INFO 3605
Fundamentals of LAN Technologies
Lecture 18 - Configuring IPv4 Addresses and Static Routes

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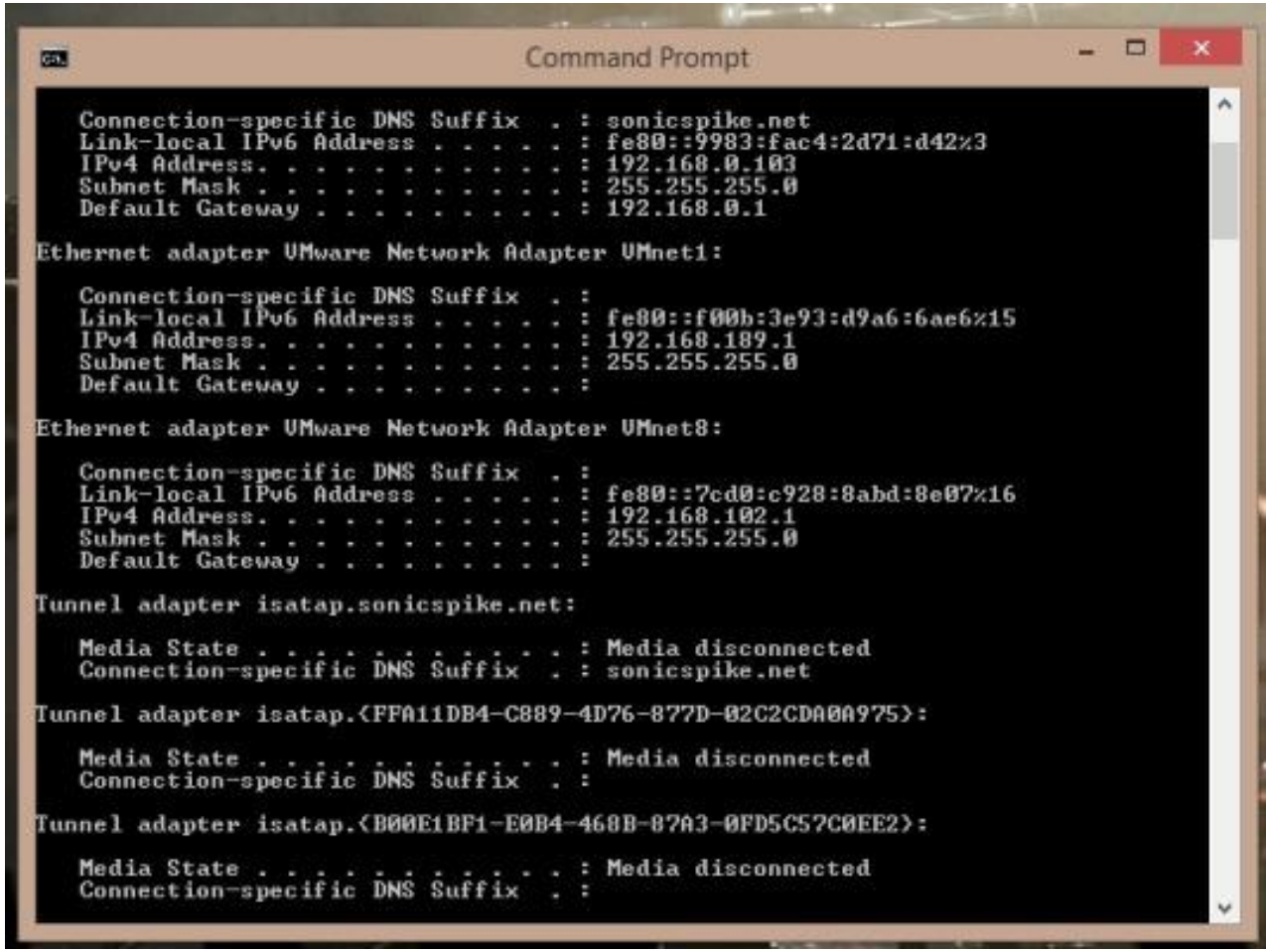
Based on Chapter 18 of Odom, Wendell. *CCENT/CCNA ICND1 100-105 official cert guide*. Indianapolis, IN: Cisco Press, 2016.

Default gateway at home

- Do you know what the default gateway is in your home network?
- Any traffic not destined to your local network goes through the default gateway.



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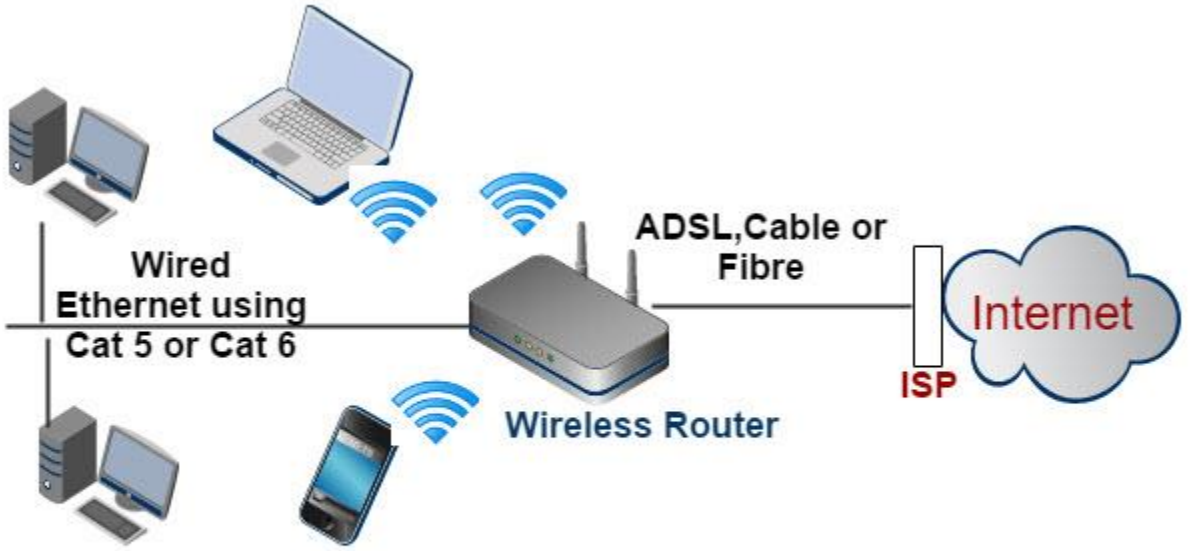

Network Diagram-Typical Simple Home Network

https://stevessmarthomeguide.com/build-home-network/

Objectives

- The student must be able to:
  - Configure, verify, and troubleshoot IPv4 addressing and subnetting
  - Understand Routing Technologies
  - Describe the routing concepts
    - Packet handling along the path through a network
    - Forwarding decision based on route lookup
    - Frame rewrite
  - Interpret the components of routing table
    - Prefix
    - Network mask
    - Next hop
    - Administrative distance
    - Gateway of last resort
    - Floating static

Quick Quiz

- A PC user opens a command prompt and uses the **ipconfig** command to see that the PC's IP address and mask are 192.168.4.77 and 255.255.255.224. The user then runs a test using the **ping 192.168.4.117** command. Which of the following answers is the most likely to happen?
  a. The PC sends packets directly to the host with address 192.168.4.117.
  b. The PC sends packets to its default gateway.
  c. The PC sends a DNS query for 192.168.4.117.
  d. The PC sends an ARP looking for the MAC address of the DHCP server.

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  b. The PC sends packets to its default gateway.

  c. The PC sends a DNS query for 192.168.4.117.

  d. The PC sends an ARP looking for the MAC address of the DHCP server.

Quick Quiz

- Router R1 lists a route in its routing table. Which of the following answers list a fact from a route that the router then compares to the packet's destination address? (Choose two answers.)
  a. Mask
  b. Next-hop router
  c. Subnet ID
  d. Outgoing interface

Quick Quiz

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  a. Mask

  b. Next-hop router

  c. Subnet ID

  d. Outgoing interface

Quick Quiz

- An engineer configures a static IPv4 route on Router R1. Which of the following pieces of information should not be listed as a parameter in the configuration command that creates this static IPv4 route?
  a. The destination subnet's subnet ID
  b. The next-hop router's IP address
  c. The next-hop router's neighboring interface
  d. The subnet mask

Quick Quiz

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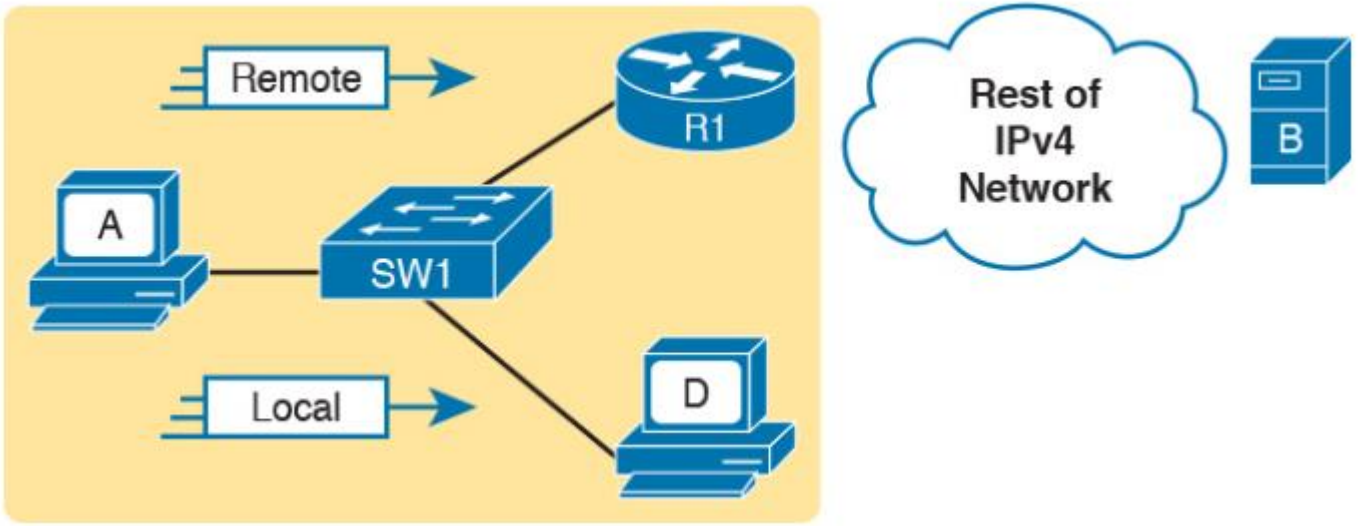
  d. The subnet mask

IP Routing

- IP routing—the process of forwarding IP packets—delivers packets across entire TCP/IP networks, from the device that originally builds the IP packet to the device that is supposed to receive the packet.
- The complete end-to-end routing process relies on :
  - network layer logic on hosts and on routers.
  - The routing process also relies on data-link and physical details at each link.
  - IP routing relies on serial links, Ethernet LANs, wireless LANs, etc.

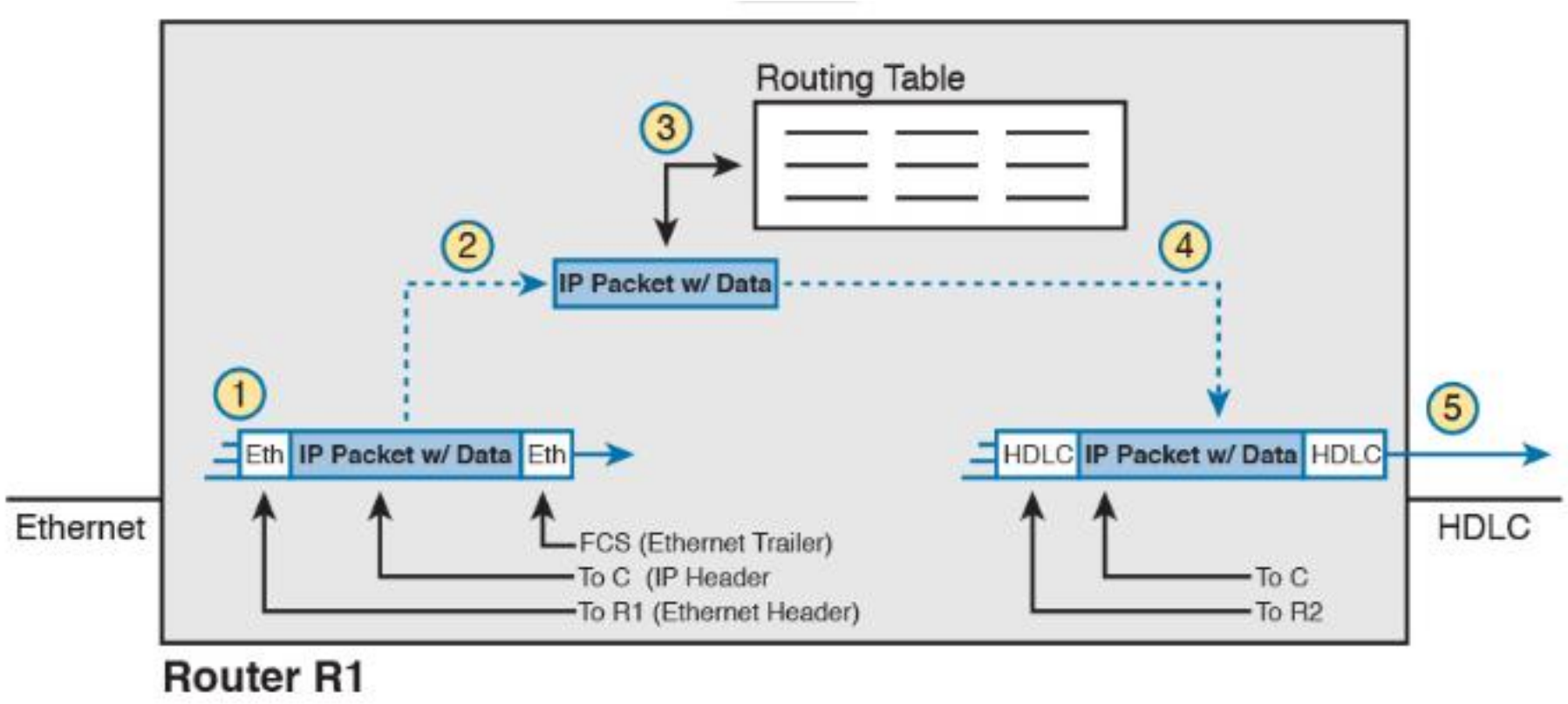
IPv4 Routing Process Reference

- NB: **Default gateway** and **default router** are synonyms



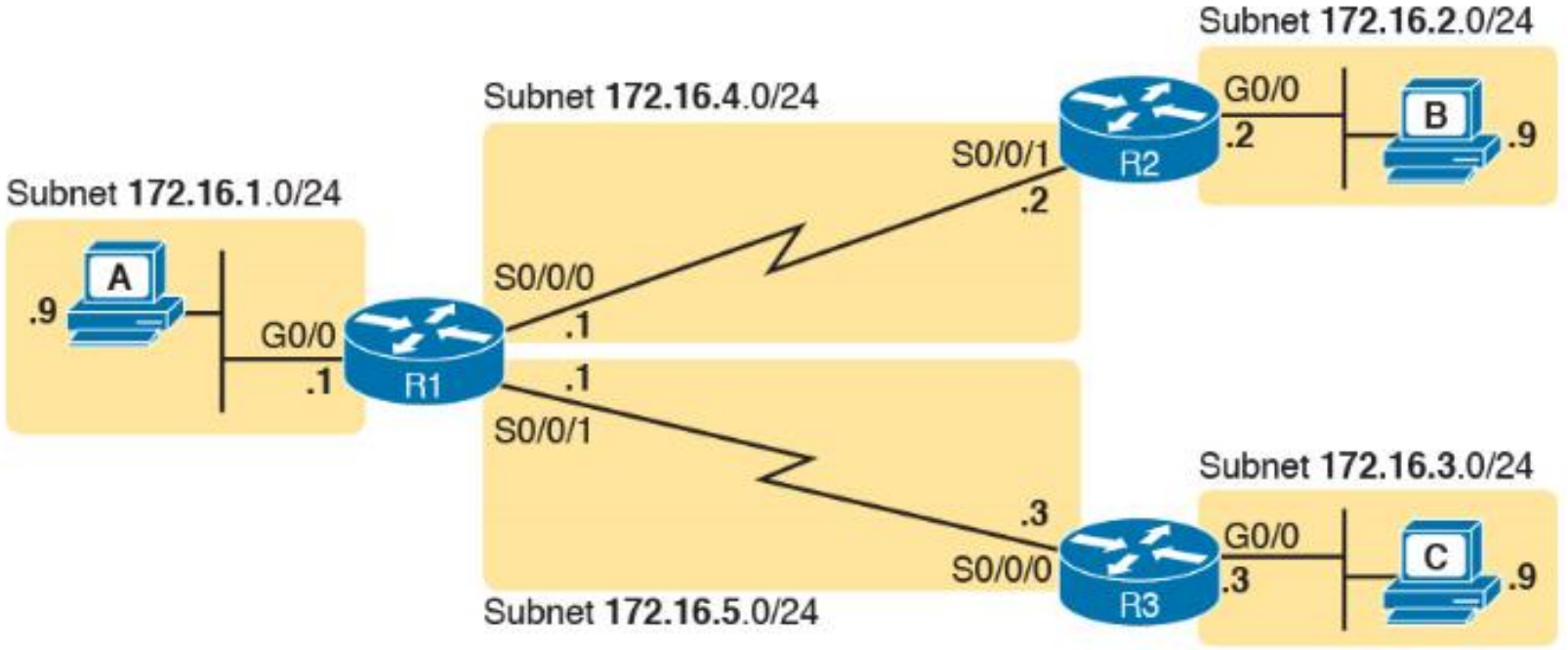
IPv4 Routing Process Reference

- Router Routing Logic Summary



An Example of IP Routing

- IPv4 Network Used to Show Five-Step Routing Example
- Host A IP: 172.16.1.9
- R1 LAN IP Address: 172.16.1.1
- R1 Serial IP Address: 172.16.4.1
- Host B IP: 172.16.2.9

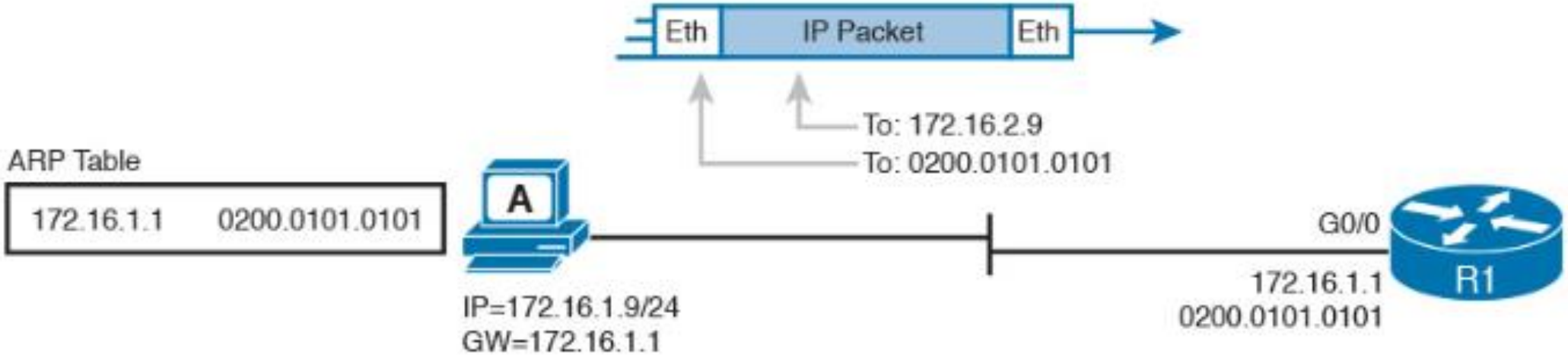


Host Forwards the IP Packet to the Default Router (Gateway)

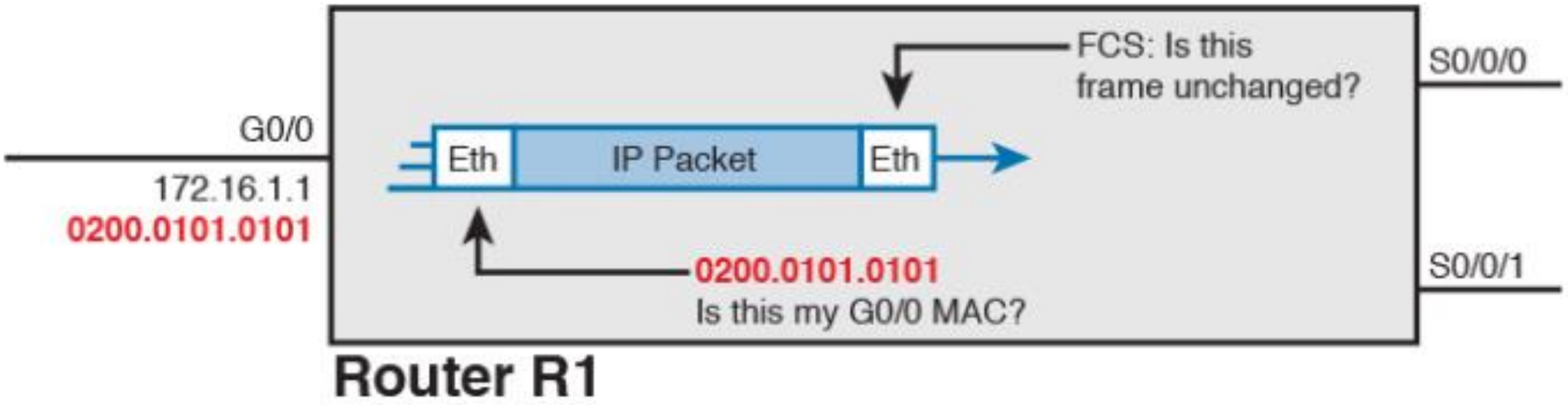
- After host A has the IP packet sitting in memory, host A's logic reduces to the following:
  - My IP address/mask is 172.16.1.9/24, so my local subnet contains numbers 172.16.1.0–172.16.1.255 (including the subnet ID and subnet broadcast address).
  - The destination address is 172.16.2.9, which is clearly not in my local subnet.
  - Send the packet to my default gateway, which is set to 172.16.1.1.
  - To send the packet, encapsulate it in an Ethernet frame. Make the destination MAC address be R1's G0/0 MAC address (host A's default gateway).

Host Forwards the IP Packet to the Default Router (Gateway)

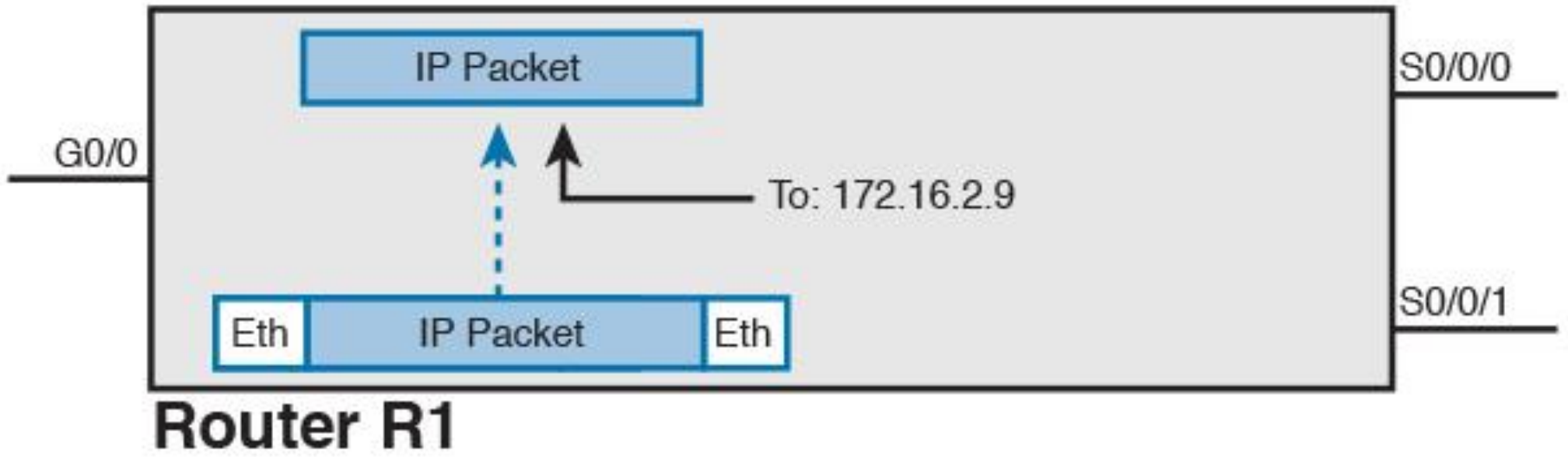
- Host A Sends Packet to Host B



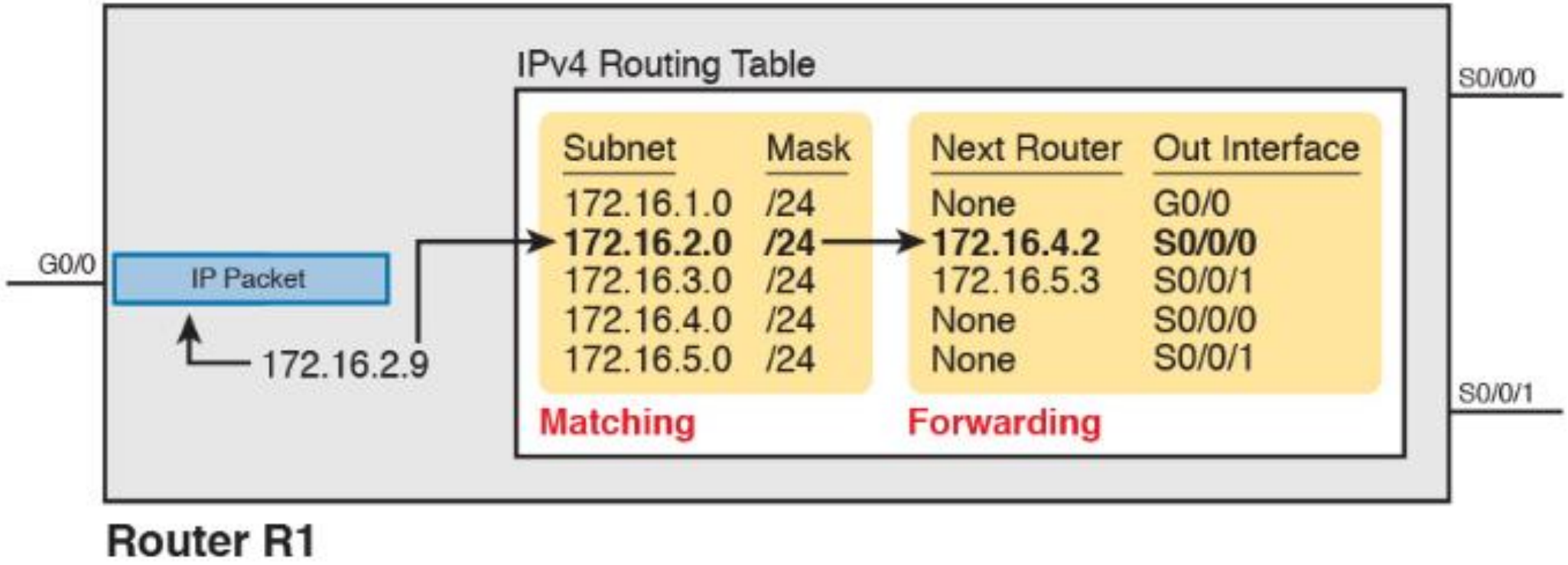
Routing Step 1: Decide Whether to Process the Incoming Frame



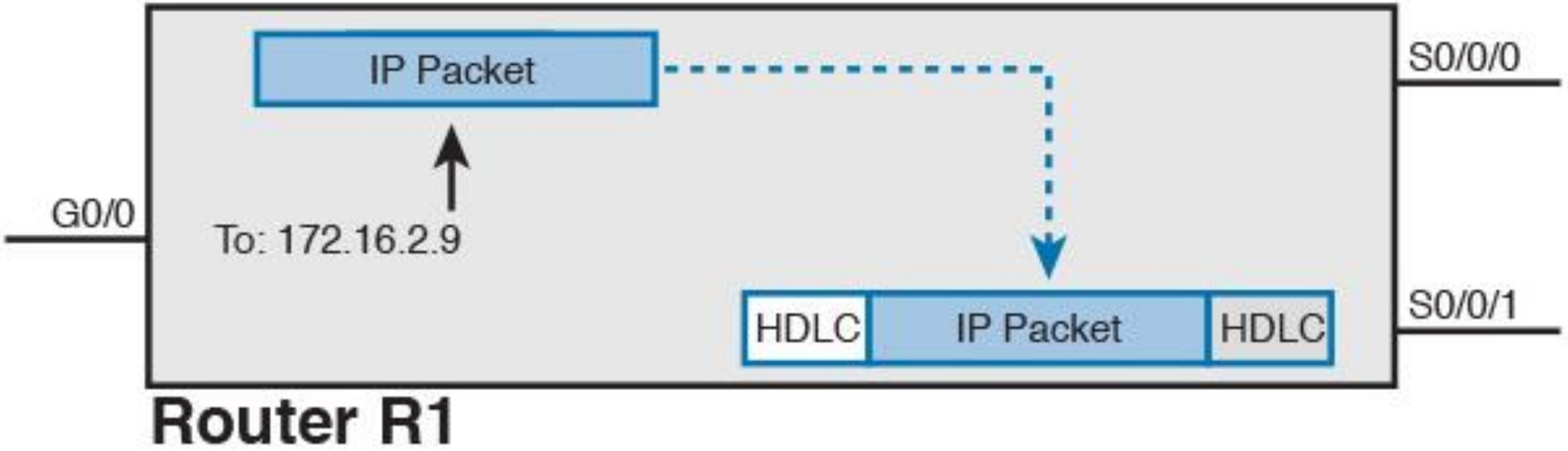
Routing Step 2: De-encapsulation of the IP Packet



Routing Step 3: Choosing Where to Forward the Packet



Routing Step 4: Encapsulating the Packet in a New Frame



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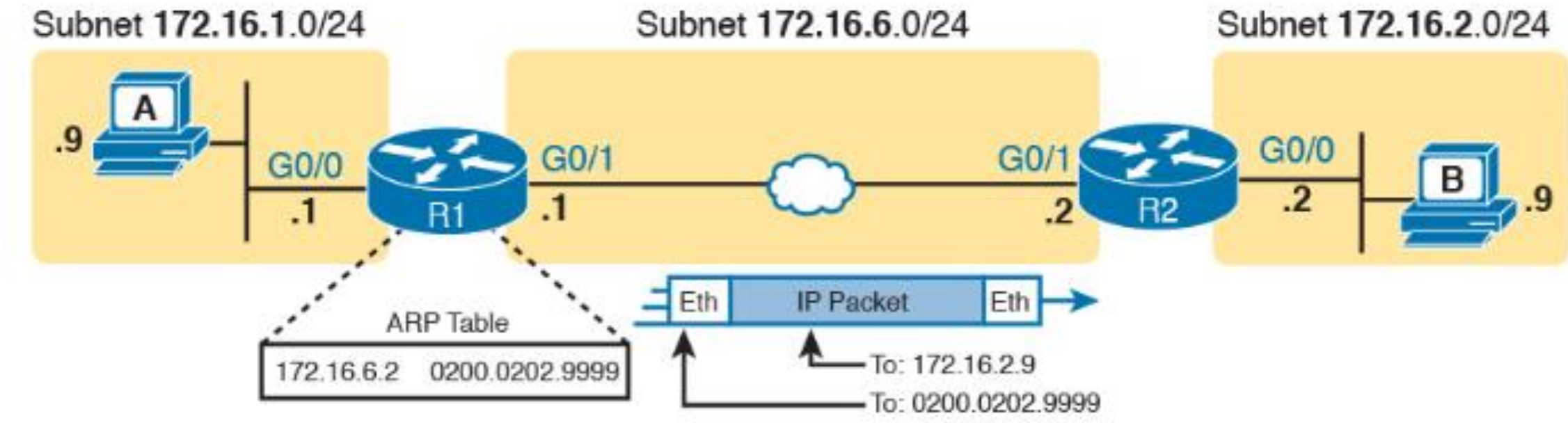
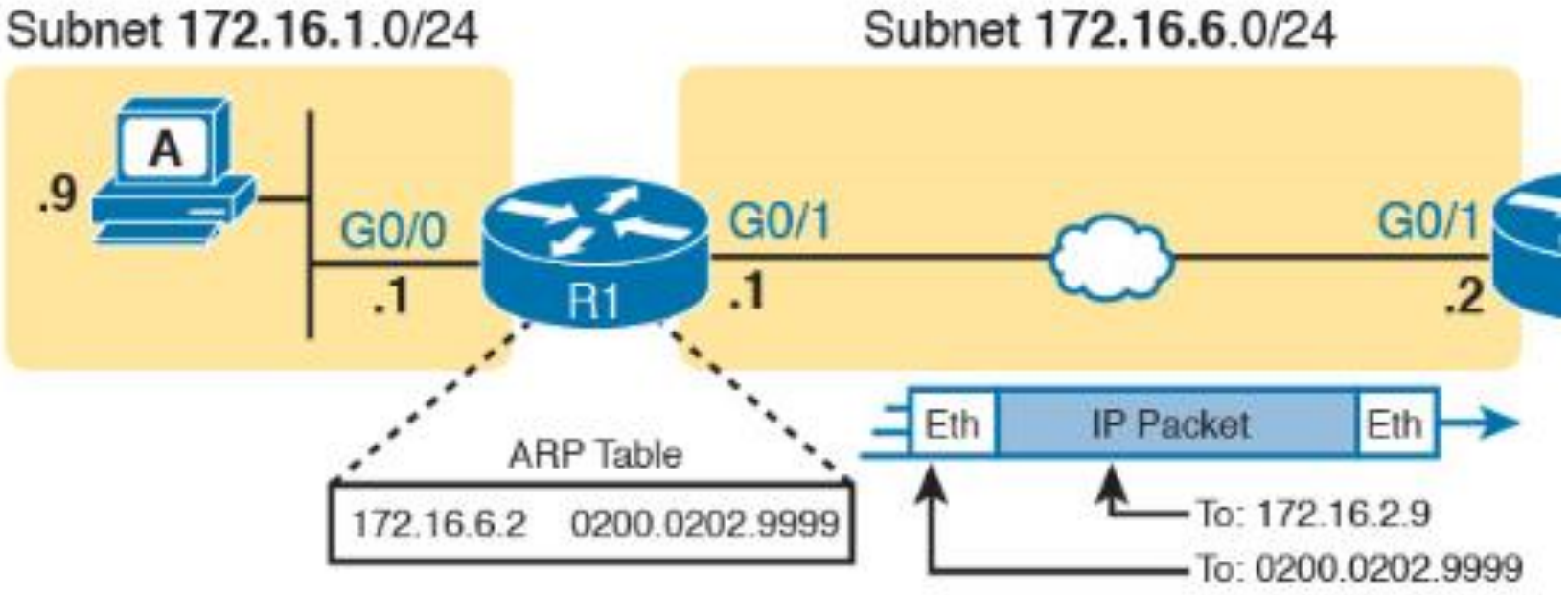


Routing Step 5: Transmitting the Frame



Configuring IP Addresses and Connected Routes

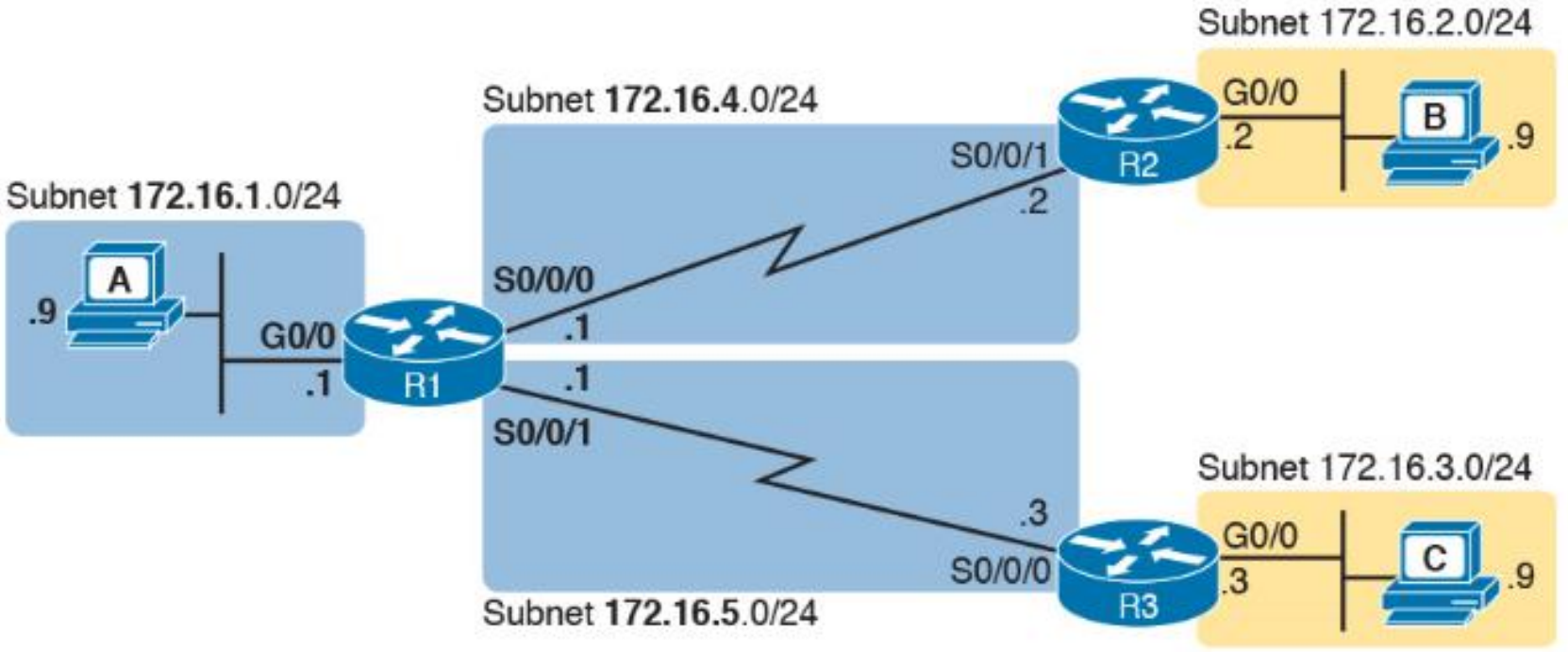
- Cisco routers enable IPv4 routing globally, by default.
- When you add a valid IP address to an interface it becomes routable.
- The router needs some routes to know where to send out the packets.
- Routers can add routes to their routing tables through three methods:
  - **Connected routes:** Added because of the configuration of the ip address interface subcommand on the local router
  - **Static routes:** Added because of the configuration of the ip route global command on the local router
  - **Routing protocols:** Added as a function by configuration on all routers, resulting in a process by which routers dynamically tell each other about the network so that they all learn routes

Connected Routes and the ip address Command

- A Cisco router automatically adds a route to its routing table for the subnet connected to each interface, assuming that the following two facts are true:
  - The interface is in a working state. In other words, the interface status in the show interfaces command lists a line status of up and a protocol status of up.
  - The interface has an IP address assigned through the ip address interface subcommand.
- Must include the mask in these IP addresses so that the subnet can be calculated.

Connected Routes and the ip address Command

- Connected and Local Routes on Router R1



Connected Routes and the ip address Command

- Connected and Local Routes on Router R1

```
! Excerpt from show running-config follows...
!
interface GigabitEthernet0/0
 ip address 172.16.1.1 255.255.255.0
!
interface Serial0/0/0
 ip address 172.16.4.1 255.255.255.0
!
interface Serial0/0/1
 ip address 172.16.5.1 255.255.255.0

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
```

Connected Routes and the ip address Command

- Connected and Local Routes on Router R1
- The local routes define a route for the one specific IP address configured on the router interface.
- Each local route has a /32 prefix length, defining a host route, which defines a route just for that one IP address.

```
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
       + - replicated route, % - next hop override

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 6 subnets, 2 masks
C        172.16.1.0/24 is directly connected, GigabitEthernet0/0
L        172.16.1.1/32 is directly connected, GigabitEthernet0/0
C        172.16.4.0/24 is directly connected, Serial0/0/0
L        172.16.4.1/32 is directly connected, Serial0/0/0
C        172.16.5.0/24 is directly connected, Serial0/0/1
L        172.16.5.1/32 is directly connected, Serial0/0/1
```

The ARP Table on a Cisco Router

- The IPv4 ARP table lists the IPv4 address and matching MAC address of hosts connected to the same subnet as the router.
- When forwarding a packet to a host on the same subnet, the router encapsulates the packet, with a destination MAC address as found in the ARP table.

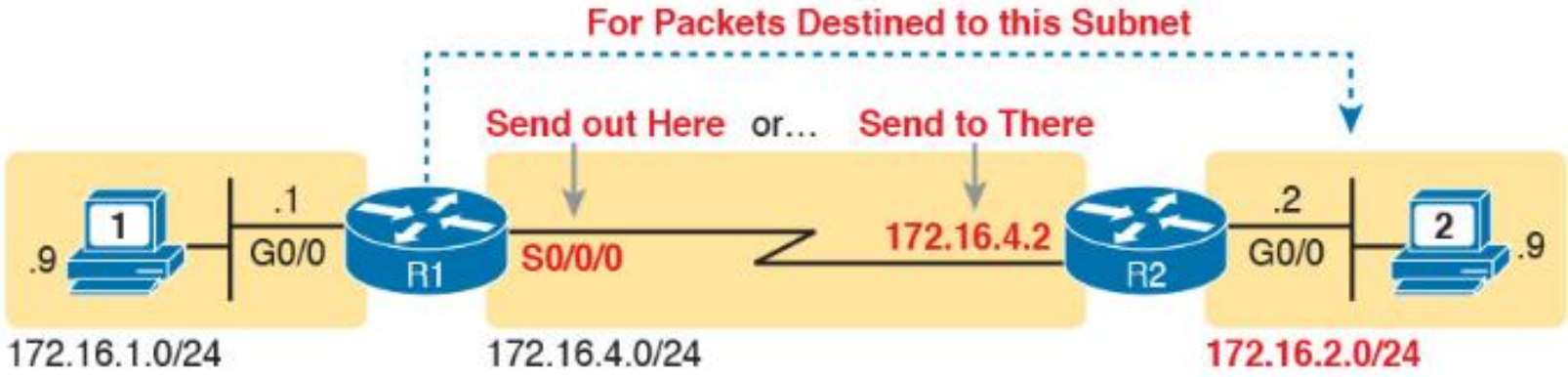
```
R2# show ip arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  172.16.1.1             -   0200.2222.2222  ARPA   GigabitEthernet0/0
Internet  172.16.1.9            35   0200.3333.3333  ARPA   GigabitEthernet0/0
```

The ARP Table on a Cisco Router

- When router R1 forwards a packet to host A (172.16.1.9), R1 does the following:
  - **1.** R1 looks in its ARP table for an entry for 172.16.1.9.
  - **2.** R1 encapsulates the IP packet in an Ethernet frame, adding destination 0200.3333.3333 to the Ethernet header (as taken from the ARP table).
  - **3.** R1 transmits the frame out interface G0/0.

Static Route Configuration

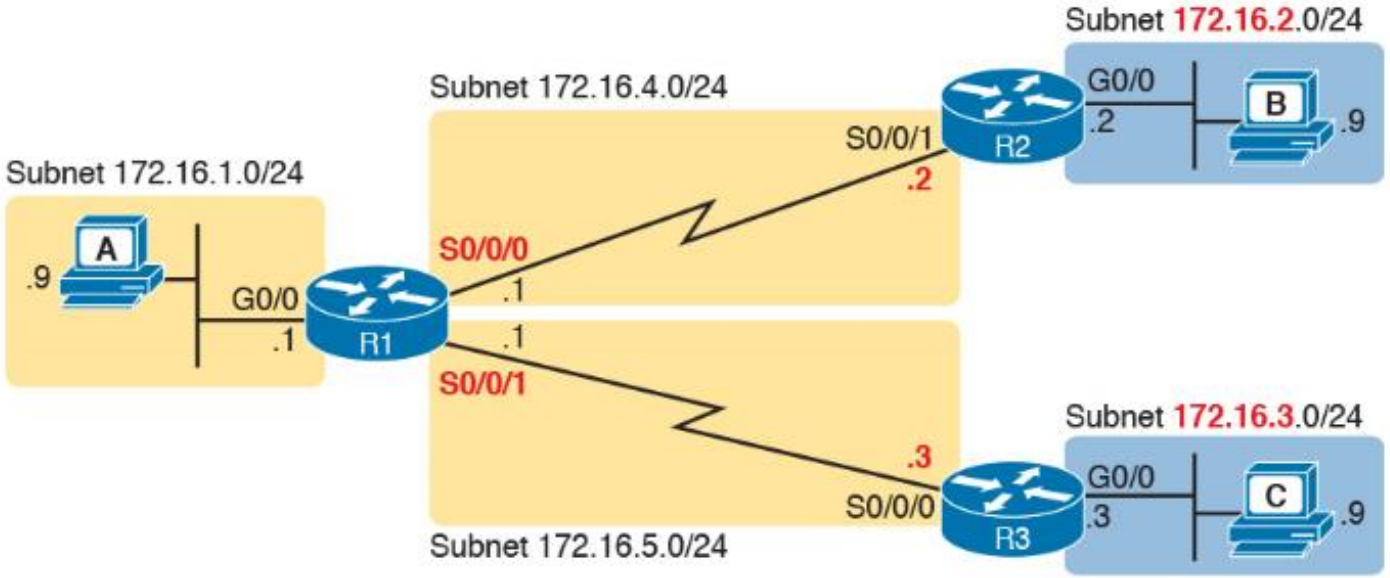
- IOS allows the definition of individual static routes using the ip route global configuration command.
- Every ip route command defines a destination that can be matched, usually with a subnet ID and mask.



- R1 will configure the subnet ID and mask, and either R1's outgoing interface (S0/0/0), or R2 as the next-hop router IP address (172.16.4.2).

Static Route Configuration

- The first command shows subnet 172.16.2.0, mask 255.255.255.0, which sits on a LAN near Router R2.
- The Second command has same logic ad the first but instead of identifying the next router by IP address, it lists the local router's outgoing interface.
- To send packets to the subnet off Router R3, send them out my own local S0/0/1 interface (which happens to connect to R3).




```
ip route 172.16.2.0 255.255.255.0 172.16.4.2
ip route 172.16.3.0 255.255.255.0 S0/0/1
```

Static Route Configuration

- The routes created by these two ip route commands actually look a little different in the IP routing table.
  - Both are static routes.
- The route that used the outgoing interface configuration is also noted as a connected route; this is just a quirk of the output of the show ip route command.

```
R1# show ip route static
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
! lines omitted for brevity
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 10 subnets, 2 masks
S        172.16.2.0/24 [1/0] via 172.16.4.2
S        172.16.3.0/24 is directly connected, Serial0/0/1
```

Static Host Routes

- A host route as a route for a single host address, as noted with the IP address and a /32 mask.
- The ip route command can create static routes for remote hosts by using a mask of 255.255.255.255.
- Useful for cases in which redundant paths exist, and you want traffic to most of the hosts in the subnet to flow over one path, and traffic for one specific host to flow over the other path.

```
ip route 10.1.1.0 255.255.255.0 10.2.2.2
ip route 10.1.1.9 255.255.255.255 10.9.9.9
```

Static Host Routes

```
ip route 10.1.1.0 255.255.255.0 10.2.2.2
ip route 10.1.1.9 255.255.255.255 10.9.9.9
```

- Note that these two routes overlap:
  - a packet sent to 10.1.1.9 that arrives at the router would match both routes.
  - When that happens, routers use the most specific route (that is, the route with the longest prefix length).
- a packet sent to 10.1.1.9 would be forwarded to next-hop router 10.9.9.9,
- and packets sent to other destinations in subnet 10.1.1.0/24 would be sent to next-hop router 10.2.2.2.

Static Routes with No Competing Routes

- If the configured route has no competing routes, the router still checks a few rules before adding the route to its IP routing table.
  - The router first checks for any competing routes (that is, whether there are any other routes for the exact same subnet).
  - Even if no competing routes exist, IOS also considers the following before adding the route to its routing table:
    - For ip route commands that list an outgoing interface, that interface must be in an up/up state.
    - For ip route commands that list a next-hop IP address, the local router must have a route to reach that next-hop address.

Static Routes with No Competing Routes

- R1's command ip route 172.16.2.0 255.255.255.0 172.16.4.2 defines a static route.
- Assume there were no competing routes and all links were working.
- Based on this route, R1 looks at its IP routing table and finds a route matching next-hop address 172.16.4.2 (R1's connected route for subnet 172.16.4.0/24).
- As a result, R1 adds the static route to subnet 172.16.2.0/24.
- If R1's S0/0/0 were to fail, R1 would remove its connected route to 172.16.4.0/24, which would then cause R1 to remove its static route to 172.16.2.0/24.

```
ip route 172.16.2.0 255.255.255.0 172.16.4.2
ip route 172.16.3.0 255.255.255.0 S0/0/1
```

Static Routes with No Competing Routes

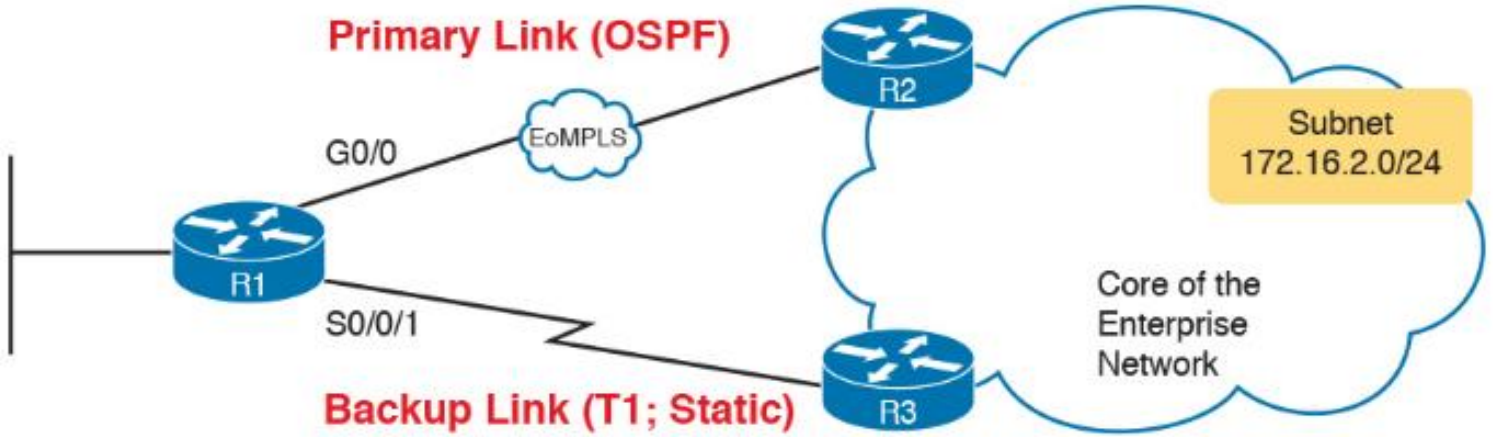
- Permanently Adding Static Routes to the IP Routing Table (Router R1) so that IOS always putting the IP route in the routing table.

```
ip route 172.16.2.0 255.255.255.0 172.16.4.2 permanent
ip route 172.16.3.0 255.255.255.0 S0/0/1 permanent
```

- NB: If an interface fails, the route would still be present and could cause unexpected results.

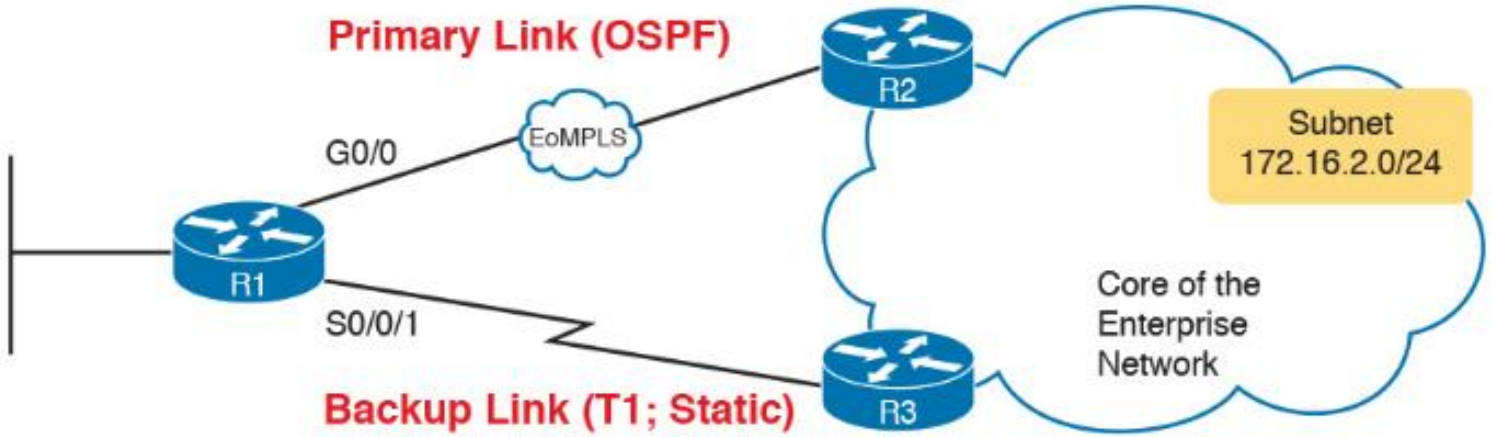
Static Routes with Competing Routes

- There may be more than one static route to a destination network.
- In these cases, the router must first decide which routing source has the better administrative distance, with lower being better, and then use the route learned from the better source.
- Using a Floating Static Route to Key Subnet 172.16.2.0/24



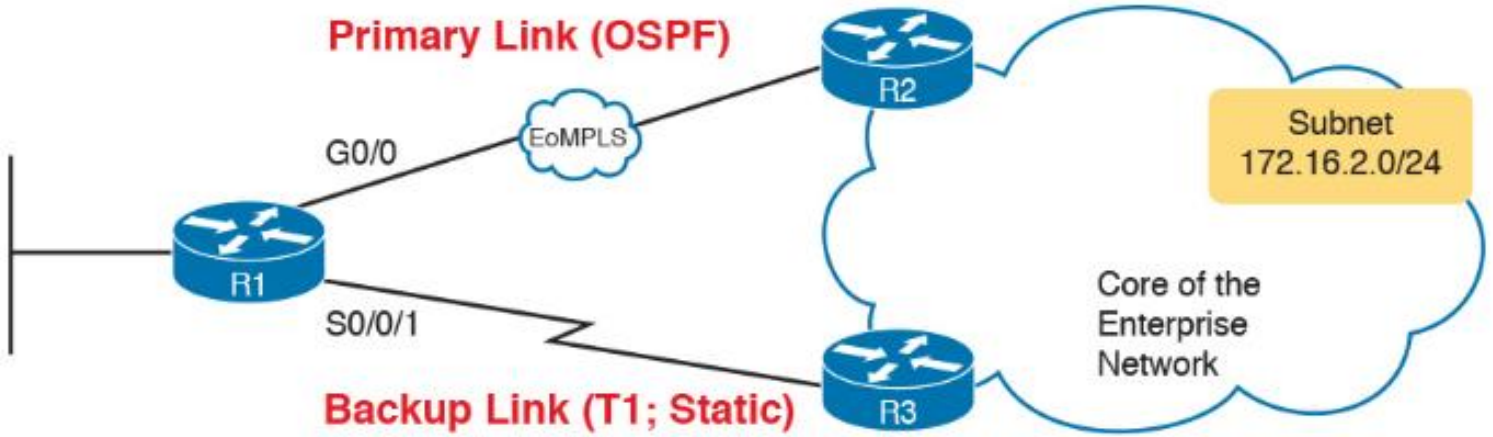
Static Routes with Competing Routes

- A branch office with two WAN links:
  - one very fast Gigabit Ethernet link and
  - one rather slow (but cheap) T1.
- The network uses Open Shortest Path First Version 2 (OSPFv2) over the primary link, learning a route for subnet 172.16.2.0/24.
- R1 also defines a static route over the backup link to that exact same subnet, so R1 must choose whether to use the static route or the OSPF-learned route.



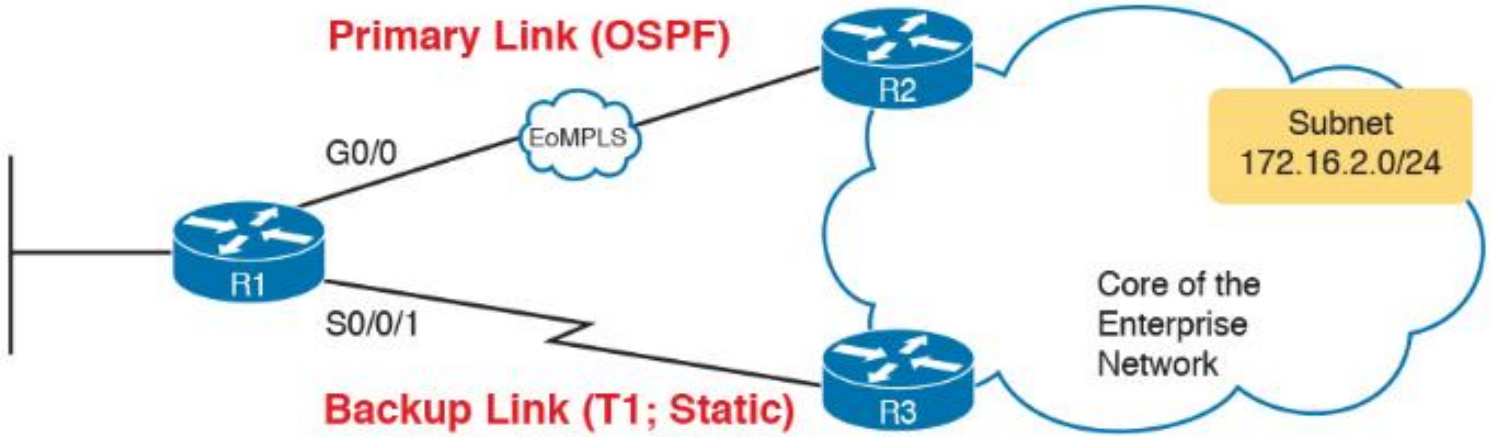
Static Routes with Competing Routes

- IOS considers static routes better than OSPF-learned routes.
- By default, IOS gives static routes an administrative distance of 1 and OSPF routes an administrative distance of 110.
- To instead prefer the OSPF routes, the configuration would need to change the administrative distance settings and use what many networkers call a floating static route.



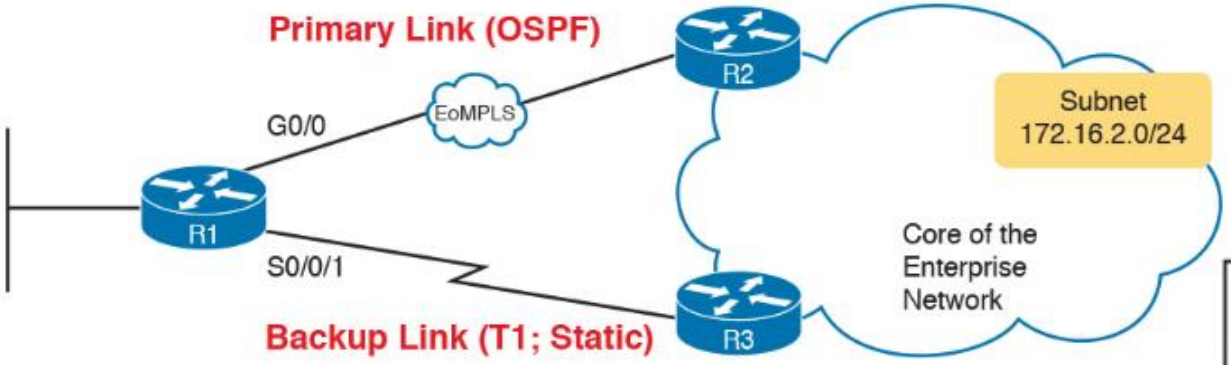
Static Routes with Competing Routes

- To implement a floating static route, just override the default administrative distance on the static route, making the value larger than the default administrative distance of the routing protocol.
- The ip route 172.16.2.0 255.255.255.0 172.16.5.3 130 command on R1 would do exactly that, setting the static route's administrative distance to 130.



Static Routes with Competing Routes

- Displaying the Administrative Distance of the Static Route




```
R1# show ip route static
! Legend omitted for brevity

      172.16.0.0/16 is variably subnetted, 6 subnets, 2 masks
S        172.16.2.0/24 is directly connected, Serial0/0/1

R1# show ip route 172.16.2.0
Routing entry for 172.16.2.0/24
  Known via "static", distance 130, metric 0 (connected)
  Routing Descriptor Blocks:
  * directly connected, via Serial0/0/1
      Route metric is 0, traffic share count is 1
```

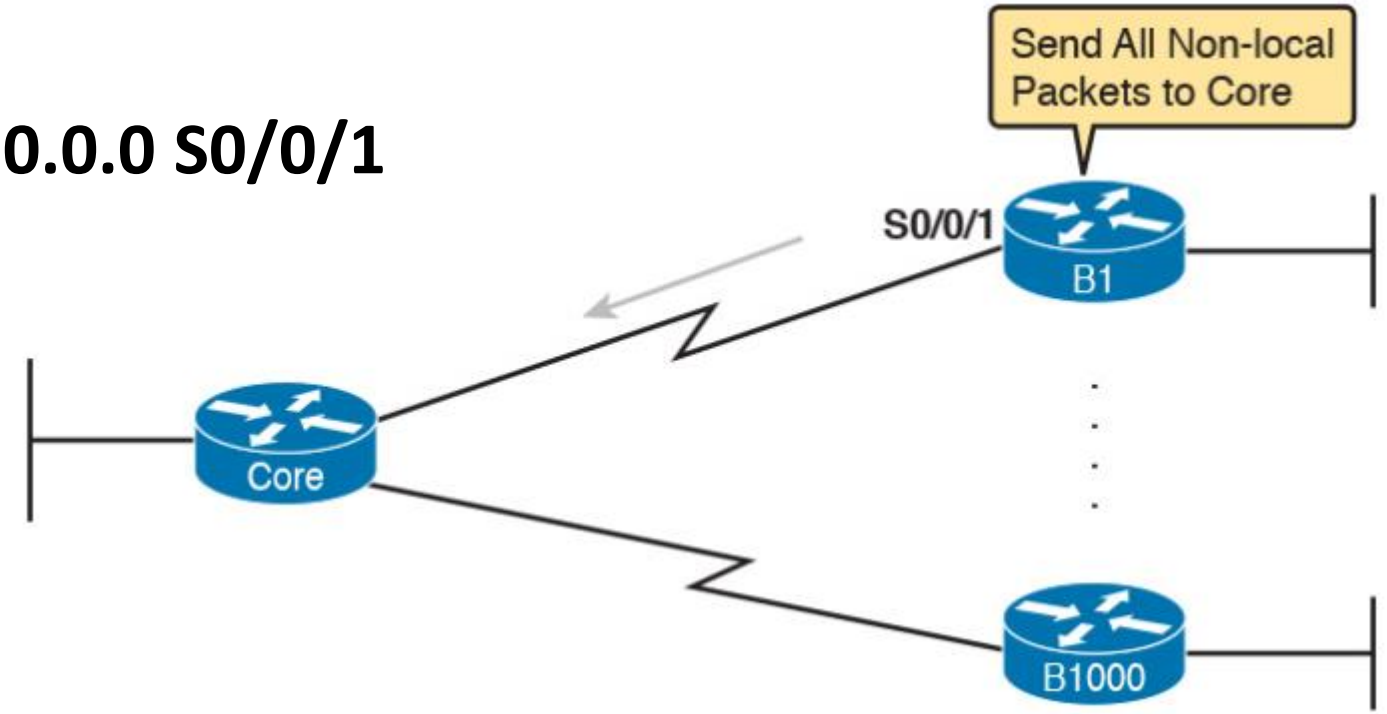
Static Default Routes

- When a router tries to route a packet, the router might not match the packet's destination IP address with any route.
  - In this situation, the router normally just discards the packet.
- Routers can be configured so that they use either a statically configured or dynamically learned default route.
- The default route matches all packets, so that if a packet does not match any other more specific route in the routing table, the router can at least forward the packet based on the default route.

Static Default Routes

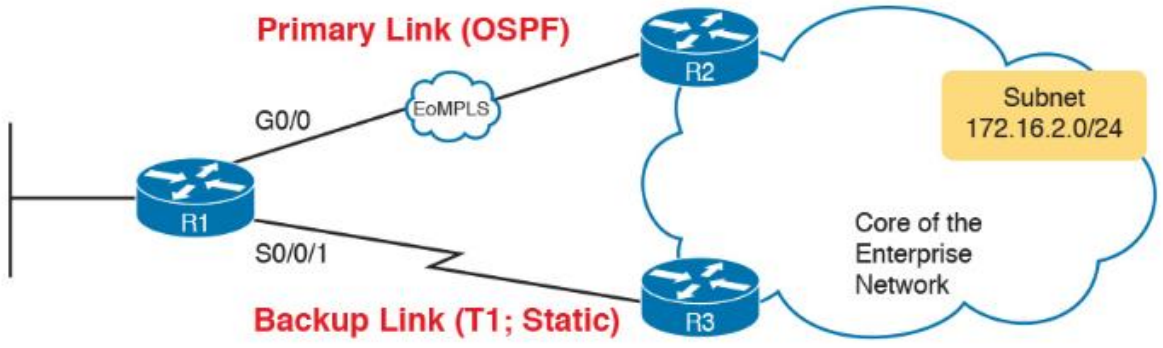
- Example Use of Static Default Routes at 1000 Low-Speed Remote Sites.
- On router B1

ip route 0.0.0.0 0.0.0.0 S0/0/1



Static Default Routes

- Adding a Static Default Route on R2




```
R2# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)# ip route 0.0.0.0 0.0.0.0 s0/0/1
R2(config)# ^Z
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
       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
       + - replicated route, % - next hop override

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

S*    0.0.0.0/0 is directly connected, Serial0/0/1
      172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks
C        172.16.2.0/24 is directly connected, GigabitEthernet0/0
L        172.16.2.2/32 is directly connected, GigabitEthernet0/0
C        172.16.4.0/24 is directly connected, Serial0/0/1
L        172.16.4.2/32 is directly connected, Serial0/0/1
```

- The **show ip route** lists the route with a code of S, meaning static, but also with a *, meaning it is a candidate default route.
- The “Gateway of Last Resort” refers to the chosen default route, which in this case is the just-configured static route with outgoing interface S0/0/1.

Troubleshooting Incorrect Static Routes that Appear in the IP Routing Table

- A static route is only as good as the input typed into the ip route command.
- Example:
  - Address 192.168.1.101 and .102, with mask /26

  ip route 192.168.1.64 255.255.255.224 192.168.1.65
  - The range of addresses in subnet 192.168.1.64, with mask 255.255.255.224, does not include the .101 and .102 addresses.
  - But have a subnetting math mistake.

Troubleshooting Incorrect Static Routes that Appear in the IP Routing Table

- Check on these items:
  - Is there a subnetting math error in the subnet ID and mask?
  - Is the next-hop IP address correct, and referencing an IP address on a neighboring router?
  - Is the outgoing interface correct, and referencing an interface on the local route (that is, the same router where the static route is configured)?

The Static Route Does Not Appear in the IP Routing Table

- Reasons why a route may not show in a routing table:
  - The outgoing interface listed in the ip route command is not up/up.
  - The next-hop router IP address listed in the ip route command is not reachable (that is, there is no route that matches the next-hop address).
  - A better competing route (another route to the exact same subnet ID and mask) exists, and that competing route has a better (lower) administrative distance.

The Correct Static Route Appears but Works Poorly

- Route may be up but packet may not get through:
  - The static route could be set as permanent.
    - Even if the interface is down, the route is still available/being advertised to other routers.
  - The **ip route … permanent** command, tells the IOS to ignore route checks.

Command Configuration Reference

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Command	Description
ip address *ip-address mask*	Interface subcommand that assigns the interface's IP address
interface *type number.subint*	Global command to create a subinterface and to enter configuration mode for that subinterface
encapsulation dot1q *vlan-id* [native]	A subinterface subcommand that tells the router to use 802.1Q trunking, for a particular VLAN, and with the native keyword, to not encapsulate in a trunking header
encapsulation isl *vlan-identifier*	A subinterface subcommand that tells the router to use ISL trunking for a particular VLAN
sdm prefer lanbase-routing	A command on Cisco switches that enables the switch to support IP routing if configured
[no] ip routing	Global command that enables (**ip routing**) or disables (**no ip routing**) the routing of IPv4 packets on a router or Layer 3 switch
interface vlan *vlan_id*	Global command on a Layer 3 switch to create a VLAN interface and to enter configuration mode for that VLAN interface
ip route *prefix mask* {*ip-address* | *interface-type interface-number*} [*distance*] [permanent]	Global configuration command that creates a static route

EXEC Command Reference

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Command	Description
show ip route	Lists the router's entire routing table
show ip route [connected | static | rip]	Lists a subset of the IP routing table
show ip route *ip-address*	Lists detailed information about the route that a router matches for the listed IP address
show vlans	Lists VLAN configuration and statistics for VLAN trunks configured on routers
show arp, show ip arp	Lists the router's IPv4 ARP table
clear ip arp [*ip-address*]	Removes all dynamically learned ARP table entries, or if the command lists an IP address, removes the entry for that IP address only

What do you know now?

- Which of the following commands correctly configures a static route?
  a. ip route 10.1.3.0 255.255.255.0 10.1.130.253
  b. ip route 10.1.3.0 serial 0
  c. ip route 10.1.3.0 /24 10.1.130.253
  d. ip route 10.1.3.0 /24 serial 0

What do you know now?

- Which of the following commands correctly configures a static route?

  a. ip route 10.1.3.0 255.255.255.0 10.1.130.253

  b. ip route 10.1.3.0 serial 0

  c. ip route 10.1.3.0 /24 10.1.130.253

  d. ip route 10.1.3.0 /24 serial 0

What do you know now?

- A network engineer configures the **ip route 10.1.1.0 255.255.255.0 s0/0/0** command on a router, and then issues a **show ip route** command from enable mode. No routes for subnet 10.1.1.0/24 appear in the output. Which of the following could be true?
  a. The ip route command has incorrect syntax and was rejected in config mode.
  b. interface s0/0/0 is down.
  c. The router has no up/up interfaces in Class A network 10.0.0.0.
  d. The ip route command is missing a next-hop router IP address.

What do you know now?

- A network engineer configures the **ip route 10.1.1.0 255.255.255.0 s0/0/0** command on a router, and then issues a **show ip route** command from enable mode. No routes for subnet 10.1.1.0/24 appear in the output. Which of the following could be true?
  a. The ip route command has incorrect syntax and was rejected in config mode.
  b. interface s0/0/0 is down.
  c. The router has no up/up interfaces in Class A network 10.0.0.0.
  d. The ip route command is missing a next-hop router IP address.

Summary

- Steps taken by a host when forwarding IP packets.
- Steps taken by a router when forwarding IP packets.
- Breakdown of IP routing table with matching and forwarding details.
- Three common sources from which routers build IP routes.
- Rules regarding when a router creates a connected route.
- Troubleshooting checklist for routes that do appear in the IP routing table.
- Troubleshooting checklist for static routes that do not appear in the IP routing table.

End of Lecture 18, Further Reading, References

- Odom, Wendell. *CCENT/CCNA ICND1 100-105 official cert guide*. Indianapolis, IN: Cisco Press, 2016.