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.

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5.1 Ethernet Protocol

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LLC and MAC Sublayers

Ethernet

- Most widely used LAN technologies (de facto standard).
- Operates in the Data Link layer (OSI Layer 2) and the Physical layer (OSI Layer 1).
- Supports data bandwidths of 10 Mbps (Ethernet), 100 Mbps (Fast Ethernet), 1000 Mbps (Gigabit Ethernet).
- Modern and upcoming technology supports 10Gbps, 40Gbps & 100Gbps.

Ethernet Standards

- Define OSI Layer 2 protocols and Layer 1 technologies
- Define 2 sub-layers in OSI Layer 2:
  - Logical link control (LLC)
  - MAC

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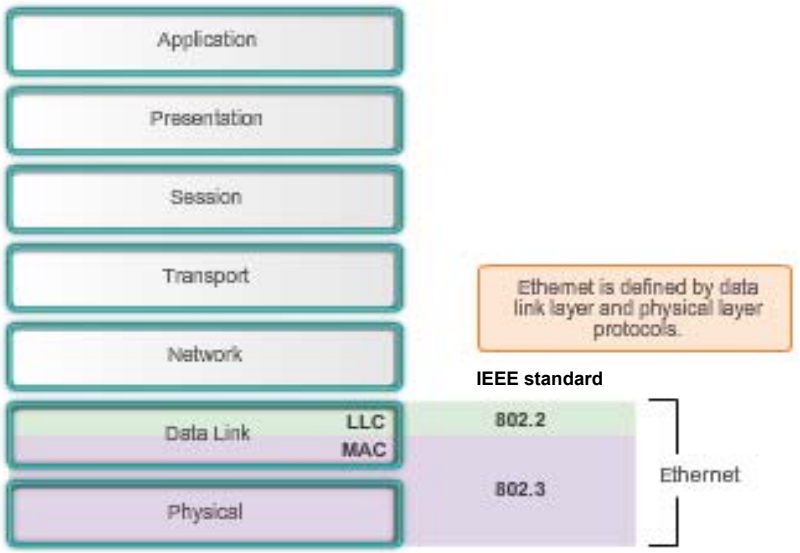
LLC and MAC Sublayers (cont.)



LLC and MAC Sublayers (cont.)

LLC (Logical Link Control)

- Is the upper sublayer and defines software to handle communication between the upper / lower layers.
- It takes the Network layer PDU (the packet) and adds control information to help deliver the packet to the destination.

MAC (Media Access Control)

- This is the lower sublayer and is implemented through hardware, typically in the computer NIC.
- MAC has 2 primary responsibilities:
  - Data encapsulation.
  - Media access control.

MAC Sublayer

1. Data encapsulation

- The Data Link layer (OSI layer 2) PDU is known as the Frame.
- The MAC sublayer encapsulates the Network layer PDU (packet) with a header and trailer to create the frame before sending it out.
- The trailer contains a cyclic redundancy check (CRC) of the frame contents for *error detection*.
- When the MAC sublayer receives a frame, it removes the header and trailer of the received frame before sending it up to the Network layer.

MAC Sublayer (cont.)

2. MAC

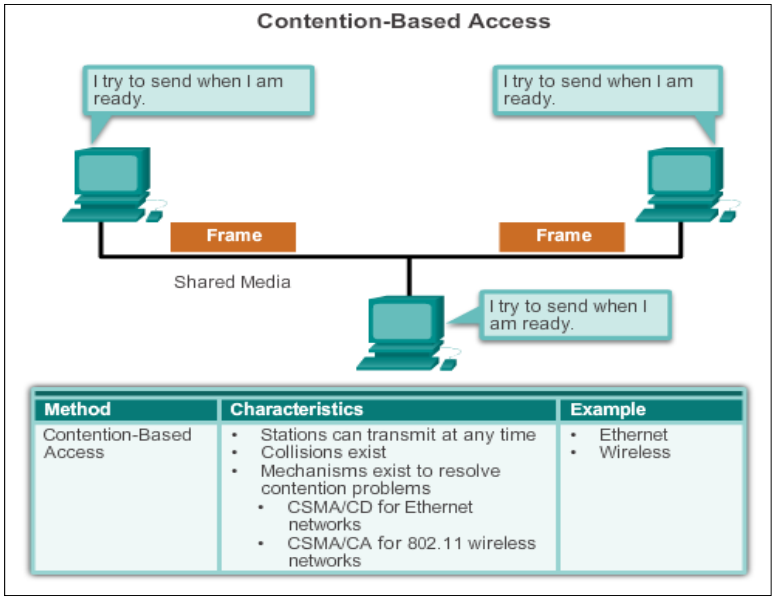
- The MAC sublayer communicates directly with the physical layer.
- It places frames on the media and receive frames from the media.

Problem: If multiple devices on a single medium attempt to forward data simultaneously, the data will collide resulting in corrupted, unusable data.

Solution: Ethernet controls the problem using the technology Carrier Sense Multiple Access (CSMA) where a device that wishes to transmit data will:-

- Check the media if it is carrying any signal.
- If no signal is detected, the device transmits its data.

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

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Media Access Control (cont.)

- CSMA is usually implemented together with a method for resolving media contention:

1. **CSMA/CD** (Carrier Sense Multiple Access with **Collision Detection**)
2. **CSMA/CA** (Carrier Sense Multiple Access with **Collision Avoidance**)

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Media Access Control (cont.)

CSMA/CD (Collision Detection)

- The device checks the media for presence of data signal.
- If there is no data signal, it shows that the media is free. The device can transmit data.
- If signals are detected, it shows that another device is transmitting. The device will wait until the media is free.
- Modern networks today uses intermediate network devices like switches that prevent collisions between end-devices such that CSMA/CD is no longer necessary.
- Wireless connections in a LAN environment still have to take collisions into account.

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Media Access Control (cont.)

CSMA/CA (Collision Avoidance)

- Wireless device examines the media for the presence of data signal.
- If the media is free, the wireless 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.

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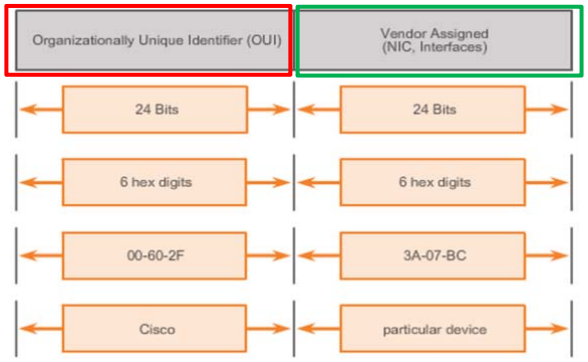
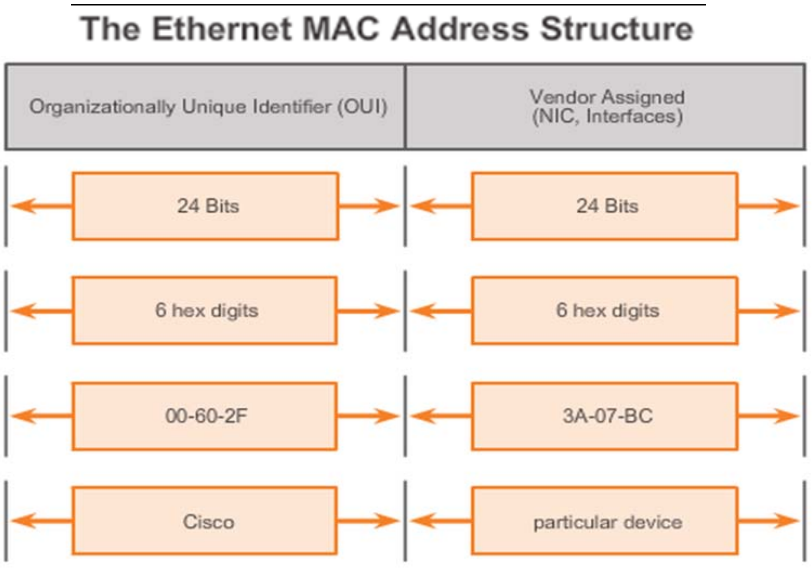
MAC Address: Ethernet Identity

- Layer 2 Ethernet MAC address is a 48-bit (6 bytes) binary value, expressed as 12 hexadecimal digits. (Example: 6C-62-6D-B1-FD-B9)
  - The first 3 bytes (24 bits) is a unique number to represent the vendor / manufacturer – Organizationally Unique Identifier (OUI).
  - The last 3 bytes (24 bits) is a unique value assigned by the manufacturer or vendor.



MAC Address: Ethernet Identity



Frame Processing

- Before a device can forward a message to the Ethernet network, it attaches header information to the packet which contains the source and destination MAC address.
- When a device receives a frame, the NIC checks the frame header to see if the destination MAC address matches its physical MAC address stored in RAM.
- No match, the device discards the frame.
- If it matches, the NIC passes the frame up the OSI layers, where further de-encapsulation processes take place.

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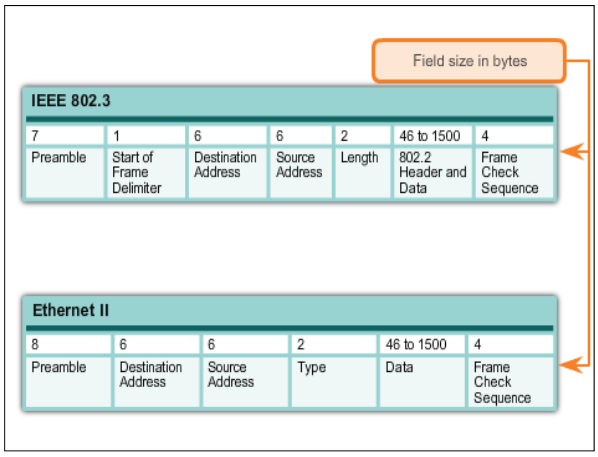
Ethernet Encapsulation

- 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 to the Layer 3 PDU to encapsulate it.
- Ethernet II is the Ethernet frame format used in TCP/IP networks.

Comparison of 802.3 and Ethernet II Frame Structures and Field Size



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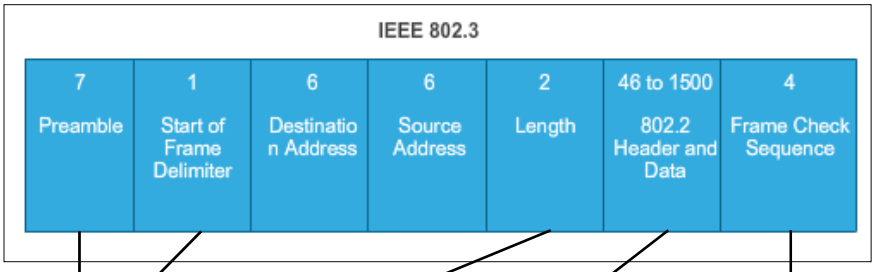
Introduction to the Ethernet Frame



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

Length/Type – Defines the length of the frame's data field and list which protocol is implemented.

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

Frame Check Seq - Used to detect errors in a frame with cyclic redundancy check (CRC); if calculations match at source and receiver, no error occurred.

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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

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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
```

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

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

With Periods 0060.2F3A.07BC

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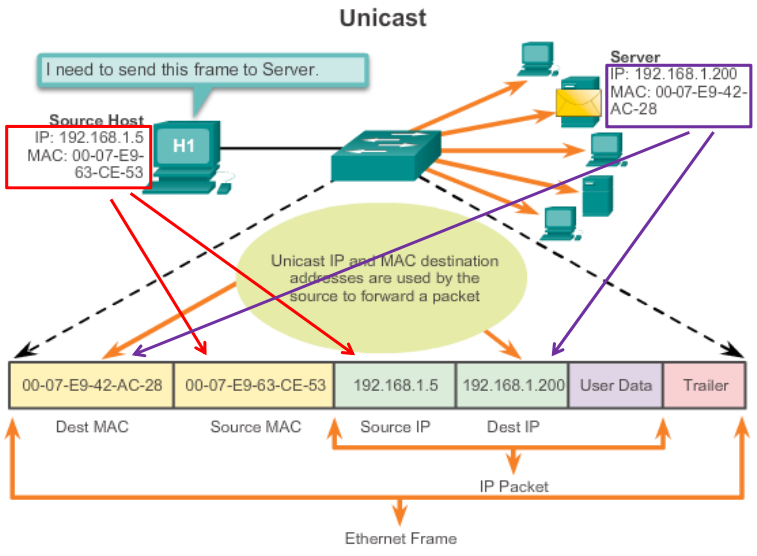
Unicast MAC Address



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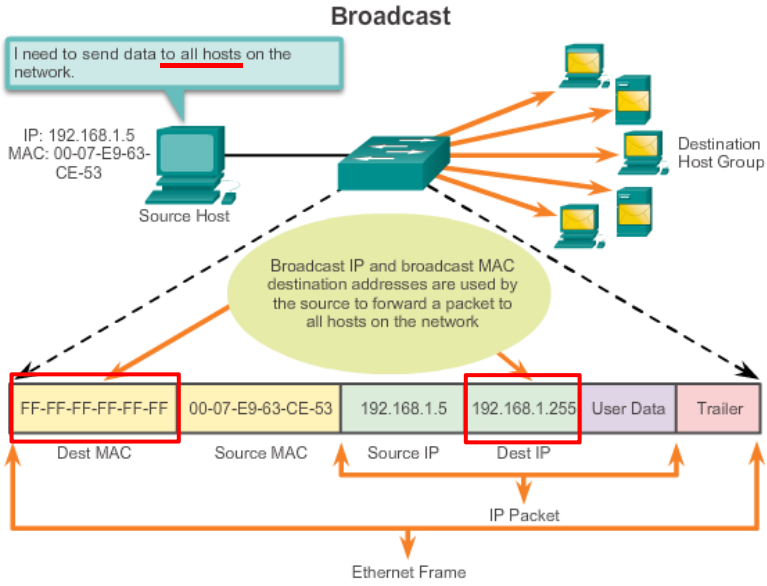
Broadcast MAC Address



MAC and IP Address

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.

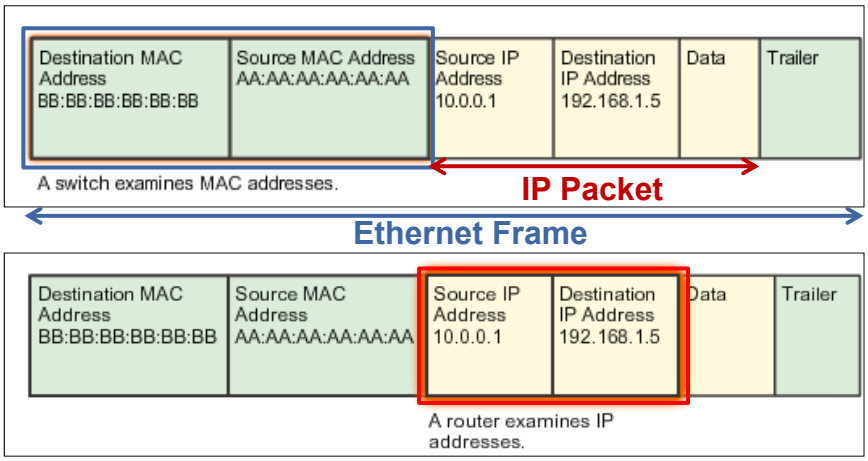
IP Address

- 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

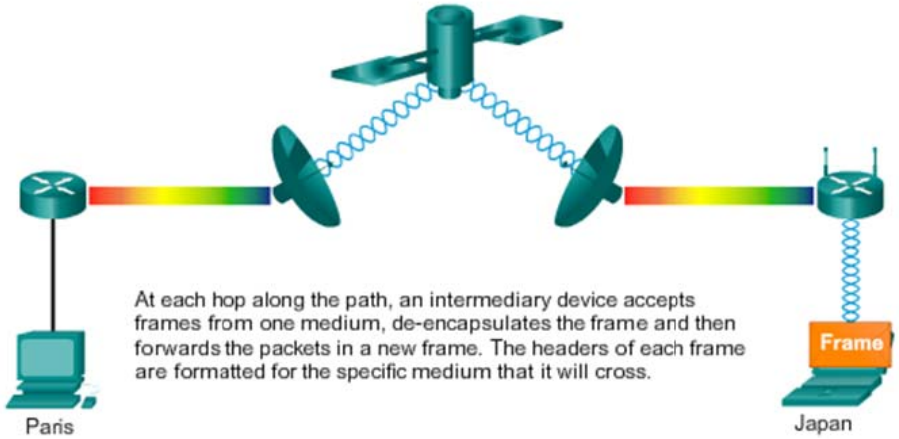


End-to-End Connectivity

The Data Link Layer

Data link layer protocols govern how to format a frame for use on different media.

Different protocols may be in use for different media.



At each hop along the path, an intermediary device accepts frames from one medium, de-encapsulates the frame and then forwards the packets in a new frame. The headers of each frame are formatted for the specific medium that it will cross.

5.2 Address Resolution Protocol (ARP)

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Address Resolution Protocol

Purpose

- Computer A wants to send data to computer B.
- Computer A needs to know the physical or MAC address (Layer 2 address) of computer B in the Ethernet network in order to create the frame.

ARP provides two basic functions:

1. Resolving IPv4 addresses to MAC addresses.
2. Maintaining a table of mappings.

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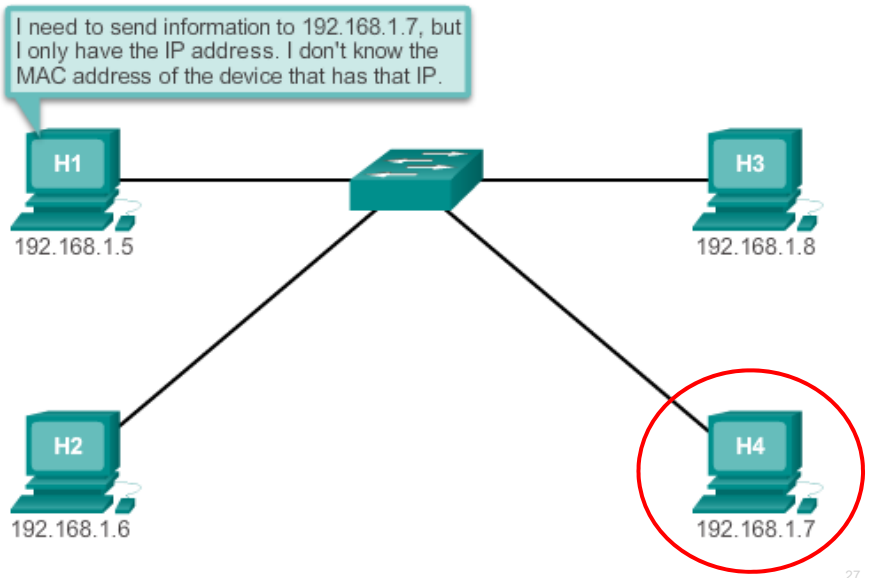
Introduction to ARP



ARP Functions/Operation

ARP Table

- A table in devices (computers, switches) listing the physical MAC addresses of destination IP addresses.
- Mapping entries are created when a device receives Layer 2 frames.

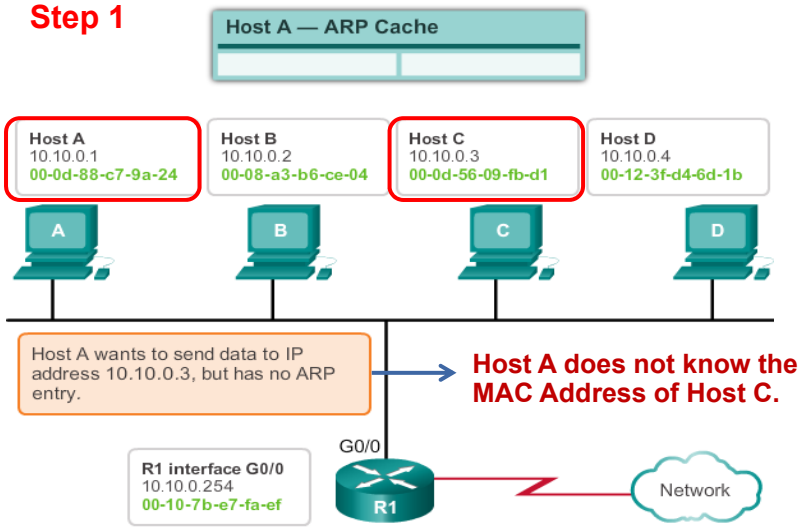
ARP Request

- 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.

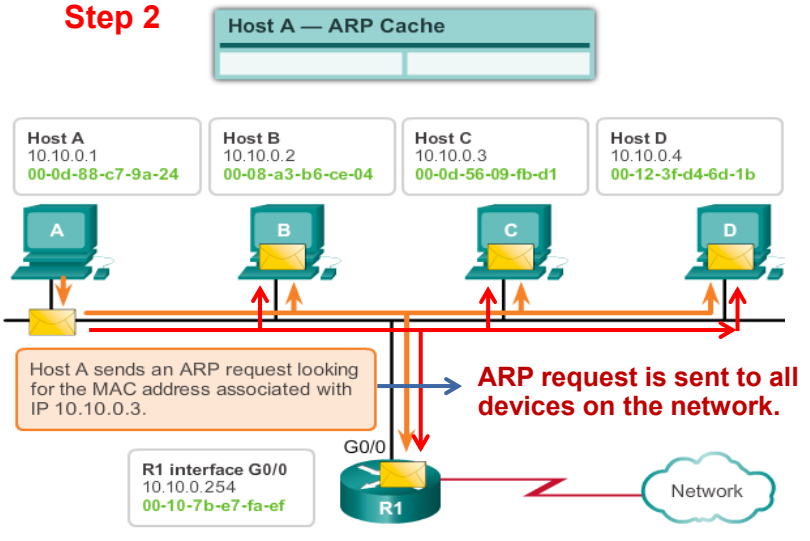
ARP Operation

The ARP Process — Communicating Locally

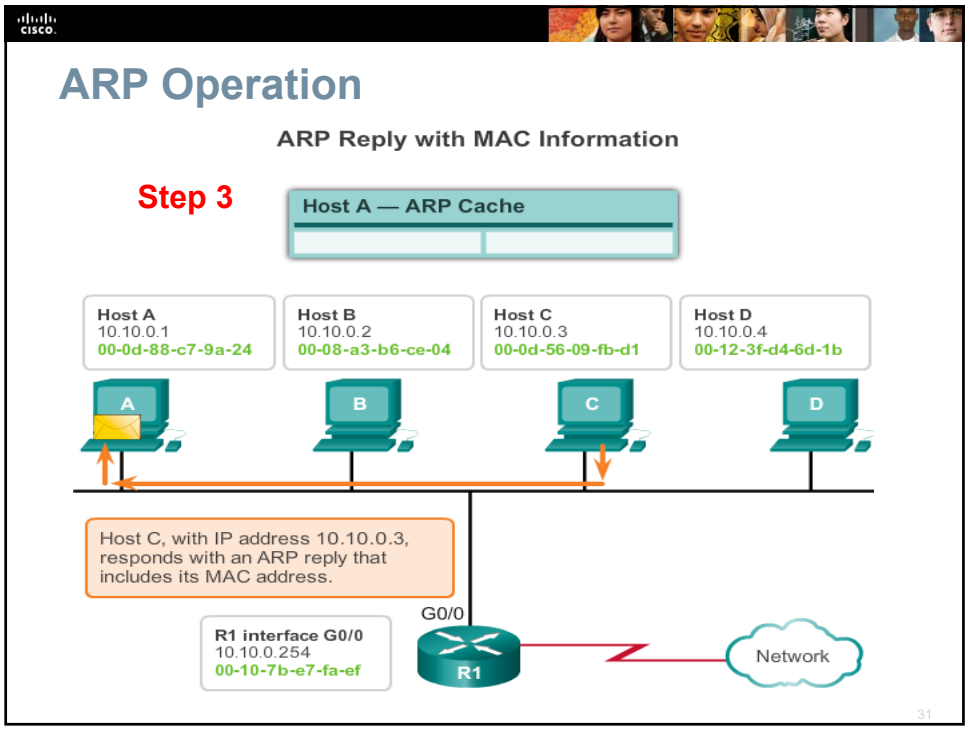


ARP Operation

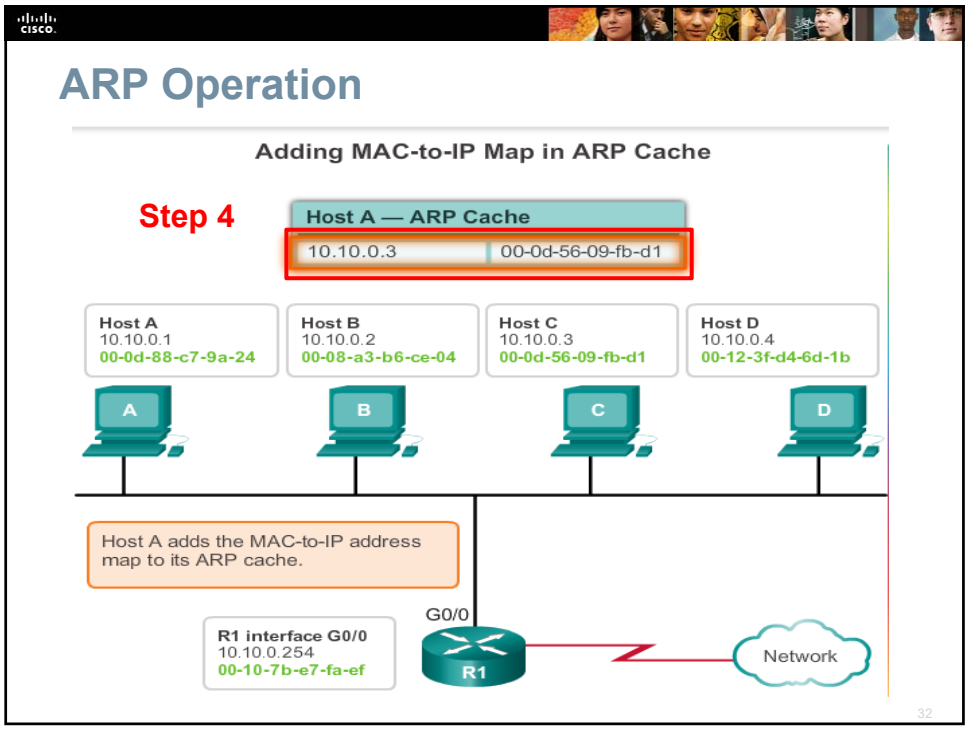
Broadcasting an ARP Request



ARP Operation

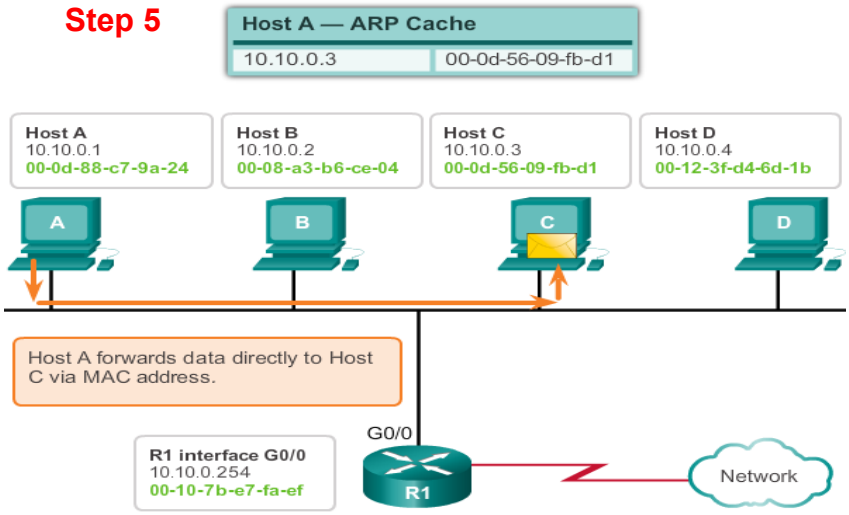


ARP Operation



ARP Operation

Forwarding Data with MAC Address Information



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ARP Role in Remote Communication

What if the destination host is not in the same Local Area Network (LAN) or same subnet?

- The computer will use the MAC address of the default gateway (the router interface of this subnet).
- If the computer does not know the MAC address of the default gateway (not in the ARP table), an ARP request is sent out to retrieve the MAC address of the default gateway.

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5.3 LAN Switches

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Switch Port Fundamentals

Layer 2 LAN Switch

- Connects end devices (PC, IP phones, network printers etc.) to the network.
- Performs switching and filtering based only on MAC addresses.
- Builds a MAC address table which maps MAC addresses to port numbers.
- Uses the MAC address table to make forwarding decisions.
- Requires routers to route data between different subnets.

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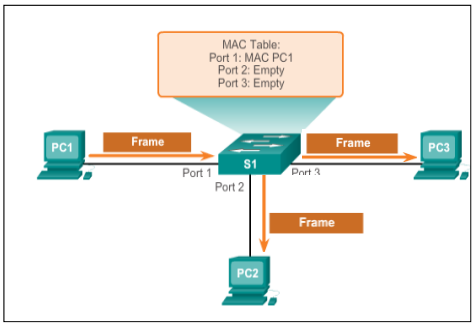
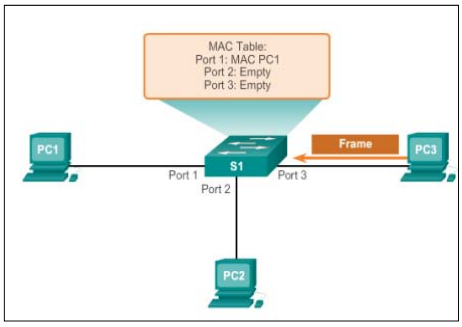
Switch MAC Address Table





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 (PC3) replies to the broadcast with a unicast frame addressed to PC 1.

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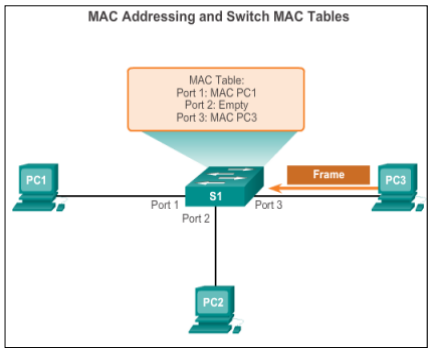
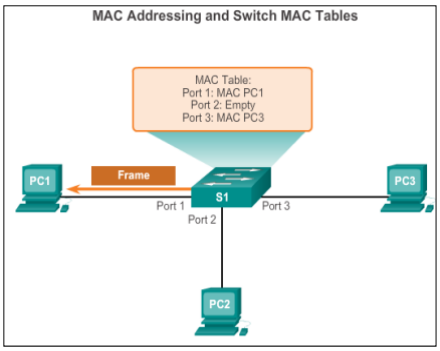
Switch MAC Address Table (cont.)





5. The switch enters the source MAC address of PC3 and the port number of the switch port that received the frame into the address table.
6. The destination address of the frame and its associated port is found in the MAC address table.
7. 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.

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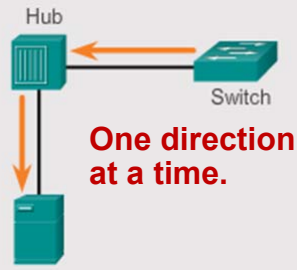
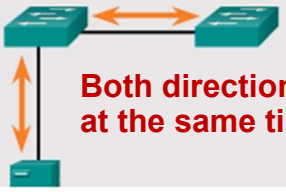
Duplex Settings

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



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Summary

- Ethernet is the most widely used LAN technology 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.
- The Layer 2 addressing provided by Ethernet supports unicast, multicast, and broadcast communications.
- Ethernet uses the Address Resolution Protocol (ARP) to determine the MAC addresses of destinations and map them against known Network layer IP addresses.
- A Layer 2 switch builds a MAC address table that it uses to make forwarding decisions.

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