Chapter 5: Ethernet

Introduction to Networks

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Chapter 5: Objectives

Upon completion of this chapter, you will be able to:

- Describe the operation of the Ethernet sublayers.
- Identify the major fields of the Ethernet frame.
- Describe the purpose and characteristics of the Ethernet MAC address.
- Describe the purpose of ARP.
- Explain how ARP requests impact network and host performance.
- Explain basic switching concepts.
- Compare fixed configuration and modular switches.
- Configure a Layer 3 switch.

Chapter 5

5.0 Introduction

5.1 Ethernet Protocol

5.2 Address Resolution Protocol

5.3 LAN Switches

5.4 Summary

5.1 Ethernet Protocol

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LLC and MAC Sublayers

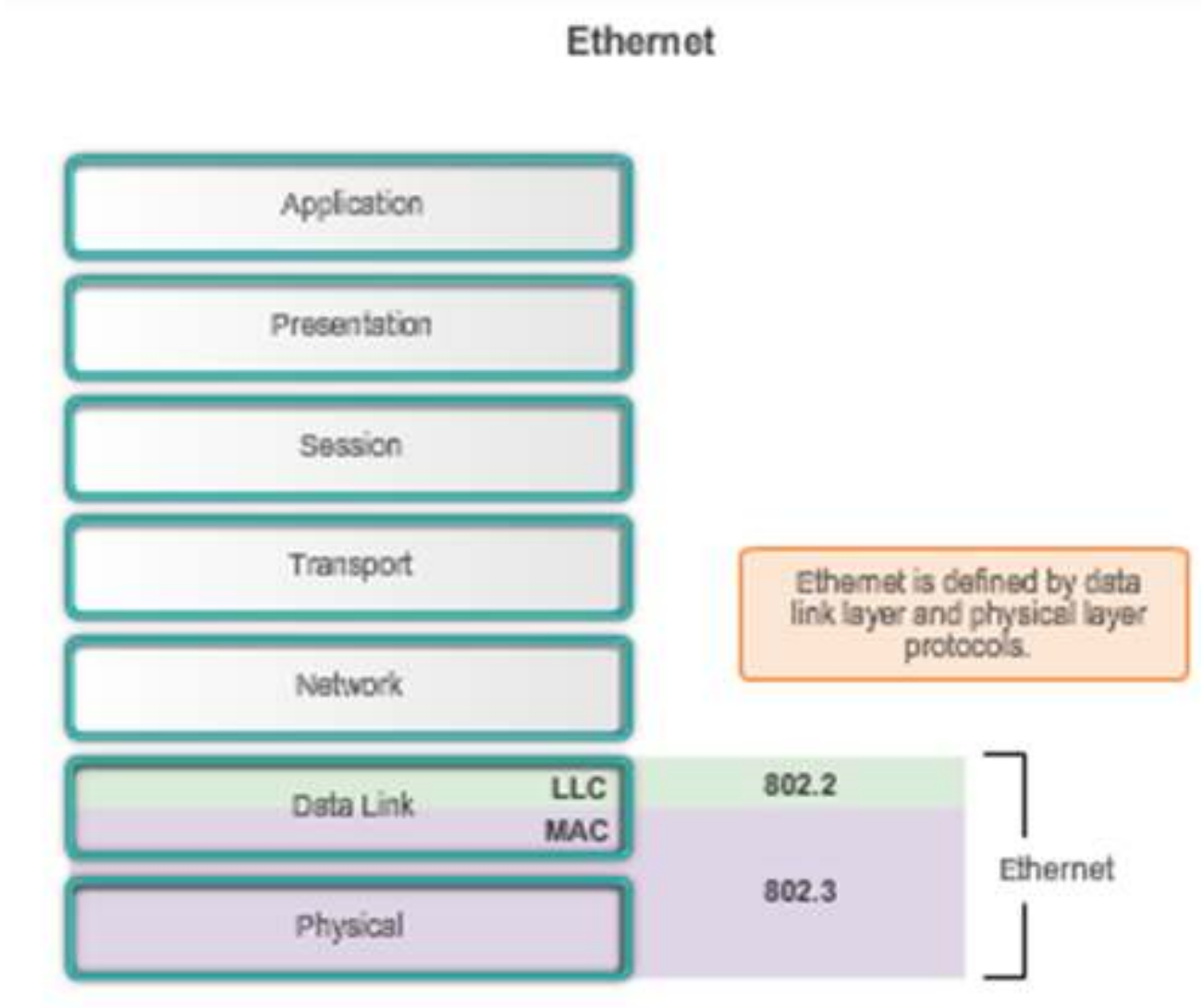
Ethernet

- One of the most widely used LAN technologies
- Operates in the data link layer and the physical layer
- Family of networking technologies that are defined in the IEEE 802.2 and 802.3 standards
- Supports data bandwidths of 10, 100, 1000, 10,000, 40,000, and 100,000 Mbps (100 Gbps)

Ethernet Standards

- Define Layer 2 protocols and Layer 1 technologies
- Two separate sub layers of the data link layer to operate – Logical link control (LLC) and the MAC sublayers

LLC and MAC Sublayers (cont.)



LLC and MAC Sublayers (cont.)

LLC

- Handles communication between upper and lower layers.
- Takes the network protocol data and adds control information to help deliver the packet to the destination.

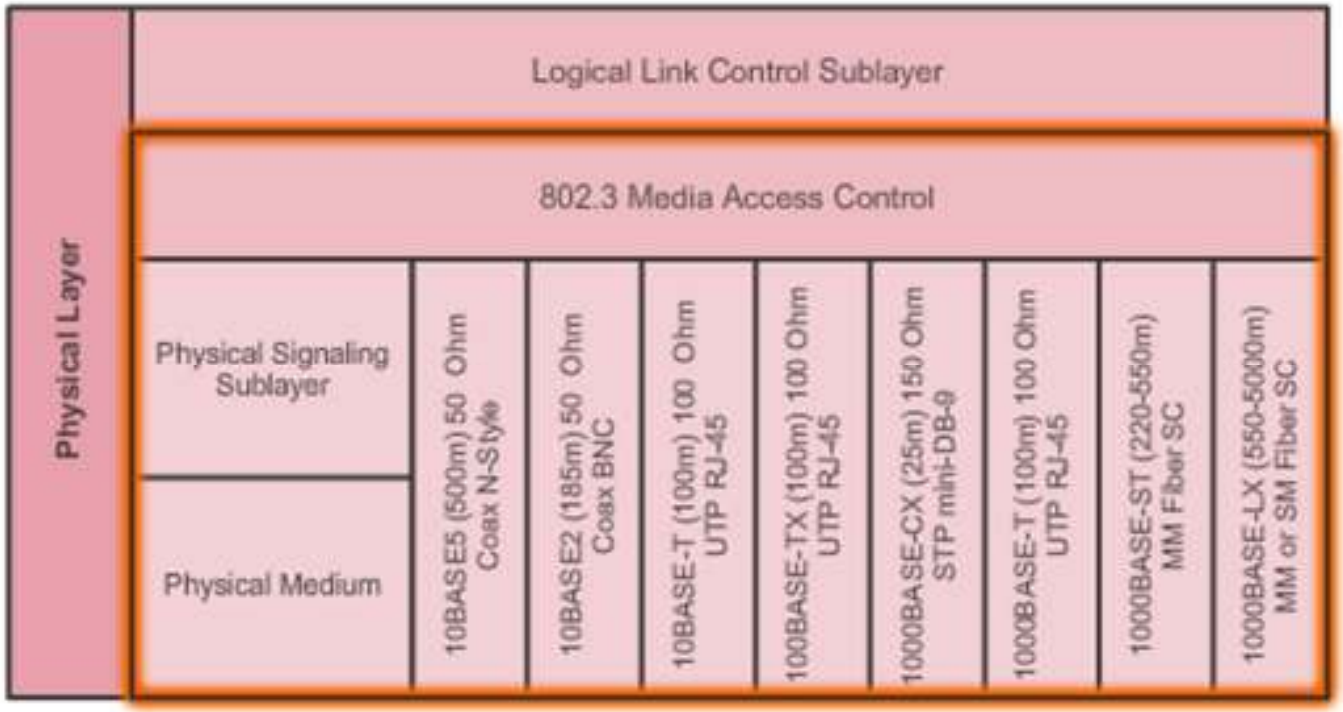
MAC

- Constitutes the lower sublayer of the data link layer.
- Implemented by hardware, typically in the computer NIC.
- Two primary responsibilities:
  - Data encapsulation
  - Media access control

MAC Sublayer

Data Encapsulation
- Frame delimiting
- Addressing
- Error detection

Media Access Control
- Control of frame placement on and off the media
- Media recovery



MAC Sublayer (cont.)

Data encapsulation

- Frame assembly before transmission and frame disassembly upon reception of a frame.
- MAC layer adds a header and trailer to the network layer PDU.

Provides three primary functions:

- **Frame delimiting** – Identifies a group of bits that make up a frame, synchronization between the transmitting and receiving nodes.
- **Addressing** – Each Ethernet header added in the frame contains the physical address (MAC address) that enables a frame to be delivered to a destination node.
- **Error detection** – Each Ethernet frame contains a trailer with a cyclic redundancy check (CRC) of the frame contents.

MAC Sublayer (cont.)

MAC

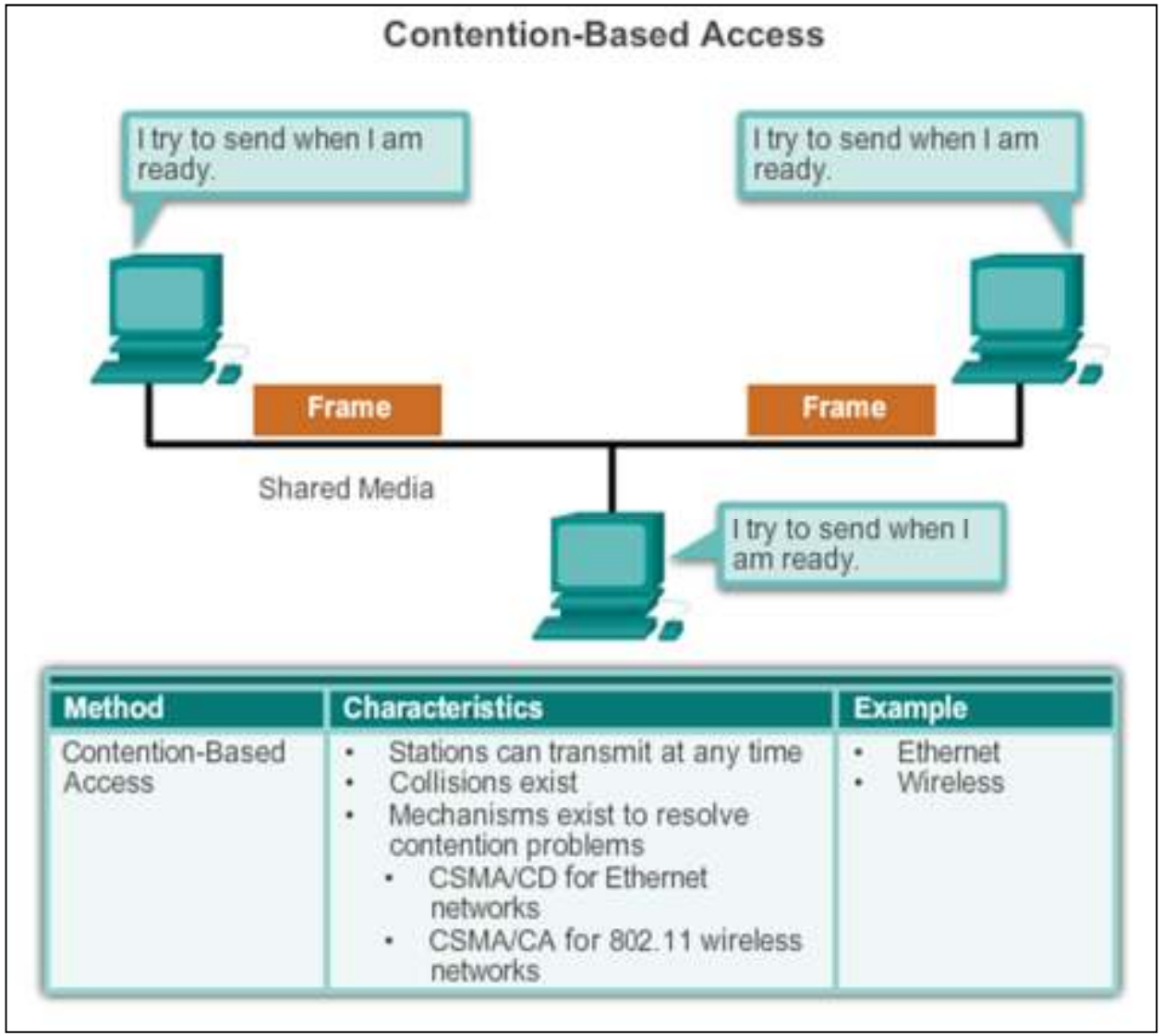
- Responsible for the placement of frames on the media and the removal of frames from the media
- Communicates directly with the physical layer
- If multiple devices on a single medium attempt to forward data simultaneously, the data will collide resulting in corrupted, unusable data
- Ethernet provides a method for controlling how the nodes share access through the use a Carrier Sense Multiple Access (CSMA) technology

Media Access Control

Carrier Sense Multiple Access (CSMA) process

- Used to first detect if the media is carrying a signal
- If no carrier signal is detected, the device transmits its data
- If two devices transmit at the same time - data collision

Media Access Control (cont.)



Method	Characteristics	Example

Contention-Based Access	• Stations can transmit at any time
	• Collisions exist
	• Mechanisms exist to resolve contention problems
	  • CSMA/CD for Ethernet networks
	  • CSMA/CA for 802.11 wireless networks
		• Ethernet
		• Wireless

Media Access Control (cont.)

CSMA is usually implemented in conjunction with a method for resolving media contention. The two commonly used methods are:
CSMA/Collision Detection and **CSMA/Collision Avoidance**

CSMA/Collision Detection

- The device monitors the media for the presence of a data signal
- If a data signal is absent, indicating that the media is free, the device transmits the data
- If signals are then detected that show another device was transmitting at the same time, all devices stop sending & try again later
- While Ethernet networks are designed with CSMA/CD technology, with today's intermediate devices, collisions do not occur and the processes utilized by CSMA/CD are really unnecessary
- Wireless connections in a LAN environment still have to take collisions into account

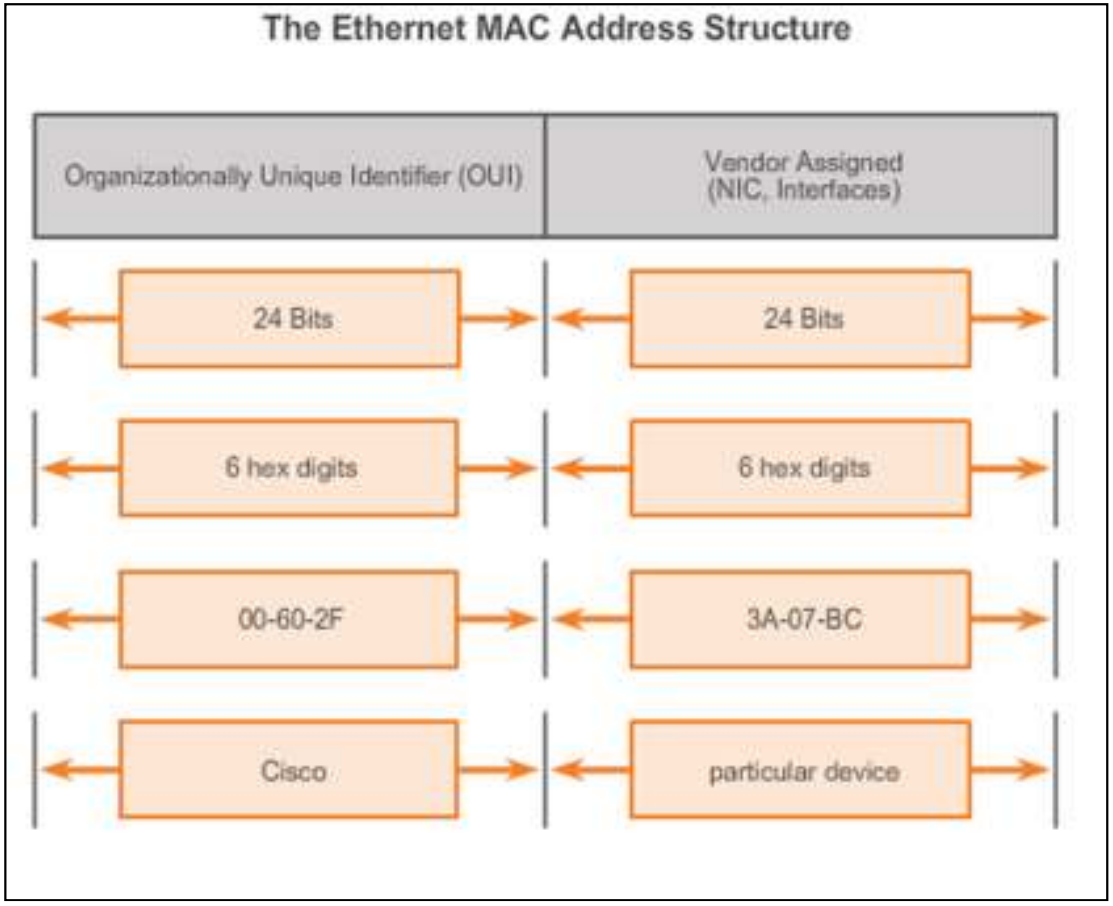
Media Access Control (cont.)

CSMA/Collision Avoidance (CSMA/CA) media access method

- Device examines the media for the presence of data signal - if the media is free, the device sends a notification across the media of its intent to use it
- The device then sends the data.
- Used by 802.11 wireless networking technologies

MAC Address: Ethernet Identity

- Layer 2 Ethernet MAC address is a 48-bit binary value expressed as 12 hexadecimal digits.
- IEEE requires a vendor to follow these rules:
  - Must use that vendor's assigned OUI as the first 3 bytes.
  - All MAC addresses with the same OUI must be assigned a unique value in the last 3 bytes.



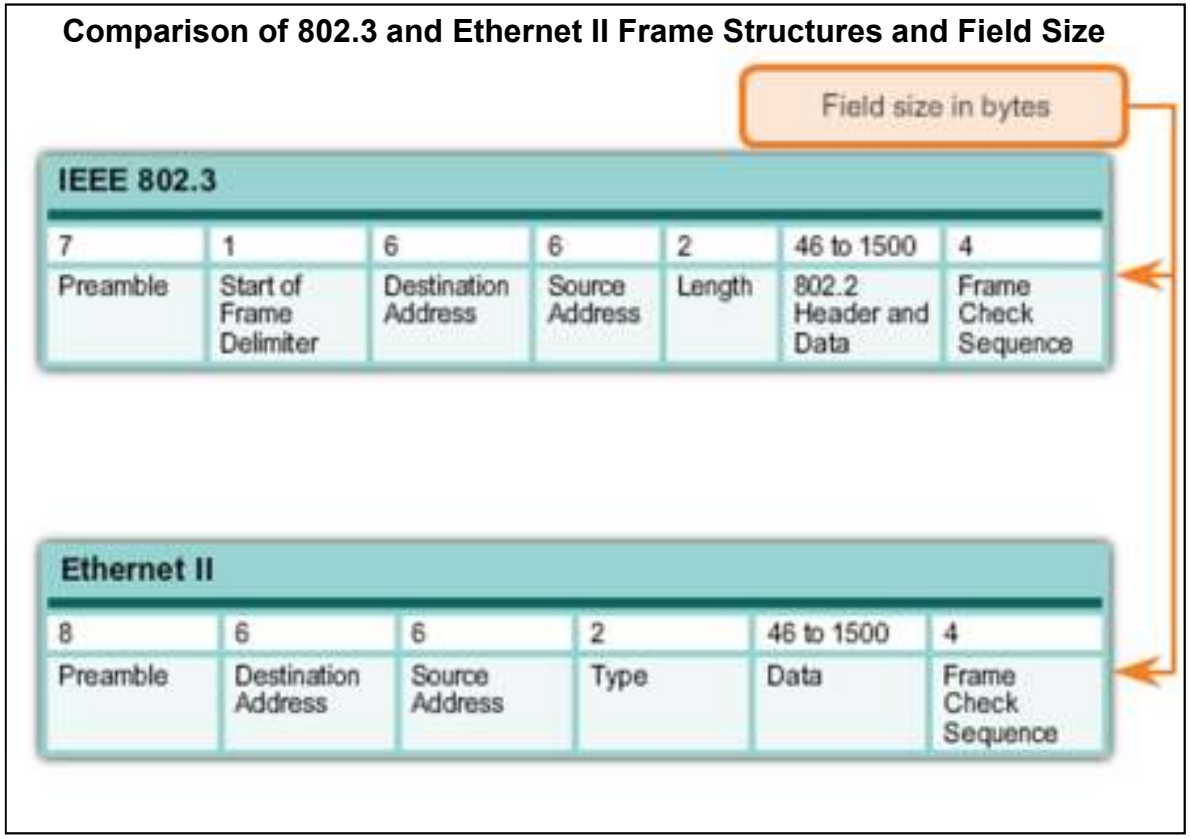
Frame Processing

- MAC addresses assigned to workstations, servers, printers, switches, and routers.
- Example MACs:
  - 00-05-9A-3C-78-00
  - 00:05:9A:3C:78:00
  - 0005.9A3C.7800.
- When a device is forwarding a message to an Ethernet network, attaches header information to the packet, contains the source and destination MAC address.
- Each NIC views information to see if the destination MAC address in the frame matches the device's physical MAC address stored in RAM.
- No match, the device discards the frame.
- Matches the destination MAC of the frame, the NIC passes the frame up the OSI layers, where the de-encapsulation process takes place.

Ethernet Encapsulation

- Early versions of Ethernet were slow at 10 Mb/s.
- Now operate at 10 Gb/s per second and faster.
- Ethernet frame structure adds headers and trailers around the Layer 3 PDU to encapsulate the message being sent.
- Ethernet II is the Ethernet frame format used in TCP/IP networks.

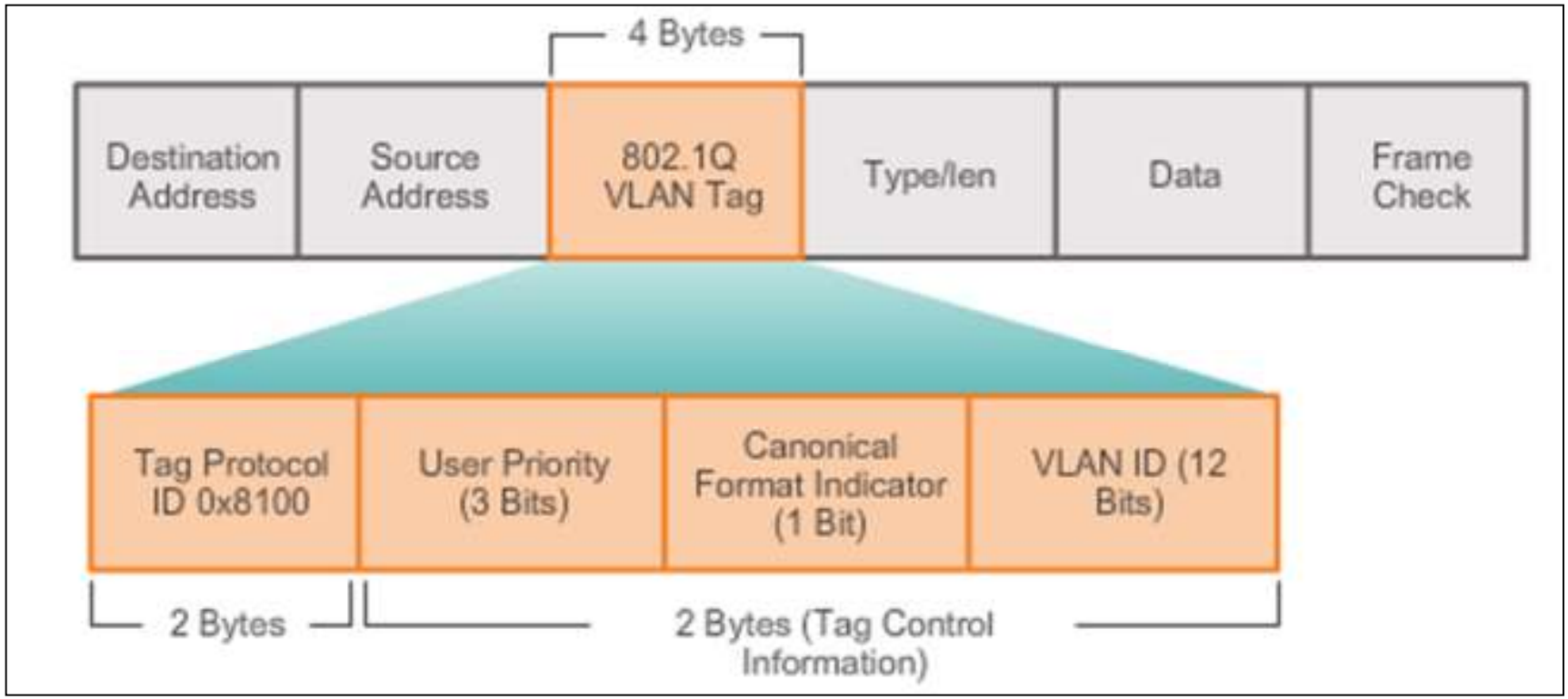
Comparison of 802.3 and Ethernet II Frame Structures and Field Size



Ethernet Frame Size

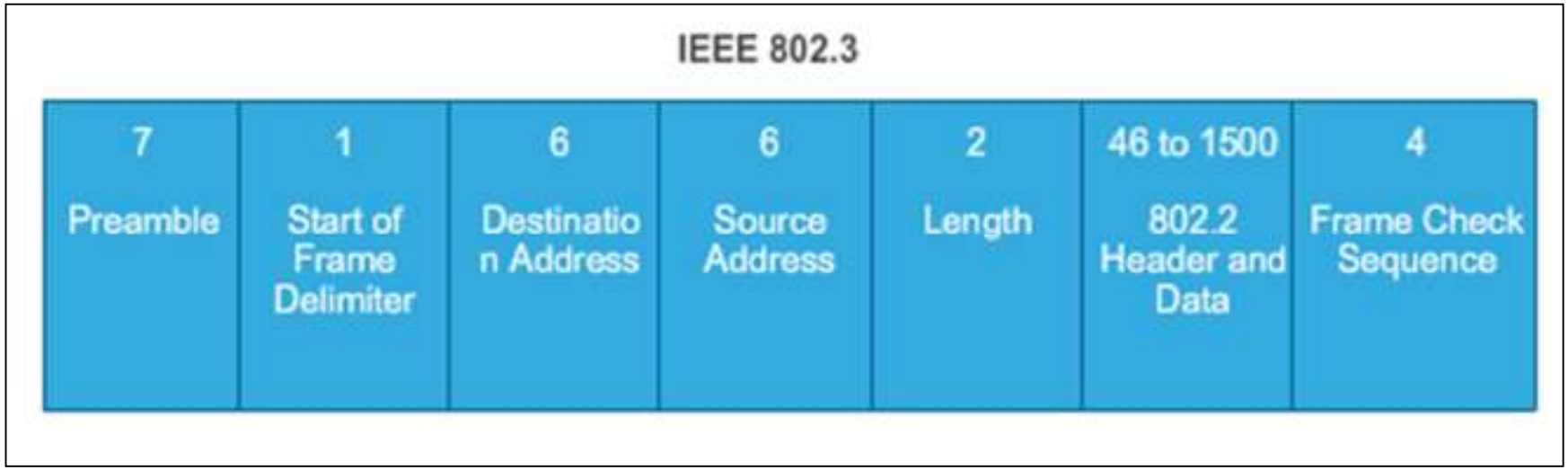
- Ethernet II and IEEE 802.3 standards define the minimum frame size as 64 bytes and the maximum as 1518 bytes
- Less than 64 bytes in length is considered a "collision fragment" or "runt frame”
- If size of a transmitted frame is less than the minimum or greater than the maximum, the receiving device drops the frame
- At the physical layer, different versions of Ethernet vary in their method for detecting and placing data on the media

Ethernet Frame Size (cont.)



The figure displays the fields contained in the 802.1Q VLAN tag

Introduction to the Ethernet Frame

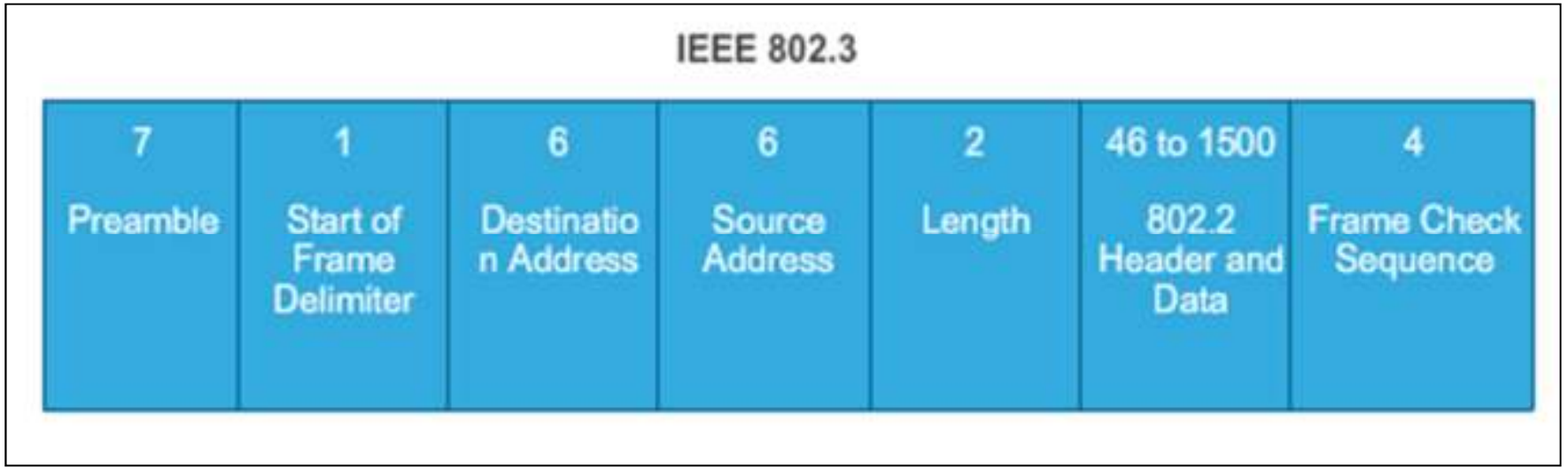


Preamble and Start Frame Delimiter Fields – Used for synchronization between the sending and receiving devices.

Length/Type Field – Defines the exact length of the frame's data field; describes which protocol is implemented.

Data and Pad Fields – Contains the encapsulated data from a higher layer, an IPv4 packet.

Introduction to the Ethernet Frame (cont.)



Frame Check Sequence Field

Used to detect errors in a frame with cyclic redundancy check (4 bytes); if calculations match at source and receiver, no error occurred.

MAC Addresses and Hexadecimal

Decimal and Binary equivalents of 0 to F Hexadecimal

Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Selected Decimal, Binary and Hexadecimal equivalents

Decimal	Binary	Hexadecimal
0	0000 0000	00
1	0000 0001	01
2	0000 0010	02
3	0000 0011	03
4	0000 0100	04
5	0000 0101	05
6	0000 0110	06
7	0000 0111	07
8	0000 1000	08
10	0000 1010	0A
15	0000 1111	0F
16	0001 0000	10
32	0010 0000	20
64	0100 0000	40
128	1000 0000	80
192	1100 0000	C0
202	1100 1010	CA
240	1111 0000	F0
255	1111 1111	FF

MAC Address Representations

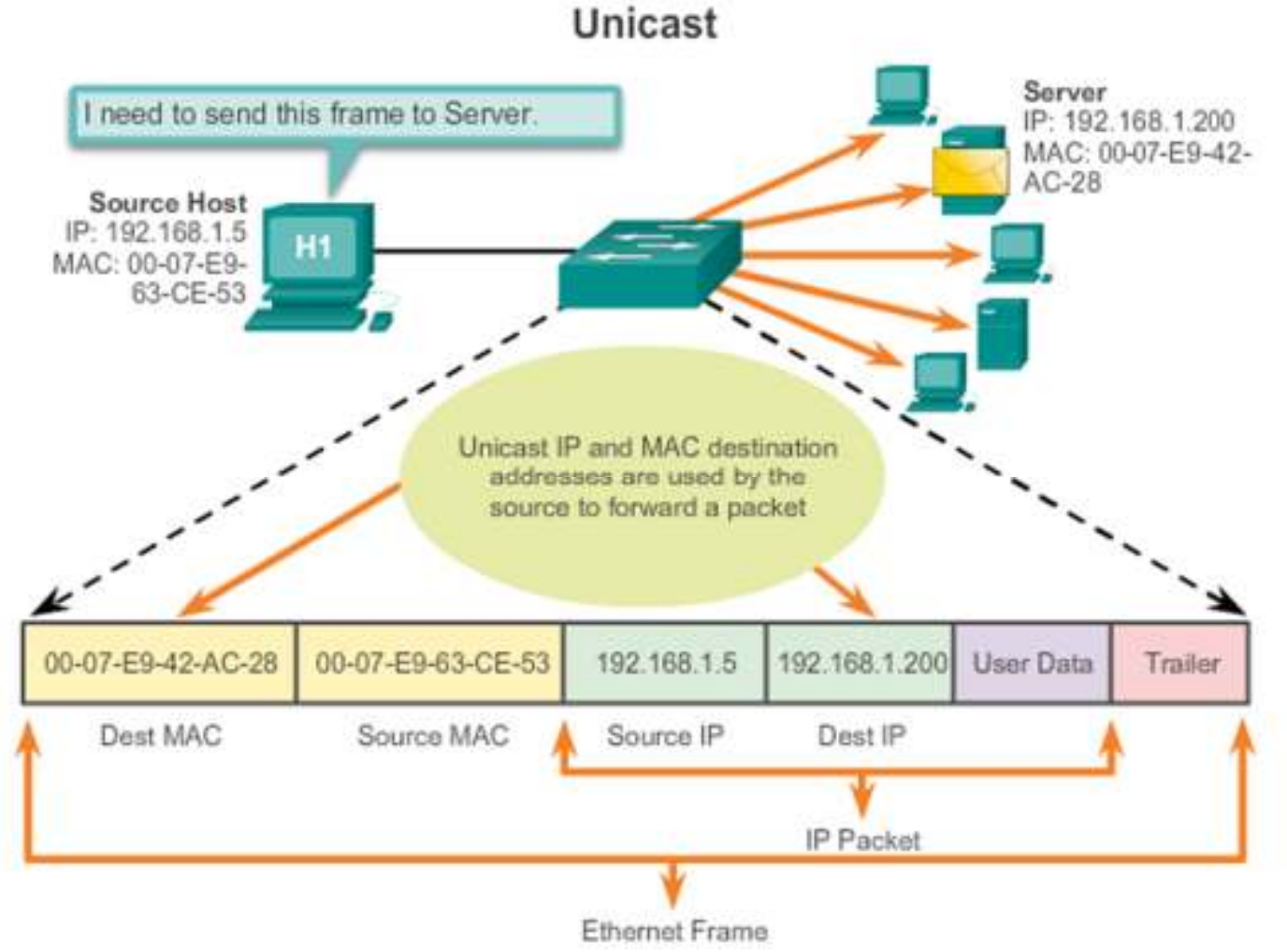
```
C:\>ipconfig/all

Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . : example.com
   Description . . . . . . . . . . . : Intel(R) Gigabit Network Connection
   Physical Address. . . . . . . . . : 00-18-DE-C7-F3-FB
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IPv4 Address. . . . . . . . . . . : 192.168.1.67(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Monday, November 26, 2012 12:14:48 PM
   Lease Expires . . . . . . . . . . : Saturday, December 01, 2012 12:15:02 AM
   Default Gateway . . . . . . . . . : 192.168.1.254
   DHCP Server . . . . . . . . . . . : 192.168.1.254
   DNS Servers . . . . . . . . . . . : 192.168.1.254
```

With Dashes 00-60-2F-3A-07-BC

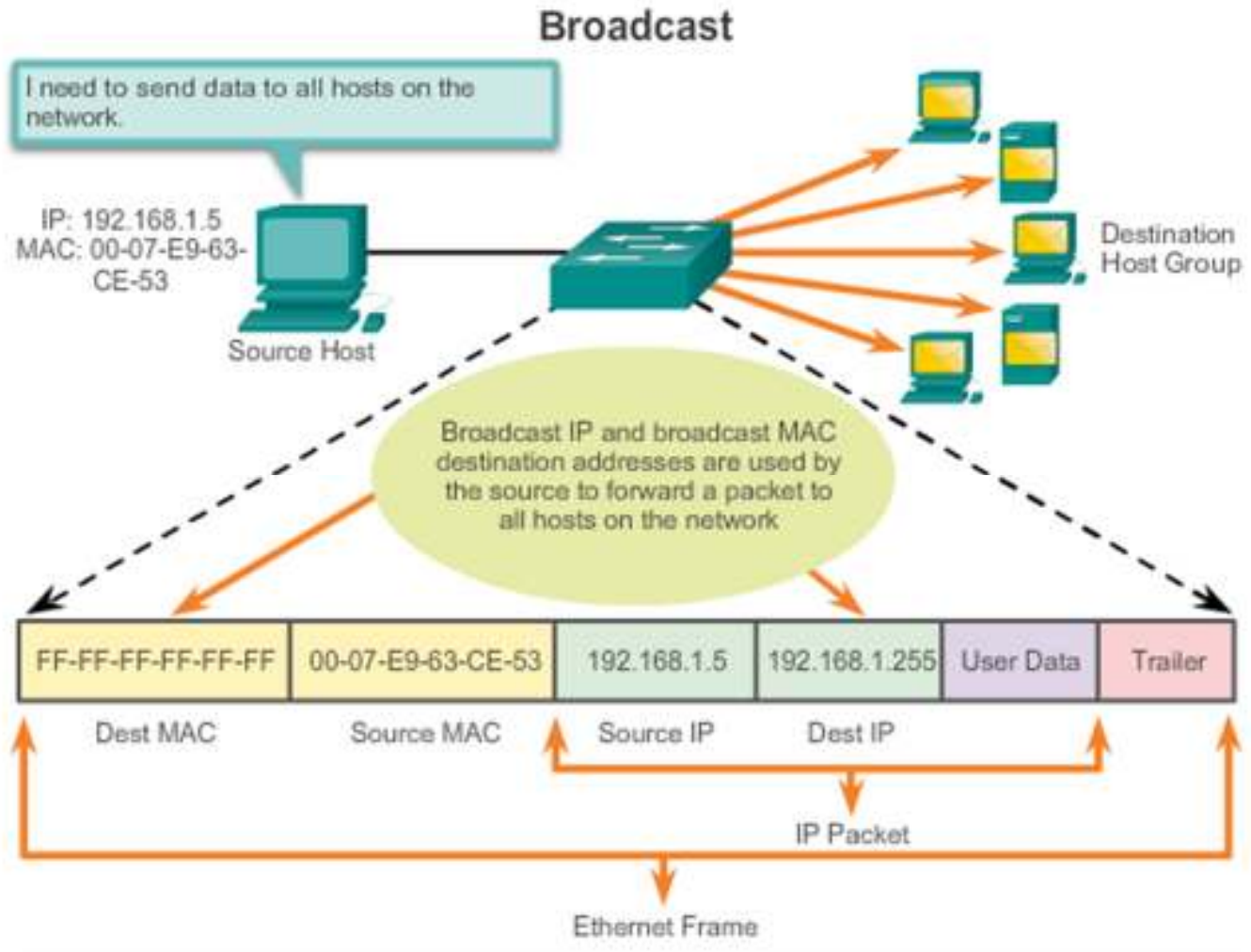
With Colons 00:60:2F:3A:07:BC

With Periods 0060.2F3A.07BC

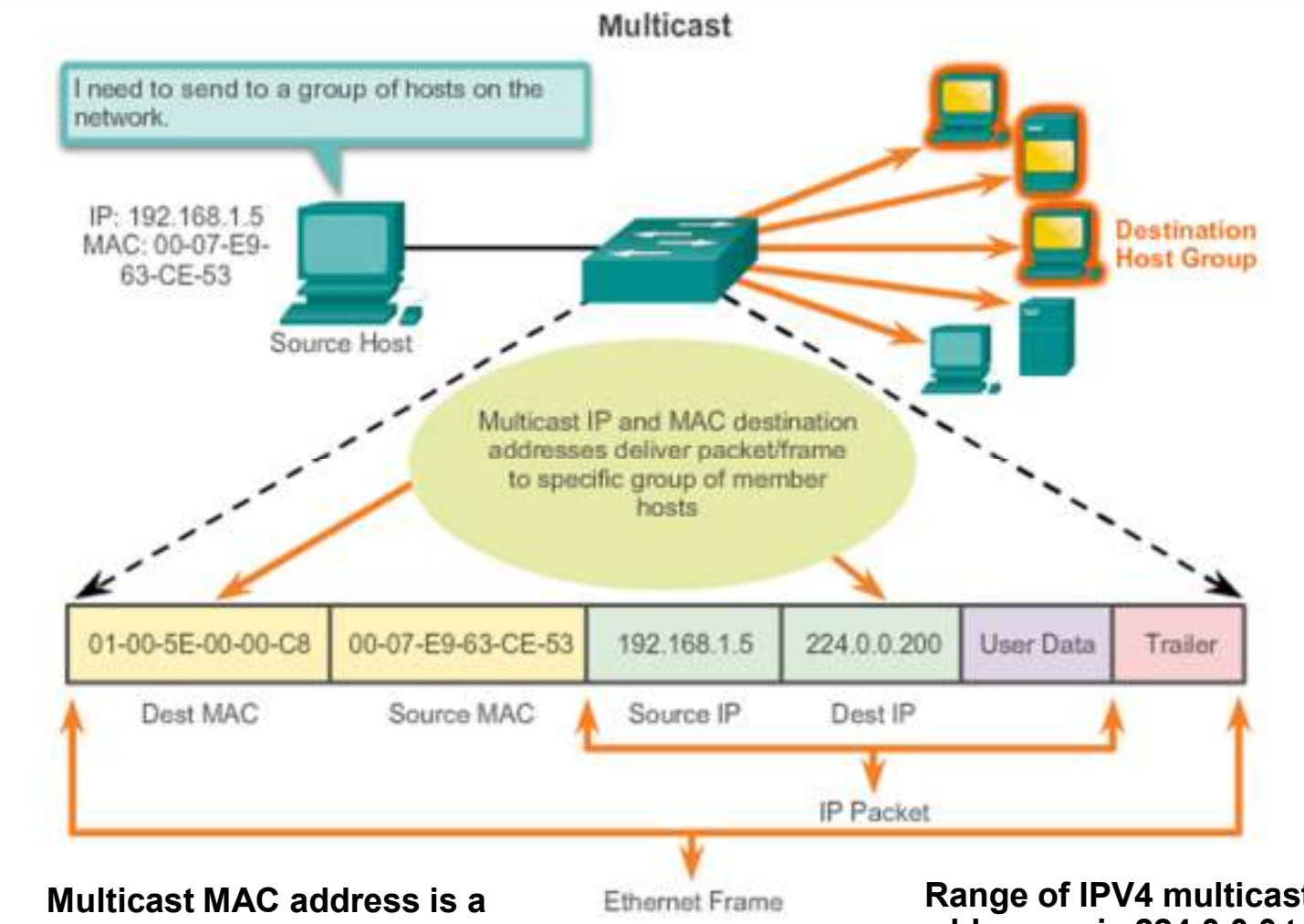
Unicast MAC Address



Broadcast MAC Address



Multicast MAC Address



Multicast MAC address is a special value that begins with 01-00-5E in hexadecimal

Range of IPV4 multicast addresses is 224.0.0.0 to 239.255.255.255

MAC and IP

MAC Address

- This address does not change
- Similar to the name of a person
- Known as physical address because physically assigned to the host NIC

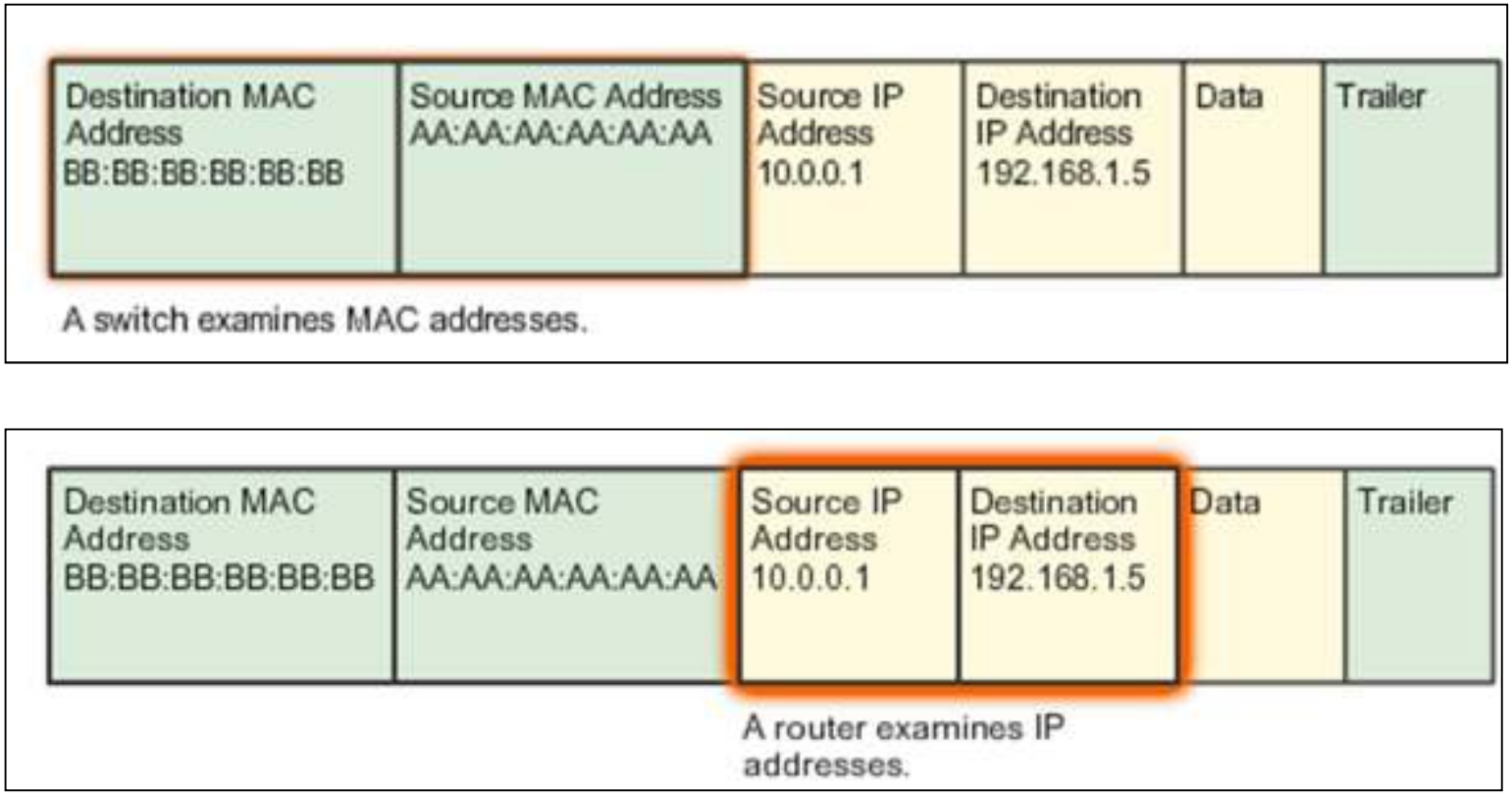
IP Address

- Similar to the address of a person
- Based on where the host is actually located
- Known as a logical address because assigned logically
- Assigned to each host by a network administrator

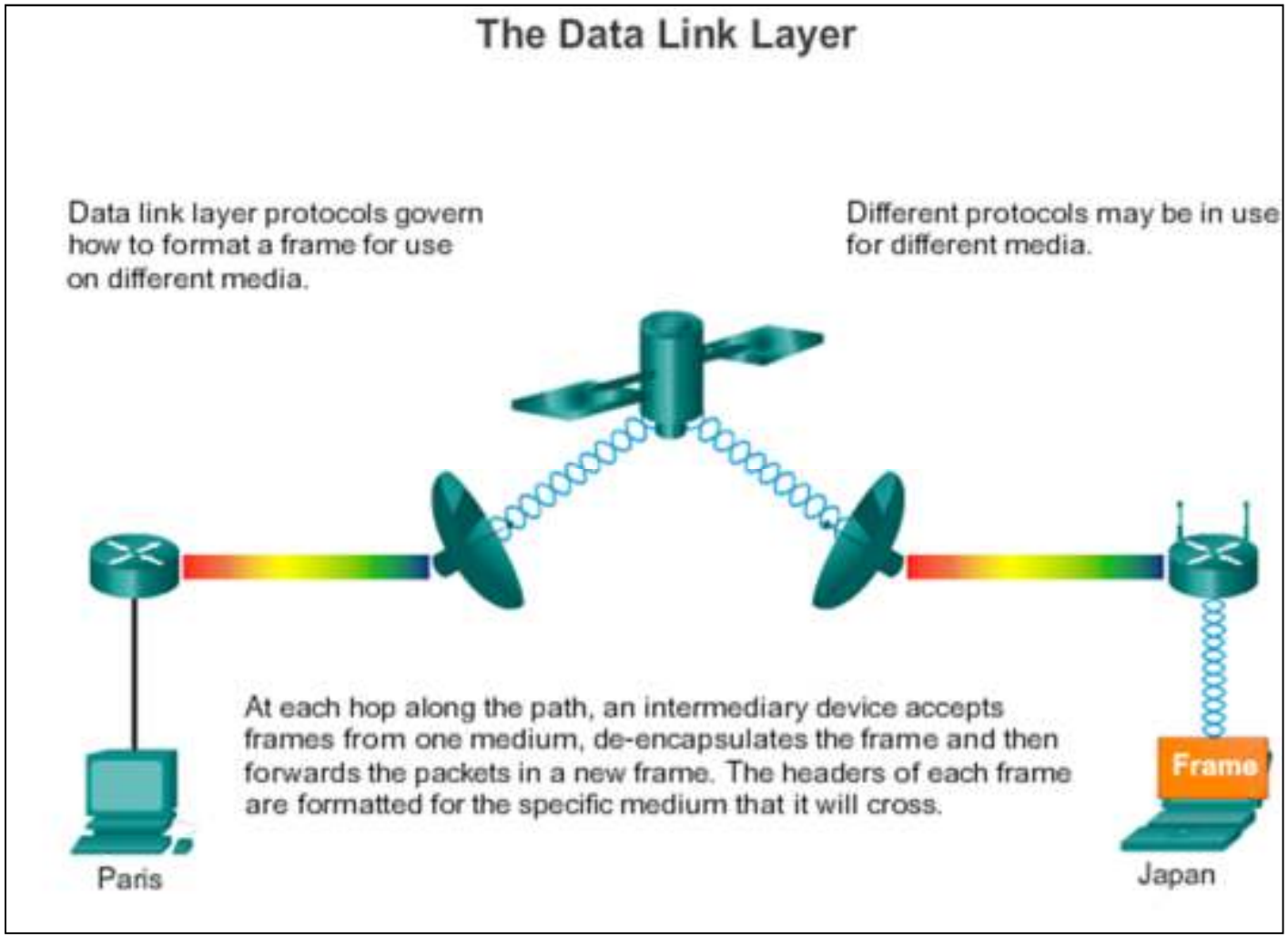
Both the physical MAC and logical IP addresses are required for a computer to communicate just like both the name and address of a person are required to send a letter.

End-to-End Connectivity, MAC, and IP

IP Packet Encapsulated in an Ethernet Frame



End-to-End Connectivity, MAC, and IP (cont.)



5.2 Address Resolution Protocol

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Introduction to ARP

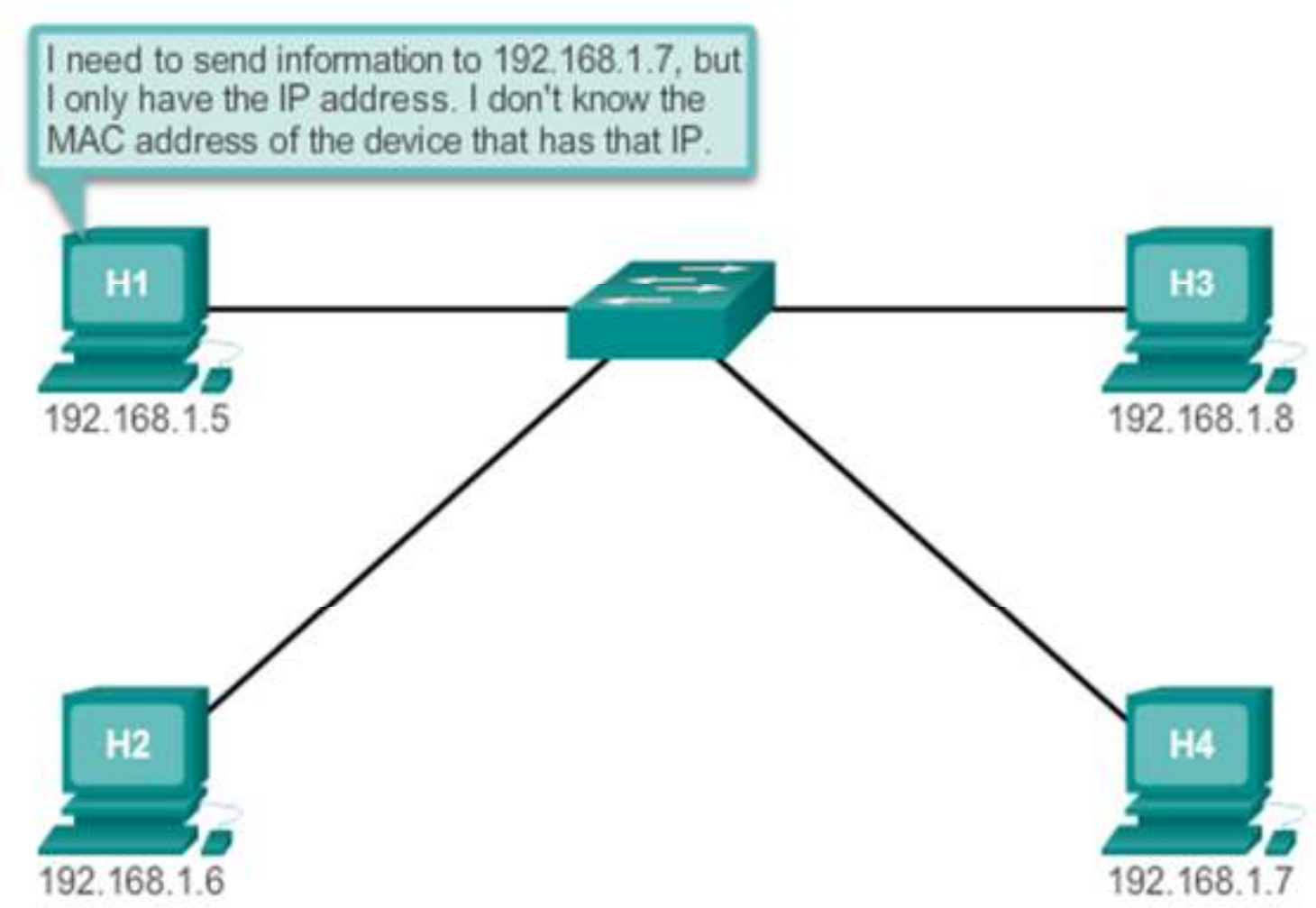
ARP Purpose

- Sending node needs a way to find the MAC address of the destination for a given Ethernet link

The ARP protocol provides two basic functions:

- Resolving IPv4 addresses to MAC addresses
- Maintaining a table of mappings

Introduction to ARP (cont.)



ARP Functions/Operation

ARP Table

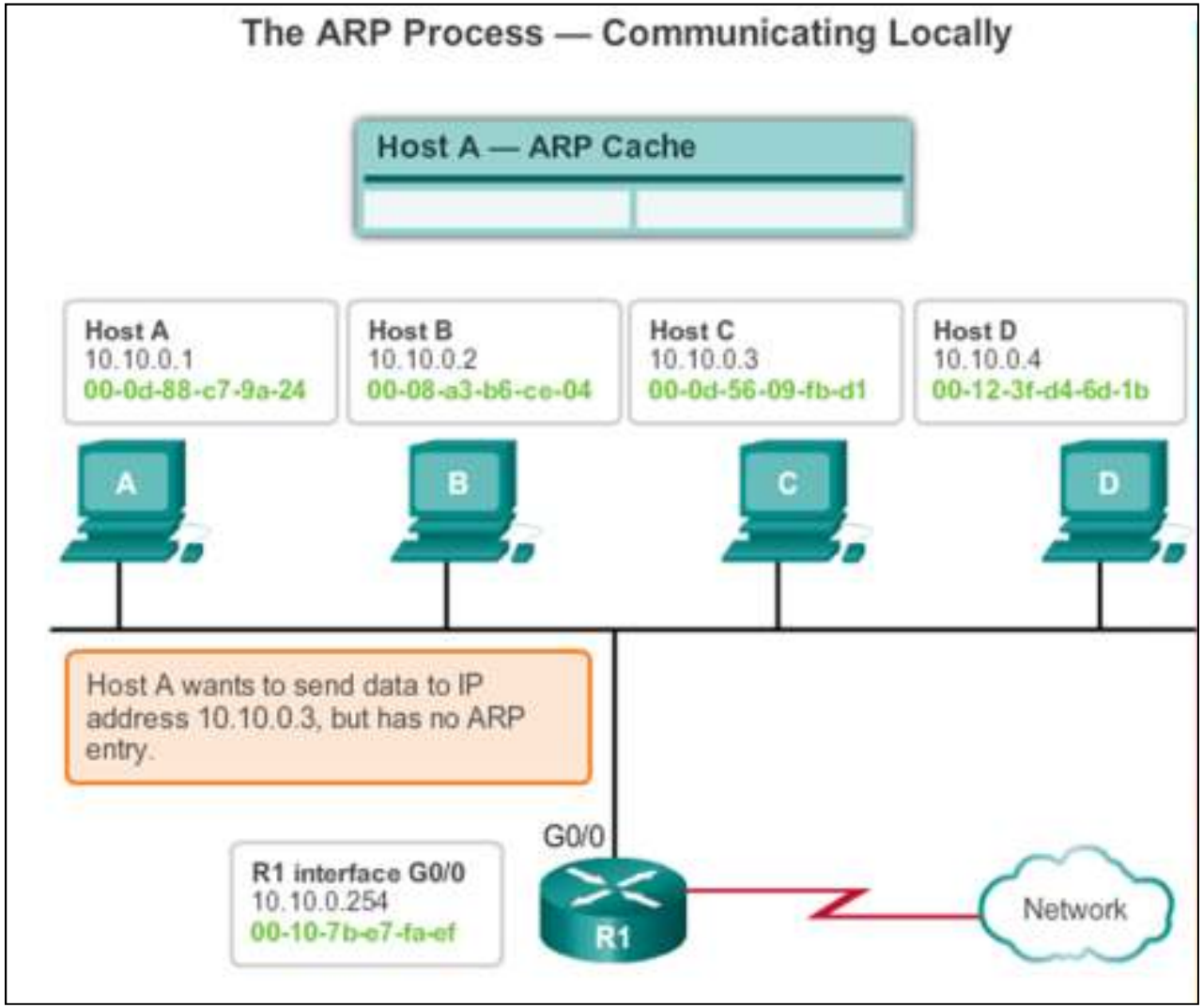
- Used to find the data link layer address that is mapped to the destination IPv4 address.
- As a node receives frames from the media, it records the source IP and MAC address as a mapping in the ARP table.

ARP Request

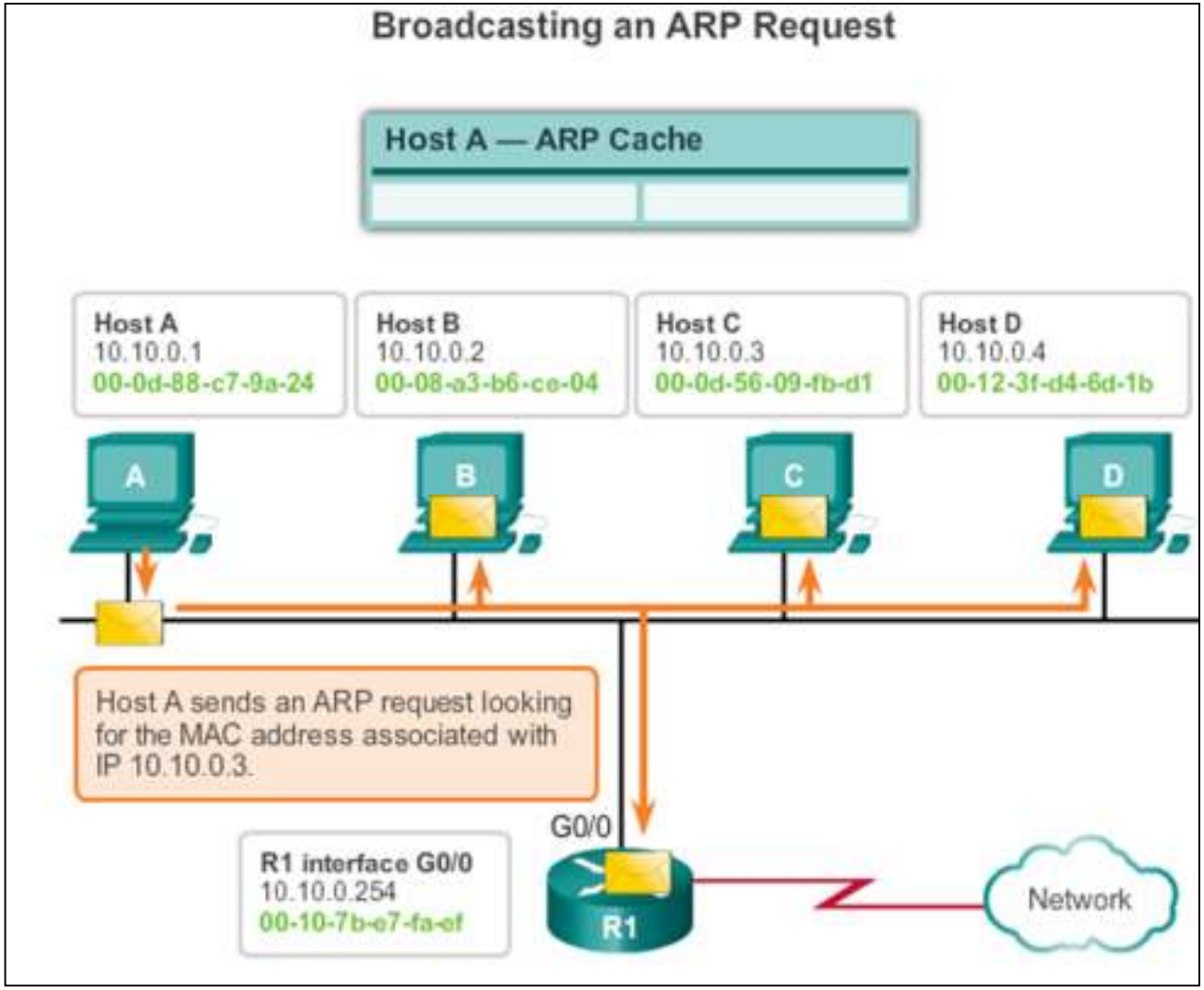
- Layer 2 broadcast to all devices on the Ethernet LAN.
- The node that matches the IP address in the broadcast will reply.
- If no device responds to the ARP request, the packet is dropped because a frame cannot be created.

Note: Static map entries can be entered in an ARP table, but this is rarely done.

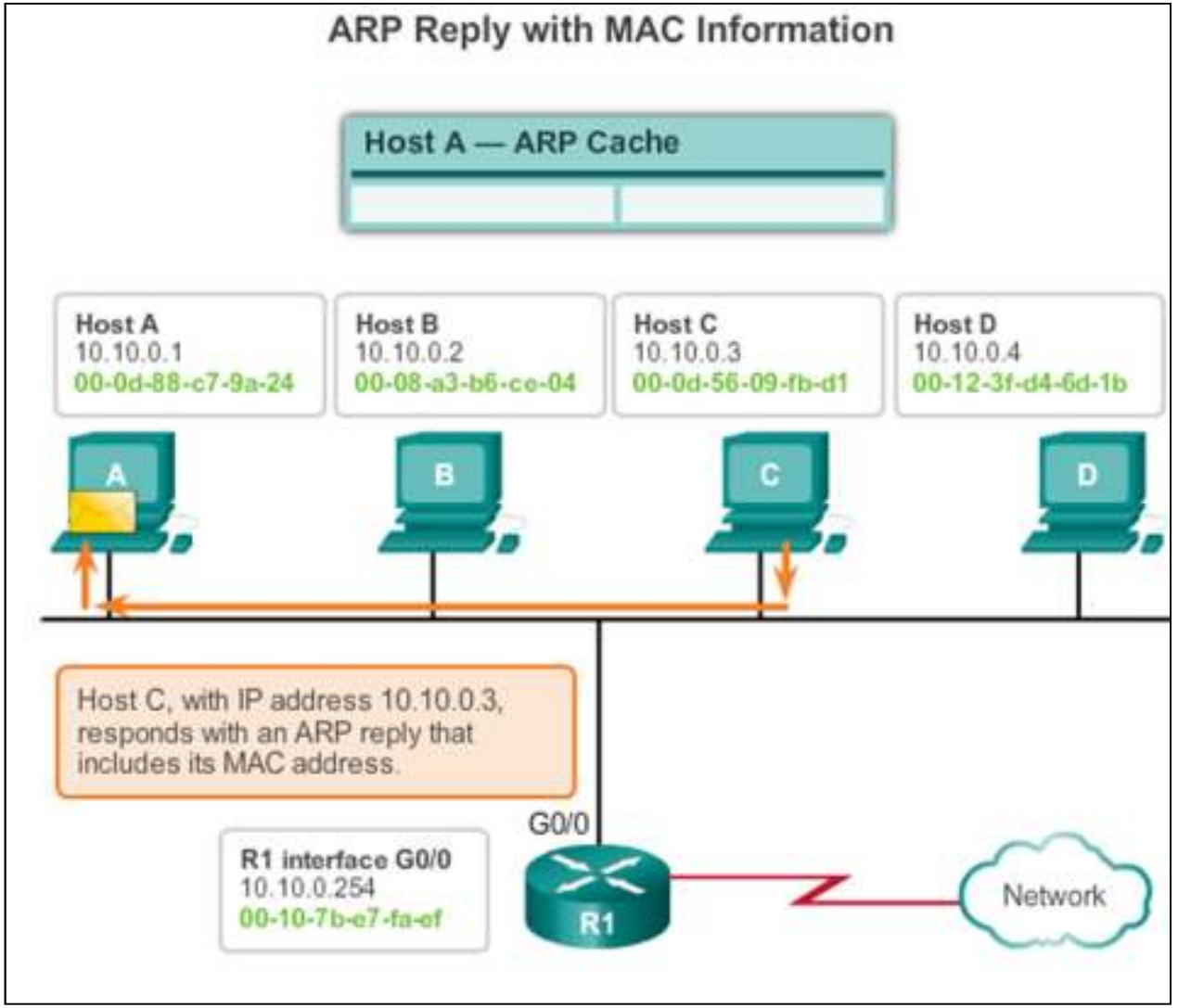
ARP Operation



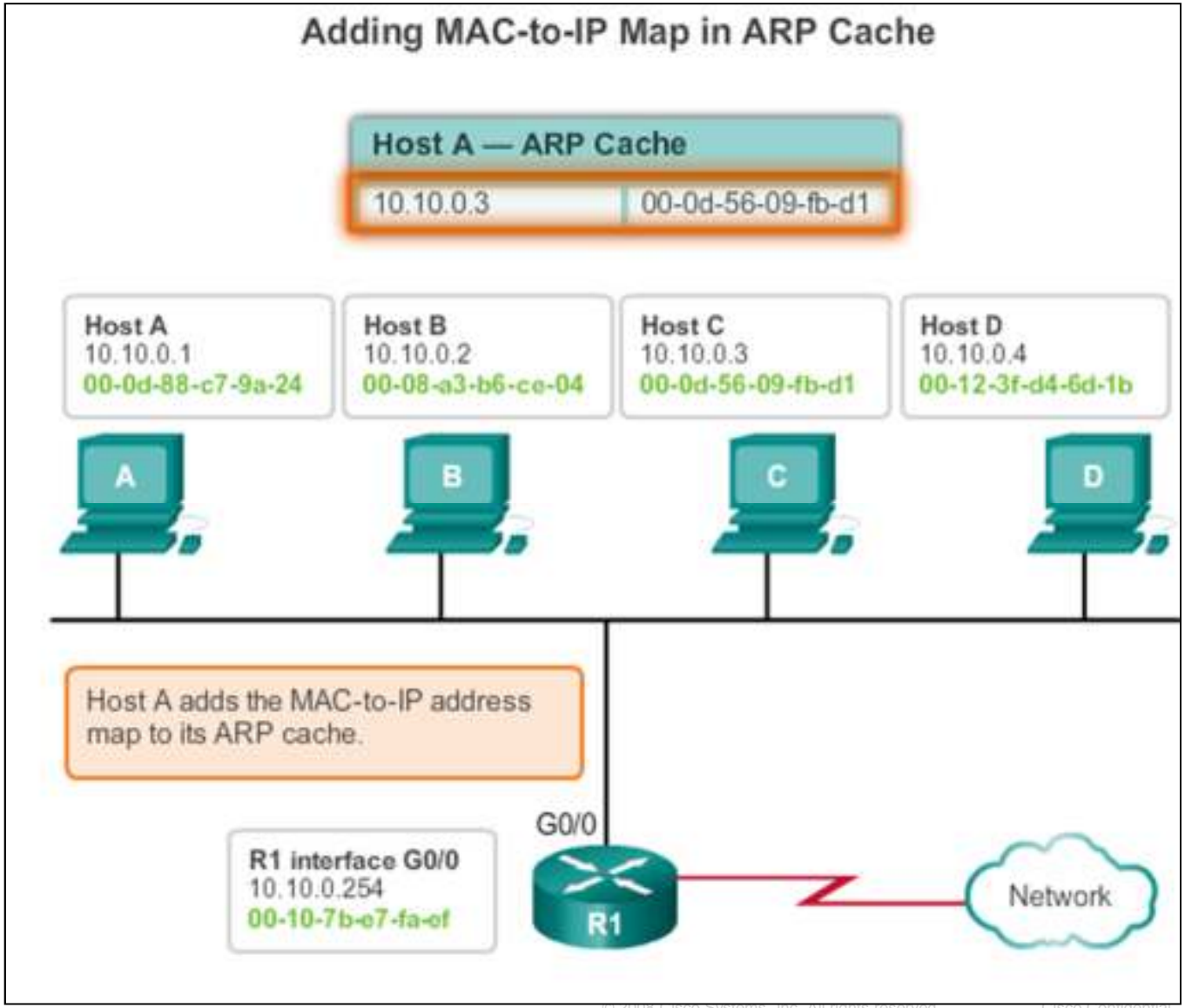
ARP Operation (cont.)



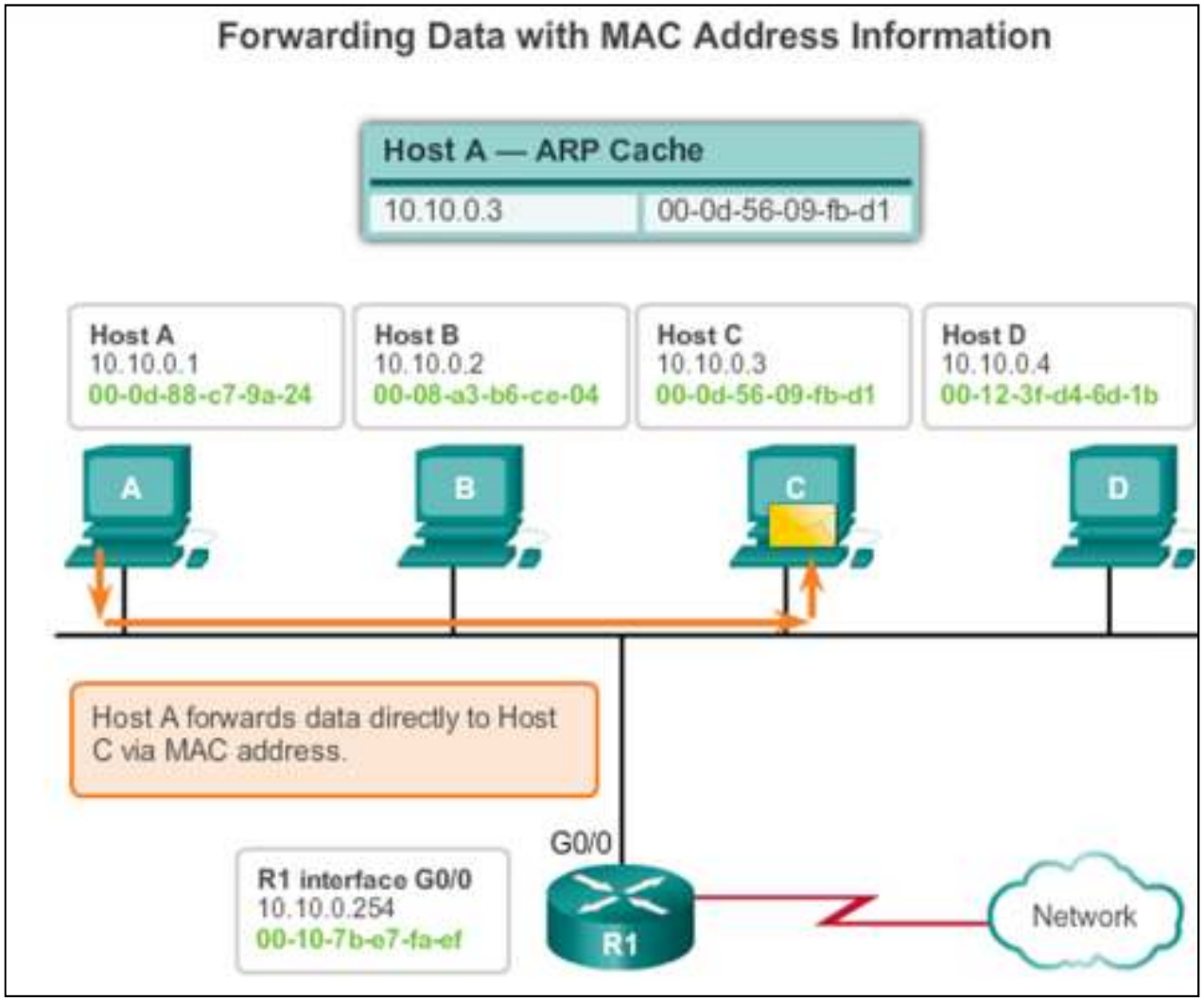
ARP Operation (cont.)



ARP Operation (cont.)



ARP Functions/Operation (cont.)

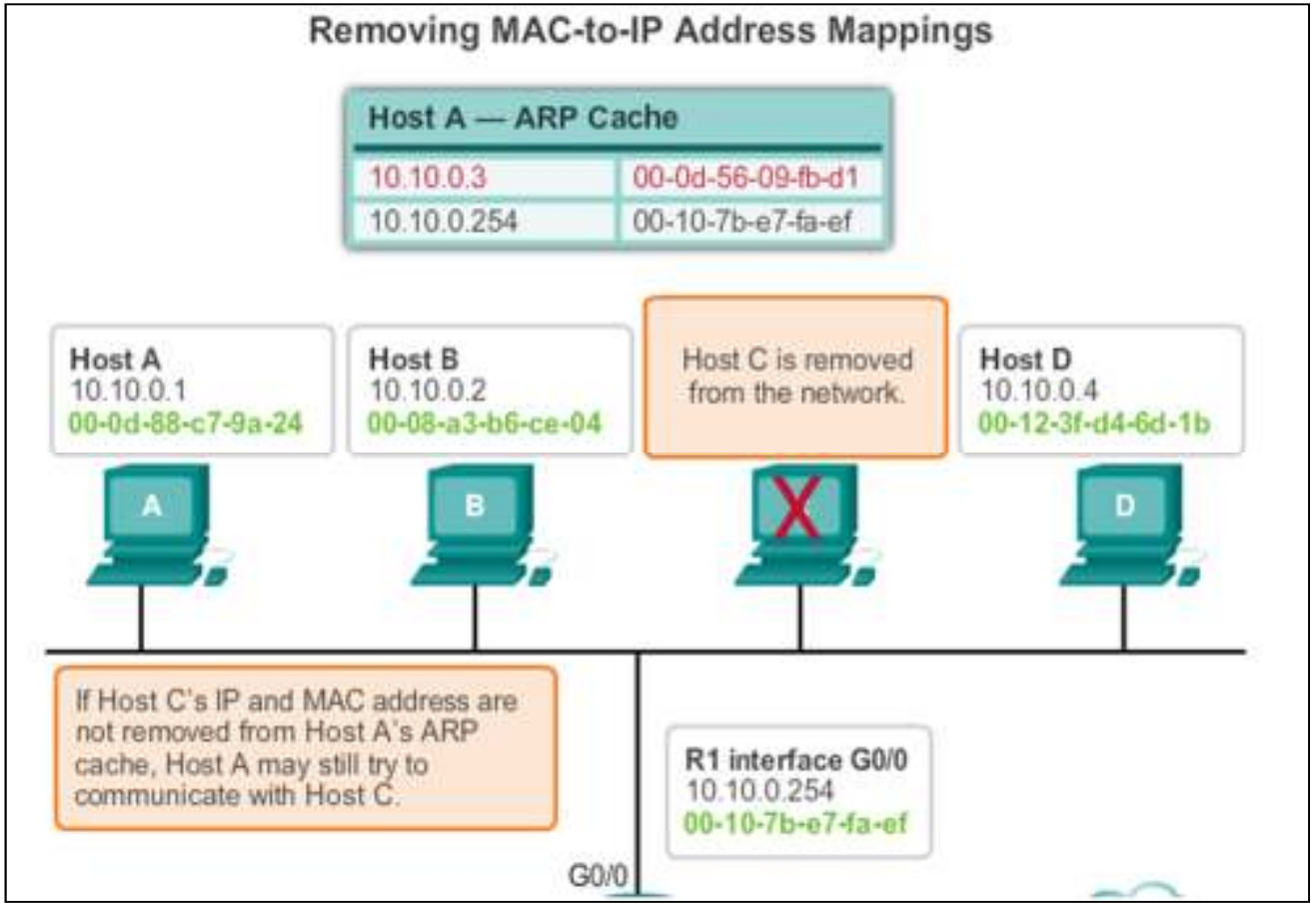


ARP Role in Remote Communication

- If the destination IPv4 host is on the local network, the frame will use the MAC address of this device as the destination MAC address.
- If the destination IPv4 host is not on the local network, the source uses the ARP process to determine a MAC address for the router interface serving as the gateway.
- In the event that the gateway entry is not in the table, an ARP request is used to retrieve the MAC address associated with the IP address of the router interface.

Removing Entries from an ARP Table

- The ARP cache timer removes ARP entries that have not been used for a specified period of time.
- Commands may also be used to manually remove all or some of the entries in the ARP table.



ARP Tables on Networking Devices

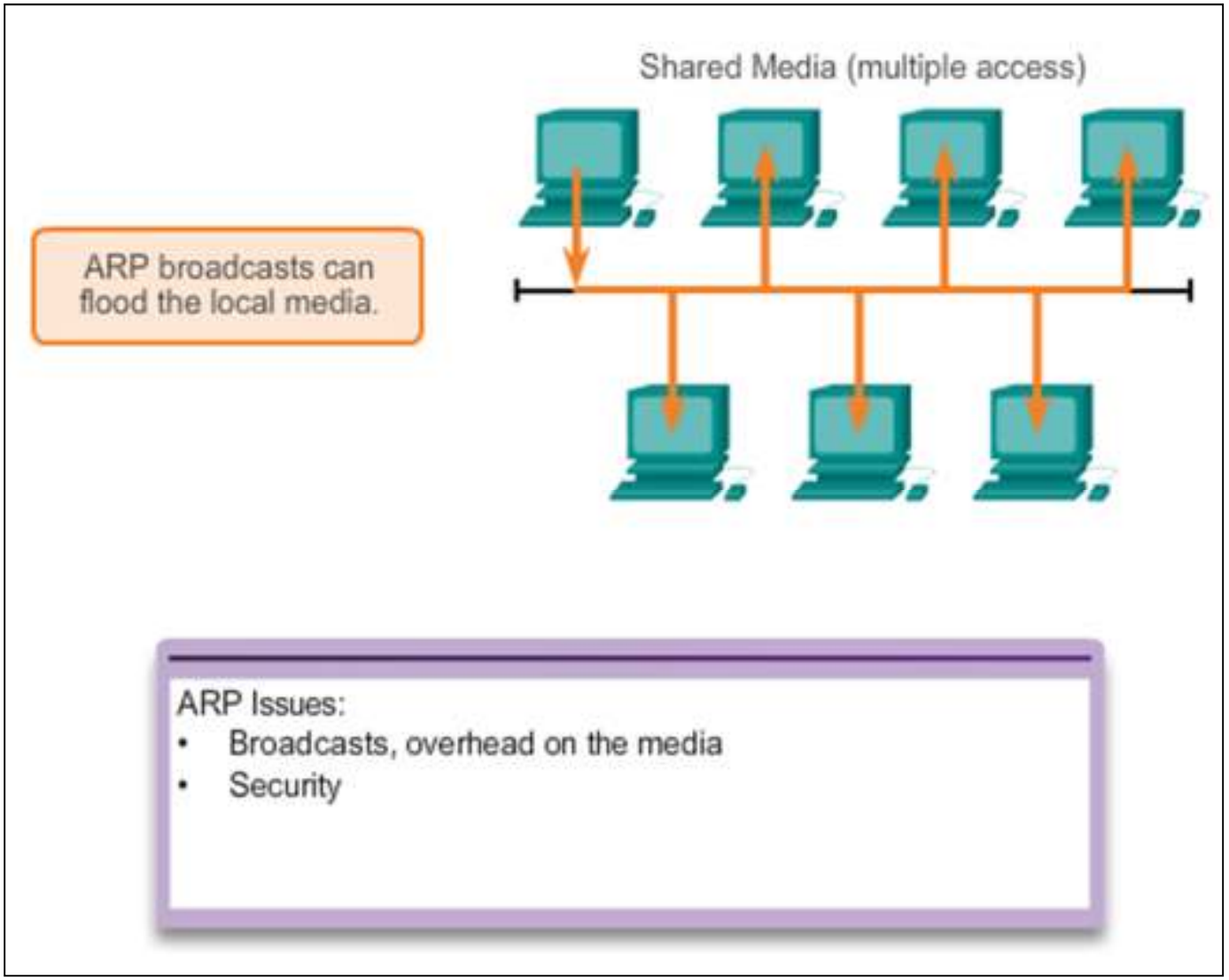
```
Router#show ip arp

                    Age
Protocol  Address          (min)  Hardware Addr   Type   Interface
Internet  172.16.233.229    -     0000.0c59.f892  ARPA   Ethernet0/0
Internet  172.16.233.218    -     0000.0c07.ac00  ARPA   Ethernet0/0
Internet  172.16.168.11     -     0000.0c63.1300  ARPA   Ethernet0/0
Internet  172.16.168.254    9     0000.0c36.6965  ARPA   Ethernet0/0
```

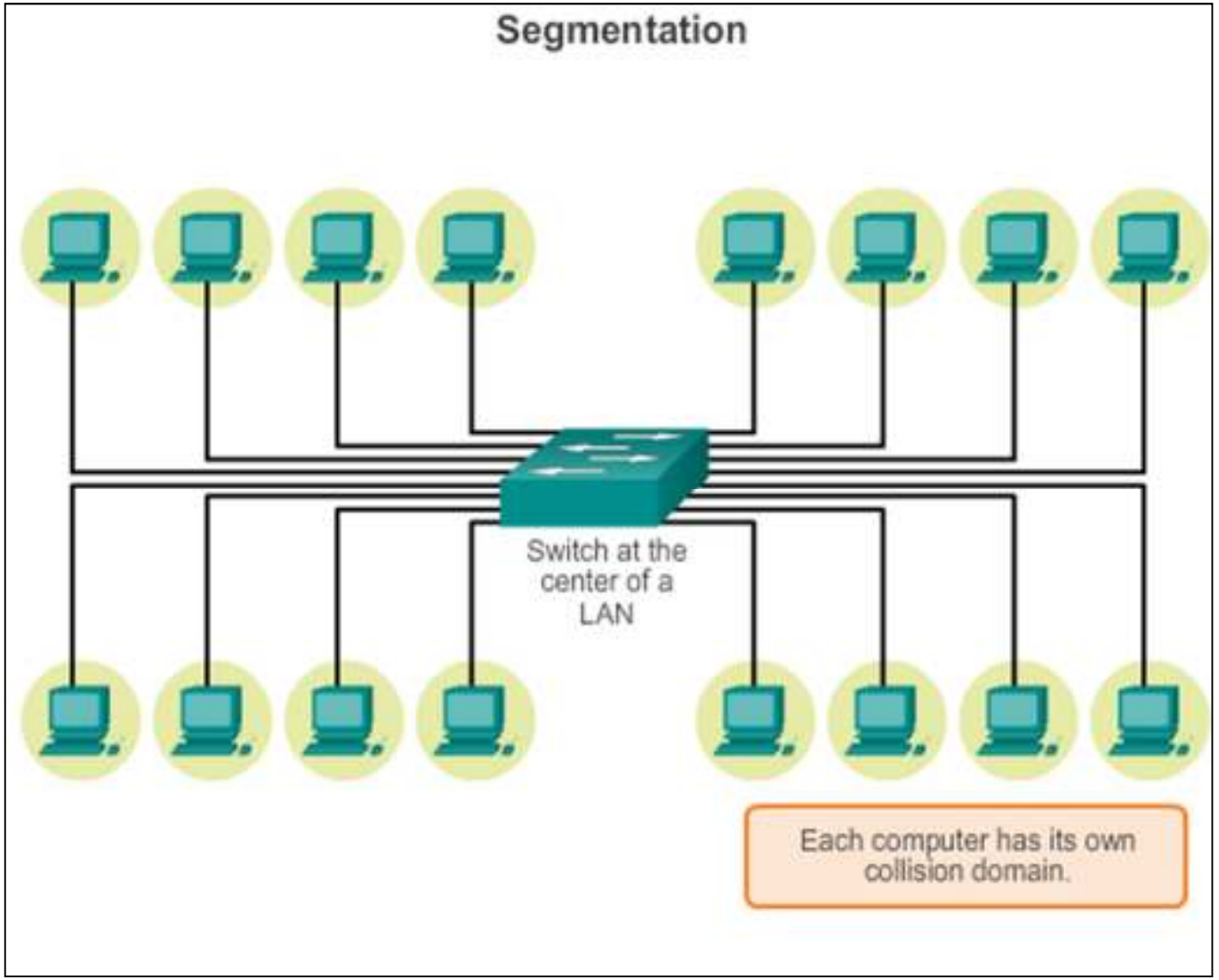
```
C:\>arp -a

Interface: 192.168.1.67 --- 0xa
  Internet Address      Physical Address      Type
  192.168.1.254         64-0f-29-0d-36-91     dynamic
  192.168.1.255         ff-ff-ff-ff-ff-ff     static
  224.0.0.22            01-00-5e-00-00-16     static
  224.0.0.251           01-00-5e-00-00-fb     static
  224.0.0.252           01-00-5e-00-00-fc     static
  255.255.255.255       ff-ff-ff-ff-ff-ff     static
```

How ARP Can Create Problems



Mitigating ARP Problems



5.3 LAN Switches

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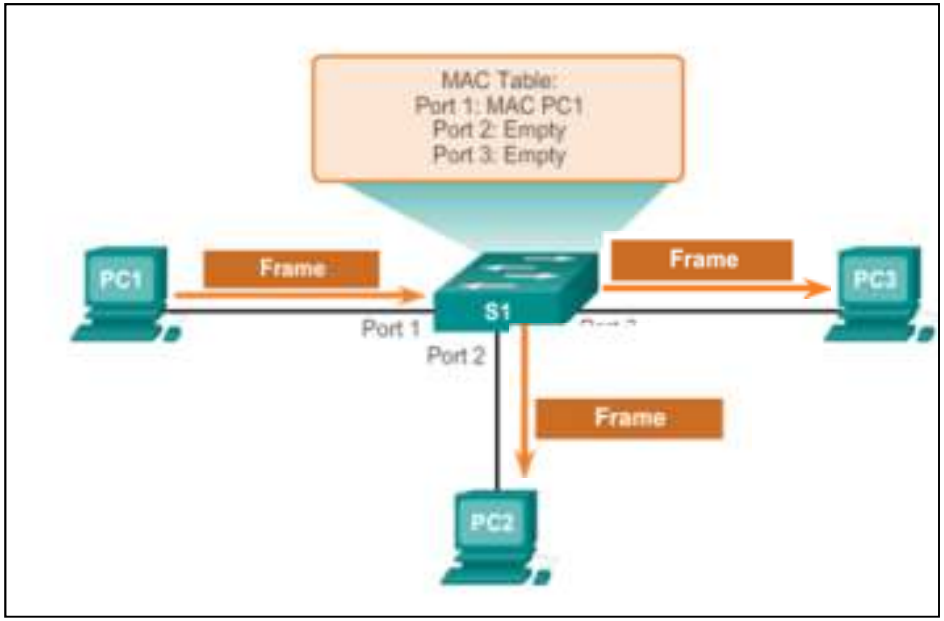
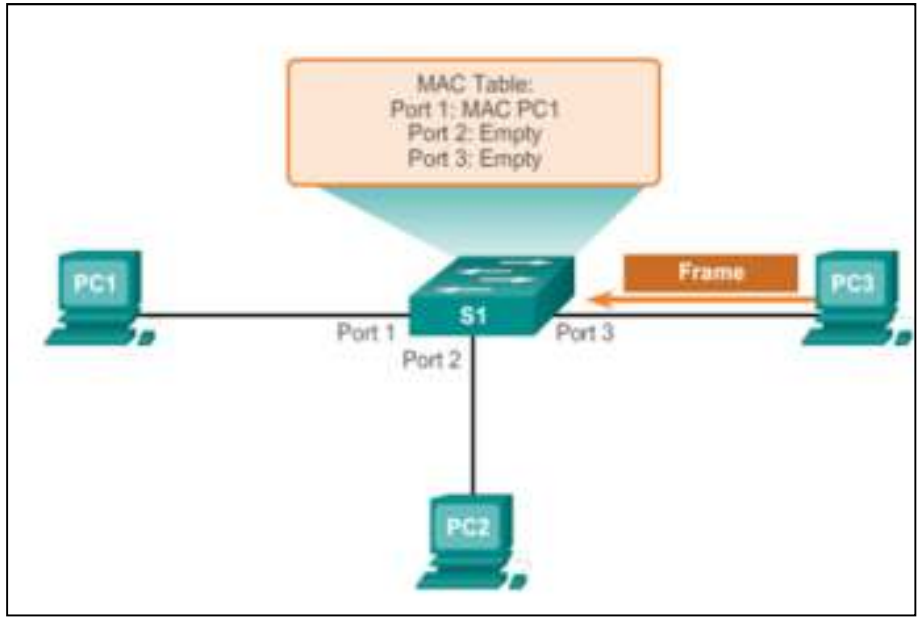
Switch Port Fundamentals

Layer 2 LAN Switch

- Connects end devices to a central intermediate device on most Ethernet networks
- Performs switching and filtering based only on the MAC address
- Builds a MAC address table that it uses to make forwarding decisions
- Depends on routers to pass data between IP subnetworks

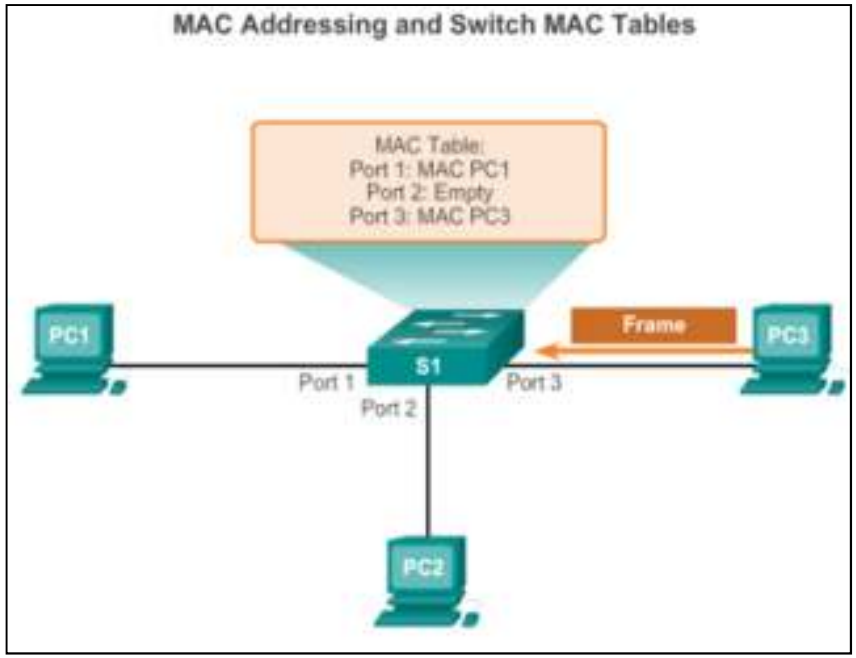
Switch MAC Address Table

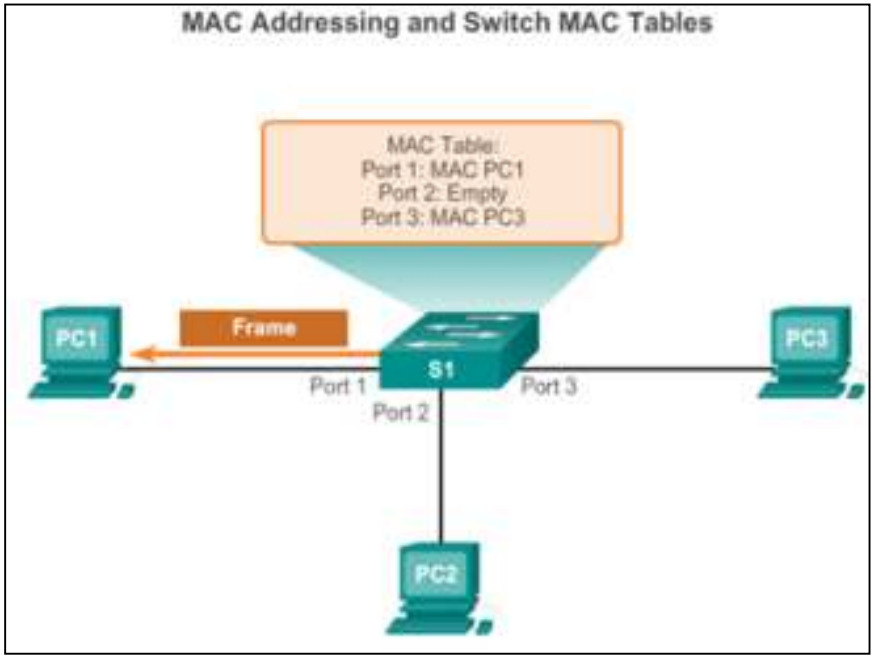




1. The switch receives a broadcast frame from PC 1 on Port 1.
2. The switch enters the source MAC address and the switch port that received the frame into the address table.
3. Because the destination address is a broadcast, the switch floods the frame to all ports, except the port on which it received the frame.
4. The destination device replies to the broadcast with a unicast frame addressed to PC 1.

Switch MAC Address Table (cont.)





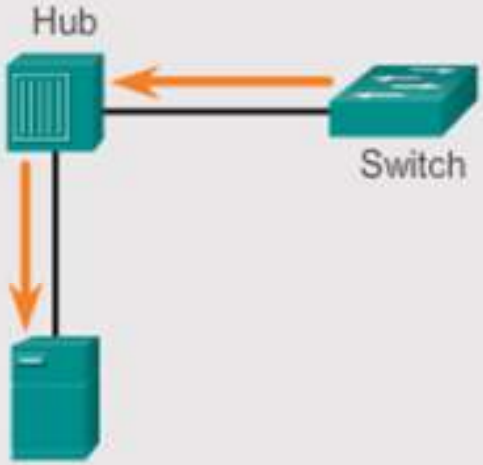
5. The switch enters the source MAC address of PC 2 and the port number of the switch port that received the frame into the address table. The destination address of the frame and its associated port is found in the MAC address table.

6. The switch can now forward frames between source and destination devices without flooding, because it has entries in the address table that identify the associated ports.

Duplex Settings

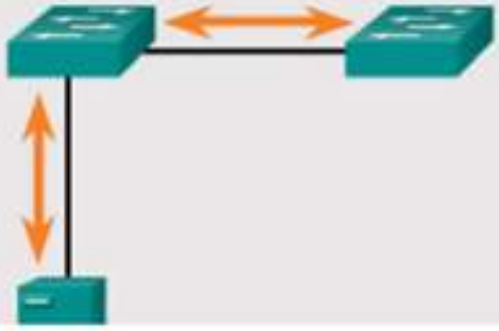
Half Duplex (CSMA/CD)

- Unidirectional data flow
- Higher potential for collision
- Hub connectivity

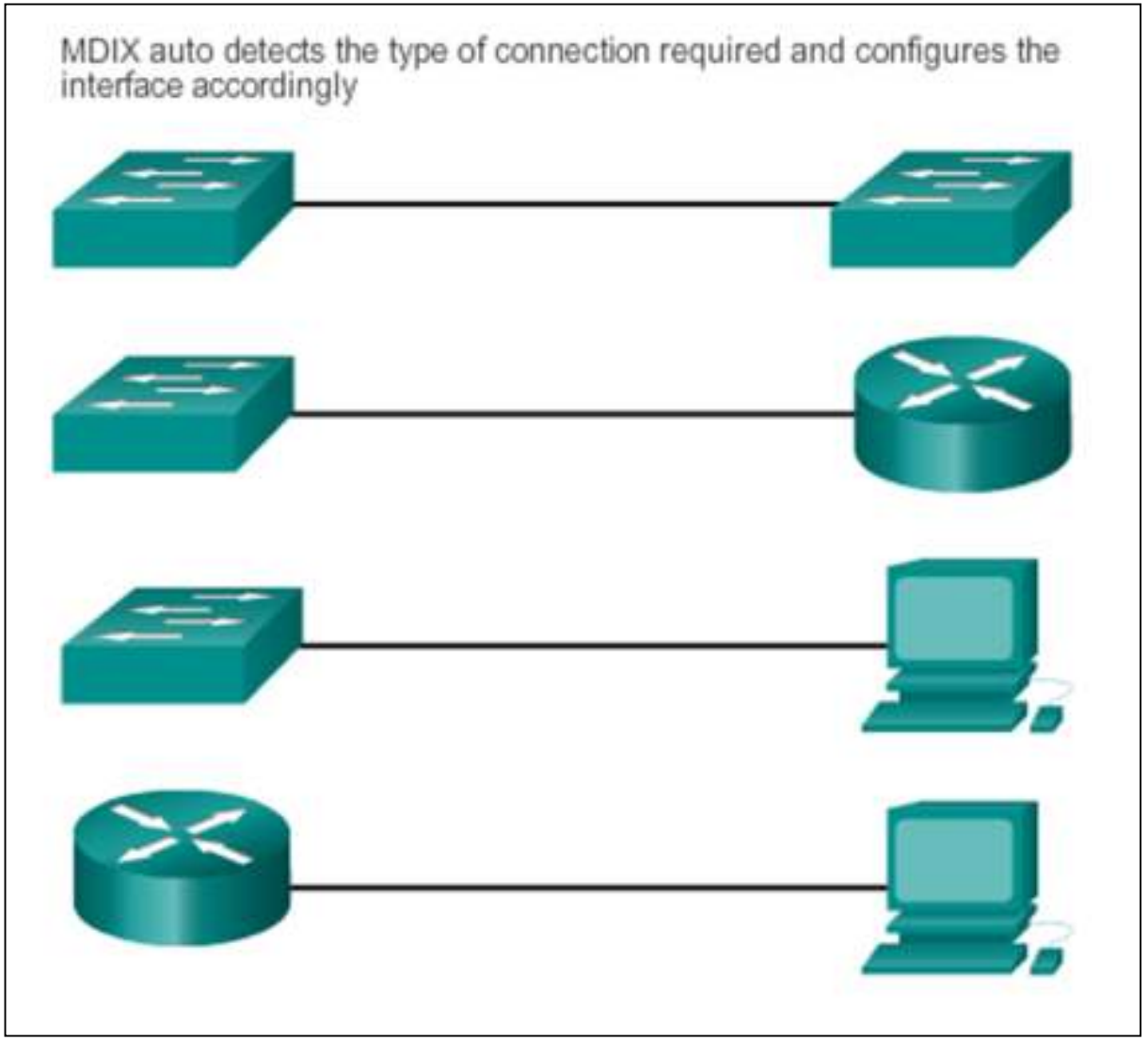


Full Duplex

- Point-to-point only
- Attached to dedicated switched port
- Requires full-duplex support on both ends
- Collision-free
- Collision detect circuit disabled



Auto-MDIX



Frame Forwarding Methods on Cisco Switches

Store-and-forward

A store-and-forward switch receives the entire frame, and computes the CRC. If the CRC is valid, the switch looks up the destination address, which determines the outgoing interface. The frame is then forwarded out the correct port.

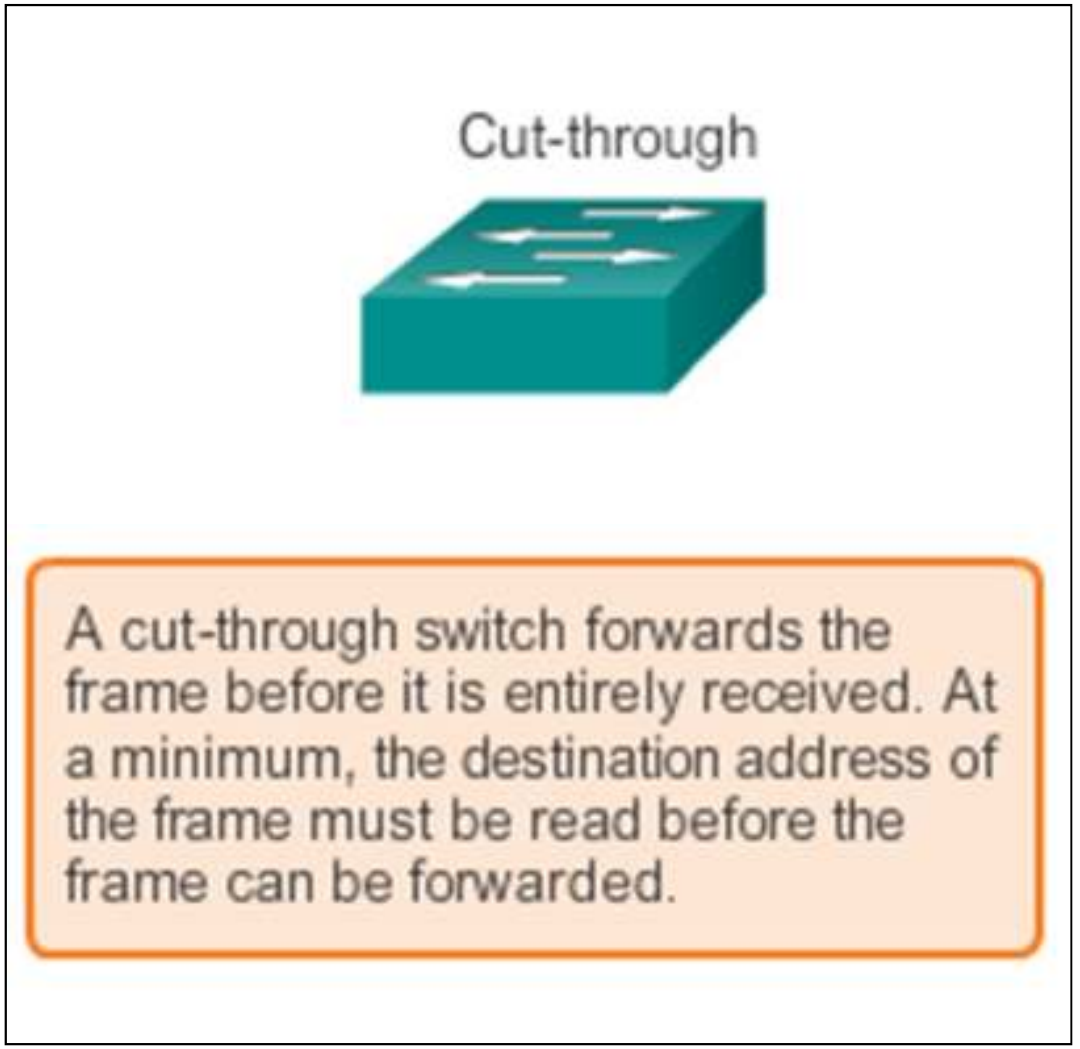
Cut-through Switching

Fast-forward switching:

- Lowest level of latency immediately forwards a packet after reading the destination address, typical cut-through method of switching

Fragment-free switching:

- Switch stores the first 64 bytes of the frame before forwarding, most network errors and collisions occur during the first 64 bytes

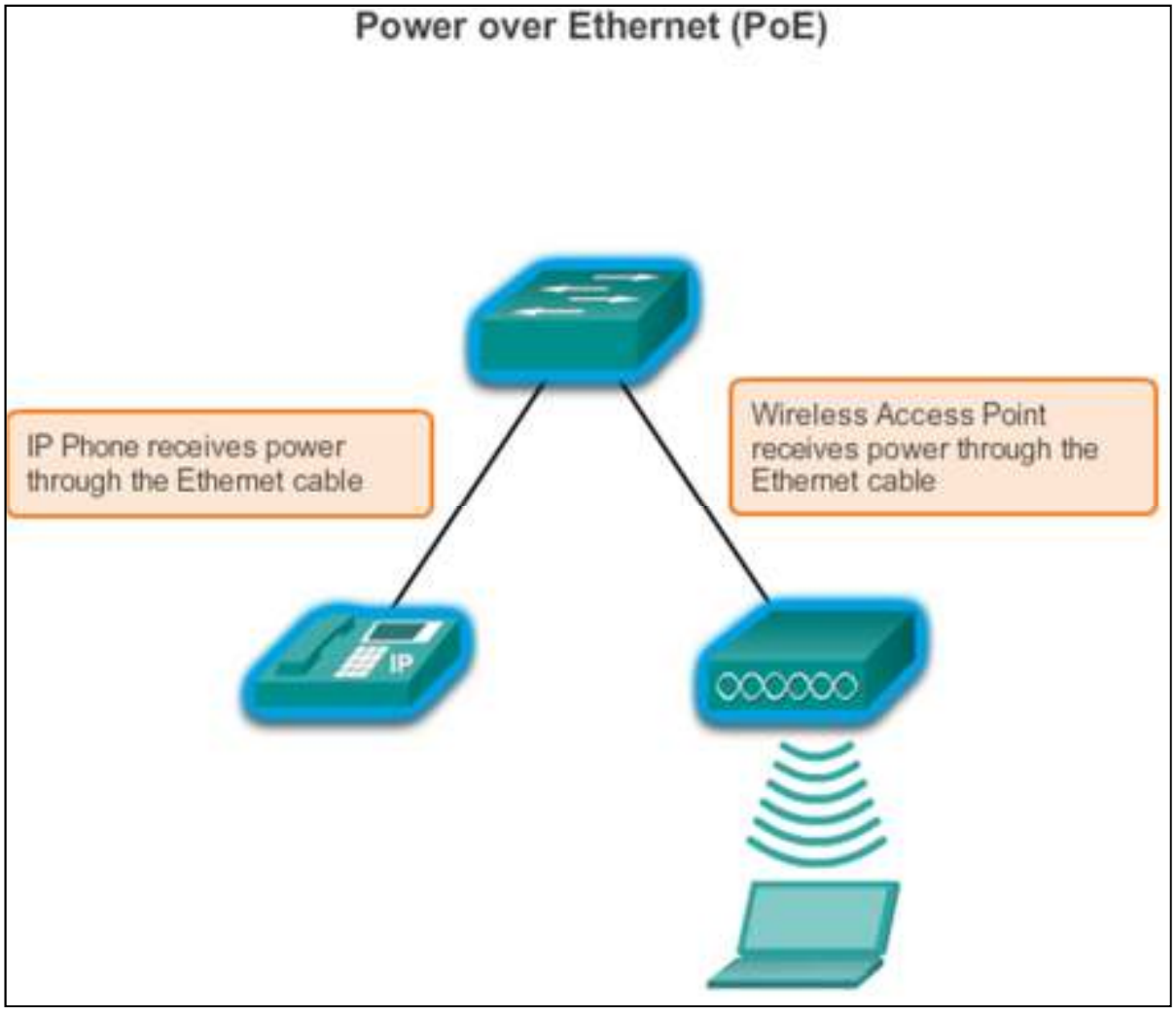


Memory Buffering on Switches

Port-Based and Shared Memory Buffering

Port-based memory	In port-based memory buffering, frames are stored in queues that are linked to specific incoming and outgoing ports.
Shared memory	Shared memory buffering deposits all frames into a common memory buffer, which all the ports on the switch share.

Fixed versus Modular Configuration



Fixed versus Modular Configuration (cont.)

Switch Form Factors

Fixed Configuration Switches

Features and options are limited to those that originally come with the switch.

Modular Configuration Switches

The chassis accepts line cards that contain the ports.

Stackable Configuration Switches

Fixed or Modular

Module Options for Cisco Switch Slots

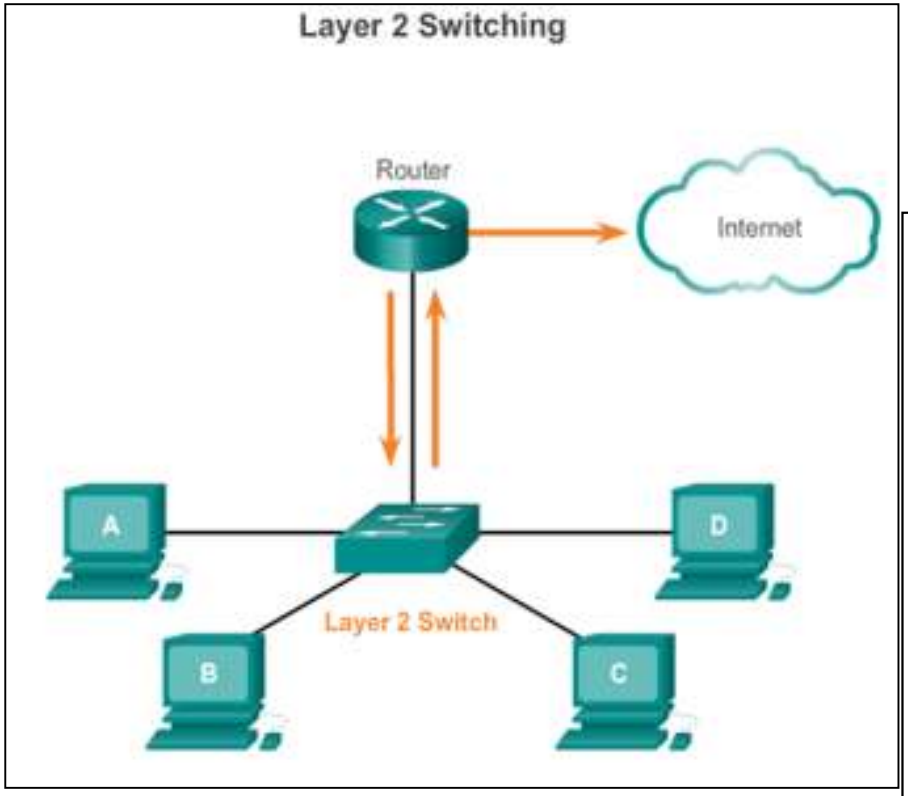
SFP Modules

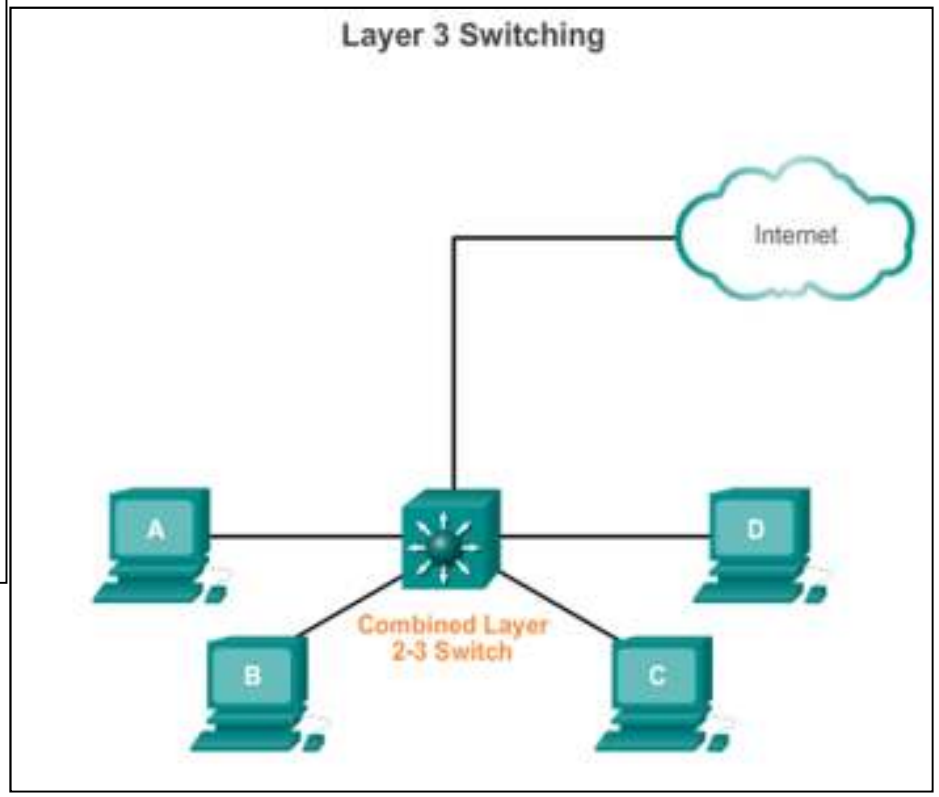
Cisco Optical Gigabit Ethernet SFP

Cisco 1000BASE-T Copper SFP

Cisco 2-channel 1000BASE-BX Optical SFP

Layer 2 versus Layer 3 Switching





Cisco Express Forwarding

Cisco devices which support Layer 3 switching utilize Cisco Express Forwarding (CEF). Two main components of CEF operation are the:

- Forwarding Information Base (FIB)
  - Conceptually it is similar to a routing table.
  - A networking device uses this lookup table to make destination-based switching decisions during Cisco Express Forwarding operation.
  - Updated when changes occur in the network and contains all routes known at the time.
- Adjacency Tables
  - Maintain layer 2 next-hop addresses for all FIB entries.

Types of Layer 3 Interfaces

The major types of Layer 3 interfaces are:

- **Switch Virtual Interface (SVI)** – Logical interface on a switch associated with a virtual local-area network (VLAN).
- **Routed Port** – Physical port on a Layer 3 switch configured to act as a router port. Configure routed ports by putting the interface into Layer 3 mode with the **no switchport** interface configuration command.
- **Layer 3 EtherChannel** – Logical interface on a Cisco device associated with a *bundle* of routed ports.

Configuring a Routed Port on a Layer 3 Switch

Routed Port Configuration

```
S1(config)#interface f0/6
S1(config-if)#no switchport
S1(config-if)#ip address 192.168.200.1 255.255.255.0
S1(config-if)#no shutdown
S1(config-if)#end
S1#
*Mar  1 00:15:40.115: %SYS-5-CONFIG_I: Configured from console by console
S1#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
Vlan1                  unassigned      YES unset  administratively down down
FastEthernet0/1        unassigned      YES unset  down                  down
FastEthernet0/2        unassigned      YES unset  down                  down
FastEthernet0/3        unassigned      YES unset  down                  down
FastEthernet0/4        unassigned      YES unset  down                  down
FastEthernet0/5        unassigned      YES unset  down                  down
FastEthernet0/6        192.168.200.1   YES manual up                    up
FastEthernet0/7        unassigned      YES unset  up                    up
FastEthernet0/8        unassigned      YES unset  up                    up
<output omitted>
```

Chapter 5

Summary

- Ethernet is the most widely used LAN technology used today.
- Ethernet standards define both the Layer 2 protocols and the Layer 1 technologies.
- The Ethernet frame structure adds headers and trailers around the Layer 3 PDU to encapsulate the message being sent.
- As an implementation of the IEEE 802.2/3 standards, the Ethernet frame provides MAC addressing and error checking.
- Replacing hubs with switches in the local network has reduced the probability of frame collisions in half-duplex links.
- The Layer 2 addressing provided by Ethernet supports unicast, multicast, and broadcast communications.
- Ethernet uses the Address Resolution Protocol to determine the MAC addresses of destinations and map them against known Network layer addresses.

Summary (cont.)

- Each node on an IP network has both a MAC address and an IP address.
- The ARP protocol resolves IPv4 addresses to MAC addresses and maintains a table of mappings.
- A Layer 2 switch builds a MAC address table that it uses to make forwarding decisions.
- Layer 3 switches are also capable of performing Layer 3 routing functions, reducing the need for dedicated routers on a LAN.
- Layer 3 switches have specialized switching hardware so they can typically route data as quickly as they can switch.