Introduction to Routing and Packet Forwarding

Routing Protocols and Concepts – Chapter 1

Cisco | Networking Academy®
Mind Wide Open™

Objectives

- Identify a router as a computer with an OS and hardware designed for the routing process.
- Demonstrate the ability to configure devices and apply addresses.
- Describe the structure of a routing table.
- Describe how a router determines a path and switches packets

Router as a Computer

- Describe the basic purpose of a router

  -Computers that specialize in sending packets over the data network. They are responsible for interconnecting networks by selecting the best path for a packet to travel and forwarding packets to their destination

- Routers are the network center

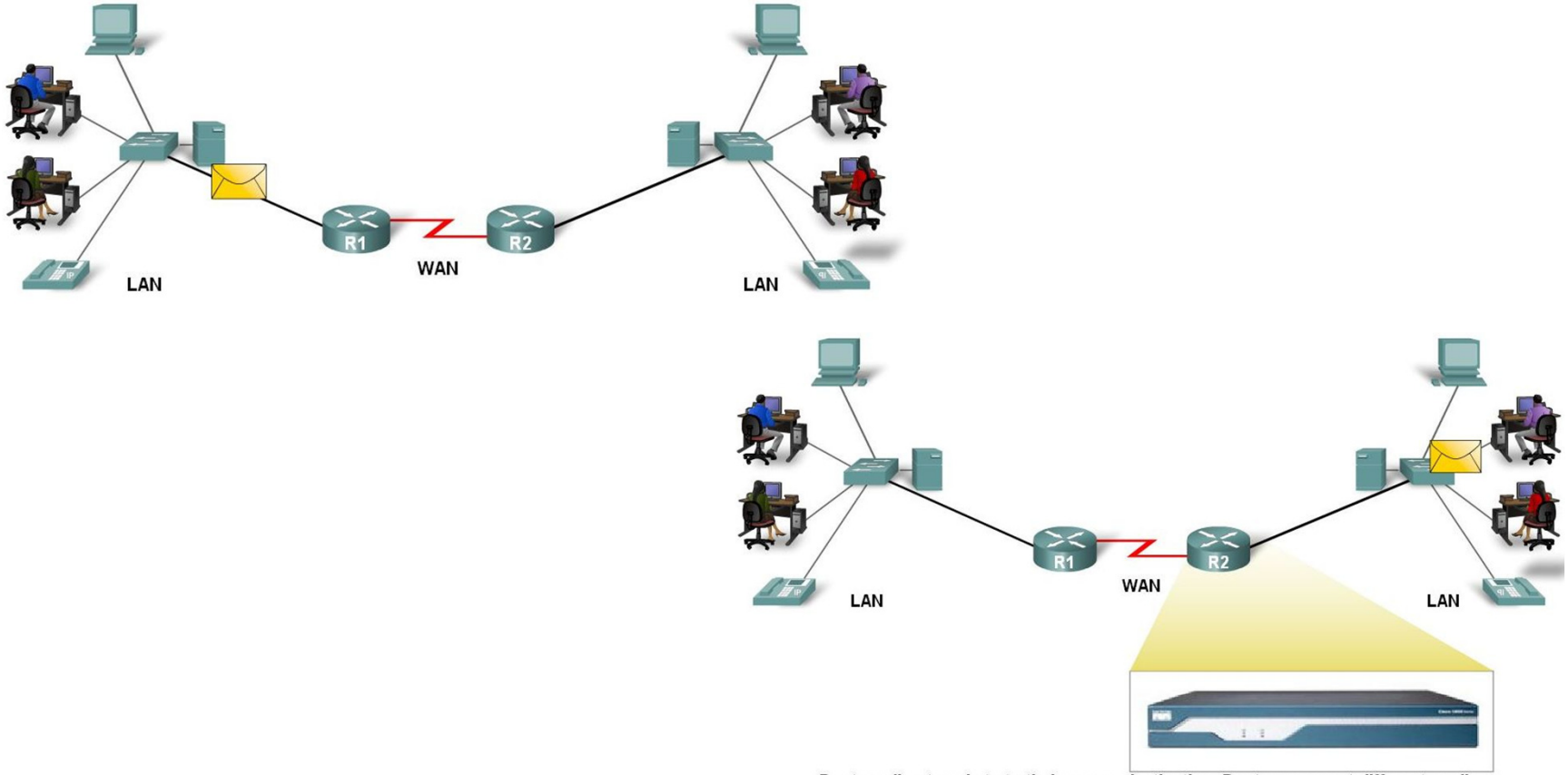
  -Routers generally have 2 connections:

    -WAN connection (Connection to ISP)

    -LAN connection

Router as a Computer

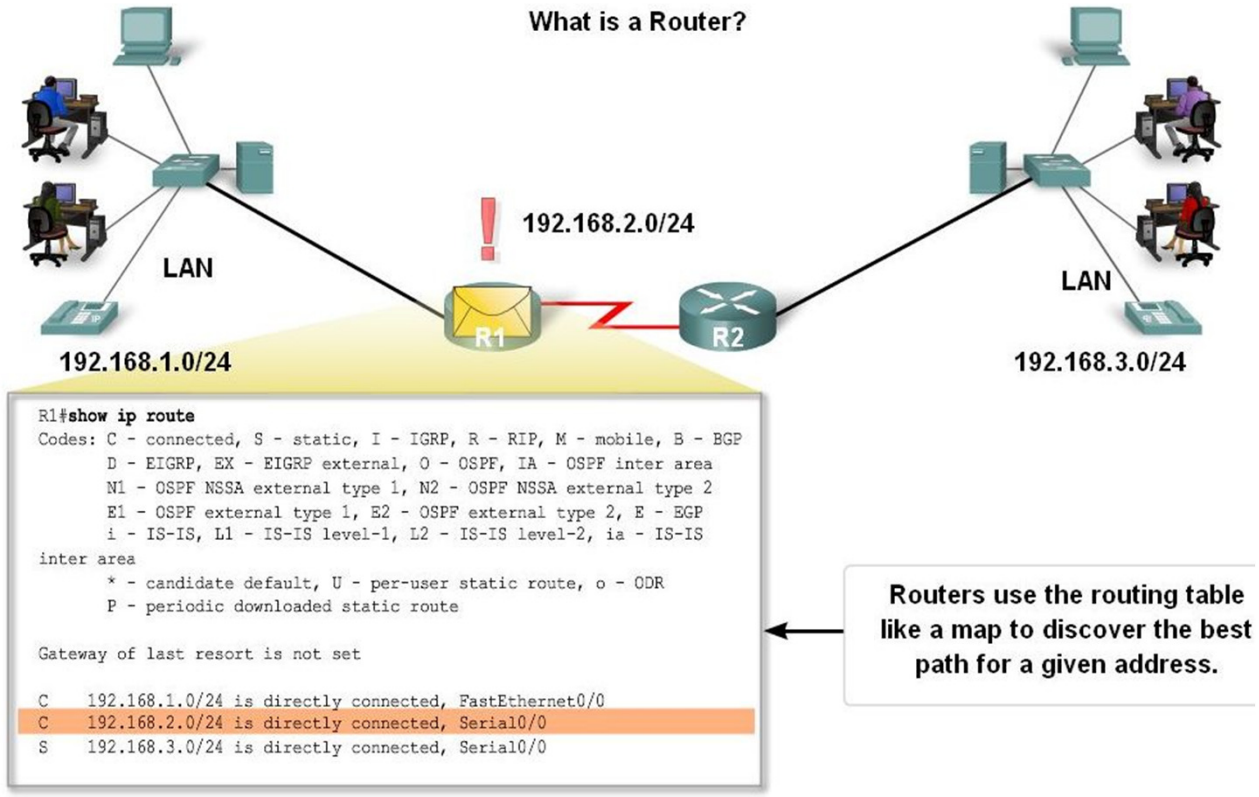
- Data is sent in form of packets between 2 end devices
- Routers are used to direct packet to its destination



Routers direct packets to their proper destination. Routers connect different media.

Router as a Computer

- Routers examine a packet's destination IP address and determine the best path by enlisting the aid of a routing table

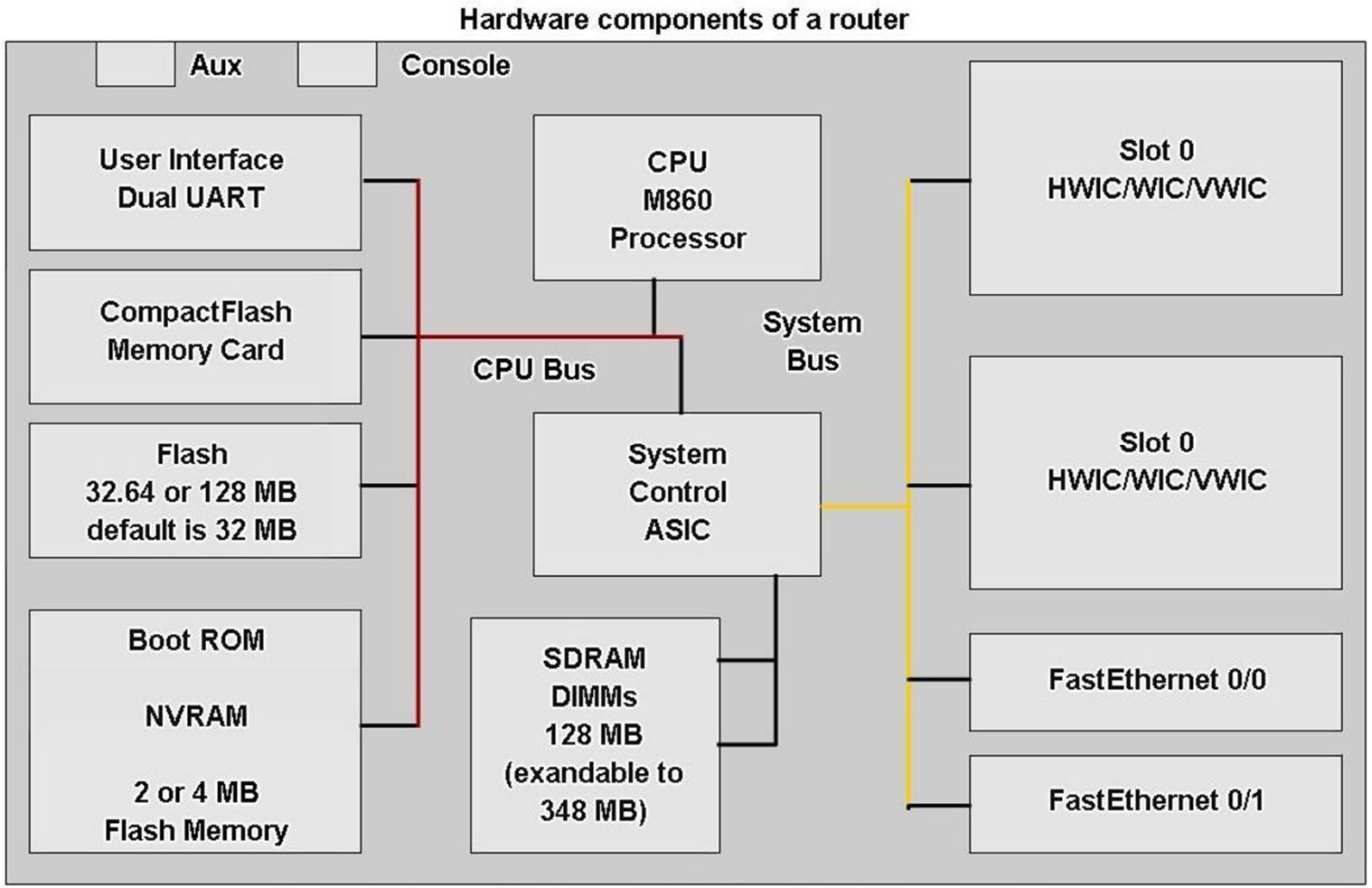


Router as a Computer

- Router components and their functions”
  - **CPU** - Executes operating system instructions
  - **Random access memory (RAM)** - Contains the running copy of configuration file. Stores routing table. RAM contents lost when power is off
  - **Read-only memory (ROM)** - Holds diagnostic software used when router is powered up. Stores the router’s bootstrap program.
  - **Non-volatile RAM (NVRAM)** - Stores startup configuration. This may include IP addresses (Routing protocol, Hostname of router)
  - **Flash memory** - Contains the operating system (Cisco IOS)
  - **Interfaces** - There exist multiple physical interfaces that are used to connect network. Examples of interface types:
    - -Ethernet / fast Ethernet interfaces
    - -Serial interfaces
    - -Management interfaces

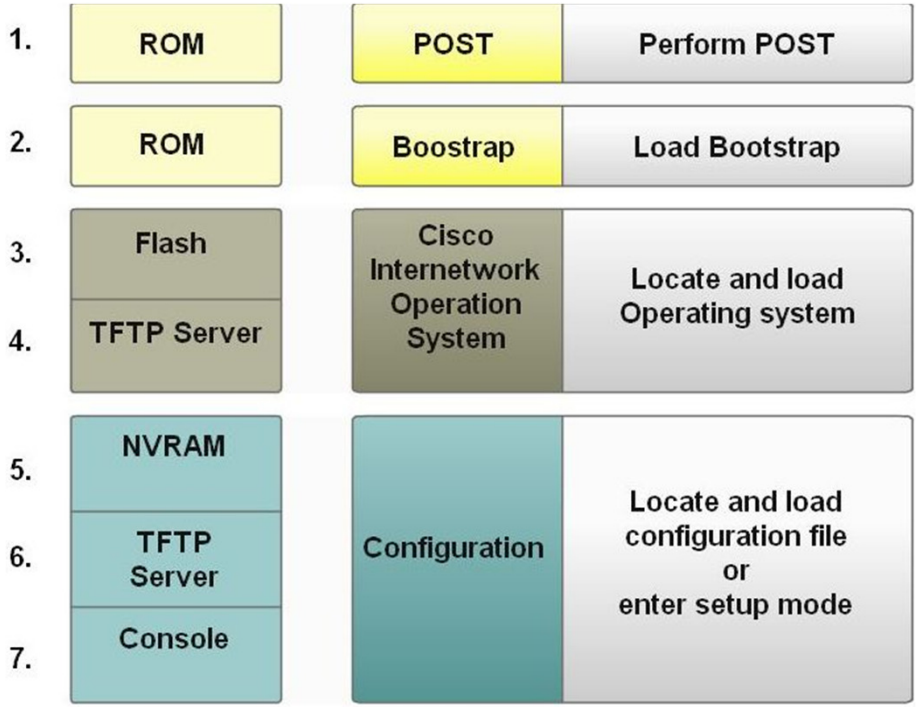
Router as a Computer

- Router components



Router as a Computer

- Major phases to the router boot-up process
  - Test router hardware
    - Power-On Self Test (POST)
    - Execute bootstrap loader
  - Locate & load Cisco IOS software
    - -Locate IOS
    - -Load IOS
  - Locate & load startup configuration file or enter setup mode
    - -Bootstrap program looks for configuration file



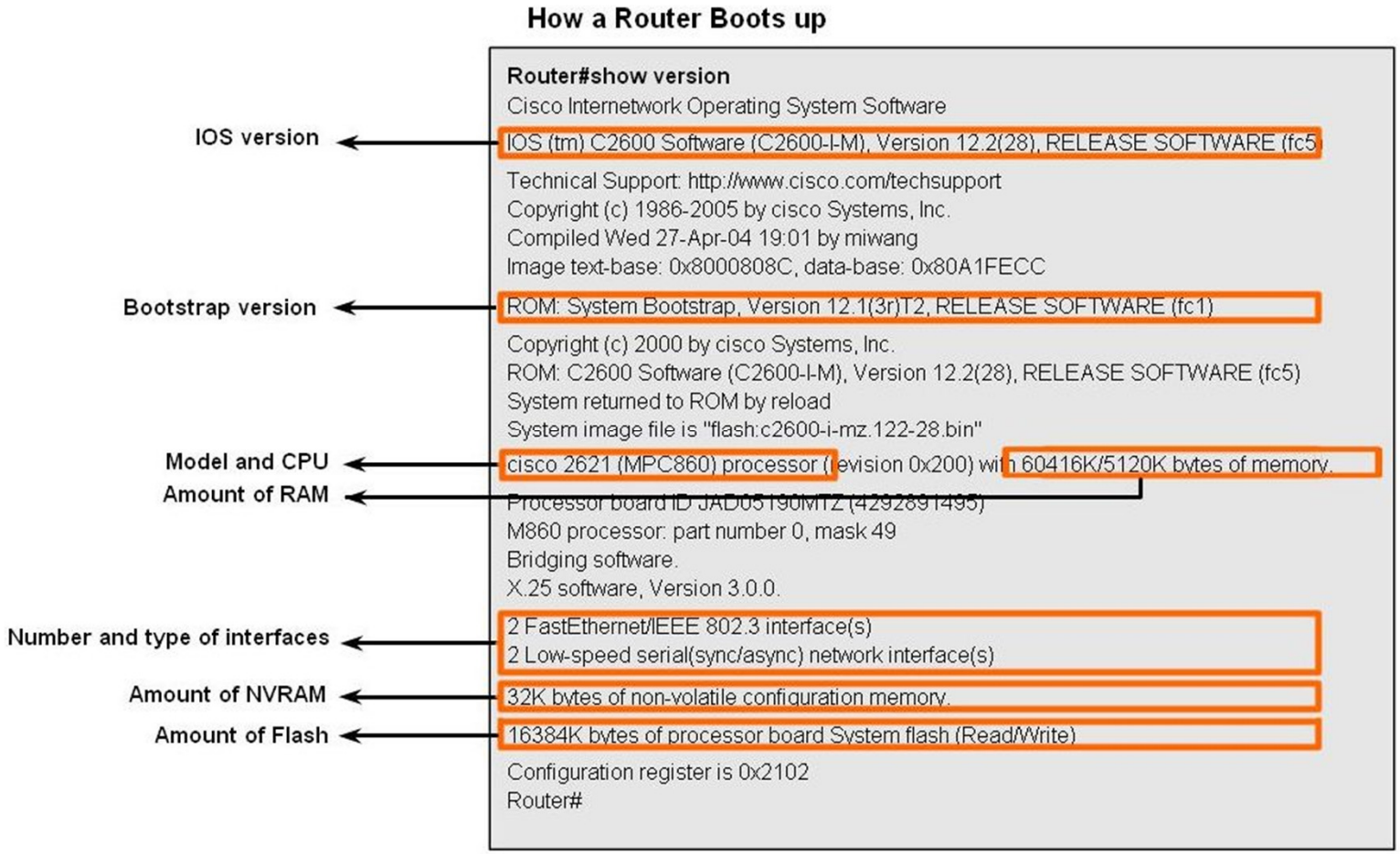
Router as a Computer

- Verify the router boot-up process:

  -The show version command is used to view information about the router during the bootup process. Information includes:

  - Platform model number
  - Image name & IOS version
  - Bootstrap version stored in ROM
  - Image file name & where it was loaded from
  - Number & type of interfaces
  - Amount of NVRAM
  - Amount of flash
  - Configuration register

Router as a Computer



Router as a Computer

- Router Interface is a physical connector that enables a router to send or receive packets
- Each interface connects to a separate network
- Consist of socket or jack found on the outside of a router
- Types of router interfaces:
  - -Ethernet
  - -Fastethernet
  - -Serial
  - -DSL
  - -ISDN
  - -Cable

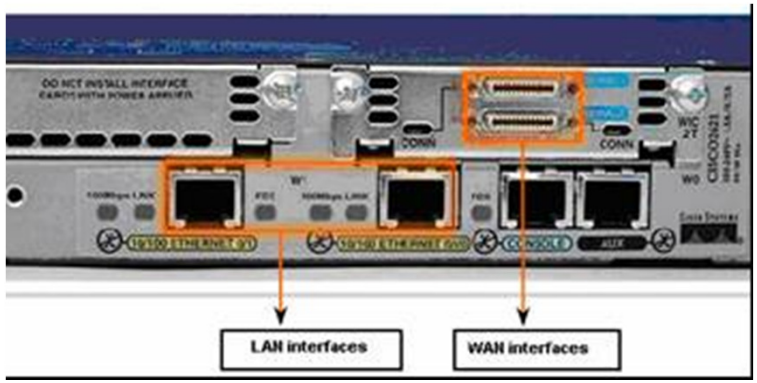
Each individual interface connects to a different network. Thus each interface has an IP address/mask from that network.

Router as a Computer

- Two major groups of Router Interfaces

  LAN Interfaces:

  - Are used to connect router to LAN network
  - Has a layer 2 MAC address
  - Can be assigned a Layer 3 IP address
  - Usually consist of an RJ-45 jack



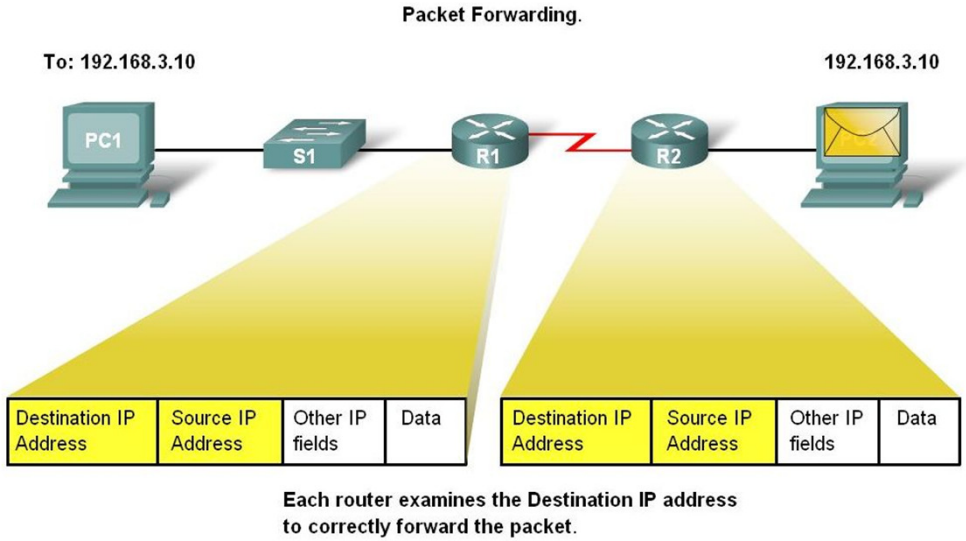
- WAN Interfaces
  - Are used to connect routers to external networks that interconnect LANs.
  - Depending on the WAN technology, a layer 2 address may be used.
  - Uses a layer 3 IP address

Router as a Computer

- Routers and the Network Layer

  Routers use destination IP address to forward packets

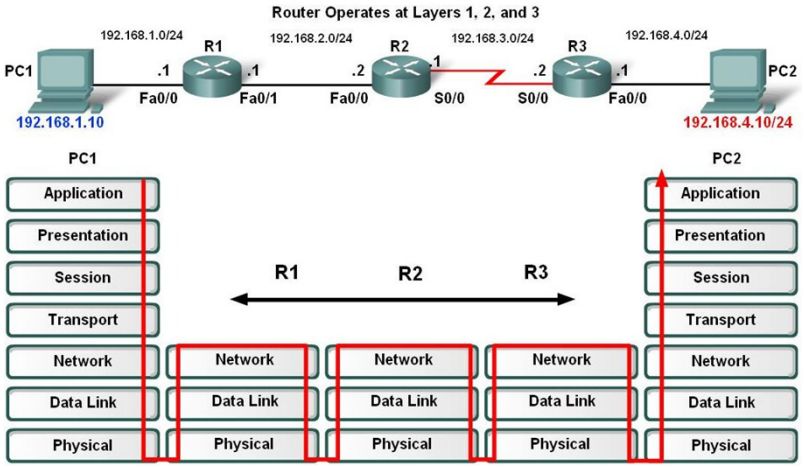
  - The path a packet takes is determined after a router consults information in the routing table.
  - After router determines the best path
  - Packet is encapsulated into a frame
  - Frame is then placed on network medium in form of Bits



Router as a Computer

- Routers Operate at Layers 1, 2 & 3
  - Router receives a stream of encoded bits
  - Bits are decoded and passed to layer 2
  - Router de-encapsulates the frame
  - Remaining packet passed up to layer 3

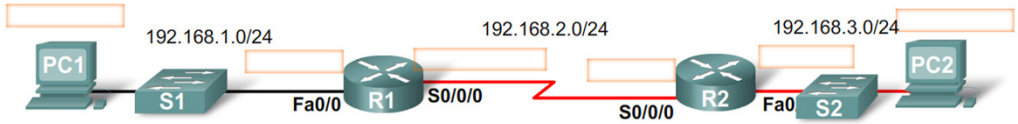
    -Routing decision made at this layer by examining destination IP address
  - Packet is then re-encapsulated & sent out outbound interface



Configure Devices and Apply Addresses

- Implementing Basic Addressing Schemes
- When designing a new network or mapping an existing network you must provide the following information in the form of a document:
  - -Topology drawing that Illustrates physical connectivity
  - –Address table that provides the following information:
    - Device name
    - Interfaces used
    - IP addresses
    - Default gateway

Documenting an Addressing Scheme



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		255.255.255.0	N/A
	S0/0/0		255.255.255.0	N/A
PC1	N/A	192.168.1.10	255.255.255.0	192.168.1.1
PC2	N/A		255.255.255.0	

Configure Devices and Apply Addresses

- Basic Router Configuration
- A basic router configuration should contain the following:

  -Router name - Host name should be unique

  -Banner - At a minimum, banner should warn against unauthorized use

  -Passwords - Use strong passwords

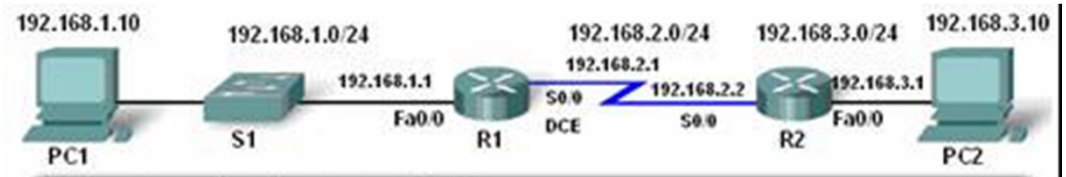
  -Interface configurations - Specify interface type, IP address and subnet mask. Describe purpose of interface. Issue no shutdown command. If DCE serial interface issue clock rate command.

- After entering in the basic configuration the following tasks should be completed

  -Verify basic configuration and router operations.

  -Save the changes on a router

Configure Devices and Apply Addresses



Basic router configuration command syntax	
Naming the router	Router(config)# hostname name
Setting Passwords	Router(config)# enable secret password
	Router(config)# line console 0
	Router(config-line)# password password
	Router(config-line)# login
	Router(config)# line vty 0 4
	Router(config-line)# password password
	Router(config-line)# login
Configuring an interface	Router(config)# interface type number
	Router(config-if)# ip address address mask
	Router(config-if)# description description
	Router(config-if)# no shutdown
Configuring a message-of-the-day banner	Router(config)# banner motd # message #
Saving changes on a router	Router# copy running-config startup-config
Examining the output of show commands	Router# show running-config
	Router# show ip route
	Router# ip interface brief
	Router# interfaces

Configure Devices and Apply Addresses

- Verify Basic Router Configuration

  -Issue the *show running-config* command

  -Save the basic router configuration by Issuing the *copy running-config startup-config* command

  -Additional commands that will enable you to further verify router configuration are:

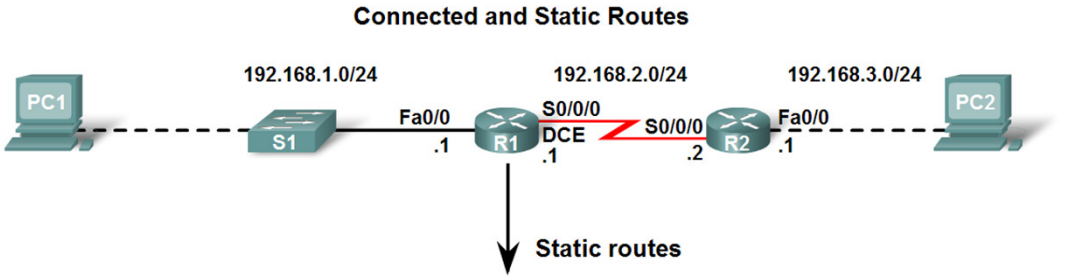
  - Show running-config - Displays configuration currently in RAM
  - Show startup-config - Displays configuration file NVRAM
  - Show IP route - Displays routing table
  - Show interfaces - Displays all interface configurations
  - Show IP int brief - Displays abbreviated interface configuration information

Routing Table Structure

- Routing Table is stored in ram and contains information about:
  - Directly connected networks - this occurs when a device is connected to another router interface
  - Remotely connected networks - this is a network that is not directly connected to a particular router
  - Detailed information about the networks include source of information, network address & subnet mask, and Ip address of next-hop router
- Show ip route command is used to view a routing table

Routing Table Structure

- Adding a connected network to the routing table
  - -Router interfaces
    - Each router interface is a member of a different network
    - Activated using the *no shutdown* command
    - In order for static and dynamic routes to exist in routing table you must have directly connected networks




```
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, Serial0/0/0
S    192.168.3.0/24 [1/0] via 192.168.2.2
```

Routing Table Structure

- Static routes in the routing table

  -Includes: network address and subnet mask and IP address of next hop router or exit interface

  -Denoted with the code **S** in the routing table

  -Routing tables must contain directly connected networks used to connect remote networks before static or dynamic routing can be used

- When to use static routes

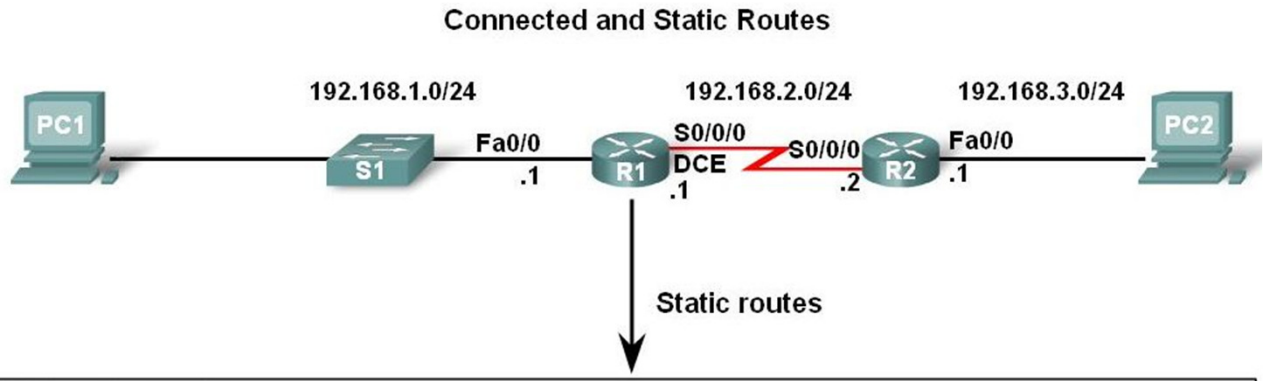
  -When network only consists of a few routers

  -Network is connected to internet only through one ISP

  -Hub & spoke topology is used on a large network

Routing Table Structure

- Connected and Static routes




```
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
S    192.168.3.0/24 [1/0] via 192.168.2.2
```

Routing Table Structure

- Dynamic routing protocols
  - -Used to add remote networks to a routing table
  - -Are used to discover networks
  - -Are used to update and maintain routing tables
- Automatic network discovery
  - -Routers are able discover new networks by sharing routing table information

Routing Table Structure

- Maintaining routing tables

  -Dynamic routing protocols are used to share routing information with other router & to maintain and up date their own routing table.

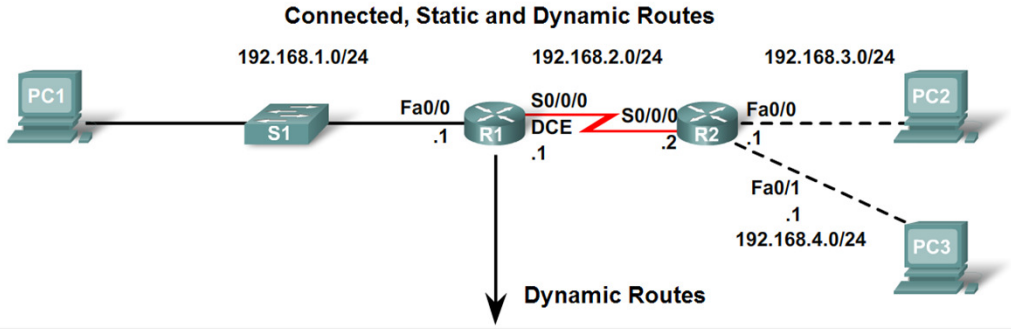
- IP routing protocols. Example of routing protocols include:

  -RIP

  -IGRP

  -EIGRP

  -OSPF




```
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, Serial0/0/0
S    192.168.3.0/24 [1/0] via 192.168.2.2
R    192.168.4.0/24 [120/1] via 192.168.2.2, 00:00:20, Serial0/0/0
```

Routing Table Structure

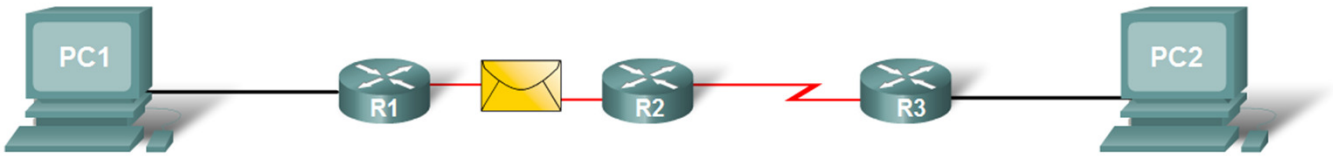
- Routing Table Principles

-3 principles regarding routing tables:

- Every router makes its decisions alone, based on the information it has in its routing table.
- Different routing table may contain different information
- A routing table can tell how to get to a destination but not how to get back

Routing Principle 3 in Action

R1 has a route to PC2's network.

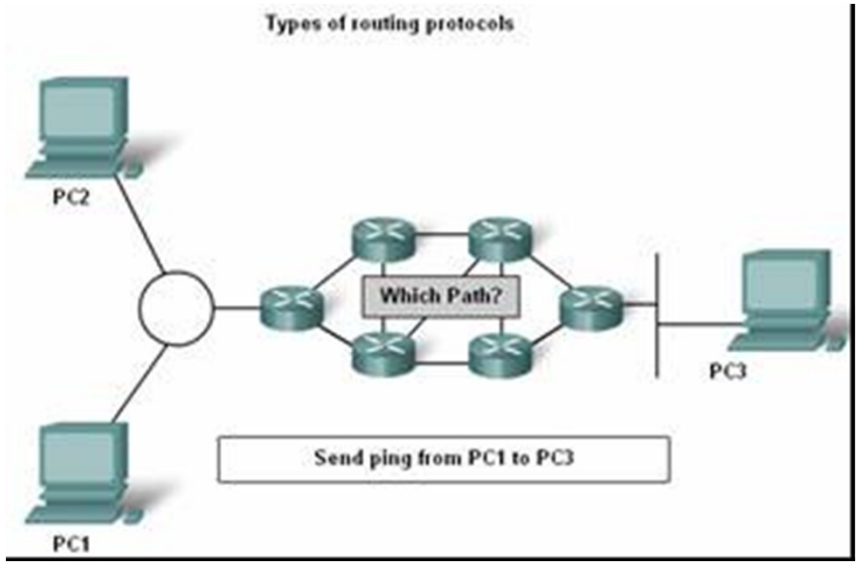


Routing Table Structure

- Effects of the 3 Routing Table Principles

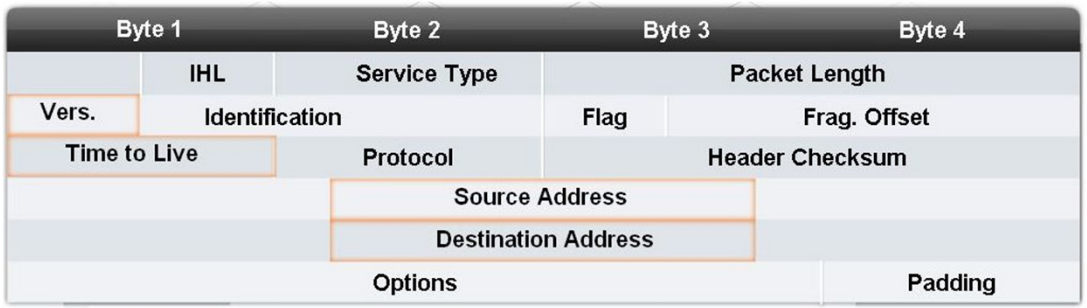
  -Packets are forwarded through the network from one router to another, on a hop by hop basis.

  -Packets can take path “X” to a destination but return via path “Y” (Asymmetric routing).



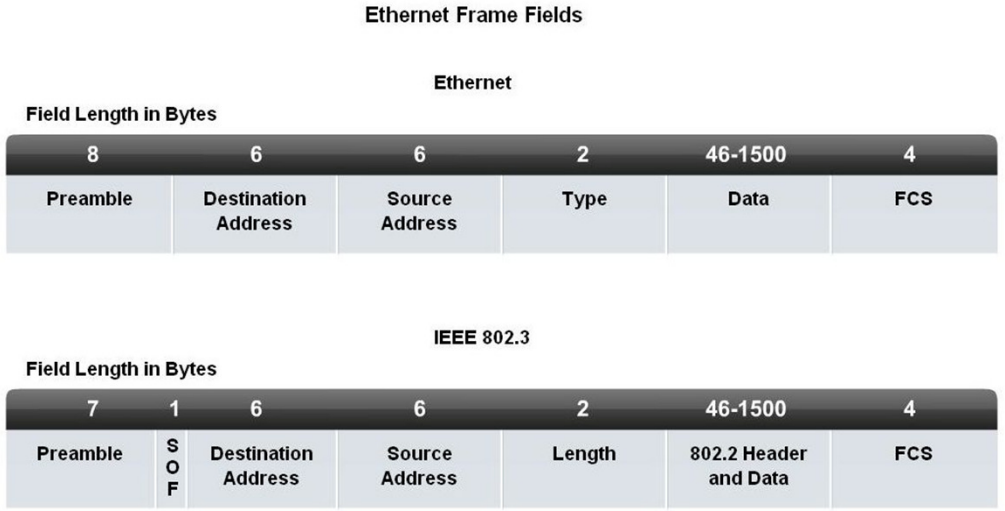
Router Paths and Packet Switching

- Internet Protocol (IP) packet format contains fields that provide information about the packet and the sending and receiving hosts
- Fields that are importance for CCNA students:
  - -Destination IP address
  - -Source IP address
  - -Version & TTL
  - -IP header length
  - -Precedence & type of service
  - -Packet length



Router Paths and Packet Switching

- MAC Layer Frame Format
- MAC Frames are also divided into fields. They include:
  - -Preamble
  - -Start of frame delimiter
  - -Destination MAC address
  - -Source MAC address
  - -Type/length
  - -Data and pad
  - -Frame check sequence

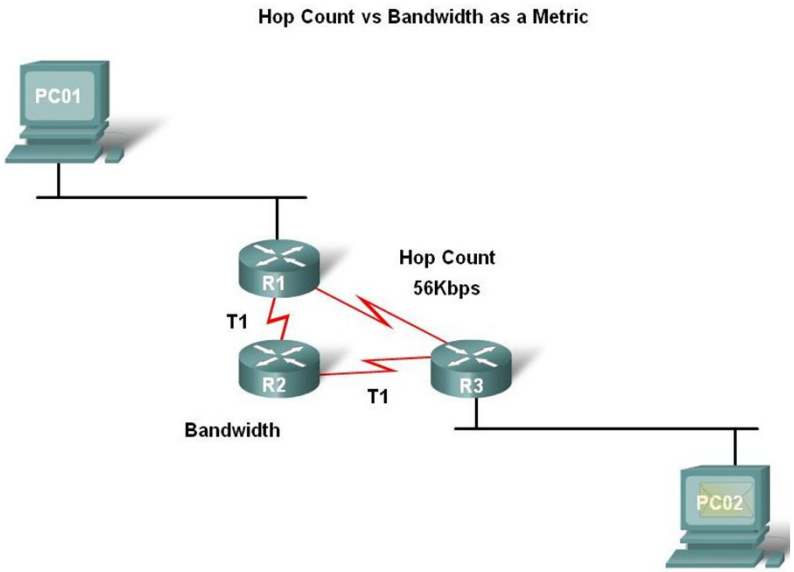


Router Paths and Packet Switching

- A **Metric** is a numerical value used by routing protocols help determine the best path to a destination
  - –The smaller the metric value the better the path
- 2 types of metrics used by routing protocols are:

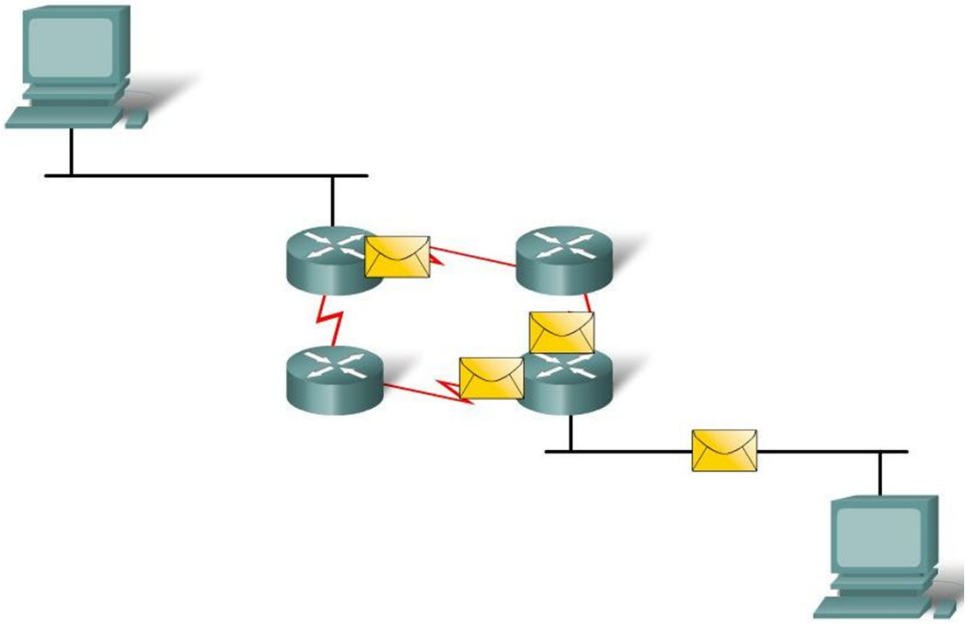
  -Hop count - this is the number of routers a packet must travel through to get to its destination

  -Bandwidth - this is the “speed” of a link also known as the data capacity of a link



Router Paths and Packet Switching

- **Equal cost metric** is a condition where a router has multiple paths to the same destination that all have the same metric
- To solve this dilemma, a router will use Equal Cost Load Balancing. This means the router sends packets over the multiple exit interfaces listed in the routing table.



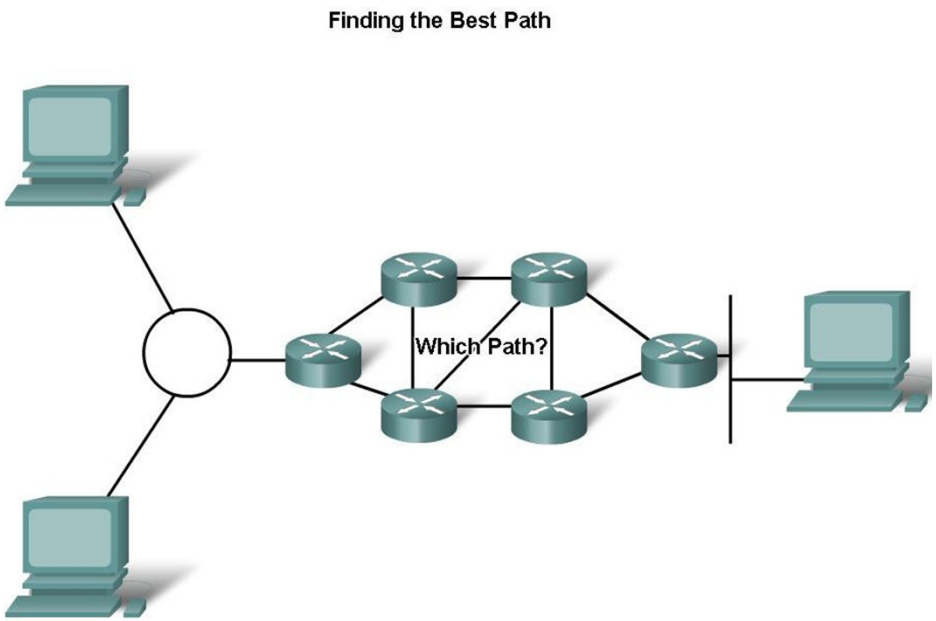
Router Paths and Packet Switching

- **Path determination** is a process used by a router to pick the best path to a destination
- One of 3 path determinations results from searching for the best path

  Directly connected network

  Remote network

  No route determined



Routers determine the best path to the destination

Router Paths and Packet Switching

- **Switching Function** of Router is the process used by a router to switch a packet from an incoming interface to an outgoing interface on the same router.

  -A packet received by a router will do the following:

  - Strips off layer 2 headers.
  - Examines destination IP address located in Layer 3 header to find best route to destination.
  - Re-encapsulates layer 3 packet into layer 2 frame.
  - Forwards frame out exit interface.

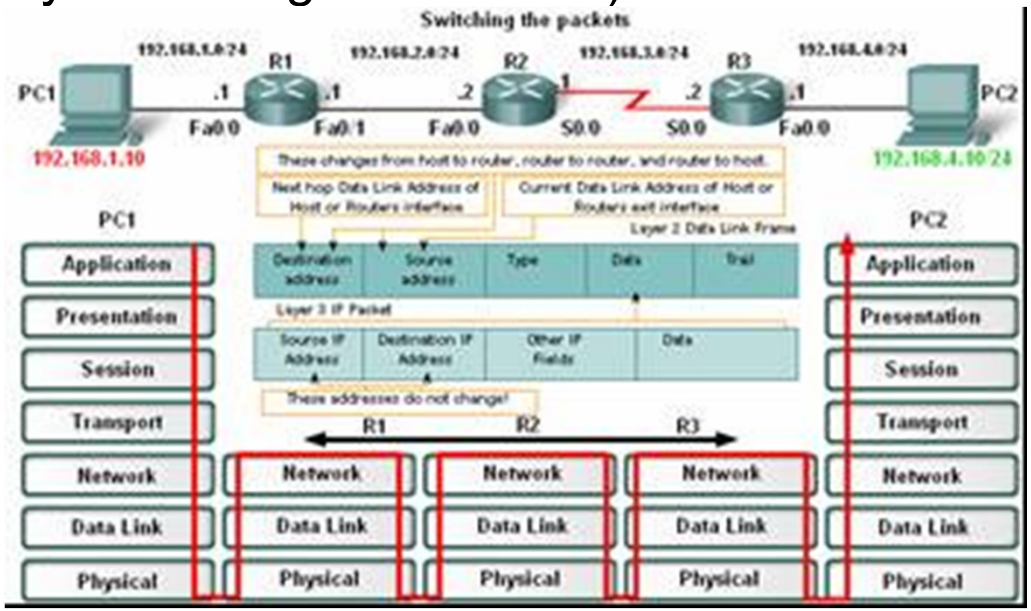
Router Paths and Packet Switching

- As a packet travels from one networking device to another

  -The Source and Destination IP addresses **NEVER** change

  -The Source & Destination MAC addresses **CHANGE** as packet is forwarded from one router to the next.

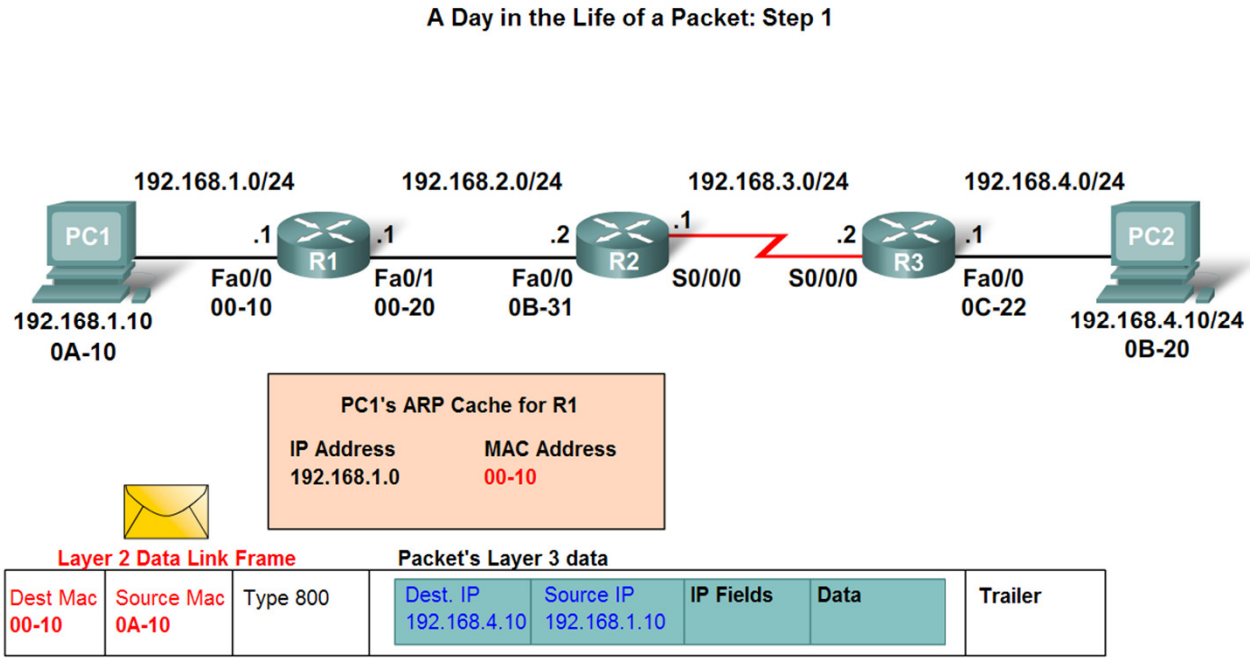
  -TTL field decrement by one until a value of zero is reached at which point router discards packet (prevents packets from endlessly traversing the network)



Router Paths and Packet Switching

- Path determination and switching function details. PC1 Wants to send something to PC 2 here is part of what happens

  Step 1 - PC1 encapsulates packet into a frame. Frame contains R1's destination MAC address



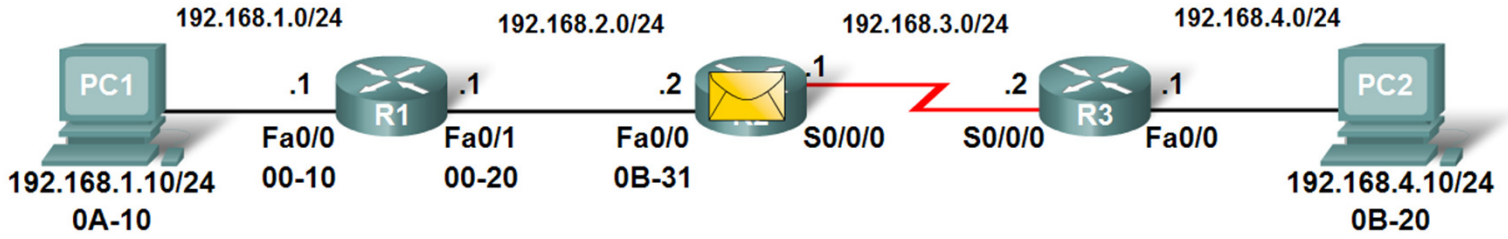
Router Paths and Packet Switching

Step 2 - R1 receives Ethernet frame.

- R1 sees that destination MAC address matches its own MAC.
- R1 then strips off Ethernet frame.
- R1 Examines destination IP.
- R1 consults routing table looking for destination IP.
- After finding destination IP in routing table, R1 now looks up next hop IP address.
- R1 re-encapsulates IP packet with a new Ethernet frame.
- R1 forwards Ethernet packet out Fa0/1 interface.

Router Paths and Packet Switching

A day in a life of a packet: Step 2



Layer 2 Data Link Frame

Packet's Layer 3 data

Dest Mac 0B-31		Type 800	Dest. IP 192.168.4.10	Source IP 192.168.1.10	IP Fields	Data	Trailer

R1's ARP Cache

IP Address	MAC Address
192.168.2.2	OB-31

R1's Routing Table

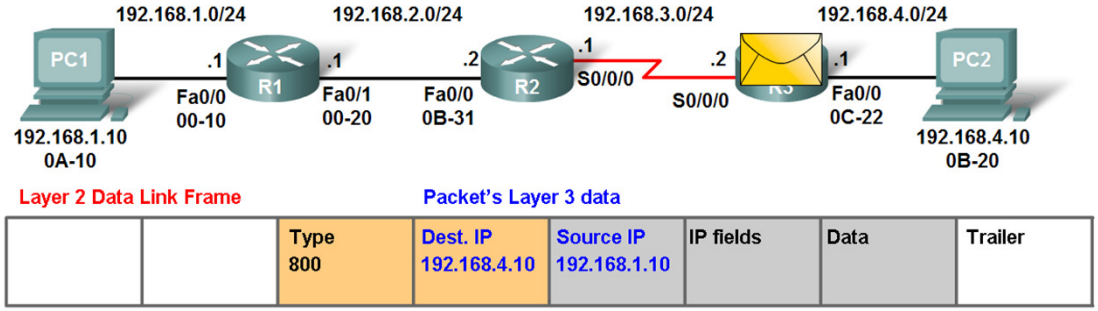
Network	Hops	Next Hop IP	Exit Interface
192.168.1.0/24	0	Dir. Connect	Fa0/0
192.168.2.0/24	0	Dir. Connect	Fa0/1
192.168.3.0/24	1	192.168.2.2	Fa0/1
192.168.4.0/24	**2**	**192.168.2.2**	**Fa0/1**

Router Paths and Packet Switching

- Path determination and switching function details. PC1 Wants to send something to PC 2 here is part of what happens

Step 3 - Packet arrives at R2

- R2 receives Ethernet frame
- R2 sees that destination MAC address matches its own MAC
- R2 then strips off Ethernet frame
- R2 Examines destination IP
- R2 consults routing table looking for destination IP
- After finding destination IP in routing table, R2 now looks up next hop IP address
- R2 re-encapsulates IP packet with a new data link frame
- R2 forwards Ethernet packet out S0/0 interface



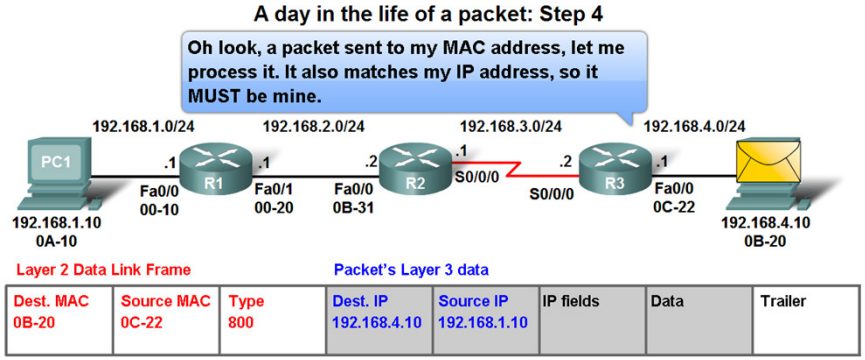
Router Paths and Packet Switching

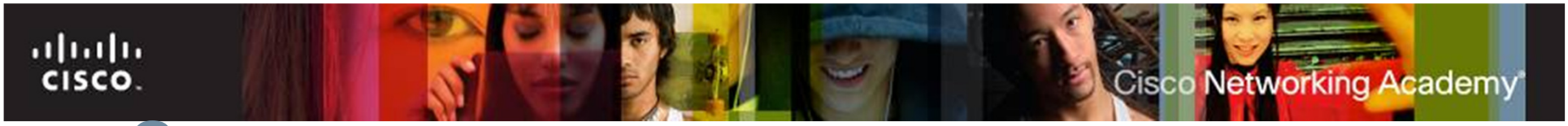
- Path determination and switching function details. PC1 Wants to send something to PC 2 here is part of what happens

Step 4 - Packet arrives at R3

- R3 receives PPP frame
- R3 then strips off PPP frame
- R3 Examines destination IP
- R3 consults routing table looking for destination IP
- After finding destination IP in routing table, R3 is directly connected to destination via its fast Ethernet interface
- R3 re-encapsulates IP packet with a new Ethernet frame
- R3 forwards Ethernet packet out Fa0/0 interface

Step 5 - IP packet arrives at PC2. Frame is decapsulated & processed by upper layer protocols.





Summary

- Routers are computers that specialize in sending data over a network.
- Routers are composed of:
  - -Hardware i.e. CPU, Memory, System bus, Interfaces
  - -Software used to direct the routing process
    - IOS
    - Configuration file
- Routers need to be configured. Basic configuration consists of:
  - -Router name
  - -Router banner
  - -Password(s)
  - -Interface configurations i.e. IP address and subnet mask
- Routing tables contain the following information
  - -Directly connected networks
  - -Remotely connected networks
  - -Network addresses and subnet masks
  - -IP address of next hop address

Summary

- Routers determine a packets path to its destination by doing the following
  - Receiving an encapsulated frame & examining destination MAC address.
  - If the MAC address matches then Frame is de-encapsulated so that router can examine the destination IP address.
  - If destination IP address is in routing table or there is a static route then Router determines next hop IP address. Router will re-encapsulate packet with appropriate layer 2 frame and send it out to next destination.
  - Process continues until packet reaches destination.
  - Note - only the MAC addresses will change the source and destination IP addresses do not change.