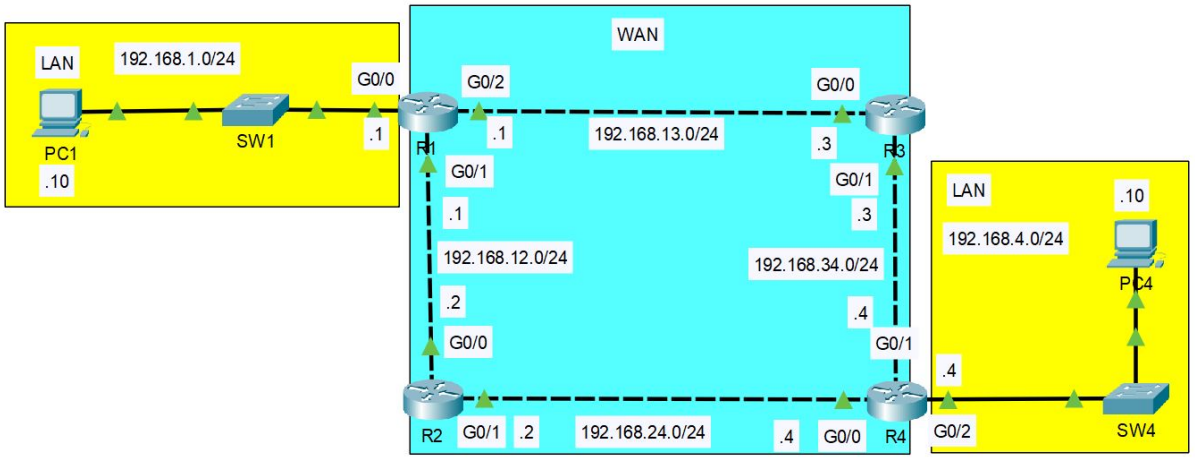
DAY 11.5 - Static Routing

Static Routing

Review: `Local` & `Connected` Routes:




```
R2>en
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#int g0/0
R2(config-if)#ip address 192.168.12.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#int g0/1
R2(config-if)#ip address 192.168.24.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#do show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0     192.168.12.2    YES manual up                    up
GigabitEthernet0/1     192.168.24.2    YES manual up                    up
GigabitEthernet0/2     unassigned      YES NVRAM  administratively down down
Vlan1                  unassigned      YES unset  administratively down down
```

```
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, E - EGP
       i - IS-IS, 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

Gateway of last resort is not set

     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
```

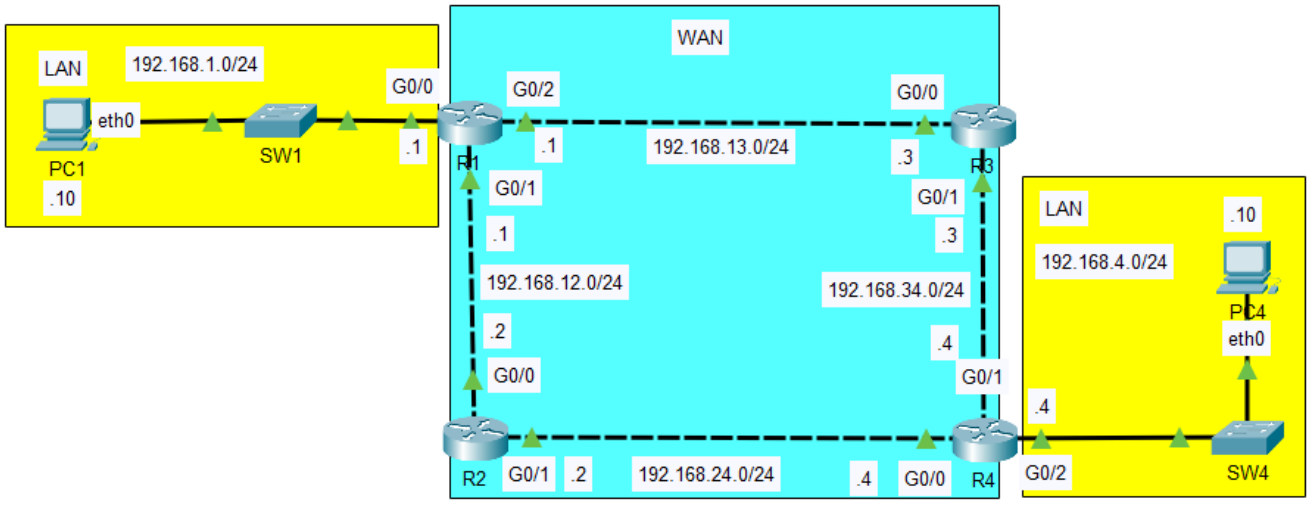
The following routes are automatically added to the routing table for each interface with an IP address configured:

1. `C` - **Connected**:
    1. A route to the network the interface is connected to. (With the actual netmask configured on the interface).
2. `L` - **Local**:
    1. A route to the actual IP address configured on the interface. (With a `/32` netmask)

    R2 knows how to reach its own IP addresses and destinations in its connected networks, **but** it doesn't know how to reach destinations in remote networks.

- **Knows**:
    - `192.168.12.0/24` (including `192.168.12.2/32`)
    - `192.168.24.0/24` (including `192.168.24.2/32`)
- **Doesn't know**:
    - `192.168.1.0/24`
    - `192.168.13.0/24`
    - `192.168.34.0/24`
    - `192.168.4.0/24`

Default Gateway



- End hosts like **PC1** and **PC4** can send packets directly to destinations *within* their connected network.
    - **PC1** is connected to `192.168.1.0/24`
    - **PC4** is connected to `192.168.4.0/24`

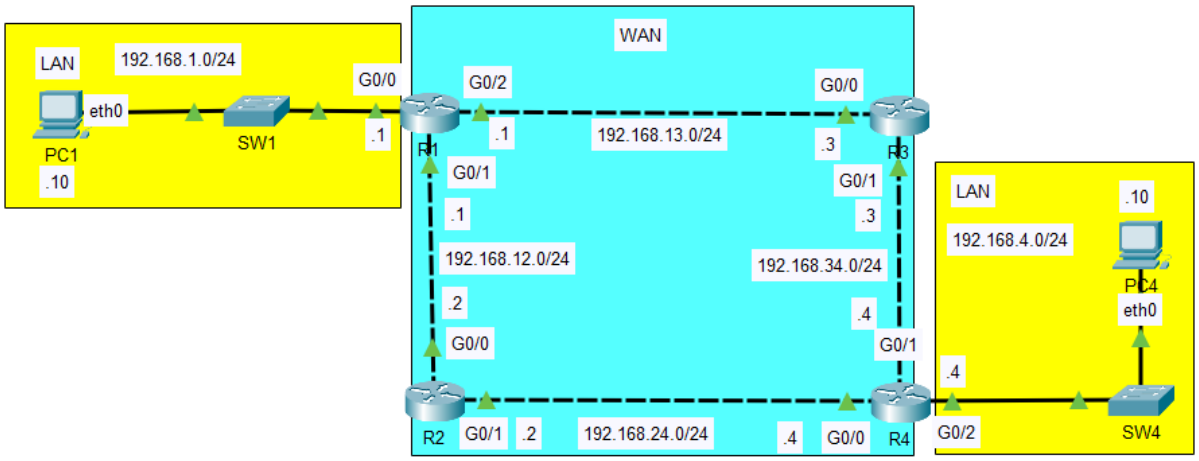
- To send packets to destinations *outside* their local network, they must send the packets to their **Default Gateway**.
    - Configuring interfaces on a Linux PC:
        - **PC1** Linux Config:

```
iface eth0 inet static
        address 192.168.1.10/24
        gateway 192.168.1.1
```

        - **PC4** Linux Config:

```
iface eth0 inet static
        address 192.168.4.10/24
        gateway 192.168.4.4
```

- The **Default Gateway** configuration is also called a **Default Route**:
    - It is a route to `0.0.0.0/0` = all netmask bits set to `0`.
        - Includes all addresses from `0.0.0.0` to `255.255.255.255`
        - The **Default Route** is the ***LEAST*** specific route possible, because it includes ***All*** the IP addresses.
            - `0.0.0.0/0` = 4,294,967,296 IP addresses.
        - The **Local Route** is the ***MOST*** specific route possible, because it includes ***One*** IP address.
            - `192.168.1.1/32` = 1 IP address.
- End hosts usually have no need for any more specific routes.
    - They just need to know that *"To send packets outside my local network, I should send them to my **default gateway**."*
        - **Source IP**: `192.168.1.10`
        - **DST IP**: `192.168.4.10`
        - ***DST MAC***: R1's **G0/0** MAC
            - To learn R1's **G0/0** MAC address, PC1 will first send an **ARP Request** to `192.168.1.1`
        - **SRC MAC**: PC1's **eth0** MAC

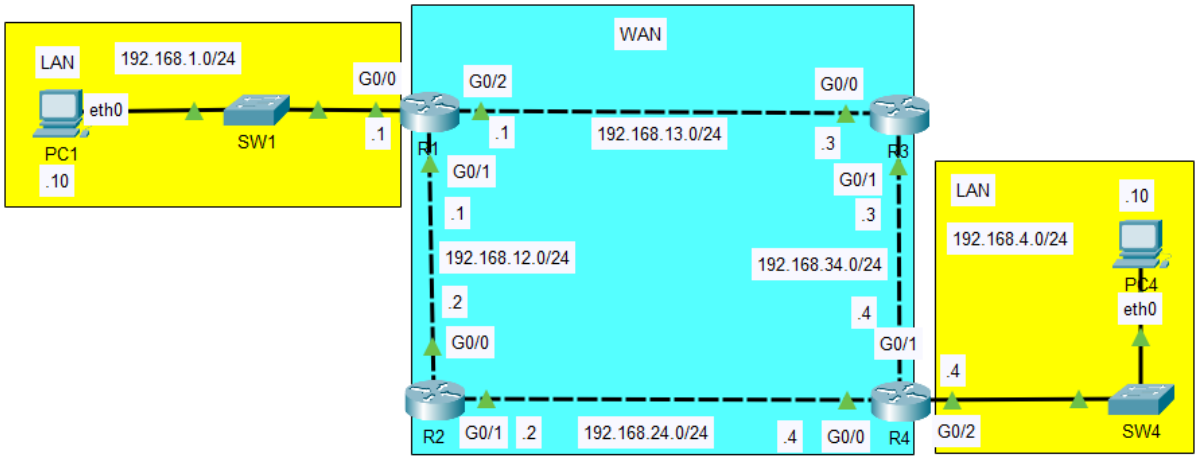


- When R1 receives the frame from PC1, it will de-encapsulate it (remove L2 header/trailer) and look at the inside packet.
- It will check its routing table for the most specific matching route:

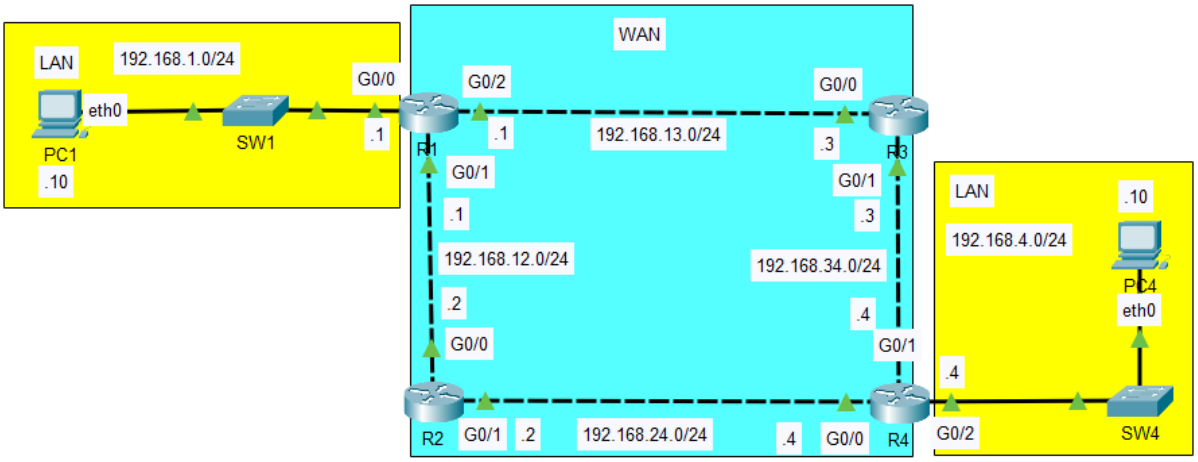
```
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, 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

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
     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, GigabitEthernet0/2
L       192.168.13.1/32 is directly connected, GigabitEthernet0/2
```

- R1 has no matching routes in its routing table.
  - It will drop the packet.
- To properly forward the packet, R1 needs a route to the destination network of `192.168.4.0/24`.
  - Routes are instructions: *"To send a packet to destinations in network `192.168.4.0/24`, forward the packet to `Next Hop Y`"*
- There are two possible path packets from **PC1 to PC4** can take:
  1. PC1 → R1 → **R3** → R4 → PC4
  2. PC1 → R1 → **R2** → R4 → PC4
  - For now, we will use the path via **R3** and not **R2**
    - Though it is possible to configure the routers to:
      - **Load-Balance** between path `1` and path `2`.
      - Use path `1` as the main path and path `2` as a backup path.

Static Route Configuration



- Each router in the path needs ***TWO*** routes:
  - a route to `192.168.1.0/24` (**PC1** network) and
  - a route to `192.168.4.0/24` (**PC4** network)
- This ensures **Two-Way Reachability**
  - **PC1** can send packets to **PC4** & Vice-Versa.
- Routers don't need routes to all networks in the path to the destination.
  - **R1** doesn't need a route to `192.168.34.0/24`, it only needs to know a route to **R3**. **R3** will handle the route to `192.168.34.0/24` by itself.
  - **R4** also doesn't need a route to `192.168.13.0/24`, **R3** will handle it.
- **R1** already has a **Connected Route** to `192.168.1.0/24`.
- **R4** already has a **Connected Route** to `192.168.4.0/24`
- The other routes (Non-**Connected Routes**) still needed to be manually configured using **Static Route**.



Router	Destination	Next-Hop	Note
R1	`192.168.1.0/24`	**Connected**	-
	`192.168.4.0/24`	`192.168.13.3`	R3's G0/0
R3	`192.168.1.0/24`	`192.168.13.1`	R1's G0/2
	`192.168.4.0/24`	`192.168.34.4`	R4's G0/1
R4	`192.168.1.0/24`	`192.168.34.3`	R3's G0/1
	`192.168.4.0/24`	**Connected**	-

- To allow **PC1 and PC4** to communicate with each other over the network, we will configure the **Static Routes** on **R1, R3, R4** based on the pre-planning table above.
- Use `ip route ip-address netmask next-hop`
  - Where:
    - `ip-address`: The **Destination**'s IP address.
    - `netmask`: The netmask of Destination's network.
    - `next-hop`: Next-Hop IP Address

Demo:

```
R1(config)#ip route 192.168.4.0 255.255.255.0 192.168.13.3
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, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter are
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

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
S    192.168.4.0/24 [1/0] via 192.168.13.3
     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, GigabitEthernet0/2
L       192.168.13.1/32 is directly connected, GigabitEthernet0/2
```

- Added R1's **Static Route** via:
  `ip route 192.168.4.0 255.255.255.0 192.168.13.3`
  - Where:

    - `192.168.4.0` = Destination Network
    - `255.255.255.0` = Destination Netmask
    - `192.168.13.3` = Next Hop
- A Code `S` **Static Route** is added.
    - The **[1/0]** display for **Static Routes** means:
        - **[Administrative Distance / Metric]**
        - The concept will be covered later.

```
R3(config)#ip route 192.168.1.0 255.255.255.0 192.168.13.1
R3(config)#ip route 192.168.4.0 255.255.255.0 192.168.34.4
R3(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, E - EGP
       i - IS-IS, 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

Gateway of last resort is not set

S     192.168.1.0/24 [1/0] via 192.168.13.1
S     192.168.4.0/24 [1/0] via 192.168.34.4
      192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.13.0/24 is directly connected, GigabitEthernet0/0
L        192.168.13.3/32 is directly connected, GigabitEthernet0/0
      192.168.34.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.34.0/24 is directly connected, GigabitEthernet0/1
L        192.168.34.3/32 is directly connected, GigabitEthernet0/1
```

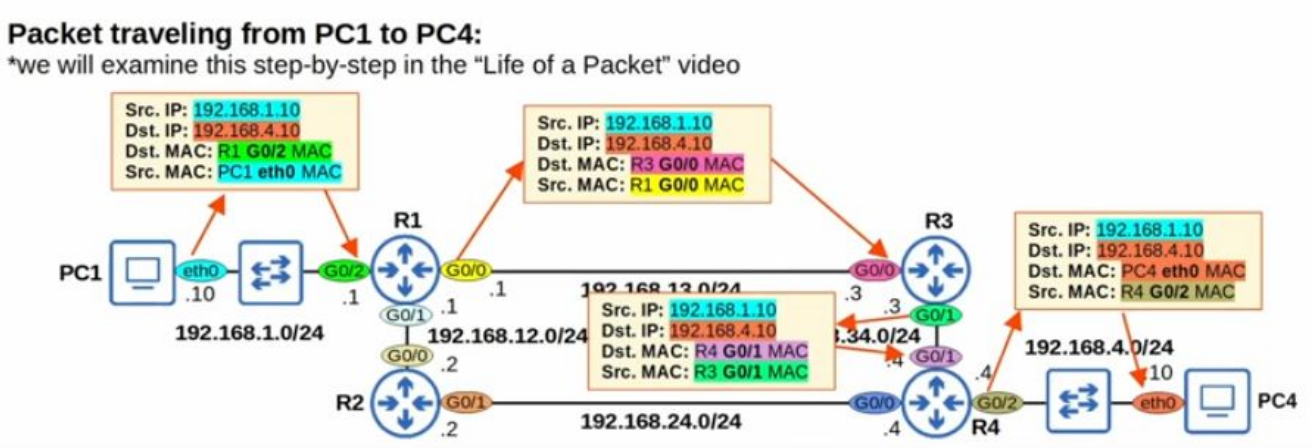
- R3 needed 2 routes.

```
R4(config)#ip route 192.168.1.0 255.255.255.0 192.168.34.3
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, E - EGP
       i - IS-IS, 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

Gateway of last resort is not set

S     192.168.1.0/24 [1/0] via 192.168.34.3
      192.168.4.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.4.0/24 is directly connected, GigabitEthernet0/2
L        192.168.4.4/32 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, GigabitEthernet0/0
L        192.168.24.4/32 is directly connected, GigabitEthernet0/0
      192.168.34.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.34.0/24 is directly connected, GigabitEthernet0/1
L        192.168.34.4/32 is directly connected, GigabitEthernet0/1
```

- R4 needed 1 route.

Testing Communication

If the ping is successful, it means that there is two-way reachability.
PC1 can reach PC4 and vice-versa.



Note the relationship between IP and MAC address. (**ARP**ing for the **MAC** of the next hop while the IP address stay the same until the end).

`exit-interface`

Instead of configuring next hop, we can configure an exit interface (just send a packet out of this) instead of explicitly telling the ip address of the next hop.

- `ip route ip-address netmask exit-interface`
- `ip route ip-address netmask exit-interface next-hop`

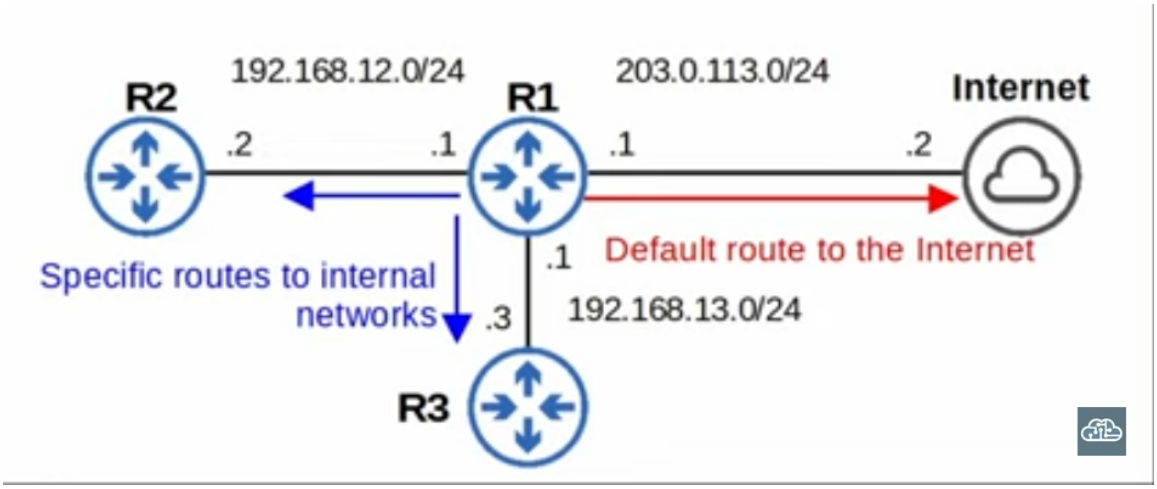
```
R2(config)#ip route 192.168.1.0 255.255.255.0 g0/0
%Default route without gateway, if not a point-to-point interface,
R2(config)#do show ip rou
Codes: L - local, C - connected, S - static, R - RIP, M - mobile,
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter a
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external typ
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - E
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

S    192.168.1.0/24 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       192.168.12.2/32 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
```

Note: Specifying only the `exit-interface` without a `next-hop` will show the Static Route as directly connected.

It is better to specify `next-hop` instead of only having `exit-interface` and without specifying a `next-hop`.

Default Route

- A **Default Route** is a route to `0.0.0.0/0`
  - `0.0.0.0/0 is the *least specific* route possible; it includes every possible IP address.
- If the router doesn't have any more specific routes that match a packet's destination IP address, the router will forward the packet using the **Default Route**.
- A default route is often used to direct traffic to the internet.
  - More specific routes are used for destinations in the internal corporate network.
  - Traffic to destinations outside of the internal network is sent to the internet.




```
R1(config)# ip route 0.0.0.0 0.0.0.0 203.0.113.2
R1(config)# do show ip route
!most codes omitted
       ia - IS-IS inter area, * - candidate default, U - per-user static route
!most codes omitted
Gateway of last resort is 203.0.113.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 203.0.113.2
S     10.0.0.0/8 [1/0] via 192.168.12.2
S     172.16.0.0/16 [1/0] via 192.168.13.3
      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
      203.0.113.0/24 is variably subnetted, 2 subnets, 2 masks
C        203.0.113.0/24 is directly connected, GigabitEthernet0/2
L        203.0.113.1/32 is directly connected, GigabitEthernet0/2
```

- Gateway of last resort usually means the default route.
- Same structure of command as other `ip route` settings.

Examine the diagram below. How many static routes would you have to configure on R3 for it to know all other destination networks shown in the diagram?

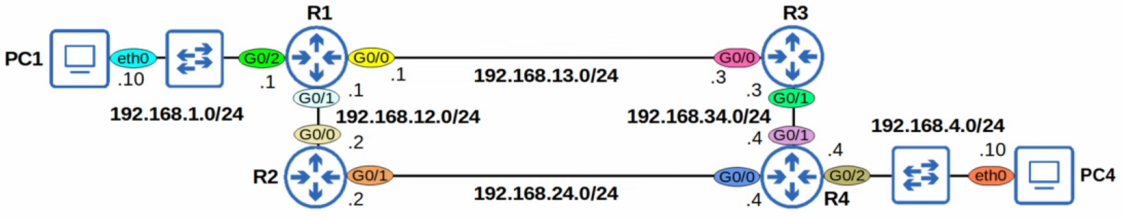
a) One route

b) Two routes

c) Three routes

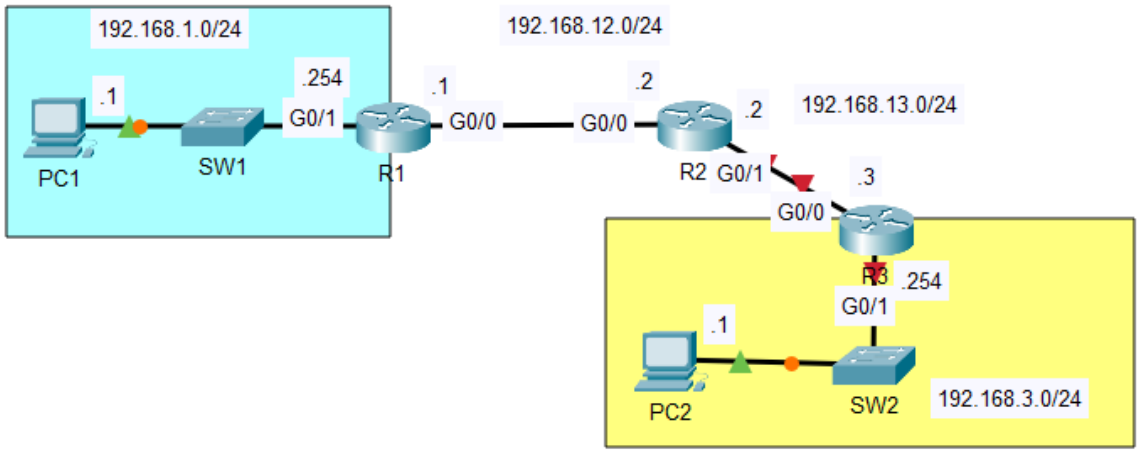
d) Four routes

R3 knows how to reach its own IP addresses and destinations in its connected networks, but it doesn't know how to reach destinations in remote networks.
Knows:
192.168.13.0/24 (incl. 192.168.13.3/32)
192.168.34.0/24 (incl. 192.168.34.3/32)
Doesn't know:
192.168.1.0/24
192.168.4.0/24
192.168.12.0/24
192.168.24.0/24



Packet Tracer Lab

Configuration

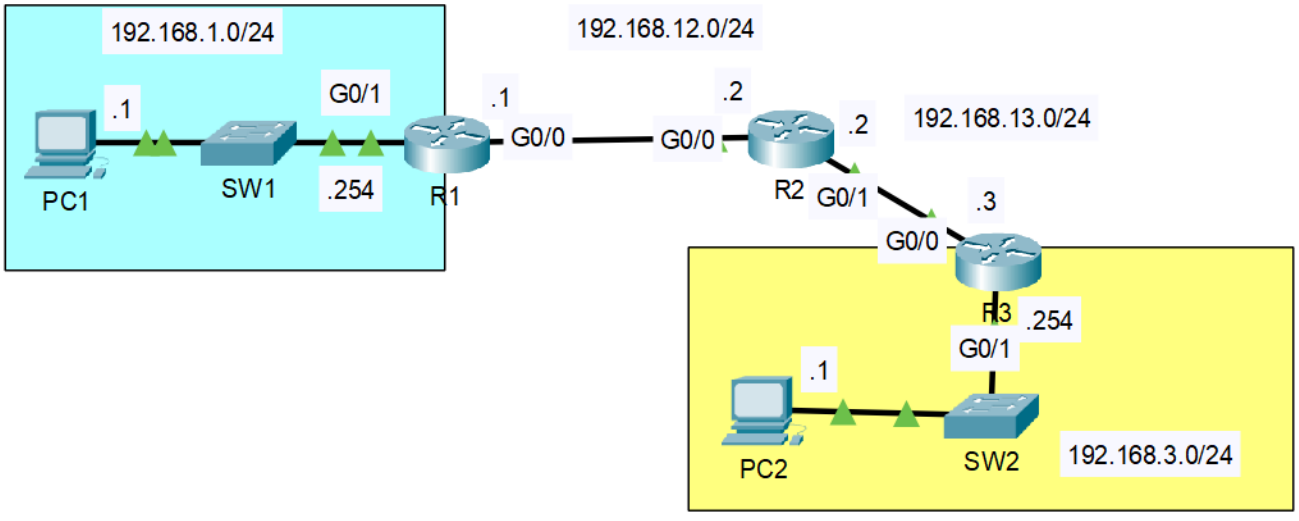


All devices have NO pre-configurations:

1. Configure the PCs and routers according to the network diagram (hostnames, IP addresses, etc.)
   Remember to configure the gateway on the PCs.
   (You don't have to configure the switches)

2. Configure static routes on the routers to enable PC1 to successfully ping PC2.

Troubleshooting



PC1 and PC2 are unable to ping eachother.

There is one misconfiguration on each router.

Find and fix the misconfigurations.

You have successfully completed the lab when PC1 and PC2 can ping eachother.