



Chapter 1: Routing Concepts



Routing and Switching Essentials v6.0

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Chapter 1 - Sections & Objectives

1.1 Router Initial Configuration

- Describe the primary functions and features of a router.
- Configure basic settings on a router to route between two directly-connected networks, using CLI.
- Verify connectivity between two networks that are directly connected to a router.

1.2 Routing Decisions

- Explain the encapsulation and de-encapsulation process used by routers when switching packets between interfaces.
- Explain the path determination function of a router.

1.3 Router Operation

- Explain routing table entries for directly connected networks.
- Explain how a router builds a routing table of directly connected networks.
- Explain how a router builds a routing table using static routes.
- Explain how a router builds a routing table using a dynamic routing protocol.



1.1 Router Initial Configuration



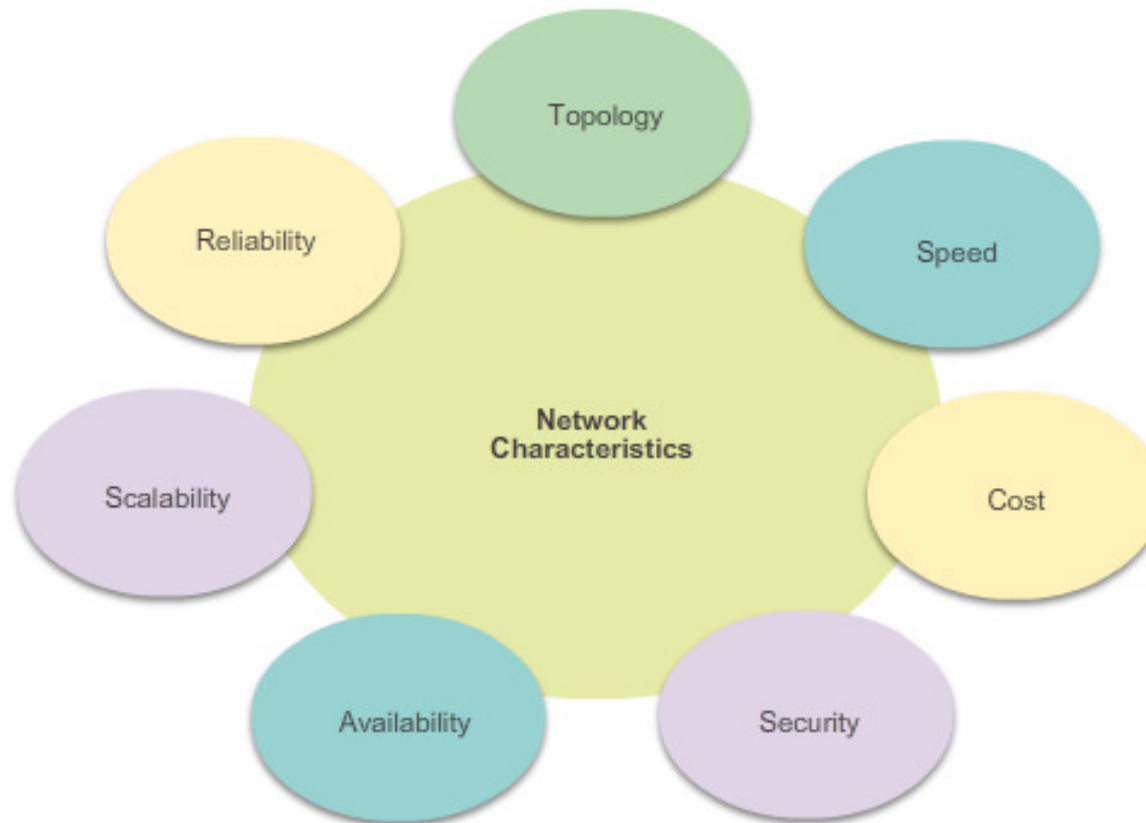
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Router Functions

Characteristics of a Network

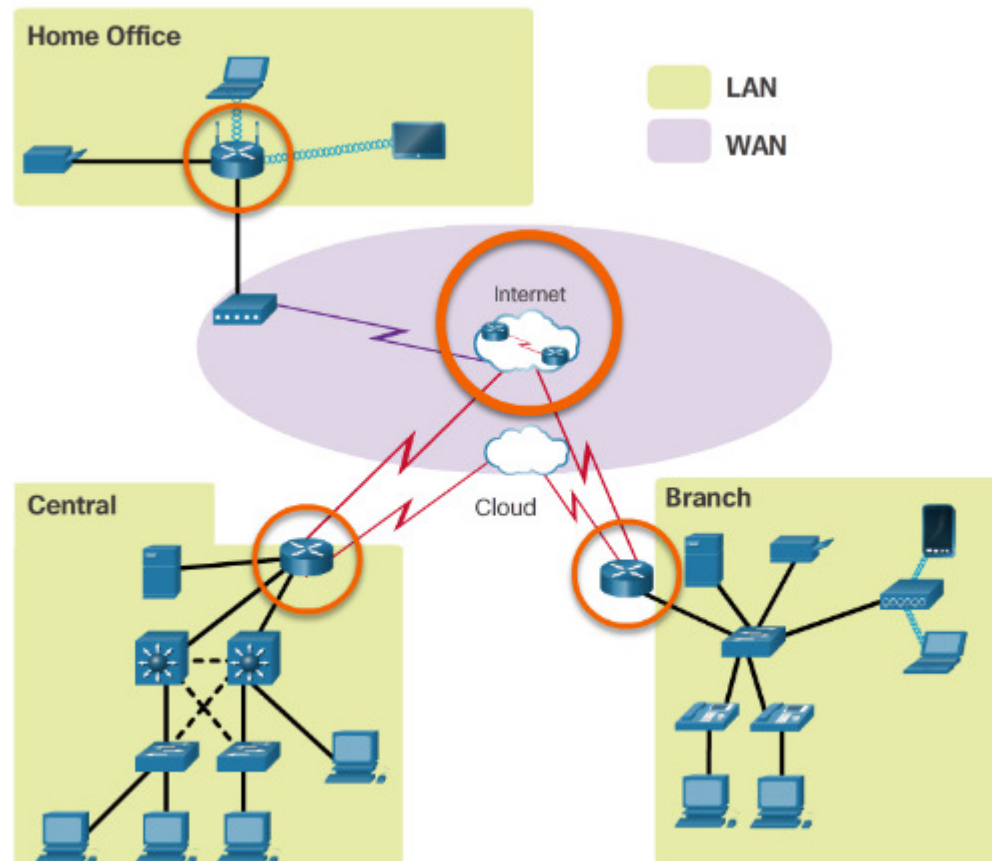
Network Characteristics



Router Functions

Why Routing?

The router is responsible for the routing of traffic between networks.



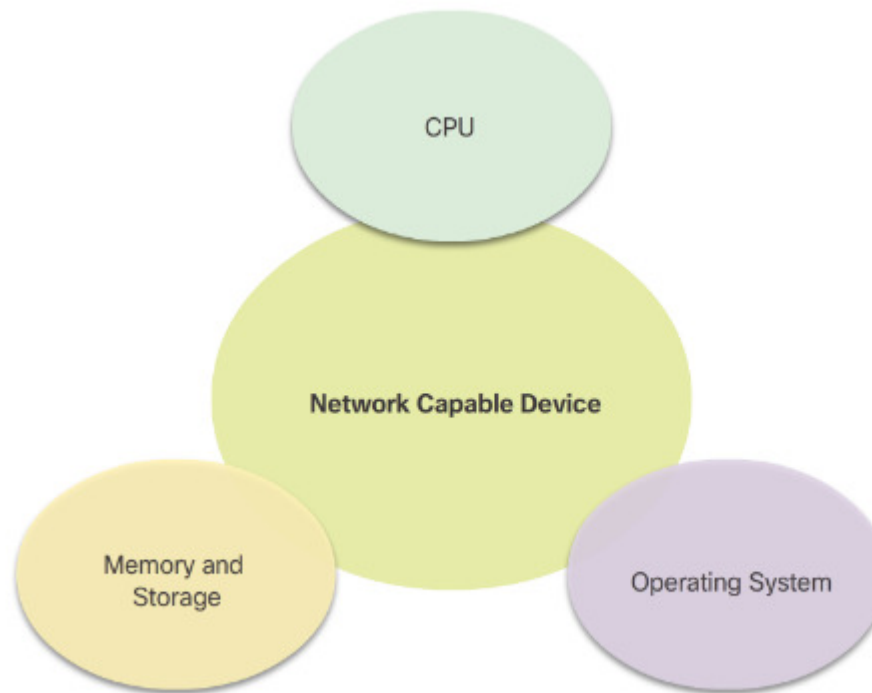


Router Functions

Routers are Computers

Routers are specialized computers containing the following required components to operate:

- Central processing unit (CPU)
- Operating system (OS) - Routers use Cisco IOS
- Memory and storage (RAM, ROM, NVRAM, Flash, hard drive)

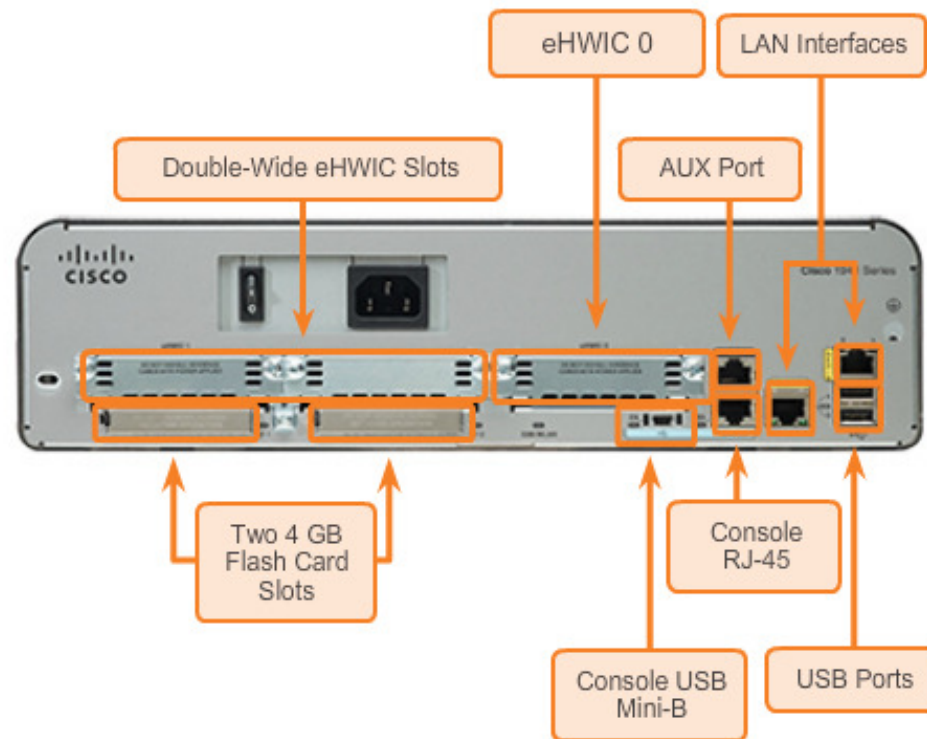


Router Functions

Routers are Computers (cont.)

Routers use specialized ports and network interface cards to interconnect to other networks.

Back Panel of a Router





Router Functions

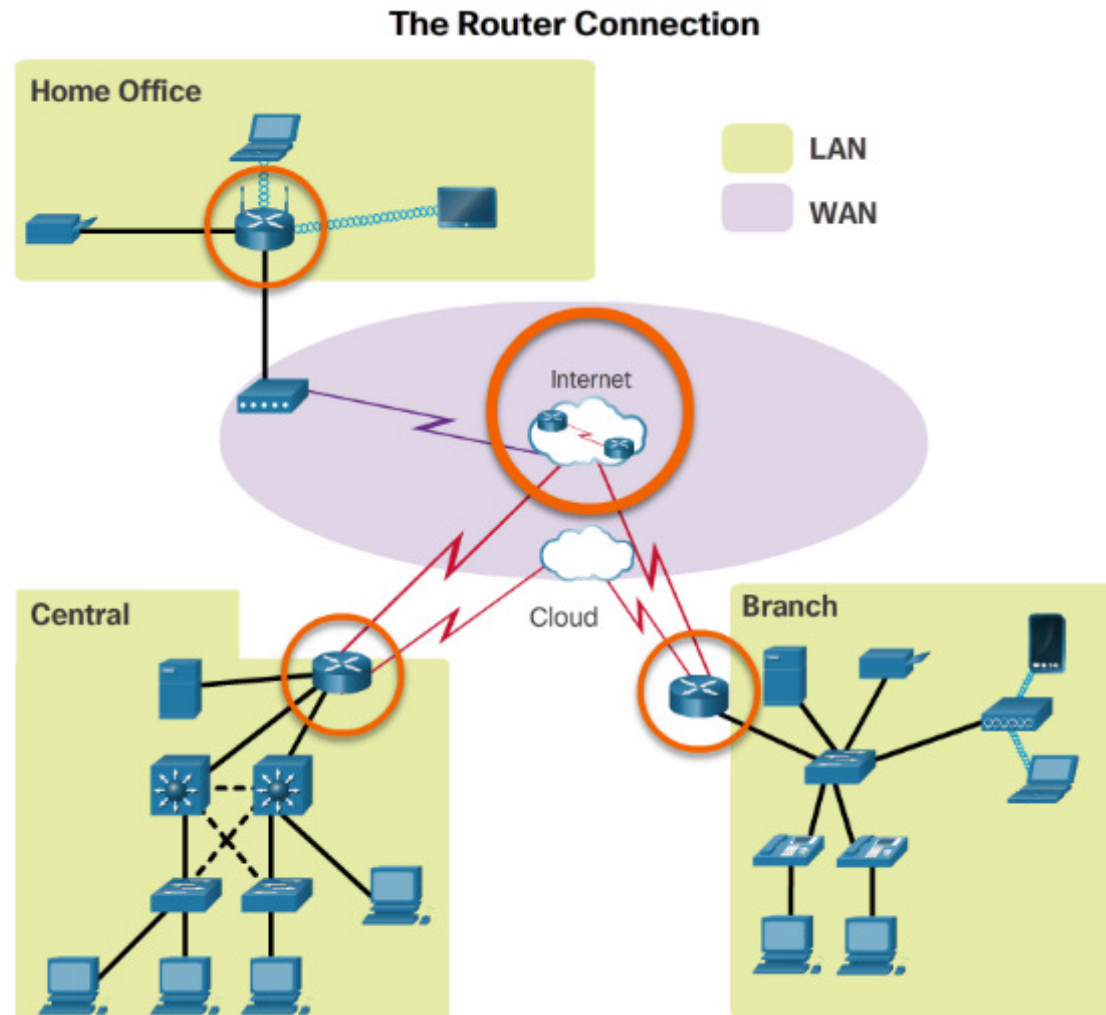
Routers are Computers

Router Memory

Memory	Description
Random Access Memory (RAM)	<p>Volatile memory that provides temporary storage for various applications and processes including:</p> <ul style="list-style-type: none"> • Running IOS • Running configuration file • IP routing and ARP tables • Packet buffer
Read-Only Memory (ROM)	<p>Non-volatile memory that provides permanent storage for:</p> <ul style="list-style-type: none"> • Bootup instructions • Basic diagnostic software • Limited IOS in case the router cannot load the full featured IOS
Non-Volatile Random Access Memory (NVRAM)	<p>Non-volatile memory that provides permanent storage for the:</p> <ul style="list-style-type: none"> • Startup configuration file
Flash	<p>Non-volatile memory that provides permanent storage for:</p> <ul style="list-style-type: none"> • IOS • Other system-related files

Router Functions

Routers Interconnect Networks

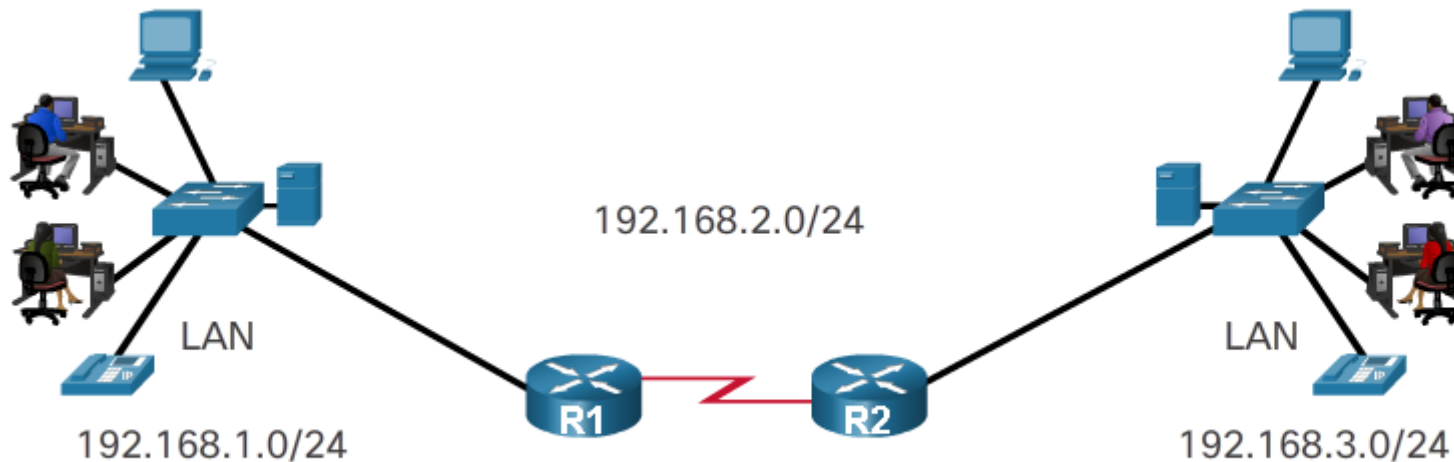




Router Functions

Routers Choose Best Paths

- Routers use static routes and dynamic routing protocols to learn about remote networks and build their routing tables.
- Routers use routing tables to determine the best path to send packets.
- Routers encapsulate the packet and forward it to the interface indicated in routing table.

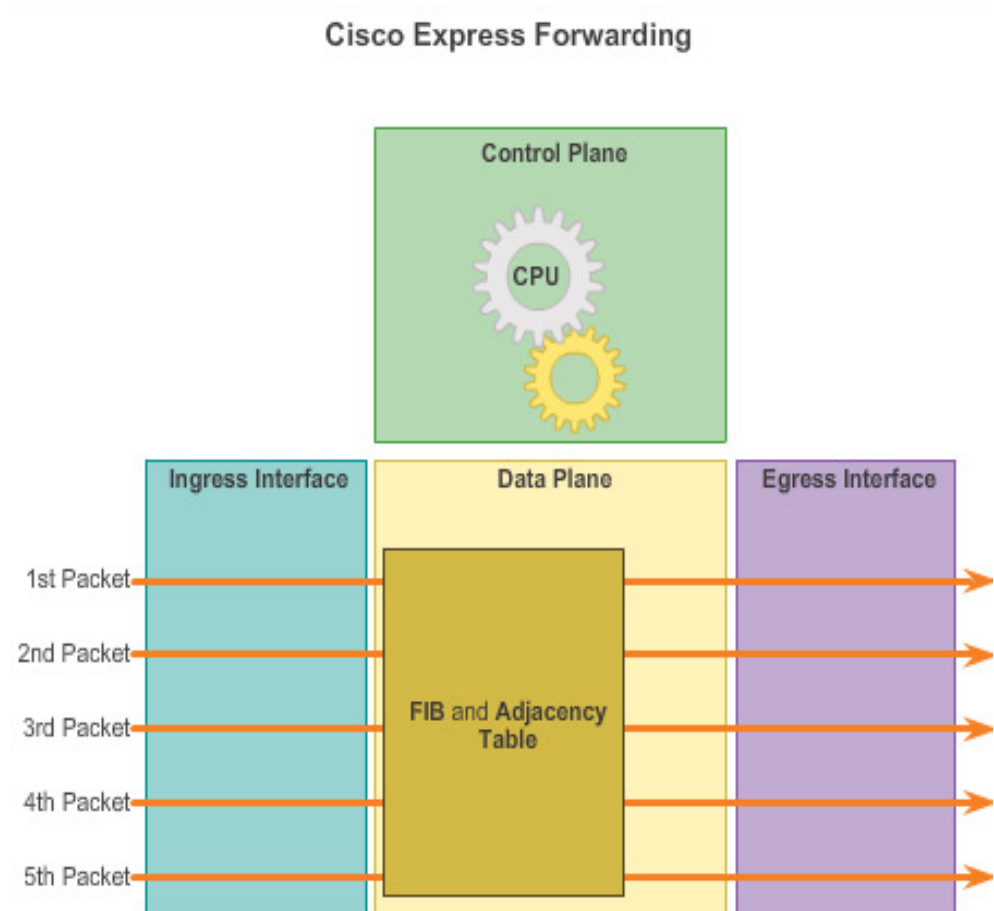




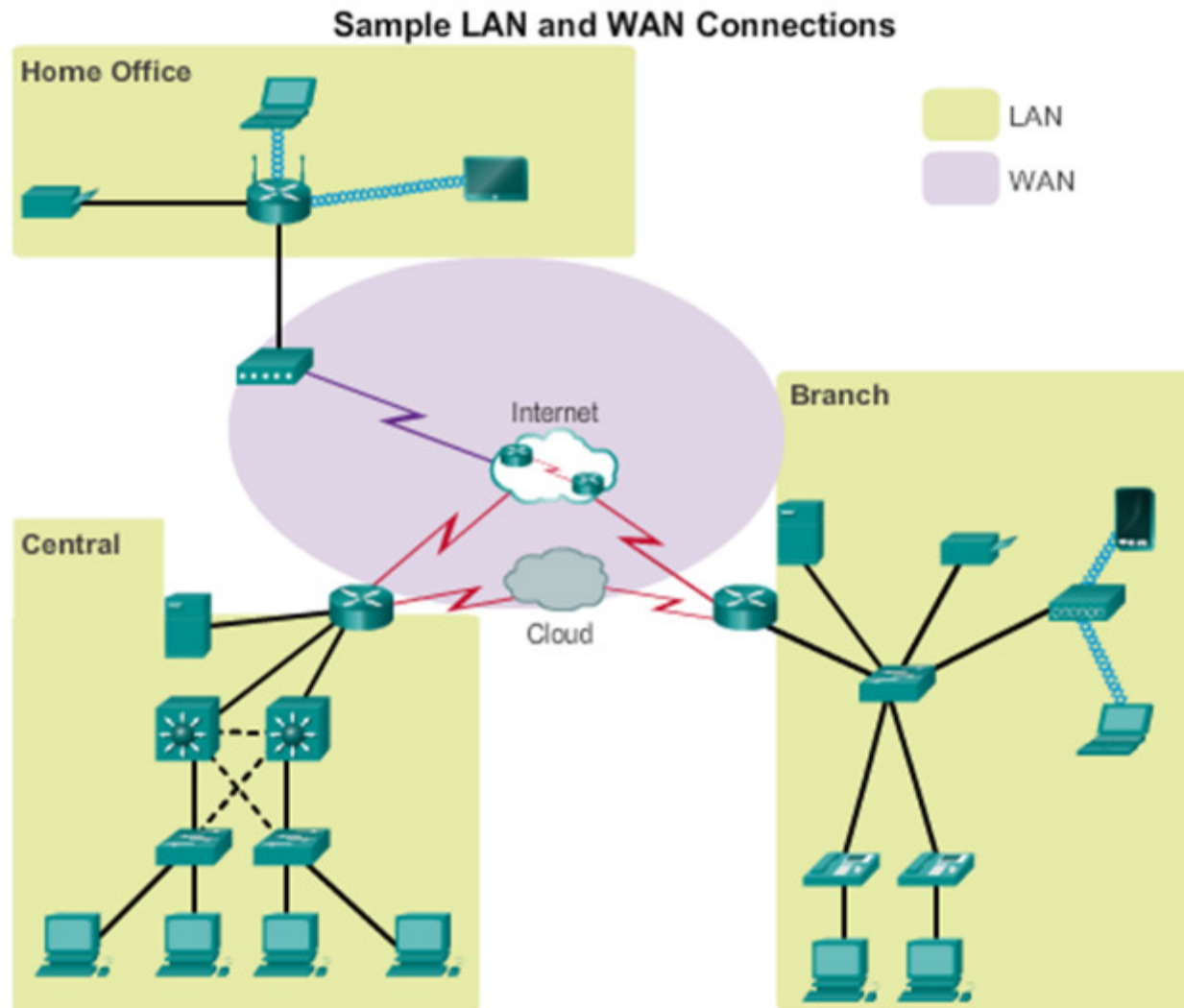
Router Functions

Packet Forwarding Methods

- **Process switching** – An older packet forwarding mechanism still available for Cisco routers.
- **Fast switching** – A common packet forwarding mechanism which uses a fast-switching cache to store next hop information.
- **Cisco Express Forwarding (CEF)** – The most recent, fastest, and preferred Cisco IOS packet-forwarding mechanism.



Connect Devices Connect to a Network





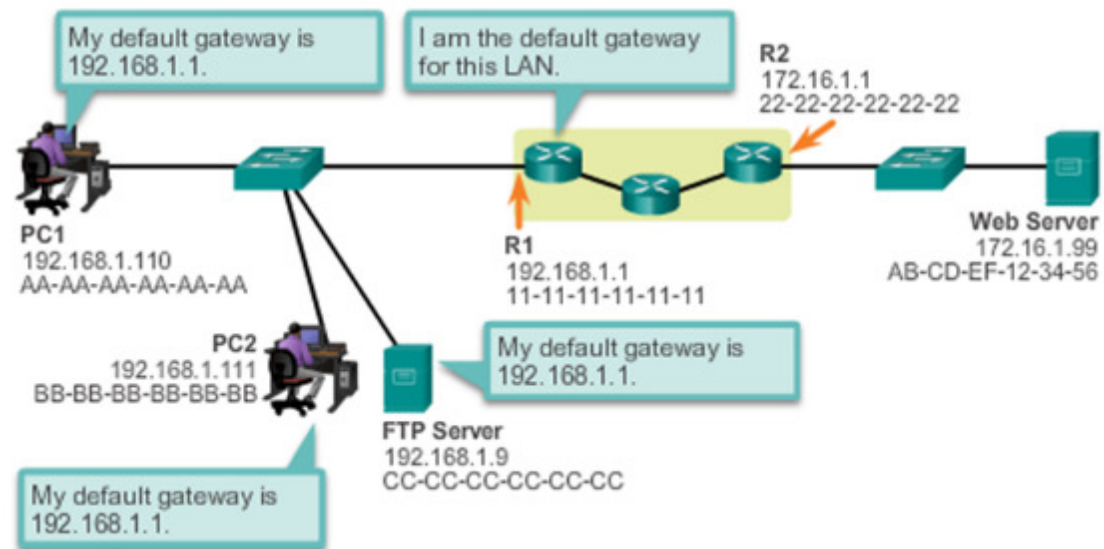
Connect Devices

Default Gateways

To enable network access devices, must be configured with the following IP address information:

- **IP address** - Identifies a unique host on a local network.
- **Subnet mask** - Identifies the host's network subnet.
- **Default gateway** - Identifies the router a packet is sent to when the destination is not on the same local network subnet.

Destination MAC Address	Source MAC Address	Source IP Address	Destination IP Address	Data
11-11-11-11-11-11	AA-AA-AA-AA-AA-AA	192.168.1.110	172.16.1.99	



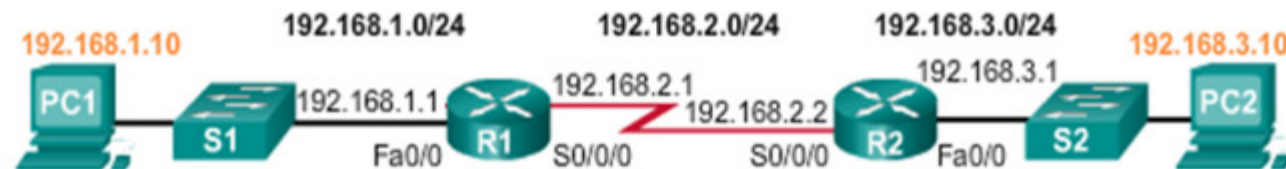


Connect Devices

Document Network Addressing

Network documentation should include at least the following in a topology diagram and addressing table:

- Device names
- Interfaces
- IP addresses and subnet masks
- Default gateways



Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	Fa0/0	192.168.1.1	255.255.255.0	N/A
	S0/0/0	192.168.2.1	255.255.255.0	N/A
R2	Fa0/0	192.168.3.1	255.255.255.0	N/A
	S0/0/0	192.168.2.2	255.255.255.0	N/A
PC1	N/A	192.168.1.10	255.255.255.0	192.168.1.1
PC2	N/A	192.168.3.10	255.255.255.0	192.168.3.1



Connect Devices

Enable IP on a Host

Statically Assigned IP address – The host is manually assigned an IP address, subnet mask and default gateway. A DNS server IP address can also be assigned.

- Used to identify specific network resources such as network servers and printers.
- Can be used in very small networks with few hosts.

Dynamically Assigned IP Address – IP Address information is dynamically assigned by a server using Dynamic Host Configuration Protocol (DHCP).

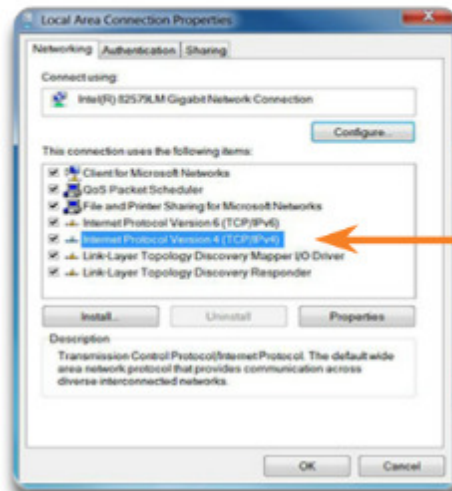
- Most hosts acquire their IP address information through DHCP.
- DHCP services can be provided by Cisco routers.



Connect Devices

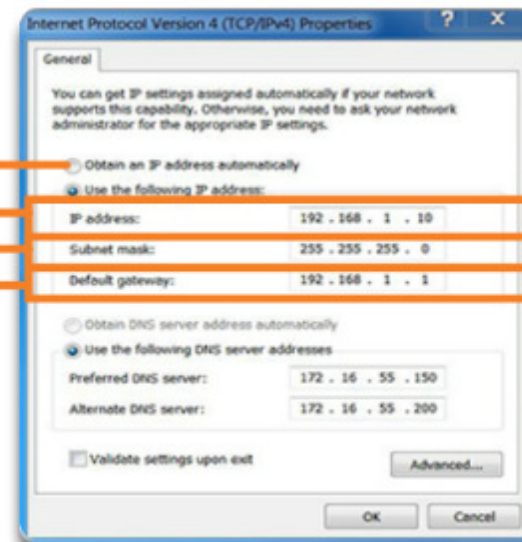
Enable IP on a Host

Statically Assigning an IP Address



For static assignments, enter addresses:

IP Address
Subnet Mask
Default Gateway

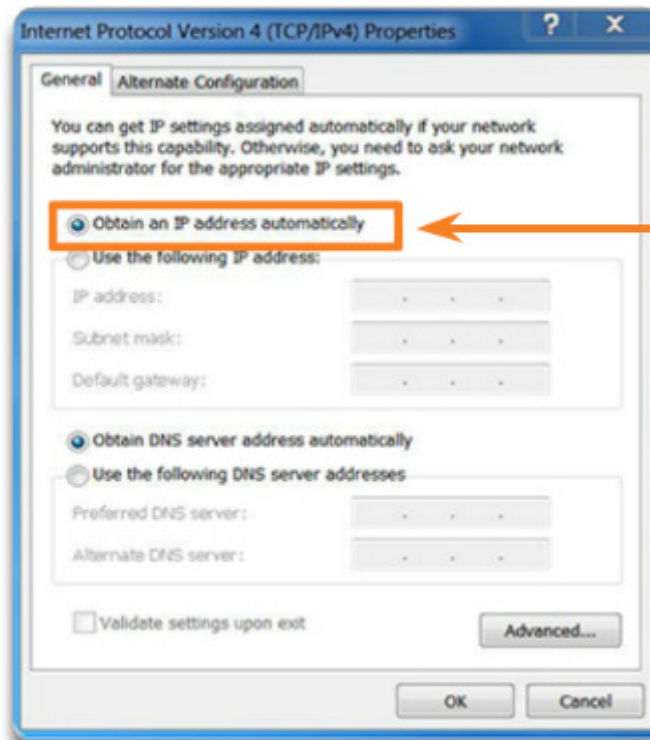




Connect Devices

Enable IP on a Host

Dynamically Assigning an IP Address



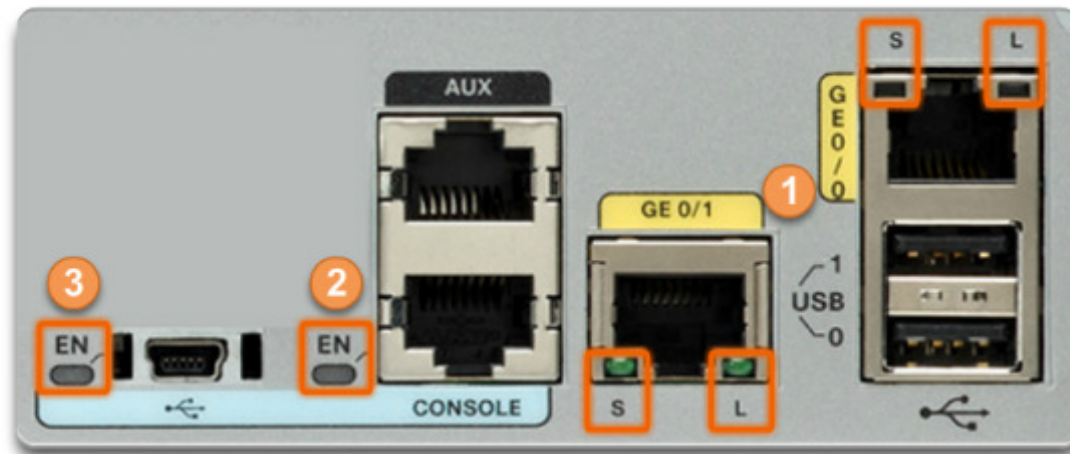
This property will set the device to obtain an IP address automatically.



Connect devices

Device LEDs

CISCO 1941 LEDs





#	Port	LED	Color	Description
1	GE0/0 and GE0/1	S (Speed)	1 blink + pause	Port operating at 10 Mb/s
			2 blink + pause	Port operating at 100 Mb/s
			3 blink + pause	Port operating at 1000 Mb/s
		L (Link)	Green	Link is active
			Off	Link is inactive
2	Console	EN	Green	Port is active
			Off	Port is inactive
3	USB	EN	Green	Port is active
			Off	Port is inactive



Connect Devices

Console Access

Console Connection Requirements

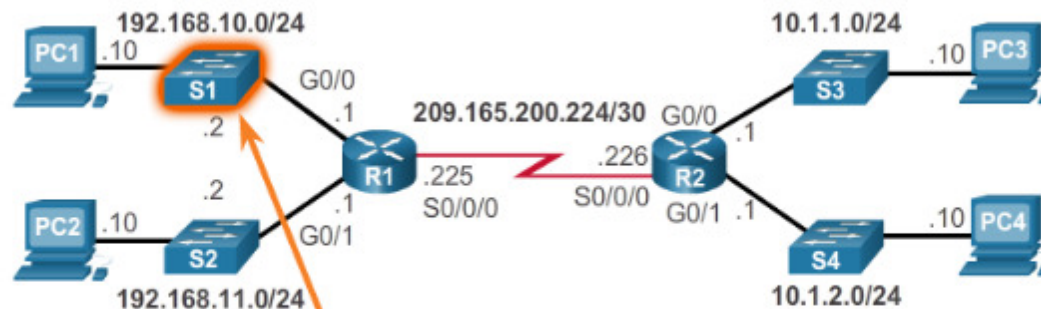
Port on Computer	Cable Required	Port on ISR	Terminal Emulation
Serial Port	RJ-45-to-DB-9 Console Cable	RJ-45 Console Port	 <p>Tera Term</p>
USB Type-A Port	<ul style="list-style-type: none"> • USB-to-RS-232 compatible serial port adapter • Adapter may require a software driver • RJ-45-to-DB-9 console cable 		 <p>PuTTY</p>
	<ul style="list-style-type: none"> • USB Type-A to USB Type-B (Mini-B USB) • A device driver is required and available from cisco.com. 	USB Type-B (Mini-B USB)	



Connect Devices

Enable IP on a Switch

- Network infrastructure devices require IP addresses to enable remote management.
- On a switch, the management IP address is assigned on a virtual interface called a switched virtual interface (SVI)



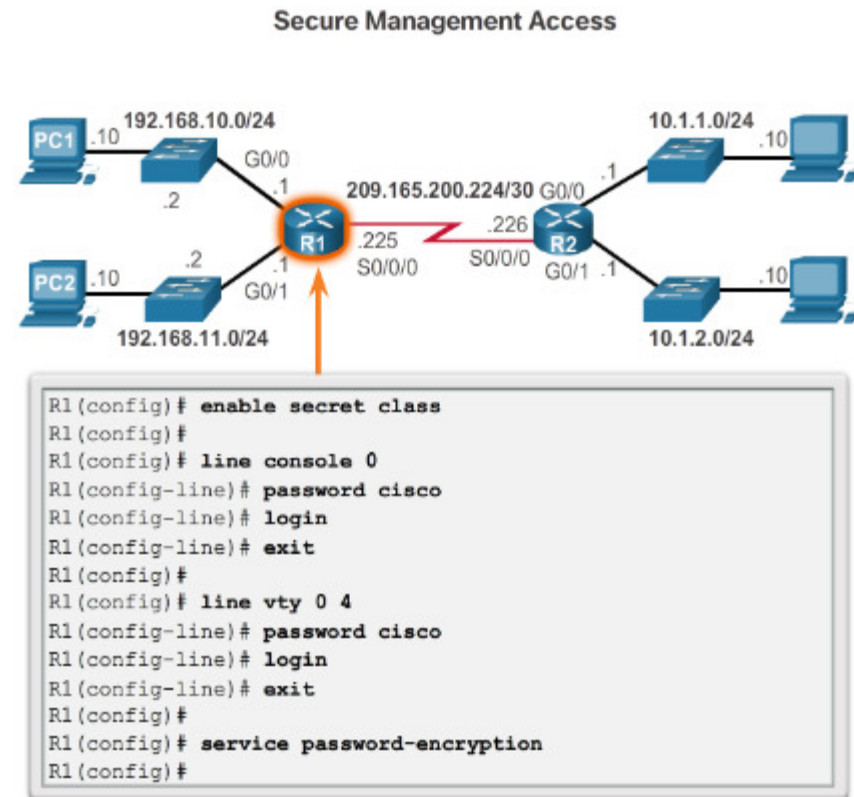
```
S1(config)# interface vlan 1
S1(config-if)# ip address 192.168.10.2 255.255.255.0
S1(config-if)# no shutdown
%LINK-5-CHANGED: Interface Vlan1, changed state to up
S1(config-if)# exit
S1(config)#
S1(config)# ip default-gateway 192.168.10.1
S1(config)#
```



Router Basic Settings

Configure Router Basic Settings

- **Name the device** – Distinguishes it from other routers
- **Secure management access** – Secures privileged EXEC, user EXEC, and Telnet access, and encrypts passwords .
- **Configure a banner** – Provides legal notification of unauthorized access.
- **Save the Configuration**





Router Basic Settings

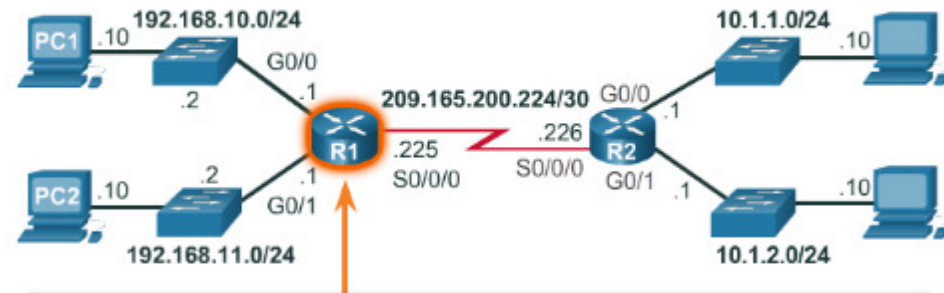
Configure an IPv4 Router Interface

To be available, a router interface must be:

- Configured with an address and subnet mask.
- Activated using **no shutdown** command. By default LAN and WAN interfaces are not activated.
- Configured with the clock rate command on the Serial cable end labeled DCE.

Optional description can be included.

Configure the G0/0 Interface



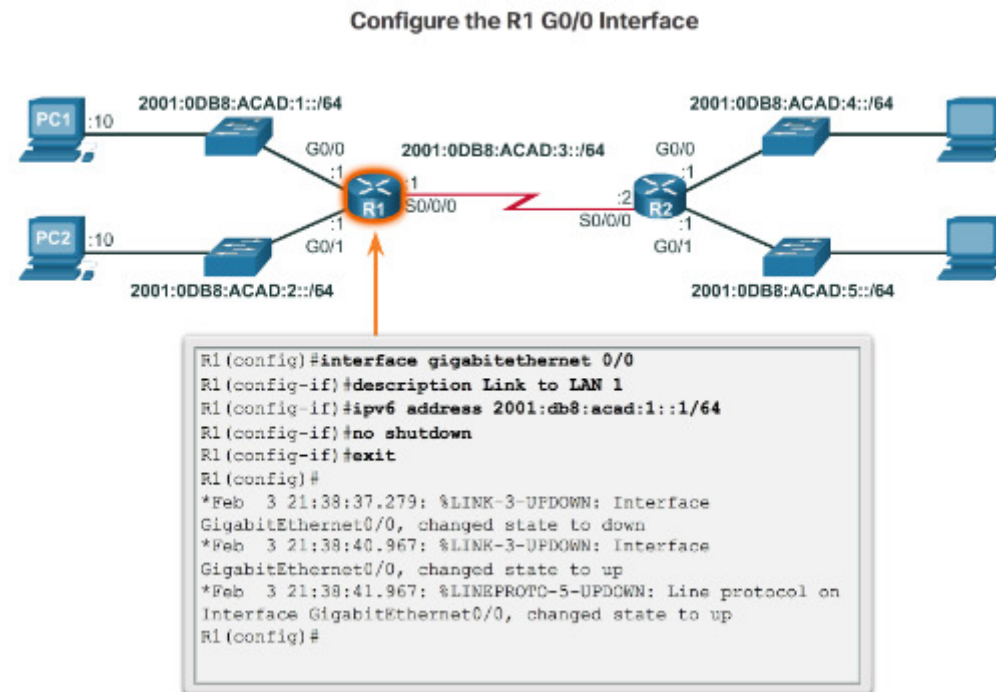
```
R1(config)# interface gigabitethernet 0/0
R1(config-if)# description Link to LAN 1
R1(config-if)# ip address 192.168.10.1 255.255.255.0
R1(config-if)# no shutdown
R1(config-if)# exit
R1(config)#
*Jan 30 22:04:47.551: %LINK-3-UPDOWN: Interface
GigabitEthernet0/0, changed state to down
R1(config)#
*Jan 30 22:04:50.899: %LINK-3-UPDOWN: Interface
GigabitEthernet0/0, changed state to up
*Jan 30 22:04:51.899: %LINEPROTO-5-UPDOWN: Line protocol on
Interface GigabitEthernet0/0, changed state to up
R1(config)#
```

Router Basic Settings

Configure an IPv6 Router Interface

Configure interface with IPv6 address and subnet mask:

- Use the **ipv6 address** *ipv6-address/ipv6-length* [link-local | eui-64] interface configuration command.
- Activate using the **no shutdown** command.



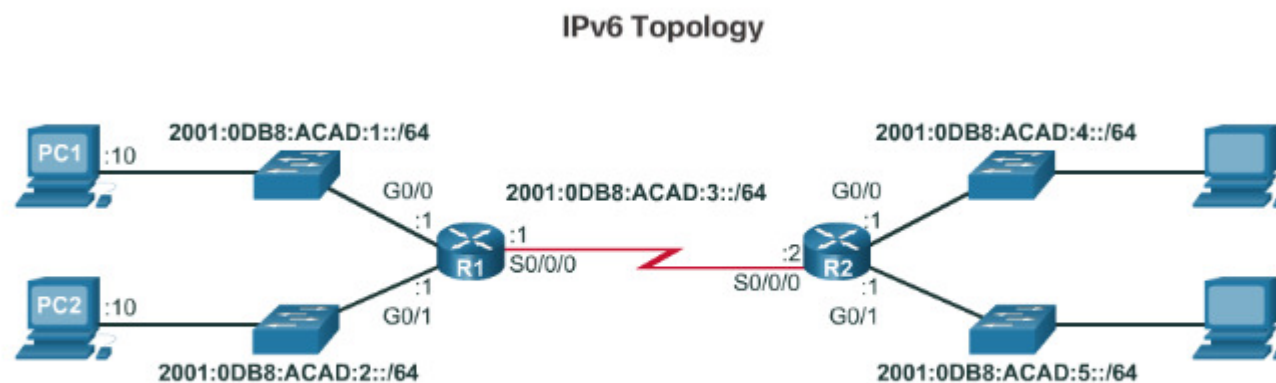


Router Basic Settings

Configure an IPv6 Router Interface (cont.)

IPv6 interfaces can support more than one address:

- Configure a specified global unicast – **ipv6address** *ipv6-address /ipv6-length*
- Configure a global IPv6 address with an interface identifier (ID) in the low-order 64 bits - **ipv6address** *ipv6-address /ipv6-length* eui-64
- Configure a link-local address - **ipv6address** *ipv6-address /ipv6-length* link-local



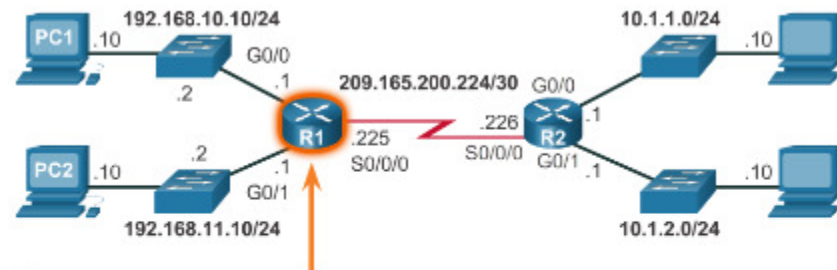
Router Basic Settings

Configure an IPv4 Loopback Interface

A loopback interface is a logical interface that is internal to the router:

- It is not assigned to a physical port, it is considered a software interface that is automatically in an UP state.
- A loopback interface is useful for testing.
- It is important in the OSPF routing process.

Configure the Loopback0 Interface



```

R1(config)# interface loopback 0
R1(config-if)# ip address 10.0.0.1 255.255.255.0
R1(config-if)# exit
R1(config)#
*Jan 30 22:04:50.899: %LINK-3-UPDOWN: Interface loopback0,
changed state to up
*Jan 30 22:04:51.899: %LINEPROTO-5-UPDOWN: Line protocol on
Interface loopback0, changed state to up
    
```



Verify Connectivity of Directly Connected Networks

Verify Interface Settings

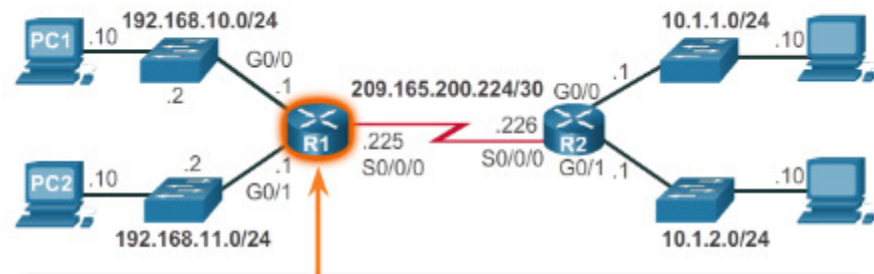
Show commands are used to verify operation and configuration of interface:

- **show ip interfaces brief**
- **show ip route**
- **show running-config**

Show commands that are used to gather more detailed interface information:

- **show interfaces**
- **show ip interfaces**

Display Interface Summaries



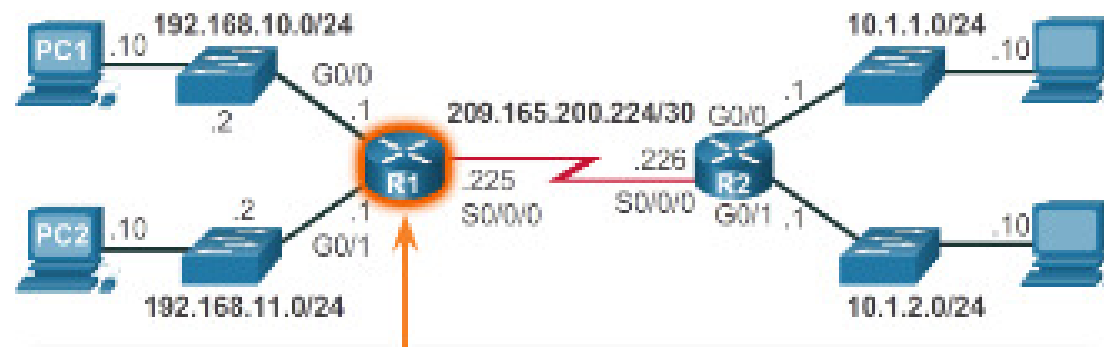
```

R1# show ip interface brief
Interface                               IP-Address      OK? Method Status
Embedded-Service-Engine0/0            unassigned      YES unset  administ
GigabitEthernet0/0                     192.168.10.1    YES manual  up
GigabitEthernet0/1                     192.168.11.1    YES manual  up
Serial0/0/0                            209.165.200.225 YES manual  up
Serial0/0/1                            unassigned      YES unset  administ
R1#
  
```

Verify Connectivity of Directly Connected Networks

Verify Interface Settings (cont.)

Verify the Routing Table



```

R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - m
<output omitted>

Gateway of last resort is not set

192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C    192.168.10.0/24 is directly connected, GigabitEthernet0/0
L    192.168.10.1/32 is directly connected, GigabitEthernet0/0
192.168.11.0/24 is variably subnetted, 2 subnets, 2 masks
C    192.168.11.0/24 is directly connected, GigabitEthernet0/1
L    192.168.11.1/32 is directly connected, GigabitEthernet0/1
209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks

```

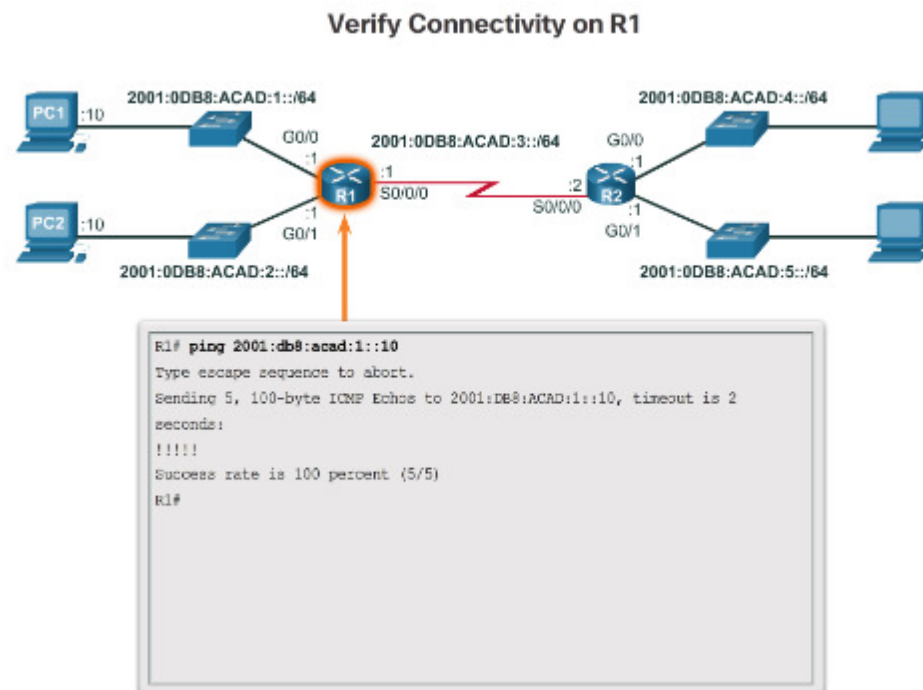


Verify Connectivity of Directly Connected Networks

Verify IPv6 Interface Settings

Common commands to verify the IPv6 interface configuration:

- **show ipv6 interface brief** - displays a summary for each of the interfaces.
- **show ipv6 interface gigabitethernet 0/0** - displays the interface status and all the IPv6 addresses for this interface.
- **show ipv6 route** - verifies that IPv6 networks and specific IPv6 interface addresses have been installed in the IPv6 routing table.





Verify Connectivity of Directly Connected Networks

Filter Show Command Output

Show command output can be managed using the following command and filters:

- Use the **terminal length** *number* command to specify the number of lines to be displayed.
- To filter specific output of commands use the **(|)pipe character** after show command. Parameters that can be used after pipe include:
 - **section, include, exclude, begin**

Filtering Show Commands

```
R1# show running-config | section line vty
line vty 0 4
password 7 030752180500
login
transport input all
R1#
```

Filtering Show Commands

```
R1# show ip interface brief
Interface          IP-Address      OK? Method Status
Embedded-Service-Engine0/0 unassigned      YES unset  administ
GigabitEthernet0/0  192.168.10.1    YES manual  up
GigabitEthernet0/1  192.168.11.1    YES manual  up
Serial0/0/0         209.165.200.225 YES manual  up
Serial0/0/1         unassigned      YES unset  administ
R1#
R1# show ip interface brief | include up
GigabitEthernet0/0  192.168.10.1    YES manual  up
GigabitEthernet0/1  192.168.11.1    YES manual  up
Serial0/0/0         209.165.200.225 YES manual  up
R1#
```



Verify Connectivity of Directly Connected Networks

Command History Feature

The command history feature temporarily stores a list of executed commands for access:

- To recall commands press **Ctrl+P** or the **UP Arrow**.
- To return to more recent commands press **Ctrl+N** or the **Down Arrow**.
- By default, command history is enabled and the system captures the last 10 commands in the buffer. Use the **show history** privileged EXEC command to display the buffer contents.
- Use the **terminal history size** user EXEC command to increase or decrease size of the buffer.

```
R1# terminal history size 200
R1#
R1# show history
  show ip interface brief
  show interface g0/0
  show ip interface g0/1
  show ip route
  show ip route 209.165.200.224
  show running-config interface s0/0/0
  terminal history size 200
  show history
R1#
```



1.2 Routing Decisions



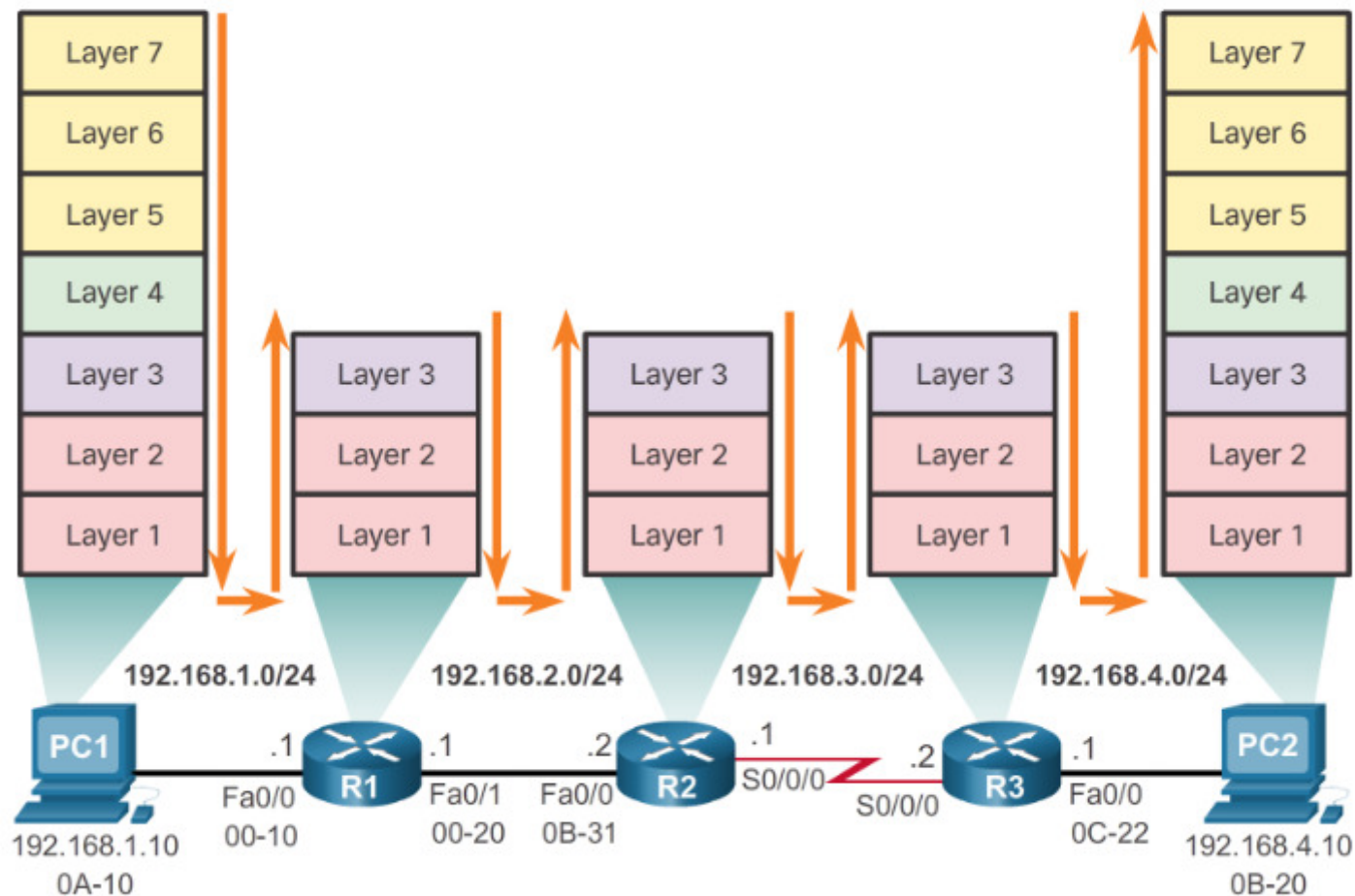
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Switching Packets Between Networks

Router Switching Function

Encapsulating and De-Encapsulating Packets



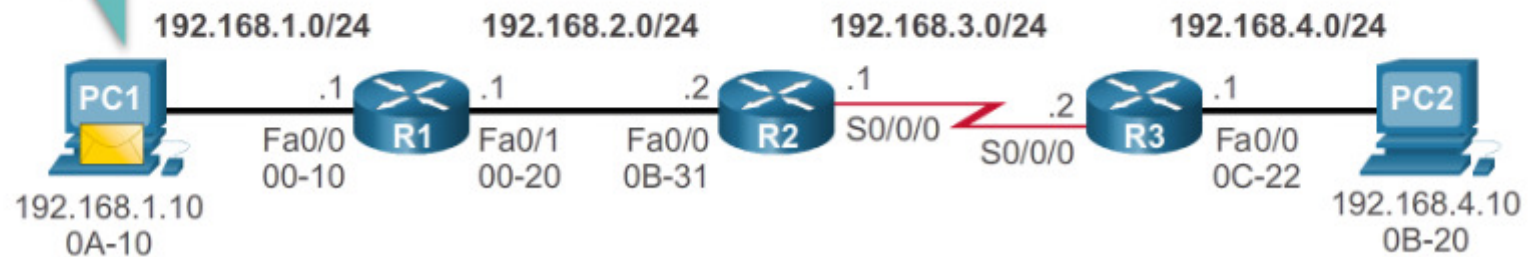


Switching Packets Between Networks

Send a Packet

PC1 Sends a Packet to PC2

Because PC2 is on different network, I will encapsulate the packet and send it to the router on MY network. Let me find that MAC address....



Layer 2 Data Link Frame

Dest. MAC	Source MAC	Type	Source IP	Dest. IP	IP fields	Data	Trailer
00-10	0A-10	0x800	192.168.1.10	192.168.4.10			

Packet's Layer 3 data

PC1's ARP Cache for R1

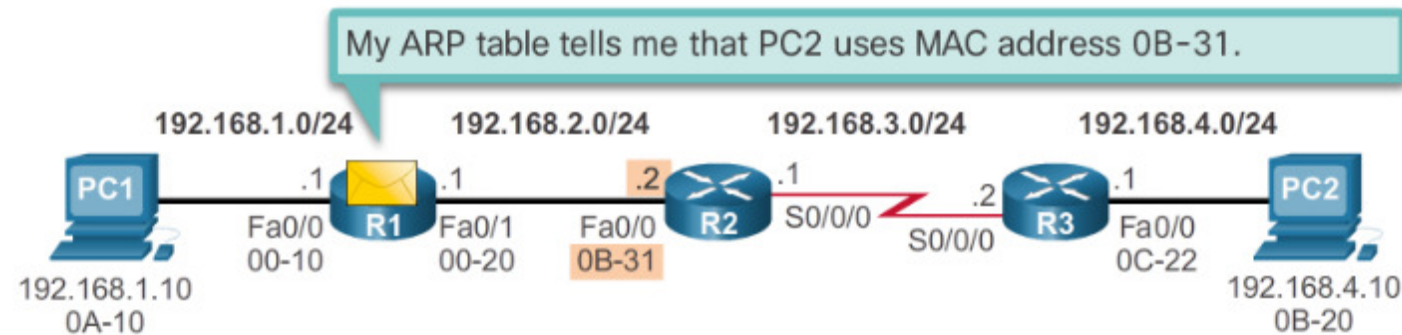
IP Address	MAC Address
192.168.1.1	00-10



Switching Packets Between Networks

Forward to Next Hop

R1 Forwards the Packet to PC2



Layer 2 Data Link Frame

Dest. MAC 0B-31		Type 0x800	Source IP 192.168.1.10	Dest. IP 192.168.4.10	IP fields	Data	Trailer
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Packet's Layer 3 data

R1's ARP Cache

IP Address	MAC Address
192.168.2.2	0B-31

R1's Routing Table

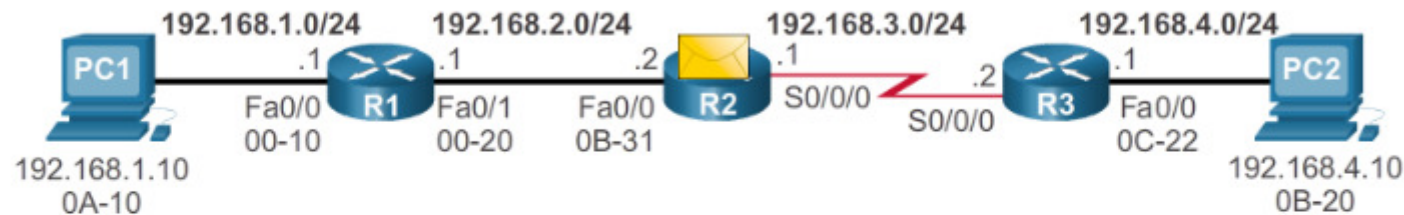
Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	0	Dir. Connect.	Fa0/0
192.168.2.0/24	0	Dir. Connect.	Fa0/1
192.168.3.0/24	1	192.168.2.2	Fa0/1
192.168.4.0/24	2	192.168.2.2	Fa0/1



Switching Packets Between Networks

Packet Routing

R2 Forwards the Packet to R3



Layer 2 Data Link Frame

Packet's Layer 3 data

			Source IP 192.168.1.10	Dest. IP 192.168.4.10	IP fields	Data	Trailer
--	--	--	---------------------------	--------------------------	-----------	------	---------

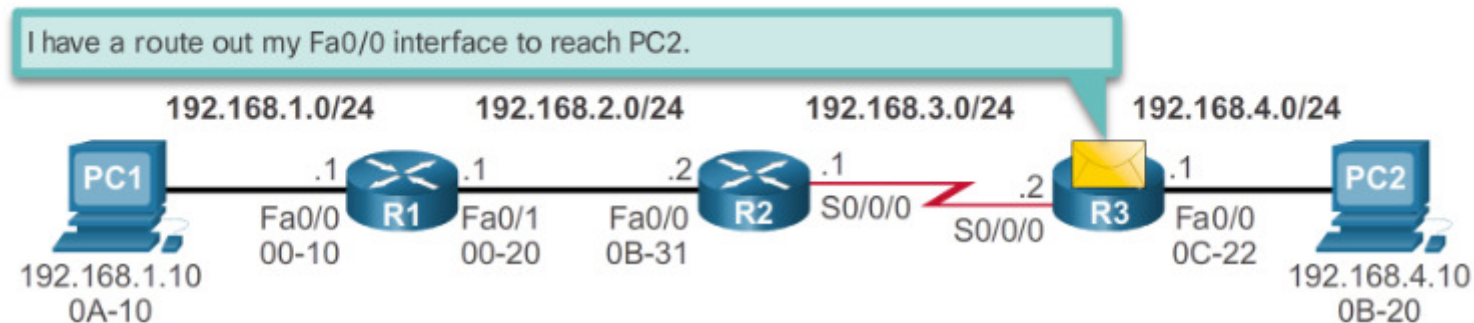
R2's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	1	192.168.3.1	Fa0/0/0
192.168.2.0/24	0	Dir. Connect.	Fa0/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	1	192.162.3.2	S0/0/0



Switching Packets Between Networks Reach the Destination

R3 Forwards the Packet to PC2



Layer 2 Data Link Frame

Layer 2 Data Link Frame		Packet's Layer 3 data					
		Type 0x800	Source IP 192.168.1.10	Dest. IP 192.168.4.10	IP fields	Data	Trailer

R3's Routing Table

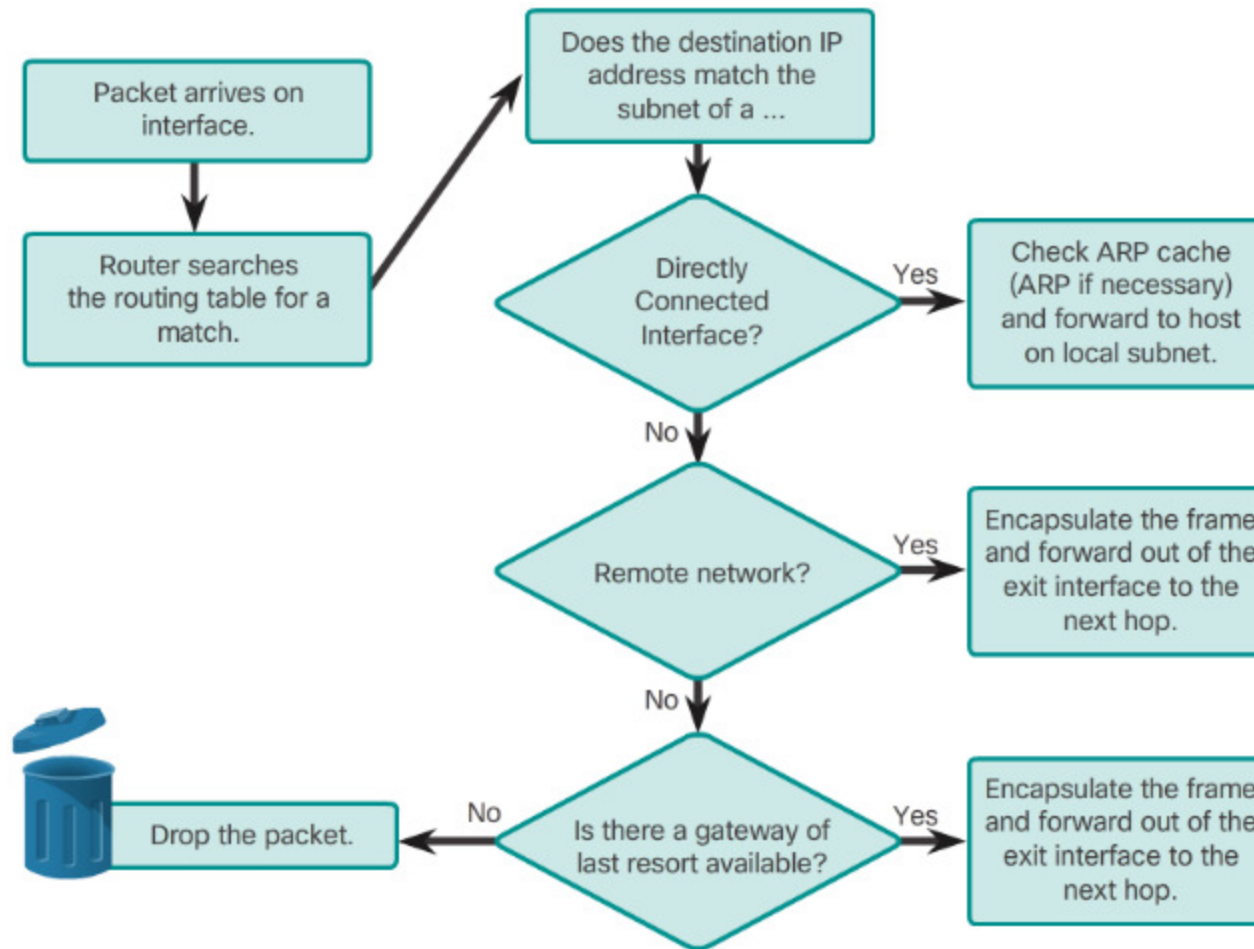
Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	2	192.168.3.1	S0/0/0
192.168.2.0/24	1	192.168.3.1	S0/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	0	Dir. Connect.	Fa0/0



Path Determination

Routing Decisions

Packet Forwarding Decision Process





Path Determination

Best Path

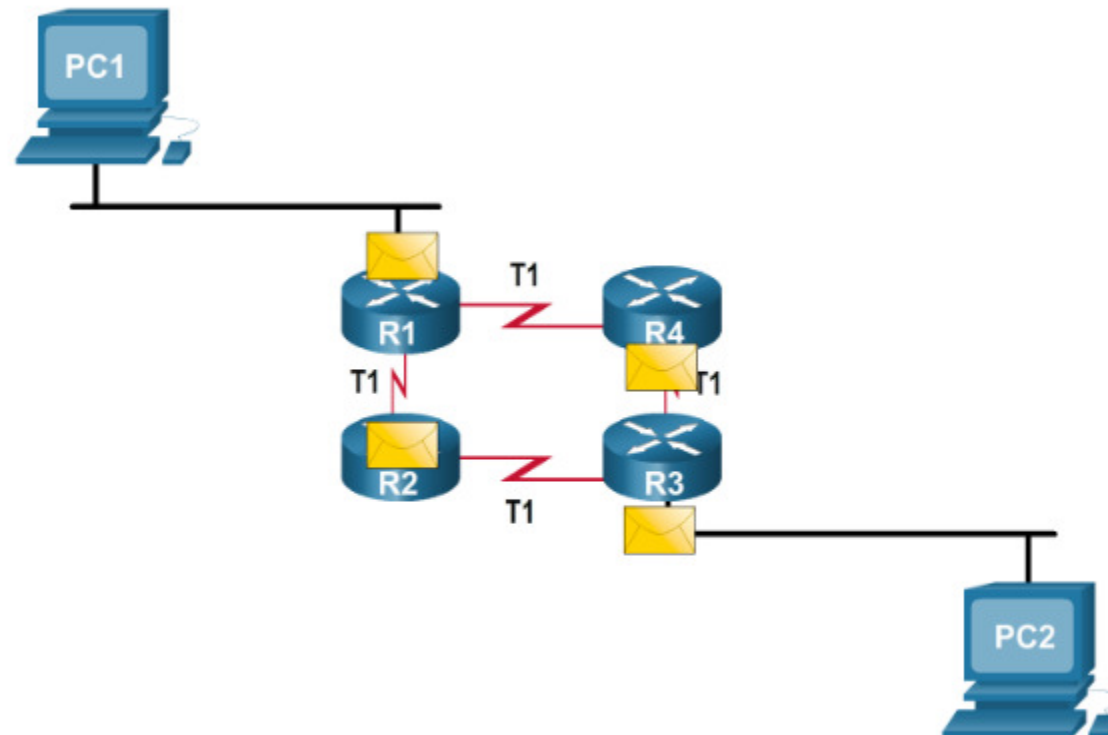
- **Best path is selected by a routing protocol based on the value or metric it uses to determine the distance to reach a network:**
 - A metric is the value used to measure the distance to a given network.
 - Best path to a network is the path with the lowest metric.
- **Dynamic routing protocols use their own rules and metrics to build and update routing tables:**
 - Routing Information Protocol (RIP) - Hop count
 - Open Shortest Path First (OSPF) - Cost based on cumulative bandwidth from source to destination
 - Enhanced Interior Gateway Routing Protocol (EIGRP) - Bandwidth, delay, load, reliability



Path Determination

Load Balancing

- When a router has two or more paths to a destination with equal cost metrics, then the router forwards the packets using both paths equally:
 - Equal cost load balancing can improve network performance.
 - Equal cost load balancing can be configured to use both dynamic routing protocols and static routes.





Path Determination

Administrative Distance

- If multiple paths to a destination are configured on a router, the path installed in the routing table is the one with the lowest Administrative Distance (AD):
 - A static route with an AD of 1 is more reliable than an EIGRP-discovered route with an AD of 90.
 - A directly connected route with an AD of 0 is more reliable than a static route with an AD of 1.

Route Source	Administrative Distance
Connected	0
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200



1.3 Router Operation



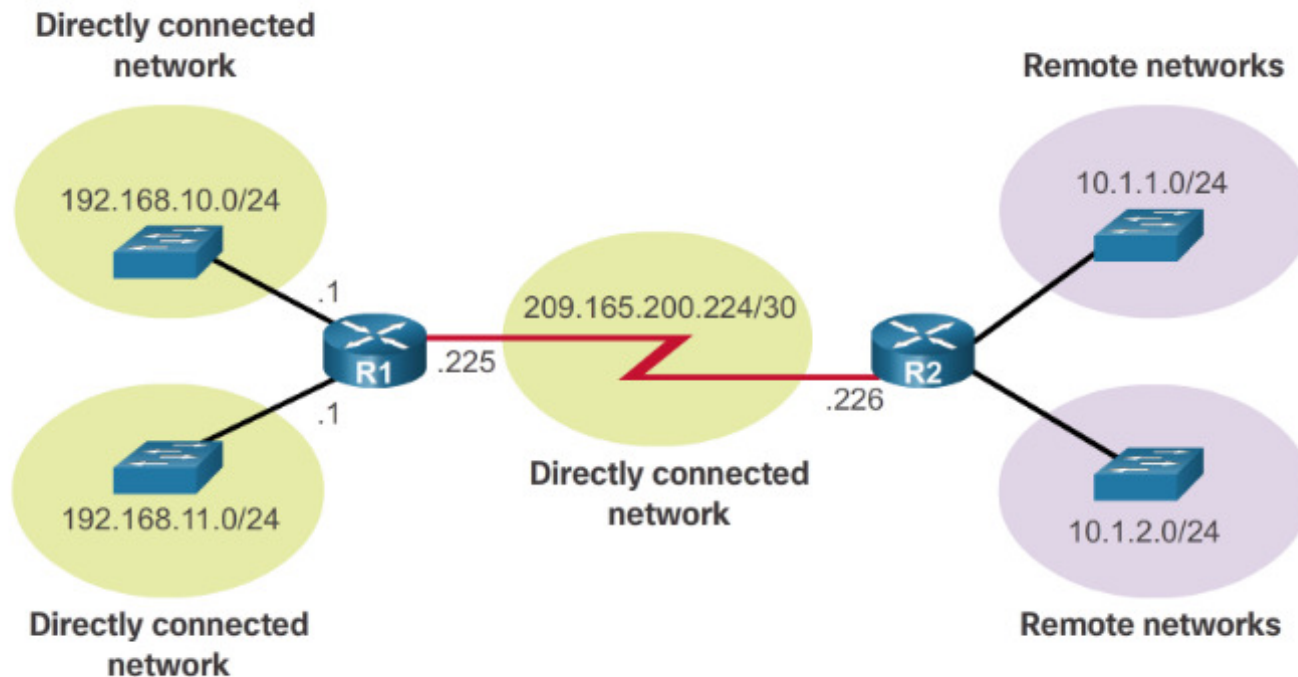
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Analyze the Routing Table

The Routing Table

- A routing table is a file stored in RAM that contains information about:
 - Directly connected routes
 - Remote routes





Analyze the Routing Table

Routing Table Sources

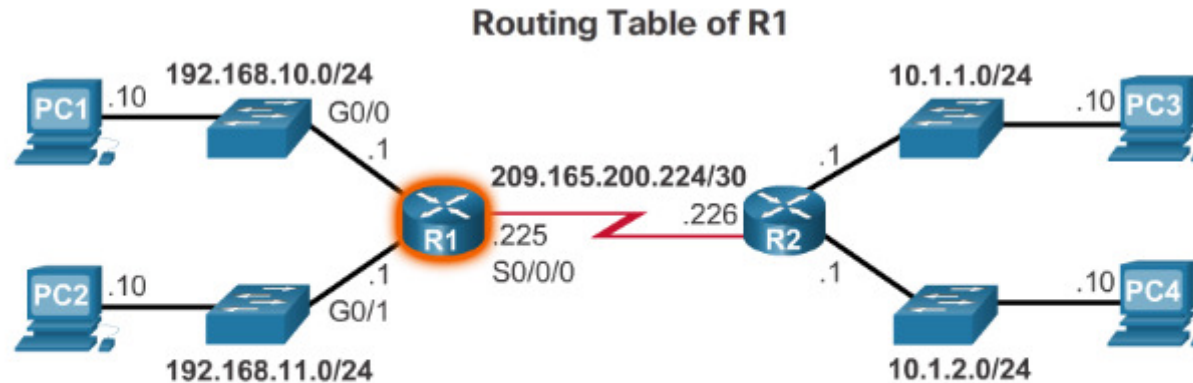
The **show ip route** command is used to display the contents of the routing table:

- **Local route interfaces** - Added to the routing table when an interface is configured. (displayed in IOS 15 or newer for IPv4 routes and all IOS releases for IPv6 routes.)
- **Directly connected interfaces** - Added to the routing table when an interface is configured and active.
- **Static routes** - Added when a route is manually configured and the exit interface is active.
- **Dynamic routing protocol** - Added when EIGRP or OSPF are implemented and networks are identified.



Analyze the Routing Table

Routing Table Sources (cont.)



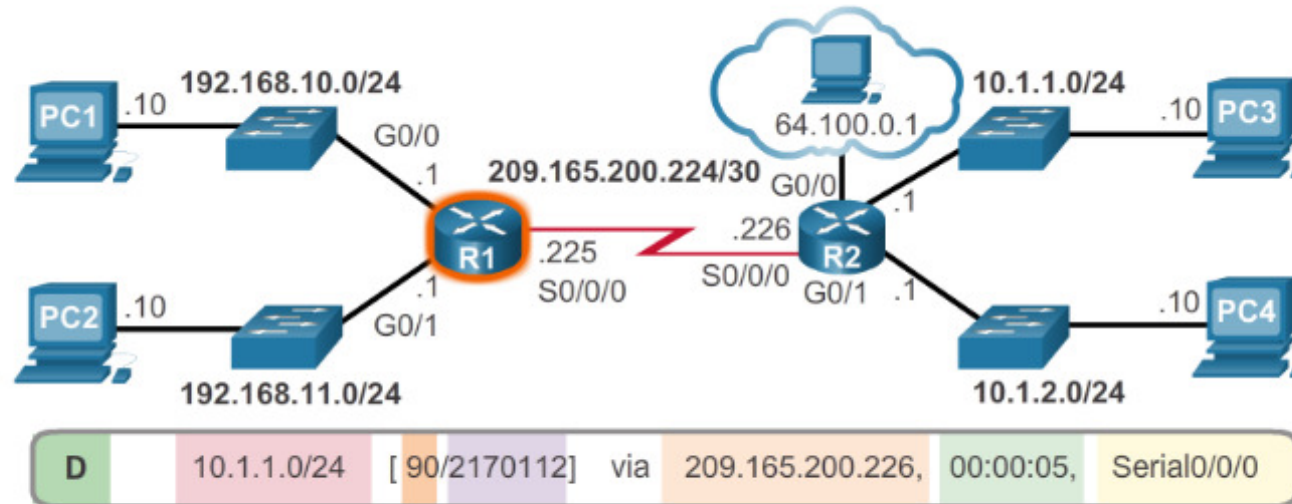
```
R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, 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
Gateway of last resort is not set
  10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
D    10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05,
```



Analyze the Routing Table

Remote Network Routing Entries

Interpreting the entries in the routing table



Legend

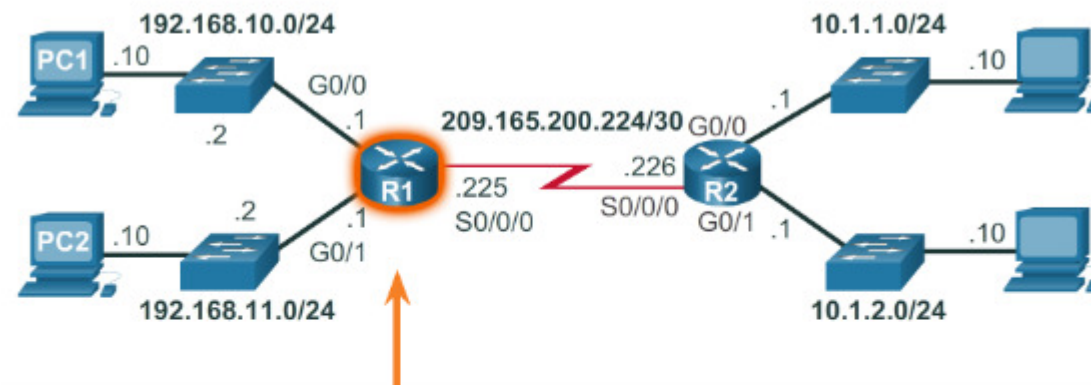
- Identifies how the network was learned by the router.
- Identifies the destination network.
- Identifies the administrative distance (trustworthiness) of the route source.
- Identifies the metric to reach the remote network.
- Identifies the next-hop IP address to reach the remote network.
- Identifies the amount of elapsed time since the network was discovered.
- Identifies the outgoing interface on the router to reach the destination network.

Directly Connected Routes

Directly Connected Interfaces

A newly deployed router, without any configured interfaces, has an empty routing table.

Empty Routing Table



```
R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

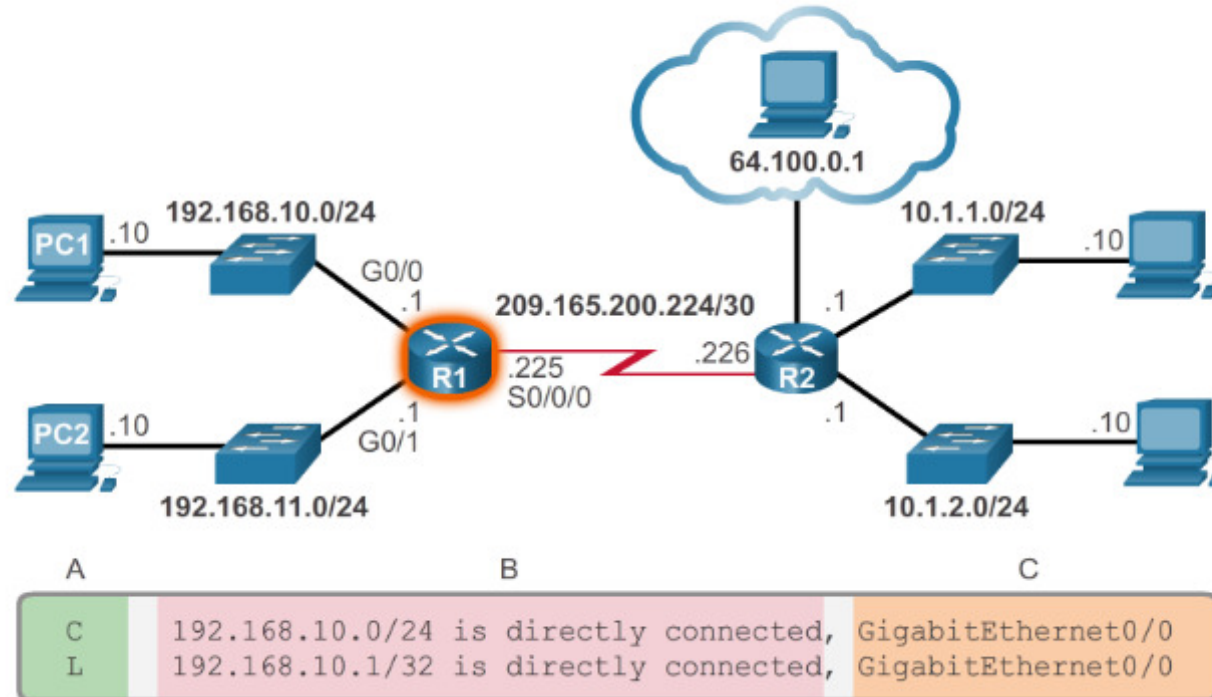
R1#
```




Directly Connected Routes

Directly Connected Routing Table Entries

Directly Connected Network Entry Identifiers



Legend

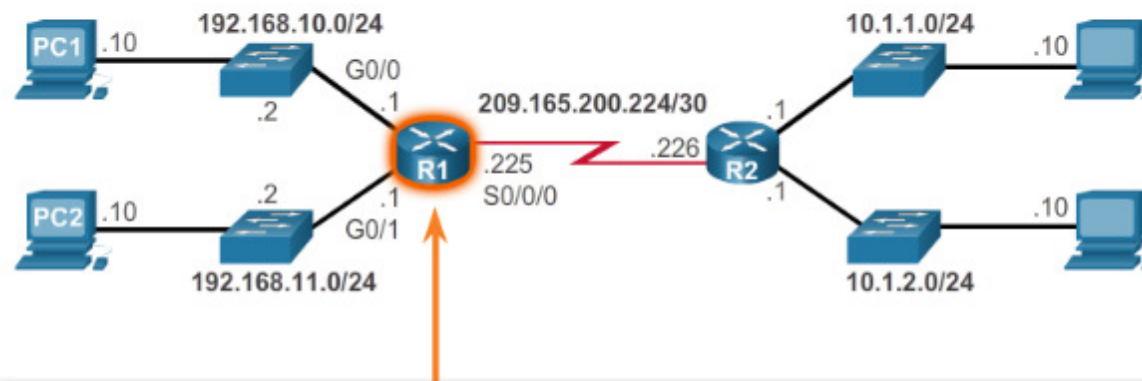
- Identifies how the network was learned by the router.
- Identifies the destination network and how it is connected.
- Identifies the interface on the router connected to the destination network.



Directly Connected Routes

Directly Connected Example

Verifying the Directly Connected Routing Table Entries



```
R1# show ip route | begin Gateway
```

```
Gateway of last resort is not set
```

```
192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
```

```
C    192.168.10.0/24 is directly connected, GigabitEthernet0/0
```

```
L    192.168.10.1/32 is directly connected, GigabitEthernet0/0
```

```
192.168.11.0/24 is variably subnetted, 2 subnets, 2 masks
```

```
C    192.168.11.0/24 is directly connected, GigabitEthernet0/1
```

```
L    192.168.11.1/32 is directly connected, GigabitEthernet0/1
```

```
209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
```

```
C    209.165.200.224/30 is directly connected, Serial0/0/0
```

```
L    209.165.200.225/32 is directly connected, Serial0/0/0
```

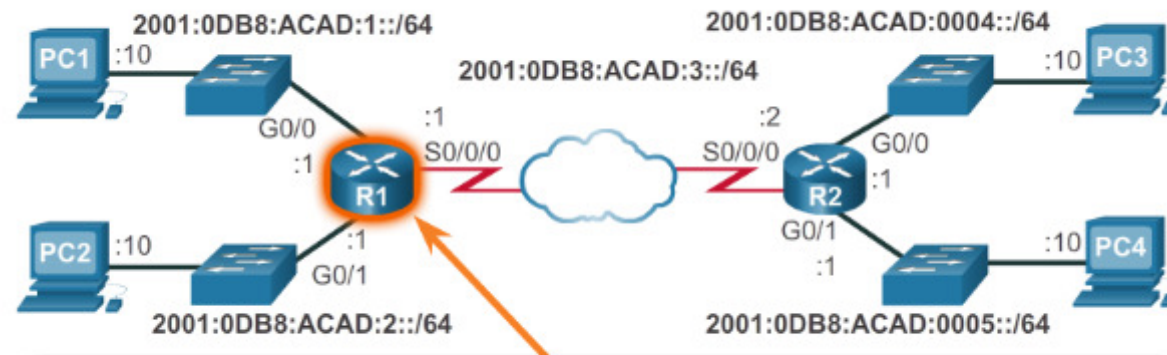
```
R1#
```



Directly Connected Routes

Directly Connected IPv6 Example

Show the IPv6 Route Table



```
R1# show ipv6 route
IPv6 Routing Table - default - 5 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
```



Statically Learned Routes

Static Routes

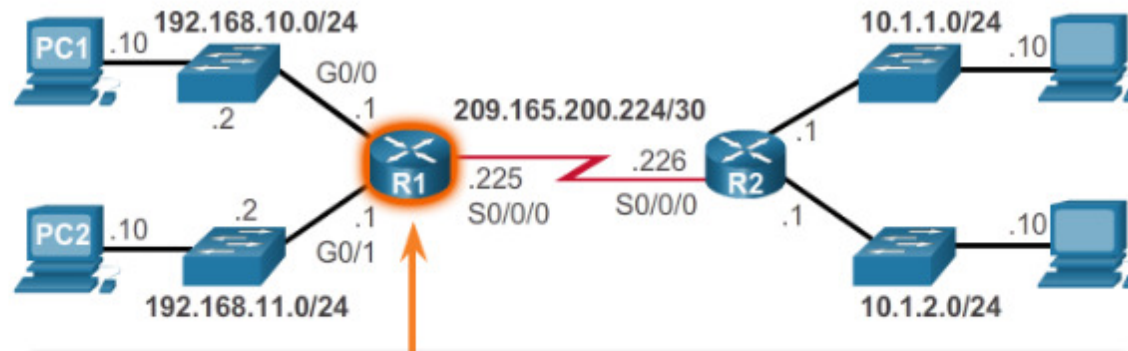
Static routes and default static routes can be implemented after directly connected interfaces are added to the routing table:

- Static routes are manually configured.
- They define an explicit path between two networking devices.
- Static routes must be manually updated if the topology changes.
- Their benefits include improved security and control of resources.
- Configure a static route to a specific network using the **ip route** *network mask {next-hop-ip | exit-intf}* command.
- A default static route is used when the routing table does not contain a path for a destination network.
- Configure a default static route using the **ip route** 0.0.0.0 0.0.0.0 {*exit-intf | next-hop-ip*} command.

Statically Learned Routes

Static Route Example

Entering and Verifying a Static Default Route



```
R1(config)# ip route 0.0.0.0 0.0.0.0 Serial0/0/0
R1(config)# exit
R1#
*Feb 1 10:19:34.483: %SYS-5-CONFIG_I: Configured from console
by console

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

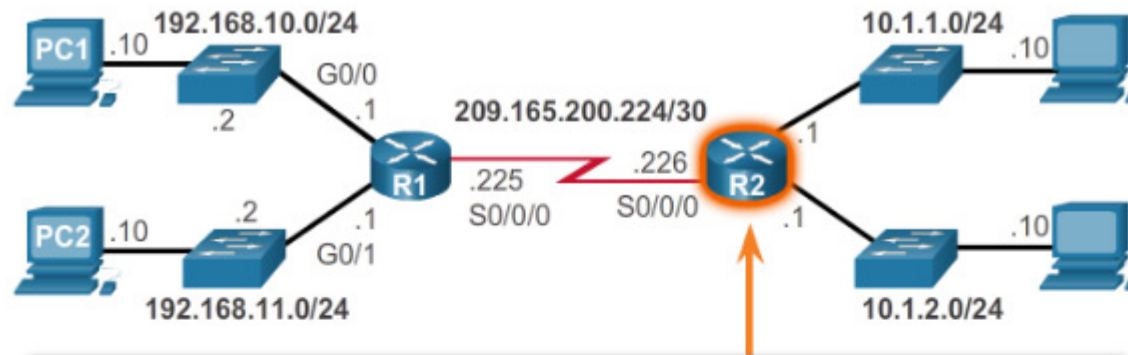
S* 0.0.0.0/0 is directly connected, Serial0/0/0
  192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C   192.168.10.0/24 is directly connected, GigabitEthernet0/0
L   192.168.10.1/32 is directly connected, GigabitEthernet0/0
  192.168.11.0/24 is variably subnetted, 2 subnets, 2 masks
C   192.168.11.0/24 is directly connected, GigabitEthernet0/1
L   192.168.11.1/32 is directly connected, GigabitEthernet0/1
```




Statically Learned Routes

Static Route Example (cont.)

Entering and Verifying a Static Route



```
R2(config)# ip route 192.168.10.0 255.255.255.0 s0/0/0
R2(config)# ip route 192.168.11.0 255.255.255.0 209.165.200.225
R2(config)# exit
R2#
R2# show ip route | begin Gateway
Gateway of last resort is not set

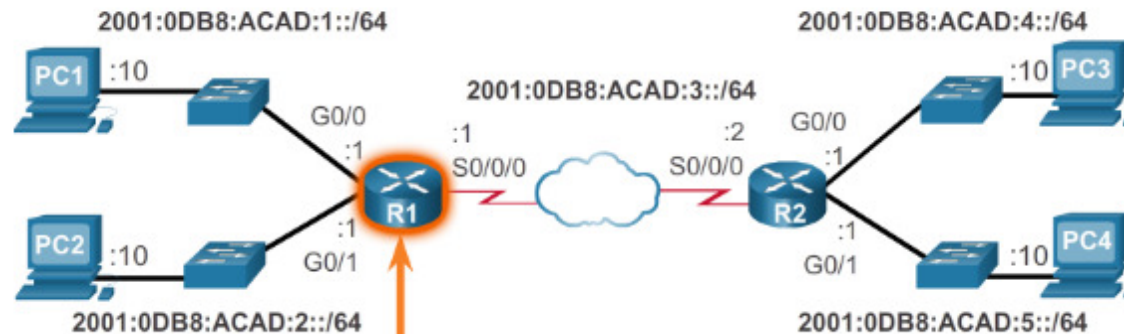
10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C    10.1.1.0/24 is directly connected, GigabitEthernet0/0
L    10.1.1.1/32 is directly connected, GigabitEthernet0/0
C    10.1.2.0/24 is directly connected, GigabitEthernet0/1
L    10.1.2.1/32 is directly connected, GigabitEthernet0/1
S    192.168.10.0/24 is directly connected, Serial0/0/0
S    192.168.11.0/24 [1/0] via 209.165.200.225
209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C    209.165.200.224/30 is directly connected, Serial0/0/0
```



Statically Learned Routes

Static IPv6 Route Examples

Entering and Verifying an IPv6 Static Default Route



```
R1(config)# ipv6 route ::/0 s0/0/0
R1(config)# exit
R1#

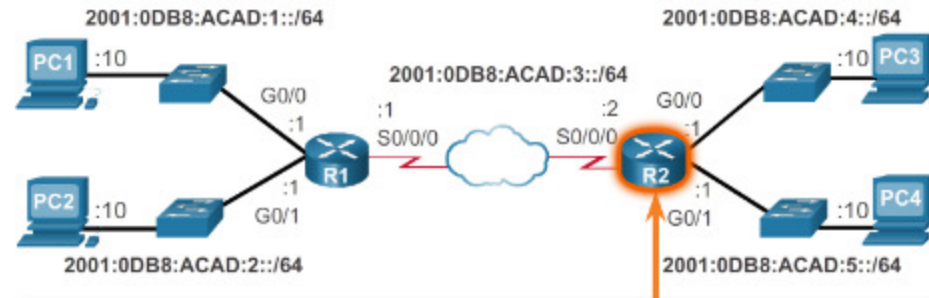
R1# show ipv6 route
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static
route
B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary,
D - EIGRP
EX - EIGRP external, ND - ND Default, NDp - ND Prefix,
DCE - Destination
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
S ::/0 [1/0]
  via Serial0/0/0, directly connected
C 2001:0DB8:ACAD:1::/64 [0/0]
  via GigabitEthernet0/0, directly connected
```



Statically Learned Routes

Static IPv6 Route Examples

Entering and Verifying IPv6 Static Routes



```
R2(config)# ipv6 route 2001:0DB8:ACAD:1::/64 2001:0DB8:ACAD:3::1
R2(config)# ipv6 route 2001:0DB8:ACAD:2::/64 s0/0/0
R2(config)# ^Z
R2#
```

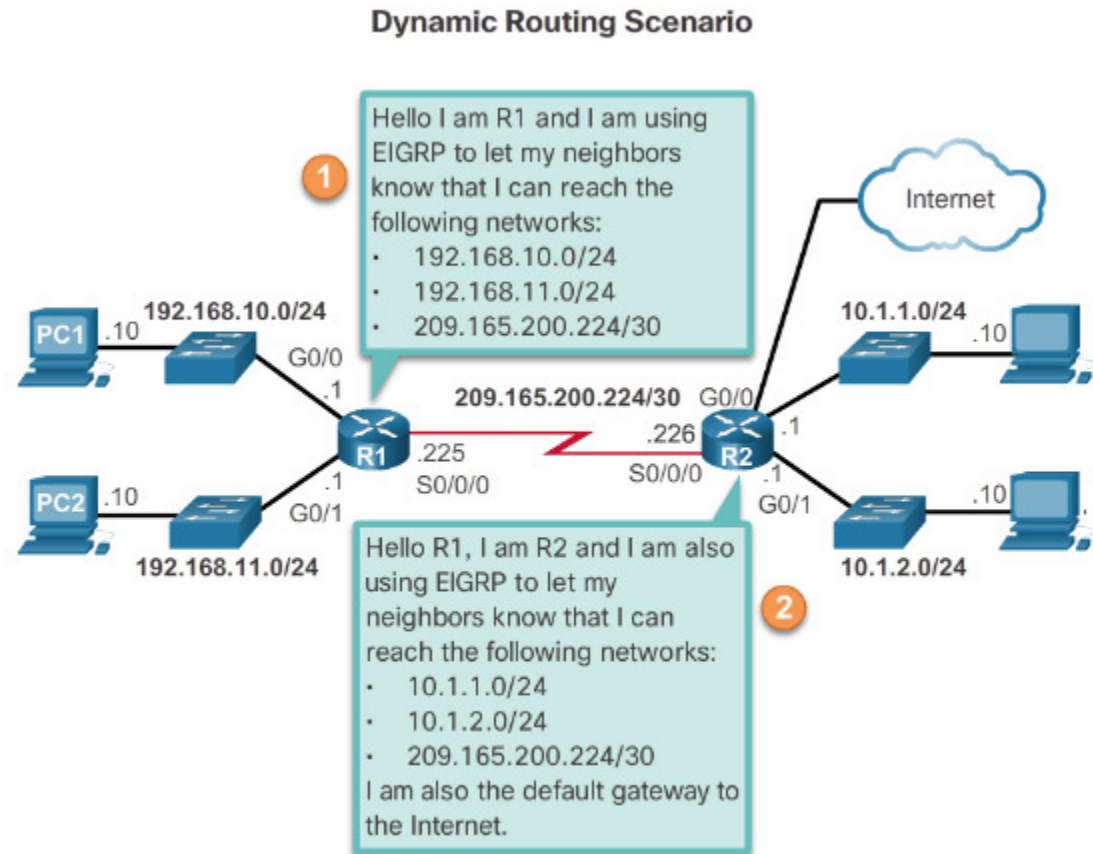
```
R2# show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static,
       U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary,
       D - EIGRP
       EX - EIGRP external, ND - 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
S 2001:0DB8:ACAD:1::/64 [1/0]
  via 2001:0DB8:ACAD:3::1
S 2001:0DB8:ACAD:2::/64 [1/0]
  via Serial0/0/0, directly connected
```




Dynamic Routing Protocols

Dynamic Routing

- Dynamic routing is used by routers to share information about the reachability and status of remote networks.
- It performs network discovery and maintains routing tables.
- Routers have converged after they have finished exchanging and updating their routing tables.





Dynamic Routing Protocols

IPv4 Routing Protocols

Cisco routers can support a variety of dynamic IPv4 routing protocols including:

- **EIGRP** – Enhanced Interior Gateway Routing Protocol
- **OSPF** – Open Shortest Path First
- **IS-IS** – Intermediate System-to-Intermediate System
- **RIP** – Routing Information Protocol

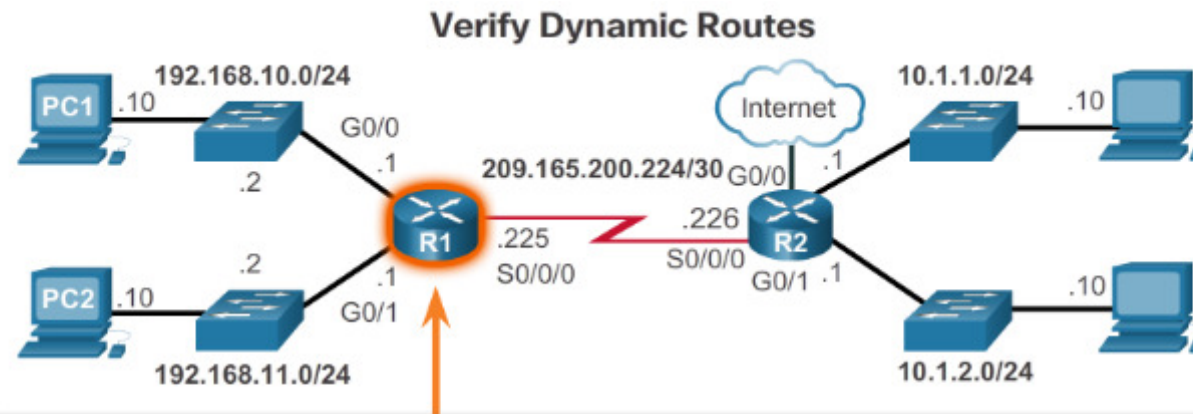
Use the **router ?** Command in global configuration mode to determine which routing protocols are supported by the IOS.

```
R1(config)# router ?
  bgp      Border Gateway Protocol (BGP)
  eigrp     Enhanced Interior Gateway Routing Protocol (EIGRP)
  isis      ISO IS-IS
  iso-igrp  IGRP for OSI networks
  mobile    Mobile routes
  odr       On Demand stub Routes
  ospf      Open Shortest Path First (OSPF)
  ospfv3    OSPFv3
  rip       Routing Information Protocol (RIP)
R1(config)# router
```



Dynamic Routing Protocols

IPv4 Dynamic Routing Examples



```
R1# show ip route | begin Gateway
Gateway of last resort is 209.165.200.226 to network 0.0.0.0

D*EX 0.0.0.0/0 [170/2297856] via 209.165.200.226, 00:07:29, Serial0/0/0
      10.0.0.0/24 is subnetted, 2 subnets
D      10.1.1.0 [90/2172416] via 209.165.200.226, 00:07:29, Serial0/0/0
D      10.1.2.0 [90/2172416] via 209.165.200.226, 00:07:29, Serial0/0/0
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C      192.168.10.0/24 is directly connected, GigabitEthernet0/0
L      192.168.10.1/32 is directly connected, GigabitEthernet0/0
      192.168.11.0/24 is variably subnetted, 2 subnets, 2 masks
C      192.168.11.0/24 is directly connected, GigabitEthernet0/1
L      192.168.11.1/32 is directly connected, GigabitEthernet0/1
      209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C      209.165.200.224/30 is directly connected, Serial0/0/0
L      209.165.200.225/32 is directly connected, Serial0/0/0
R1#
```



Dynamic Routing Protocols

IPv6 Routing Protocols

Cisco routers can support a variety of dynamic IPv6 routing protocols including:

- **RIPng** (RIP next generation)
- **OSPFv3**
- **EIGRP** for IPv6

Use the **ipv6 router ?** command to determine which routing protocols are supported by the IOS

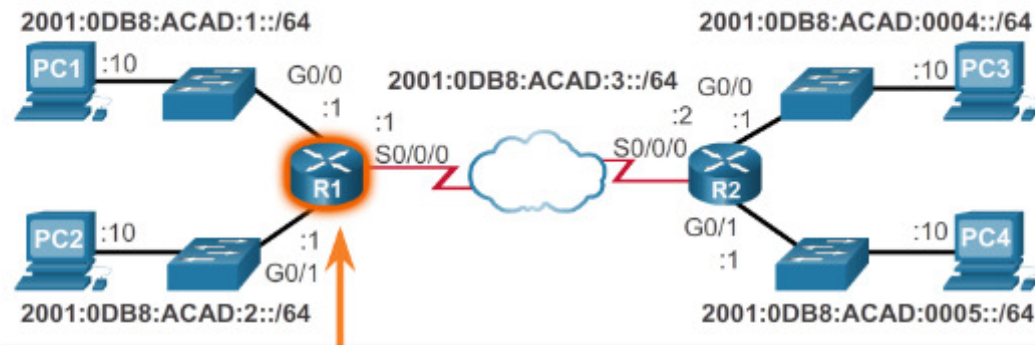
```
R1(config)# ipv6 router ?  
  eigrp      Enhanced Interior Gateway Routing Protocol (EIGRP)  
  ospf       Open Shortest Path First (OSPF)  
  rip        IPv6 Routing Information Protocol (RIPv6)  
  
R1(config)# router
```



Dynamic Routing Protocols

IPv6 Dynamic Routing Examples

Verify Dynamic Routes



```
R1# show ipv6 route
IPv6 Routing Table - default - 9 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:3::/64 [0/0]
  via Serial0/0/0, directly connected
L 2001:DB8:ACAD:3::1/128 [0/0]
  via Serial0/0/0, receive
D 2001:DB8:ACAD:4::/64 [90/2172416]
  via FE80::D68C:B5FF:FECE:A120, Serial0/0/0
D 2001:DB8:ACAD:5::/64 [90/2172416]
  via FE80::D68C:B5FF:FECE:A120, Serial0/0/0
L FF00::/8 [0/0]
  via Null0, receive
R1#
```




1.4 Chapter Summary



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Chapter Summary

Summary

- Describe the primary functions and features of a router.
- Configure basic settings on a router to route between two directly-connected networks, using CLI.
- Verify connectivity between two networks that are directly connected to a router.
- Explain how routers use information in data packets to make forwarding decisions in a small to medium-sized business network.
- Explain the encapsulation and de-encapsulation process used by routers when switching packets between interfaces.
- Explain the path determination function of a router.
- Explain how a router learns about remote networks when operating in a small to medium-sized business network.
- Explain how a router builds a routing table of directly connected networks.
- Explain how a router builds a routing table using static routes.
- Explain how a router builds a routing table using a dynamic routing protocol.

