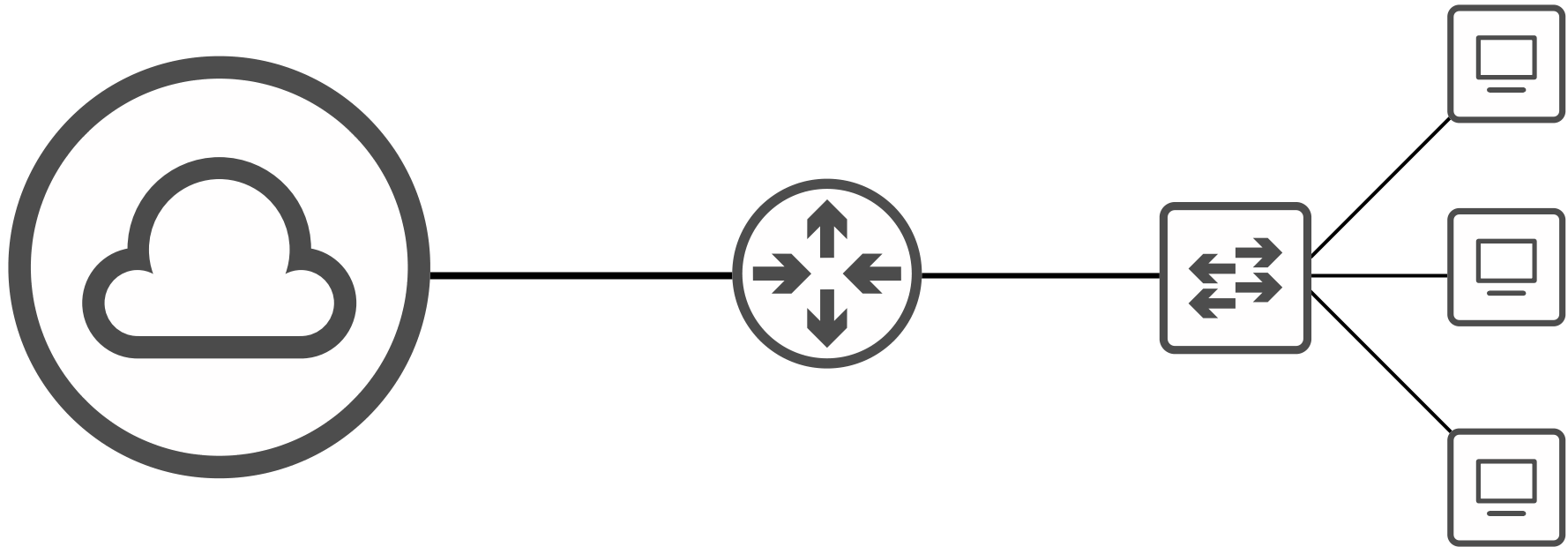- What is routing?

- The routing table on a Cisco router
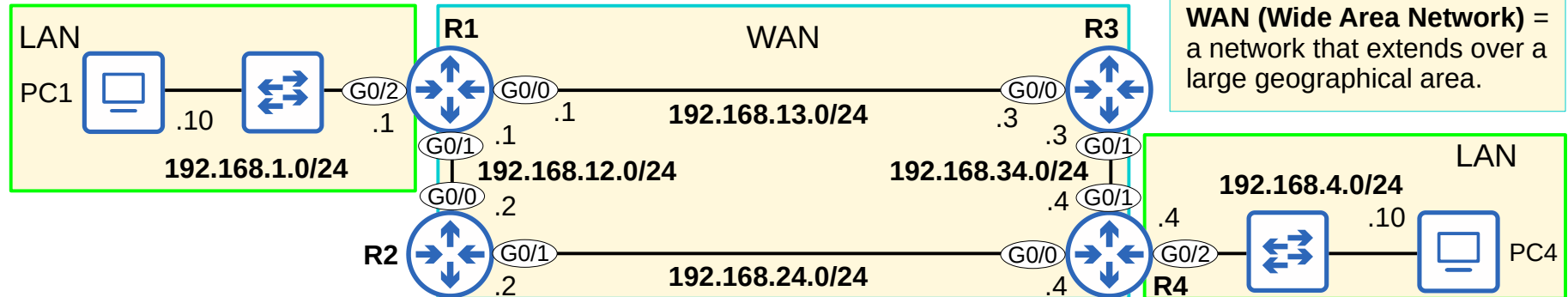 → **Connected** and **Local** routes

- Routing fundamentals (route selection)

- **Routing** is the process that routers use to determine the path that IP packets should take over a network to reach their destination.
  - →Routers store routes to all of their known destinations in a **routing table**.
  - →When routers receive packets, they look in the **routing table** to find the best route to forward that packet.

- There are two main routing methods (methods that routers use to learn routes):
  Dynamic Routing: Routers use *dynamic routing protocols* (ie. OSPF) to share routing information with each other automatically and build their routing tables.
  - →We will cover this later in the course.

  Static Routing: A network engineer/admin manually configures routes on the router.
  - →We will cover this in the next video.

  > **next-hop** = the next router in the path to the destination.

- A **route** tells the router: *to send a packet to destination X, you should send the packet to* **next-hop** *Y.*
  - →or, if the destination is directly connected to the router, *send the packet directly to the destination*.
  - →or, if the destination is the router's own IP address, *receive the packet for yourself (don't forward it)*.

- In the next video, we will configure **static routes** on the routers to allow PC1 and PC4 to communicate with each other.
  - →This video will focus on two types of routes automatically added to a router's routing table.

> **WAN (Wide Area Network)** = a network that extends over a large geographical area.

R1 Pre-configurations (IP Addresses)

```
R1# conf t
R1(config)# interface g0/0
R1(config-if)# ip address 192.168.13.1 255.255.255.0
R1(config-if)# no shutdown

R1(config-if)# interface g0/1
R1(config-if)# ip address 192.168.12.1 255.255.255.0
R1(config-if)# no shutdown

R1(config-if)# interface g0/2
R1(config-if)# ip address 192.168.1.1 255.255.255.0
R1(config-if)# no shutdown

R1# show ip int br
Interface              IP-Address       OK? Method Status                 Protocol
GigabitEthernet0/0     192.168.13.1     YES manual up                     up
GigabitEthernet0/1     192.168.12.1     YES manual up                     up
GigabitEthernet0/2     192.168.1.1      YES manual up                     up
GigabitEthernet0/3     unassigned       YES NVRAM  administratively down down
```
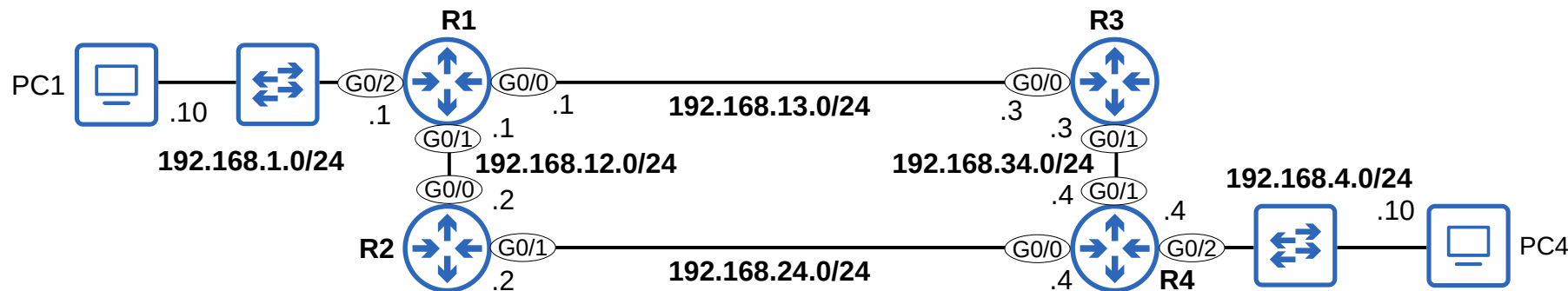
There is no need to use **exit** to return to global config mode before entering **interface g0/1**. You can use the **interface g0/1** command directly from interface config mode.

Routing Table (`show ip route`)

```
R1# show ip route
```

Use the command `show ip route` to view the routing table.

```
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        192.168.1.1/32 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, GigabitEthernet0/1
L        192.168.12.1/32 is directly connected, GigabitEthernet0/1
      192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.13.0/24 is directly connected, GigabitEthernet0/0
L        192.168.13.1/32 is directly connected, GigabitEthernet0/0
```

The `Codes` legend in the output of `show ip route` lists the different protocols which routers can use to learn routes.

- **L - local**
→ A route to the actual IP address configured on the interface. (with a /32 netmask)
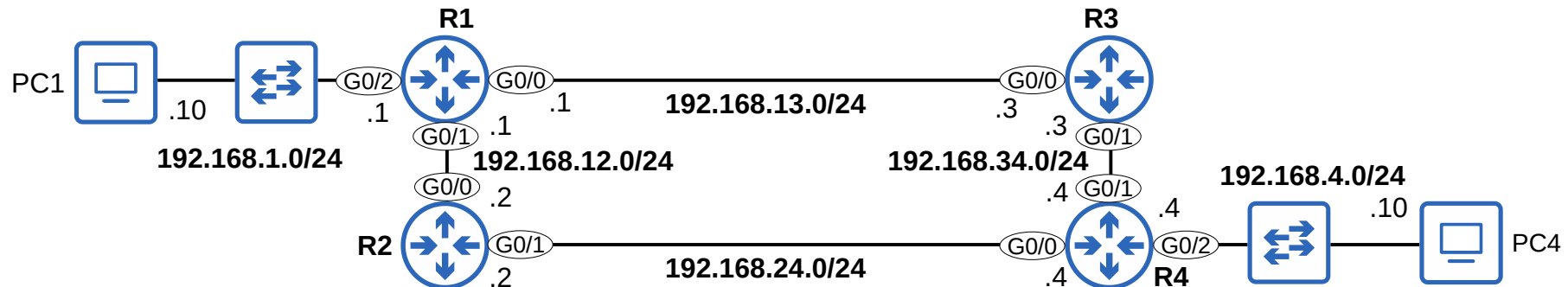- **C - connected**
→ A route to the network the interface is connected to. (with the actual netmask configured on the interface)

When you configure an IP address on an interface and enable it with **no shutdown**, 2 routes (per interface) will automatically be added to the routing table:
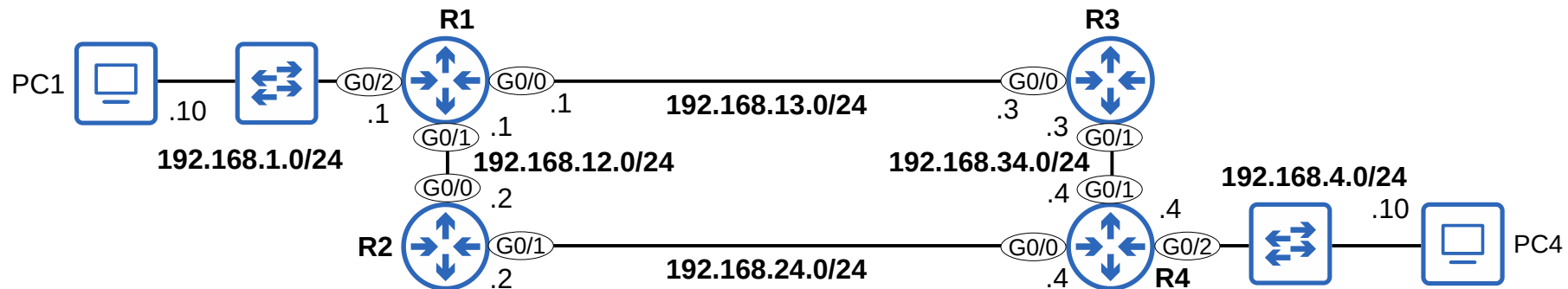→ a **connected** route
→ a **local** route

Connected and Local routes

```
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/2
L        192.168.1.1/32 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, GigabitEthernet0/1
L        192.168.12.1/32 is directly connected, GigabitEthernet0/1
      192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.13.0/24 is directly connected, GigabitEthernet0/0
L        192.168.13.1/32 is directly connected, GigabitEthernet0/0
```

- A **connected** route is a route to the network the interface is connected to.
- R1 G0/2 IP = 192.168.1.1/24
- Network Address = 192.168.1.0/24
- It provides a route to all hosts in that network (ie. 192.168.1.10, 192.168.1.100, 192.168.1.232, etc.)
- R1 knows: "If I need to send a packet to any host in the 192.168.1.0/24 network, I should send it out of G0/2".

- A **local** route is a route to the exact IP address configured on the interface.
- A /32 netmask is used to specify the exact IP address of the interface.
  → /32 means all 32 bits are 'fixed', they can't change.
- Even though R1's G0/2 is configured as 192.168.1.1/24, the connected route is to 192.168.1.1/32.
- R1 knows: "If I receive a packet destined for this IP address, the message is for me".

192 . 168 . 1 . 0 /24

255 . 255 . 255 . 0

=FIXED (can't change)   =not fixed

```
C        192.168.1.0/24 is directly connected, GigabitEthernet0/2
```

- **192.168.1.0/24** *matches* 192.168.1.0 ~ 192.168.1.255.
  → If R1 receives a packet with a destination in that range, it will send the packet out of G0/2.

A route **matches** a packet's destination if the packet's destination IP address is part of the network specified in the route.

192.168.1.2 = **match**
→ Send packet out of G0/2
192.168.1.7 = **match**
→ Send packet out of G0/2
192.168.1.89 = **match**
→ Send packet out of G0/2
192.168.2.1 = **no match**
→ Send the packet using a different route, or drop the packet if there is no matching route.

192.168.1.1 /32

255.255.255.255

=FIXED (can't change)

192.168.1.1/32 matches ONLY 192.168.1.1
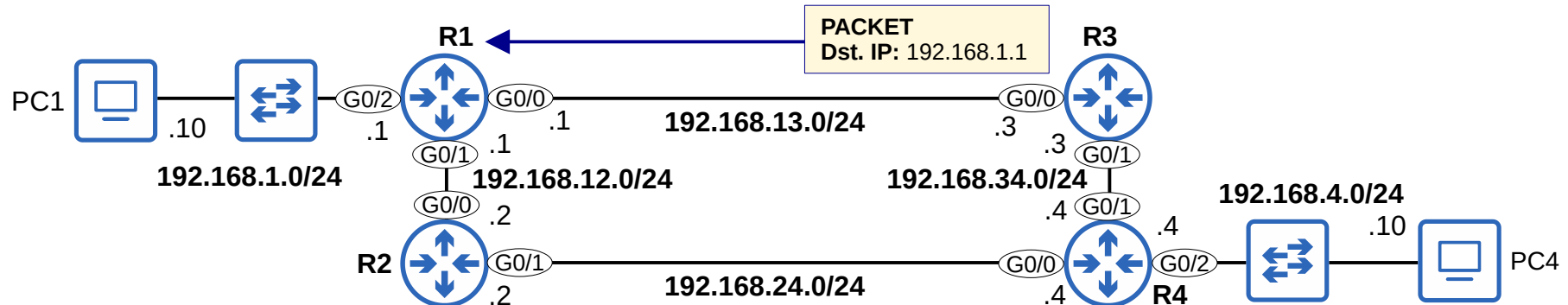
Route Selection

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

- A packet destined for **192.168.1.1** is matched by both routes:
  192.168.1.0/24
  192.168.1.1/32

- Which route will R1 use for a packet destined for 192.168.1.1?
  → It will choose the **most specific** matching route.

- The route to **192.168.1.0/24** includes 256 different IP addresses (192.168.1.0 – 192.168.1.255)
- The route to **192.168.1.1/32** includes only 1 IP address (192.168.1.1)
  → This route is more **specific**.

- **Most specific** matching route = the matching route with the **longest prefix length**.

When R1 receives a packet destined for 192.168.1.1, it will select the route to 192.168.1.1/32.
→ R1 will receive the packet for itself, rather than forward it out of G0/2.
Local route = keep the packet, don't forward

```
     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/2
L        192.168.1.1/32 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, GigabitEthernet0/1
L        192.168.12.1/32 is directly connected, GigabitEthernet0/1
     192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.13.0/24 is directly connected, GigabitEthernet0/0
L        192.168.13.1/32 is directly connected, GigabitEthernet0/0
```
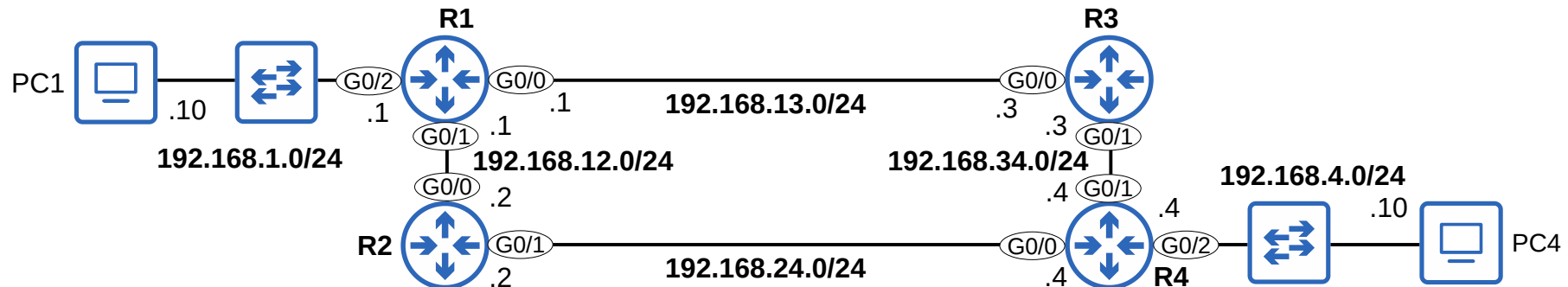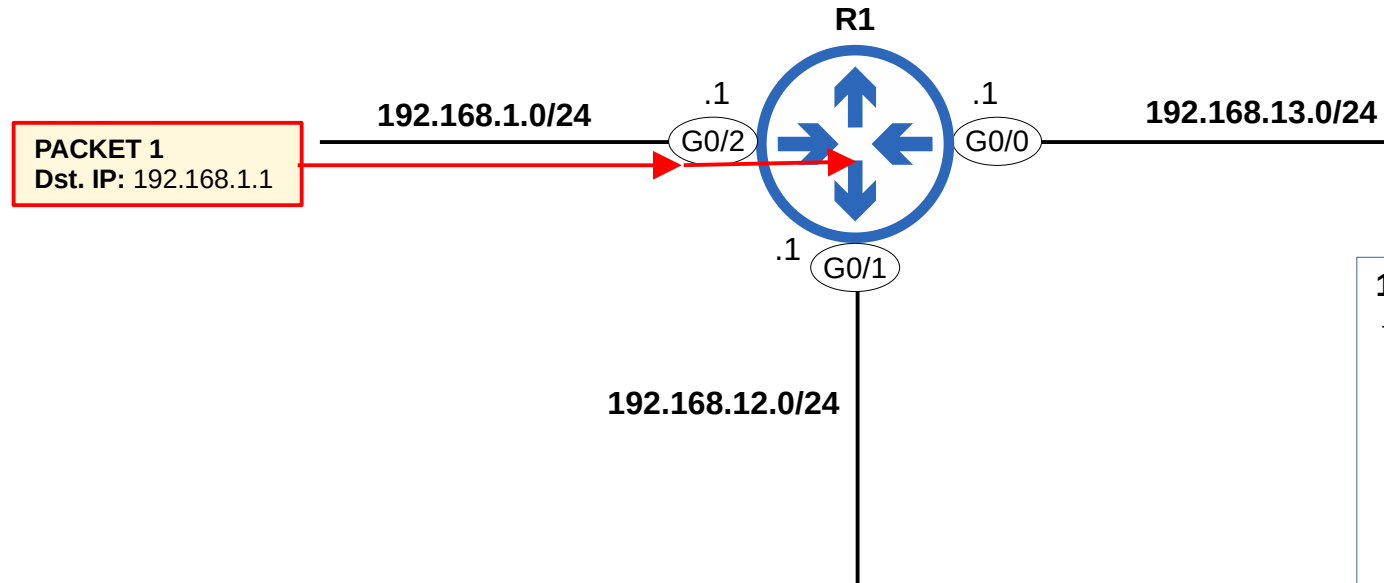
- These three lines are not routes. They mean the following:
- `192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks`
  →In the routing table, there are two routes to *subnets* that fit within the 192.168.1.0/24 Class C network, with two different netmasks (/24 and /32).
- `192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks`
  →In the routing table, there are two routes to *subnets* that fit within the 192.168.12.0/24 Class C network, with two different netmasks (/24 and /32).
- `192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks`
  →In the routing table, there are two routes to *subnets* that fit within the 192.168.13.0/24 Class C network, with two different netmasks (/24 and /32).

- We will cover **subnetting** soon (in another video)! For now, I just wanted to point out that these three lines are not routes.

```
        192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.1.0/24 is directly connected, GigabitEthernet0/2
L          192.168.1.1/32 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, GigabitEthernet0/1
L          192.168.12.1/32 is directly connected, GigabitEthernet0/1
        192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.13.0/24 is directly connected, GigabitEthernet0/0
L          192.168.13.1/32 is directly connected, GigabitEthernet0/0
```

R1

192.168.1.0/24

.1
G0/2

.1
G0/0

192.168.13.0/24

PACKET 1
Dst. IP: 192.168.1.1

.1
G0/1

192.168.12.0/24

1) Dst. IP 192.168.1.1
→Receive for myself

```
        192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.1.0/24 is directly connected, GigabitEthernet0/2
L          192.168.1.1/32 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, GigabitEthernet0/1
L          192.168.12.1/32 is directly connected, GigabitEthernet0/1
        192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.13.0/24 is directly connected, GigabitEthernet0/0
L          192.168.13.1/32 is directly connected, GigabitEthernet0/0
```
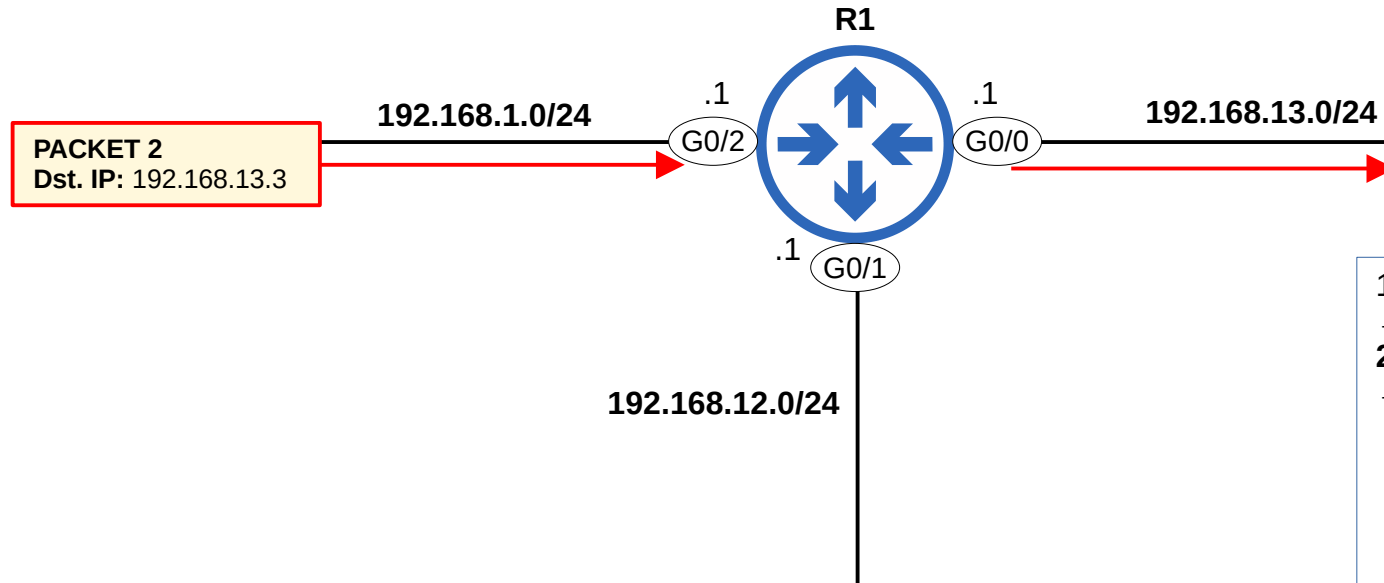
R1

192.168.1.0/24   .1   .1   **192.168.13.0/24**

G0/2   G0/0

PACKET 2
Dst. IP: 192.168.13.3

.1
G0/1

192.168.12.0/24

1) Dst. IP 192.168.1.1
→Receive for myself
2) Dst. IP 192.168.13.3
→Send to the destination (connected to G0/0)

```
        192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.1.0/24 is directly connected, GigabitEthernet0/2
L          192.168.1.1/32 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, GigabitEthernet0/1
L          192.168.12.1/32 is directly connected, GigabitEthernet0/1
        192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.13.0/24 is directly connected, GigabitEthernet0/0
L          192.168.13.1/32 is directly connected, GigabitEthernet0/0
```
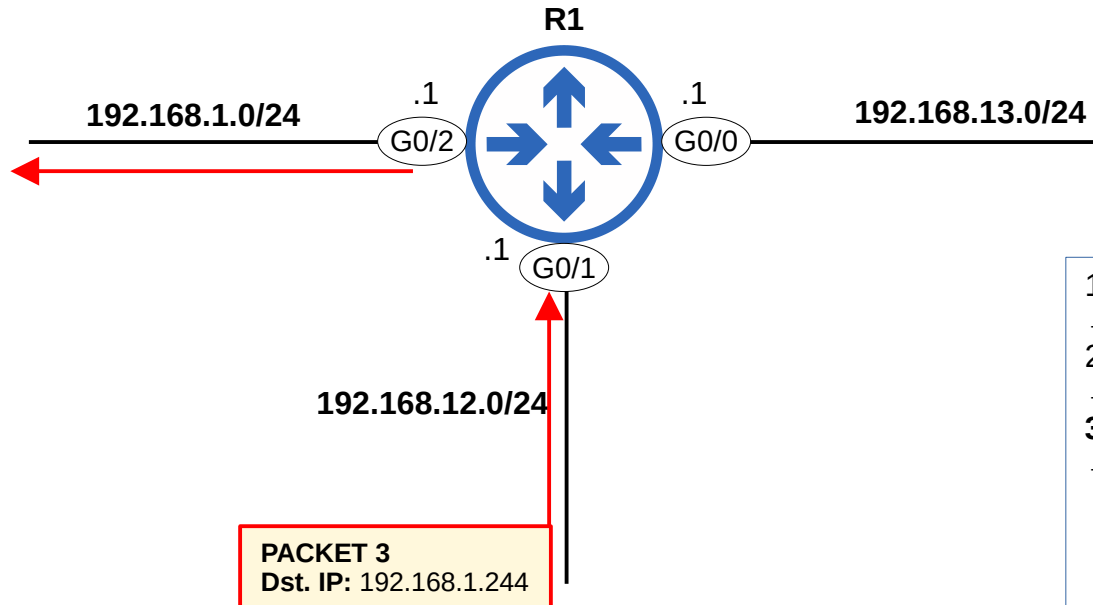
R1

192.168.1.0/24 .1 G0/2   .1 G0/0 192.168.13.0/24

.1 G0/1

192.168.12.0/24

PACKET 3
Dst. IP: 192.168.1.244

1) Dst. IP 192.168.1.1
→ Receive for myself
2) Dst. IP 192.168.13.3
→ Send to the destination (connected to G0/0)
3) Dst. IP 192.168.1.244
→ Send to the destination (connected to G0/2)

```
        192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.1.0/24 is directly connected, GigabitEthernet0/2
L          192.168.1.1/32 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, GigabitEthernet0/1
L          192.168.12.1/32 is directly connected, GigabitEthernet0/1
        192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.13.0/24 is directly connected, GigabitEthernet0/0
L          192.168.13.1/32 is directly connected, GigabitEthernet0/0
```
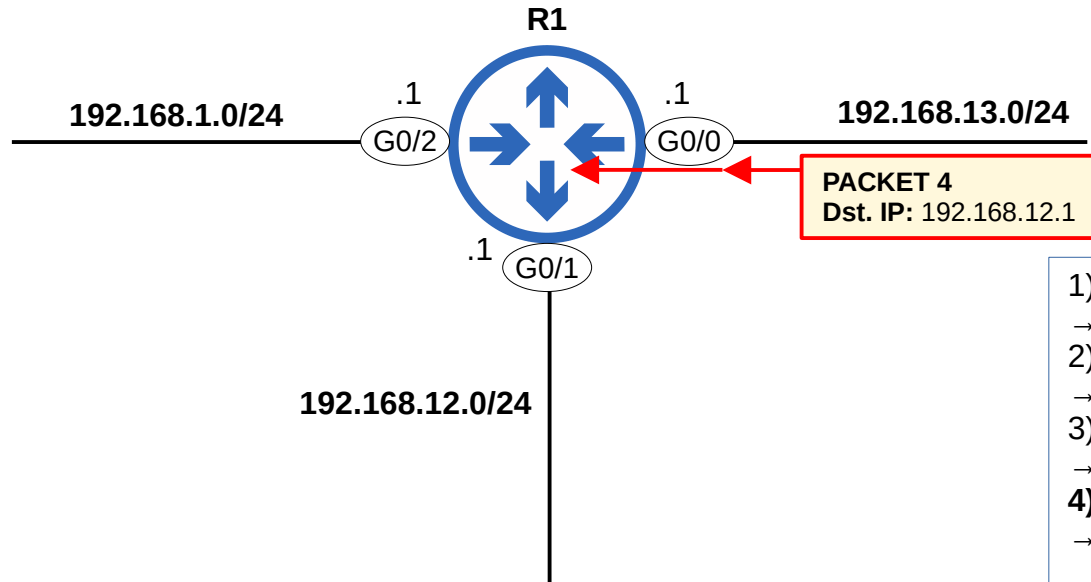
R1

192.168.1.0/24 .1 G0/2

.1 G0/0 **192.168.13.0/24**

PACKET 4
Dst. IP: 192.168.12.1

.1 G0/1

192.168.12.0/24

1) Dst. IP 192.168.1.1
→ Receive for myself
2) Dst. IP 192.168.13.3
→ Send to the destination (connected to G0/0)
3) Dst. IP 192.168.1.244
→ Send to the destination (connected to G0/2)
4) Dst. IP 192.168.12.1
→ Receive for myself

Route Selection Practice (5)

```
        192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.1.0/24 is directly connected, GigabitEthernet0/2
L          192.168.1.1/32 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, GigabitEthernet0/1
L          192.168.12.1/32 is directly connected, GigabitEthernet0/1
        192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.13.0/24 is directly connected, GigabitEthernet0/0
L          192.168.13.1/32 is directly connected, GigabitEthernet0/0
```
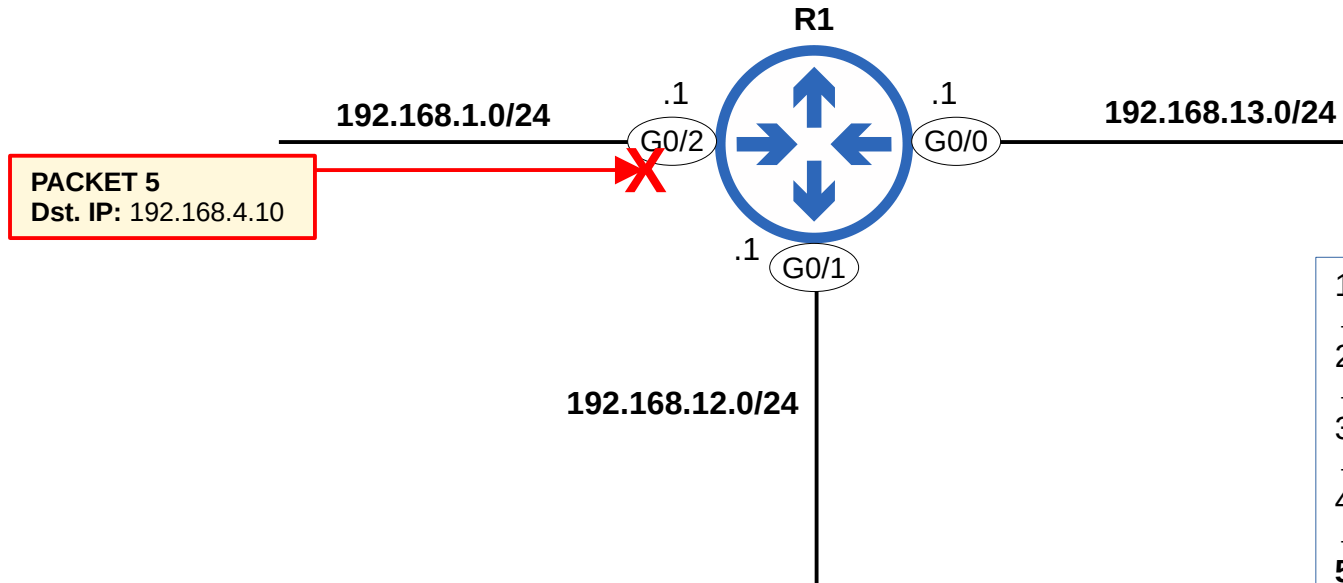
R1

192.168.1.0/24 .1 G0/2 .1 G0/0 **192.168.13.0/24**

PACKET 5
Dst. IP: 192.168.4.10

.1 G0/1

192.168.12.0/24

1) Dst. IP 192.168.1.1
→Receive for myself
2) Dst. IP 192.168.13.3
→Send to the destination (connected to G0/0)
3) Dst. IP 192.168.1.244
→Send to the destination (connected to G0/2)
4) Dst. IP 192.168.12.1
→Receive for myself
5) Dst. IP 192.168.4.10
→Drop (no route)

- Routers store information about destinations they know in their **routing table**.
  → When they receive packets, the look in the routing table to find the best route to forward the packet.

- Each **route** in the routing table is an instruction:
  → To reach destinations in network X, send the packet to **next-hop** Y (the next router in the path to the destination).
  → If the destination is directly connected (**Connected** route) send the packet directly to the destination.
  → If the destination if your own IP address (**Local** route), receive the packet for yourself.
  *We will look at how **next-hops** work in the next video on **static routes**.

- When you configure an IP address on an interface and enable the interface, two routes are automatically added to the routing table:
  Connected route (code **C** in the routing table): A route to the network connected to the interface.
  → ie. if the interface's IP is **192.168.1.1/24**, the route will be to **192.168.1.0/24**.
  → Tells the router: "To send a packet to a destination in this network, send it out of the interface specified in the route".

  Local route (code **L** in the routing table): A route to the exact IP address configured on the interface.
  → ie. if the interface's IP is **192.168.1.1/24**, the route will be to **192.168.1.1/32**.
  → Tells the router: "Packets to this destination are for you. You should receive them for yourself (not forward them)".

- A route **matches** a destination if the packet's destination IP address is part of the network specified in the route.
  → ie. a packet to **192.168.1.60** is matched by a route to **192.168.1.0/24**, but not by a route to **192.168.0.0/24**.

- If a router receives a packet and it doesn't have a route that matches the packet's destination, it will **drop** the packet.
  → This is different than switches, which **flood** frames if they don't have a MAC table entry for the destination.

- If a router receives a packet and it has multiple routes that match the packet's destination, it will use the ***most specific** matching route* to forward the packet.
  → **Most specific** matching route = the matching route with the longest prefix length.
  → This is different than switches, which look for an **exact** match in the MAC address table to forward frames.

- What is routing?

- The routing table on a Cisco router
  → **Connected** and **Local** routes

- Routing fundamentals (route selection)

The IP address configured on a router interface will appear in the routing table as what kind of route?

a) Static

b) Connected

c) Local

d) Dynamic

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

Examine R1's routing table. What will it do when it receives a packet destined for 192.168.3.25?

```
        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
        192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.2.0/24 is directly connected, GigabitEthernet0/1
L          192.168.2.1/32 is directly connected, GigabitEthernet0/1
        192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.3.0/24 is directly connected, GigabitEthernet0/2
L          192.168.3.25/32 is directly connected, GigabitEthernet0/2
```

a) It will drop the packet.

b) It will receive the packet for itself.

c) It will forward the packet out of the G0/0 interface.

d) It will forward the packet out of the G0/2 interface.

Which of the following statements about the behavior of routers and switches are true? (select two)

a) Routers flood packets with an unknown destination.

b) Switches flood frames with an unknown destination.

c) Routers drop packets with an unknown destination.

d) Switches drop frames with an unknown destination.

Which two types of routes are automatically added to the routing table when you configure an IP address on an interface and enable it?

a) C, L

b) C, S

c) L, S

d) L, D

```
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
       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
```

Examine R1's routing table below. If R1 receives a packet destined for 10.0.1.23, how many routes match that destination? And which is the most specific matching route?

```
        10.0.0.0/24 is variably subnetted, 2 subnets, 2 masks
C          10.0.0.0/24 is directly connected, GigabitEthernet0/0
L          10.0.0.1/32 is directly connected, GigabitEthernet0/0
        10.0.2.0/24 is variably subnetted, 2 subnets, 2 masks
C          10.0.2.0/24 is directly connected, GigabitEthernet0/1
L          10.0.2.23/32 is directly connected, GigabitEthernet0/1
        10.0.1.0/24 is variably subnetted, 2 subnets, 2 masks
C          10.0.1.0/24 is directly connected, GigabitEthernet0/2
L          10.0.1.23/32 is directly connected, GigabitEthernet0/2
```

a) One matching route: 10.0.1.0/24

b) One matching route: 10.0.1.23/32

c) Two matching routes: 10.0.1.0/24, 10.0.1.23/32. Most specific: 10.0.1.23/32.

d) Two matching routes: 10.0.1.0/24, 10.0.1.23/32. Most specific: 10.0.1.0/24.