Static Routing
Routing is at the core of every data network, moving information across an internetwork from source to destination. Routers are the devices responsible for the transfer of packets from one network to the next.
Routers learn about remote networks either dynamically, using routing protocols, or manually, or using static routes. In many cases, routers use a combination of both dynamic routing protocols and static routes. This chapter focuses on static routing.
Static routes are very common and do not require the same amount of processing and overhead as dynamic routing protocols.
In this chapter, sample topologies will be used to configure IPv4 and IPv6 static routes and to present troubleshooting techniques. In the process, several important IOS commands and the resulting output will be examined. An introduction to the routing table using both directly connected networks and static routes will be included.

Sections & Objectives

- Static Routing Advantages
  - Explain how static routes are implemented in a small to medium-sized business network.
  - Explain advantages and disadvantages of static routing.
  - Explain the purpose of different types of static routes.
- Configure Static and Default Routes
  - Configure static routes to enable connectivity in a small to medium-sized business network.
  - Configure IPv4 static routes by specifying a next-hop address.
  - Configure an IPv4 default route.
  - Configure IPv6 static routes by specifying a next-hop address.
  - Configure an IPv6 default route.
  - Configure a floating static route to provide a backup connection.
  - Configure IPv4 and IPv6 static host routes that direct traffic to a specific host.

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Sections & Objectives (Cont.)

- Troubleshoot Static and Default Routes
  - Given an IP addressing scheme, configure IP address parameters on devices to provide end-to-end connectivity in a small to medium-sized business network.
  - Explain how a router processes packets when a static route is configured.
  - Troubleshoot common static and default route configuration issues.

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Implement Static Routes

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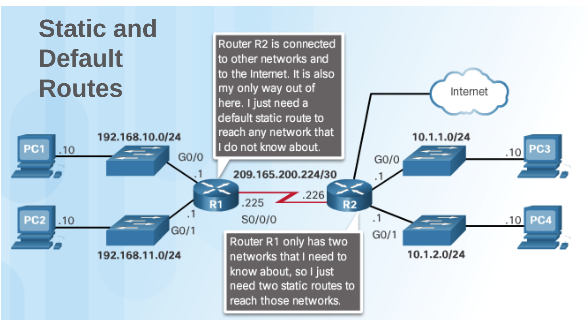
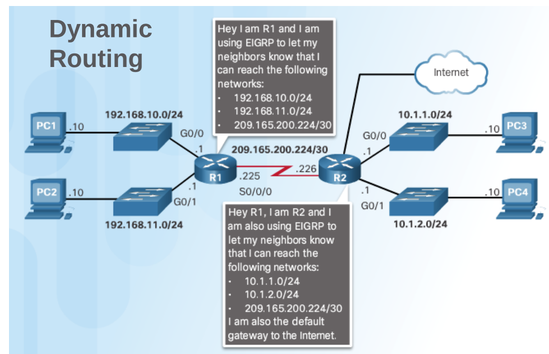
Static Routing

Reach Remote Networks

- A router learns about remote networks in two ways:
  - Manually entered into the route table using static routes
    - Static routes are not automatically updated and must be reconfigured when topology changes
  - Dynamically (Automatically) learned using a routing protocol





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Reach Remote Networks

A router can learn about remote networks in one of two ways:

- **Manually** - Remote networks are manually entered into the route table using static routes.
- **Dynamically** - Remote routes are automatically learned using a dynamic routing protocol.

Figure 1 provides a sample scenario of static routing.
Figure 2 provides a sample scenario of dynamic routing using EIGRP.

A network administrator can manually configure a static route to reach a specific network. Unlike a dynamic routing protocol, static routes are not automatically updated and must be manually reconfigured any time the network topology changes.

Static Routing

Why Use Static Routing?

Dynamic versus Static Routing

	Dynamic Routing	Static Routing
Configuration Complexity	Generally independent of the network size	Increases with network size
Topology Changes	Automatically adapts to topology changes	Administrator intervention required
Scaling	Suitable for simple and complex topologies	Suitable for simple topologies
Security	Less secure	More secure
Resource Usage	Uses CPU, memory, link bandwith	No extra resources needed
Predictability	Route depends on the current topology	Route to destination is always the same

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Why Use Static Routing?

Static routing provides some advantages over dynamic routing, including:
Static routes are not advertised over the network, resulting in better security.
Static routes use less bandwidth than dynamic routing protocols, no CPU cycles are used to calculate and communicate routes.
The path a static route uses to send data is known.
Static routing has the following disadvantages:
Initial configuration and maintenance is time-consuming.
Configuration is error-prone, especially in large networks.
Administrator intervention is required to maintain changing route information.
Does not scale well with growing networks; maintenance becomes cumbersome.
Requires complete knowledge of the whole network for proper implementation.
In the figure, dynamic and static routing features are compared. Notice that the advantages of one method are the disadvantages of the other.
Static routes are useful for smaller networks with only one path to an outside network. They also provide security in a larger network for certain types of traffic or links to other networks that need more control. It is important to understand that static and dynamic routing are not mutually exclusive. Rather, most networks use a combination of dynamic routing protocols and static routes. This may result in the router having multiple paths to a destination network via static routes and dynamically learned routes. However, recall that the administrative distance (AD) value is a measure of the preference of route sources. Route sources with low AD

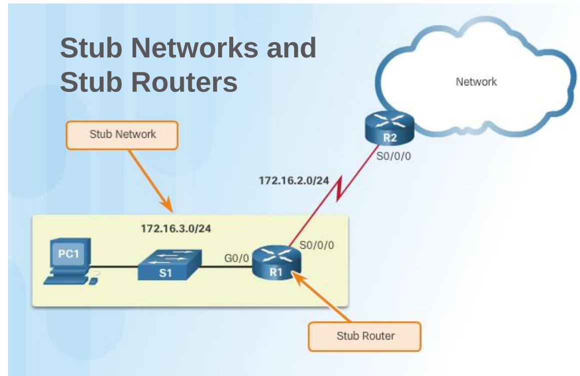
values are preferred over routes sources with higher AD values. The AD value for a static route is 1. Therefore, a static route will take precedence over all dynamically learned routes, which will have higher AD values.

Static Routing

When to Use Static Routes

Three uses for static routes:

- Smaller networks that are not expected to grow
- Routing to and from stub networks
  - Stub network accessed by a single route and has one neighbor
  - 172.16.3.0 is a stub network
- A single default route to represent a path to any network not found in the routing table
  - Use default route on R1 to point to R2 for all other networks



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When to Use Static Routes

Static routing has three primary uses:

Providing ease of routing table maintenance in smaller networks that are not expected to grow significantly.

Routing to and from stub networks. A stub network is a network accessed by a single route, and the router has only one neighbor.

Using a single default route to represent a path to any network that does not have a more specific match with another route in the routing table. Default routes are used to send traffic to any destination beyond the next upstream router.

The figure shows an example of a stub network connection and a default route connection. Notice in the figure that any network attached to R1 would only have one way to reach other destinations, whether to networks attached to R2, or to destinations beyond R2. This means that network 172.16.3.0 is a stub network and R1 is a stub router.

In this example, a static route can be configured on R2 to reach the R1 LAN. Additionally, because R1 has only one way to send out non-local traffic, a default static route can be configured on R1 to point to R2 as the next hop for all other networks.

Activity

Identify the Advantages and Disadvantages of Static Routing

Instruction

Determine whether the static routing descriptors are advantages or disadvantages of static routing.Click the appropriate field next to each descriptor to indicate your answers.

	Advantage	Disadvantage
Configuration complexity increases with network size.		✖
No extra resources (CPU, bandwidth, etc.) are needed.	✖	
Topology changes will affect configuration.		✖
Route path to destination is always the same.	✖	
Routing tables are small and maintenance is minimal.	✖	
No automatic updates will be made to the routing table if topology changes.		✖

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Types of Static Routes

Static Route Applications

Use Static Routes To:

- Connect to a specific network
- Connect a stub router
- Summarize routing table entries which reduces size of routing advertisements
- Create a backup route in case a primary route link fails

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Static Route Applications

Static routes are most often used to connect to a specific network or to provide a Gateway of Last Resort for a stub network. They can also be used to:

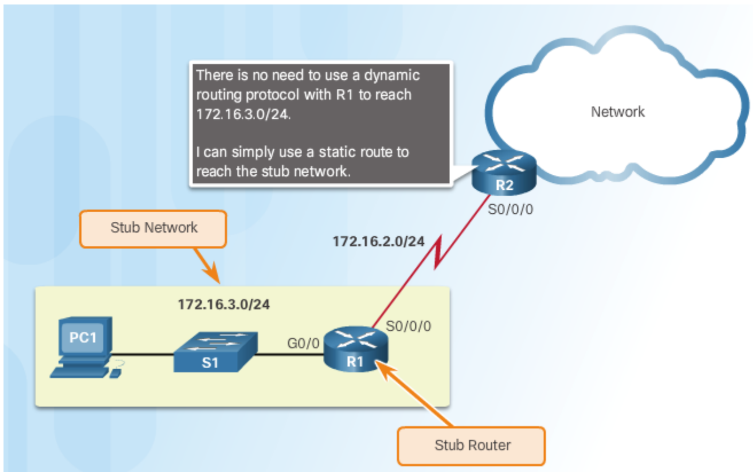
- Reduce the number of routes advertised by summarizing several contiguous networks as one static route
- Create a backup route in case a primary route link fails

The following types of IPv4 and IPv6 static routes will be discussed:

- Standard static route
- Default static route
- Summary static route
- Floating static route

Types of Static Routes
Standard Static Route

- R2 configured with a static route to reach the stub network 172.16.3.0/24



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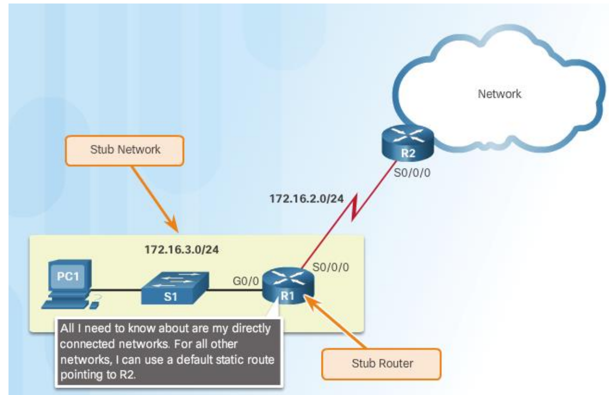
Standard Static Route
Both IPv4 and IPv6 support the configuration of static routes. Static routes are useful when connecting to a specific remote network.
The figure shows that R2 can be configured with a static route to reach the stub network 172.16.3.0/24.

Note: The example is highlighting a stub network, but in fact, a static route can be used to connect to any network.

Types of Static Routes

Default Static Route

- Default route matches all packets and is used when a packet does not match a specific route in the routing table
- Can be dynamically learned or statically configured
- Default Static route uses 0.0.0.0/0 as the destination IPv4 address
- Creates a Gateway of Last Resort
- Common use is when connecting a company's edge router to the ISP network
- Router has only one router to which it is connected



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Default Static Route

A default route is a route that matches all packets and is used by the router if a packet does not match any other, more specific route in the routing table. A default route can be dynamically learned or statically configured. A default static route is simply a static route with 0.0.0.0/0 as the destination IPv4 address. Configuring a default static route creates a Gateway of Last Resort.

Default static routes are used:

When no other routes in the routing table match the packet destination IP address. In other words, when a more specific match does not exist. A common use is when connecting a company's edge router to the ISP network.

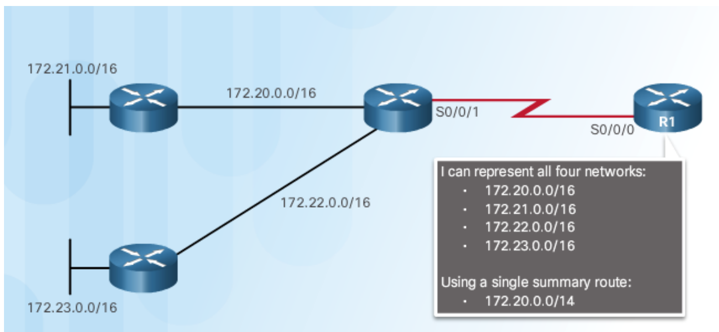
When a router has only one other router to which it is connected. In this situation, the router is known as a stub router.

Refer to the figure for a stub network default route scenario.

Types of Static Routes

Summary Static Route

- Multiple static routes can be summarized into a single network address
  - Destination networks must be contiguous
  - Multiple static routes must use the same exit interface or next hop
  - In figure, four networks is summarized into one summary static route



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Summary Static Route

To reduce the number of routing table entries, multiple static routes can be summarized into a single static route if:

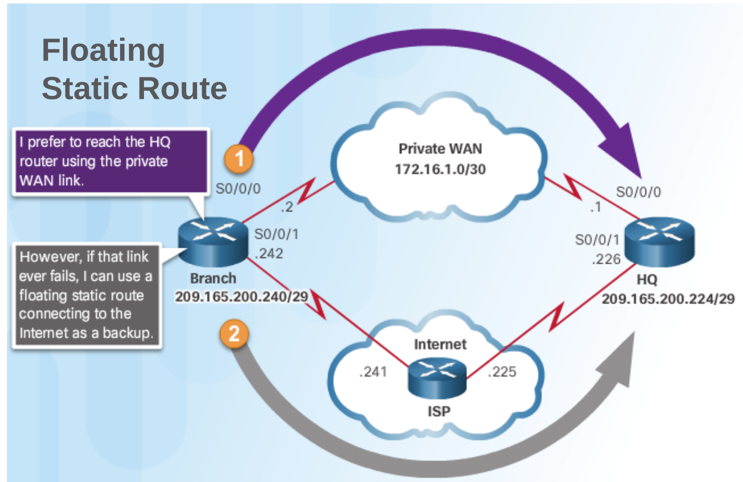
- The destination networks are contiguous and can be summarized into a single network address.
- The multiple static routes all use the same exit interface or next-hop IP address.

In the figure, R1 would require four separate static routes to reach the 172.20.0.0/16 to 172.23.0.0/16 networks. Instead, one summary static route can be configured and still provide connectivity to those networks.

Types of Static Routes

Floating Static Route

- Static routes that are used to provide a backup path
- Used when primary route is not available
- Configured with a higher administrative distance (trustworthiness) than the primary route
- Example: EIGRP administrative distance equals 90. A floating static route with an AD of 91 or higher would serve as backup route and will be used if EIGRP route goes down.



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Floating Static Route

Another type of static route is a floating static route. Floating static routes are static routes that are used to provide a backup path to a primary static or dynamic route, in the event of a link failure. The floating static route is only used when the primary route is not available.

To accomplish this, the floating static route is configured with a higher administrative distance than the primary route. The administrative distance represents the trustworthiness of a route. If multiple paths to the destination exist, the router will choose the path with the lowest administrative distance.

For example, assume that an administrator wants to create a floating static route as a backup to an EIGRP-learned route. The floating static route must be configured with a higher administrative distance than EIGRP. EIGRP has an administrative distance of 90. If the floating static route is configured with an administrative distance of 95, the dynamic route learned through EIGRP is preferred to the floating static route. If the EIGRP-learned route is lost, the floating static route is used in its place.

In the figure, the Branch router typically forwards all traffic to the HQ router over the private WAN link. In this example, the routers exchange route information using EIGRP. A floating static route, with an administrative distance of 91 or higher, could be configured to serve as a backup route. If the private WAN link fails and the EIGRP route disappears from the routing table, the router selects the floating static route as the best path to reach the HQ LAN.

Activity

Identify the Type od Static Route

Instructions

Determine the static route type based on each descriptor in the table.Click the appropriate field next to each descriptor to indicate your answers.

	Standard	Default	Floating
Backs up a route already discovered by a dynamic routing protocol.			✖
Matches all packets and sends them to a specific default gateway.		✖	
Useful when connecting to stub networks.	✖		
Configured with a higher administrative distance than the original dynamic routing protocol.			✖
Commonly used with edge routers to connect to the ISP network.		✖	

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Configure Static and Default Routes

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2 - Static Routing
2.2 – Configure Static and Default Routes

Configure IPv4 Static Routes

ip route Command

ip route Command Syntax

```
Router(config)# ip route network-address subnet-mask {ip-address | exit-intf}
```

Parameter	Description
network-address	Destination network address of the remote network to be added to the routing table
subnet-mask	• Subnet mask of the remote network to be added to the routing table. • The subnet mask can be modified to summarize a group of networks.
ip-address	• Commonly referred to as the next-hop router's IP address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup
exit-intf	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.
distance	• (Optional) Configures an administrative distance. • Typically used to configure a floating static route.

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ip route Command

Static routes are configured using the **ip route** global configuration command. The basic syntax for the command is shown in the figure.

The following parameters are required to configure static routing:

- *network-address* - Destination network address of the remote network to be added to the routing table, often this is referred to as the prefix.
- *subnet-mask* - Subnet mask, or just mask, of the remote network to be added to the routing table. The subnet mask can be modified to summarize a group of networks.

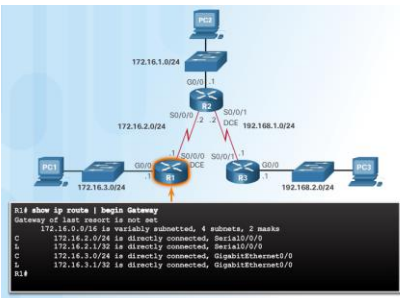
One or both of the following parameters must also be used:

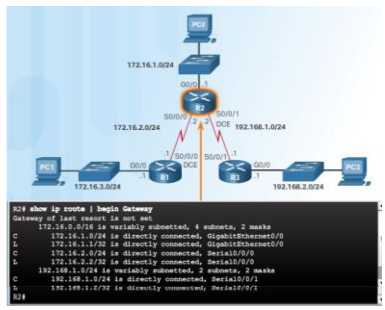
- *ip-address* - The IP address of the connecting router to use to forward the packet to the remote destination network. Commonly referred to as the next hop.
- *exit-intf* - The outgoing interface to use to forward the packet to the next hop.

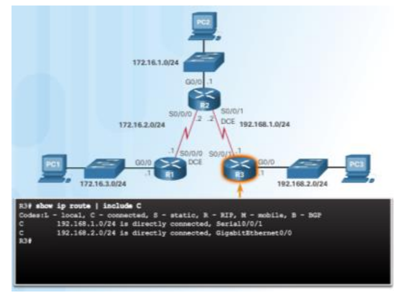
The *distance* parameter is used to create a floating static route by setting an administrative distance that is higher than a dynamically learned route.

Configure IPv4 Static Routes
Next-Hop Options

- In this example, each router only has entries for directly connected network







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Next-Hop Options

In this example, Figures 1 to 3 display the routing tables of R1, R2, and R3. Notice that each router has entries only for directly connected networks and their associated local addresses. None of the routers have any knowledge of any networks beyond their directly connected interfaces.

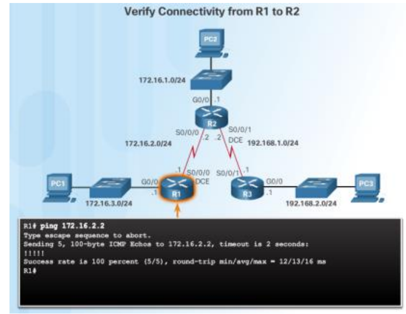
For example, R1 has no knowledge of networks:

- 172.16.1.0/24 - LAN on R2
- 192.168.1.0/24 - Serial network between R2 and R3
- 192.168.2.0/24 - LAN on R3

Configure IPv4 Static Routes

Next-Hop Options (Cont.)

- R1 does not have an entry in its routing table for the R3 LAN network
- In a static route next-hop can be identified by
  - Next-hop IP address
  - Router exit interface
  - Next-hop IP address and exit interface



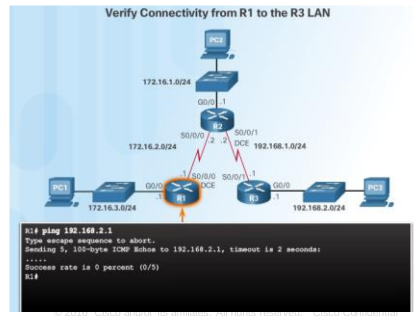


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Figure 1 displays a successful ping from R1 to R2. Figure 2 displays an unsuccessful ping to the R3 LAN. This is because R1 does not have an entry in its routing table for the R3 LAN network.

The next hop can be identified by an IP address, exit interface, or both. How the destination is specified creates one of the three following route types:

Next-hop route - Only the next-hop IP address is specified

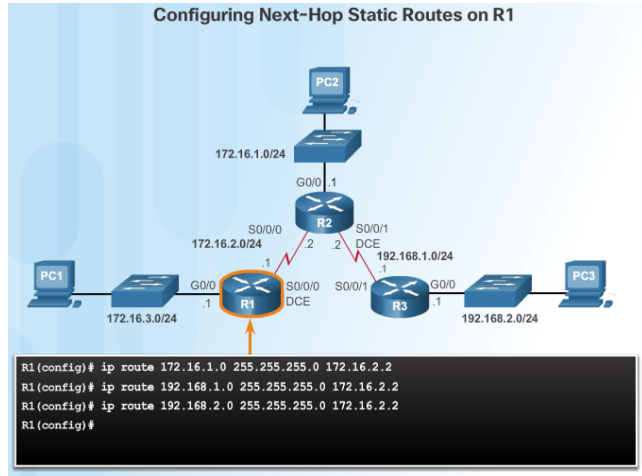
Directly connected static route - Only the router exit interface is specified

Fully specified static route - The next-hop IP address and exit interface are specified

Configure IPv4 Static Routes

Configure a Next-Hop Static Route

- In this example, only the next-hop IP address is specified
- Before packet is forwarded the router must determine the exit interface to use (route resolvability)



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Configure a Next-Hop Static Route

In a next-hop static route, only the next-hop IP address is specified. The exit interface is derived from the next hop. For example, in Figure, three next-hop static routes are configured on R1 using the IP address of the next hop, R2.

Before any packet is forwarded by a router, the routing table process must determine the exit interface to use to forward the packet. This is known as route resolvability.

Configure IPv4 Static Routes

Configure a Next-Hop Static Route (Cont.)

- In example, when a packet is destined for 192.168.2.0/24 network, R1:
  - Looks for match (#1) and needs to forward packets to 172.16.2.2
  - R1 must determine how to reach 172.16.2.2 first
  - Searches a second time for 172.16.2.0/24 (#2) and matches to exit interface s0/0/0
  - Takes two routing table lookups, process referred to as recursive lookup
  - If the exit interface is “down” or “administratively down” then the static route configured with next-hop will not be installed in routing table

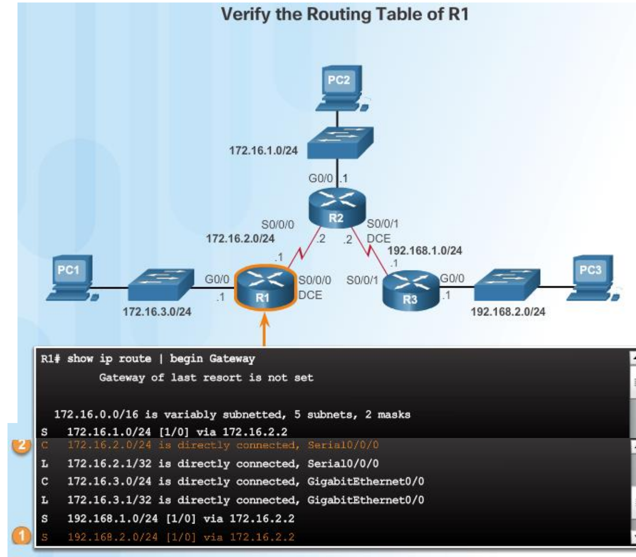

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Figure details the basic packet forwarding process in the routing table for R1. When a packet is destined for the 192.168.2.0/24 network, R1:

1. Looks for a match in the routing table and finds that it has to forward the packets to the next-hop IPv4 address 172.16.2.2, as indicated by the label 1 in the figure. Every route that references only a next-hop IPv4 address and does not reference an exit interface must have the next-hop IPv4 address resolved using another route in the routing table with an exit interface.
2. R1 must now determine how to reach 172.16.2.2; therefore, it searches a second time for a 172.16.2.2 match. In this case, the IPv4 address matches the route for the directly connected network 172.16.2.0/24 with the exit interface Serial 0/0/0, as indicated by the label 2 in the figure. This lookup tells the routing table process that this packet is forwarded out of that interface.

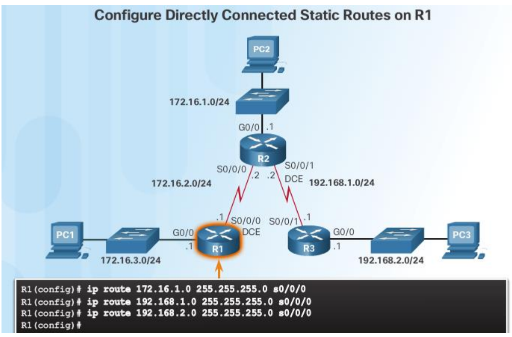
It actually takes two routing table lookup processes to forward any packet to the 192.168.2.0/24 network. When the router performs multiple lookups in the routing table before forwarding a packet, it is performing a process known as a recursive lookup. Because recursive lookups consume router resources, they should be avoided when possible.

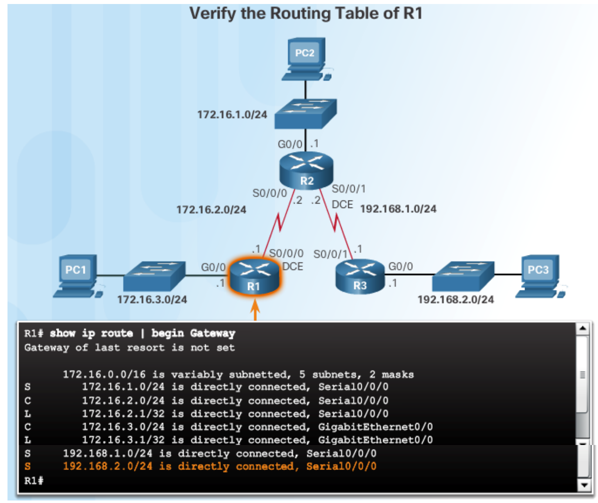
A recursive static route is valid (that is, it is a candidate for insertion in the routing table) only when the specified next hop resolves, either directly or indirectly, to a valid exit interface. If the exit interface is “down” or “administratively down”, then the static route will not be installed in the routing table.

Configure IPv4 Static Routes

Configure a Directly Connected Static Route

- Use the exit interface to specify next-hop so no other lookups are required
- Administrative distance of static route is 1





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Configure a Directly Connected Static Route

When configuring a static route, another option is to use the exit interface to specify the next-hop address.

In Figure 1, three directly connected static routes are configured on R1 using the exit interface. The routing table for R1 in Figure 2 shows that when a packet is destined for the 192.168.2.0/24 network, R1 looks for a match in the routing table, and finds that it can forward the packet out of its Serial 0/0/0 interface. No other lookups are required.

Notice how the routing table looks different for the route configured with an exit interface than for the route configured with a recursive entry.

Configuring a directly connected static route with an exit interface allows the routing table to resolve the exit interface in a single search, instead of two searches.

Although the routing table entry indicates "directly connected", the administrative distance of the static route is still 1. Only a directly connected interface can have an administrative distance of 0.

Note: For point-to-point interfaces, you can use static routes that point to the exit interface or to the next-hop address. For multipoint/broadcast interfaces, it is more suitable to use static routes that point to a next-hop address.

Configure IPv4 Static Routes

Configure a Directly Connected Static Route (Cont.)

- Cisco Express Forwarding (CEF)
  - default behavior on IOS 12.0 or later
  - provides optimized lookup
  - uses a Forwarding Information Base (FIB) which is a copy of the routing table and an adjacency table that includes Layer 2 addresses
  - no recursive lookup needed for next-hop IP address lookups

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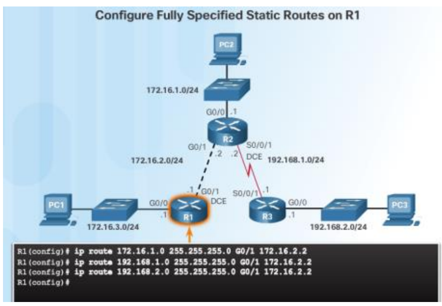
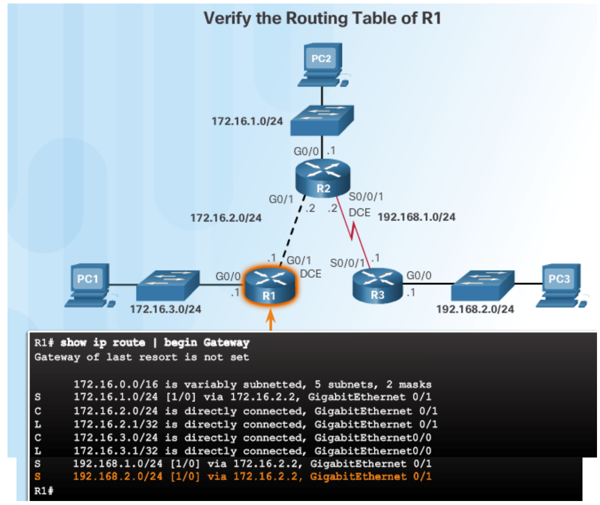
CEF (Cisco Express Forwarding) is the default behavior on most platforms running IOS 12.0 or later. CEF provides optimized lookup for efficient packet forwarding by using two main data structures stored in the data plane: a FIB (Forwarding Information Base), which is a copy of the routing table, and an adjacency table that includes Layer 2 addressing information. The information combined in both of these tables work together so there is no recursive lookup needed for next-hop IP address lookups. In other words, a static route using a next-hop IP requires only a single lookup when CEF is enabled on the router. Although static routes that use only an exit interface on point-to-point networks are common, the use of the default CEF forwarding mechanism makes this practice unnecessary. CEF is discussed in more detail later in the course.

Configure IPv4 Static Routes

Configure a Fully Specified Static Route

- Both the exit interface and the next-hop IP address are specified
- When exit interface is an Ethernet network, fully specified static route is used
- Note: With CEF, a next-hop address could be used instead





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Fully Specified Static Route

In a fully specified static route, both the exit interface and the next-hop IP address are specified. This is another type of static route that is used in older IOSs, prior to CEF. This form of static route is used when the exit interface is a multi-access interface and it is necessary to explicitly identify the next hop. The next hop must be directly connected to the specified exit interface.

Suppose that the network link between R1 and R2 is an Ethernet link and that the GigabitEthernet 0/1 interface of R1 is connected to that network, as shown in Figure 1. CEF is not enabled. To eliminate the recursive lookup, a directly connected static route can be implemented using the following command:

R1(config)# **ip route 192.168.2.0 255.255.255.0 GigabitEthernet 0/1**

However, this may cause unexpected or inconsistent results. The difference between an Ethernet multi-access network and a point-to-point serial network is that a point-to-point serial network has only one other device on that network, the router at the other end of the link. With Ethernet networks, there may be many different devices sharing the same multi-access network, including hosts and even multiple routers. By only designating the Ethernet exit interface in the static route, the router will not have sufficient information to determine which device is the next-hop device.

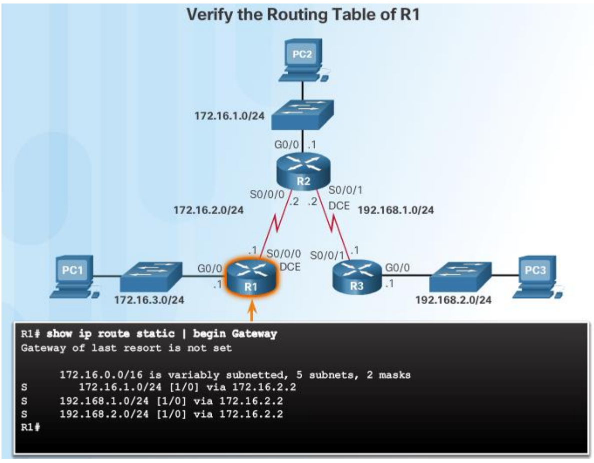
R1 knows that the packet needs to be encapsulated in an Ethernet frame and sent out the GigabitEthernet 0/1 interface. However, R1 does not know the next-hop IPv4 address; therefore, it cannot determine the destination MAC address for the Ethernet frame.

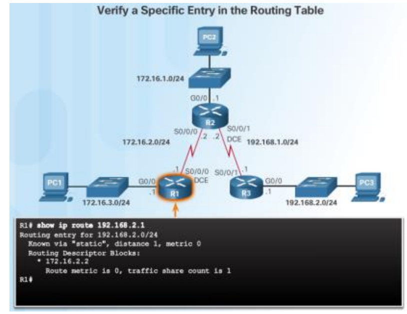
Depending upon the topology and the configurations on other routers, this static route may or may not work. It is recommended that when the exit interface is an Ethernet network, that a fully specified static route is used, including both the exit interface and the next-hop address.
As shown in Figure 2, when forwarding packets to R2, the exit interface is GigabitEthernet 0/1 and the next-hop IPv4 address is 172.16.2.2.

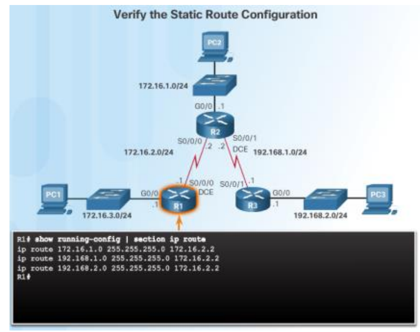
Note: With the use of CEF, a fully specified static route is no longer necessary. A static route using a next-hop address should be used.

Configure IPv4 Static Routes

Verify a Static Route







Verify a Static Route

Along with**ping**and**traceroute**, useful commands to verify static routes include:

- **show ip route**
- **show ip route static**
- **show ip route** *network*

Figure 1 displays sample output of the **show ip route static** command. In the example, the output is filtered using the pipe and **begin** parameter. The output reflects the use of static routes using the next-hop address.

Figure 2 displays sample output of the **show ip route 192.168.2.1** command.

Figure 3 verifies the **ip route** configuration in the running configuration.

Configure IPv4 Default Routes

Default Static Route

- Default static routes are commonly used when connecting:
  - An edge router to a service provider network
  - A stub router (a router with only one upstream neighbor router)
- Default route is used when no other routes in the routing table match the destination IP

Default Static Route Syntax

```
Router(config)#ip route 0.0.0.0 0.0.0.0 {ip-address | exit-intf}
```

Parameter	Description
0.0.0.0 0.0.0.0	Matches any network address.
ip-address	• Commonly referred to as the next-hop router's IP address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
exit-intf	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

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Default Static Route

Routers commonly use default routes that are either configured locally or learned from another router, using a dynamic routing protocol. A default route does not require any left-most bits to match between the default route and the destination IPv4 address. A default route is used when no other routes in the routing table match the destination IP address of the packet. In other words, if a more specific match does not exist, then the default route is used as the Gateway of Last Resort.

Default static routes are commonly used when connecting:

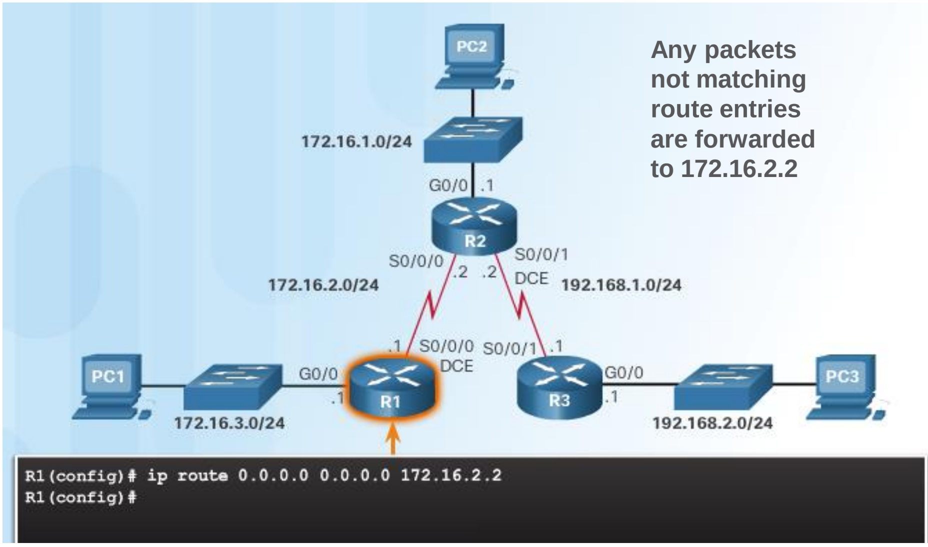
- An edge router to a service provider network
- A stub router (a router with only one upstream neighbor router)

As shown in the figure, the command syntax for a default static route is similar to any other static route, except that the network address is **0.0.0.0** and the subnet mask is **0.0.0.0**.

Note: An IPv4 default static route is commonly referred to as a quad-zero route.

Configure IPv4 Default Routes

Configure a Default Static Route



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Configure a Default Static Route

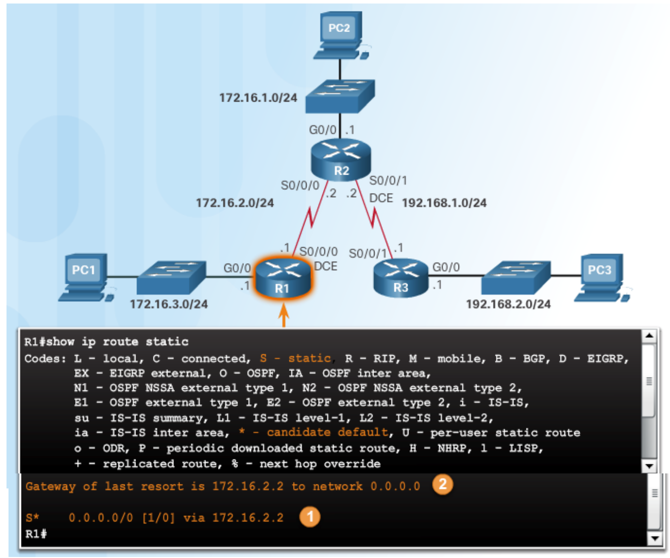
R1 can be configured with three static routes to reach all of the remote networks in the example topology. However, R1 is a stub router because it is only connected to R2. Therefore, it would be more efficient to configure a default static route.

The example in the figure configures a default static route on R1. With the configuration shown in the example, any packets not matching more specific route entries are forwarded to 172.16.2.2.

Configure IPv4 Default Routes

Verify a Default Static Route

- **show ip route static** displays just the static routes
  - **S** indicates static route
  - candidate default route indicated by *
  - /0 mask in route entry indicates none of the bits are required to match



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Verify a Default Static Route

In the figure, the **show ip route static** command output displays the contents of the static routes in the routing table. Note the asterisk (*)next to the route with code 'S'. As displayed in the Codes table in the figure, the asterisk indicates that this static route is a candidate default route, which is why it is selected as the Gateway of Last Resort.

The key to this configuration is the /0 mask. The subnet mask in a routing table determines how many bits must match between the destination IP address of the packet and the route in the routing table. A binary 1 indicates that the bits must match. A binary 0 indicates that the bits do not have to match. A /0 mask in this route entry indicates that none of the bits are required to match. The default static route matches all packets for which a more specific match does not exist.

Configure IPv6 Static Routes

The ipv6 route Command

```
Router(config)# ipv6 route ipv6-prefix/prefix-length {ipv6-address | exit-intf}
```

Parameter	Description
`ipv6-prefix`	Destination network address of the remote network to be added to the routing table.
`prefix-length`	Prefix length of the remote network to be added to the routing table.
`ipv6-address`	• Commonly referred to as the next-hop router's IP address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
`exit-intf`	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

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The ipv6 route Command

Static routes for IPv6 are configured using the **ipv6 route** global configuration command. Figure 1 shows the simplified version of the command syntax.

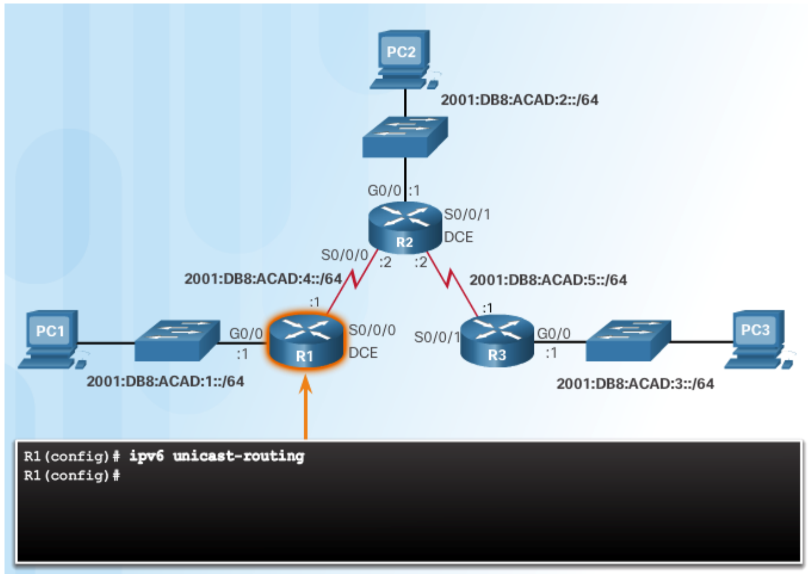
Most of parameters are identical to the IPv4 version of the command. An IPv6 static route can also be implemented as:

- Standard IPv6 static route
- Default IPv6 static route
- Summary IPv6 static route
- Floating IPv6 static route

Configure IPv6 Static Routes

The ipv6 route Command (Cont.)

- **ipv6 unicast-routing** enables the router to forward IPv6 packets



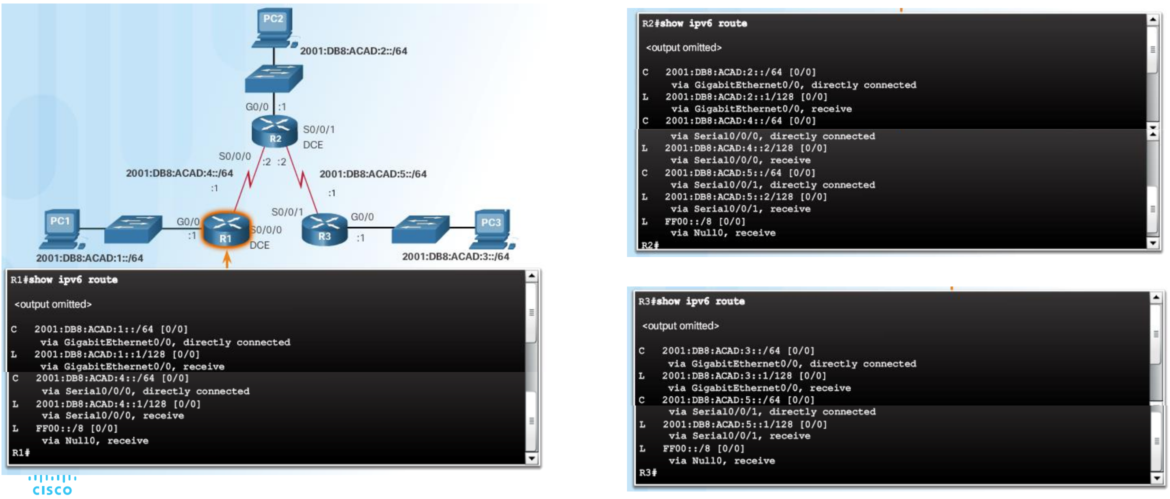
As with IPv4, these routes can be configured as recursive, directly connected, or fully specified.

The **ipv6 unicast-routing** global configuration command must be configured to enable the router to forward IPv6 packets. Figure 2 displays the enabling of IPv6 unicast routing.

Configure IPv6 Static Routes

Next-Hop Options

- Each router only knows about directly connected networks
  - R1 can **ping** R2 (ipv6 2001:DB8:ACAD:4::2) but cannot **ping** R3 (ipv6 2001:DB8:ACAD:3::2)



Next-Hop Options

In this example, Figures 1 to 3 display the routing tables of R1, R2, and R3. Each router has entries only for directly connected networks and their associated local addresses. None of the routers have any knowledge of any networks beyond their directly connected interfaces.

For example, R1 has no knowledge of networks:

- 2001:DB8:ACAD:2::/64 - LAN on R2
- 2001:DB8:ACAD:5::/64 - Serial network between R2 and R3
- 2001:DB8:ACAD:3::/64 - LAN on R3

Configure IPv6 Static Routes

Next-Hop Options (Cont.)

- Next hop can be identified by an IPv6 address, exit interface, or both.
- Destination is specified by one of three route types:
  - **Next-hop static IPv6 route** - Only the next-hop IPv6 address is specified
  - **Directly connected static IPv6 route** - Only the router exit interface is specified
  - **Fully specified static IPv6 route** - The next-hop IPv6 address and exit interface are specified

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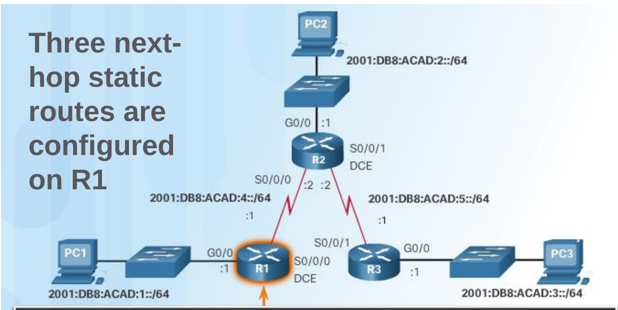
R1 does not have an entry in its routing table for that network.
The next hop can be identified by an IPv6 address, exit interface, or both. How the destination is specified creates one of three route types:

- **Next-hop static IPv6 route** - Only the next-hop IPv6 address is specified
- **Directly connected static IPv6 route** - Only the router exit interface is specified
- **Fully specified static IPv6 route** - The next-hop IPv6 address and exit interface are specified

Configure IPv6 Static Routes

Configure a Next Hop Static IPv6 Route




```
R1(config)# ipv6 route 2001:DB8:ACAD:2::/64  2001:DB8:ACAD:4::2
R1(config)# ipv6 route 2001:DB8:ACAD:5::/64  2001:DB8:ACAD:4::2
R1(config)# ipv6 route 2001:DB8:ACAD:3::/64  2001:DB8:ACAD:4::2
R1(config)#
```

As with IPv4, must resolve the route to determine the exit interface to use to forward the packet

```
R1# show ipv6 route
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route, B - BGP,
       R - RIP, H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea,
       IS - ISIS summary, D - EIGRP, EX - EIGRP external, ND - ND Default,
       NDp - ND Prefix, DCE - Destination, NDr - Redirect, O - OSPF Intra,
       OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1,
       ON2 - OSPF NSSA ext 2

C   2001:DB8:ACAD:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
1 S   2001:DB8:ACAD:2::/64 [1/0]
     via 2001:DB8:ACAD:4::2
2 S   2001:DB8:ACAD:3::/64 [1/0]
     via 2001:DB8:ACAD:4::2
C   2001:DB8:ACAD:4::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:ACAD:4::1/128 [0/0]
     via Serial0/0/0, receive
S   2001:DB8:ACAD:5::/64 [1/0]
     via 2001:DB8:ACAD:4::2
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```

The IPv6 address matches the route for the directly connected network 2001:DB8:ACAD:4::/64 with the exit interface Serial 0/0/0.

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Configure a Next-Hop Static IPv6 Route

In a next-hop static route, only the next-hop IPv6 address is specified. The exit interface is derived from the next hop. For instance, in Figure 1, three next-hop static routes are configured on R1.

As with IPv4, before any packet is forwarded by the router, the routing table process must resolve the route to determine the exit interface to use to forward the packet. The route resolvability process will vary depending upon the type of forwarding mechanism being used by the router. CEF (Cisco Express Forwarding) is the default behavior on most platforms running IOS 12.0 or later.

Figure 2 details the basic packet forwarding route resolvability process in the routing table for R1 without the use of CEF. When a packet is destined for the 2001:DB8:ACAD:3::/64 network, R1:

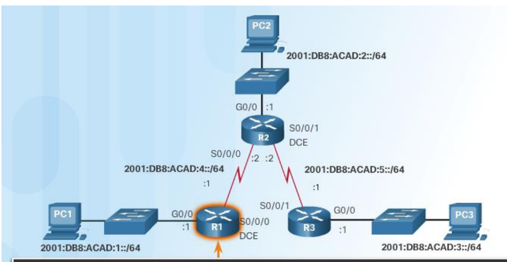
1. Looks for a match in the routing table and finds that it has to forward the packets to the next-hop IPv6 address 2001:DB8:ACAD:4::2. Every route that references only a next-hop IPv6 address and does not reference an exit interface must have the next-hop IPv6 address resolved using another route in the routing table with an exit interface.

2. R1 must now determine how to reach 2001:DB8:ACAD:4::2; therefore, it searches a second time looking for a match. In this case, the IPv6 address matches the route for the directly connected network 2001:DB8:ACAD:4::/64 with the exit interface Serial 0/0/0. This lookup tells the routing table process that this packet is forwarded out of that interface.

Therefore, it actually takes two routing table lookup processes to forward any packet to the 2001:DB8:ACAD:3::/64 network. When the router has to perform multiple lookups in the routing table before forwarding a packet, it is performing a process known as a recursive lookup.
A recursive static IPv6 route is valid (that is, it is a candidate for insertion in the routing table) only when the specified next hop resolves, either directly or indirectly, to a valid exit interface.

Configure a Directly Connected Static IPv6 Route

- Alternative to next hop is to specify the exit interface
- Packet destined for 2001:DB8:ACAD:3::/64 network, forwarded out Serial 0/0/0 – no other lookups needed




```
R1(config)# ipv6 route 2001:DB8:ACAD:2::/64 s0/0/0
R1(config)# ipv6 route 2001:DB8:ACAD:5::/64 s0/0/0
R1(config)# ipv6 route 2001:DB8:ACAD:3::/64 s0/0/0
R1(config)#
R1#
```

```
R1# show ipv6 route
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2
       IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external
       ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
C   2001:DB8:ACAD:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
S   2001:DB8:ACAD:2::/64 [1/0]
     via Serial0/0/0, directly connected
S   2001:DB8:ACAD:3::/64 [1/0]
     via Serial0/0/0, directly connected
C   2001:DB8:ACAD:4::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:ACAD:4::1/128 [0/0]
     via Serial0/0/0, receive
S   2001:DB8:ACAD:5::/64 [1/0]
     via Serial0/0/0, directly connected
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```

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Configure a Directly Connected Static IPv6 Route

When configuring a static route on point-to-point networks, an alternative to using the next-hop IPv6 address is to specify the exit interface. This is an alternative used in older IOSs or whenever CEF is disabled, to avoid the recursive lookup problem.

For instance, in Figure 1, three directly connected static routes are configured on R1 using the exit interface.

The IPv6 routing table for R1 in Figure 2 shows that when a packet is destined for the 2001:DB8:ACAD:3::/64 network, R1 looks for a match in the routing table and finds that it can forward the packet out of its Serial 0/0/0 interface. No other lookups are required.

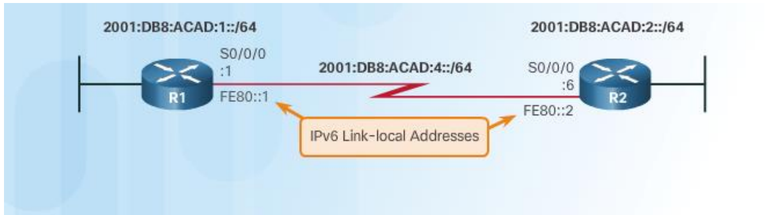
Notice how the routing table looks different for the route configured with an exit interface than the route configured with a recursive entry.

Configuring a directly connected static route with an exit interface allows the routing table to resolve the exit interface in a single search instead of two searches. Recall that with the use of the CEF forwarding mechanism, static routes with an exit interface are considered unnecessary. A single lookup is performed using a combination of the FIB and adjacency table stored in the data plane.

Configure IPv6 Static Routes

Configure a Fully Specified Static IPv6 Route

- Fully specified static route must be used if IPv6 link-local address is used as next-hop




```
R1(config)# ipv6 route 2001:db8:acad:2::/64 fe80::2
% Interface has to be specified for a link-local nexthop
R1(config)# ipv6 route 2001:db8:acad:2::/64 s0/0/0 fe80::2
R1(config)#
```

```
R1# show ipv6 route static | begin 2001:DB8:ACAD:2::/64
S    2001:DB8:ACAD:2::/64 [1/0]
      via FE80::2, Serial0/0/0
```

Configure a Fully Specified Static IPv6 Route

In a fully specified static route, both the exit interface and the next-hop IPv6 address are specified. Similar to fully specified static routes used with IPv4, this would be used if CEF were not enabled on the router and the exit interface was on a multi-access network. With CEF, a static route using only a next-hop IPv6 address would be the preferred method even when the exit interface is a multi-access network.

Unlike IPv4, there is a situation in IPv6 when a fully specified static route must be used. If the IPv6 static route uses an IPv6 link-local address as the next-hop address, a fully specified static route including the exit interface must be used. Figure 1 shows an example of a fully qualified IPv6 static route using an IPv6 link-local address as the next-hop address.

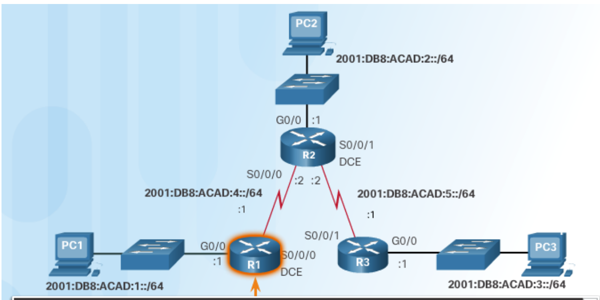
The reason a fully specified static route must be used is because IPv6 link-local addresses are not contained in the IPv6 routing table. Link-local addresses are only unique on a given link or network. The next-hop link-local address may be a valid address on multiple networks connected to the router. Therefore, it is necessary that the exit interface be included.

In Figure 1, a fully specified static route is configured using R2’s link-local address as the next-hop address. Notice that IOS requires that an exit interface be specified.

Figure 2 shows the IPv6 routing table entry for this route. Notice that both the next-hop link-local address and the exit interface are included.

Configure IPv6 Static Routes

Verify IPv6 Static Routes




```
R1# show ipv6 route static
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route, B - BGP,
       R - RIP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary,
       D - EIGRP, EX - EIGRP external, ND - ND Default, NDp - ND Prefix,
       DCE - Destination, NDr - Redirect, O - OSPF Intra, OI - OSPF Inter,
       OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1,
       ON2 - OSPF NSSA ext 2
S   2001:DB8:ACAD:2::/64 [1/0]
     via 2001:DB8:ACAD:4::2
S   2001:DB8:ACAD:3::/64 [1/0]
     via 2001:DB8:ACAD:4::2
S   2001:DB8:ACAD:5::/64 [1/0]
     via 2001:DB8:ACAD:4::2
R1#
```

```
R1# show ipv6 route 2001:db8:acad:3::
Routing entry for 2001:DB8:ACAD:3::/64
  Known via "static", distance 1, metric 0
  Route count is 1/1, share count 0
  Routing paths:
    2001:DB8:ACAD:4::2
      Last updated 00:19:11 ago
R1#
```

```
R1# show running-config | section ipv6 route
ipv6 route 2001:DB8:ACAD:2::/64 2001:DB8:ACAD:4::2
ipv6 route 2001:DB8:ACAD:3::/64 2001:DB8:ACAD:4::2
ipv6 route 2001:DB8:ACAD:5::/64 2001:DB8:ACAD:4::2
R1#
```

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Verify IPv6 Static Routes

Along with **ping** and **traceroute**, useful commands to verify static routes include:

- **show ipv6 route**
- **show ipv6 route static**
- **show ipv6 route network**

Figure 1 displays sample output of the **show ipv6 route static** command. The output reflects the use of static routes using next-hop global unicast addresses.

Figure 2 displays sample output from the **show ip route 2001:DB8:ACAD:3::** command.

Figure 3 verifies the **ipv6 route** configuration in the running configuration.

Configure IPv6 Default Routes

Default Static IPv6 Route

- Default static route matches all packets not specified in routing table

```
Router(config)# ipv6 route ::/0 {ipv6-address | exit-intf}
```

Parameter	Description
::/0	Matches any IPv6 prefix regardless of prefix length.
ipv6-address	• Commonly referred to as the next-hop router's IPv6 address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
exit-intf	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

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Default Static IPv6 Route

A default route is a static route that matches all packets. Instead of routers storing routes for all of the networks in the Internet, they can store a single default route to represent any network that is not in the routing table. A default route does not require any left-most bits to match between the default route and the destination IPv6 address.

Routers commonly use default routes that are either configured locally, or learned from another router using a dynamic routing protocol. They are used when no other routes match the packet's destination IP address in the routing table. In other words, if a more specific match does not exist, then use the default route as the Gateway of Last Resort.

Default static routes are commonly used when connecting:

- A company's edge router to a service provider network.
- A router with only an upstream neighbor router. The router has no other neighbors and is therefore, referred to as a stub router.

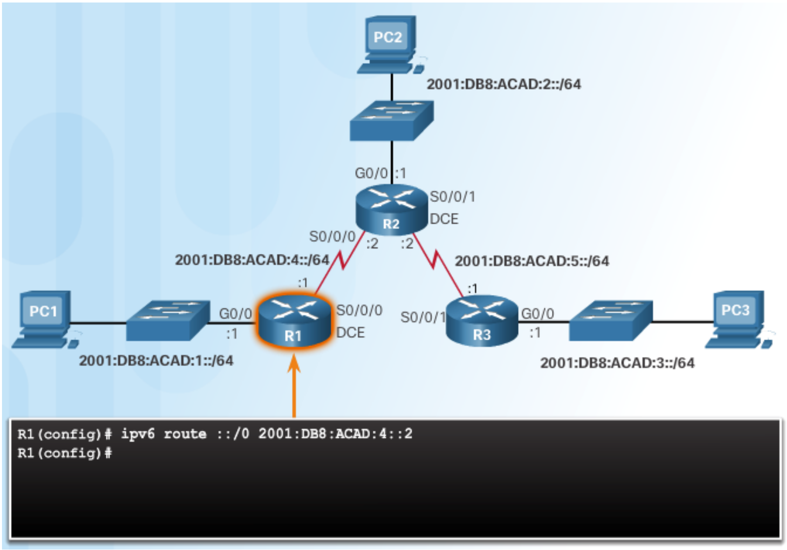
As shown in the figure, the command syntax for a default static route is similar to any other static route, except that the ipv6-prefix/prefix-length is **::/0**, which matches all routes.

The basic command syntax of a default static route is:

ipv6 route ::/0 {*ipv6-address* | *exit-intf*}

Configure IPv6 Default Routes

Configure a Default Static IPv6 Route



- R1 is a stub router because it is only connected to R2
- More efficient to configure a default static IPv6 route in this topology

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Configure a Default Static IPv6 Route

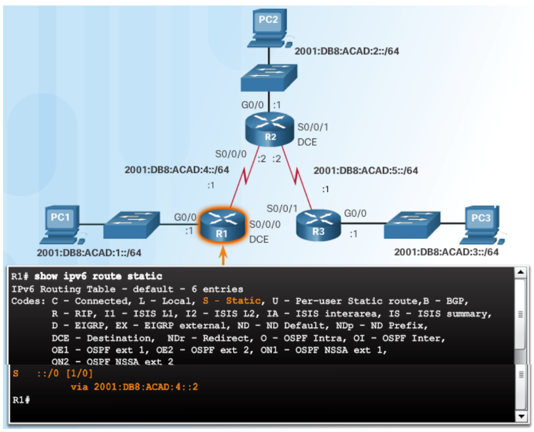
R1 can be configured with three static routes to reach all of the remote networks in our topology. However, R1 is a stub router because it is only connected to R2. Therefore, it would be more efficient to configure a default static IPv6 route.

The example in the figure displays a configuration for a default static IPv6 route on R1.

Configure IPv6 Default Routes

Verify a Default Static Route

- **::/0** mask indicates that none of the bits are required to match
- If a more specific match does not exist, the default static IPv6 route matches all packets.



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Verify a Default Static Route

In Figure 1, the **show ipv6 route static** command output displays the contents of the routing table.

Unlike IPv4, IPv6 does not explicitly state that the default IPv6 is the Gateway of Last Resort.

The key to this configuration is the ::/0 mask. Remember that the IPv6 prefix-length in a routing table determines how many bits must match between the destination IP address of the packet and the route in the routing table. The ::/0 mask indicates that none of the bits are required to match. As long as a more specific match does not exist, the default static IPv6 route matches all packets.

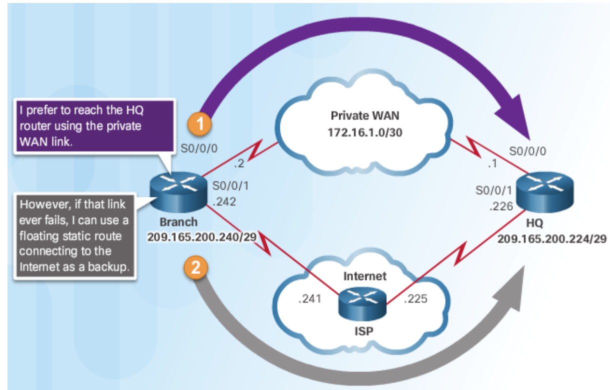
Figure 2 displays a successful ping to the R3 LAN interface.

Configure Floating Static Routes

Floating Static Routes

Floating static routes have an administrative distance greater than the dynamic routing protocol or other static route

- Used as backup routes
- Administrative distance of common routing protocols
  - EIGRP = 90
  - IGRP = 100
  - OSPF = 110
  - IS-IS = 115
  - RIP = 120
- By default, AD of static route = 1
- Static route AD can be increased to make route less desirable until preferred route is lost



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Floating Static Routes

Floating static routes are static routes that have an administrative distance greater than the administrative distance of another static route or dynamic routes. They are very useful when providing a backup to a primary link, as shown in the figure.

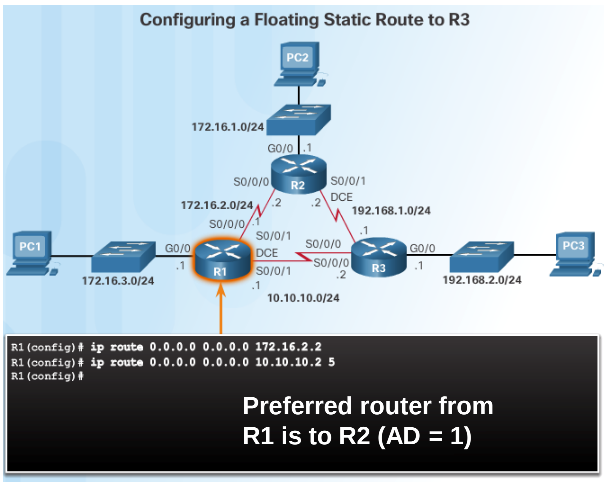
By default, static routes have an administrative distance of 1, making them preferable to routes learned from dynamic routing protocols. For example, the administrative distances of some common dynamic routing protocols are:

- EIGRP = 90
- IGRP = 100
- OSPF = 110
- IS-IS = 115
- RIP = 120

The administrative distance of a static route can be increased to make the route less desirable than that of another static route or a route learned through a dynamic routing protocol. In this way, the static route "floats" and is not used when the route with the better administrative distance is active. However, if the preferred route is lost, the floating static route can take over, and traffic can be sent through this alternate route.

Configure Floating Static Routes

Configure a Floating Static Route



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Configure an IPv4 Floating Static Route

IPv4 floating static routes are configured using the **ip route** global configuration command and specifying an administrative distance. If no administrative distance is configured, the default value (1) is used.

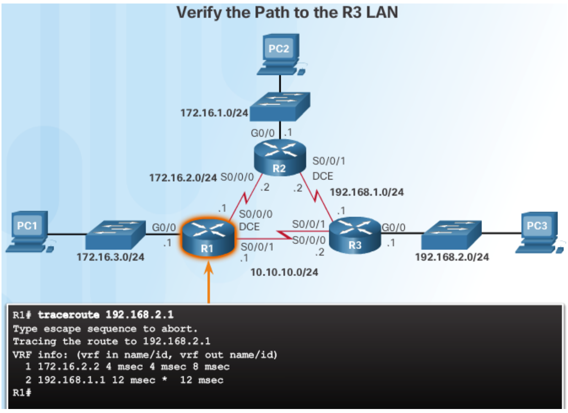
Refer to the topology in Figure 1. In this scenario, the preferred default route from R1 is to R2. The connection to R3 should be used for backup only.

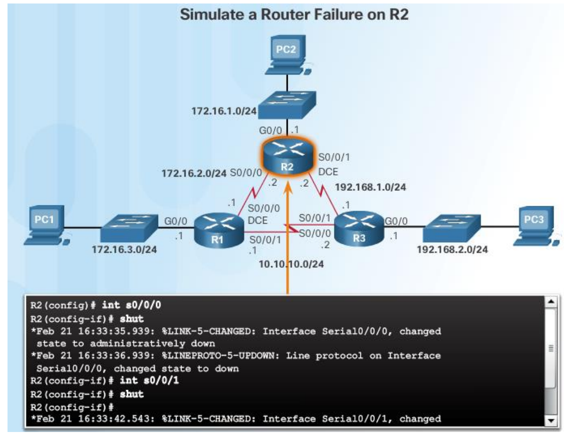
R1 is configured with a default static route pointing to R2. Because no administrative distance is configured, the default value (1) is used for this static route. R1 is also configured with a floating static default pointing to R3 with an administrative distance of 5. This value is greater than the default value of 1 and therefore; this route floats and is not present in the routing table, unless the preferred route fails.

Figure 2 verifies that the default route to R2 is installed in the routing table. Note that the backup route to R3 is not present in the routing table.

Configure Floating Static Routes

Test the IPv4 Floating Static Route





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Test the IPv4 Floating Static Route

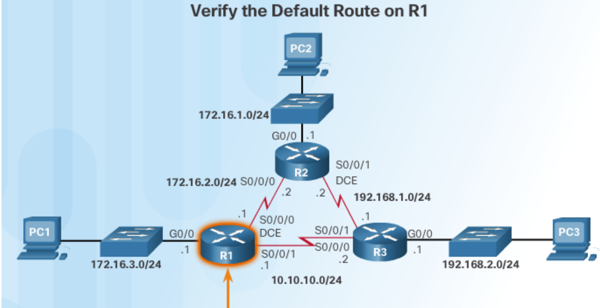
Because the default static route on R1 to R2 has an administrative distance of 1, traffic from R1 to R3 should go through R2. The output in Figure 1 confirms that traffic between R1 and R3 flows through R2.

What would happen if R2 failed? To simulate this failure both serial interfaces of R2 are shut down, as shown in Figure 2.

Configure Floating Static Routes

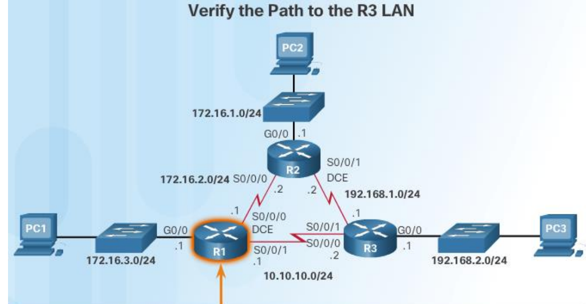
Test the IPv4 Floating Static Route (Cont.)

Verify the Default Route on R1




```
*Feb 21 16:35:58.435: %LINK-3-UPDOWN: Interface Serial0/0/0, changed
 state to down
*Feb 21 16:35:59.435: %LINEPROTO-5-UPDOWN: Line protocol on Interface
 Serial0/0/0, changed state to down
R1#
R1# show ip route static | begin Gateway
Gateway of last resort is 0.0.0.0 to network 0.0.0.0
S*    0.0.0.0/0 [5/0] via 10.10.10.2
R1#
```

Verify the Path to the R3 LAN




```
R1# traceroute 192.168.2.1
Type escape sequence to abort.
Tracing the route to 192.168.2.1
VRF info: (vrf in name/id, vrf out name/id)
  1 10.10.10.2 4 msec 4 msec *
R1#
```

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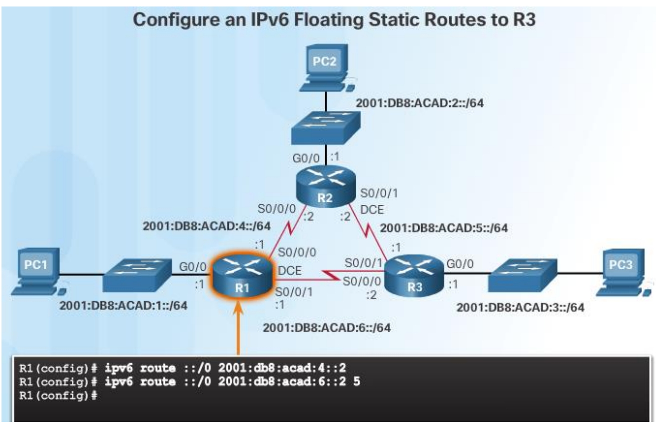
Notice in Figure 1 that R1 automatically generates messages indicating that the serial interface to R2 is down. A look at the routing table verifies that the default route is now pointing to R3 using the floating static default route configured with an AD value of 5 and a next-hop of 10.10.10.2.

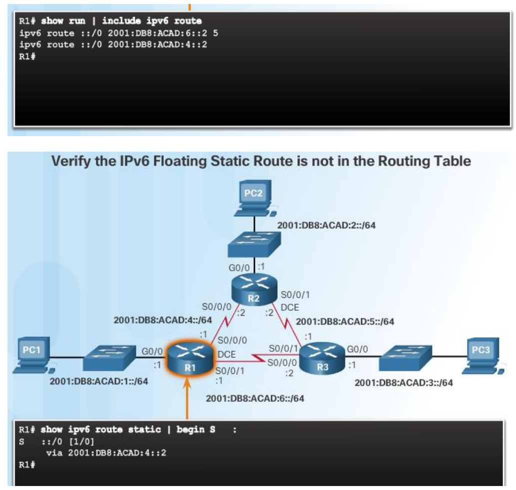
The output in Figure 2 confirms that traffic now flows directly between R1 and R3.

Configure Floating Static Routes

Configure an IPv6 Floating Static Route

- Similar to IPv4 floating static routes





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Configure an IPv6 Floating Static Route

IPv6 floating static routes are configured using the **ipv6 route** global configuration command and specifying an administrative distance. If no administrative distance is configured, the default value (1) is used.

Refer to the topology in Figure 1. In this scenario, the preferred default route from R1 is to R2. The connection to R3 should be used for backup only.

R1 is configured with an IPv6 default static route pointing to R2. Because no administrative distance is configured, the default value (1) is used for this static route.

R1 is also configured with an IPv6 floating static default pointing to R3 with an administrative distance of 5. This value is greater than the default value of 1 and therefore; this route floats and is not present in the routing table, unless the preferred route fails.

Figure 2 verifies that both IPv6 static default routes are in the running configuration.

Figure 3 verifies that the IPv6 static default route to R2 is installed in the routing table. Note that the backup route to R3 is not present in the routing table.

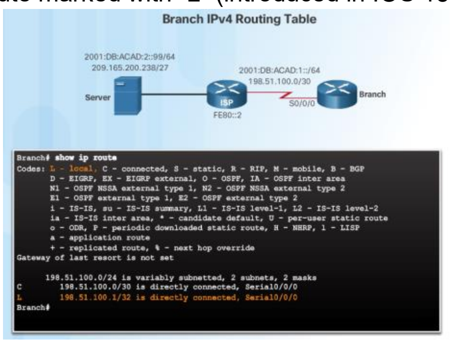
The process for testing the IPv6 floating static route is the same as for the IPv4 floating static route. Shut down the interfaces on R2 to simulate a failure. R1 will install the route to R3 in the route table and use it to send default traffic.

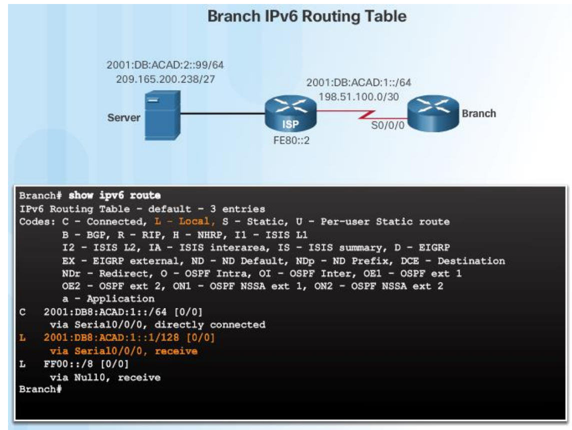
Configure Static Host Routes

Automatically Installed Host Routes

Host route is an IPv4 address with a 32-bit mask or IPv6 address with a 128-bit mask.

- Automatically installed when IP address is configured
- Configured as a static host route
- Allows more efficiency for packets directed to the router
- Local route marked with “L” (introduced in IOS 15)





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Automatically Installed Host Routes

A host route is an IPv4 address with a 32-bit mask or an IPv6 address with a 128-bit mask. There are three ways a host route can be added to the routing table:

Automatically installed when an IP address is configured on the router (as shown in Figures 1 and 2)

Configured as a static host route

Host route automatically obtained through other methods (discussed in later courses)

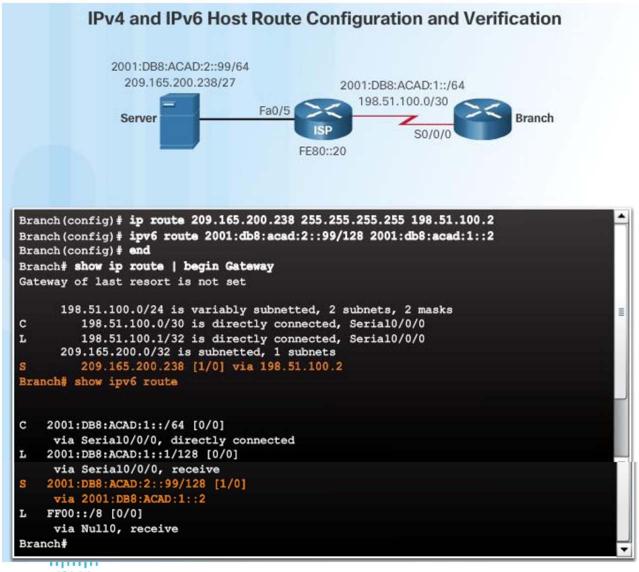
Cisco IOS automatically installs a host route, also known as a local host route, when an interface address is configured on the router. A host route allows for a more efficient process for packets that are directed to the router itself, rather than for packet forwarding. This is in addition to the connected route, designated with a C in the routing table for the network address of the interface.

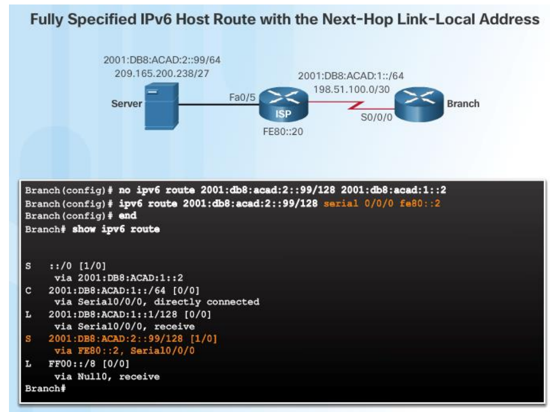
When an active interface on a router is configured with an IP address, a local host route is automatically added to the routing table. The local routes are marked with “L” in the output of the routing table. The IP addresses assigned to the Branch Serial0/0/0 interface are 198.51.100.1/30 for IPv4 and 2001:DB8:ACAD:1::1/64 for IPv6. The local routes for the interface are installed by the IOS in the routing table as shown in the output in Figure 1 for IPv4 and Figure 2 for IPv6.

Note: For IPv4, the local routes marked with “L” were introduced with IOS version 15.

Configure Static Host Routes

Configure IPv4 and IPv6 Static Host Routes





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Configure IPv4 and IPv6 Static Host Routes

A host route can be a manually configured static route to direct traffic to a specific destination device, such as an authentication server. The static route uses a destination IP address and a 255.255.255.255 (/32) mask for IPv4 host routes and a /128 prefix length for IPv6 host routes. Static routes are marked with “S” in the output of the routing table. An IPv4 and an IPv6 host route is configured on the BRANCH router to access the server in the topology in Figure 1.

For IPv6 static routes, the next-hop address can be the link-local address of the adjacent router. However, you must specify an interface type and an interface number when using a link-local address as the next hop, as shown in Figure 2.

Troubleshoot Static and Default Routes

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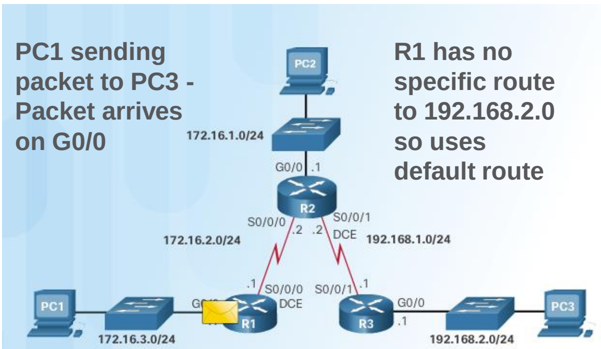
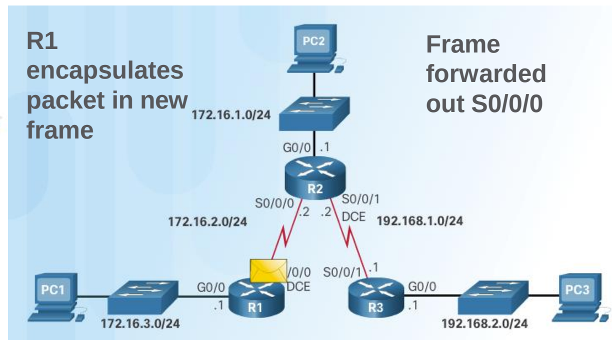
Packet Processing with Static Routes

Static Routes and Packet Forwarding





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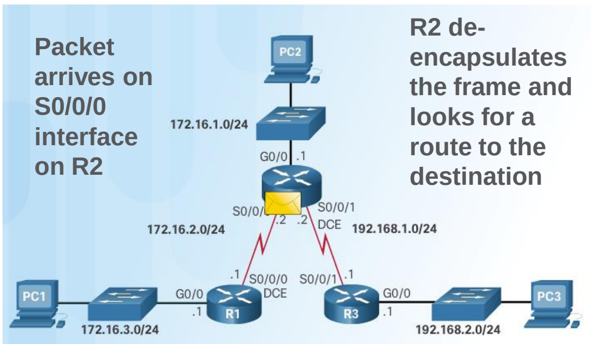
Static Routes and Packet Forwarding

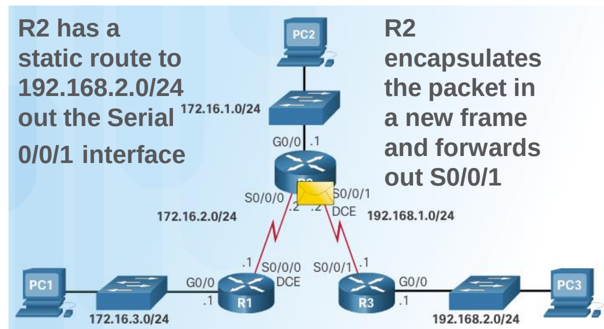
The following example describes the packet forwarding process with static routes. In the figures, PC1 is sending a packet to PC3:

1. The packet arrives on the GigabitEthernet 0/0 interface of R1.
2. R1 does not have a specific route to the destination network, 192.168.2.0/24; therefore, R1 uses the default static route.
3. R1 encapsulates the packet in a new frame. Because the link to R2 is a point-to-point link, R1 adds an "all 1s" address for the Layer 2 destination address.

Packet Processing with Static Routes

Static Routes and Packet Forwarding (Cont.)





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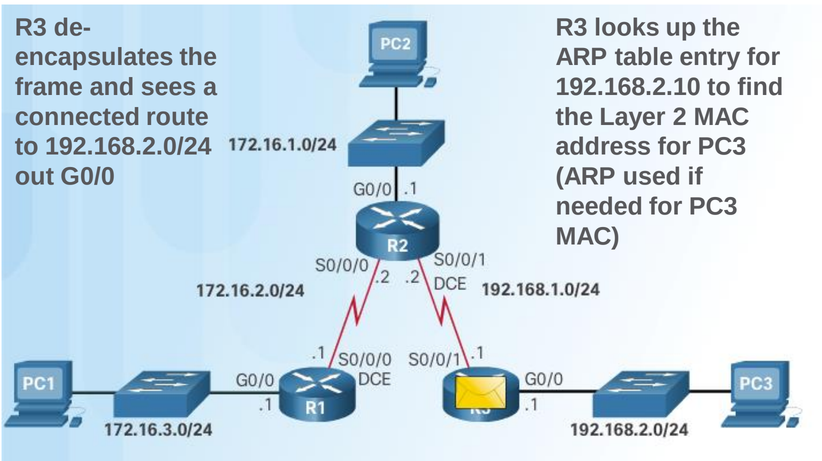
The process continue in the 2 figures:

4. In R1, The frame is forwarded out of the Serial 0/0/0 interface. The packet arrives on the Serial 0/0/0 interface on R2.
5. R2 de-encapsulates the frame and looks for a route to the destination. R2 has a static route to 192.168.2.0/24 out of the Serial 0/0/1 interface.
6. R2 encapsulates the packet in a new frame. Because the link to R3 is a point-to-point link, R2 adds an "all 1s" address for the Layer 2 destination address.
7. The frame is forwarded out of the Serial 0/0/1 interface. The packet arrives on the Serial 0/0/1 interface on R3.

Packet Processing with Static Routes

Static Routes and Packet Forwarding (Cont.)



- R3 encapsulates the packet in a new frame with the MAC address of the G0/0 interface as the source Layer 2 address and the MAC address of PC3 as the destination MAC address
- Frame is forwarded out of G0/0 interface and packet arrives on the NIC interface of PC3

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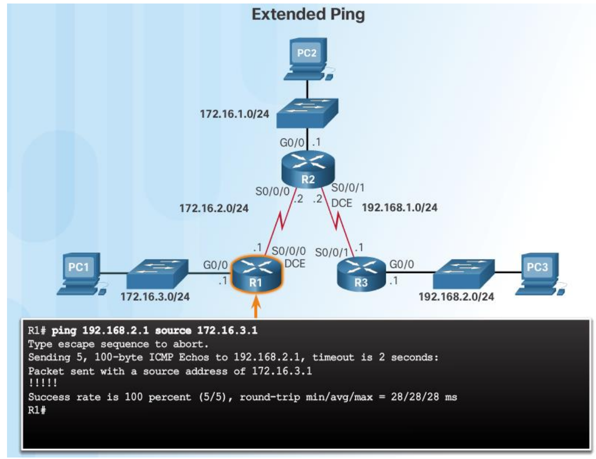
8. R3 de-encapsulates the frame and looks for a route to the destination. R3 has a connected route to 192.168.2.0/24 out of the GigabitEthernet 0/0 interface.
9. R3 looks up the ARP table entry for 192.168.2.10 to find the Layer 2 Media Access Control (MAC) address for PC3. If no entry exists, R3 sends an Address Resolution Protocol (ARP) request out of the GigabitEthernet 0/0 interface, and PC3 responds with an ARP reply, which includes the PC3 MAC address.
10. R3 encapsulates the packet in a new frame with the MAC address of the GigabitEthernet 0/0 interface as the source Layer 2 address and the MAC address of PC3 as the destination MAC address.
11. The frame is forwarded out of GigabitEthernet 0/0 interface. The packet arrives on the network interface card (NIC) interface of PC3.

Troubleshoot a Missing Route

- Common IOS troubleshooting commands include:
  - **ping**
  - **traceroute**
  - **show ip route**
  - **show ip interface brief**
  - **show cdp neighbors detail**



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Troubleshoot a Missing Route

Networks are subject to forces that can cause their status to change quite often:

- An interface fails
- A service provider drops a connection
- Links become oversaturated
- An administrator enters a wrong configuration

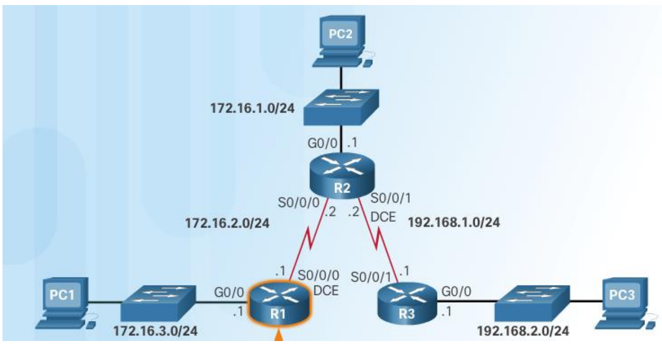
When there is a change in the network, connectivity may be lost. Network administrators are responsible for pinpointing and solving the problem. To find and solve these issues, a network administrator must be familiar with tools to help isolate routing problems quickly.

Common IOS troubleshooting commands include:

- **ping**
- **traceroute**
- **show ip route**
- **show ip interface brief**
- **show cdp neighbors detail**

Figure displays the result of an extended ping from the source interface of R1 to the LAN interface of R3. An extended ping is an enhanced version of the ping utility. Extended ping enables you to specify the source IP address for the ping packets.

Troubleshoot a Missing Route (Cont.)




```
R1# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.1.0/24 [1/0] via 172.16.2.2
C        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.1/32 is directly connected, Serial0/0/0
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0
S     192.168.1.0/24 [1/0] via 172.16.2.2
S     192.168.2.0/24 [1/0] via 172.16.2.2
R1#
```

```
R1# show ip interface brief
Interface                  IP-Address   OK? Method Status                Protocol
Embedded-Service-Engine0/0 unassigned   YES unset  administratively down down
GigabitEthernet0/0         172.16.3.1   YES manual up                    up
GigabitEthernet0/1         unassigned   YES unset  administratively down down
Serial0/0/0                172.16.2.1   YES manual up                    up
Serial0/0/1                unassigned   YES unset  administratively down down
R1#
```

```
R1# traceroute 192.168.2.1
Type escape sequence to abort.
Tracing the route to 192.168.2.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.2.2 4 msec 4 msec 8 msec
  2 192.168.1.1 12 msec 12 msec *
R1#
```

```
R1# show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge,
                  B - Source Route Bridge, S - Switch, H - Host,
                  I - IGMP, r - Repeater, P - Phone, D - Remote,
                  C - CVTA, M - Two-port Mac Relay

Device ID   Local Intrfce  Holdtme  Capability  Platform   Port ID
netlab-cs5  Gig 0/0         156      S I        WS-C2960-  Fas 0/1
R2          Ser 0/0/0       153      R S I      CISCO1941  Ser 0/0/0
R1#
```

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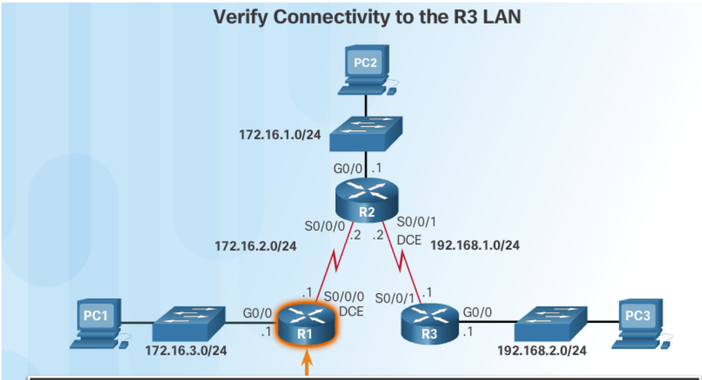
Figure 1 displays the result of a traceroute from R1 to the R3 LAN.
Figure 2 displays the routing table of R1.
Figure 3 provides a quick status of all interfaces on the router.
Figure 4 provides a list of directly connected Cisco devices. This command validates Layer 2 (and therefore Layer 1) connectivity. For example, if a neighbor device is listed in the command output, but it cannot be pinged, then Layer 3 addressing should be investigated.

Troubleshoot IPv4 Static and Default Route Configuration

Solve a Connectivity Problem




```
R1# ping 192.168.2.1 source g0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
Packet sent with a source address of 172.16.3.1
.....
Success rate is 0 percent (0/5)
R1#
```

```
R1# traceroute 192.168.2.1
Type escape sequence to abort.
Tracing the route to 192.168.2.1
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.2.2 4 msec 4 msec 8 msec
  2 172.16.2.1 12 msec 12 msec 12 msec
  3 172.16.2.2 12 msec 8 msec 8 msec
  4 172.16.2.1 20 msec 16 msec 20 msec
  5 172.16.2.2 16 msec 16 msec 16 msec
  6 172.16.2.1 20 msec 20 msec 24 msec
  7 172.16.2.2 20 msec
```

A traceroute reveals that R2 forwards the traceroute back to R1. R1 returns it to R2

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Solve a Connectivity Problem

Finding a missing (or misconfigured) route is a relatively straightforward process, if the right tools are used in a methodical manner.

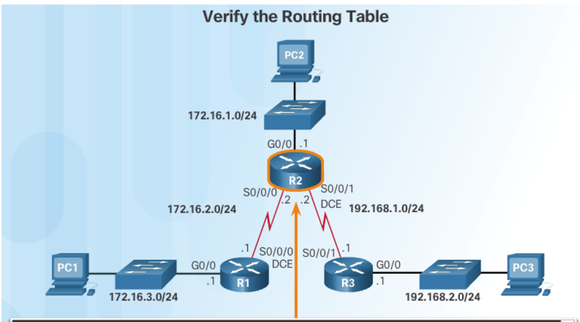
For instance, in this example, the user at PC1 reports that he cannot access resources on the R3 LAN. This can be confirmed by pinging the LAN interface of R3 using the LAN interface of R1 as the source (see Figure 1). The results show that there is no connectivity between these LANs.

A traceroute in Figure 2 reveals that R2 is not responding as expected. For some reason, R2 forwards the traceroute back to R1. R1 returns it to R2. This loop would continue until the time to live (TTL) value decrements to zero, in which case, the router would then send an Internet Control Message Protocol (ICMP) destination unreachable message to R1.

Troubleshoot IPv4 Static and Default Route Configuration

Solve a Connectivity Problem (Cont.)

Verify the Routing Table




```
      172.16.0.0/16 is variably subnetted, 5 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        172.16.2.0/24 is directly connected, Serial0/0/0
L        172.16.2.2/32 is directly connected, Serial0/0/0
S        172.16.3.0/24 is directly connected, Serial0/0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Serial0/0/1
L        192.168.1.2/32 is directly connected, Serial0/0/1
S       192.168.2.0/24 [1/0] via 172.16.2.1
R2#
```

Static route to 192.168.2.0/24 has been configured using the next-hop address 172.16.2.1.

```
R2# show running-config | section ip route
ip route 172.16.3.0 255.255.255.0 172.16.2.1
ip route 192.168.2.0 255.255.255.0 172.16.2.1
R2#
R2# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)# no ip route 192.168.2.0 255.255.255.0 172.16.2.1
R2(config)# ip route 192.168.2.0 255.255.255.0 192.168.1.1
R2(config)#
```

Incorrect route is removed and the correct route is then entered

```
R1# ping 192.168.2.1 source g0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
Packet sent with a source address of 172.16.3.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms
R1#
```

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The next step is to investigate the routing table of R2, because it is the router displaying a strange forwarding pattern. The routing table in Figure 1 reveals that the 192.168.2.0/24 network is configured incorrectly. A static route to the 192.168.2.0/24 network has been configured using the next-hop address 172.16.2.1. Using the configured next-hop address, packets destined for the 192.168.2.0/24 network are sent back to R1. It is clear from the topology that the 192.168.2.0/24 network is connected to R3, not R1. Therefore, the static route to the 192.168.2.0/24 network on R2 must use next-hop 192.168.1.1, not 172.16.2.1.

Figure 2 shows output from the running configuration that reveals the incorrect **ip route** statement. The incorrect route is removed, and the correct route is then entered.

Figure 3 verifies that R1 can now reach the LAN interface of R3. As a last step in confirmation, the user on PC1 should also test connectivity to the 192.168.2.0/24 LAN.

Chapter Summary

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Conclusion

Static Routing

- Explain how static routes are implemented in a small to medium-sized business network.
- Configure static routes to enable connectivity in a small to medium-sized business network.
- Troubleshoot static and default route configurations.

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New Terms and Commands

• stub network • stub router • Standard static route	• Summary static route • Floating static route • exit interface

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New Terms and Commands

New Terms and Commands

• next-hop IP address • next-hop static route • directly connected static route • fully specified static route	• recursive lookup • link-local address • host route • local host route

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New Terms and Commands