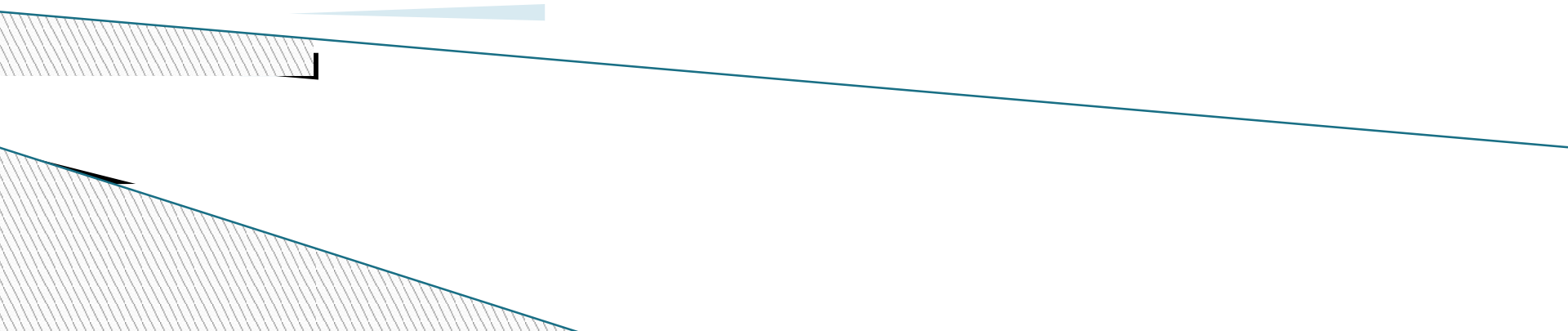
Introduction to Routing and Packet Forwarding

Informatika - ITI



Objectives

- Identifikasi router sebagai sebuah komputer dengan OS dan hardware yang didesain untuk proses routing
- Mendemontrasikan kemampuan untuk mengkonfigurasi device
- Menjelaskan struktur dari routing table
- Menjelaskan bagaimana sebuah router menentukan jalur dan menukar paket data

Router Versus Bridge ?

Cara kerja router hampir sama dengan bridge jaringan, yaitu dapat meneruskan paket data jaringan dan dapat pula membagi jaringan menjadi beberapa segmen atau menyatukan segemen-segmen yg panjang. Namun, router berjalan pada lapisan ketiga model OSI (lapisan jaringan) dan memakai skema pengalamatan yang digunakan pada lapisan tersebut, seperti alamat IP.

Bridge jaringan berjalan di lintasan kedua pada model OSI (lapisan data link) dan memakai skema pengalamatan yang digunakan pada lapisan tersebut, yaitu MAC address. Lalu, kapan penggunaan router dilakukan dan kapan penggunaan bridge jaringan dilakukan?

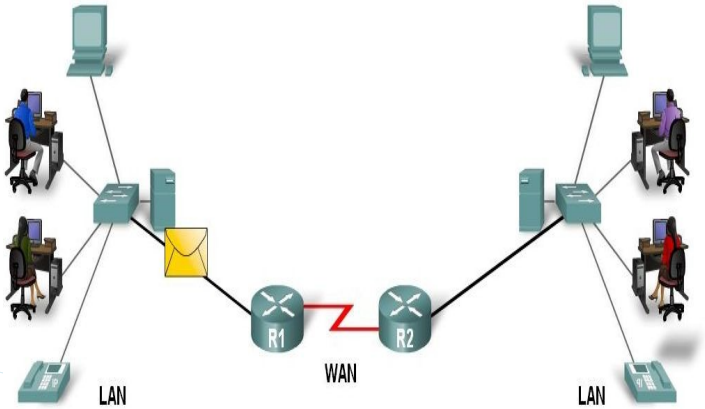
Sebaiknya, bridge digunakan untuk menghubungkan segmen-segmen jaringan yang menjalankan protokol jaringan sama, misalnya segmen jaringan berbasis IP dengan segmen jaringan IP lainnya. Bridge juga dapat dipakai ketika di dalam jaringan terdapat protokol-protokol yang tidak dapat melakukan routing, sama seperti NetBEUI. Router sangat cocok digunakan untuk menghubungkan segmen-segmen jaringan yang menjalankan protokol jaringan tidak sama atau berbeda. Secara keseluruhan, router lebih cerdas daripada bridge. Router dapat meningkatkan bandwidth jaringan karena router tidak meneruskan paket broadcast ke jaringan yang dituju. Penggunaan router yang paling banyak diakukan adalah saat kita akan menghubungkan jaringan ke internet.

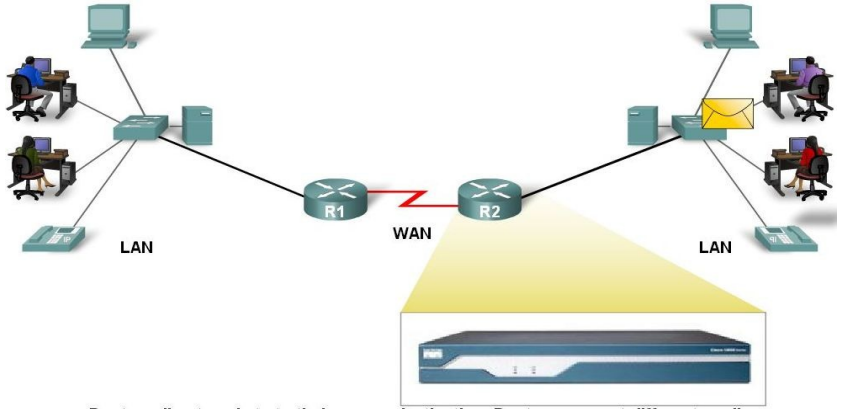
Router as a Computer

- Menggambarkan tujuan dari sebuah router
  - Komputer yang spesialisasinya dalam pengiriman paket melalui jaringan data. Mereka bertanggung jawab untuk interkoneksi jaringan dengan memilih jalur terbaik untuk paket perjalanan dan paket forwarding ke tujuan mereka.
- Routers adalah pusat jaringan
  - Routers umumnya mempunyai 2 koneksi:
    - WAN connection (Connection to ISP)
    - LAN connection

Router as a Computer

- Data dikirim dalam bentuk paket diantara 2 end devices
- Routers digunakan untuk meneruskan paket ke tujuannya

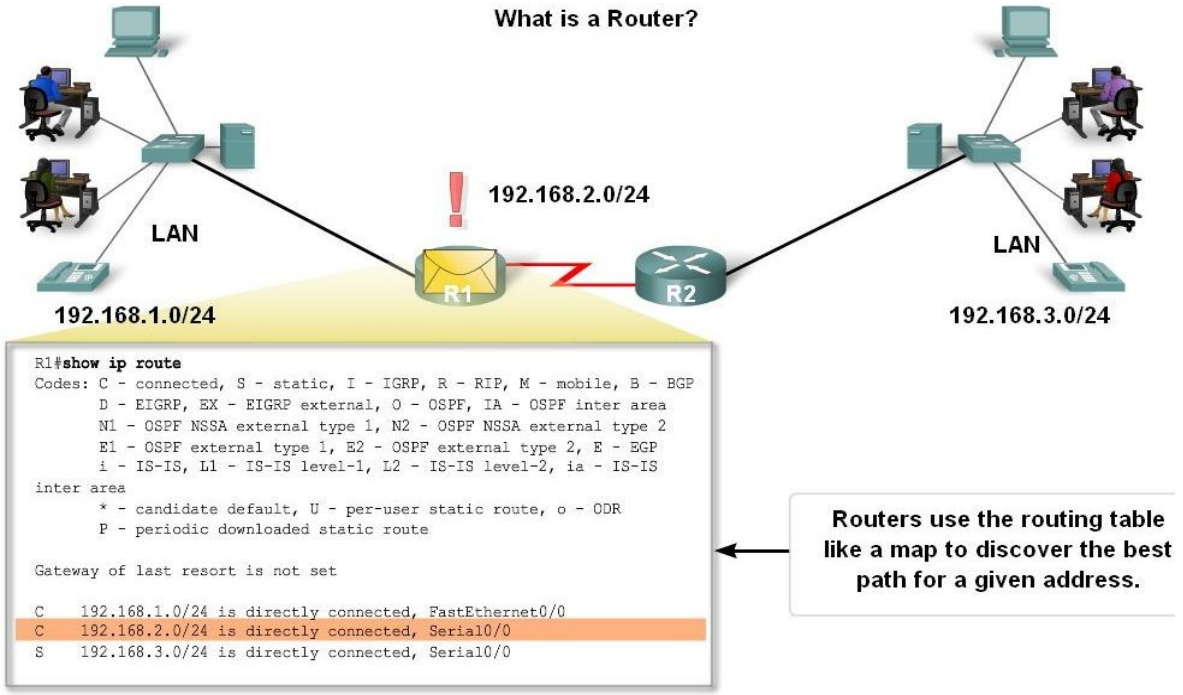




Routers direct packets to their proper destination. Routers connect different media.

Router as a Computer

- Routers **memeriksa alamat IP** dari paket dan **menentukan jalur terbaik** dari menggunakan listing dengan bantuan **table routing.**

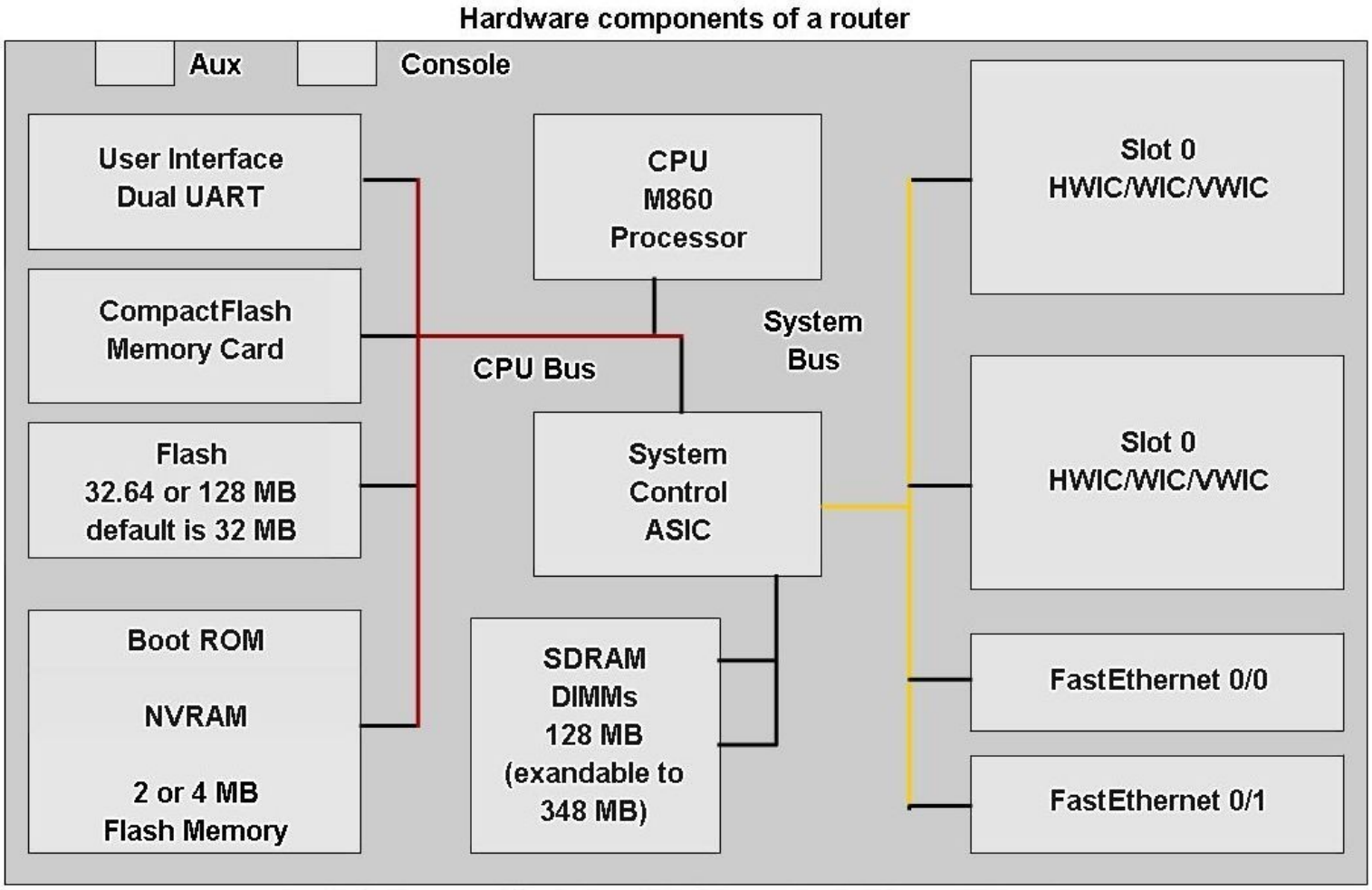


Router as a Computer

- 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

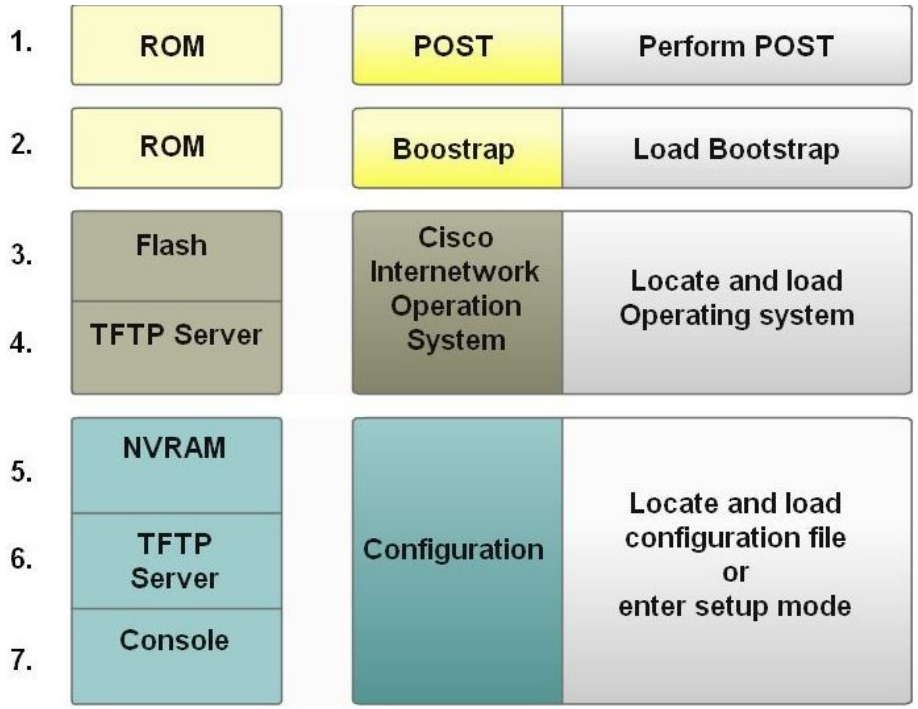
Router as a Computer

- Komponen Router



Router as a Computer

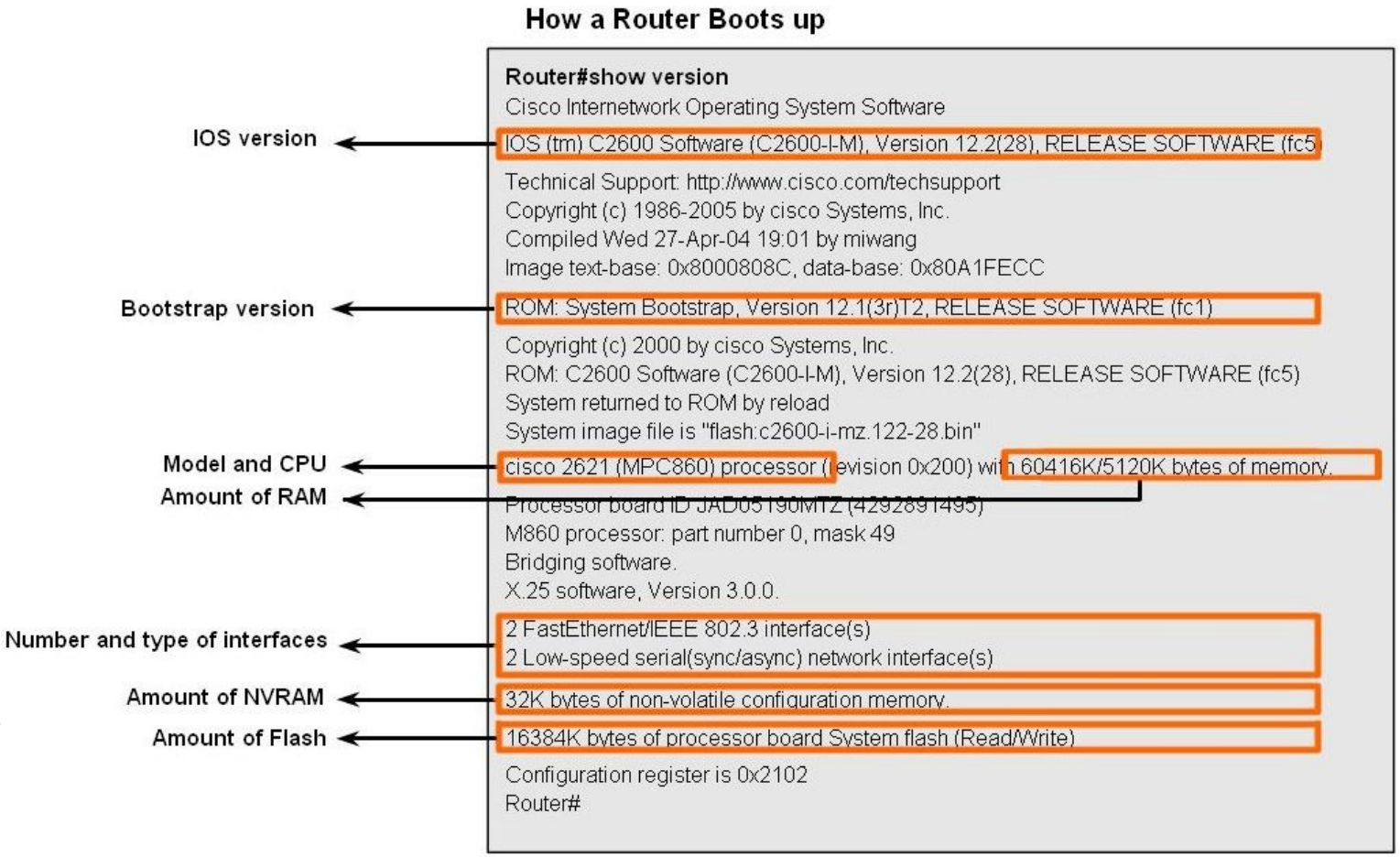
- Major phases to the router boot-up process
  - Test router hardware
    - Power-On Self Test (POST)
    - Execute bootstrap loader
  - Locate & load Cisco IOS software
    - Locate IOS
    - Load IOS
  - Locate & load startup configuration file or enter setup mode
    - Bootstrap program looks for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



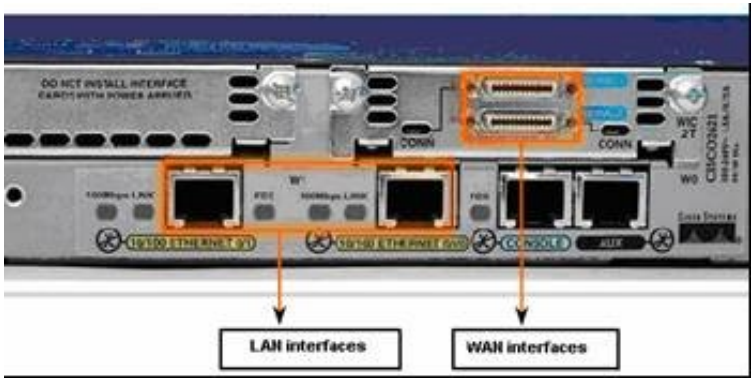
Router as a Computer

- 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

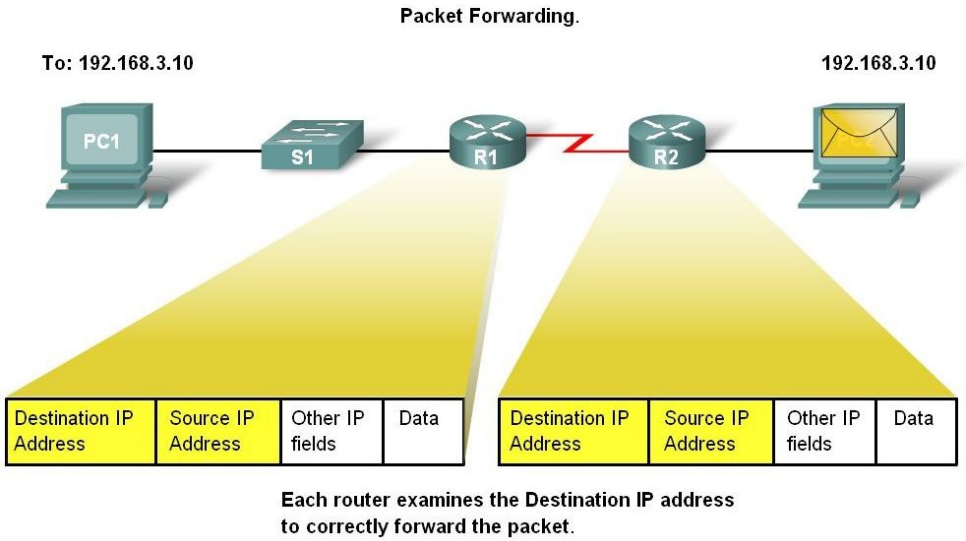
- Two major groups of Router Interfaces
  - LAN Interfaces:
    - Are used to connect router to LAN network
    - Has a layer 2 MAC address
    - Can be assigned a Layer 3 IP address
    - Usually consist of an RJ-45 jack



- 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

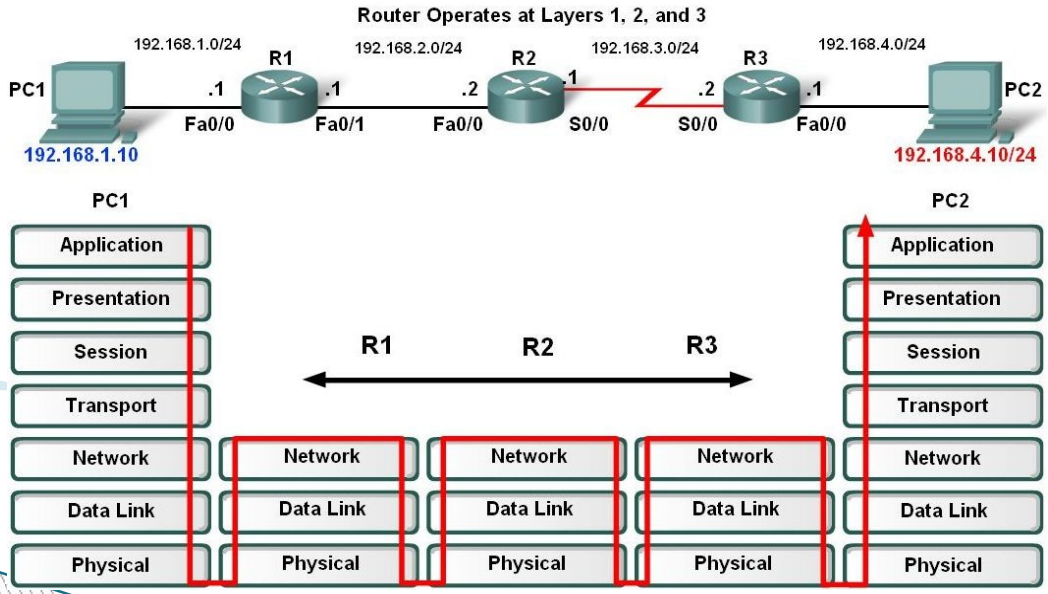


Router as a Computer

- 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

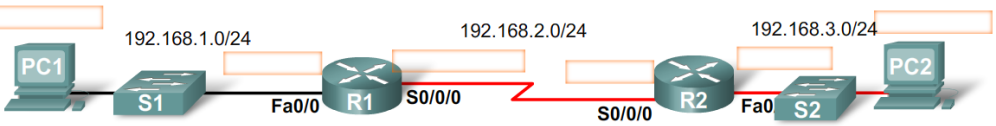
  - Packet is then re-encapsulated & sent out outbound interface



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 tha information:
    - Device name
    - Interfaces used
    - IP addresses
    - Default gatewa

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

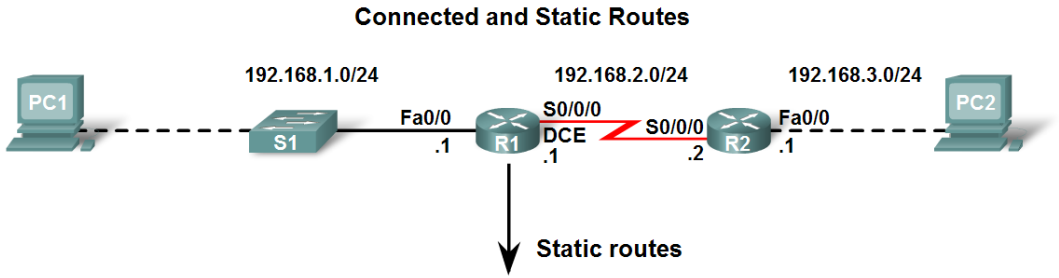
- Verify Basic Router Configuration
  - -Issue the *show running-config* command
  - -Save the basic router configuration by Issuing the *copy running-config startup-config* command
  - -Additional commands that will enable you to further verify router configuration are:
    - Show running-config - Displays 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



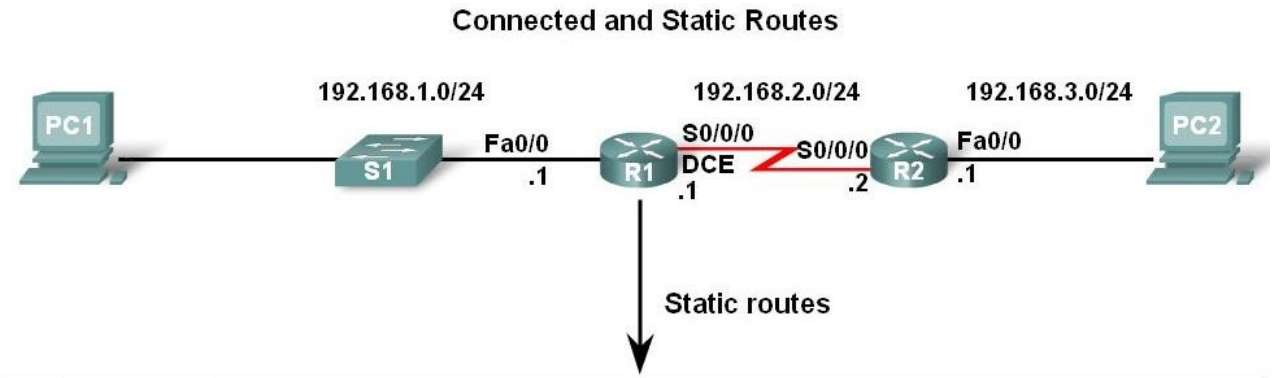

```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP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

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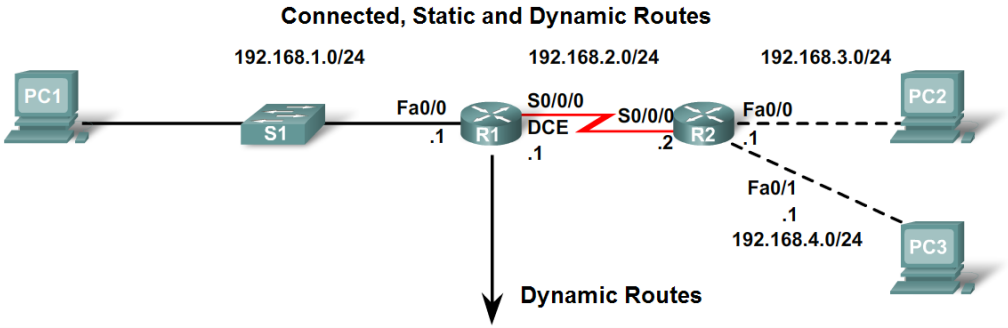
S    192.168.3.0/24 [1/0] via 192.168.2.2
```

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

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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
```
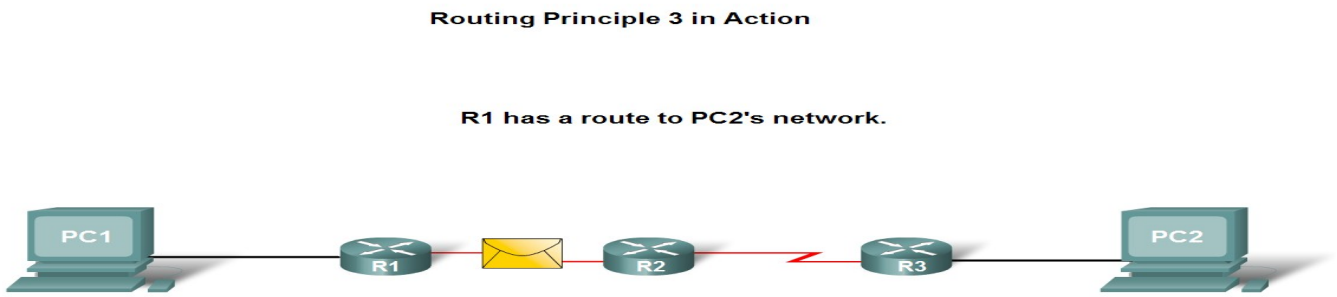
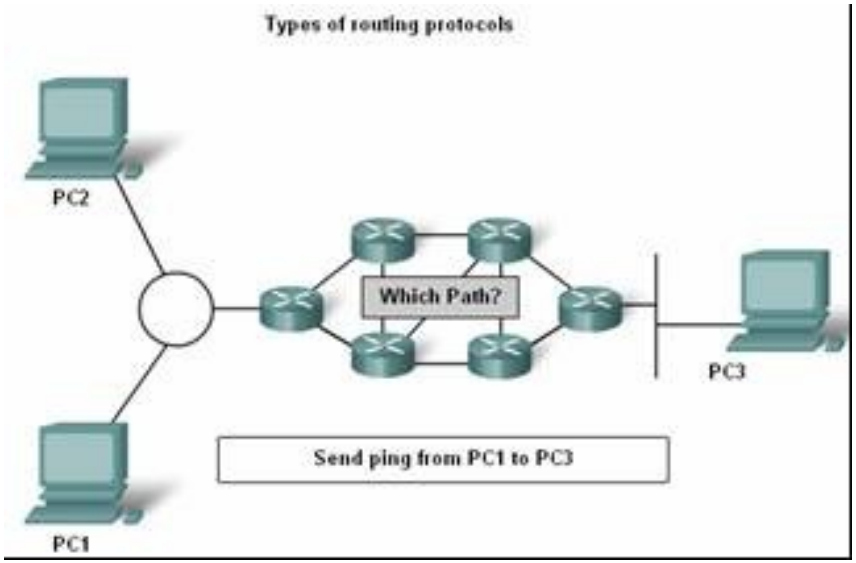

Routing Table Structure

- Routing Table Principles
  - 3 principles regarding routing tables:
    - Setiap router membuat keputusannya sendiri, berdasarkan pada informasi di table routingnya.
    - Routing table yang berbeda berisi informasi yang berbeda.
    - Sebuah routing table dapat memberitahukan jalur bagaimana mencapai tujuan dan tetapi tidak bisa memberitahukan bagaiamana jalur kembali



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).

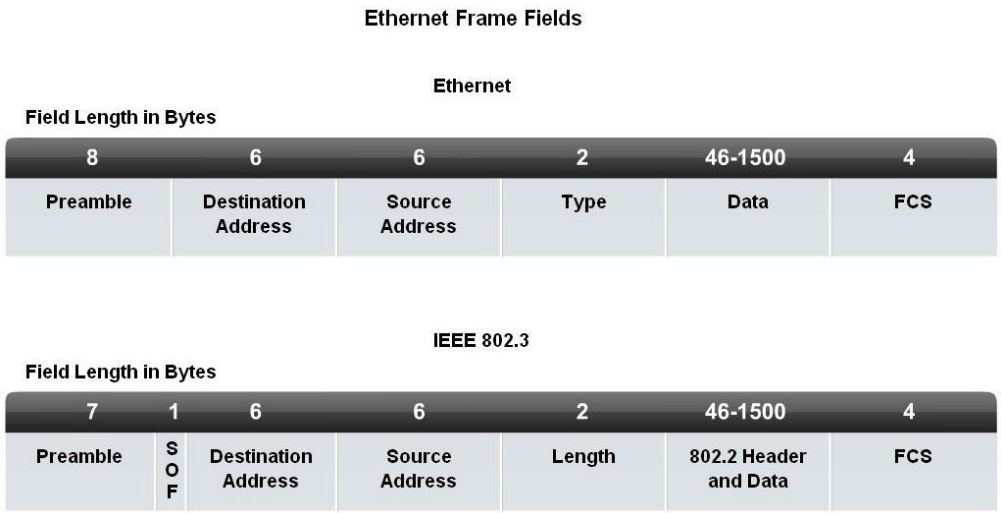


Router Paths and Packet Switching

- 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

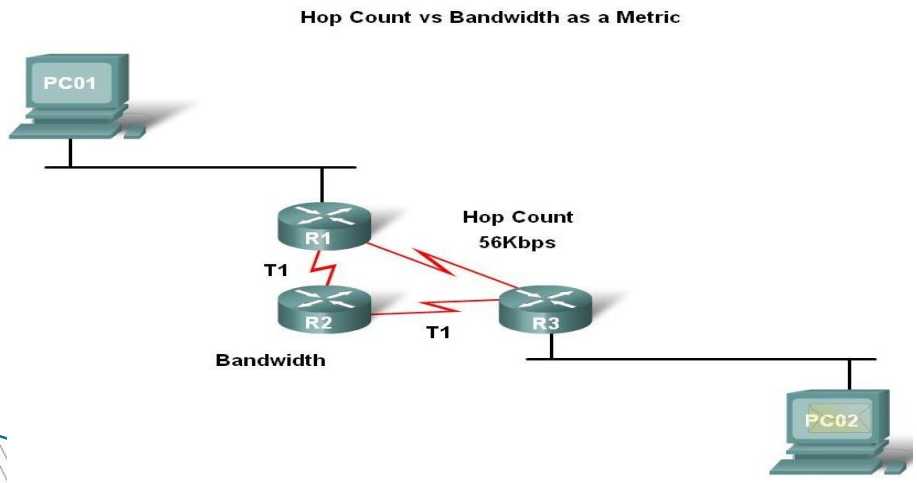
Router Paths and Packet Switching

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



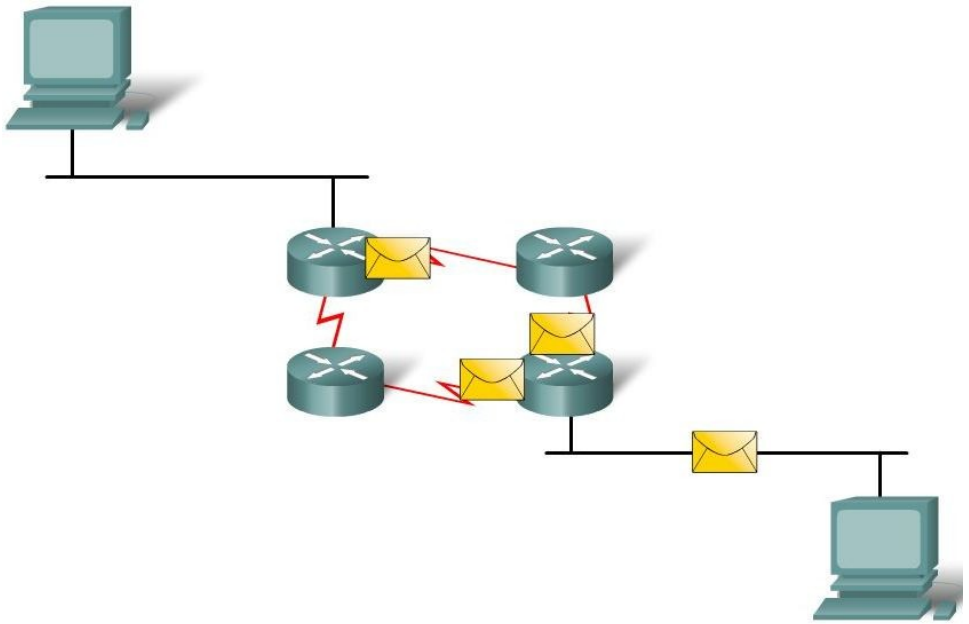
Router Paths and Packet Switching

- 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



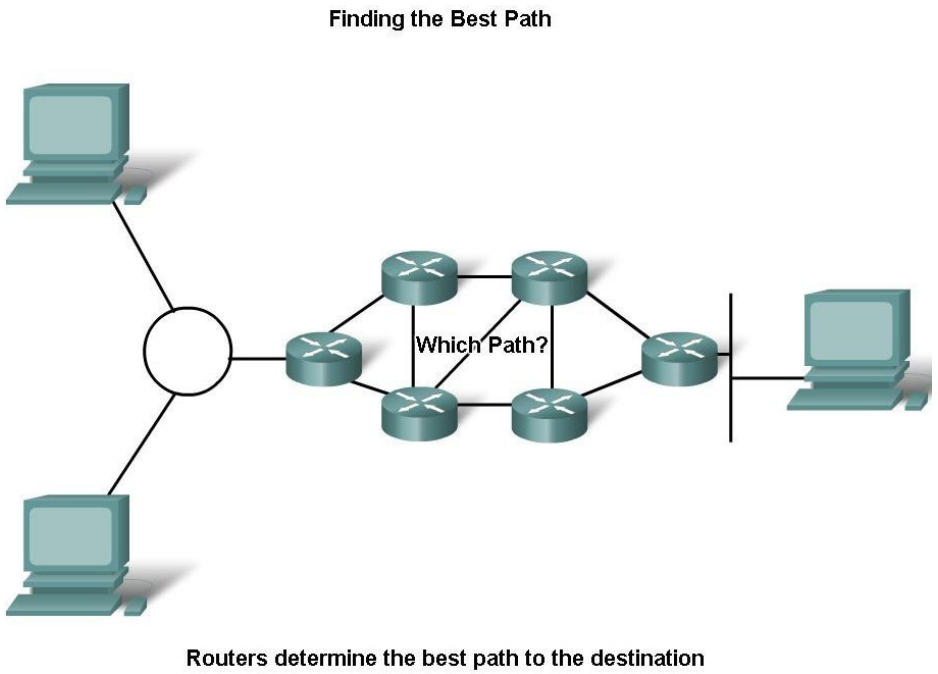
Router Paths and Packet Switching

- **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

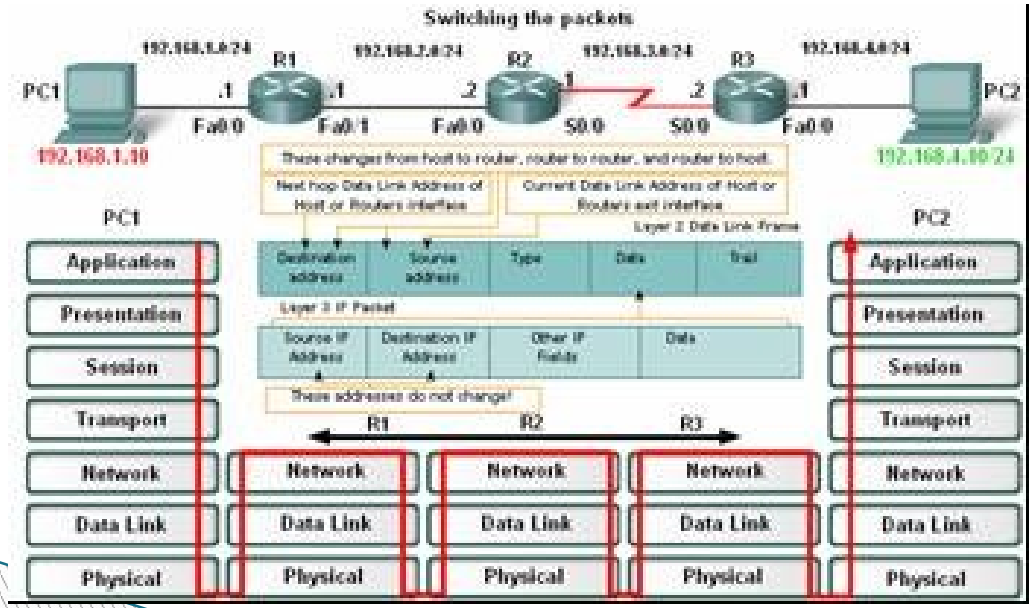


Router Paths and Packet Switching

- **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.

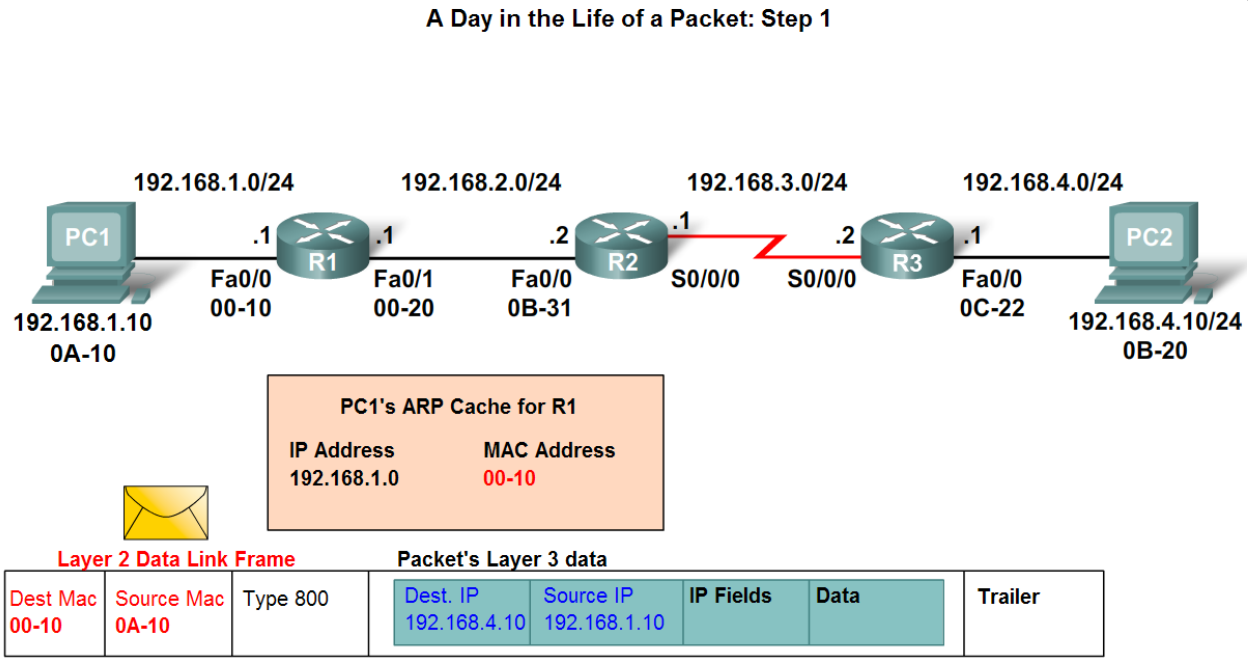
Router Paths and Packet Switching

- 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

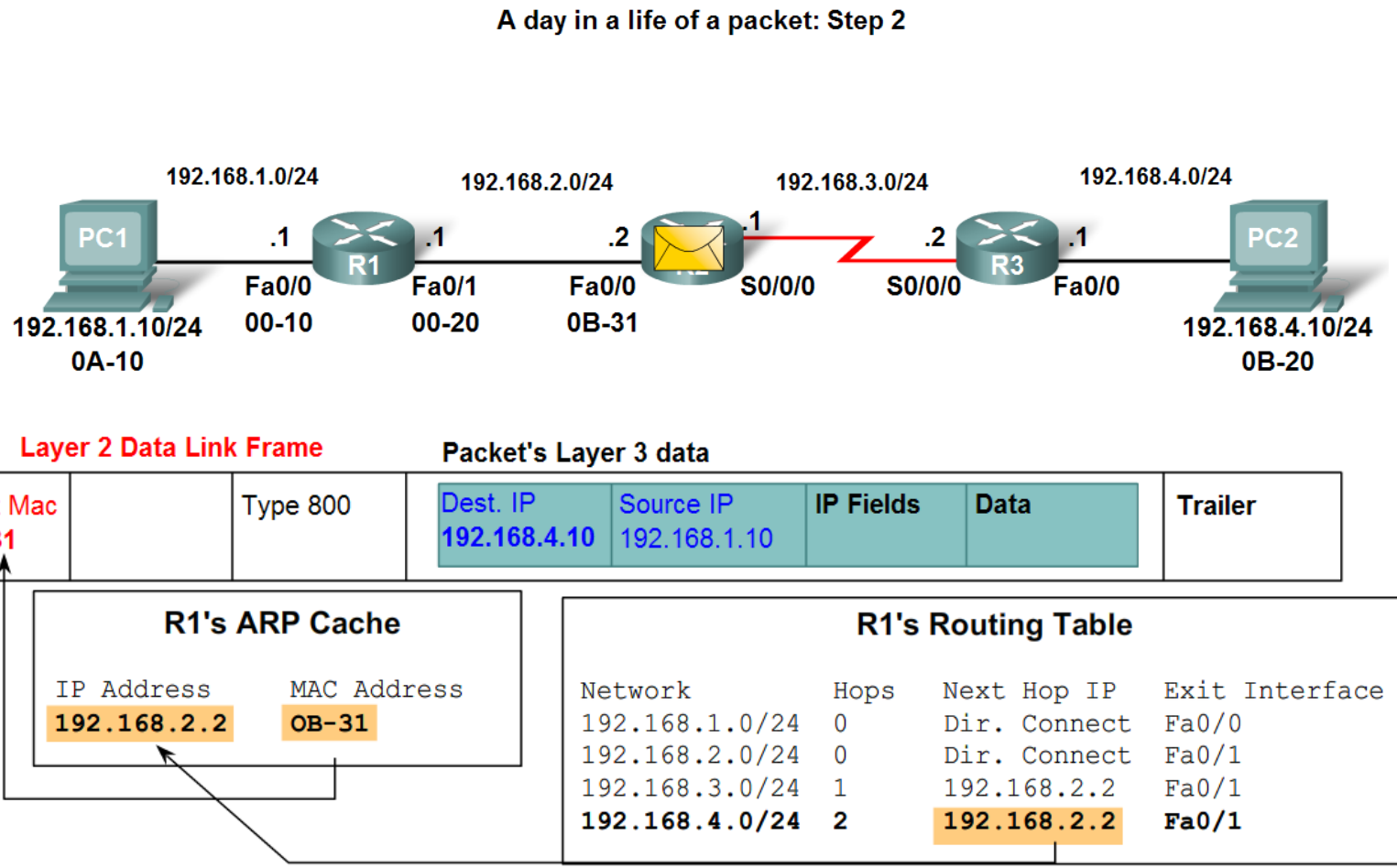
- Path determination and switching function details. PC1 Wants to send something to PC 2 here is part of what happens
  - **Step 1** - PC1 encapsulates packet into a frame. Frame contains R1's destination MAC address



Router Paths and Packet Switching

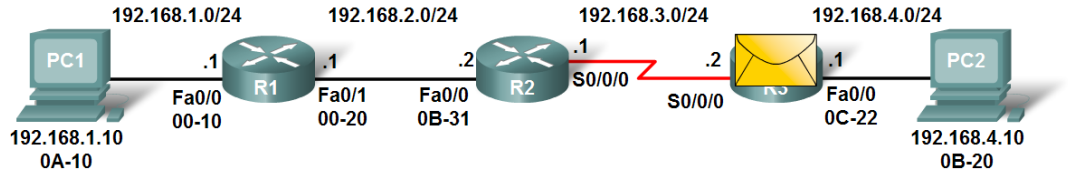
- **Step 2** - R1 receives Ethernet frame.
  - R1 sees that destination MAC address matches its own MAC.
  - R1 then strips off Ethernet frame.
  - R1 Examines destination IP.
  - R1 consults routing table looking for destination IP.
  - After finding destination IP in routing table, R1 now looks up next hop IP address.
  - R1 re-encapsulates IP packet with a new Ethernet frame.
  - R1 forwards Ethernet packet out Fa0/1 interface.

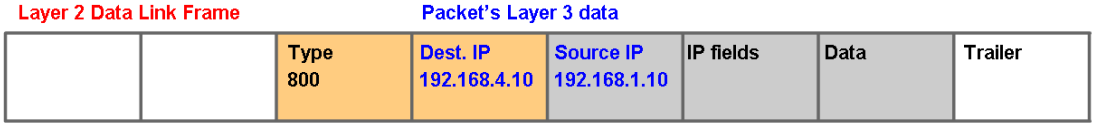
Router Paths and Packet Switching



Router Paths and Packet Switching

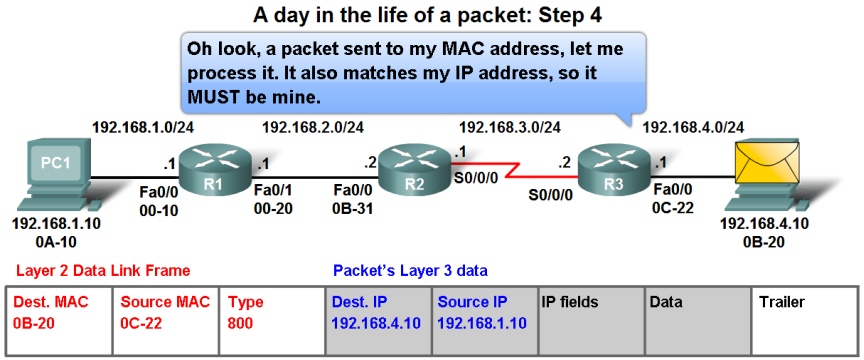
- Path determination and switching function details. PC1 Wants to send something to PC 2 here is part of what happens
  - **Step 3** - Packet arrives at R2
    - R2 receives Ethernet frame
    - R2 sees that destination MAC address matches its own MAC
    - R2 then strips off Ethernet frame
    - R2 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 decap er layer protoc



Open Source Router

- Mikrotic
- Freesco
- Xorp
- Vyatta
- Dll

XORP

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.