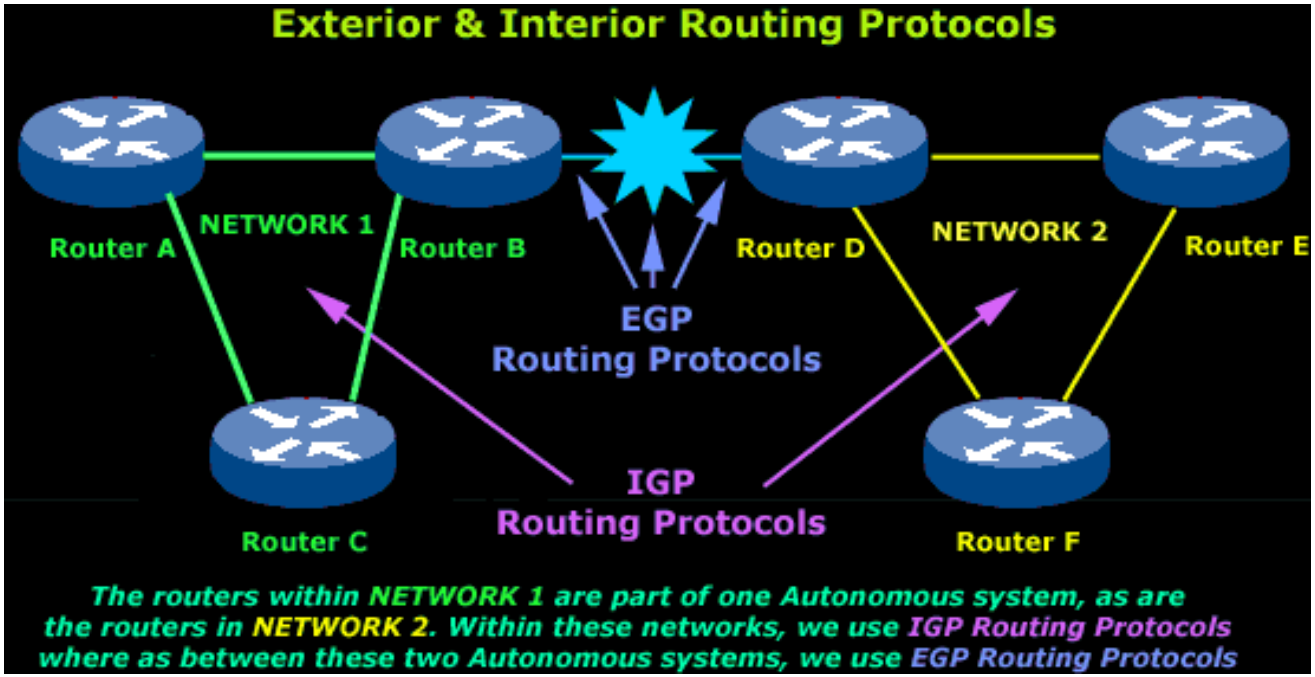
CIS 3210



Routing Concepts and Configuration

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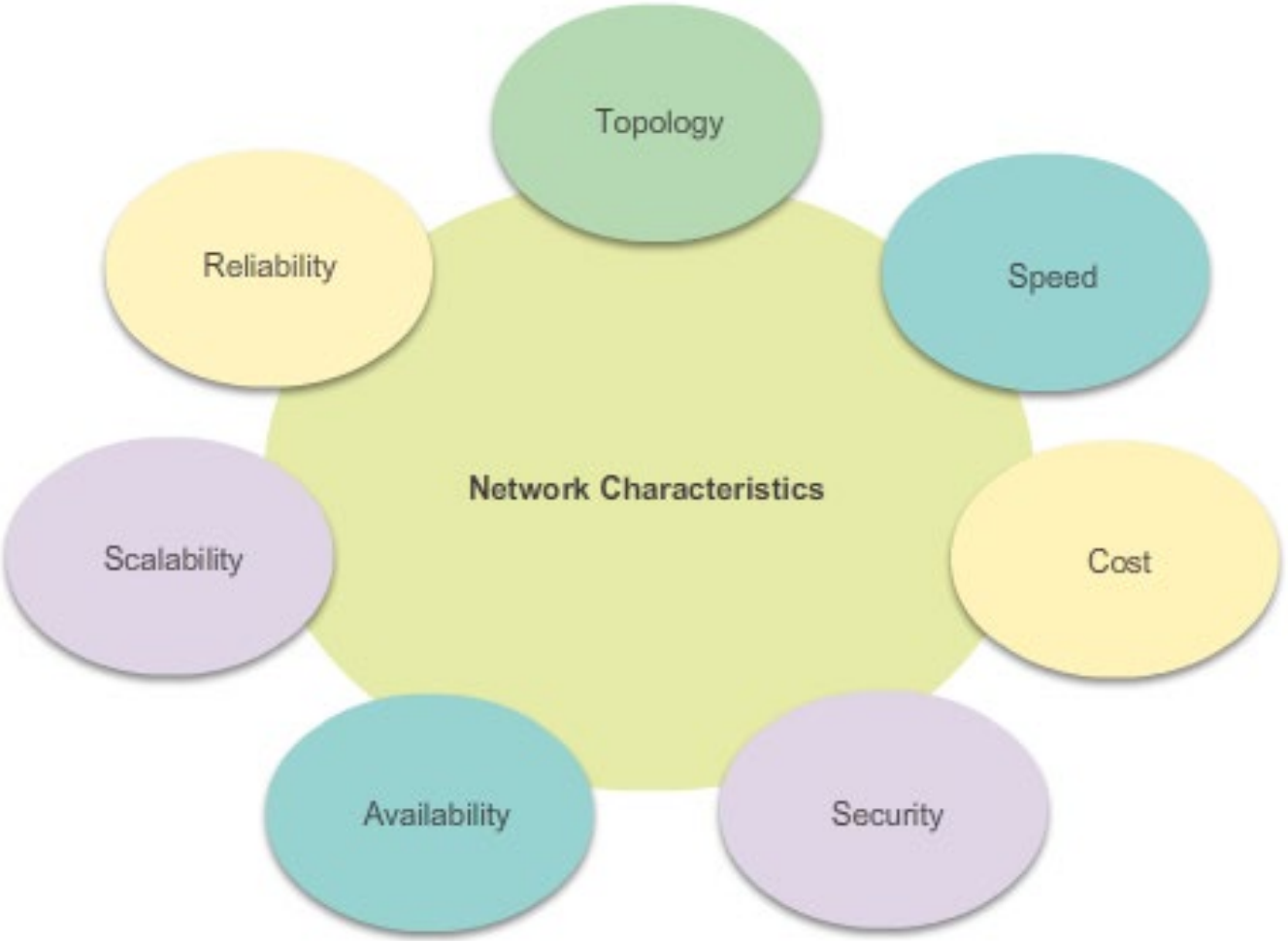
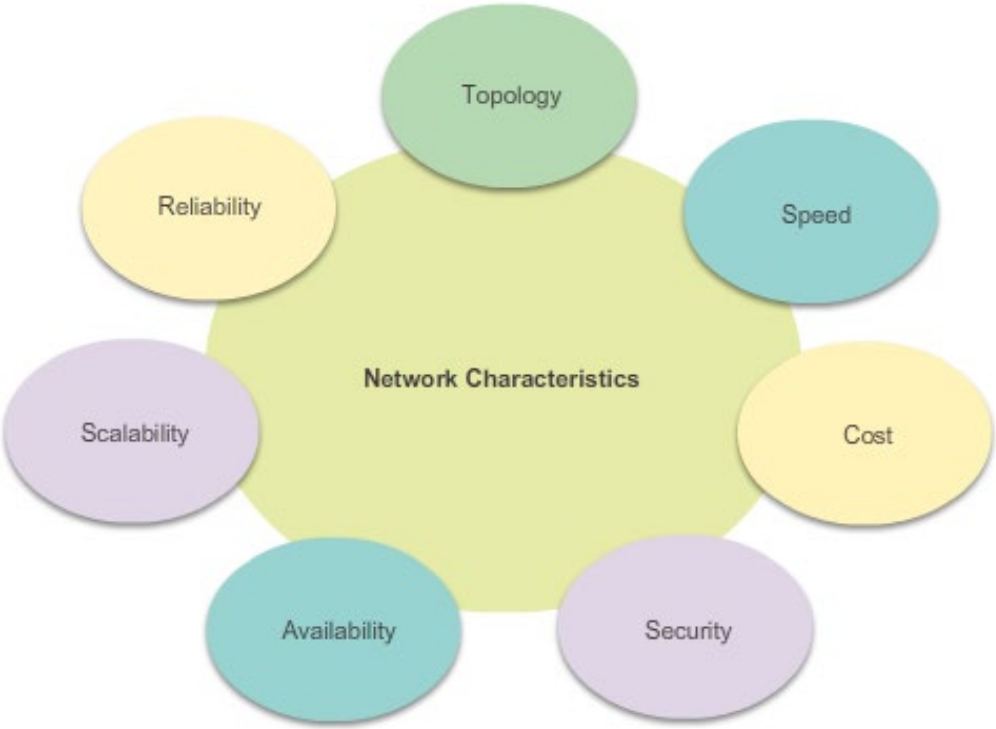
Note

- This course is about understanding, analyzing, and troubleshooting networks, not how to type commands.
- Example: **`show ip route`**
  - Type in the command (easy)
  - Explain what the output is displaying (understanding)
  - Explain why you are seeing this information (analyzing)
  - Determine if there is anything missing or if there is something you shouldn't be seeing (troubleshooting)

Network Characteristics and Attributes

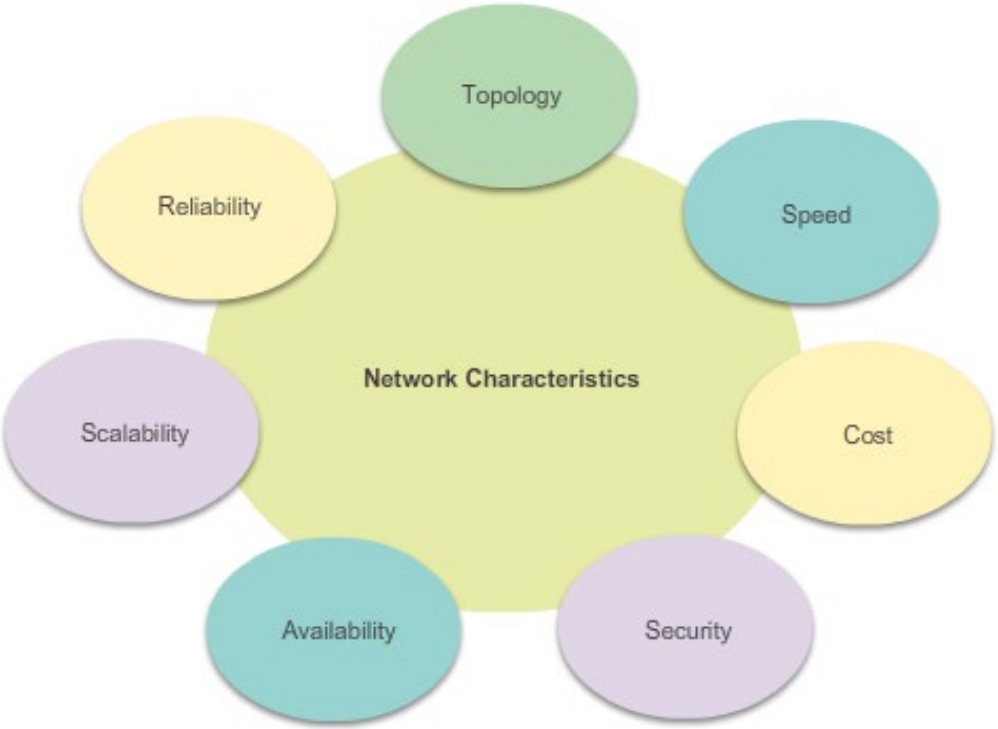


Topology



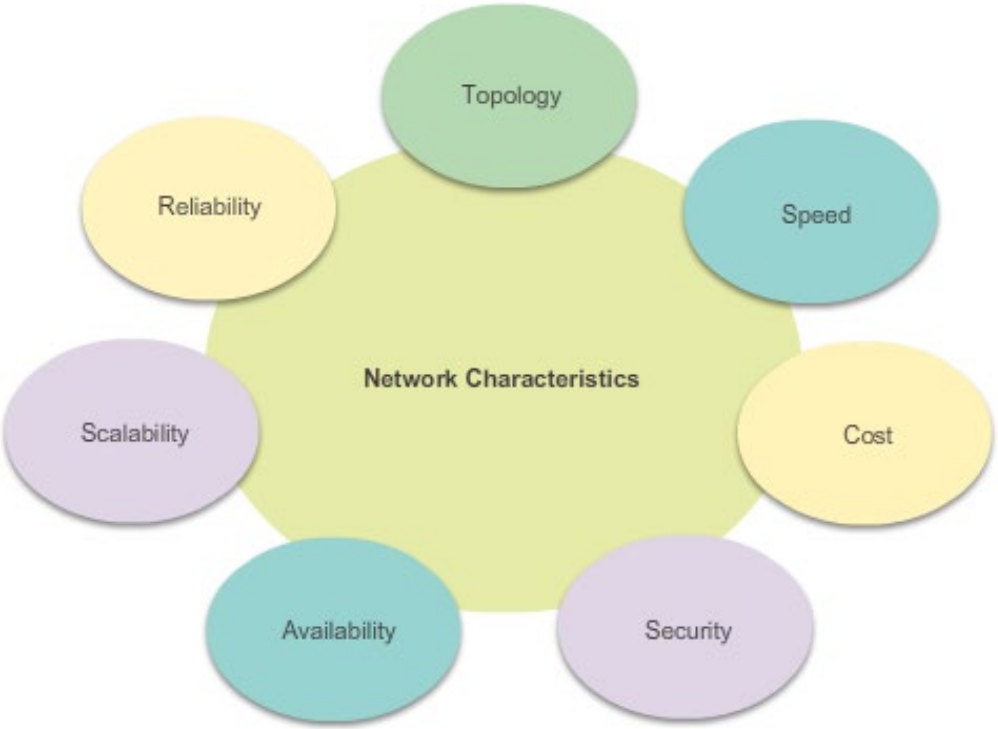
- **Physical Topology:**
  - Is the arrangement of the cables, network devices, and end systems.
  - It describes how the network devices are actually interconnected with wires and cables.
- **Logical Topology:**
  - Is the path over which the data is transferred in a network.
  - It describes how the network devices appear connected to network users.

Network Attributes



- **Speed:**
  - The measure of the data rate in bits per second (b/s) of a given link.
- **Cost:**
  - Indicates the general expense for purchasing of network components, and installation and maintenance of the network.
- **Security:**
  - Indicates how protected the network is, including the information that is transmitted over the network.

Network Attributes



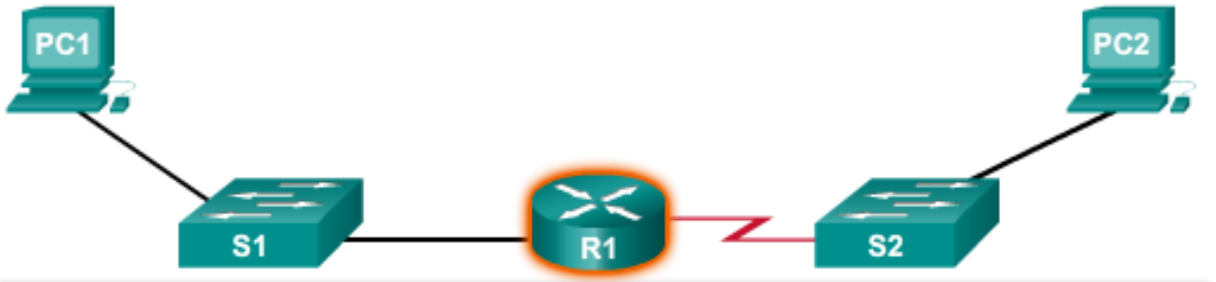
- **Availability:**
  - Is a measure of the probability that the network is available for use when it is required.
- **Scalability:**
  - Indicates how easily the network can accommodate more users and data transmission requirements.
- **Reliability**:
  - Indicates the dependability of the components that make up the network, such as the routers, switches, PCs, and servers.
  - Often measured as a probability of failure or as the mean time between failures (MTBF).

Routers

Why Routing?

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

Routers Route Packets

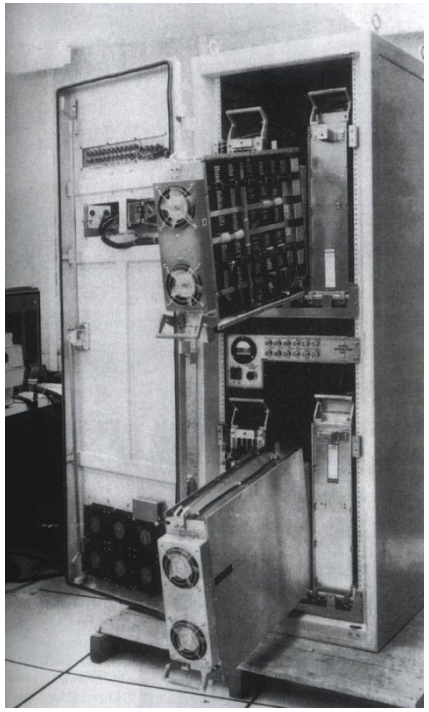



```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       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

C    192.168.1.0/24 is directly connected, FastEthernet0/0
C    192.168.2.0/24 is directly connected, Serial0/0
```

Cisco IOS command line interface (CLI) can be used to view the route table.

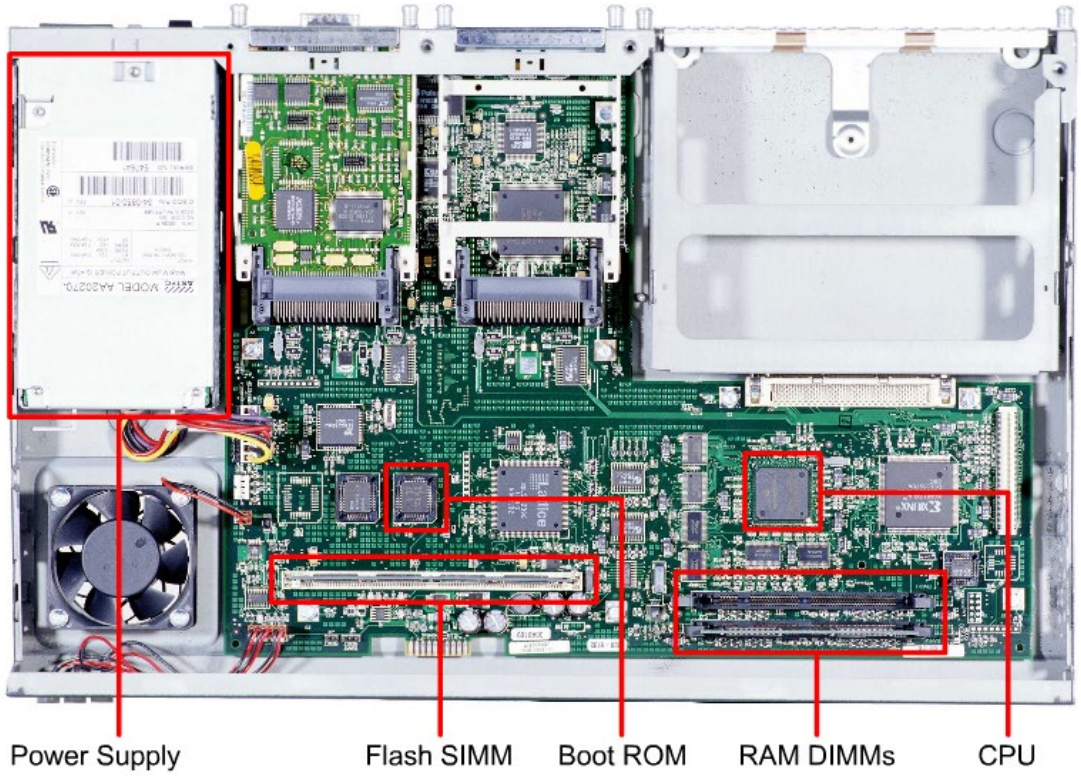
What is a Router?

Leonard Kleinrock and the first IMP.



- A router is a specialized computer!
  - It sends packets over the data network.
- It is responsible for interconnecting networks by selecting the best path for a packet to travel and forwarding packets to their destination
- The first router (ARPANET):
  - IMP (Interface Message Processor)
  - Honeywell 516 minicomputer
  - August 30, 1969

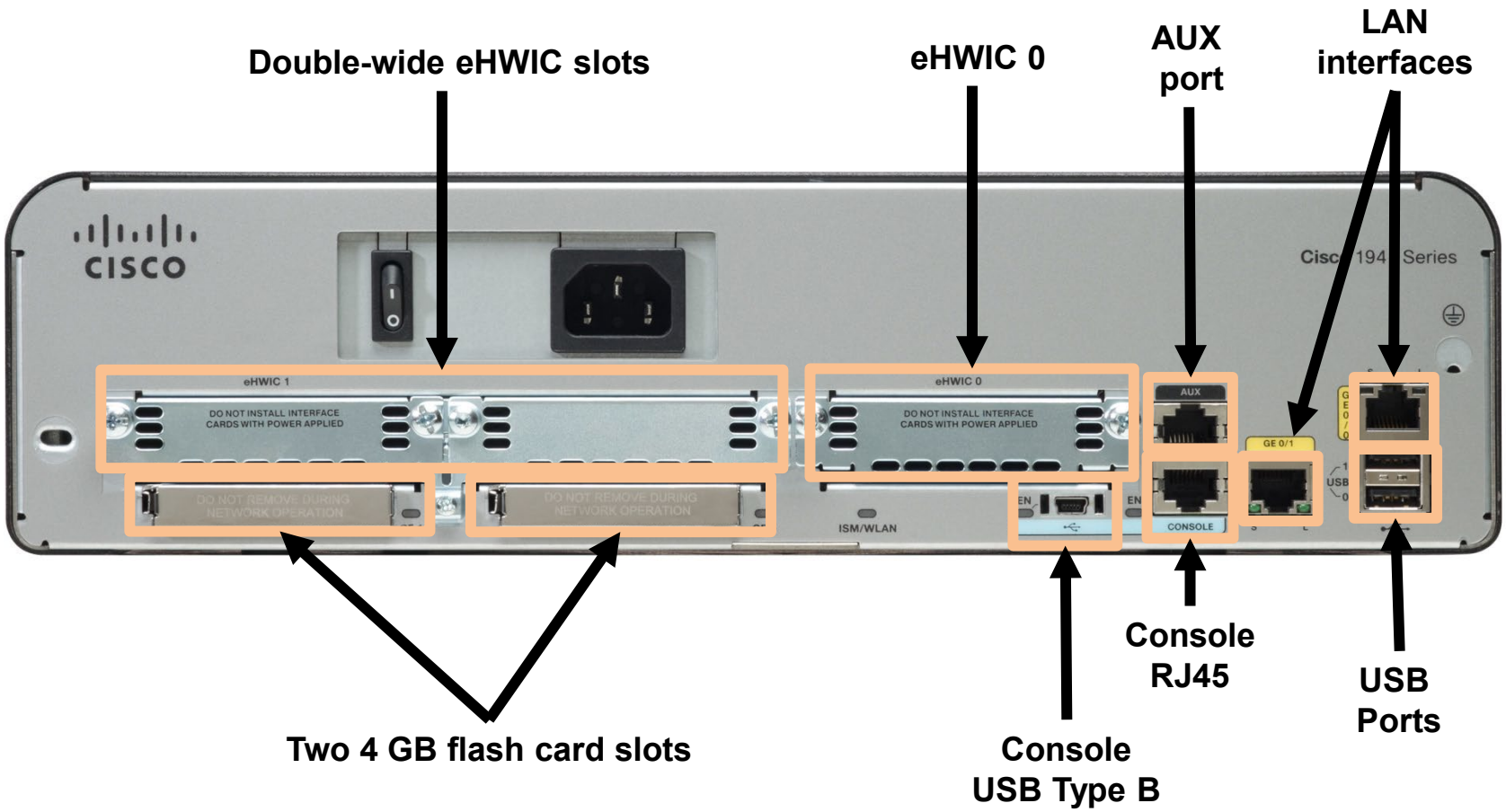
Router Components



- Regardless of their function, size or complexity, all router models are essentially computers and require:
  - Operating systems (OS)
  - Central processing units (CPU)
  - Random-access memory (RAM)
  - Read-only memory (ROM)
- *Routers also have special memory that includes Flash and non-volatile random-access memory (NVRAM).*

Router Backplane

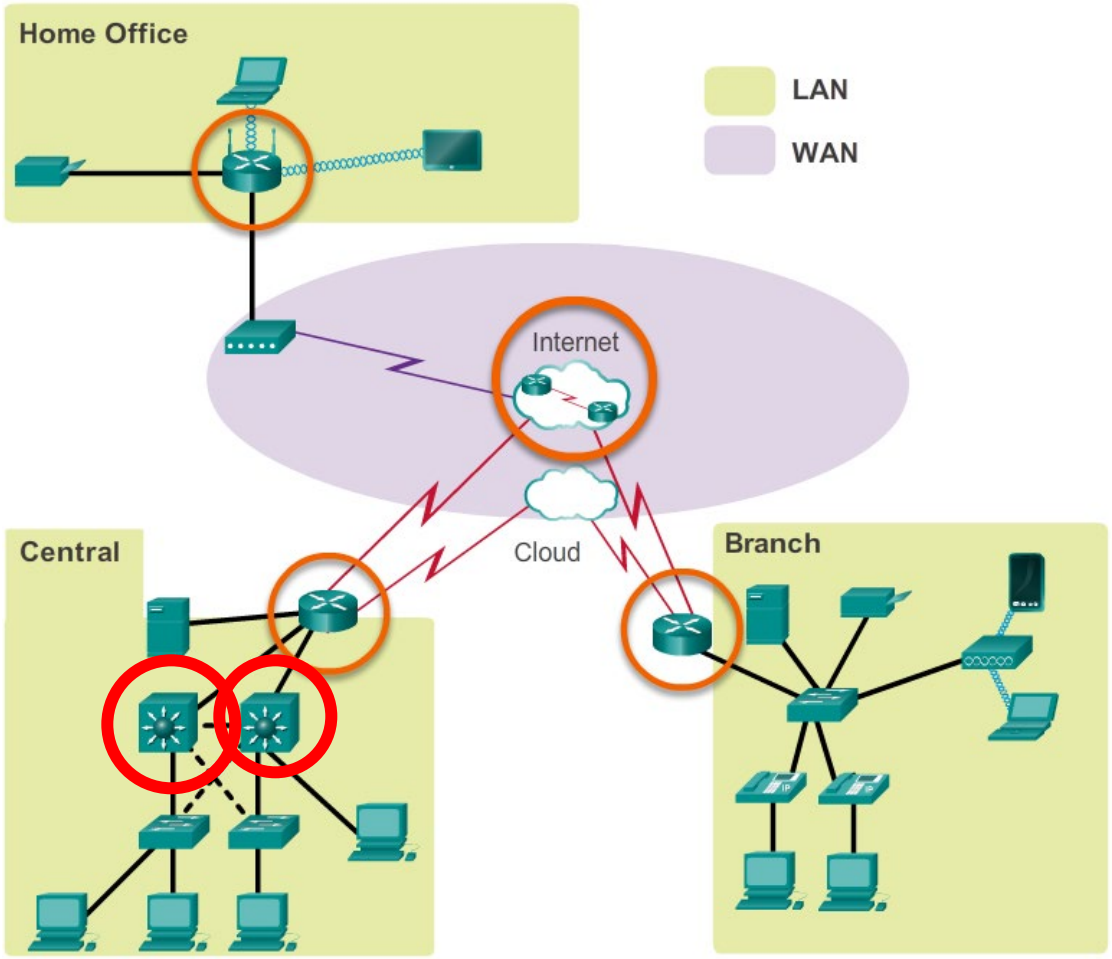
- The backplane of a router includes:



Routers vs Multilayer Switches

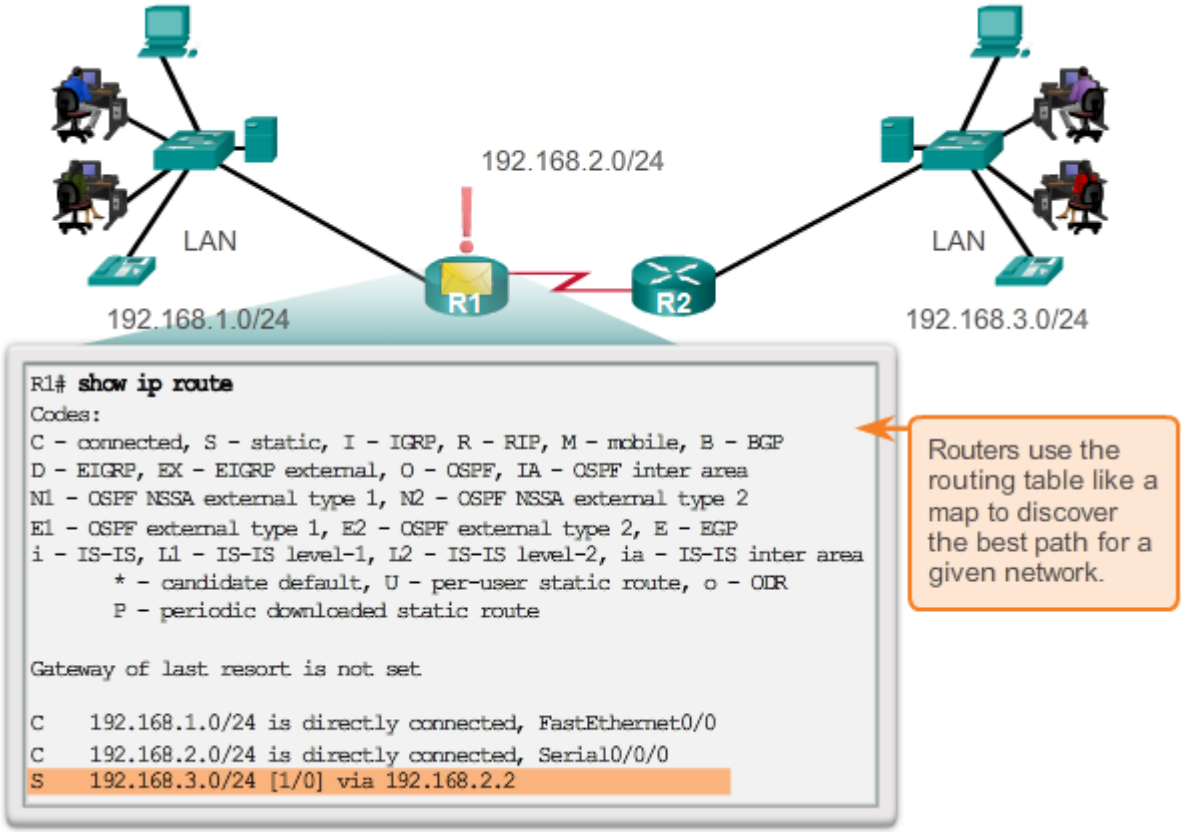
- Routers and multilayer switches both perform routing (connecting networks)
- Routers may have different types of interfaces (Ethernet, serial, ATM, etc.) while multilayer switches will only have Ethernet interfaces.
- While routers can be used to segment LAN devices, their major use is as WAN devices.
- Each devices does have its own advantages.

Routers in LANs and WANs



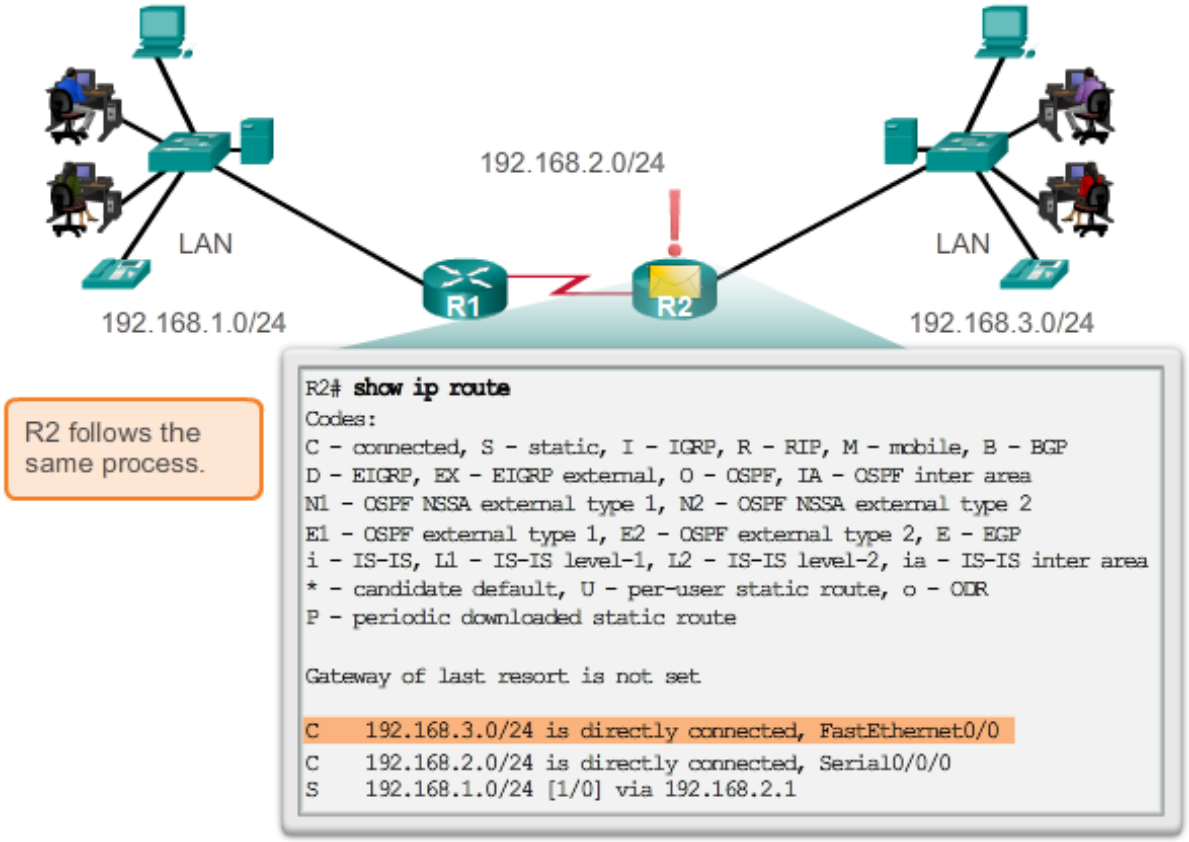
- Routers can connect multiple networks.
- Routers have multiple interfaces, each on a different IP network.

Best Path Decisions



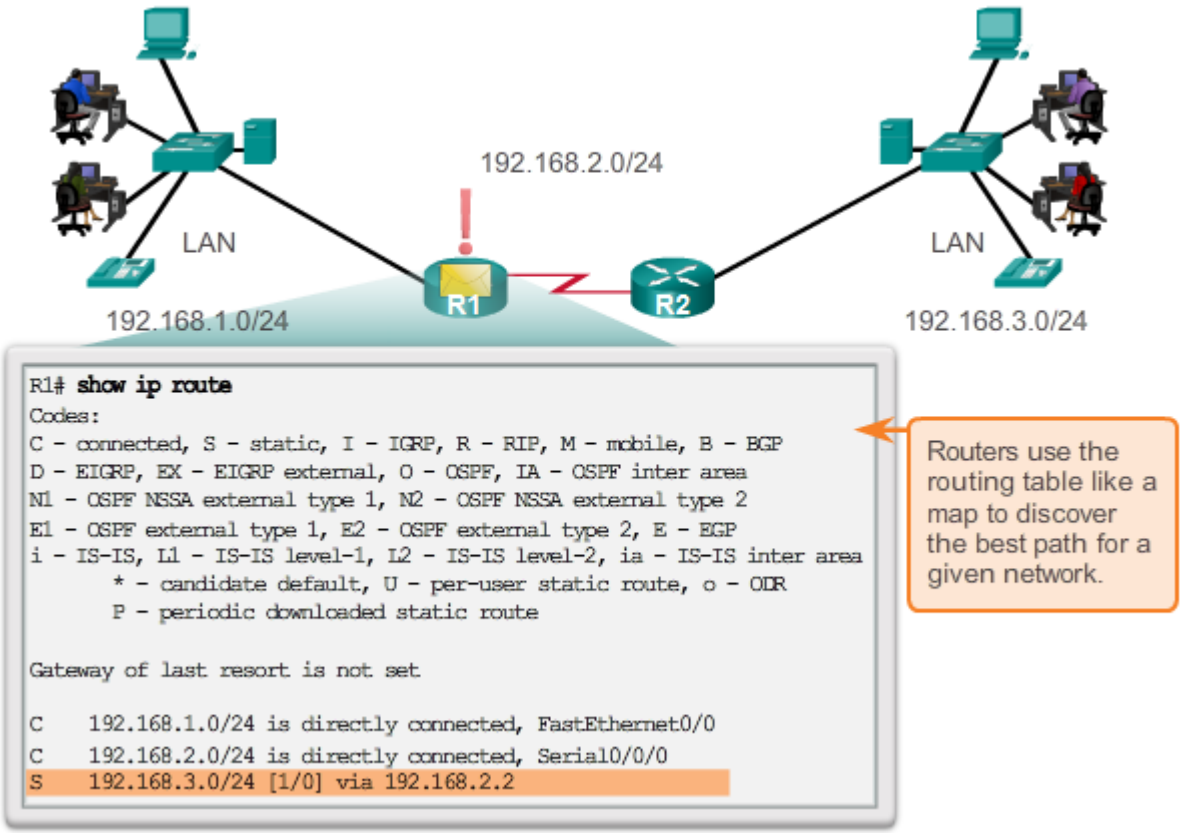
- The primary responsibility of a router is to direct packets by:
  - Determining the best path to send packets
  - Forwarding packets toward their destination

Best Path Decisions



- 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



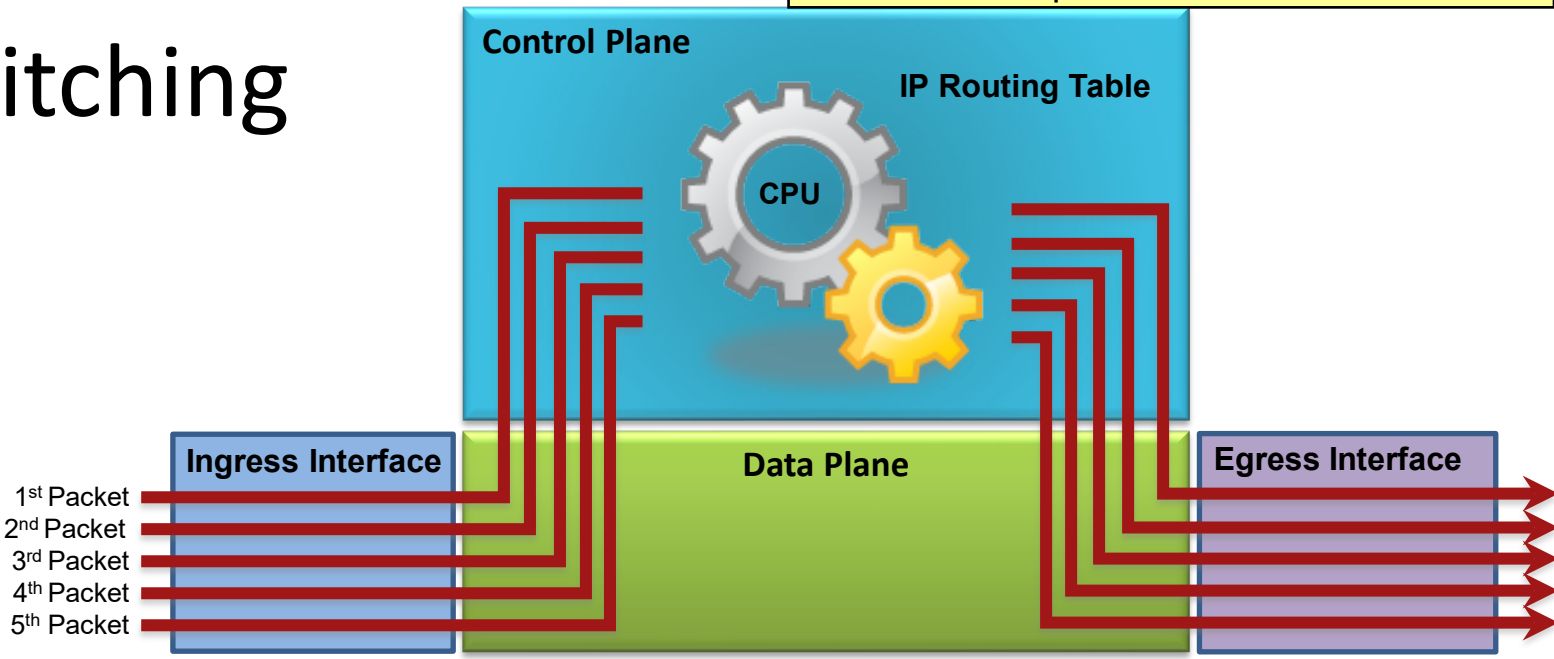
- Routing tables can be created:
  - Manually with static routes
  - Dynamically with routing protocols
- Routing protocols exchanges network topology (path) information with other routers.

Best Path Decisions

- The router uses its routing table to determine the best path to forward the packet.
  - The router examines its destination IP address of received packets and searches for the best match in the routing table.
  - The routing table entries also includes the interface to be used to forward the packet.
  - Once a match is found, the router encapsulates the IP packet into the data link frame of the outgoing or exit interface.
  - The packet is then forwarded toward its destination.
- Routers support three packet-forwarding mechanisms:
  - Process switching
  - Fast Switching
  - Cisco Express Forwarding (CEF)

Process Switching

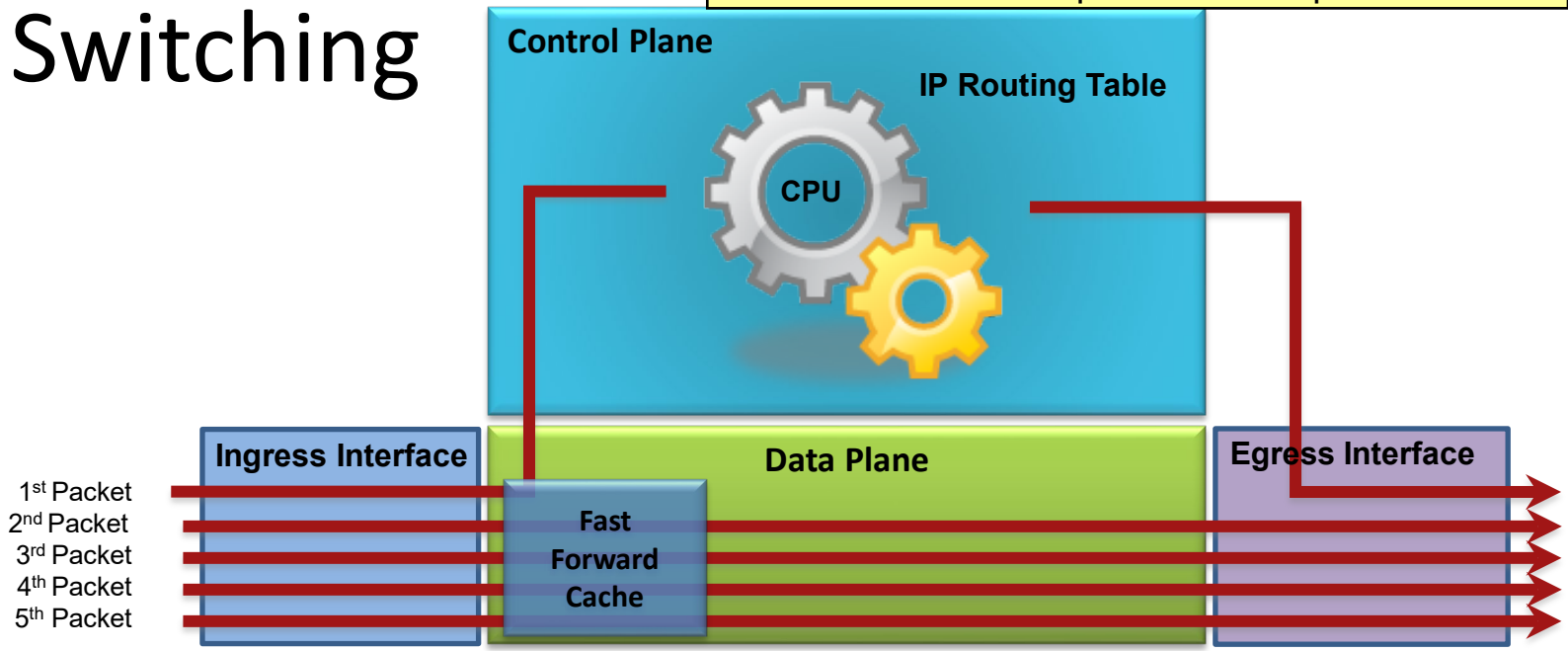
Analogy: Process switching solves a problem by doing math long hand, even if it is the identical problem.



- Earliest switching method. (Applies to both routers and multilayer switches.)
- This is an older packet forwarding mechanism.
  - When a packet arrives on an interface, it is forwarded to the control plane where the CPU examines the routing table, determines the exit interface and forwards the packet.
  - It does this for every packet, even if the destination is the same for a stream of packets.

Analogy: Fast switching solves a problem by doing math long hand one time and remembering the answer for subsequent identical problems.

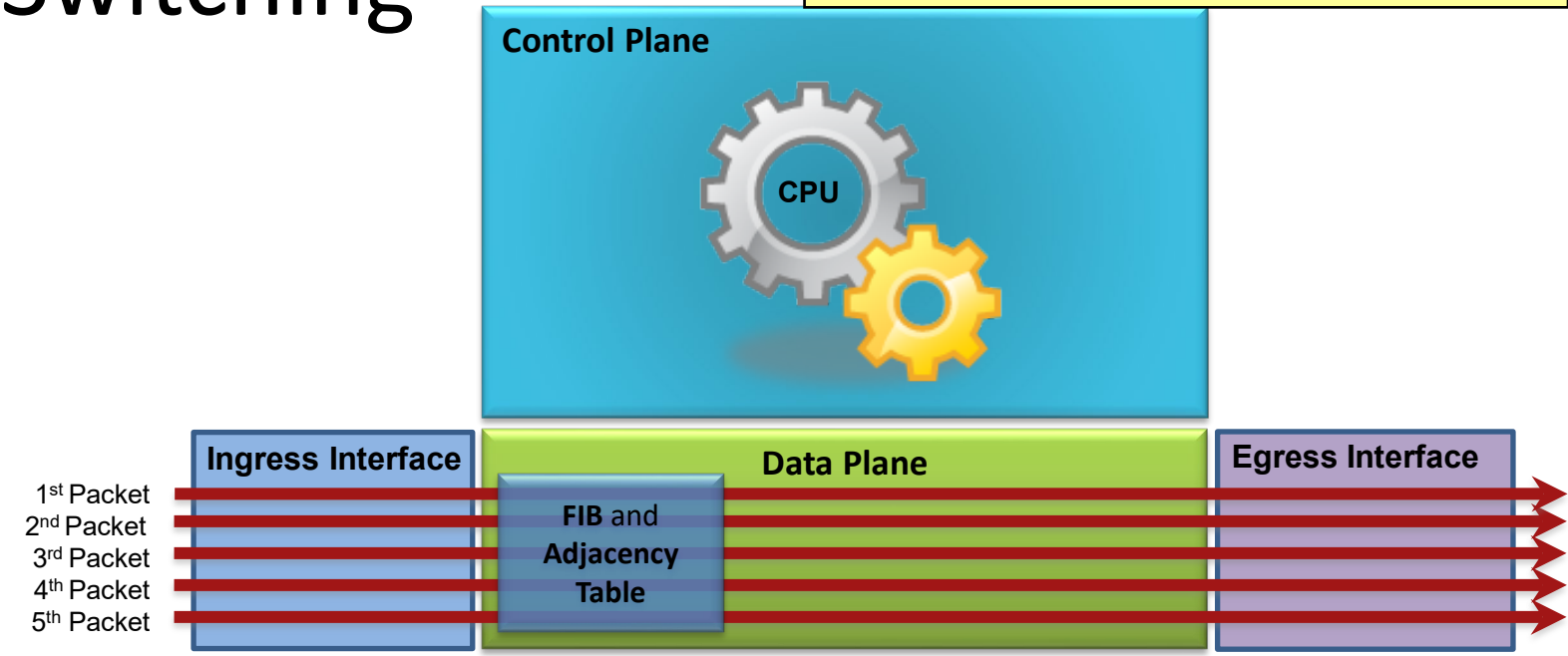
Fast Switching



- As routers had to process more packets, it was determined process switching was not fast enough.
- Next evolution in packet switching was Fast Switching. (Applies to both routers and multilayer switches.)
  - The first packet is process-switched (CPU + routing table) but it also uses a fast-switching cache to store next-hop information of the flow.
  - The next packets in the flow are forwarded using the cache and without CPU intervention.

CEF Switching

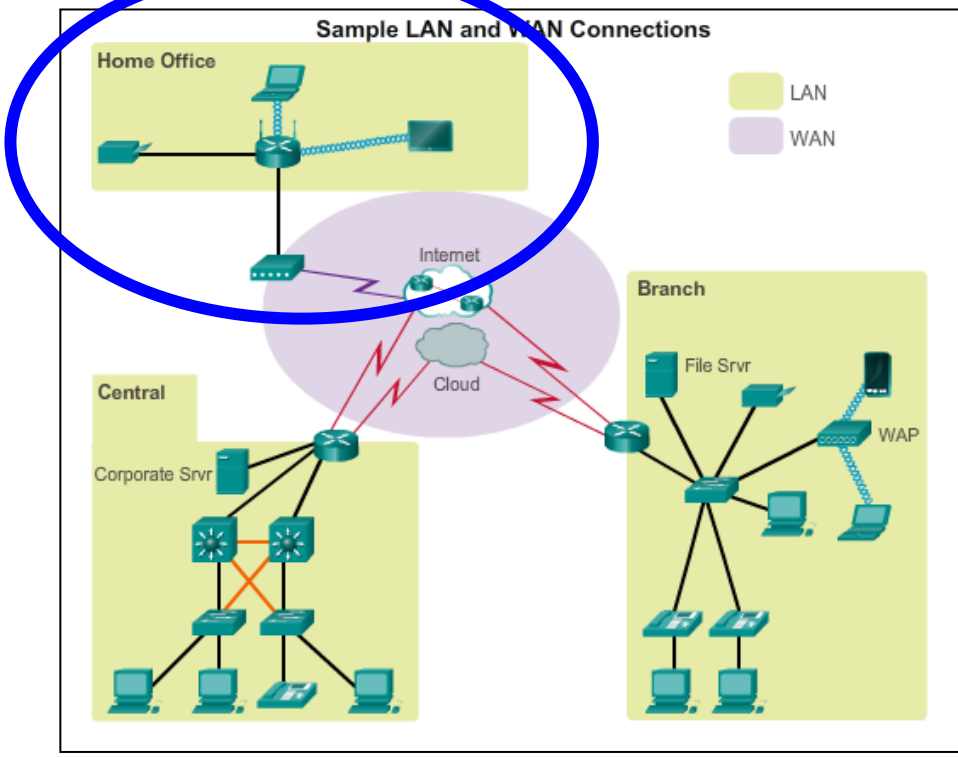
Analogy: CEF solves every possible problem ahead of time in a spreadsheet.



- Preferred and default Cisco IOS packet-forwarding mechanism for routers and multilayer switches.
  - CEF copies the routing table to the Forwarding Information Base (FIB)
  - CEF creates an adjacency table which contains all the layer 2 information a router would have to consider when forwarding a packet such as Ethernet destination MAC address.
  - The adjacency table is created from the ARP table.

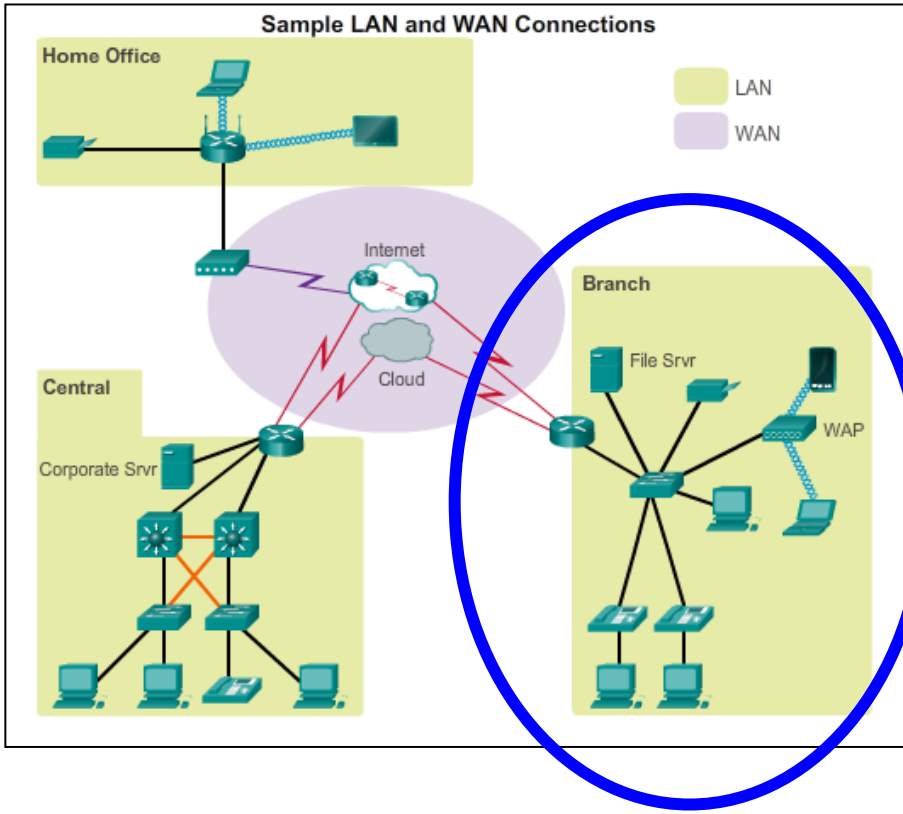
Home Office Devices Connect …

- Laptops and tablets connect wirelessly to a home router.
- A network printer connects using an Ethernet cable to the switch port on the home router.
- The home router connects to the service provider cable modem using an Ethernet cable.
- The cable modem connects to the Internet service provider (ISP) network.



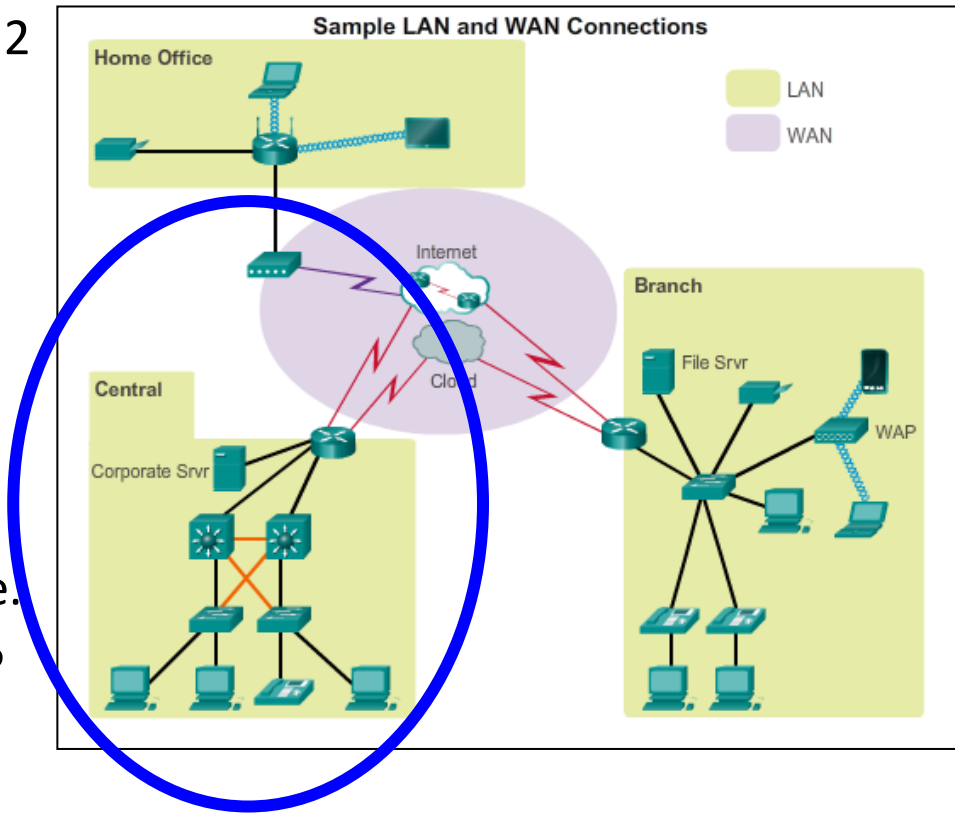
Branch Site Devices Connect …

- Corporate resources (i.e., file servers and printers) connect to Layer 2 switches.
- PCs and VoIP phones connect to Layer 2 Ethernet switches.
- Laptops and smartphones connect wirelessly to WAPs.
- WAPs connect to switches.
- Layer 2 switches connect to the edge router.
- The edge router connects to a WAN service provider (SP) and an ISP for backup purposes.



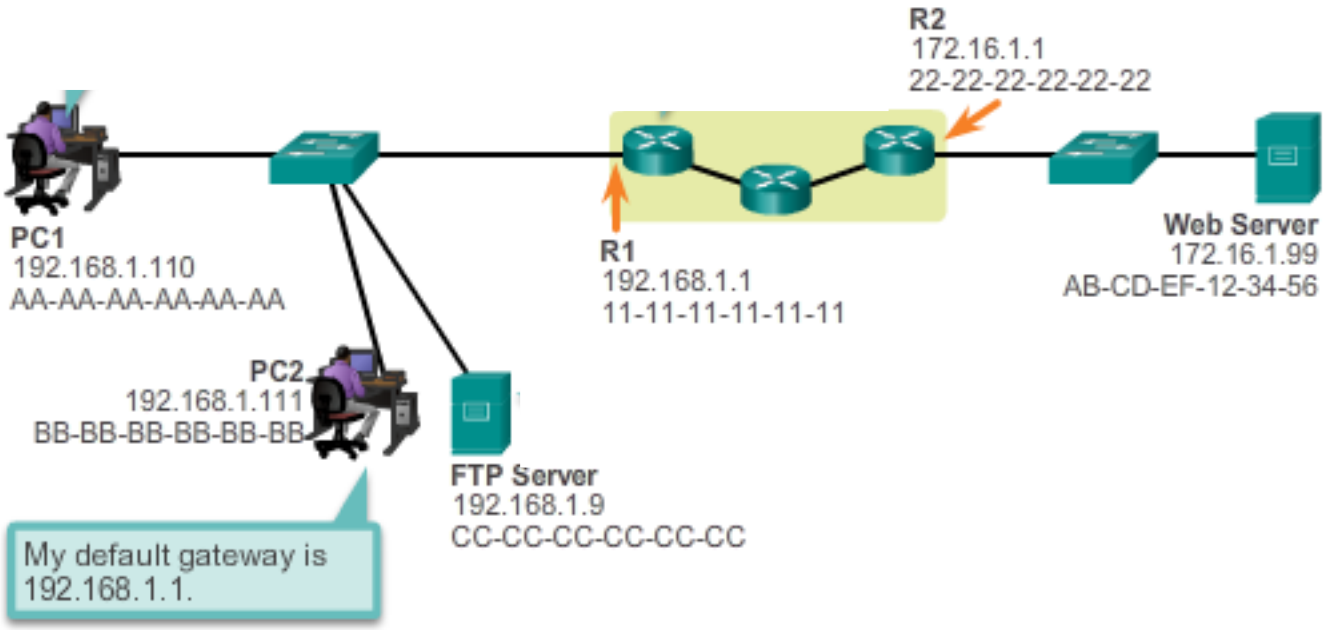
Central Site Devices Connect …

- PCs and VoIP phones connect to Layer 2 Ethernet switches.
- Layer 2 switches connect to Layer 3 switches using Ethernet fiber-optic cables.
- Layer 3 switches connect to the edge router.
- The corporate website server is connected to the edge router interface.
- The edge router connects to a WAN SP and an ISP for backup purposes.



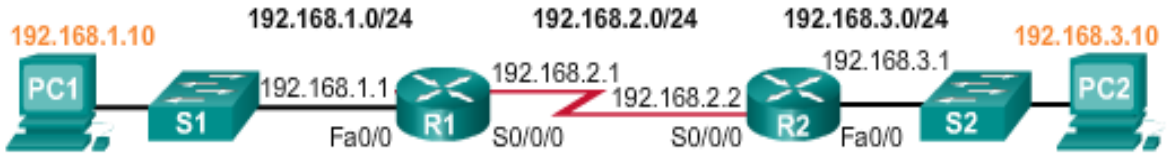
Destination MAC Address	Source MAC Address	Source IP Address	Destination MAC Address	Data
11-11-11-11-11-11	AA-AA-AA-AA-AA-AA	192.168.1.110	172.16.1.99	

Default Gateways



- To enable network access, devices must be configured with IP address information to identify the appropriate:
  - **IP address** - Identifies a unique host on a local network.
  - **Subnet mask** - Identifies with which network subnet the host can communicate.
  - **Default gateway** - Identifies the router to send a packet to when the destination is not on the same local network subnet.

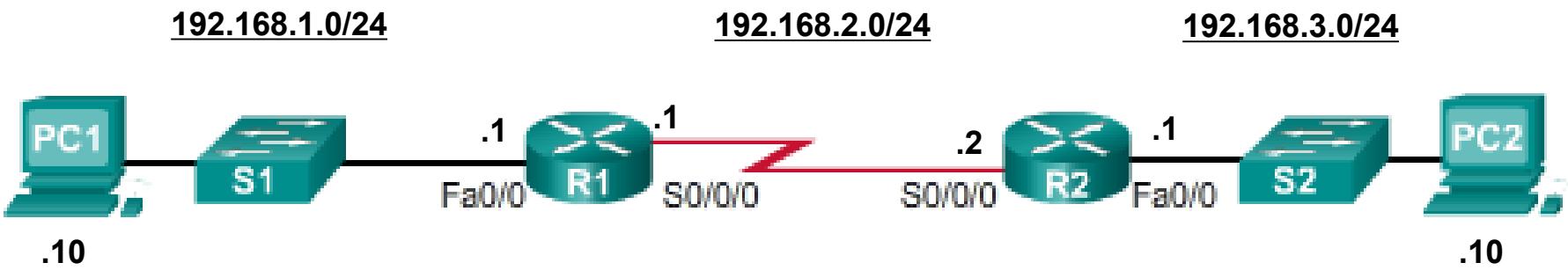
Documenting a Network



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

- Network documentation should identify:
  - Device names
  - Interfaces used in the design
  - IP addresses and subnet masks
  - Default gateway addresses
- Useful documents include:
  - Network topology diagram
  - Addressing Table

Documenting a Network

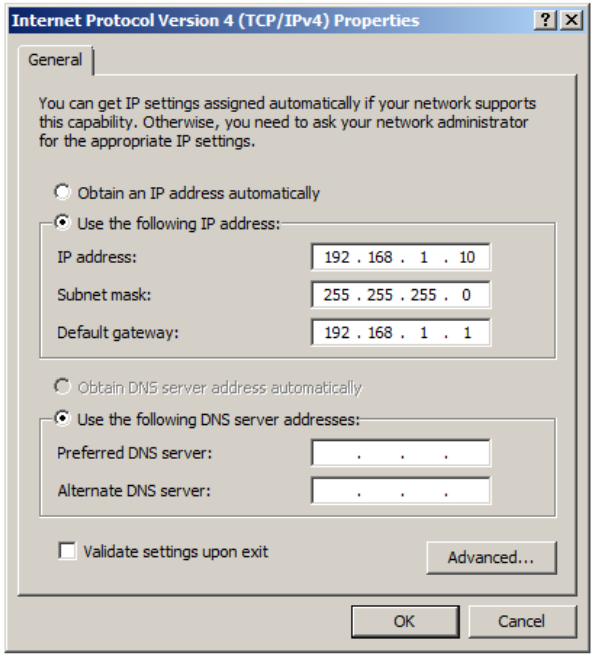


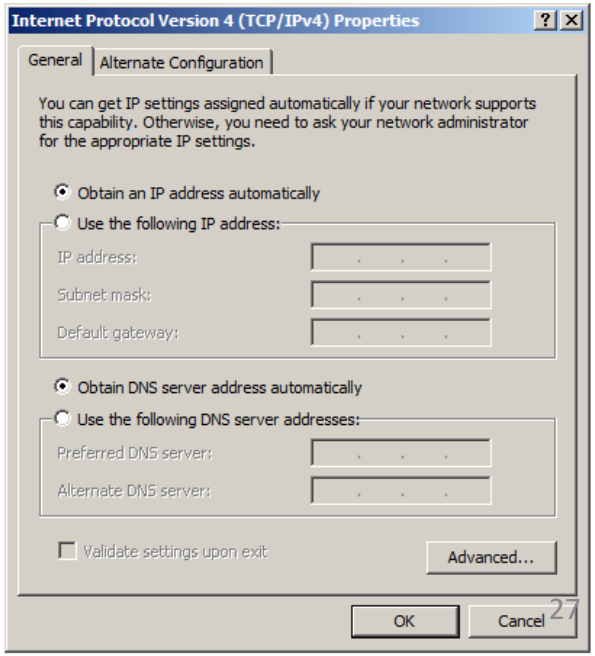
Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	Fa0/0	192.168.1.1	255.255.255.0	N/A
	S0/0/0	192.168.2.1	255.255.255.0	N/A
R2	Fa0/0	192.168.3.1	255.255.255.0	N/A
	S0/0/0	192.168.2.2	255.255.255.0	N/A
PC1	N/A	192.168.1.10	255.255.255.0	192.168.1.1
PC2	N/A	192.168.3.10	255.255.255.0	192.168.3.1

Hosts Addressing

- A host can be assigned IP address information either:
  - **Statically** - The host is manually assigned the correct IP address, subnet mask, and default gateway. The DNS server IP address can also be configured.
  - **Dynamically** - IP address information is provided by a server using the Dynamic Host Configuration Protocol (DHCP).

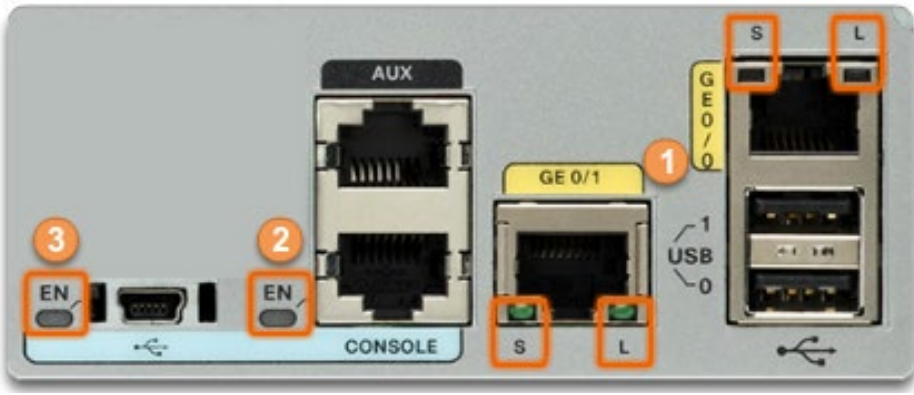
    The DHCP server provides a valid IP address, subnet mask, and default gateway for end devices. Other information may be provided by the server.





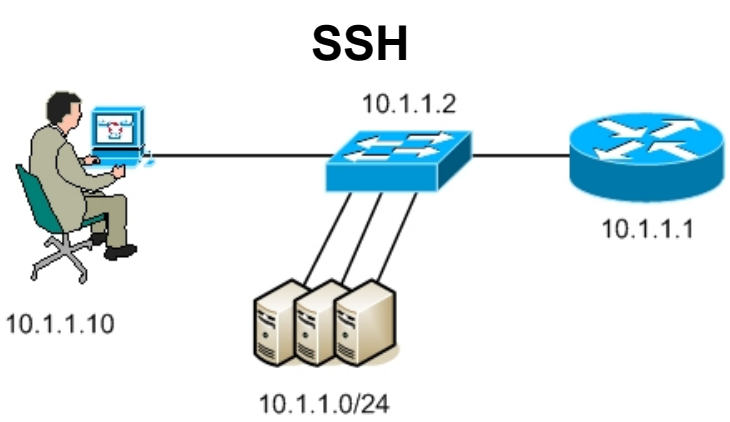
Device LEDs

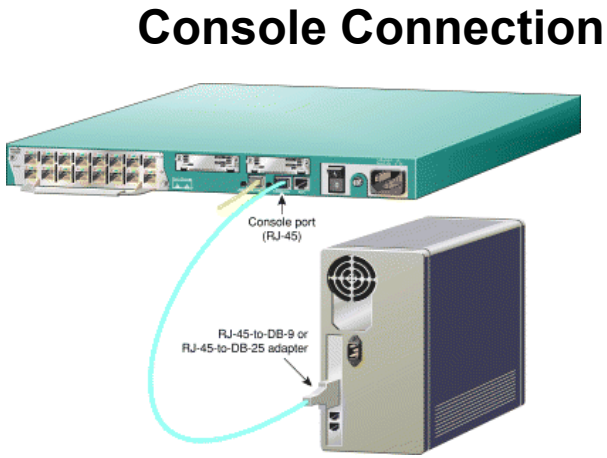
#	Port	LED	Color	Description
1	GE0/0 and GE0/1	S (Speed)	1 blink + pause	Port operating at 10 Mb/s
			2 blink + pause	Port operating at 100 Mb/s
			3 blink + pause	Port operating at 1000 Mb/s
		L (Link)	Green	Link is active
			Off	Link is inactive
2	Console	EN	Green	Port is active
			Off	Port is inactive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



- Most network interfaces have one or two LED link indicators next to the interface.
- Generally:
  - Green LED means a good connection
  - Blinking green LED indicates network activity.
  - No light then there may be a problem with either the network cable or the network itself.
- The switch port where the connection terminates would also have an LED indicator lit.
  - If one or both ends are not lit, try a different network cable.

Console Connection



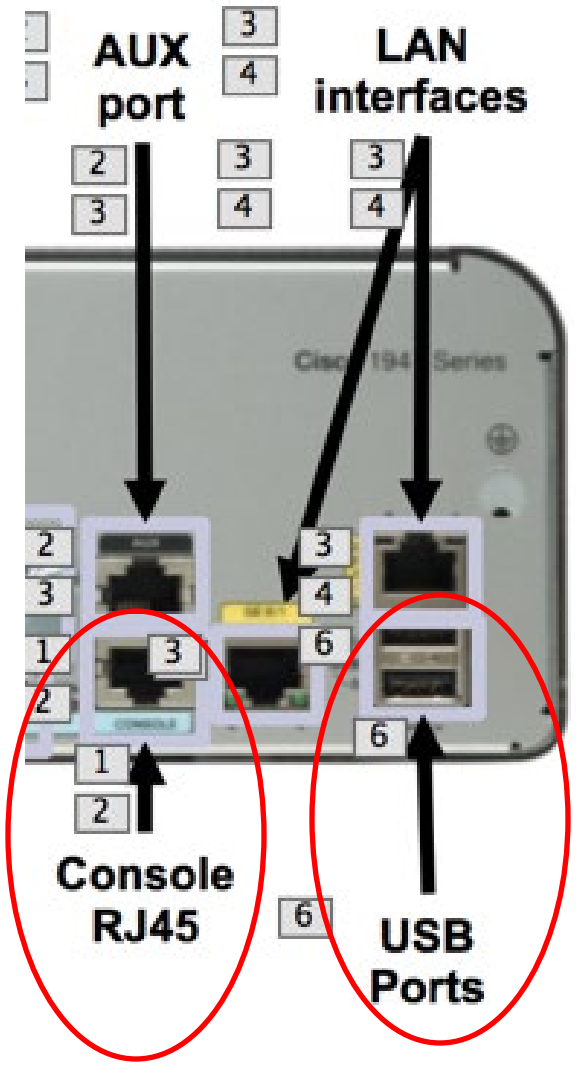


- In a production environment, infrastructure devices are commonly accessed remotely using Secure Shell (SSH) or Hypertext Transfer Protocol Secure (HTTPS).
- Console access is really only required when initially configuring a device, if remote access fails, or if the change may affect the remote access.
- Console access requires:
  - **Console cable** – RJ-45-to-DB-9 console cable
  - **Terminal emulation software** – Tera Term, PuTTY, etc.

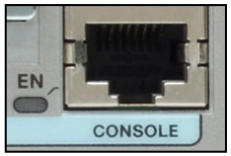
USB Serial Console Connection

- The Cisco ISR G2 supports a USB serial console connection.
  - To establish connectivity, a USB Type-A to USB Type-B (mini-B USB) is required, as well as an operating system device driver.
  - This device driver is available from http://www.cisco.com.

- Although these routers have two console ports, only one console port can be active at a time.
  - When a cable is plugged into the USB console port, the RJ-45 port becomes inactive.
  - When the USB cable is removed from the USB port, the RJ-45 port becomes active.

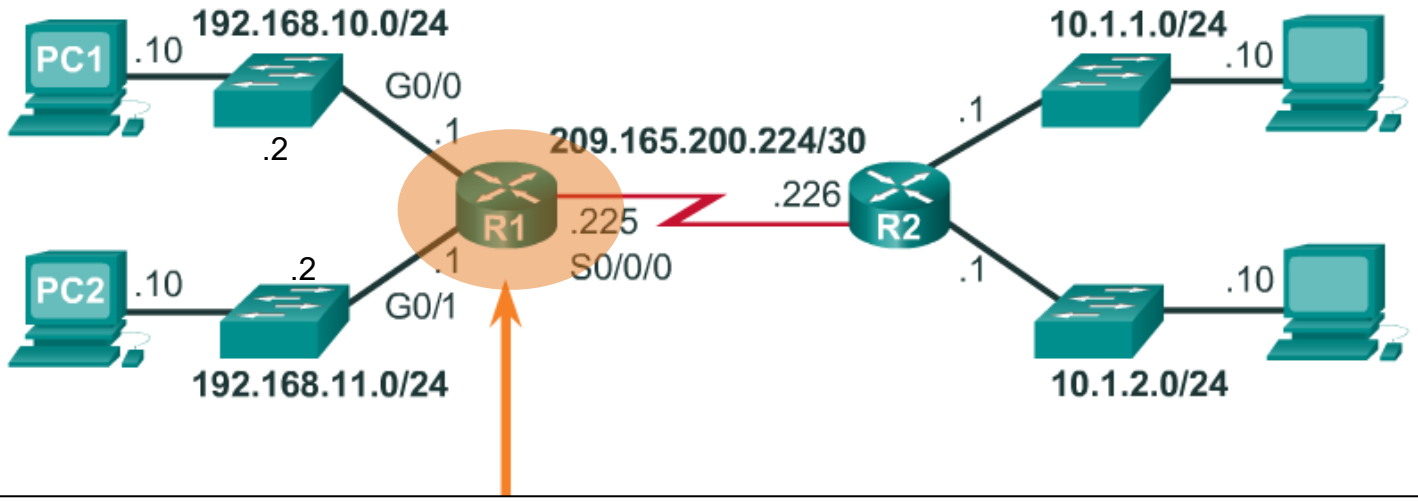


Console Connection Requirements

Port on Computer	Cable required	Port on ISR	Terminal emulation
		RJ45 Console port 	 Tera Term
USB Type-A port 			
			 PuTTY

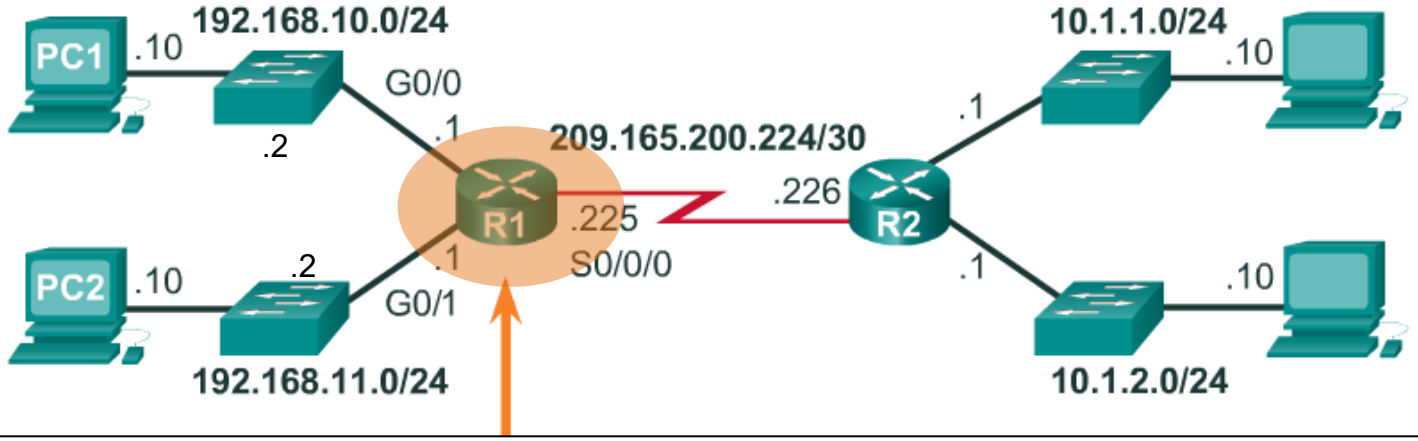
Configuring Routers

Name the Device



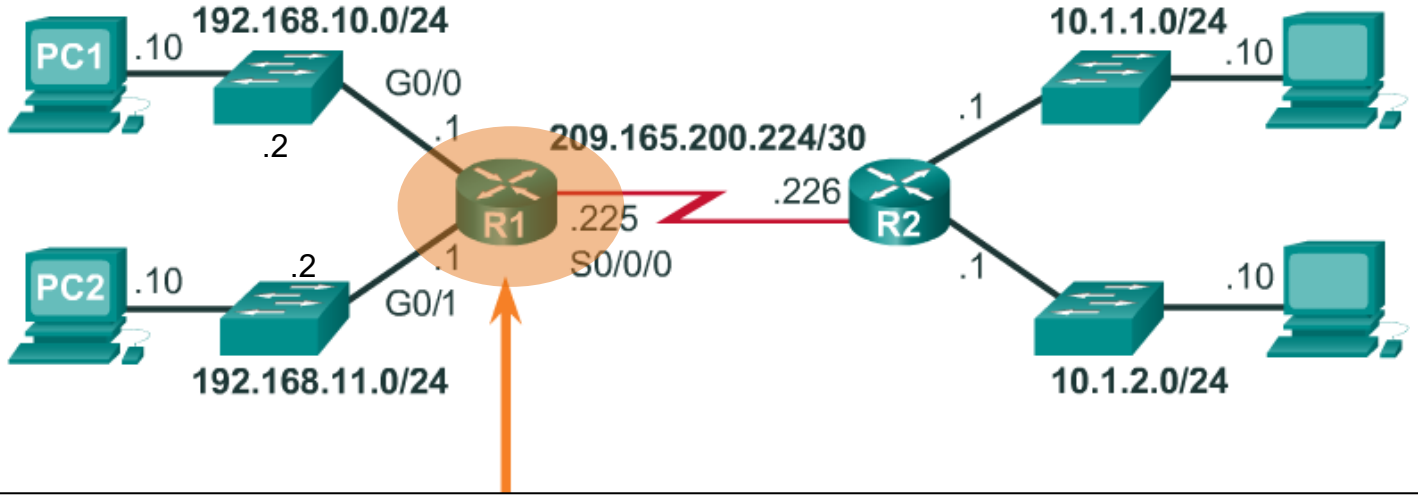

```
Router# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)# hostname R1
R1(config)#
```

Secure Management Access



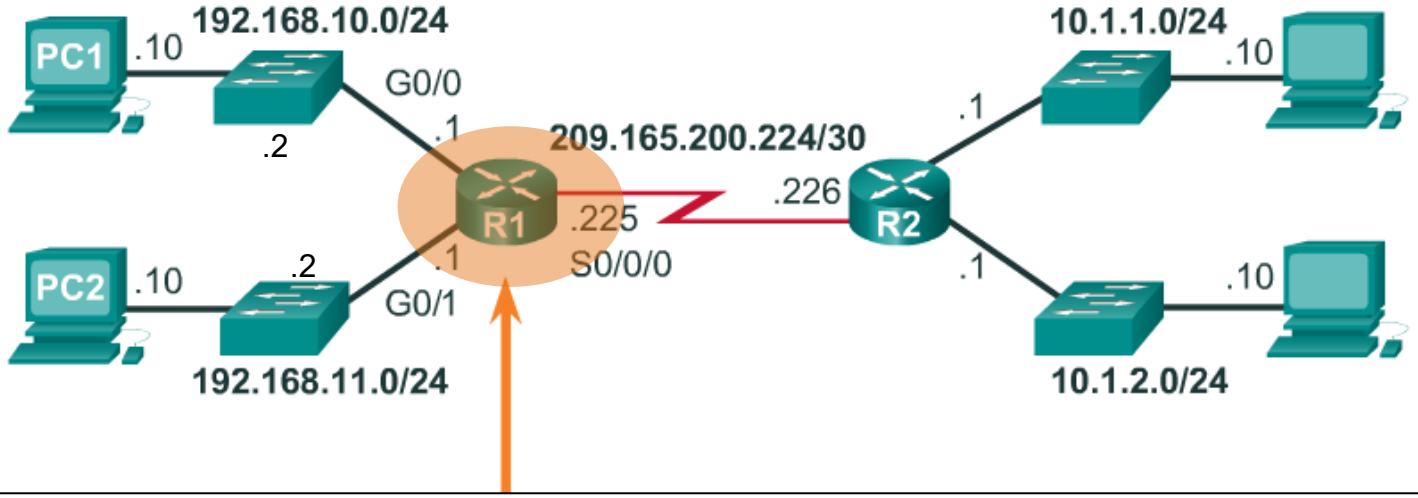

```
R1(config)# enable secret hotdog
R1(config)#
R1(config)# line console 0
R1(config-line)# password hamburger
R1(config-line)# login
R1(config-line)# exit
R1(config)# line vty 0 15
R1(config-line)# password hamburger
R1(config-line)# login
R1(config-line)# exit
R1(config)# service password-encryption
R1(config)#
```

Configure a Banner




```
R1(config)# banner motd #
Warning! Unauthorized access is prohibited!
#
R1(config)#
```

Save the Configuration

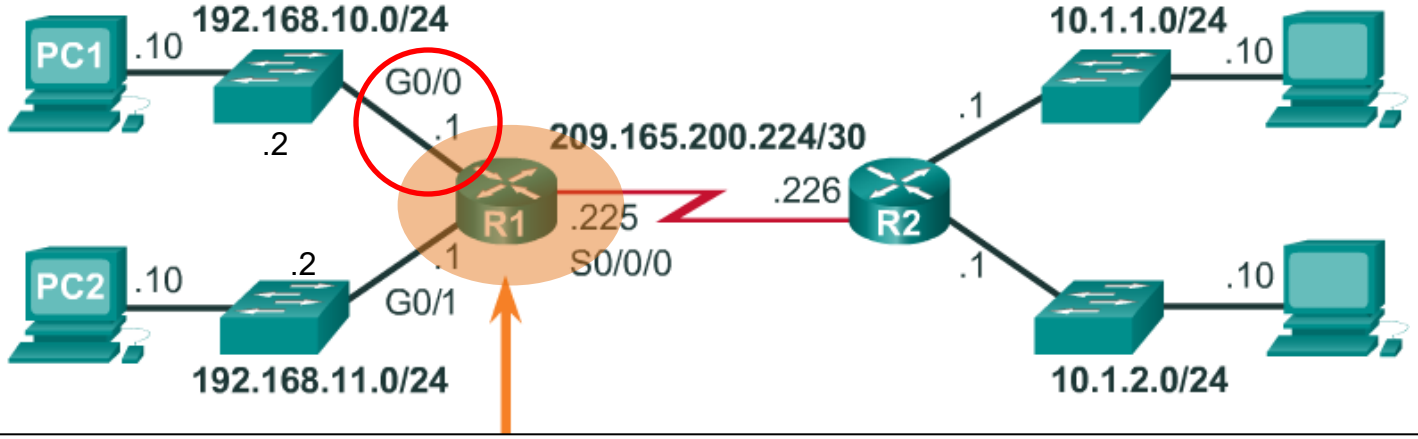



```
R1# copy running-config startup-config
Destination filename [startup-config]?
Building configuration...
[OK]
R1#
```

Configure Basic Settings on R2

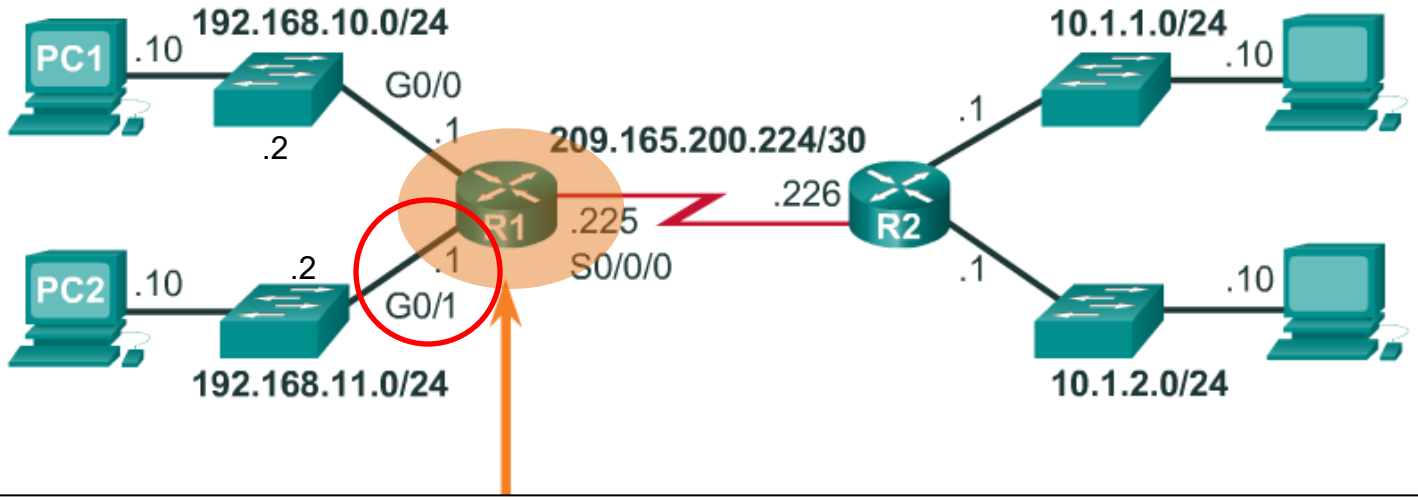
```
Router# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)# hostname R2
R2(config)# enable secret hotdog
R2(config)# line console 0
R2(config-line)# password hamburger
R2(config-line)# login
R2(config-line)# exit
R2(config)# line vty 0 15
R2(config-line)# password hamburger
R2(config-line)# login
R2(config-line)# exit
R2(config)# service password-encryption
R2(config)# banner motd #
Warning! Unauthorized access prohibited!
#
R2(config)# end
R2# copy running-config startup-config
Destination filename [startup-config]?
Building configuration...
[OK]
R2#
```

Configure the Gi0/0 Interface



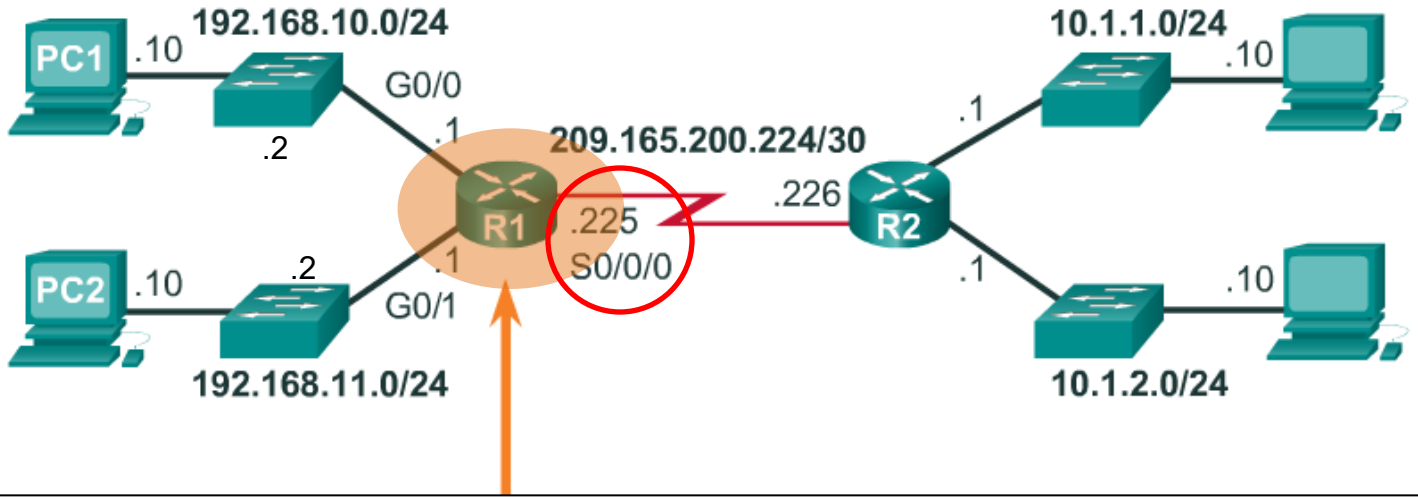

```
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# description Link to LAN 1
R1(config-if)# ip address 192.168.10.1 255.255.255.0
R1(config-if)# no shutdown
R1(config-if)# exit
R1(config)#
*Jan 30 22:04:47.551: %LINK-3-UPDOWN: Interface
GigabitEthernet0/0, changed state to down
R1(config)#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

Configure the Gi0/1 Interface




```
R1(config)# interface GigabitEthernet 0/1
R1(config-if)# description Link to LAN 2
R1(config-if)# ip address 192.168.11.1 255.255.255.0
R1(config-if)# no shutdown
R1(config-if)# exit
*Jan 30 22:06:02.543: %LINK-3-UPDOWN: Interface
GigabitEthernet0/1, changed state to down
R1(config)#
*Jan 30 22:06:05.899: %LINK-3-UPDOWN: Interface
GigabitEthernet0/1, changed state to up
*Jan 30 22:06:06.899: %LINEPROTO-5-UPDOWN: Line protocol on
Interface GigabitEthernet0/1, changed state to up
R1(config)#
```

Configure the S0/0/0 Interface




```
R1(config)# interface Serial 0/0/0
R1(config-if)# description Link to R2
R1(config-if)# ip address 209.165.200.225 255.255.255.252
R1(config-if)# clockrate 128000
R1(config-if)# no shutdown
R1(config-if)# exit
*Jan 30 23:01:17.323: %LINK-3-UPDOWN: Interface
Serial0/0/0, changed state to down
R1(config)#
```

Configure the R2 Interfaces

```
R2(config)#interface GigabitEthernet 0/0
R2(config-if)#description Link to LAN 3
R2(config-if)#ip address 10.1.1.1 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
*Jan 30 23:08:34.139: Output omitted
R2(config)#interface GigabitEthernet 0/1
R2(config-if)#description Link to LAN 4
R2(config-if)#ip address 10.1.2.1 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
*Jan 30 23:09:56.915: Output omitted
R2(config)#interface Serial 0/0/0
R2(config-if)#description Link to R1
R2(config-if)#ip address 209.165.200.226 255.255.255.252
R2(config-if)#no shutdown
R2(config-if)#exit
*Jan 30 23:09:18.451: %LINK-3-UPDOWN: Interface Serial0/0/0, changed
state to up
*Jan 30 23:09:19.451: %LINEPROTO-5-UPDOWN: Line protocol on Interface
Serial0/0/0, changed state to up
R2(config)#
```