Ip routing (UNIT -4)

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Enterprise network engineering

The term “IP routing” refers to the packet-forwarding process only.

IP routing—the process of forwarding IP packets—delivers packets across entire TCP/IP net- works, from the device that originally builds the IP packet to the device that is supposed to receive the packet.

IPv4 Routing Process Reference

The routing process starts with the host that creates the IP packet. First, the host asks the question: Is the destination IP address of this new packet in my local subnet? The host uses its own IP address/mask to determine the range of addresses in the local subnet. Based on its own opinion of the range of addresses in the local subnet, a LAN-based host acts as follows:

Step 1.

If the destination is local, send directly:

- **Find the destination host’s MAC address. Use the already-known Address Resolution Protocol (ARP) table entry, or use ARP messages to learn the infor- mation.**
- **Encapsulate the IP packet in a datalink frame, with the destination data link address of the destination host.**

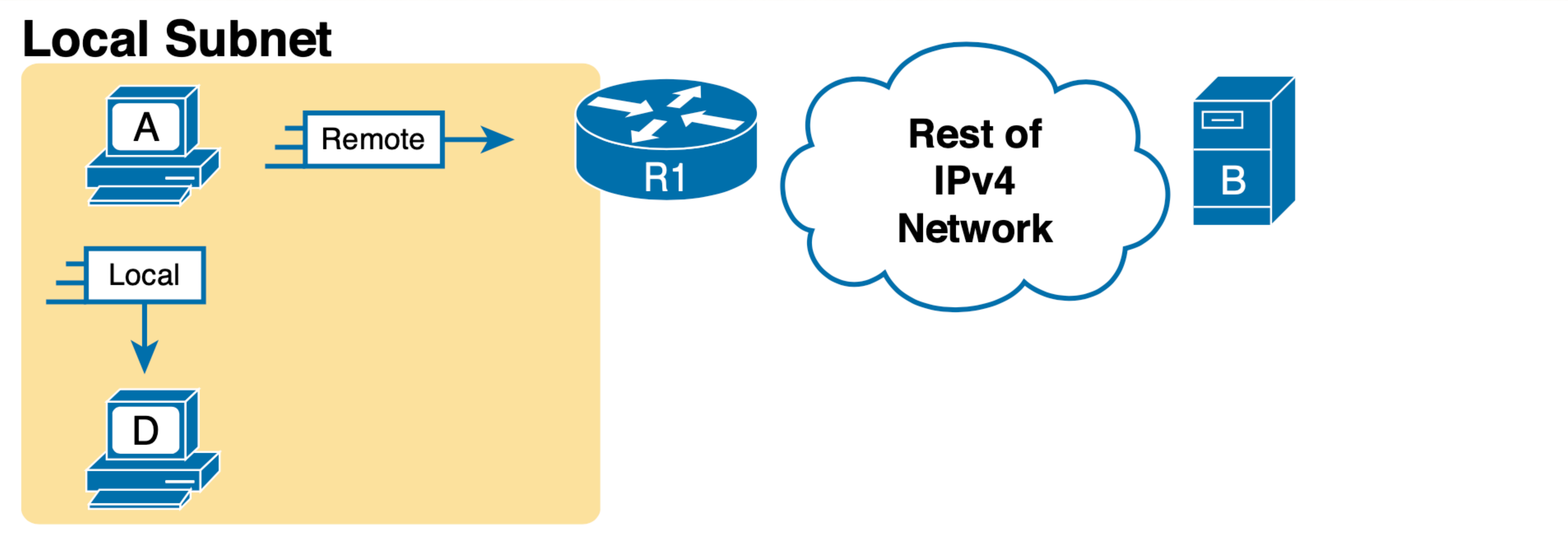
Step 2.

If the destination is not local, send to the default gateway:

A. Find the default gateway’s MAC address. Use the already-known ARP table entry, or use ARP messages to learn the information.

B. Encapsulate the IP packet in a datalink frame, with the destination data link address of the default gateway.

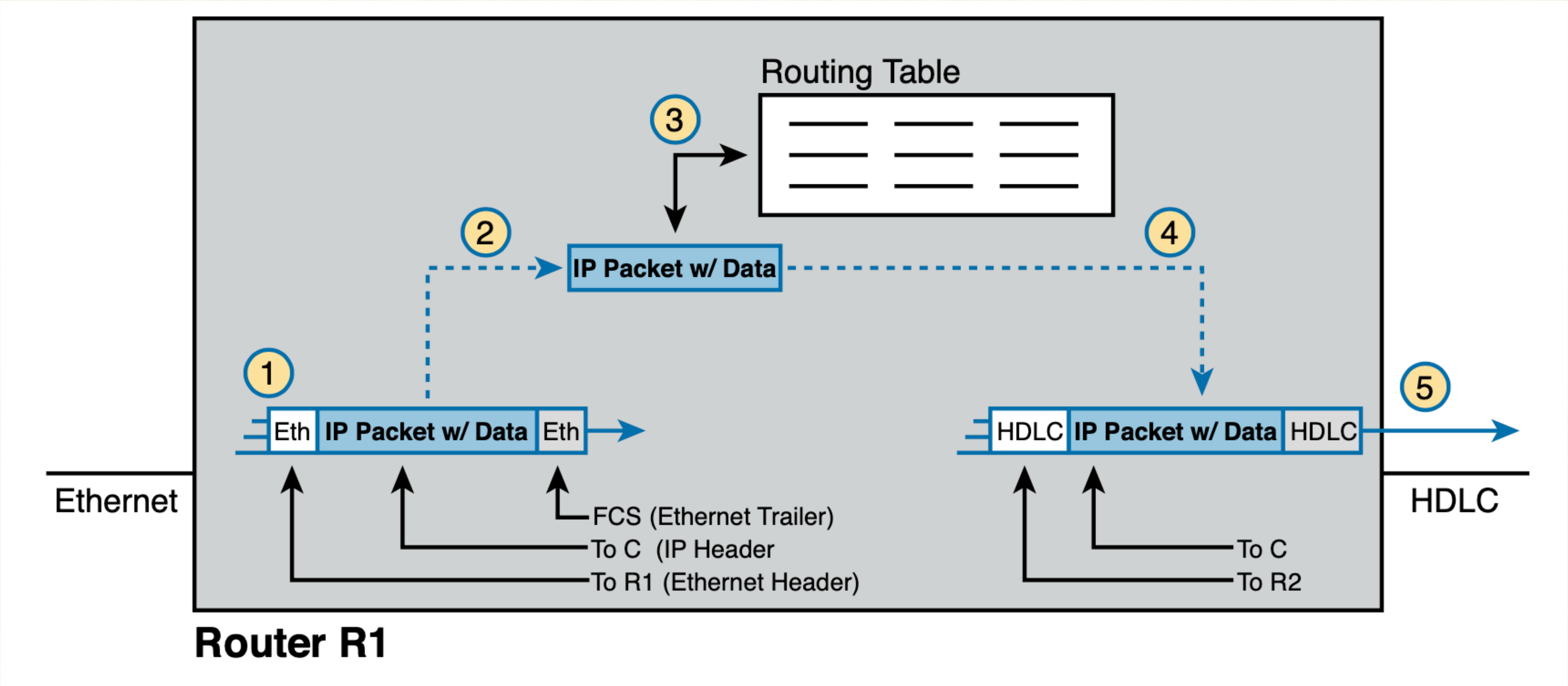
Host routing logic summary



NOTE The fact that this list has five steps, instead of breaking the logic into some other number of steps, does not matter. The concepts inside each step matter a lot—know them—but for the exams, there is no need to memorize which piece of logic goes with a particular step number.

Routers have a little more routing work to do as compared with hosts. While the host logic began with an IP packet sitting in memory, a router has some work to do before getting to that point. With the following five-step summary of a router's routing logic, the router takes the first two steps just to receive the frame and extract the IP packet, before thinking about the packet's destination address at Step 3. The steps are as follows:

1. **For each received data link frame, choose whether or not to process the frame. Process it if:**
   - **The frame has no errors (per the data link trailer Frame Check Sequence, or FCS, field)**
   - **The frame's destination data link address is the router's address (or an appropriate multicast or broadcast address).**
2. **If choosing to process the frame at Step 1, de-encapsulate the packet from inside the data link frame.**
3. **Make a routing decision. To do so, compare the packet's destination IP address to the routing table and find the route that matches the destination address. This route identifies the outgoing interface of the router and possibly the next-hop router.**
4. **Encapsulate the packet into a data link frame appropriate for the outgoing interface. When forwarding out LAN interfaces, use ARP as needed to find the next device's MAC address.**
5. **Transmit the frame out the outgoing interface, as listed in the matched IP route.**


Routing Table
3
2
IP Packet w/ Data
4
1
5
Eth
IP Packet w/ Data
Eth
HDLC
IP Packet w/ Data
HDLC
Ethernet
HDLC
FCS (Ethernet Trailer)
To C (IP Header
To R1 (Ethernet Header)
To C
To R2
Router R1

ROUTER ROUTING LOGIC SUMMARY

Router R1 processes the frame and packet as shown with the numbers in the figure, matching the same five-step process describe just before the figure, as follows:

1. **Router R1 notes that the received Ethernet frame passes the FCS check, and that the destination Ethernet MAC address is R1's MAC address, so R1 processes the frame.**

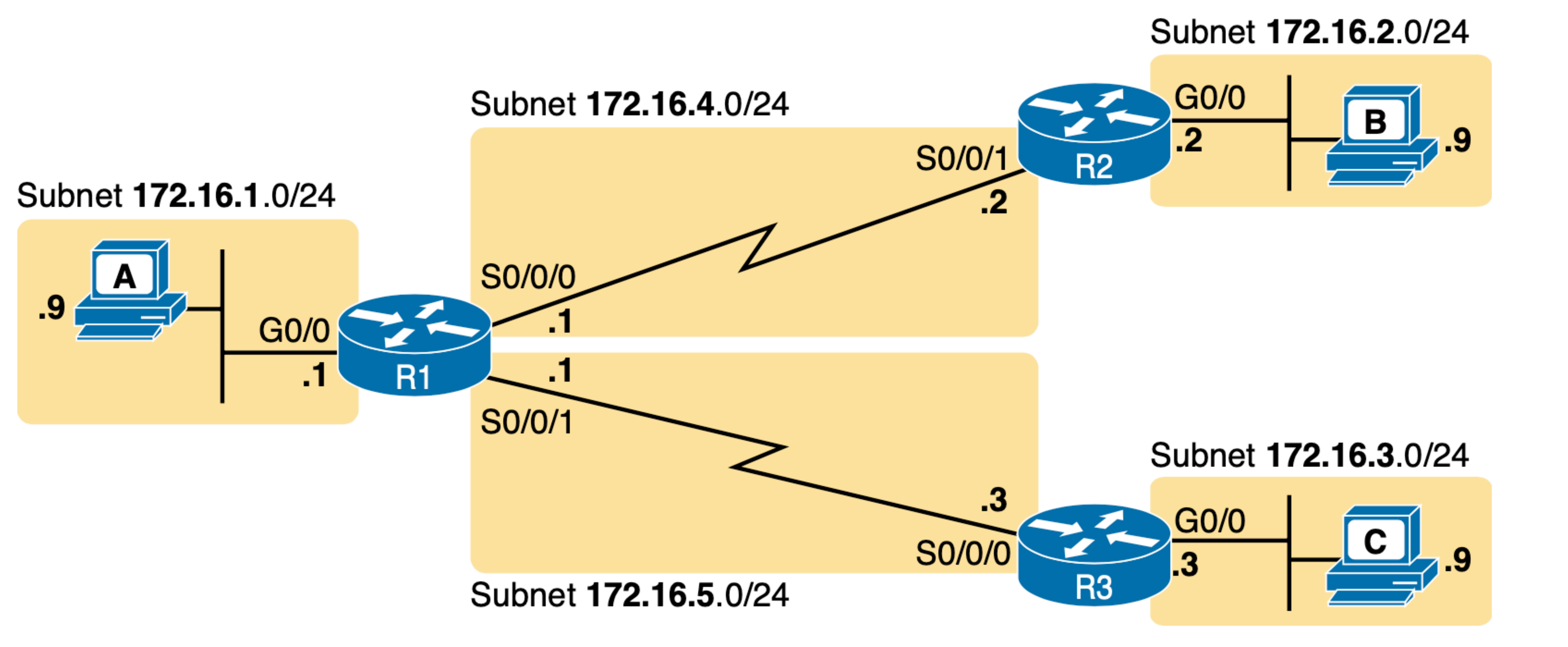
2. **R1 de-encapsulates the IP packet from inside the Ethernet frame's header and trailer.**

3. **R1 compares the IP packet's destination IP address to R1's IP routing table.**

4. **R1 encapsulates the IP packet inside a new data link frame, in this case, inside a High- Level Data Link Control (HDLC) header and trailer.**

5. **R1 transmits the IP packet, inside the new HDLC frame, out the serial link on the right.**

IPv4 network used to show five-step routing example



In this example (next page), host A uses some application that sends data to host B (172.16.2.9). 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).

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Figure 16-4 pulls these concepts together, showing the destination IP address and destination MAC address in the frame and packet sent by host A in this case.

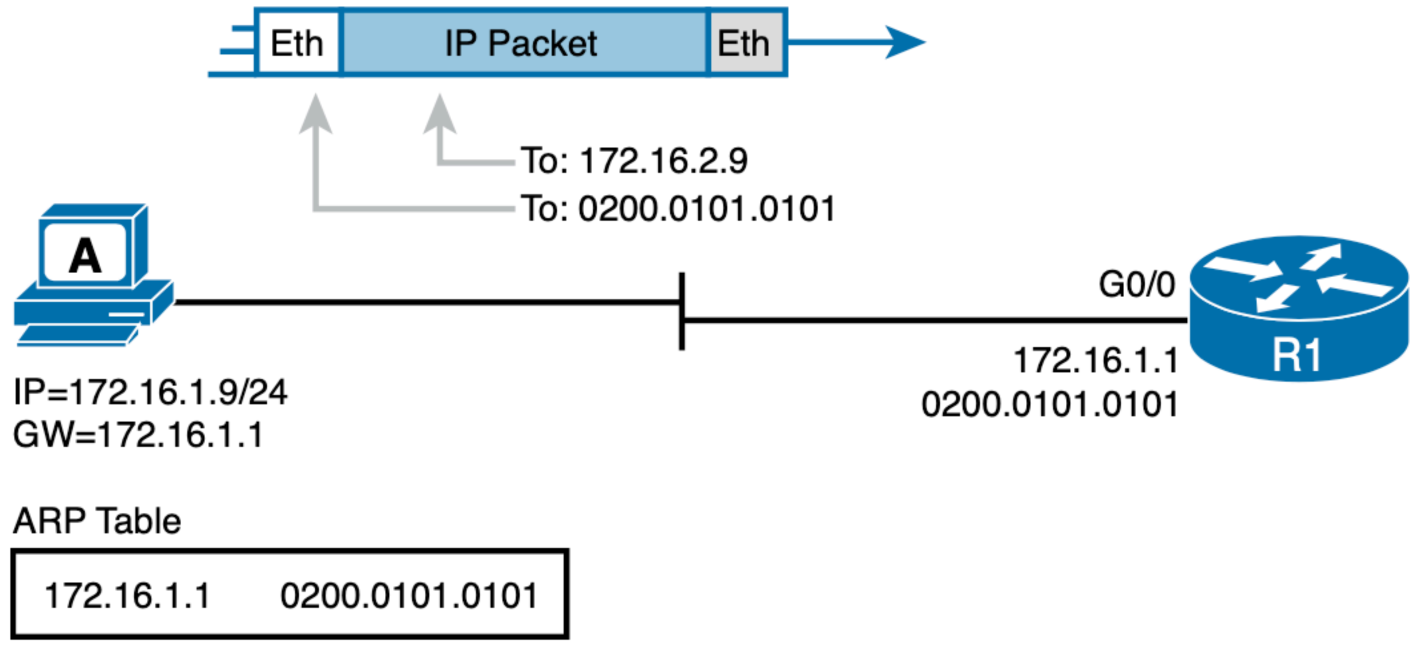

Figure 16-4 *Host A Sends Packet to Host B*

Note that the figure shows the Ethernet LAN as simple lines, but the LAN can include any of the devices discussed in Part II of this book. The LAN could be a single cable between host A and R1, or it could be 100 LAN switches connected across a huge campus of buildings. Regardless, host A and R1 sit in the same VLAN, and the Ethernet LAN then delivers the Ethernet frame to R1's G0/0 interface.

Decide Whether to Process the Incoming Frame

In this example, host A sends a frame destined for R1's MAC address. So, after the frame is received, and after R1 confirms with the FCS that no errors occurred, R1 confirms that the frame is destined for R1's MAC address (0200.0101.0101 in this case). All checks have been passed, so R1 will process the frame, as shown in Figure 16-5. (Note that the large rectangle in the figure represents the internals of Router R1.)

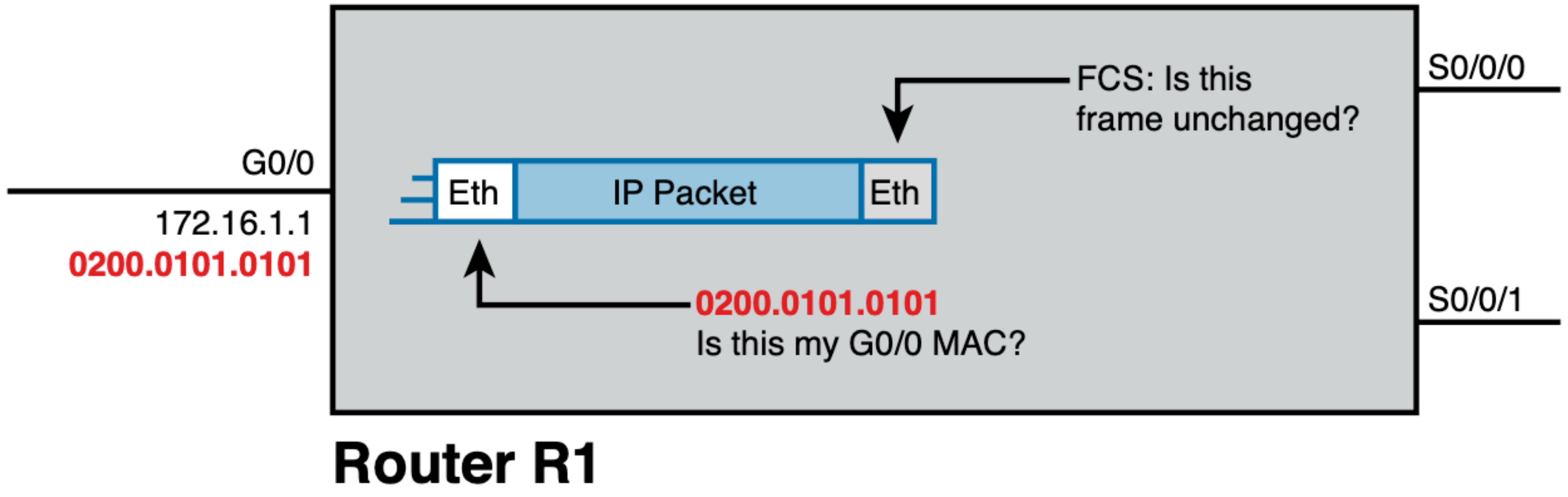

Figure 16-5 *Routing Step 1, on Router R1: Checking FCS and Destination MAC*

Routing Step 2: Deencapsulation of the IP Packet

After the router knows that it ought to process the received frame (per Step 1), the next step is a relatively simple step: deencapsulating the packet. In router memory, the router no longer needs the original frame's data link header and trailer, so the router removes and discards them, leaving the IP packet, as shown in Figure 16-6. Note that the destination IP address remains unchanged (172.16.2.9).

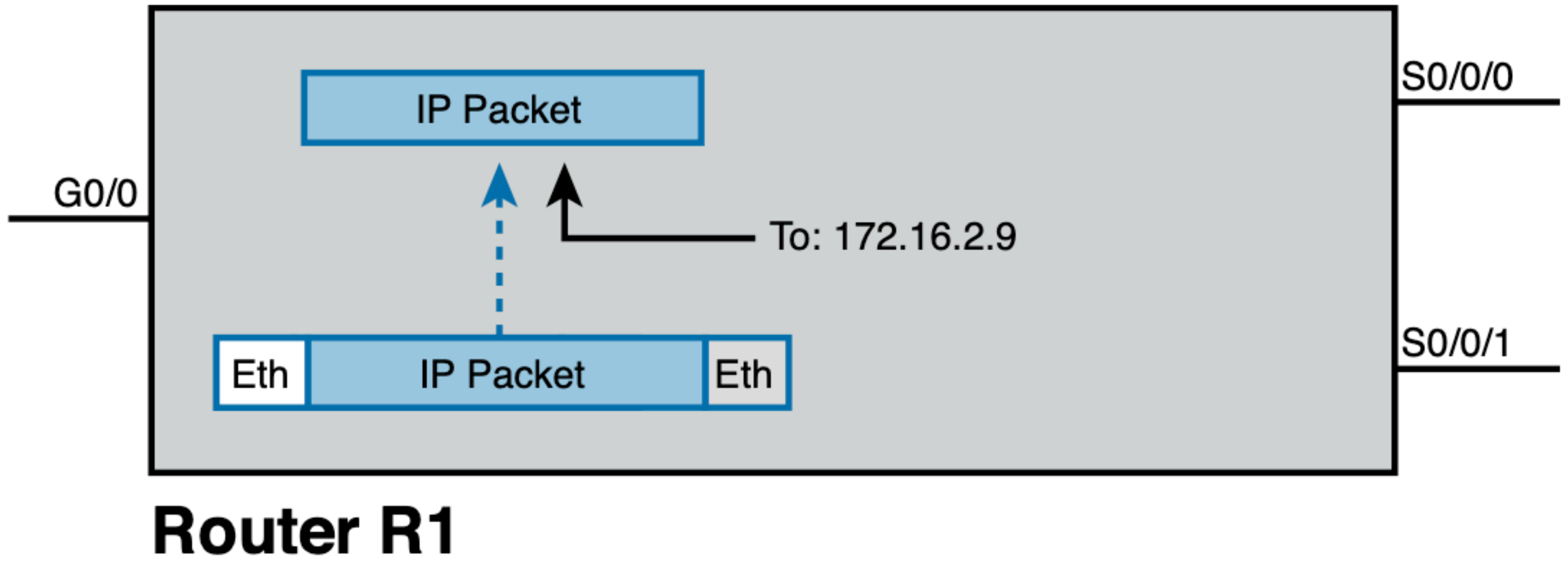

Figure 16-6 *Routing Step 2 on Router R1: Deencapsulating the Packet*

First, an IP routing table lists multiple routes. Each individual route contains several facts, which in turn can be grouped as shown in Figure 16-7. Part of each route is used to match the destination address of the packet, while the rest of the route lists forwarding instructions: where to send the packet next.

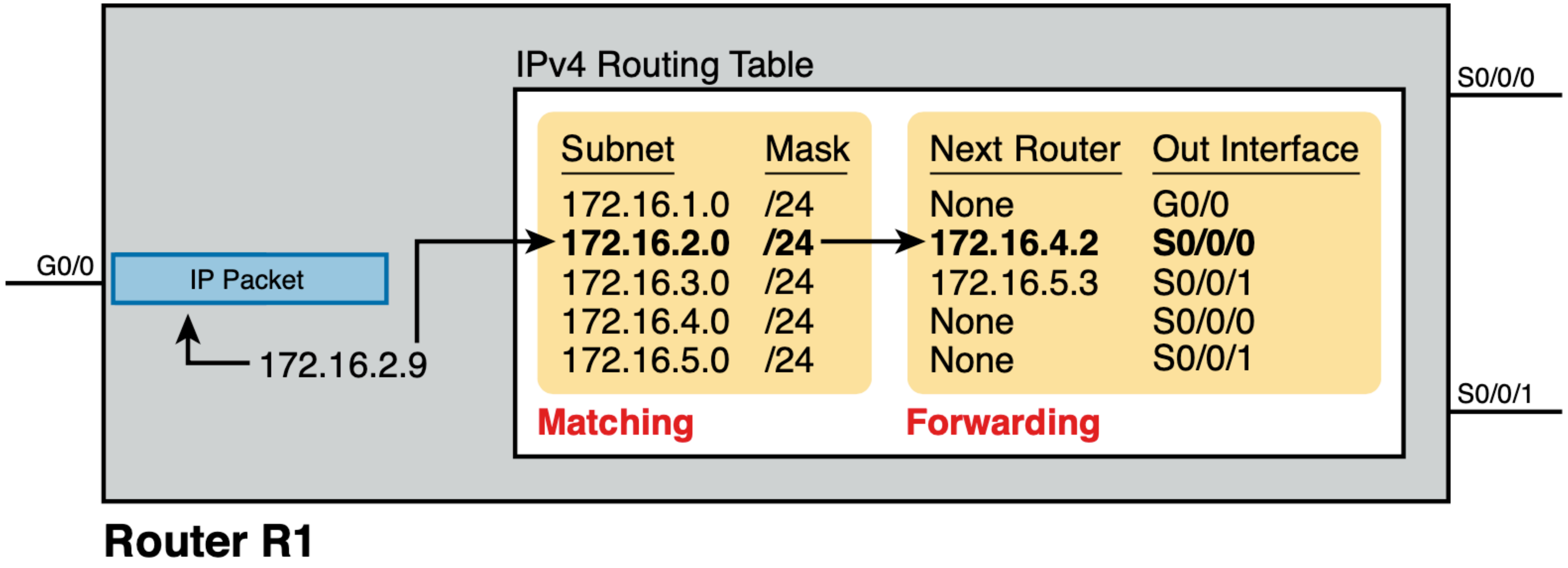

Figure 16-7 *Routing Step 3 on Router R1: Matching the Routing Table*

At this point, the router knows how it will forward the packet. However, routers cannot forward a packet without first wrapping a data link header and trailer around it (encapsulation). Encapsulating packets for serial links does not require a lot of thought, because of the simplicity of the HDLC and PPP protocols.

For example, consider this different sample network, with an Ethernet WAN link between Routers R1 and R2. R1 matches a route that tells R1 to forward the packet out R1's G0/1 Ethernet interface to 172.16.6.2 (R2) next. R1 needs to put R2's MAC address in the header, and to do that, R1 uses its IP ARP table information, as seen in Figure 16-9. If R1 did not have an ARP table entry for 172.16.6.2, R1 would first have to use ARP to learn the matching MAC address.

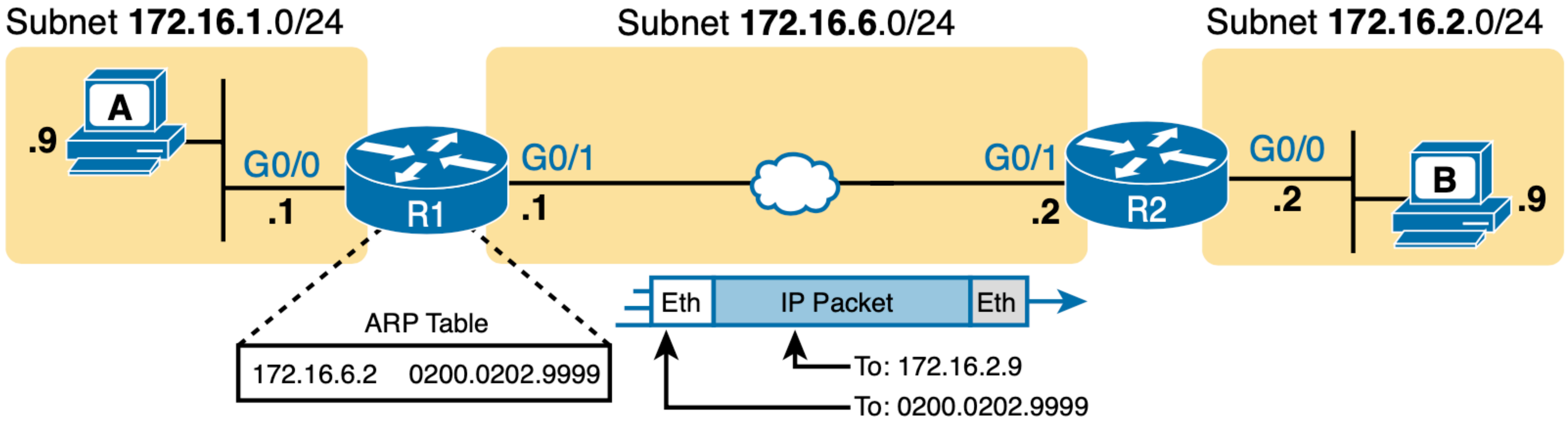

Figure 16-9 *Routing Step 4 on Router R1 with a LAN Outgoing Interface*

After the frame has been prepared, the router simply needs to transmit the frame. The router might have to wait, particularly if other frames are already waiting their turn to exit the interface.

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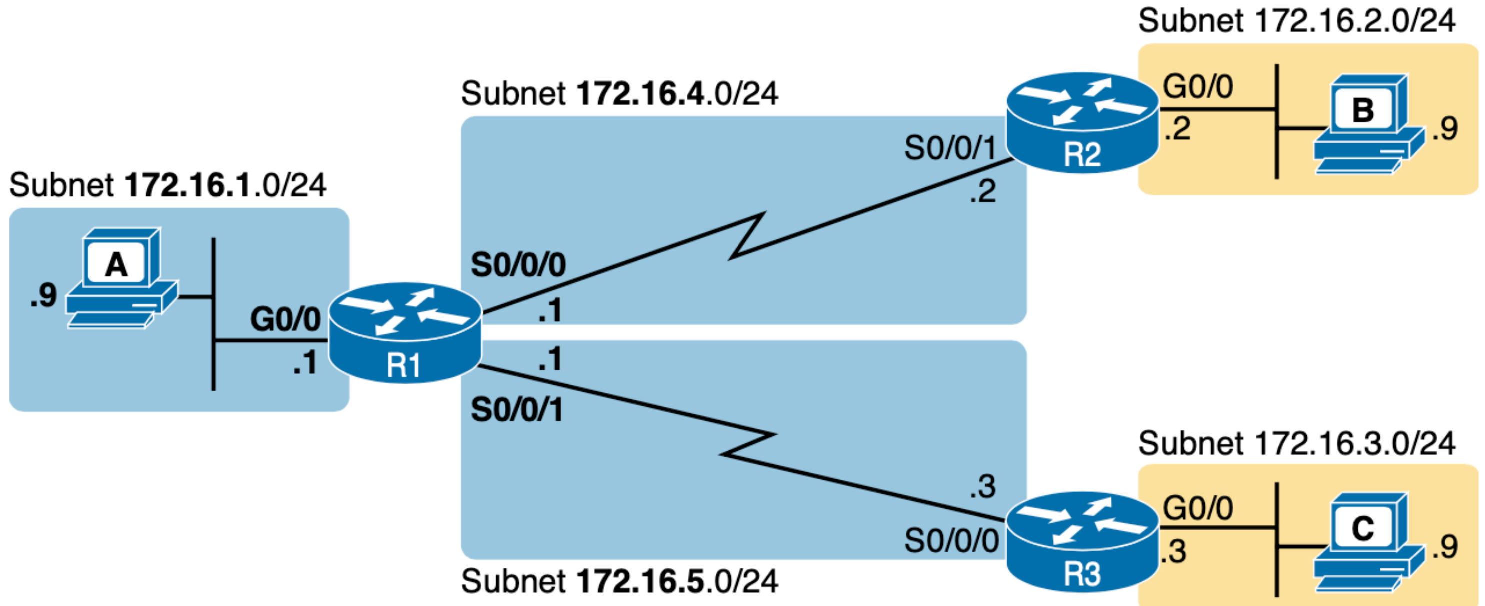

Figure 16-10 *Sample Network to Show Connected Routes*

Example 16-1 *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
       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
```

Take a moment to look closely at each of the three highlighted routes in the output of **show ip route**. Each lists a C in the first column, and each has text that says “directly connected”; both identify the route as connected to the router. The early part of each route lists the matching parameters (subnet ID and mask), as shown in the earlier example in Figure 16-7. The end of each of these routes lists the outgoing interface.

Three options exist for connecting a router to each subnet on a VLAN. However, the first option requires too many interfaces and links, and is only mentioned to make the list complete:

- Use a router, with one router LAN interface and cable connected to the switch for each and every VLAN (typically not used).
- Use a router, with a VLAN trunk connecting to a LAN switch.
- Use a Layer 3 switch.

Figure 16-11 shows an example network where the second and third options both happen to be used. The figure shows a central site campus LAN on the left, with 12 VLANs. At the central site, two of the switches act as Layer 3 switches, combining the functions of a router and a switch, routing between all 12 subnets/VLANs. The remote branch sites on the right side of the figure each use two VLANs; each router uses a VLAN trunk to connect to and route for both VLANs.

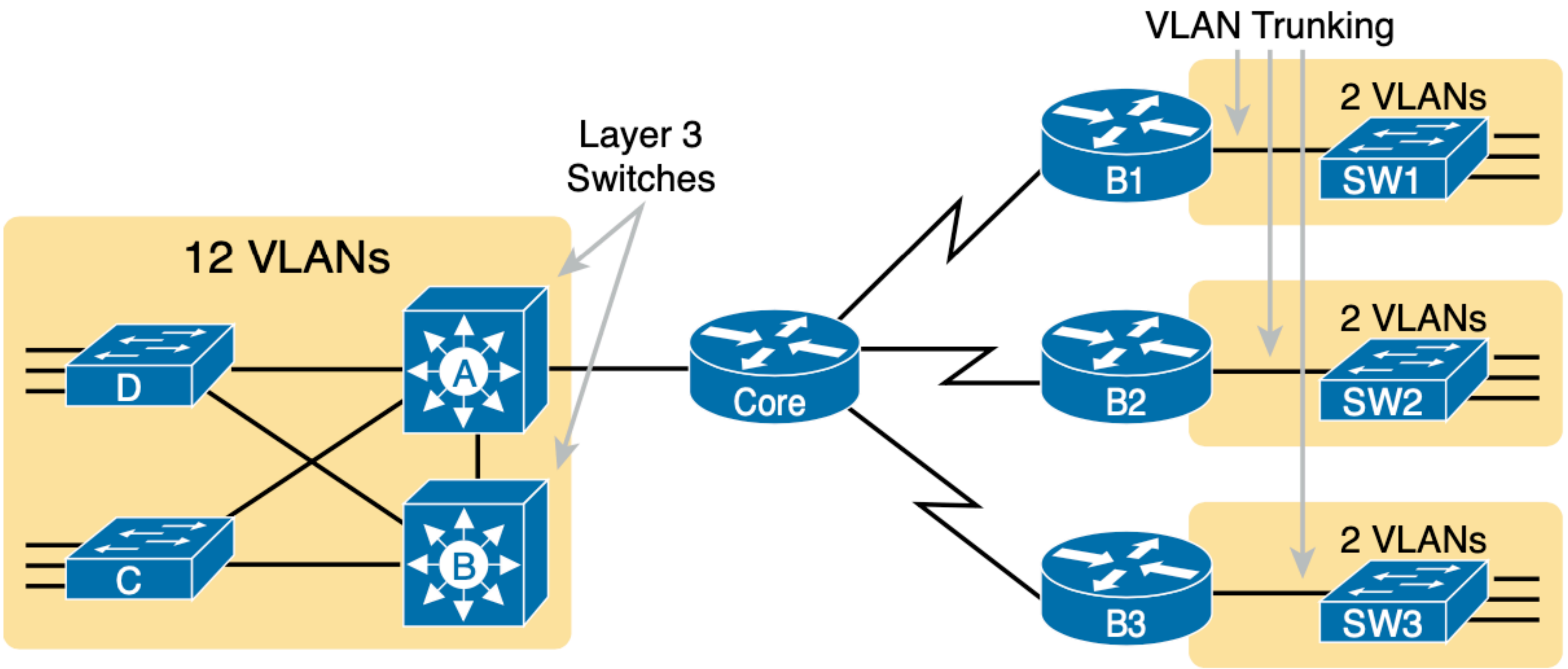

Figure 16-11 *Subinterfaces on Router R1*

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

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As an example, Figure 16-15 shows a small IP network. The diagram actually holds a subset of Figure 16-3, from earlier in this chapter, with some of the unrelated details removed. The figure shows only the details related to a static route on R1, for subnet 172.16.2.0/24, which sits on the far right. To create that static route on R1, 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).

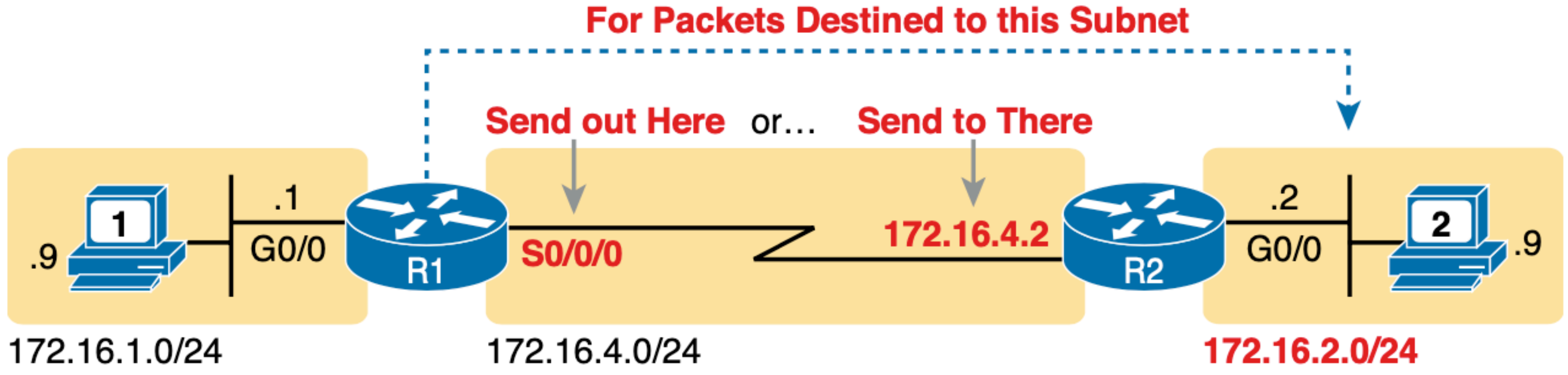

Figure 16-15 *Static Route Configuration Concept*

Example 16-9 shows the configuration of a couple of sample static routes. In particular, it shows routes on Router R1 in Figure 16-16, for the two subnets on the right side of the figure.

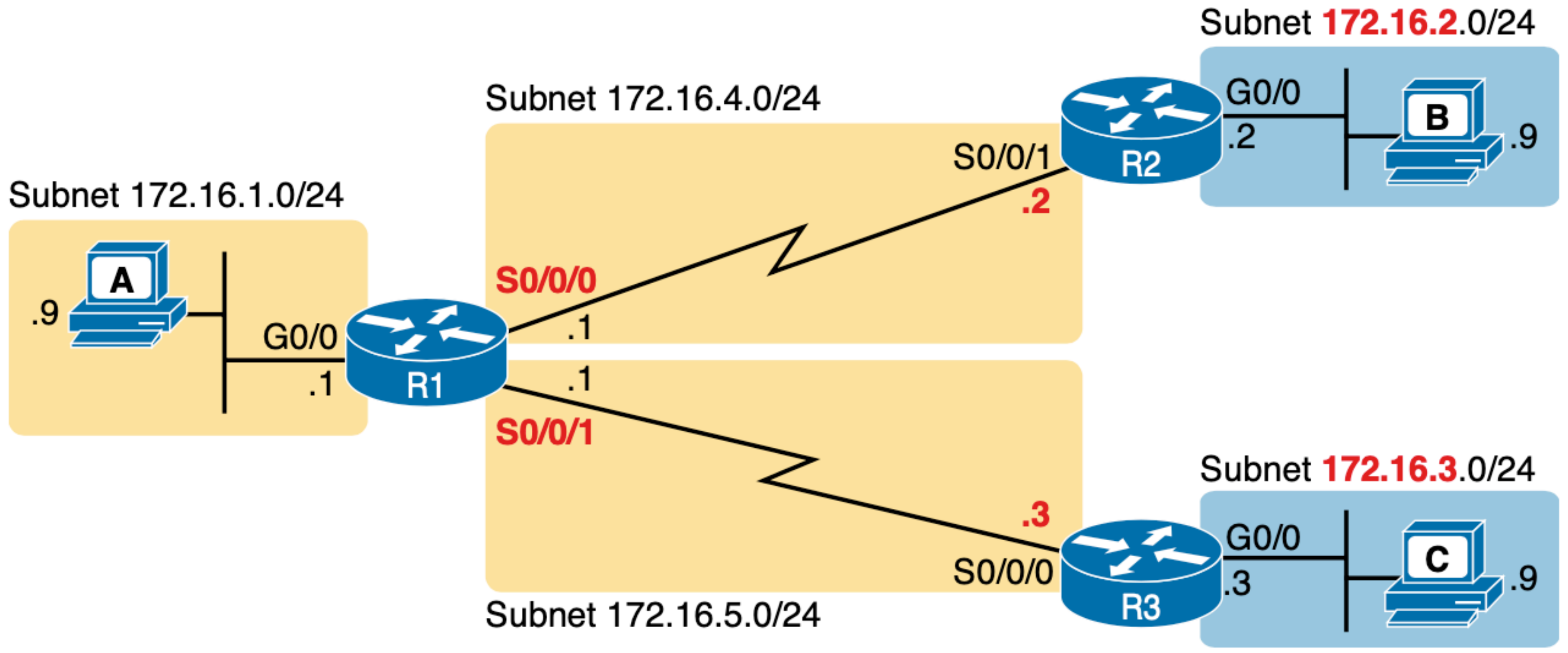

Figure 16-16 *Sample Network Used in Static Route Configuration Examples*

Example 16-9 *Static Routes Added to R1*

```
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
```

The two example **ip route** commands show the two different styles. The first command shows subnet 172.16.2.0, mask 255.255.255.0, which sits on a LAN near Router R2. That same first command lists 172.16.4.2, R2's IP address, as the next-hop router. This route basically says this: To send packets to the subnet off Router R2, send them to R2.

ASSESSMENT QUESTION - 2

Question: 1. Summarise the Five Routing step process in brief with the help of example.

Question: 2. Define the following terminology :

- IP Routing.
- Static Routes Configuration concept.
- Routing protocols.