TRƯỜNG ĐẠI HỌC CÔNG NGHỆ THÔNG TIN – ĐHQG-HCM
Khoa Mạng máy tính & Truyền thông

Định tuyến tĩnh

NT132 – Quản trị mạng và hệ thống

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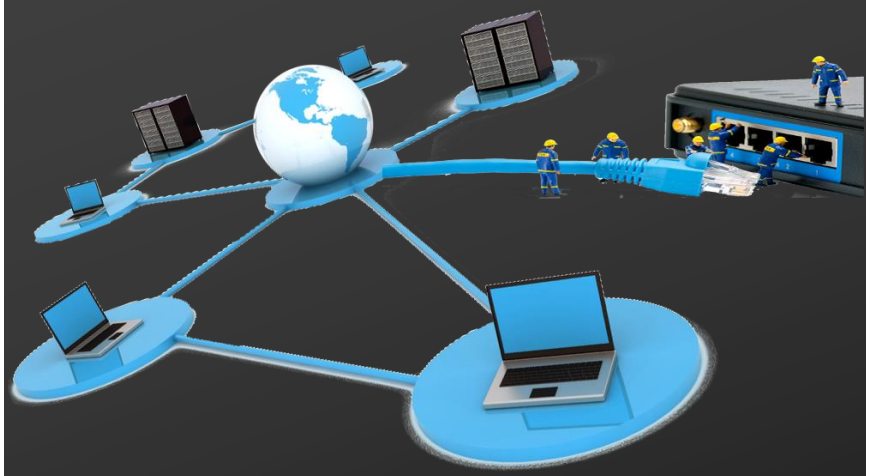


Nội dung

Định tuyến tĩnh

Hôm nay học gì?

1. Các khái niệm về định tuyến
2. Định tuyến tĩnh

Path Determination

Two Functions of a Router

When a router receives an IP packet on one interface, it determines which interface to use to forward the packet to the destination. This is known as routing. The interface that the router uses to forward the packet may be the final destination, or it may be a network connected to another router that is used to reach the destination network. Each network that a router connects to typically requires a separate interface, but this may not always be the case.

The primary functions of a router are to **determine the best path** to forward packets based on the information in its routing table, and to **forward packets** toward their destination.

Best Path Equals Longest Match

- The best path in the routing table is also known as the longest match.
- The routing table contains route entries consisting of a prefix (network address) and prefix length. For there to be a match between the destination IP address of a packet and a route in the routing table, a minimum number of far-left bits must match between the IP address of the packet and the route in the routing table. The prefix length of the route in the routing table is used to determine the minimum number of far-left bits that must match.
- The longest match is the route in the routing table that has the greatest number of far-left matching bits with the destination IP address of the packet. The longest match is always the preferred route.

Note: The term prefix length will be used to refer to the network portion of both IPv4 and IPv6 addresses.

IPv4 Longest Match Example

In the table, an IPv4 packet has the destination IPv4 address 172.16.0.10. The router has three route entries in its IPv4 routing table that match this packet: 172.16.0.0/12, 172.16.0.0/18, and 172.16.0.0/26. Of the three routes, 172.16.0.0/26 has the longest match and would be chosen to forward the packet. For any of these routes to be considered a match there must be at least the number of matching bits indicated by the subnet mask of the route.

Destination IPv4 Address		**Address in Binary**
172.16.0.10		**10101100.00010000.00000000.00**001010
Route Entry	Prefix/Prefix Length	Address in Binary
1	172.16.0.0**/12**	**10101100.0001**0000.00000000.00001010
2	172.16.0.0**/18**	**10101100.00010000.00**000000.00001010
3	172.16.0.0**/26**	**10101100.00010000.00000000.00**001010

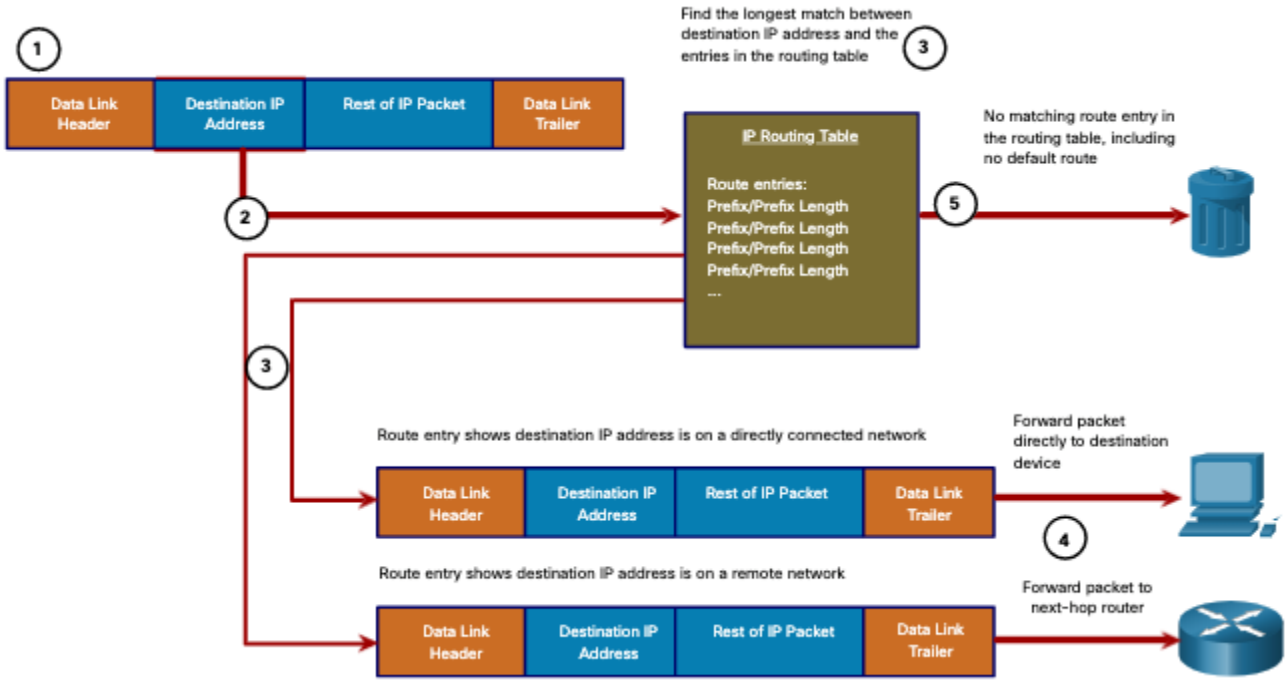
Build the Routing Table

- **Directly Connected Networks:** Added to the routing table when a local interface is configured with an IP address and subnet mask (prefix length) and is active (up and up).
- **Remote Networks:** Networks that are not directly connected to the router. Routers learn about remote networks in two ways:
  - **Static routes** - Added to the routing table when a route is manually configured.
  - **Dynamic routing protocols** - Added to the routing table when routing protocols dynamically learn about the remote network.
- **Default Route:** Specifies a next-hop router to use when the routing table does not contain a specific route that matches the destination IP address. The default route can be entered manually as a static route, or learned automatically from a dynamic routing protocol.
  - A default route has a /0 prefix length. This means that no bits need to match the destination IP address for this route entry to be used. If there are no routes with a match longer than 0 bits, the default route is used to forward the packet. The default route is sometimes referred to as a gateway of last resort.

Packet Forwarding

Packet Forwarding Decision Process

1. The data link frame with an encapsulated IP packet arrives on the ingress interface.
2. The router examines the destination IP address in the packet header and consults its IP routing table.
3. The router finds the longest matching prefix in the routing table.
4. The router encapsulates the packet in a data link frame and forwards it out the egress interface. The destination could be a device connected to the network or a next-hop router.
5. However, if there is no matching route entry the packet is dropped.



Packet Forwarding Decision Process (Cont.)

- After a router has determined the best path, it could do the following:
- **Forward the Packet to a Device on a Directly Connected Network**
  - If the route entry indicates that the egress interface is a directly connected network, the packet can be forwarded directly to the destination device. Typically this is an Ethernet LAN.
  - To encapsulate the packet in the Ethernet frame, the router needs to determine the destination MAC address associated with the destination IP address of the packet. The process varies based on whether the packet is an IPv4 or IPv6 packet.

Packet Forwarding Decision Process (Cont.)

- After a router has determined the best path, it could do the following:
- **Forward the Packet to a Next-Hop Router**
  - If the route entry indicates that the destination IP address is on a remote network, meaning a device on network that is not directly connected. The packet must be forwarded to the next-hop router. The next-hop address is indicated in the route entry.
  - If the forwarding router and the next-hop router are on an Ethernet network, a similar process (ARP and ICMPv6 Neighbor Discovery) will occur for determining the destination MAC address of the packet as described previously. The difference is that the router will search for the IP address of the next-hop router in its ARP table or neighbor cache, instead of the destination IP address of the packet.

Note: This process will vary for other types of Layer 2 networks.

Packet Forwarding Decision Process (Cont.)

- After a router has determined the best path, it could do the following:
- **Drop the Packet - No Match in Routing Table**
  - If there is no match between the destination IP address and a prefix in the routing table, and if there is no default route, the packet will be dropped.

End-to-End Packet Forwarding

The primary responsibility of the packet forwarding function is to encapsulate packets in the appropriate data link frame type for the outgoing interface. For example, the data link frame format for a serial link could be Point-to-Point (PPP) protocol, High-Level Data Link Control (HDLC) protocol, or some other Layer 2 protocol.

IP Routing Table

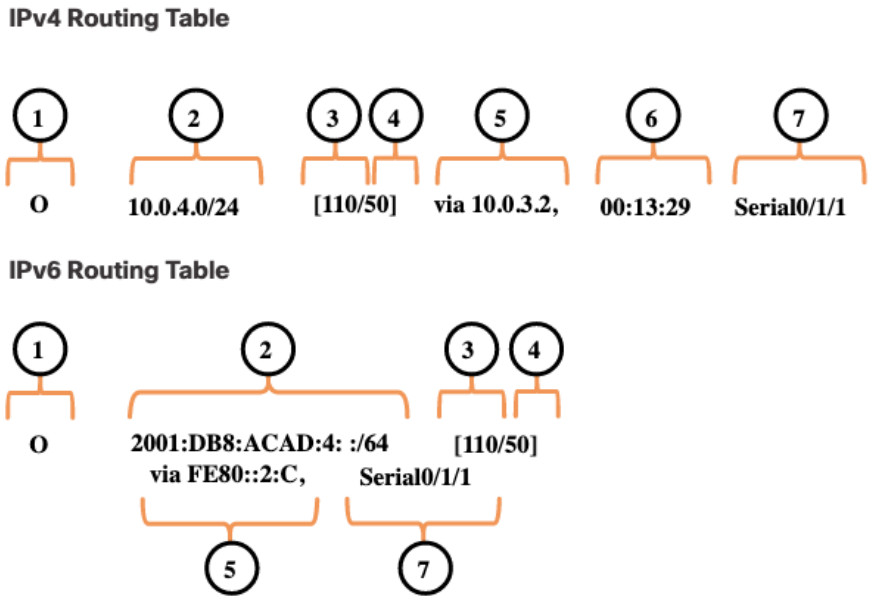
Route Sources

- A routing table contains a list of routes to known networks (prefixes and prefix lengths). The source of this information is derived from the following:
  - Directly connected networks
  - Static routes
  - Dynamic routing protocols
- The source for each route in the routing table is identified by a code. Common codes include the following:
  - **L** - Identifies the address assigned to a router interface.
  - **C** - Identifies a directly connected network.
  - **S** - Identifies a static route created to reach a specific network.
  - **O** - Identifies a dynamically learned network from another router using the OSPF routing protocol.
  - ***** - This route is a candidate for a default route.

Routing Table Entries

In the figure, the numbers identify the following information:

- **Route source** - This identifies how the route was learned.
- **Destination network (prefix and prefix length)** - This identifies the address of the remote network.
- **Administrative distance** - This identifies the trustworthiness of the route source. Lower values indicate preferred route source.
- **Metric** - This identifies the value assigned to reach the remote network. Lower values indicate preferred routes.
- **Next-hop** - This identifies the IP address of the next router to which the packet would be forwarded.
- **Route timestamp** - This identifies how much time has passed since the route was learned.
- **Exit interface** - This identifies the egress interface to use for outgoing packets to reach their final destination.



Note: The prefix length of the destination network specifies the minimum number of far-left bits that must match between the IP address of the packet and the destination network (prefix) for this route to be used.

Directly Connected Networks

To learn about any remote networks, the router must have at least one active interface configured with an IP address and subnet mask (prefix length). This is known as a directly connected network or a directly connected route. Routers add a directly connected route to its routing table when an interface is configured with an IP address and is activated.

- A directly connected network is denoted by a status code of **C** in the routing table. The route contains a network prefix and prefix length.
- The routing table also contains a local route for each of its directly connected networks, indicated by the status code of **L**.
- For IPv4 local routes the prefix length is /32 and for IPv6 local routes the prefix length is /128. This means the destination IP address of the packet must match all the bits in the local route for this route to be a match. The purpose of the local route is to efficiently determine when it receives a packet for the interface instead of a packet that needs to be forwarded.

Static Routes

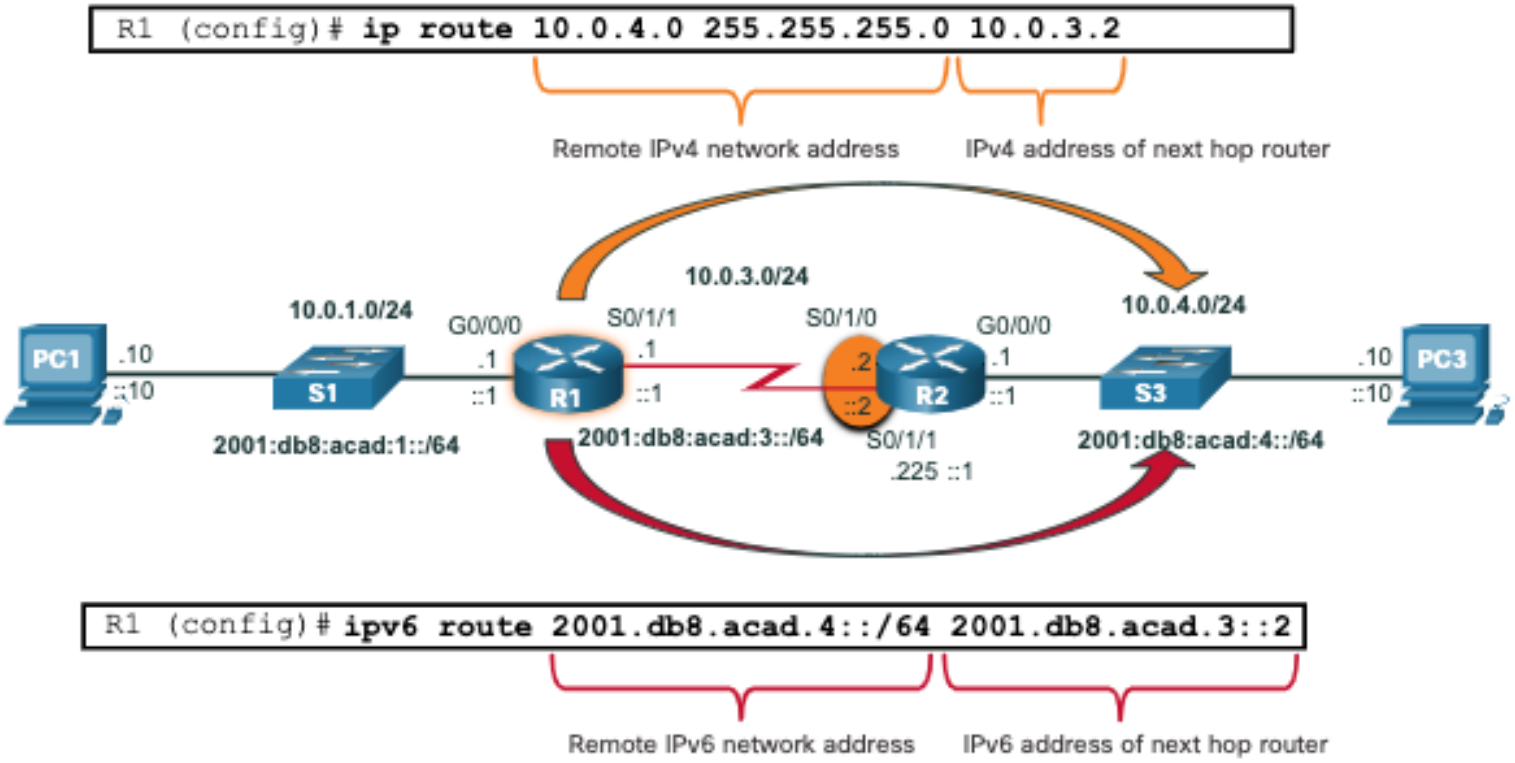
After directly connected interfaces are configured and added to the routing table, static or dynamic routing can be implemented for accessing remote networks. Static routes are manually configured. They define an explicit path between two networking devices. They are not automatically updated and must be manually reconfigured if the network topology changes.

Static routing has three primary uses:

- It provides ease of routing table maintenance in smaller networks that are not expected to grow significantly.
- It uses 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.
- It routes to and from stub networks. A stub network is a network accessed by a single route, and the router has only one neighbor.

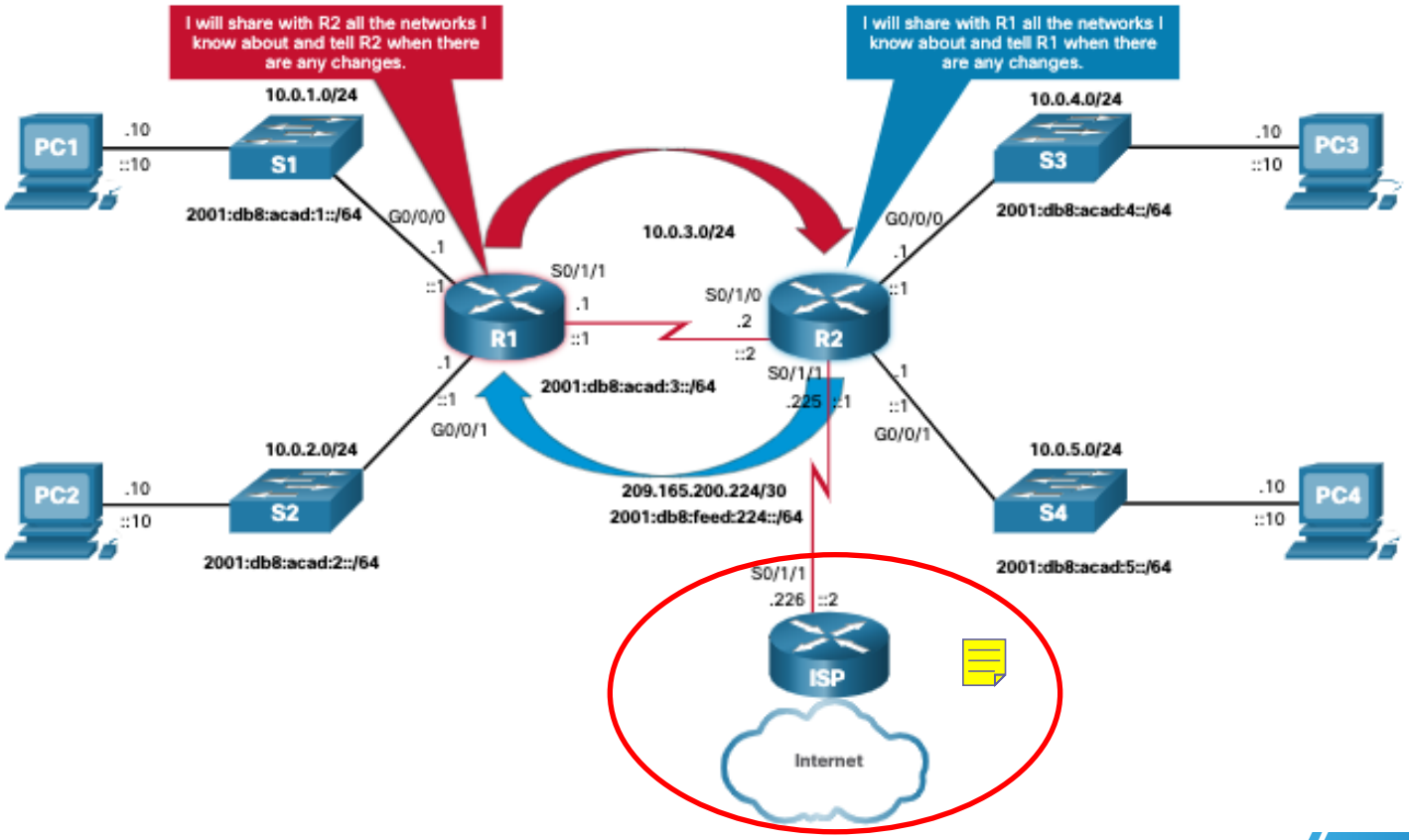
Static Routes in the IP Routing Table

The topology in the figure is simplified to show only one LAN attached to each router. The figure shows IPv4 and IPv6 static routes configured on R1 to reach the 10.0.4.0/24 and 2001:db8:acad:4::/64 networks on R2.



Dynamic Routing Protocols

Dynamic routing protocols are used by routers to automatically share information about the reachability and status of remote networks. Dynamic routing protocols perform several activities, including network discovery and maintaining routing tables.



Dynamic Routes in the Routing Table

OSPF is now being used in our sample topology to dynamically learn all the networks connected to R1 and R2. The routing table entries use the status code of **O** to indicate the route was learned by the OSPF routing protocol. Both entries also include the IP address of the next-hop router, via *ip-address*.

Note: IPv6 routing protocols use the link-local address of the next-hop router.

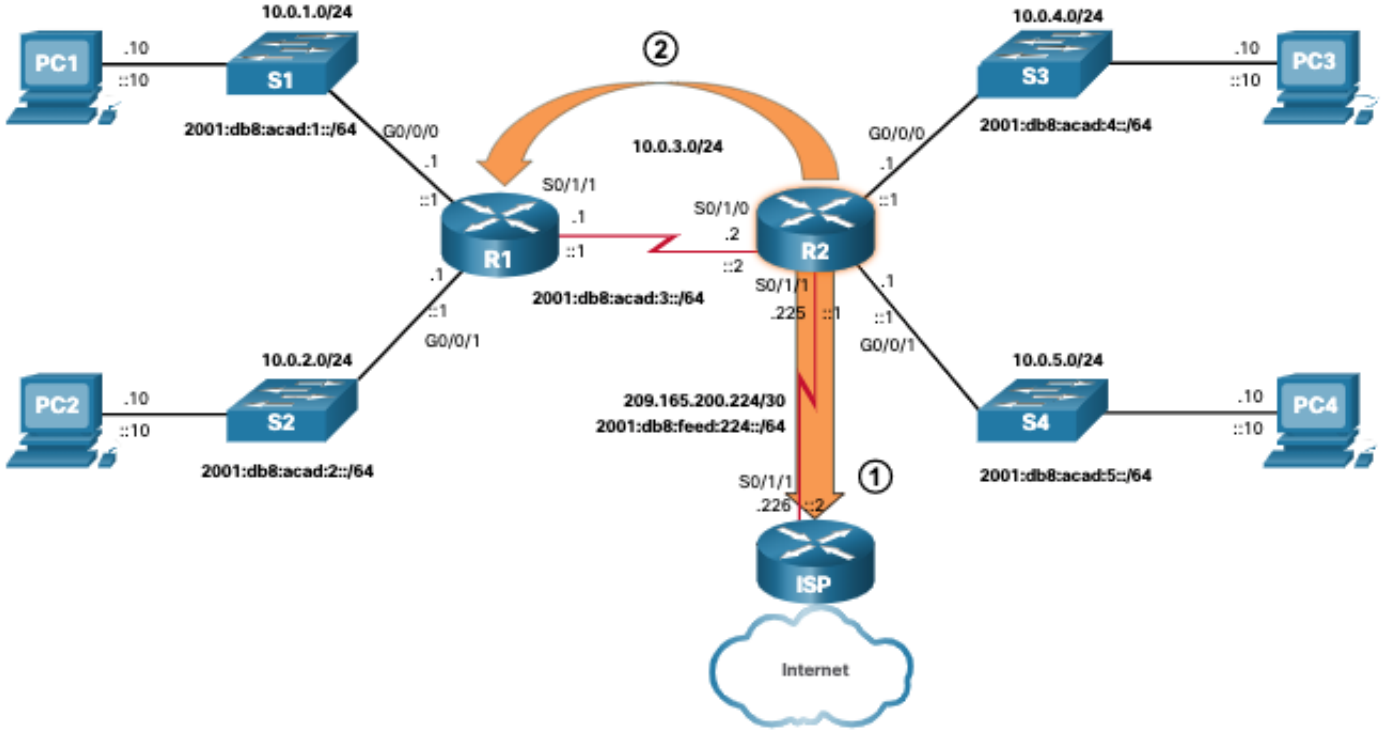
Note: OSPF routing configuration for IPv4 and IPv6 is beyond the scope of this course.

```
R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP D - EIGRP, EX -
EIGRP external, O - OSPF, IA - OSPF inter area
(output omitted for brevity)
O 10.0.4.0/24 [110/50] via 10.0.3.2, 00:24:22, Serial0/1/1
O 10.0.5.0/24 [110/50] via 10.0.3.2, 00:24:15, Serial0/1/1
R1# show ipv6 route
IPv6 Routing Table - default - 10 entries
(Output omitted)
NDr - Redirect, RL - RPL, O - OSPF Intra, OI - OSPF Inter
O 2001:DB8:ACAD:4::/64 [110/50]
   via FE80::2:C, Serial0/1/1
O 2001:DB8:ACAD:5::/64 [110/50]
   via FE80::2:C, Serial0/1/1
```

IP Routing Table

Default Route

The default route specifies a next-hop router to use when the routing table does not contain a specific route that matches the destination IP address. A default route can be either a static route or learned automatically from a dynamic routing protocol. A default route has an IPv4 route entry of **0.0.0.0/0** or an IPv6 route entry of **::/0**. This means that zero or no bits need to match between the destination IP address and the default route.



Structure of an IPv4 Routing Table

- An indented entry is known as a **child route**. A route entry is indented if it is the subnet of a classful address (class A, B or C network).
- Directly connected networks will always be indented (child routes) because the local address of the interface is always entered in the routing table as a /32.
- The child route will include the route source and all the forwarding information such as the next-hop address.
- The classful network address of this subnet will be shown above the route entry, less indented, and without a source code. That route is known as a **parent route.**

```
Router# show ip route
(Output omitted)
   192.168.1.0/24 is variably..
C     192.168.1.0/24 is direct..
L     192.168.1.1/32 is direct..
O     192.168.2.0/24 [110/65]..
O     192.168.3.0/24 [110/65]..
   192.168.12.0/24 is variab..
C     192.168.12.0/30 is direct..
L     192.168.12.1/32 is direct..
   192.168.13.0/24 is variably..
C     192.168.13.0/30 is direct..
L     192.168.13.1/32 is direct..
   192.168.23.0/30 is subnette..
O     192.168.23.0/30 [110/128]..
Router#
```

Administrative Distance

- A route entry for a specific network address (prefix and prefix length) can only appear once in the routing table. However, it is possible that the routing table learns about the same network address from more than one routing source. Except for very specific circumstances, only one dynamic routing protocol should be implemented on a router. Each routing protocol may decide on a different path to reach the destination based on the metric of that routing protocol.
- This raises a few questions, such as the following:
  - How does the router know which source to use?
  - Which route should it install in the routing table?
- Cisco IOS uses what is known as the administrative distance (AD) to determine the route to install into the IP routing table. The AD represents the "trustworthiness" of the route. The lower the AD, the more trustworthy the route source.

Administrative Distance (Cont.)

The table lists various routing protocols and their associated ADs.

Route Source	Administrative Distance
Directly connected	0
Static route	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

Static and Dynamic Routing

Static or Dynamic? (Cont.)

The table shows a comparison of some the differences between dynamic and static routing.

Feature	Dynamic Routing	Static Routing
Configuration complexity	Independent of network size	Increases with network size
Topology changes	Automatically adapts to topology changes	Administrator intervention required
Scalability	Suitable for simple to complex network topologies	Suitable for simple topologies
Security	Security must be configured	Security is inherent
Resource Usage	Uses CPU, memory, and link bandwidth	No additional resources needed
Path Predictability	Route depends on topology and routing protocol used	Explicitly defined by the administrator

Dynamic Routing Evolution (Cont.)

The table classifies the current routing protocols. Interior Gateway Protocols (IGPs) are routing protocols used to exchange routing information within a routing domain administered by a single organization. There is only one EGP and it is BGP. BGP is used to exchange routing information between different organizations, known as autonomous systems (AS). BGP is used by ISPs to route packets over the internet. Distance vector, link-state, and path vector routing protocols refer to the type of routing algorithm used to determine best path.

	Interior Gateway Protocols				**Exterior Gateway Protocols**
	Distance Vector		Link-State		Path Vector
IPv4	RIPv2	EIGRP	OSPFv2	IS-IS	BGP-4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGP-MP

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.

Static Routes

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)
```

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
```

Configure IP Static Routes

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#
```

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:

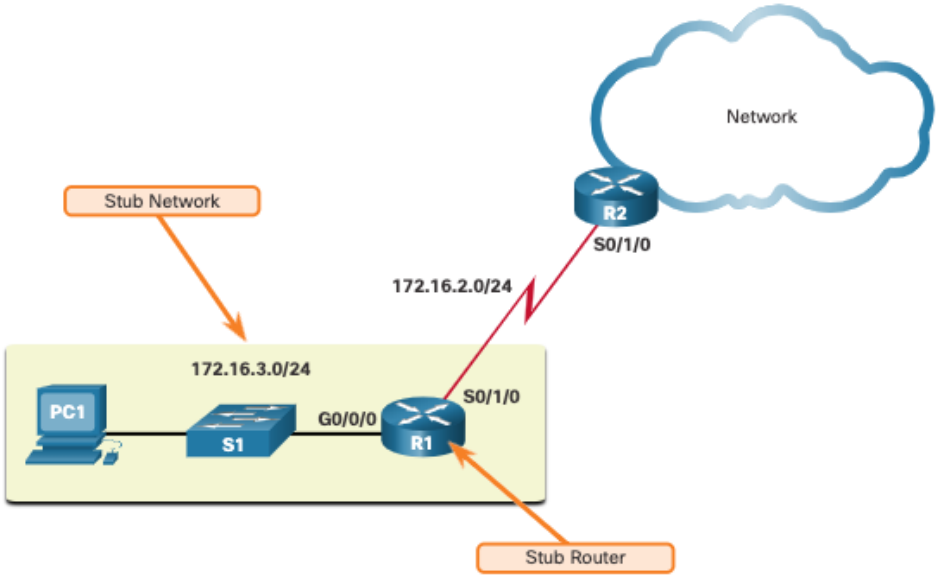
- **show ip route static**
- **show ip route** *network*
- **show running-config | section ip route**

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

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
```

Configure IP Default Static Routes

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
```

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.

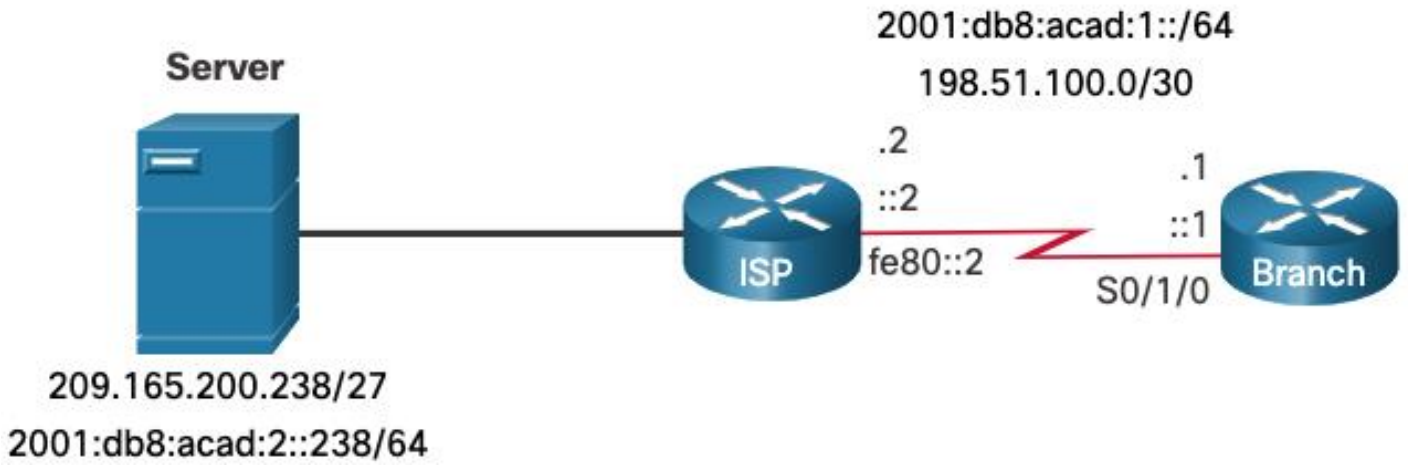
```
R1# show ip route static | begin Gateway
Gateway of last resort is 172.16.2.2 to network 0.0.0.0

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#
```

Configure Static Host Routes

Static Host Routes

A host route can be a manually configured static route to direct traffic to a specific destination device, such as the server shown in the figure. 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.



Configure Static Host Routes

The example shows the IPv4 and IPv6 static host route configuration on the Branch router to access the server.

```
Branch(config)# ip route 209.165.200.238 255.255.255.255 198.51.100.2
Branch(config)# ipv6 route 2001:db8:acad:2::238/128 2001:db8:acad:1::2
Branch(config)# exit
```

Verify Static Host Routes

A review of both the IPv4 and IPv6 route tables verifies that the routes are active.

```
Branch# show ip route | begin Gateway
Gateway of last resort is not set
      198.51.100.0/24 is variably subnetted, 2 subnets, 2 masks
C        198.51.100.0/30 is directly connected, Serial0/1/0
L        198.51.100.1/32 is directly connected, Serial0/1/0
      209.165.200.0/32 is subnetted, 1 subnets
S        209.165.200.238 [1/0] via 198.51.100.2
Branch# show ipv6 route
(Output omitted)
C   2001:DB8:ACAD:1::/64 [0/0]
     via Serial0/1/0, directly connected
L   2001:DB8:ACAD:1::1/128 [0/0]
     via Serial0/1/0, receive
S   2001:DB8:ACAD:2::238/128 [1/0]
     via 2001:DB8:ACAD:1::2
Branch#
```

Today end, **See you next week!**