Module 15: IP Static Routing

Switching, Routing, and Wireless Essentials v7.0 (SRWE)

Module Objectives

Module Title: IP Static Routing

Module Objective: Configure IPv4 and IPv6 static routes.

Topic Title	Topic Objective
Static Routes	Describe the command syntax for static routes.
Configure IP Static Routes	Configure IPv4 and IPv6 static routes.
Configure IP Default Static Routes	Configure IPv4 and IPv6 default static routes.
Configure Floating Static Routes	Configure a floating static route to provide a backup connection.
Configure Static Host Routes	Configure IPv4 and IPv6 static host routes that direct traffic to a specific host.

15.1 Static Routes

Types of Static Routes

Static routes are commonly implemented on a network. This is true even when there is a dynamic routing protocol configured.

Static routes can be configured for IPv4 and IPv6. Both protocols support the following types of static routes:

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

Static routes are configured using the **ip route** and **ipv6 route** global configuration commands.

Next-Hop Options

When configuring a static route, 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 types of static route:

- **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

IPv4 Static Route Command

IPv4 static routes are configured using the following global configuration command:

Router(config)# ip route *network-address subnet-mask { ip-address | exit-intf [ip-address]}* [distance]

Note: Either the *ip-address*, *exit-intf,* or the *ip-address* and *exit-intf* parameters must be configured.

IPv6 Static Route Command

IPv6 static routes are configured using the following global configuration command:

Router(config)# ipv6 route *ipv6-prefix/prefix-length* {*ipv6-address* | *exit-intf* [*ipv6-address*]} [*distance*]

Most of parameters are identical to the IPv4 version of the command.

Dual-Stack Topology

The figure shows a dual-stack network topology. Currently, no static routes are configured for either IPv4 or IPv6.
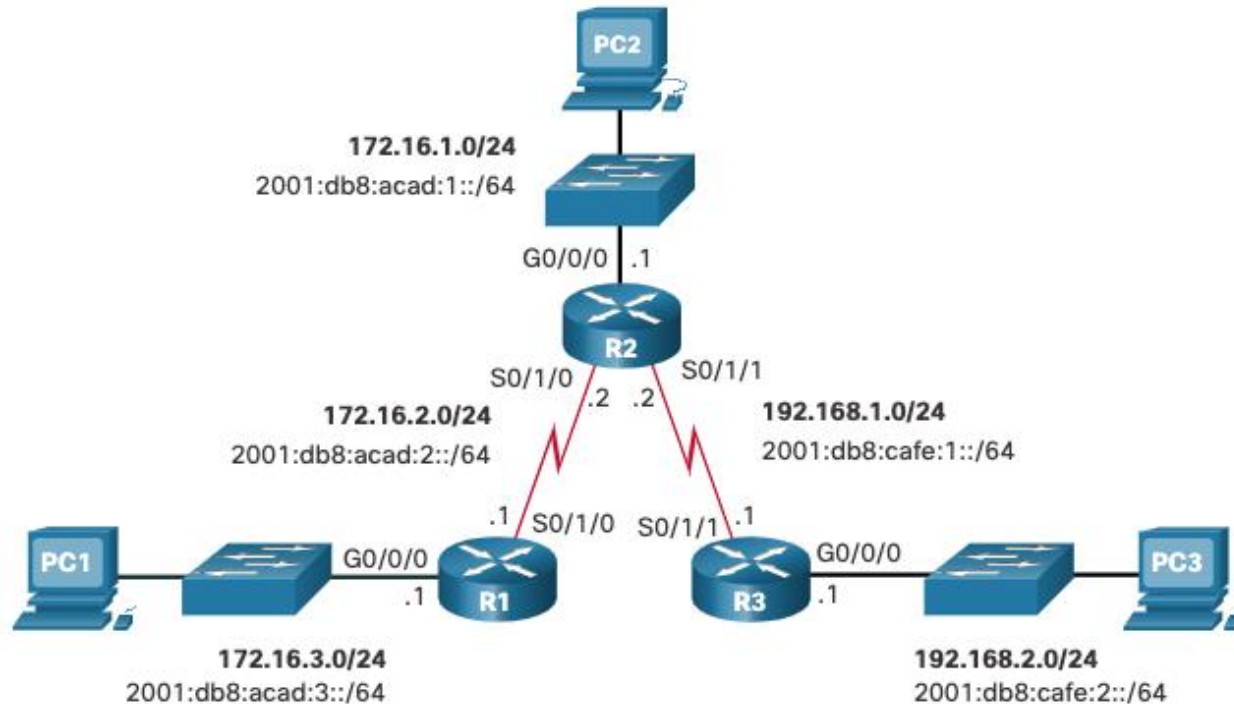
IPv4 Starting Routing Tables

- Each router has entries only for directly connected networks and associated local addresses.

- R1 can ping R2, but cannot ping the R3 LAN


```
R1# show ip route | begin Gateway
Gateway of last resort is not set
    172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks
C      172.16.2.0/24 is directly connected, Serial0/1/0
L      172.16.2.1/32 is directly connected, Serial0/1/0
C      172.16.3.0/24 is directly connected, GigabitEthernet0/0/0
L      172.16.3.1/32 is directly connected, GigabitEthernet0/0/0
R1#
R1# ping 172.16.2.2
Type escape sequence to abort. Sending 5, 100-byte ICMP Echos to 172.16.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5)
R1# ping 192.168.2.1
Type escape sequence to abort. Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
```
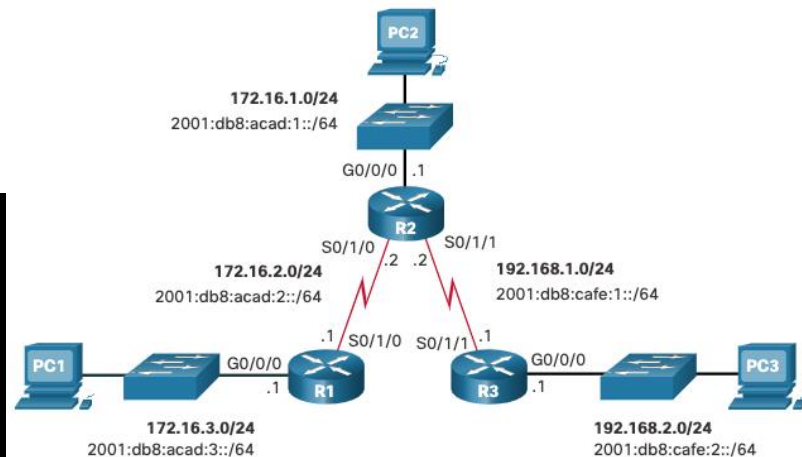
IPv6 Starting Routing Tables

- Each router has entries only for directly connected networks and associated local addresses.
- R1 can ping R2, but cannot ping the R3 LAN.

```
R1# show ipv6 route | begin C
C 2001:DB8:ACAD:2::/64 [0/0]
     via Serial0/1/0, directly connected
L 2001:DB8:ACAD:2::1/128 [0/0]
     via Serial0/1/0, receive
C 2001:DB8:ACAD:3::/64 [0/0]
     via GigabitEthernet0/0/0, directly connected
L 2001:DB8:ACAD:3::1/128 [0/0]
     via GigabitEthernet0/0/0, receive
L FF00::/8 [0/0]
     via Null0, receive
R1#
R1# ping 2001:db8:acad:2::2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:2::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 2/2/3 ms)
R1# ping 2001:DB8:cafe:2::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:CAFE:2::1, timeout is 2 seconds:
% No valid route for destination
Success rate is 0 percent (0/1)
```
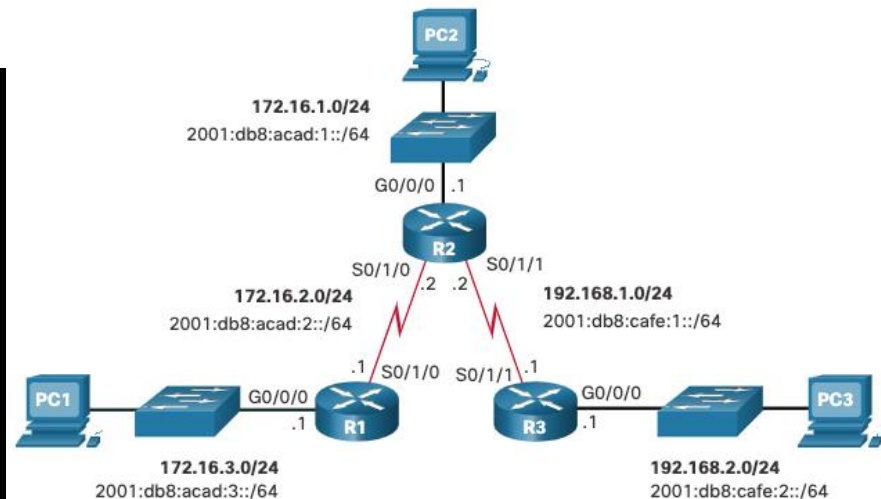
15.2 Configure IP Static Routes

IPv4 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, three next-hop IPv4 static routes are configured on R1 using the IP address of the next hop, R2.

```
R1(config)# ip route 172.16.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.2.0 255.255.255.0 172.16.2.2
```

The resulting routing table entries on R1:

```
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, Serial0/1/0
L        172.16.2.1/32 is directly connected, Serial0/1/0
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0/0
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
```
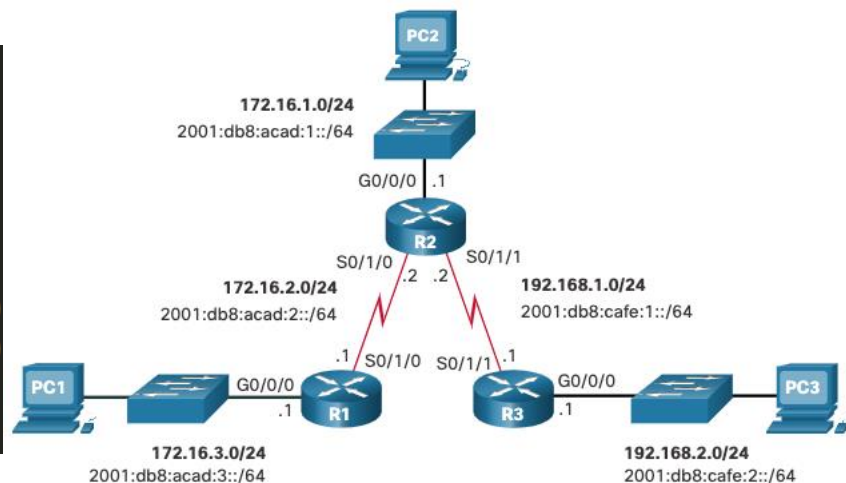
IPv6 Next-Hop Static Route

The commands to configure R1 with the IPv6 static routes to the three remote networks are as follows:

```
R1(config)# ipv6 unicast-routing

R1(config)# ipv6 route 2001:db8:acad:1::/64
2001:db8:acad:2::2

R1(config)# ipv6 route 2001:db8:cafe:1::/64
2001:db8:acad:2::2

R1(config)# ipv6 route 2001:db8:cafe:2::/64
2001:db8:acad:2::2
```

The routing table for R1 now has routes to the three remote IPv6 networks.

```
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, RL - RPL, O - OSPF Intra, OI - OSPF Inter
       OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1
       ON2 - OSPF NSSA ext 2, la - LISP alt, lr - LISP site-registrations
       ld - LISP dyn-eid, lA - LISP away, le - LISP extranet-policy
       a - Application
S   2001:DB8:ACAD:1::/64 [1/0]
     via 2001:DB8:ACAD:2::2
C   2001:DB8:ACAD:2::/64 [0/0]
     via Serial0/1/0, directly connected
L   2001:DB8:ACAD:2::1/128 [0/0]
     via Serial0/1/0, receive
C   2001:DB8:ACAD:3::/64 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   2001:DB8:ACAD:3::1/128 [0/0]
     via GigabitEthernet0/0/0, receive
S   2001:DB8:CAFE:1::/64 [1/0]
     via 2001:DB8:ACAD:2::2
S   2001:DB8:CAFE:2::/64 [1/0]
     via 2001:DB8:ACAD:2::2
L   FF00::/8 [0/0]
     via Null0, receive
```

IPv4 Directly Connected Static Route

When configuring a static route, another option is to use the exit interface to specify the next-hop address. Three directly connected IPv4 static routes are configured on R1 using the exit interface.

Note: Using a next-hop address is generally recommended. Directly connected static routes should only be used with point-to-point serial interfaces.

```
R1(config)# ip route 172.16.1.0 255.255.255.0 s0/1/0

R1(config)# ip route 192.168.1.0 255.255.255.0 s0/1/0

R1(config)# ip route 192.168.2.0 255.255.255.0 s0/1/0
```

```
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 is directly connected, Serial0/1/0
C        172.16.2.0/24 is directly connected, Serial0/1/0
L        172.16.2.1/32 is directly connected, Serial0/1/0
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0/0
S     192.168.1.0/24 is directly connected, Serial0/1/0
S     192.168.2.0/24 is directly connected, Serial0/1/0
```
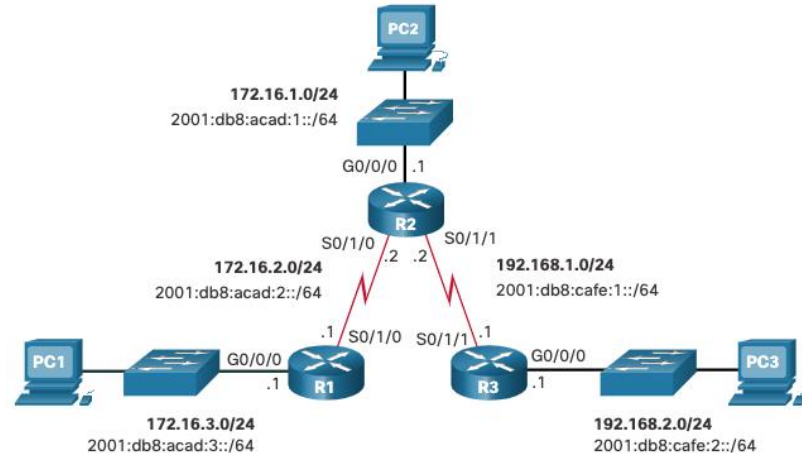
IPv6 Directly Connected Static Route

In the example, three directly connected IPv6 static routes are configured on R1 using the exit interface.

Note: Using a next-hop address is generally recommended. Directly connected static routes should only be used with point-to-point serial interfaces.

```
R1(config)# ipv6 route 2001:db8:acad:1::/64
s0/1/0
```

```
R1(config)# ipv6 route 2001:db8:cafe:1::/64
s0/1/0
```

```
R1(config)# ipv6 route 2001:db8:cafe:2::/64
s0/1/0
```

```
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, RL - RPL, O - OSPF Intra, OI - OSPF Inter
       OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1
       ON2 - OSPF NSSA ext 2, la - LISP alt, lr - LISP site-registrations
       ld - LISP dyn-eid, lA - LISP away, le - LISP extranet-policy
       a - Application
S   2001:DB8:ACAD:1::/64 [1/0]
     via Serial0/1/0, directly connected
C   2001:DB8:ACAD:2::/64 [0/0]
     via Serial0/1/0, directly connected
L   2001:DB8:ACAD:2::1/128 [0/0]
     via Serial0/1/0, receive
C   2001:DB8:ACAD:3::/64 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   2001:DB8:ACAD:3::1/128 [0/0]
     via GigabitEthernet0/0/0, receive
S   2001:DB8:CAFE:1::/64 [1/0]
     via Serial0/1/0, directly connected
S   2001:DB8:CAFE:2::/64 [1/0]
     via Serial0/1/0, directly connected
L   FF00::/8 [0/0]
     via Null0, receiveIPv6 Routing Table - default - 8 entries
R1#
```

IPv4 Fully Specified Static Route

- In a fully specified static route, both the exit interface and the next-hop IP address are specified. 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. Using an exit interface is optional, however it is necessary to use a next-hop address.

- It is recommended that when the exit interface is an Ethernet network, that the static route includes a next-hop address. You can also use a fully specified static route that includes both the exit interface and the next-hop address.
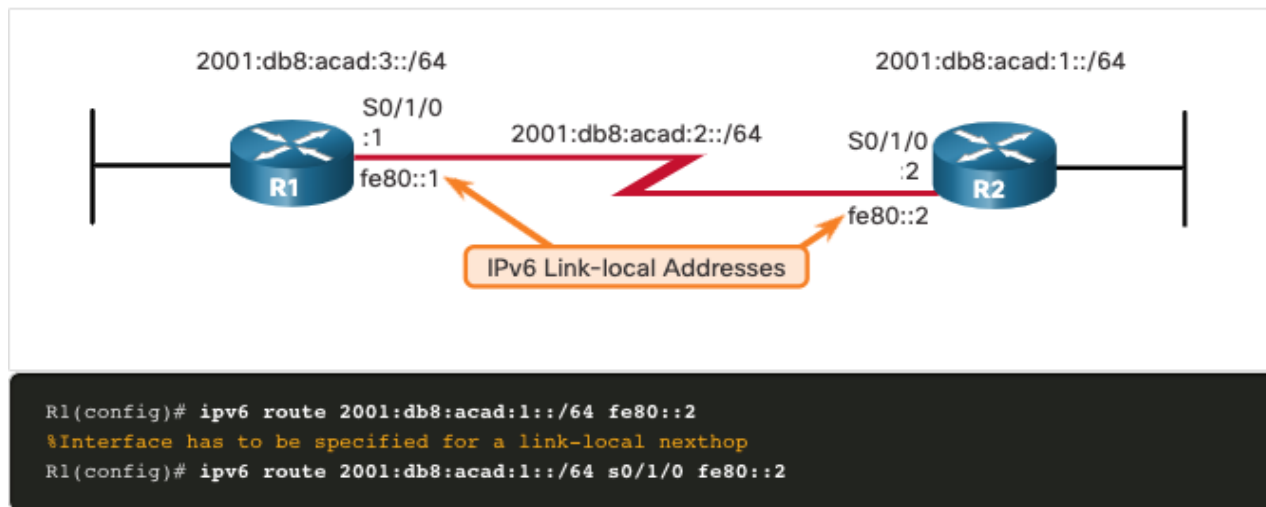
```
R1(config)# ip route 172.16.1.0 255.255.255.0 GigabitEthernet 0/0/1 172.16.2.2
R1(config)# ip route 192.168.1.0 255.255.255.0 GigabitEthernet 0/0/1 172.16.2.2
R1(config)# ip route 192.168.2.0 255.255.255.0 GigabitEthernet 0/0/1 172.16.2.2
```

```
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, GigabitEthernet0/0/1
C        172.16.2.0/24 is directly connected, GigabitEthernet0/0/1
L        172.16.2.1/32 is directly connected, GigabitEthernet0/0/1
C        172.16.3.0/24 is directly connected, GigabitEthernet0/0/0
L        172.16.3.1/32 is directly connected, GigabitEthernet0/0/0
S     192.168.1.0/24 [1/0] via 172.16.2.2, GigabitEthernet0/0/1
S     192.168.2.0/24 [1/0] via 172.16.2.2, GigabitEthernet0/0/1
```

IPv6 Fully Specified Static Route

In a fully specified static route, both the exit interface and the next-hop IPV6 address are specified.

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, use a fully specified static route. The figure shows an example of a fully specified IPv6 static route using an IPv6 link-local address as the next-hop address.


```
R1(config)# ipv6 route 2001:db8:acad:1::/64 fe80::2
%Interface has to be specified for a link-local nexthop
R1(config)# ipv6 route 2001:db8:acad:1::/64 s0/1/0 fe80::2
```

IPv6 Fully Specified Static Route (Cont.)

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.

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

```
R1# show ipv6 route static | begin 2001:db8:acad:1::/64
S    2001:DB8:ACAD:1::/64 [1/0]
     via FE80::2, Seria0/1/0
```

Verify a Static Route

Along with **show ip route**, **show ipv6 route**, **ping** and **traceroute**, other useful commands to verify static routes include the following:

- **show ip route static**
- **show ip route** *network*
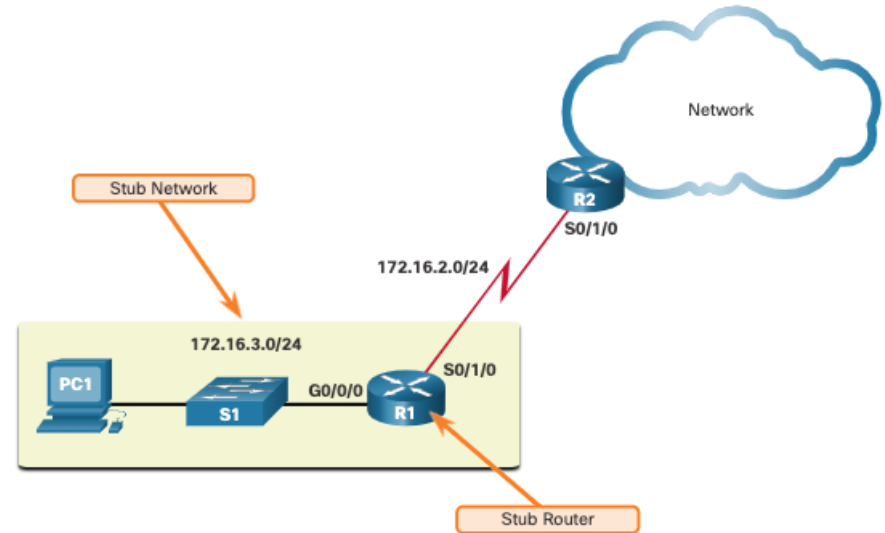- **show running-config | section ip route**

Replace **ip** with **ipv6** for the IPv6 versions of the command.

15.3 Configure IP Default Static Routes

Default Static Route

- A default route is a static route that matches all packets. A single default route represents any network that is not in the routing table.

- Routers commonly use default routes that are either configured locally or learned from another router. 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, or a stub router (a router with only one upstream neighbor router).

- The figure shows a typical default static route scenario.

Default Static Route (Cont.)

IPv4 Default Static Route: The command syntax for an IPv4 default static route is similar to any other IPv4 static route, except that the network address is **0.0.0.0** and the subnet mask is **0.0.0.0**. The 0.0.0.0 0.0.0.0 in the route will match any network address.

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

The basic command syntax for an IPv4 default static route is as follows:

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

IPv6 Default Static Route: The command syntax for an IPv6 default static route is similar to any other IPv6 static route, except that the ipv6-prefix/prefix-length is **::/0**, which matches all routes.

The basic command syntax for an IPv6 default static route is as follows:

```
Router(config)# ipv6 route ::/0 {ipv6-address | exit-intf}
```
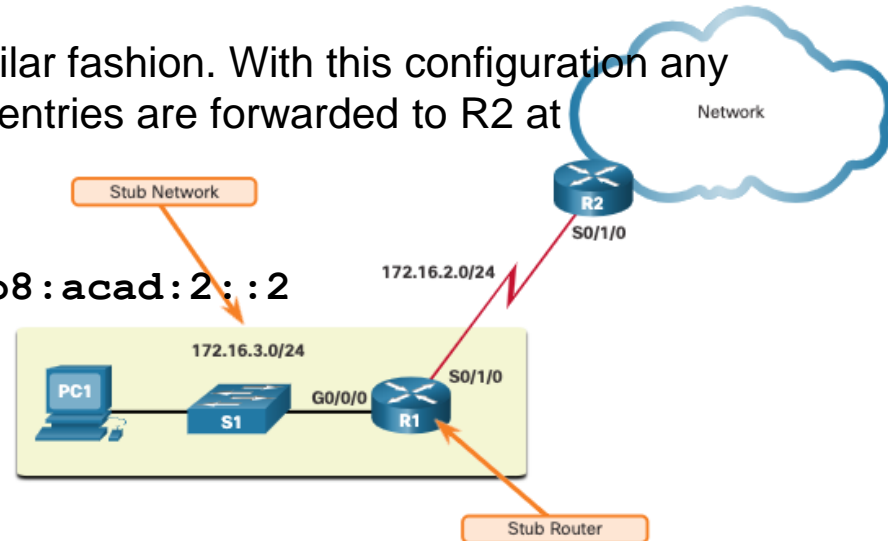
Configure a Default Static Route

The example shows an IPv4 default static route configured on R1. With the configuration shown in the example, any packets not matching more specific route entries are forwarded to R2 at 172.16.2.2.

```
R1(config)# ip route 0.0.0.0 0.0.0.0 172.16.2.2
```

An IPv6 default static route is configured in similar fashion. With this configuration any packets not matching more specific IPv6 route entries are forwarded to R2 at 2001:db8:acad:2::2

```
R1(config)# ipv6 route ::/0 2001:db8:acad:2::2
```

Verify a Default Static Route

The **show ip route static** command output from R1 displays the contents of the static routes in the routing table. Note the asterisk (*) next to the route with code 'S'. The asterisk indicates that this static route is a candidate default route, which is why it is selected as the Gateway of Last Resort.

Notice that the static default route configuration uses the /0 mask for IPv4 default routes. Remember that the IPv4 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 /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 route matches all packets.

```
R1# show ip route static
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 172.16.2.2 to network 0.0.0.0

S* 0.0.0.0/0 [1/0] via 172.16.2.2
```

Verify a Default Static Route (Cont.)

This example shows the **show ipv6 route static** command output to display the contents of the routing table.

Notice that the static default route configuration uses the ::/0 prefix for IPv6 default routes. 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. A ::/0 prefix indicates that none of the bits are required to match. As long as a more specific match does not exist, the default static route matches all packets.

```
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, 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, RL - RPL, O - OSPF Intra, OI - OSPF Inter
       OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1
       ON2 - OSPF NSSA ext 2, la - LISP alt, lr - LISP site-registrations
       ld - LISP dyn-eid, lA - LISP away, le - LISP extranet-policy
       a - Application
S    ::/0 [1/0]
     via 2001:DB8:ACAD:2::2
```

15.4 Configure Floating Static Routes

Floating Static Routes

- 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. 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.

- By default, static routes have an administrative distance of 1, making them preferable to routes learned from dynamic routing protocols.

- 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.

Configure IPv4 and IPv6 Floating Static Routes

The commands to configure default and floating IP default routes are as follows:

```
R1(config)# ip route 0.0.0.0 0.0.0.0 172.16.2.2
R1(config)# ip route 0.0.0.0 0.0.0.0 10.10.10.2 5
R1(config)# ipv6 route ::/0 2001:db8:acad:2::2
R1(config)# ipv6 route ::/0 2001:db8:feed:10::2 5
```

The **show ip route** and **show ipv6 route** output verifies that the default routes to R2 are installed in the routing table. Note that the IPv4 floating static route to R3 is not present in the routing table.
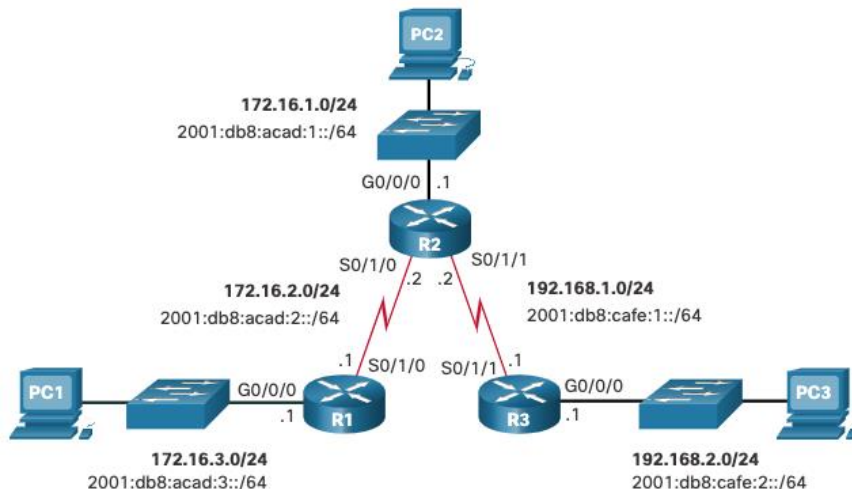
```
R1# show ip route static | begin Gateway
Gateway of last resort is 172.16.2.2 to network 0.0.0.0


S*    0.0.0.0/0 [1/0] via 172.16.2.2
R1# show ipv6 route static | begin S :
S    ::/0 [1/0]
      via 2001:DB8:ACAD:2::2
R1#
```

Test the Floating Static Routes

- What would happen if R2 failed? To simulate this, R2 shuts down both of its serial interfaces.
- R1 automatically generates syslog messages for the link going down.
- A look at R1's routing table would show the secondary route being used.


```
R1# show ip route static | begin Gateway
Gateway of last resort is 10.10.10.2 to network 0.0.0.0
S*     0.0.0.0/0 [5/0] via 10.10.10.2
R1# show ipv6 route static | begin ::
S    ::/0 [5/0]
       via 2001:DB8:FEED:10::2
R1#
```

What Did I Learn In This Module?

- Static routes can be configured for IPv4 and IPv6. Both protocols support the following types of static routes: standard static route, default static route, floating static route, and summary static route.
- When configuring a static route, 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 types of static route: next-hop, directly connected, and fully specified.
- IPv4 static routes are configured using the following global configuration command: ip route network-address subnet-mask { ip-address | exit-intf [ip=address] } [distance].
- IPv6 static routes are configured using the following global configuration command: ipv6 route ipv6-prefix/prefix-length { ipv6-address | exit-intf [ipv6-address]} [distance].
- In a next-hop static route, only the next-hop IP address is specified. The exit interface is derived from the next hop.
- When configuring a static route, another option is to use the exit interface to specify the next-hop address. Directly connected static routes should only be used with point-to-point serial interfaces.
- In a fully specified static route, both the exit interface and the next-hop IP address are specified. 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.
- In a fully specified IPv6 static route, both the exit interface and the next-hop IPv6 address are specified.

What Did I Learn In This Module? (Cont.)

- A default route is a static route that matches all packets.
- Default static routes are commonly used when connecting an edge router to a service provider network, and a stub router.
- The command syntax for an IPv4 default static route is similar to any other IPv4 static route, except that the network address is 0.0.0.0 and the subnet mask is 0.0.0.0.
- The command syntax for an IPv6 default static route is similar to any other IPv6 static route, except that the ipv6-prefix/prefix-length is ::/0, which matches all routes.
- 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 configured with a higher administrative distance than the primary route. By default, static routes have an administrative distance of 1, making them preferable to routes learned from dynamic routing protocols.
- IP floating static routes are configured by using the distance argument to specify an administrative distance.
- A host route is an IPv4 address with a 32-bit mask or an IPv6 address with a 128-bit mask.

What Did I Learn In This Module? (Cont.)

- 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, configured as a static host route, or automatically obtained through other methods not covered in this module.
- 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 can be a manually configured static route to direct traffic to a specific destination device.
- 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. To do this, the original IPv6 static host route is removed, then a fully specified route is configured with the IPv6 address of the server and the IPv6 link-local address of the ISP router.