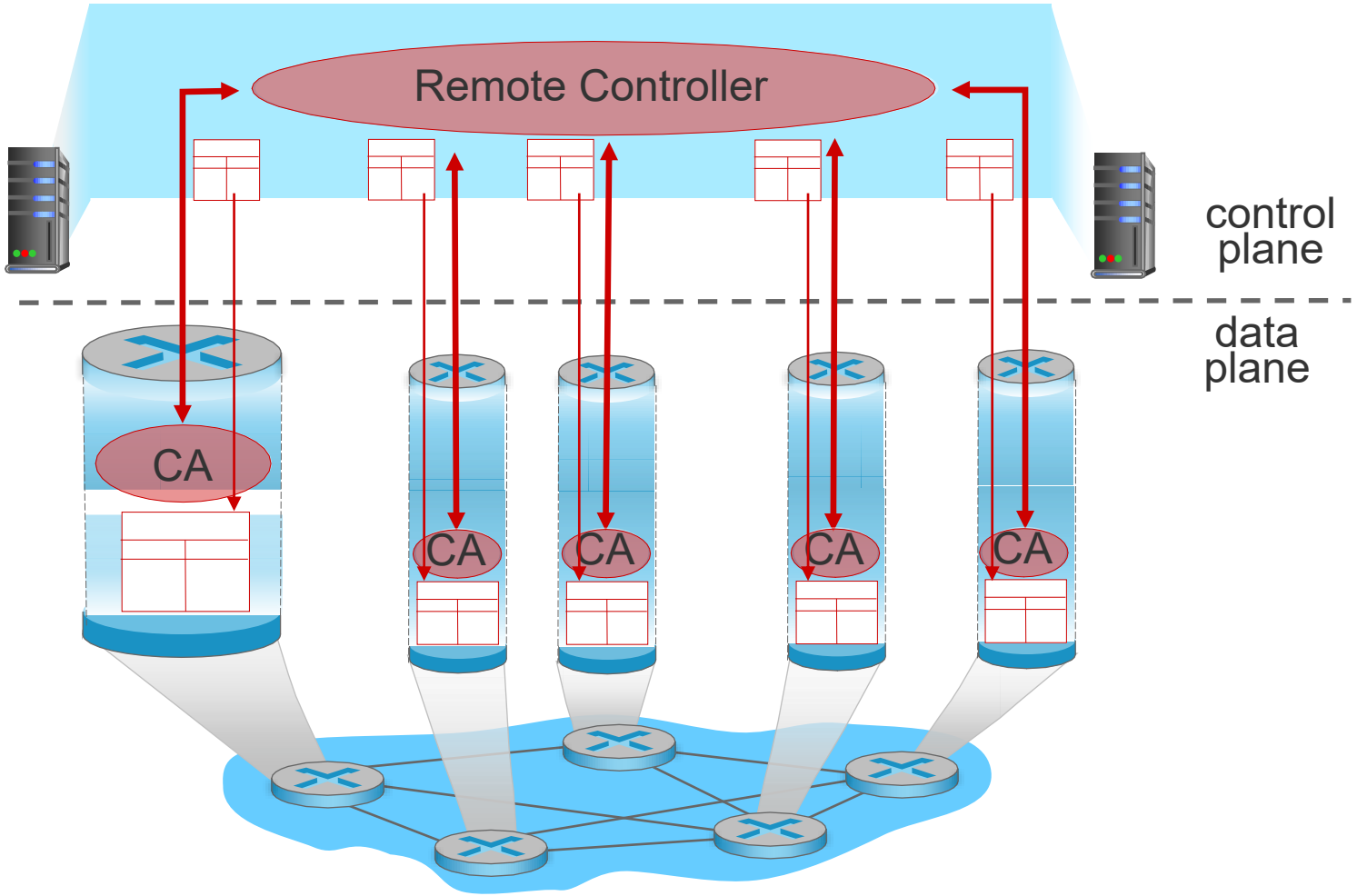
PER-ROUTER CONTROL PLANE

Individual routing algorithm components ***in each and every router*** interact with each other in control plane to compute forwarding tables



LOGICALLY CENTRALIZED CONTROL PLANE

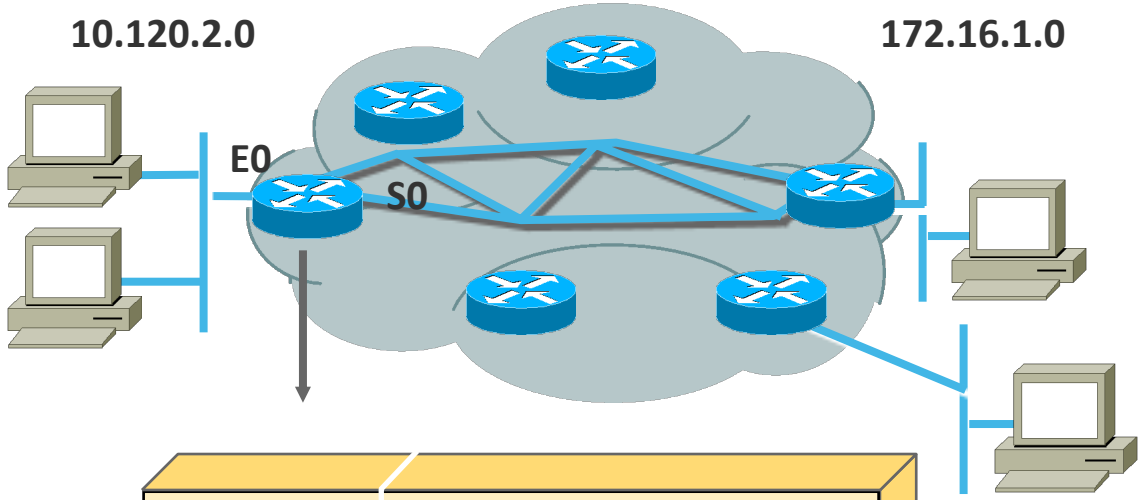
A distinct (typically remote) controller interacts with local control agents (CAs) in routers to compute forwarding tables



ROUTING PROTOCOLS

Routing protocols are used between routers to determine good paths and maintain routing tables.

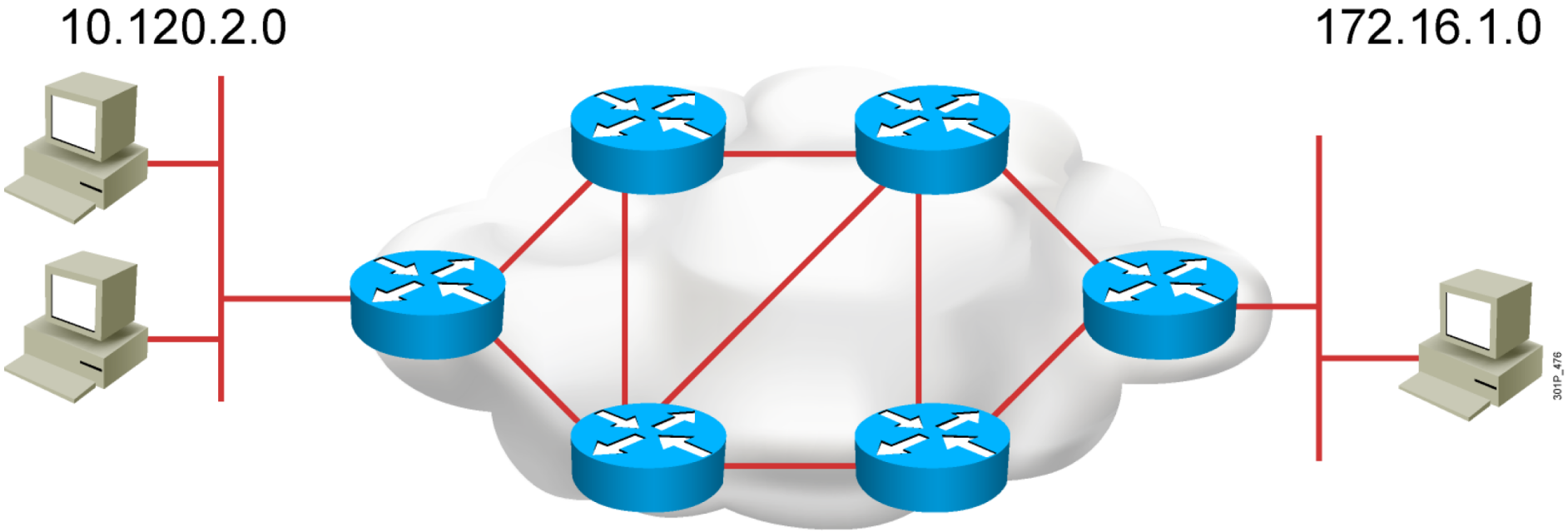
- **Path**: sequence of routers, packets will traverse in going from given initial source host to given final destination host
- "**good**": least "cost", "fastest", "least congested"
- Once the path is determined a router can route a **routed** protocol.



Network Protocol	Destination Network	Exit Interface
Connected	10.120.2.0	E0
RIP	172.16.2.0	S0
EIGRP	172.17.3.0	S1

Routed Protocol: IP
Routing protocol: RIP, EIGRP…

ROUTER OPERATIONS



A router needs to do the following:

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

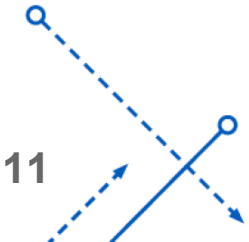
ROUTING ALGORITHM CLASSIFICATION

Q: global or decentralized information?

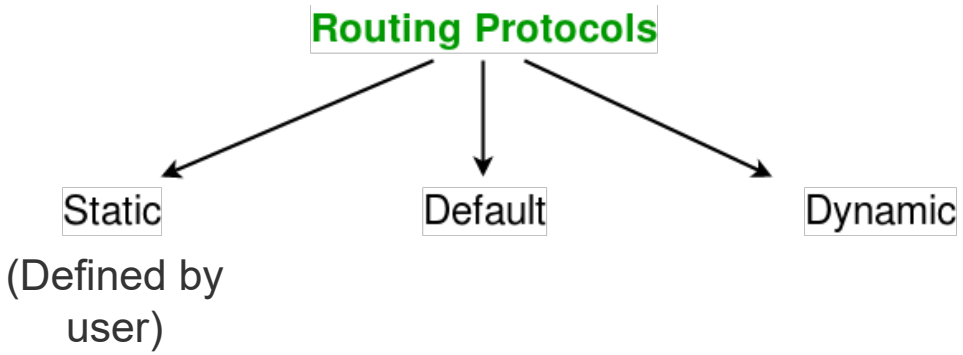
- ***Global***:
  - All routers have complete topology, link cost info
  - "**Link state**" algorithms
- ***Decentralized***:
  - Router knows physically-connected neighbors, link costs to neighbors
  - Iterative process of computation, exchange of info with neighbors
  - "**Distance vector**" algorithms

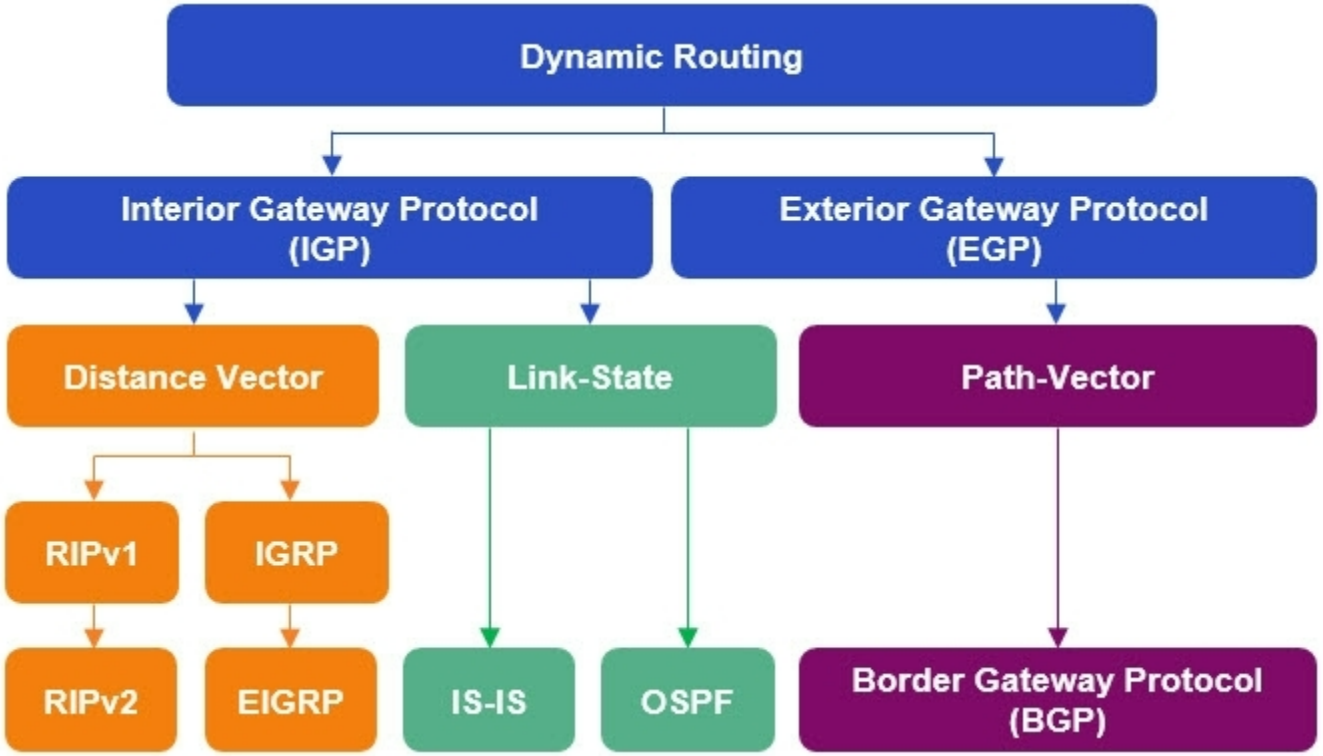
Q: static or dynamic?

- ***Static***:
  - Uses a route that a network administrator enters into the router manually
  - Routes change slowly over time
- ***Dynamic***:
  - Uses a route that a network routing protocol adjusts automatically for topology or traffic changes
  - Routes change more quickly
    - periodic update
    - in response to link cost changes



ROUTING ALGORITHM CLASSIFICATION



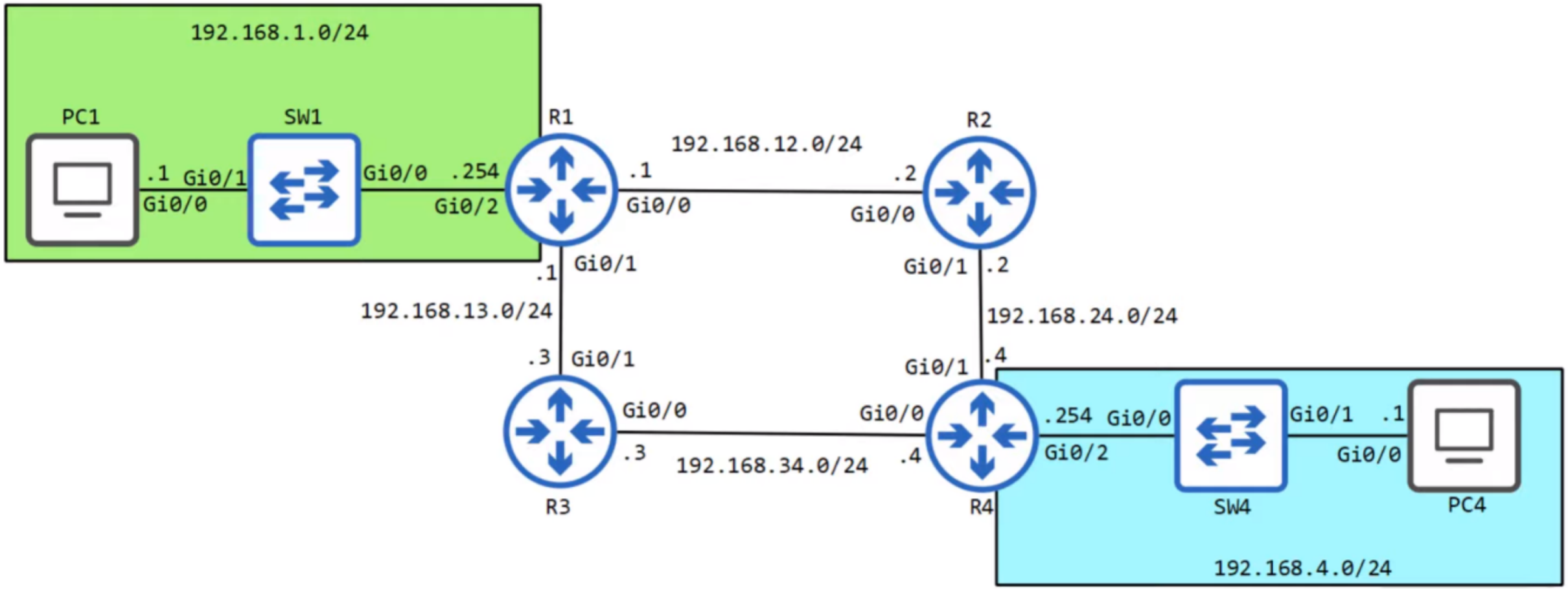


Classful	**RIP**	IGRP		EGP
Classless	**RIPv2**	**EIGRP**	**OSPFv2** IS-IS	BGPv4
IPv6	RIPng	EIGRP for IPv6	OSPFv3 IS-IS for IPv6	BGPv4 for IPv6

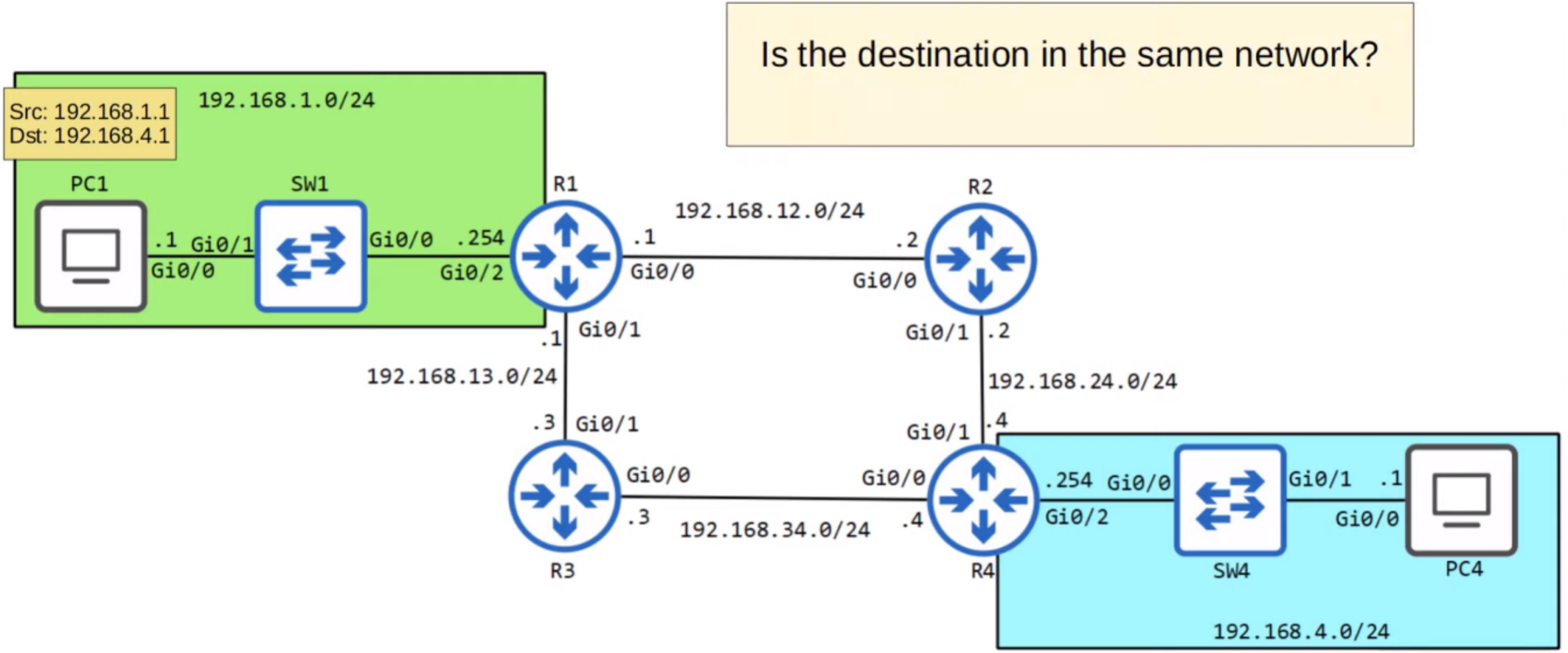
CRITERIA USED TO COMPARE ROUTING PROTOCOLS

- **Time to convergence**
  - Time to convergence defines how quickly the routers in the network topology share routing information and reach a state of consistent knowledge.
  - The faster the convergence, the more preferable the protocol.
- **Scalability**
  - Scalability defines how large a network can become based on the routing protocol that is deployed.
  - The larger the network is, the more scalable the routing protocol needs to be.
- **Resource usage**
  - Resource usage includes the requirements of a routing protocol such as memory space, CPU utilization, and link bandwidth utilization.
  - Higher resource requirements necessitate more powerful hardware to support the routing protocol operation
- **Classless (Use of VLSM) or Classful**
  - Classless routing protocols include the subnet mask in the updates.
  - This feature supports the use of Variable Length Subnet Masking (VLSM) and better route summarization.
- **Implementation & maintenance**
  - Implementation and maintenance describes the level of knowledge that is required for a network administrator to implement and maintain the network based on the routing protocol deployed.

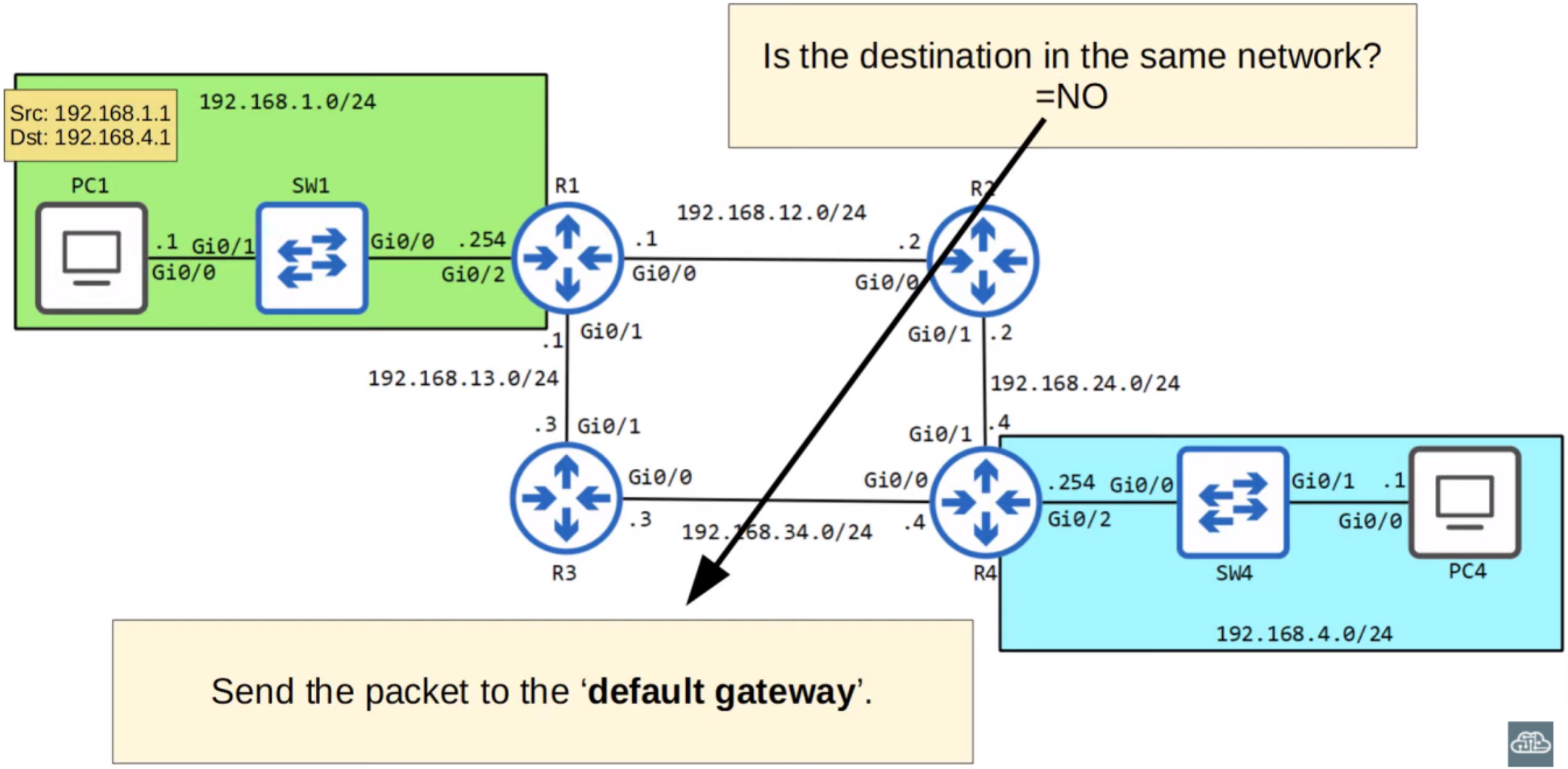
TOPOLOGY FOR THIS LESSON



TOPOLOGY FOR THIS LESSON



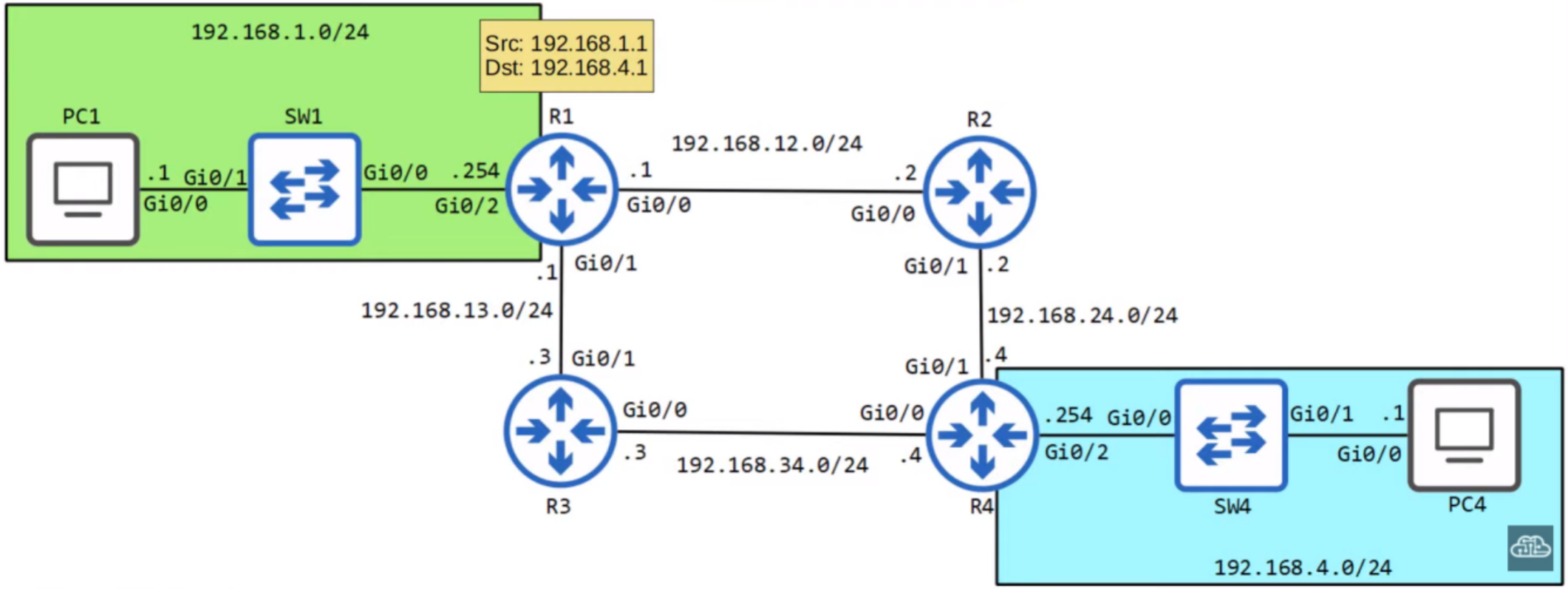
TOPOLOGY FOR THIS LESSON



TOPOLOGY FOR THIS LESSON

Compare the packet's destination IP address to the **routing table**.

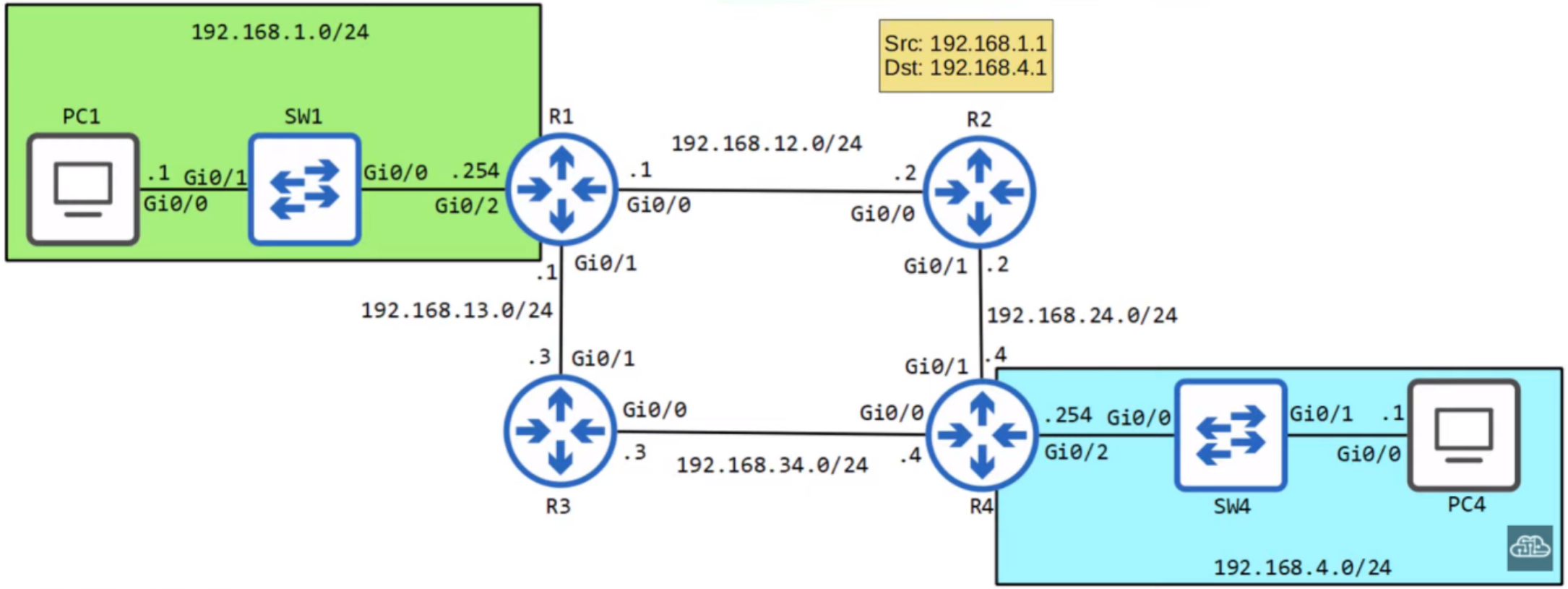
```
192.168.4.0/24 via 192.168.12.2, Gi0/0
```



TOPOLOGY FOR THIS LESSON

Compare the packet's destination IP address to the **routing table**.

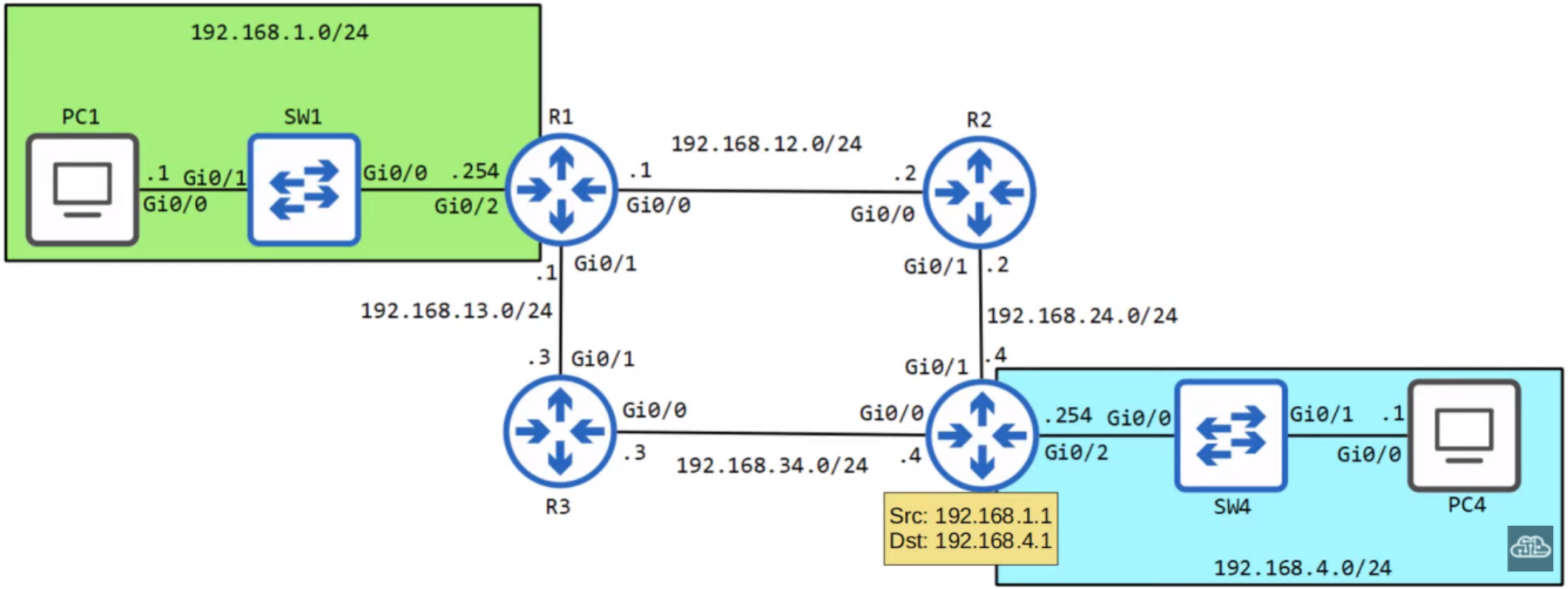
```
192.168.4.0/24 via 192.168.14.4, Gi0/1
```



TOPOLOGY FOR THIS LESSON

Compare the packet's destination IP address to the **routing table**.

```
192.168.4.0/24 is directly connected, Gi0/2
```



SHOW IP ROUTE

```
PC1#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, p - overrides from PfR

Gateway of last resort is not set

      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/0
L        192.168.1.1/32 is directly connected, GigabitEthernet0/0
PC1#
```

CONFIGURING A DEFAULT ROUTE

- To configure the **gateway of last resort** on a Cisco router, you must configure a **default route**.
- A **default route** is a route that matches ALL possible destinations.
- It is used only if a more specific route match isn't found in the routing table.
- The default route is the least specific route possible:

  IP Address: **0.0.0.0**

  Mask: **0.0.0.0**

To set the default route/gateway of last resort, configure a route to 0.0.0.0/0

The **0.0.0.0/0** range includes 0.0.0.0 ~ 255.255.255.255

= ALL possible addresses

CONFIGURING A DEFAULT ROUTE

192 . 168 . 1 . 0 /24

255 . 255 . 255 . 0

=FIXED (can't change)

=not fixed

192.168.1.0/24 matches 192.168.1.0 ~ 192.168.1.255

192.168.1.1
192.168.1.2
192.168.1.3

CONFIGURING A DEFAULT ROUTE

192 . 168 . 1 . 1 /32

255 . 255 . 255 . 255

```
     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.1.0/24 is directly connected, GigabitEthernet0/0
L       192.168.1.1/32 is directly connected, GigabitEthernet0/0
PC1#
```

192.168.1.1/32 matches ONLY 192.168.1.1

CONFIGURING A DEFAULT ROUTE

0 . 0 . 0 . 0 /0

0 . 0 . 0 . 0

=not fixed

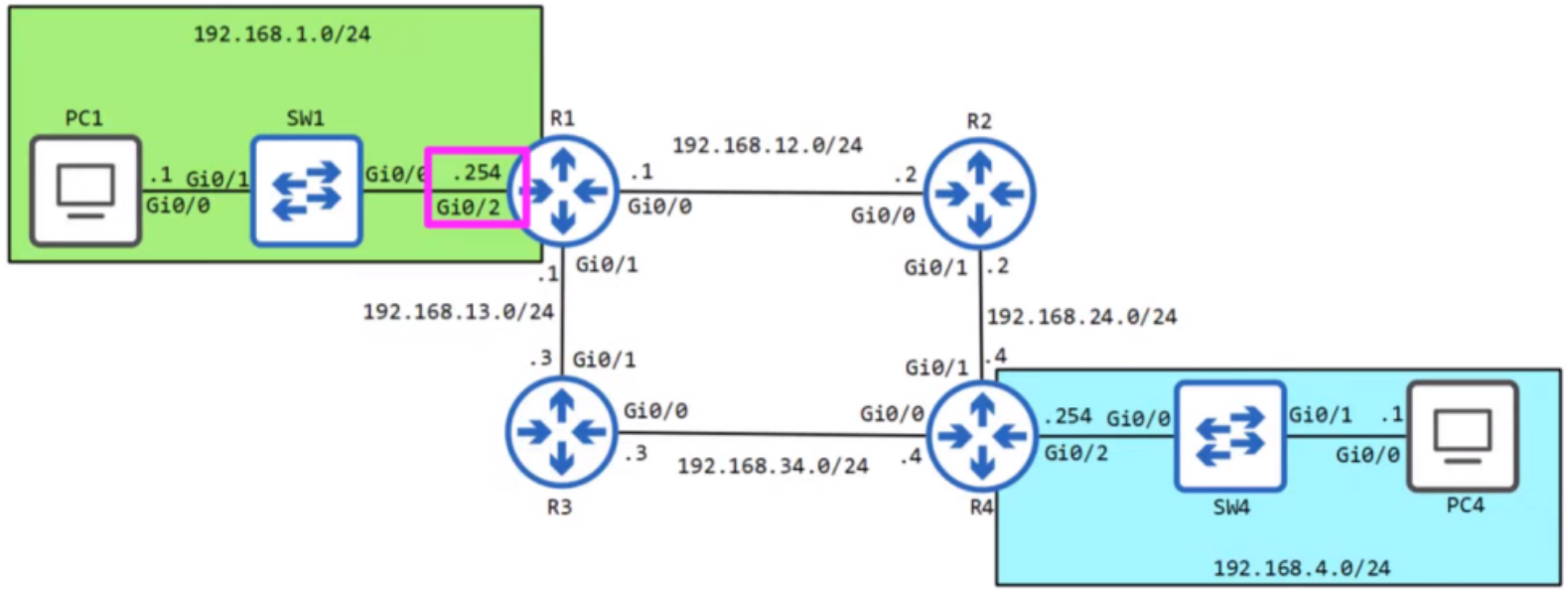
0.0.0.0/0 matches 0.0.0.0 ~ 255.255.255.255

= ALL possible addresses

CONFIGURING A STATIC ROUTE

```
ip route destination-address mask next-hop
```

```
PC1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
PC1(config)#ip route 0.0.0.0 0.0.0.0 192.168.1.254
```



DEFAULT ROUTE

```
PC1(config)#do sh 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, p - overrides from PfR

Gateway of last resort is 192.168.1.254 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 192.168.1.254
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/0
L        192.168.1.1/32 is directly connected, GigabitEthernet0/0
PC1(config)#
```

DEFAULT ROUTE

```
PC1(config)#do sh 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
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       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is 192.168.1.254 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 192.168.1.254
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/0
L        192.168.1.1/32 is directly connected, GigabitEthernet0/0
PC1(config)#
```

R1 ROUTING TABLE

```
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
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       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/2
L        192.168.1.254/32 is directly connected, GigabitEthernet0/2
      192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.12.0/24 is directly connected, GigabitEthernet0/0
L        192.168.12.1/32 is directly connected, GigabitEthernet0/0
      192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.13.0/24 is directly connected, GigabitEthernet0/1
L        192.168.13.1/32 is directly connected, GigabitEthernet0/1
R1#
```
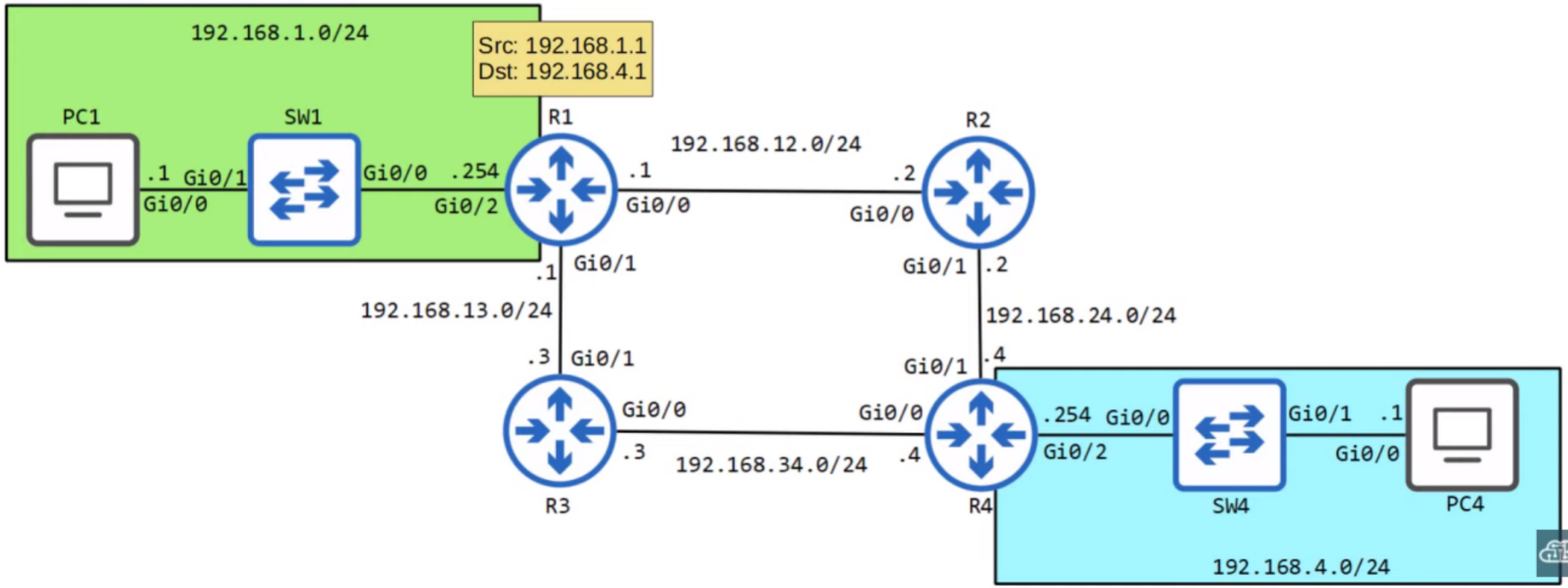

R1 ROUTING TABLE

```
ip route destination-address mask exit-interface
```

```
R1(config)#ip route 192.168.4.0 255.255.255.0 g0/0
```



R1 ROUTING TABLE

```
R1(config)#do 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, p - overrides from PfR

Gateway of last resort is not set

      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/2
L        192.168.1.254/32 is directly connected, GigabitEthernet0/2
S     192.168.4.0/24 is directly connected, GigabitEthernet0/0
      192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.12.0/24 is directly connected, GigabitEthernet0/0
L        192.168.12.1/32 is directly connected, GigabitEthernet0/0
      192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.13.0/24 is directly connected, GigabitEthernet0/1
L        192.168.13.1/32 is directly connected, GigabitEthernet0/1
```

R2 ROUTING TABLE

```
R2(config)#ip route 192.168.4.0 255.255.255.0 192.168.24.4
R2(config)#do 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, p - overrides from PfR

Gateway of last resort is not set

S     192.168.4.0/24 [1/0] via 192.168.24.4
      192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.12.0/24 is directly connected, GigabitEthernet0/0
L        192.168.12.2/32 is directly connected, GigabitEthernet0/0
      192.168.24.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.24.0/24 is directly connected, GigabitEthernet0/1
L        192.168.24.2/32 is directly connected, GigabitEthernet0/1
```

R4 ROUTING TABLE

```
R4#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, p - overrides from PfR

Gateway of last resort is not set

      192.168.4.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.4.0/24 is directly connected, GigabitEthernet0/2
L        192.168.4.254/32 is directly connected, GigabitEthernet0/2
      192.168.24.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.24.0/24 is directly connected, GigabitEthernet0/1
L        192.168.24.4/32 is directly connected, GigabitEthernet0/1
      192.168.34.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.34.0/24 is directly connected, GigabitEthernet0/0
L        192.168.34.4/32 is directly connected, GigabitEthernet0/0
```

PING FROM PC1 TO PC4

```
PC1#ping 192.168.4.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.4.1, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
PC1#
```

one-way reachability

PC4 ROUTING TABLE

```
PC4(config)#ip route 0.0.0.0 0.0.0.0 192.168.4.254
PC4(config)#do 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, p - overrides from PfR

Gateway of last resort is 192.168.4.254 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 192.168.4.254
      192.168.4.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.4.0/24 is directly connected, GigabitEthernet0/0
L        192.168.4.1/32 is directly connected, GigabitEthernet0/0
```

R4 ROUTING TABLE

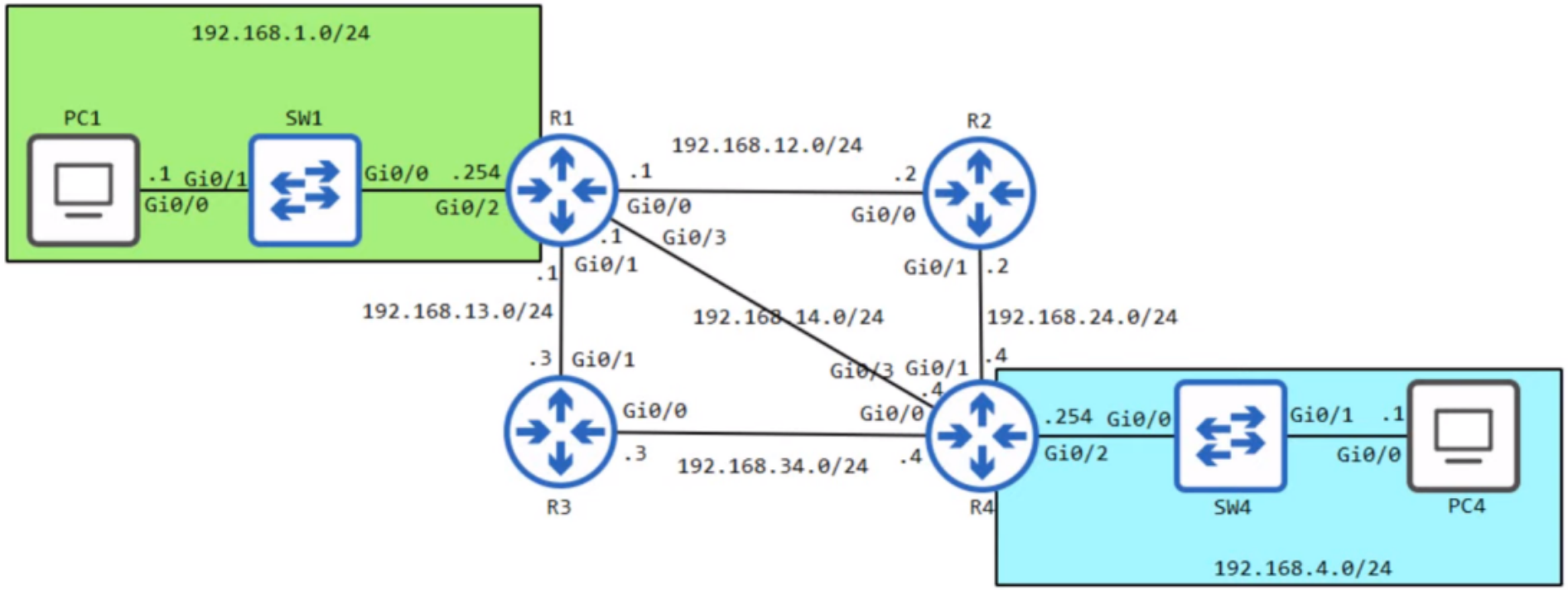
```
R4(config)#ip route 192.168.1.0 255.255.255.0 192.168.24.2
R4(config)#do show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 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, p - overrides from PfR

Gateway of last resort is not set

S     192.168.1.0/24 [1/0] via 192.168.24.2
      192.168.4.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.4.0/24 is directly connected, GigabitEthernet0/2
L        192.168.4.254/32 is directly connected, GigabitEthernet0/2
      192.168.24.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.24.0/24 is directly connected, GigabitEthernet0/1
L        192.168.24.4/32 is directly connected, GigabitEthernet0/1
      192.168.34.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.34.0/24 is directly connected, GigabitEthernet0/0
L        192.168.34.4/32 is directly connected, GigabitEthernet0/0
```

R4 ROUTING TABLE

```
R2(config)#ip route 192.168.1.0 255.255.255.0 192.168.12.1
R2(config)#do 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, p - overrides from PfR

Gateway of last resort is not set

S     192.168.1.0/24 [1/0] via 192.168.12.1
S     192.168.4.0/24 [1/0] via 192.168.24.4
      192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.12.0/24 is directly connected, GigabitEthernet0/0
L        192.168.12.2/32 is directly connected, GigabitEthernet0/0
      192.168.24.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.24.0/24 is directly connected, GigabitEthernet0/1
L        192.168.24.2/32 is directly connected, GigabitEthernet0/1
```

MOST SPECIFIC MATCHING ROUTE

- When a router looks up a destination address in its routing table, it looks for the **most specific matching** route.
- Most specific = longest prefix length (/32 > /24 > /16 > /8 > /0)



MOST SPECIFIC MATCHING ROUTE

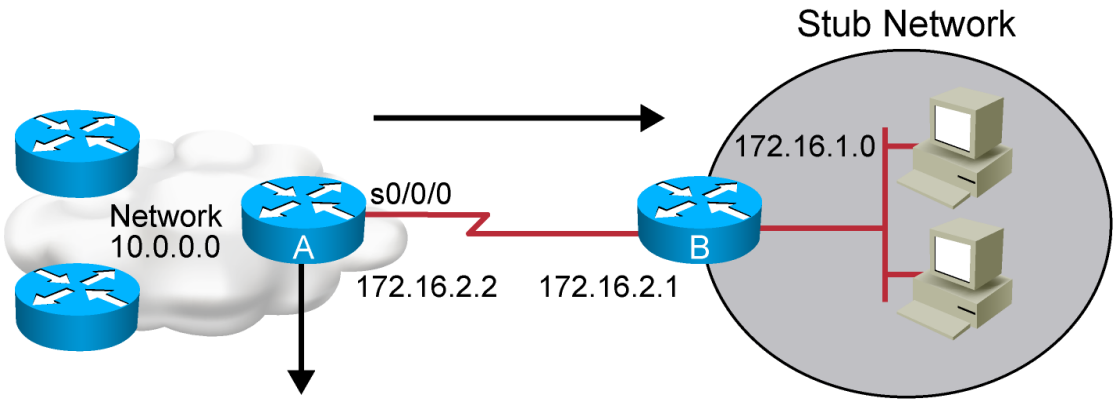
```
ping 192.168.4.1
```

```
S       192.0.0.0/8 [1/0] via 192.168.13.3
        192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.1.0/24 is directly connected, GigabitEthernet0/2
L          192.168.1.254/32 is directly connected, GigabitEthernet0/2
        192.168.4.0/24 is variably subnetted, 2 subnets, 2 masks
S          192.168.4.0/24 is directly connected, GigabitEthernet0/0
S          192.168.4.1/32 [1/0] via 192.168.14.4
        192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.12.0/24 is directly connected, GigabitEthernet0/0
L          192.168.12.1/32 is directly connected, GigabitEthernet0/0
        192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.13.0/24 is directly connected, GigabitEthernet0/1
L          192.168.13.1/32 is directly connected, GigabitEthernet0/1
        192.168.14.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.14.0/24 is directly connected, GigabitEthernet0/3
L          192.168.14.1/32 is directly connected, GigabitEthernet0/3
```

STATIC ROUTE CONFIGURATION

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

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



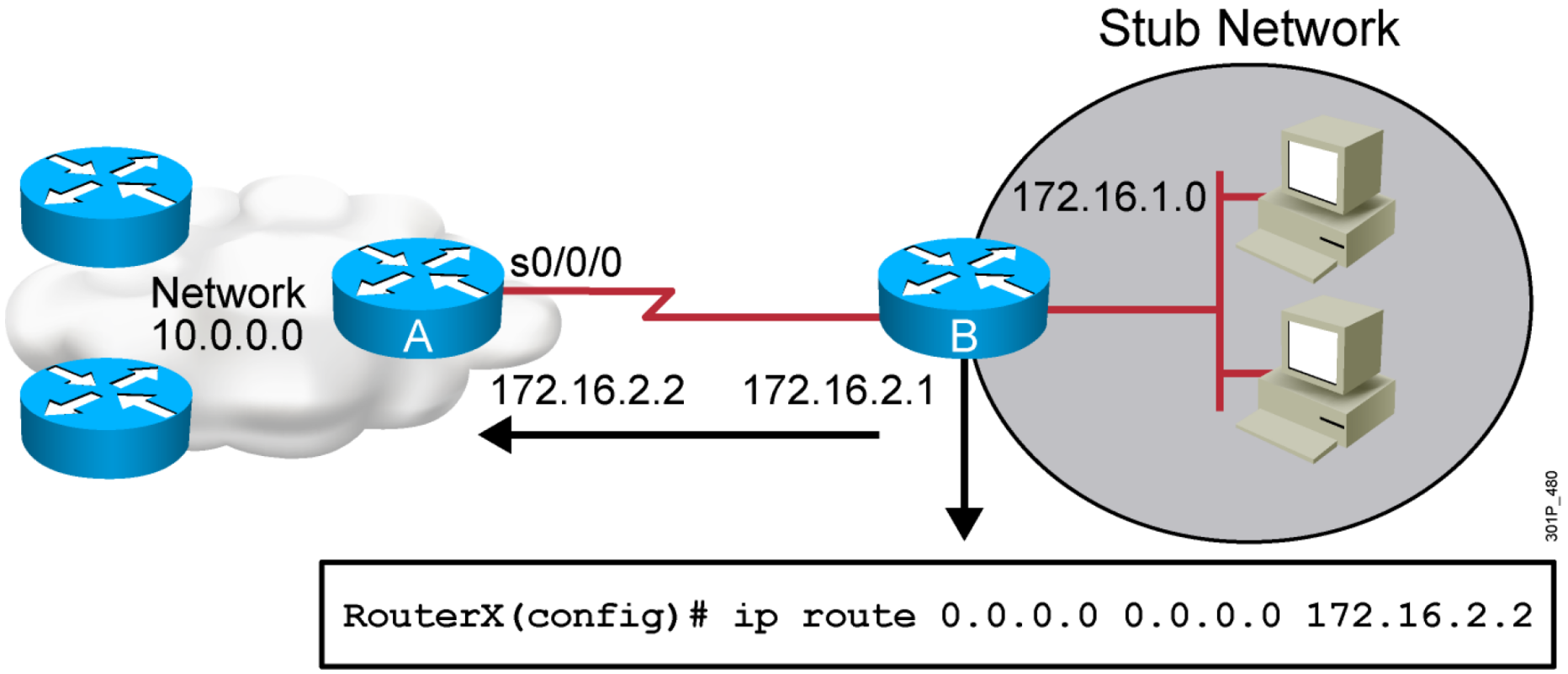

```
RouterX(config)# ip route 172.16.1.0 255.255.255.0 172.16.2.1
```

or

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

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

DEFAULT ROUTES




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

- Default routes are usually applied to **stub networks**
- This route allows the stub network to reach all known networks beyond Router A.

VERIFYING THE STATIC ROUTE CONFIGURATION

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

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

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