Chapter 5: Ethernet

CCNA Routing and Switching

Introduction to Networks v6.0

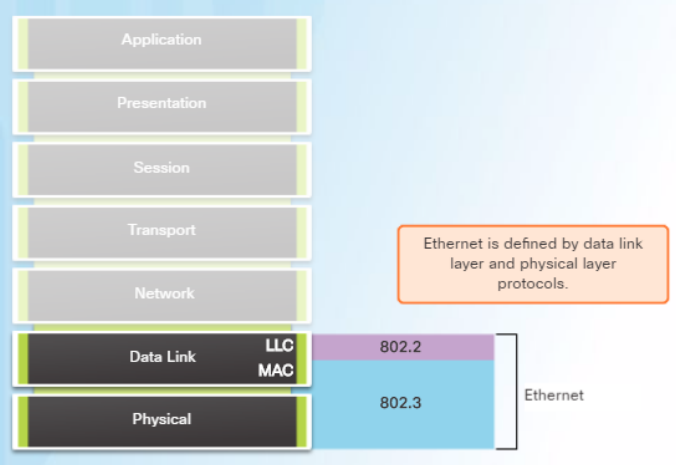
Chapter 5 - Sections & Objectives

- 5.1 Ethernet Protocol
  - Explain the operation of Ethernet.
    - Explain how the Ethernet sublayers are related to the frame fields.
    - Describe the Ethernet MAC address
- 5.2 LAN Switches
  - Explain how a switch operates.
    - Explain how a switch builds its MAC address table and forwards frames.
    - Describe switch forwarding methods and port settings available on Layer 2 switch ports.
- 5.3 Address Resolution Protocol
  - Explain how the address resolution protocol enables communication on a network.
    - Compare the roles of the MAC address and the IP address.
    - Describe the purpose of ARP.
    - Explain how ARP requests impact network and host performance.

5.1 Ethernet Protocol

Ethernet Encapsulation

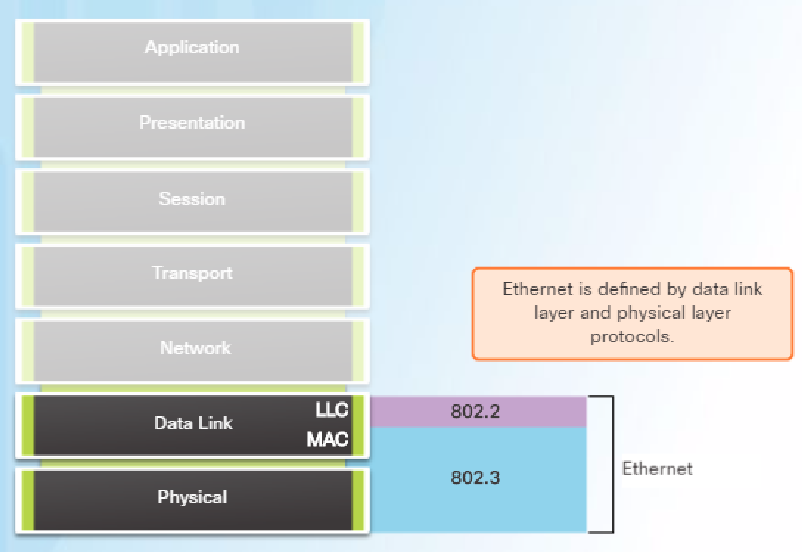
- Ethernet is the most widely used LAN technology today.
  - Defined in the IEEE 802.2 and 802.3 standards.
  - It supports data bandwidths of 10 Mb/s, 100 Mb/s, 1000 Mb/s (1 Gb/s), 10,000 Mb/s (10 Gb/s), 40,000 Mb/s (40 Gb/s), and 100,000 Mb/s (100 Gb/s).
- Ethernet operates in the **data link** layer and the **physical** layer.
- Ethernet relies on the two separate sublayers of the data link layer to operate, the Logical Link Control (LLC) and the MAC sublayers.



Ethernet Encapsulation (Cont.)

- The Ethernet **LLC** sublayer handles the communication between the upper layers and the lower layers. It is implemented **in software**, and its implementation is independent of the hardware.

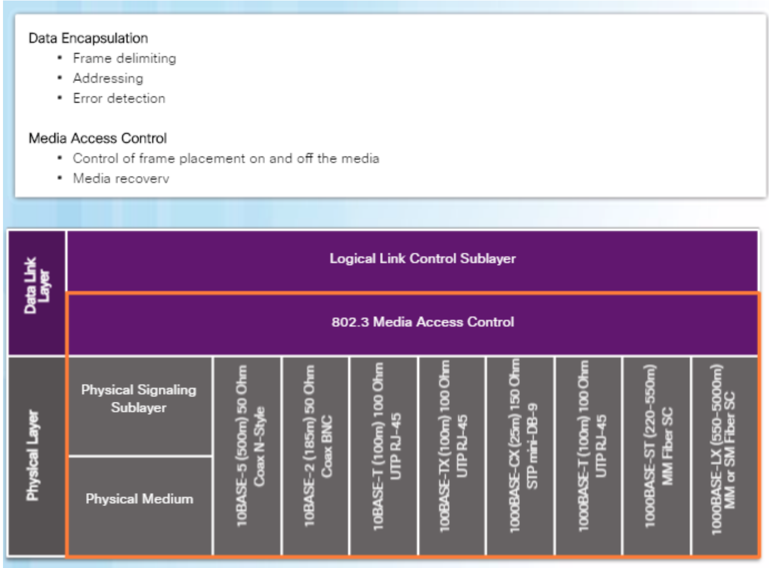
- The **MAC** sublayer constitutes the lower sublayer of the data link layer. MAC is implemented **by hardware**, typically in the computer NIC.



Ethernet Frame
MAC Sublayer

- The MAC sublayer has two primary responsibilities:
  - **Data encapsulation**
  - **Media access control**

- Data encapsulation provides three primary functions:
  - **Frame delimiting**
  - **Addressing**
  - **Error detection**



- Media access control is responsible for the **placement** of frames on the media and the **removal** of frames from the media. This sublayer communicates directly with the physical layer.

Ethernet Evolution

- Since 1973, Ethernet standards have evolved specifying faster and more flexible versions of the technology.
- Early versions of Ethernet were relatively slow at 10 Mbps.
- The latest versions of Ethernet operate at 10 Gigabits per second and faster.

Ethernet Frame Fields

- The minimum Ethernet frame size from Destination MAC address to FCS **is 64 bytes** and the maximum is **1518 bytes**.

- Frames less than 64 bytes are called a "**collision fragment**" or "**runt frame**" and are automatically **discarded** by receiving stations. Frames greater than 1500 bytes of data are considered "**jumbo**" or "**baby giant frames**".

- If the size of a transmitted frame is less than the minimum or greater than the maximum, the receiving device drops the frame.

MAC Addresses and Hexadecimal

- An Ethernet MAC address is a **48-bit binary** value expressed as **12 hexadecimal digits** (4 bits per hexadecimal digit).

- Hexadecimal is used to represent Ethernet MAC addresses and IP Version 6 addresses.
  - Hexadecimal is **a base sixteen system** using the numbers 0 to 9 and the letters A to F.
  - It is easier to express a value as a single hexadecimal digit than as four binary bits.
  - Hexadecimal is usually represented in text by the value preceded by 0x (E.g., 0x73).

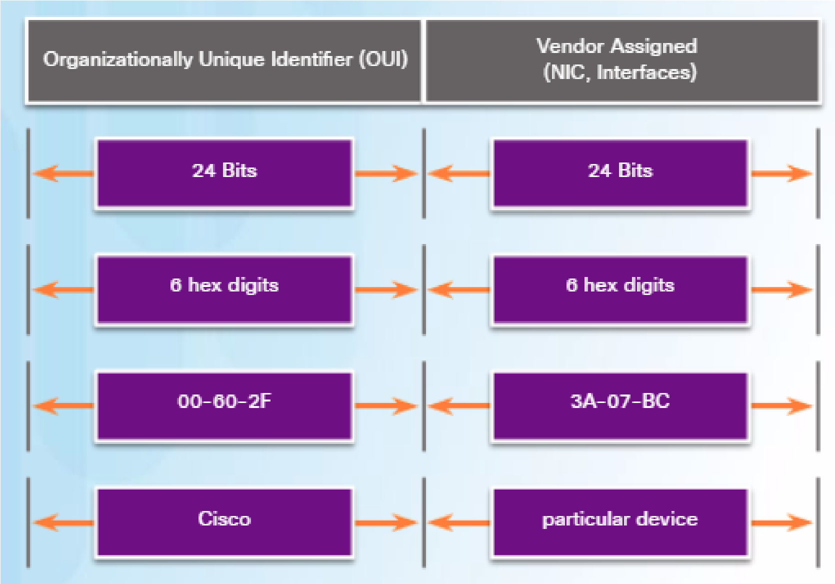
Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

- Convert the decimal or hexadecimal value to binary, and then to convert the binary value to either decimal or hexadecimal as needed.

MAC Addresses: Ethernet Identity

- MAC addresses were created to identify the **actual source and destination**.
  - The MAC address rules are established by IEEE.
  - The IEEE assigns the vendor a **3-byte** (24-bit) code, called the Organizationally Unique Identifier (**OUI**).

- IEEE requires a vendor to follow two simple rules:
  - All MAC addresses assigned to a NIC or other Ethernet device 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.

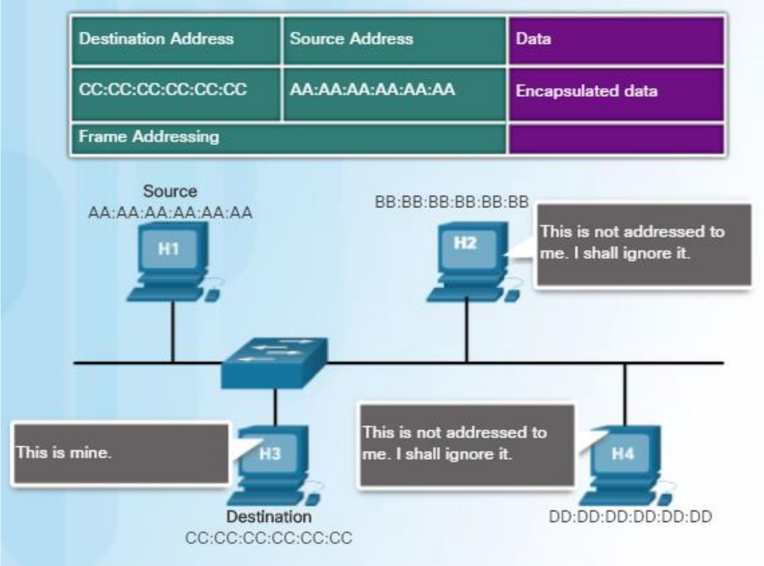


Frame Processing

- The MAC address is often referred to as a **burned-in address (BIA)** meaning the address is **encoded into the ROM chip permanently**. When the computer starts up, the first thing the NIC does is copy the MAC address from ROM into RAM.

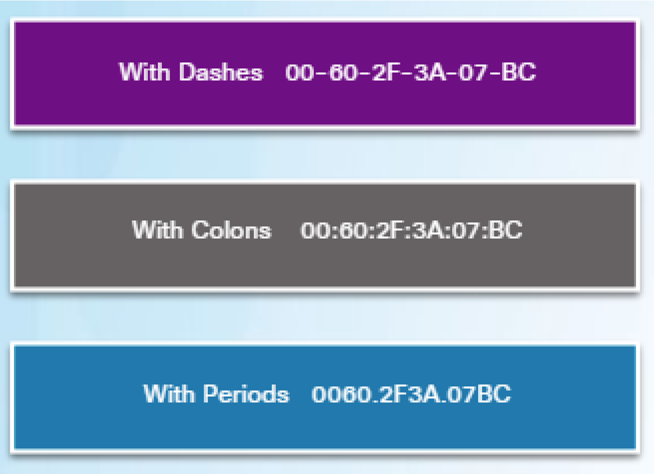
- When a device is forwarding a message to an Ethernet network, it attaches header information to the frame.

- The header information contains the source and destination MAC address.



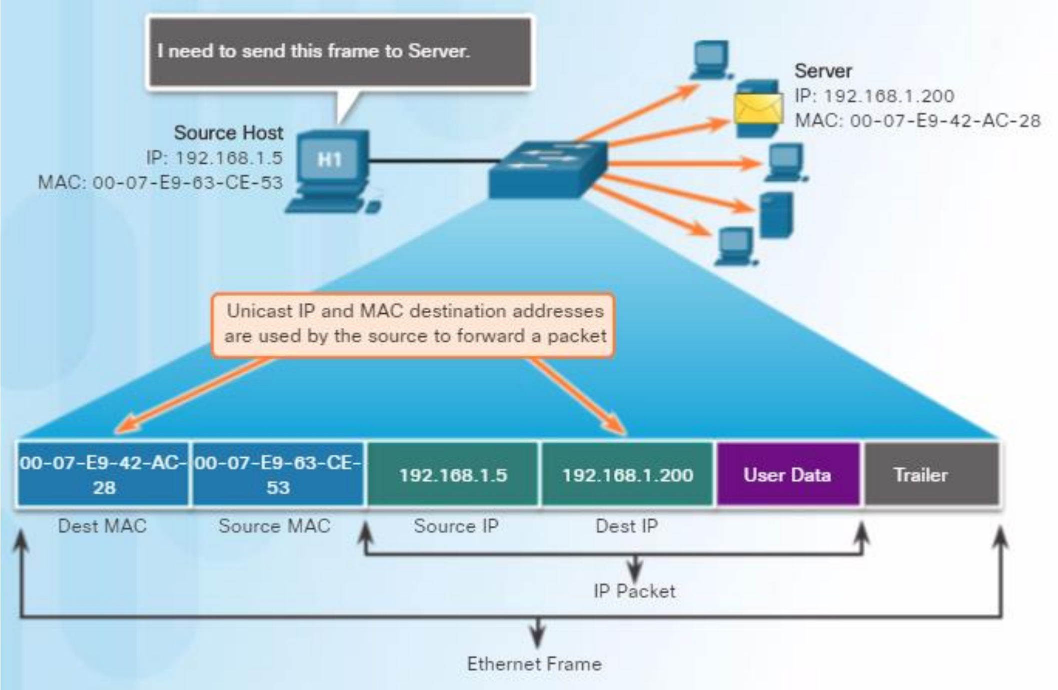
MAC Address Representations

- Use the **ipconfig /all** command on a Windows host to identify the MAC address of an Ethernet adapter. On a MAC or Linux host, the **ifconfig** command is used.
- Depending on the device and the operating system, you will see various representations of MAC addresses.



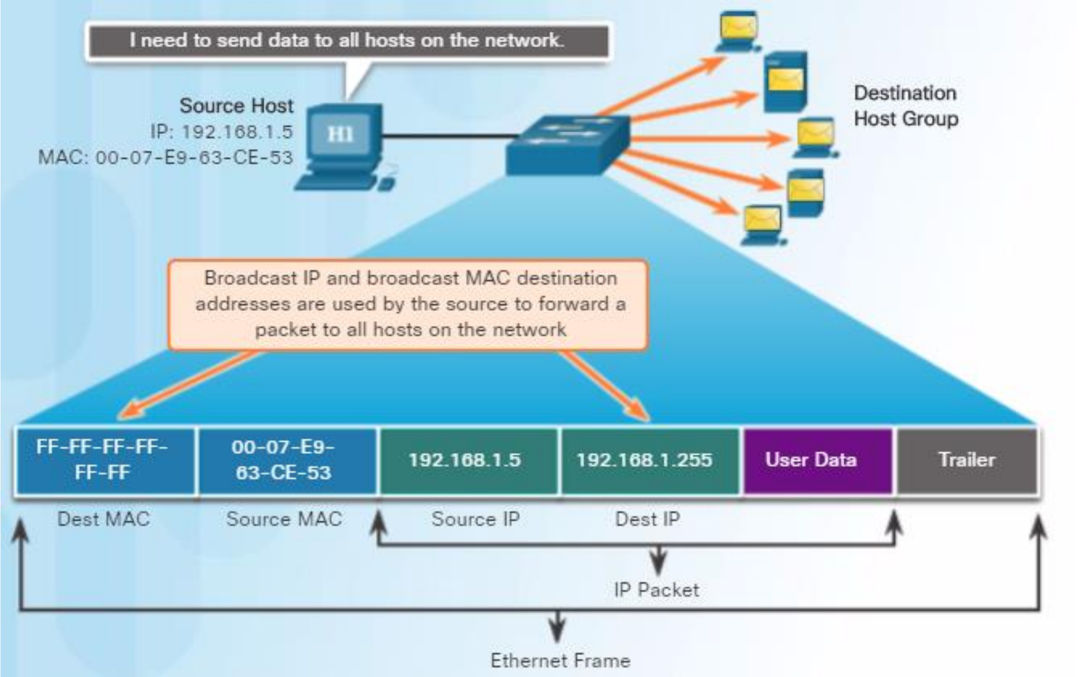
Unicast MAC Address

- A **unicast** MAC address is the unique address used when a frame is sent from a single transmitting device to a single destination device.
- For a unicast packet to be sent and received, a destination IP address must be in the IP packet header and a corresponding destination MAC address must also be present in the Ethernet frame header.



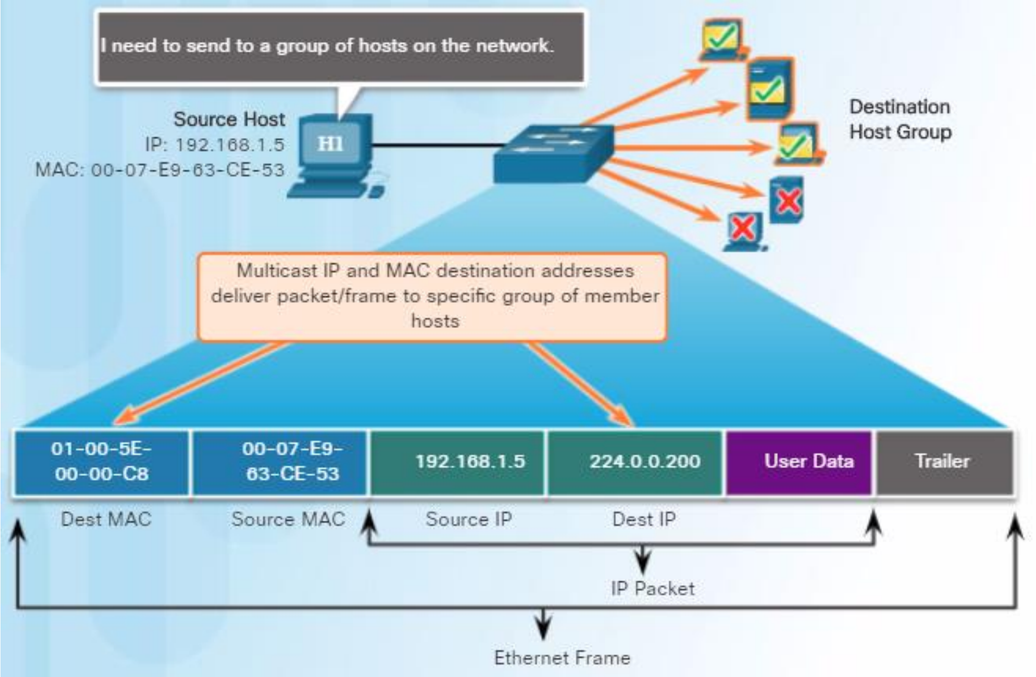
Broadcast MAC Address

- Many network protocols, such as DHCP and ARP, use **broadcasts**.
- A broadcast packet contains a destination IPv4 address that has all ones (1s) in the host portion indicating that all hosts on that local network will receive and process the packet.
- When the IPv4 broadcast packet is encapsulated in the Ethernet frame, the destination MAC address is the broadcast MAC address of **FF-FF-FF-FF-FF-FF** in hexadecimal (48 ones in binary).



Multicast MAC Address

- **Multicast** addresses allow a source device to send a packet to a group of devices.
  - Devices in a multicast group are assigned a multicast group IP address in the range of **224.0.0.0 to 239.255.255.255** (IPv6 multicast addresses begin with **FF00::/8**).
  - The multicast IP address requires a corresponding multicast MAC address that begins with **01-00-5E** in hexadecimal.



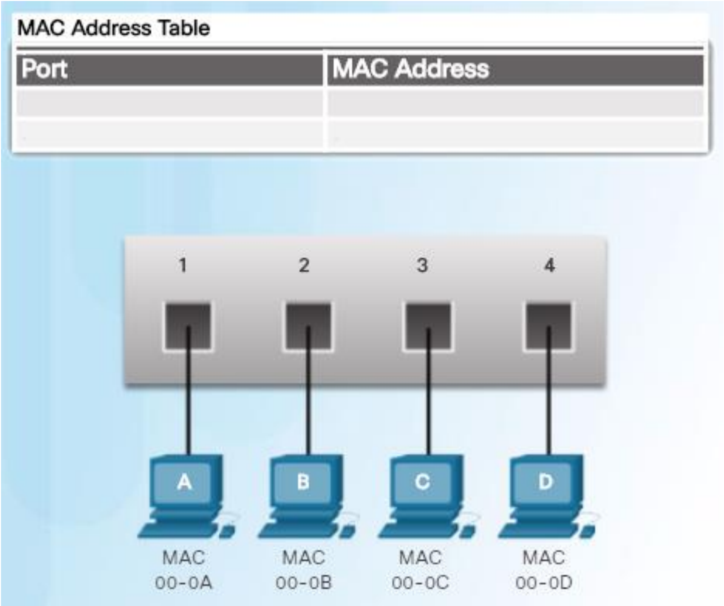
5.2 LAN Switches

Switch Fundamentals

- A Layer 2 Ethernet switch makes its forwarding decisions based only on the Layer 2 Ethernet MAC addresses.

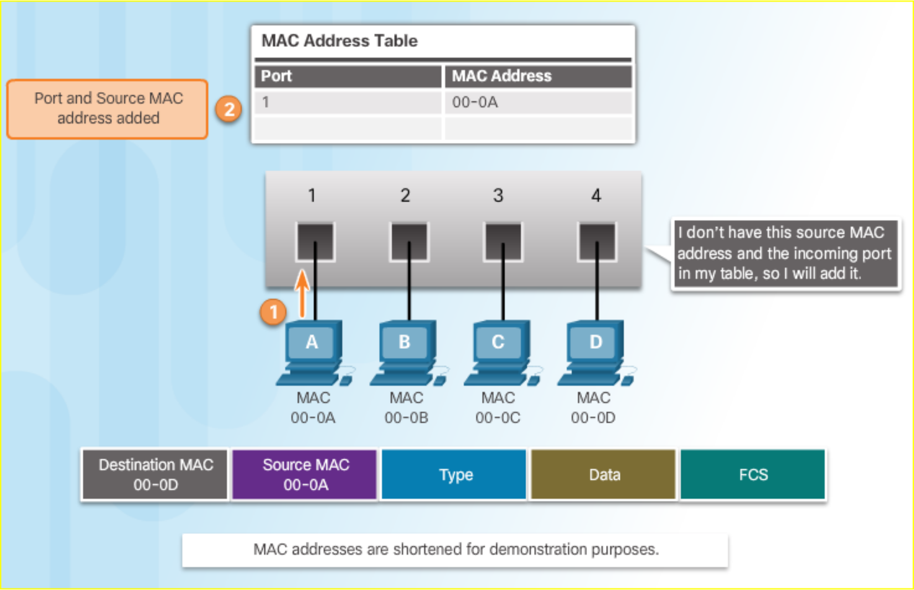
- A switch that is powered on, will have an empty MAC address table as it has not yet learned the MAC addresses for the four attached PCs.

- Note: The MAC address table is sometimes referred to as a content addressable memory **(CAM) table**.



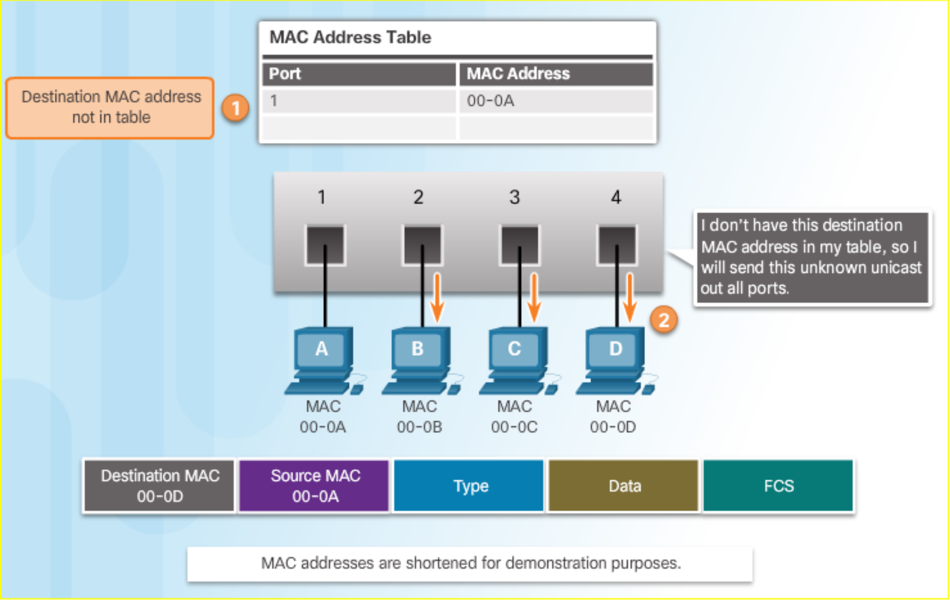
Learning MAC Addresses

- The switch **dynamically builds** the MAC address table. The process to learn the Source MAC Address is:
  - Switches **examine** all incoming frames for new source MAC address information to learn.
  - If the source MAC address is unknown, it is **added** to the table along with the **port** number.
  - If the source MAC address does exist, the switch updates the refresh timer for that entry.
  - By default, most Ethernet switches **keep** an entry in the table for **5 minutes**.



Learning MAC Addresses (Cont.)

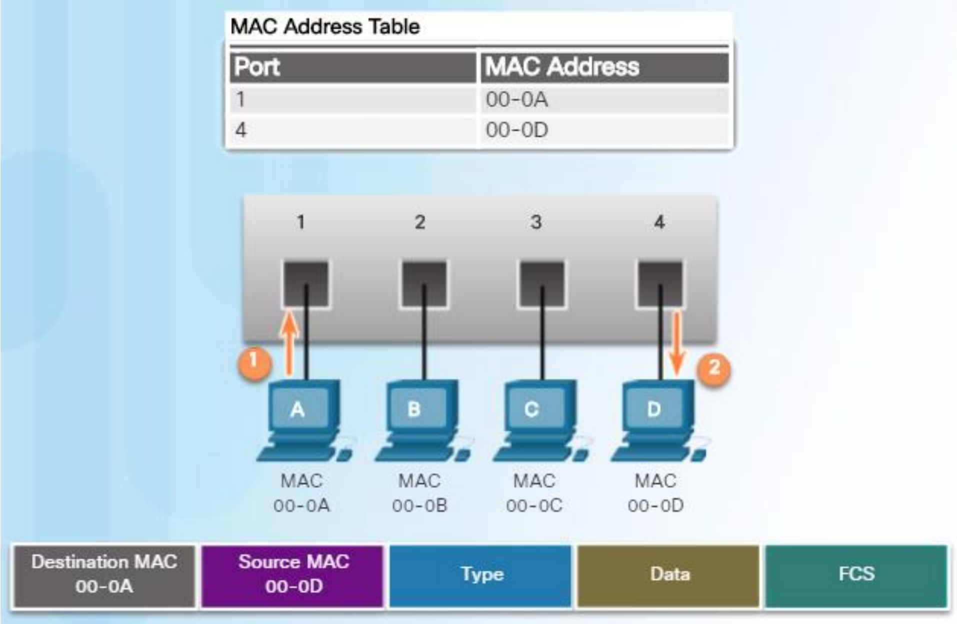
- The process to forward the Destination MAC Address is:
  - If the destination MAC address is a **broadcast or a multicast**, the frame is also flooded out all ports except the incoming port.
  - If the destination MAC address is a **unicast** address, the switch will look for a **match** in its MAC address table.
  - If the destination MAC address **is in the table**, it will forward the frame out the **specified** port.
  - If the destination MAC address **is not in the table** (i.e., an unknown unicast) the switch will forward the frame out **all ports except the incoming port**.



Filtering Frames

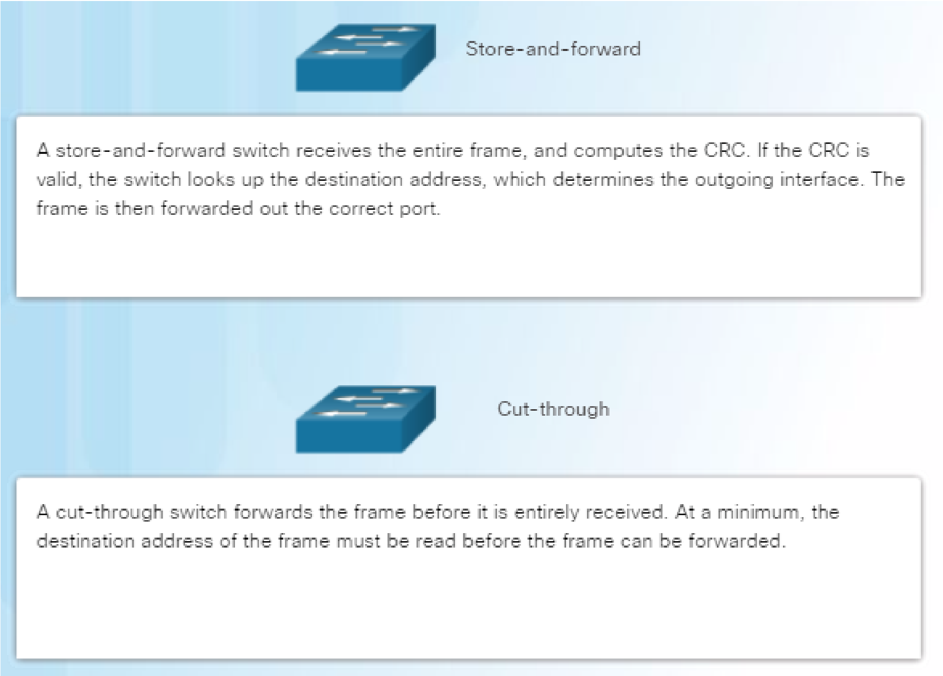
- As a switch receives frames from different devices, it is able to populate its MAC address table by examining the source MAC address of every frame.

- When the switch's MAC address table contains the destination MAC address, it is able to filter the frame and forward out a single port.



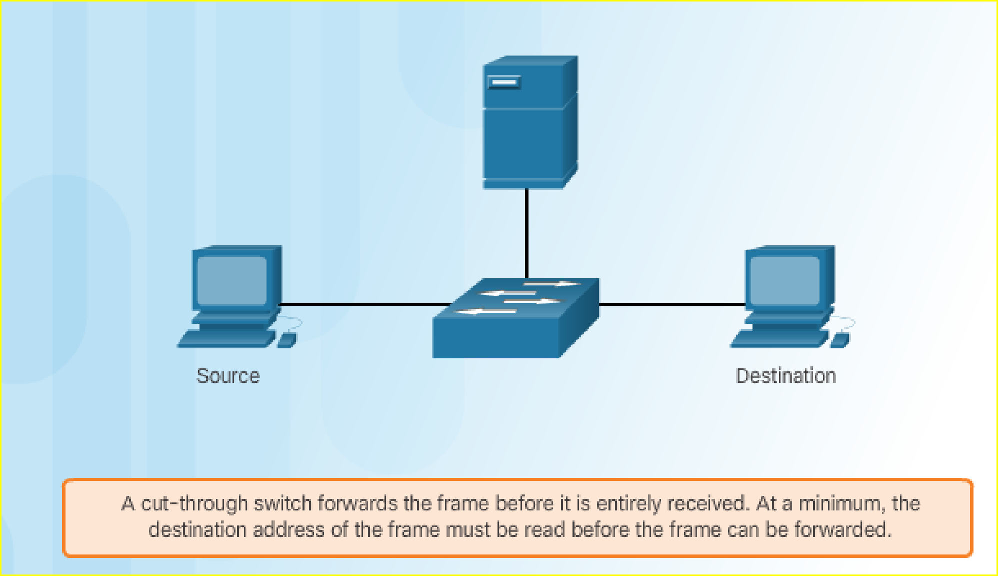
Frame Forwarding Methods on Cisco Switches

- Switches use one of the following **forwarding methods** for switching data between network ports:



Cut-Through Switching

- In **cut-through** switching, the switch **buffers just enough of the frame to read the destination MAC address** so that it can determine to which port to forward the data. The switch **does not perform any error checking** on the frame.
- There are two variants of cut-through switching:
  - **Fast-forward switching** offers the lowest level of latency. The switch **immediately forwards a packet after reading the destination address**. This is the most typical form of cut-through switching.
  - **Fragment-free switching**, in which the switch stores the **first 64 bytes** of the frame before forwarding. It is a compromise between store-and-forward and fast-forward switching.

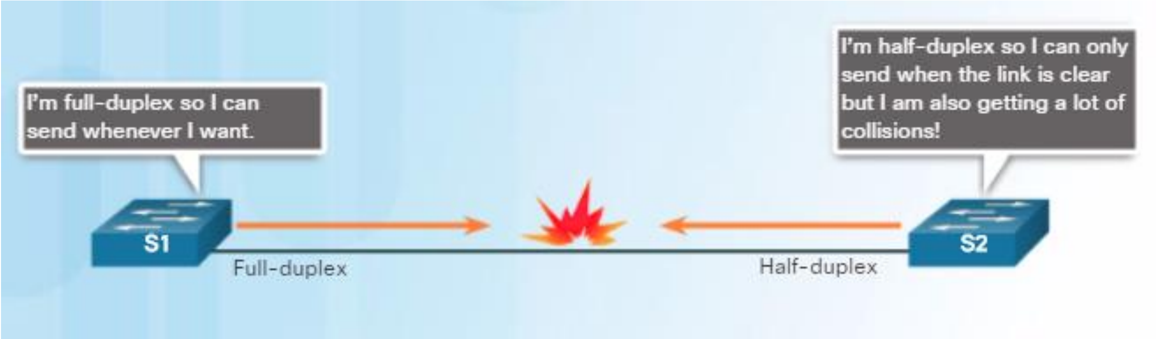


Duplex and Speed Settings

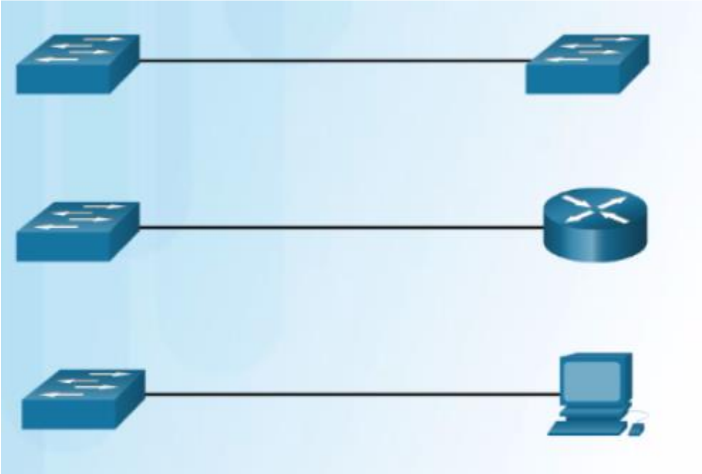
- There are two types of duplex settings used for communications on an Ethernet network:
  - **Full-duplex** – Both ends of the connection can send and receive simultaneously.
  - **Half-duplex** – Only one end of the connection can send at a time.

- **Most devices use autonegotiation** which enables two devices to automatically exchange information about speed and duplex capabilities and choose the highest performance mode.

- **Duplex mismatch** is a common cause of performance issues with Ethernet links. It occurs when one port on the link operates at half-duplex while the other port operates at full-duplex.



Auto-MDIX

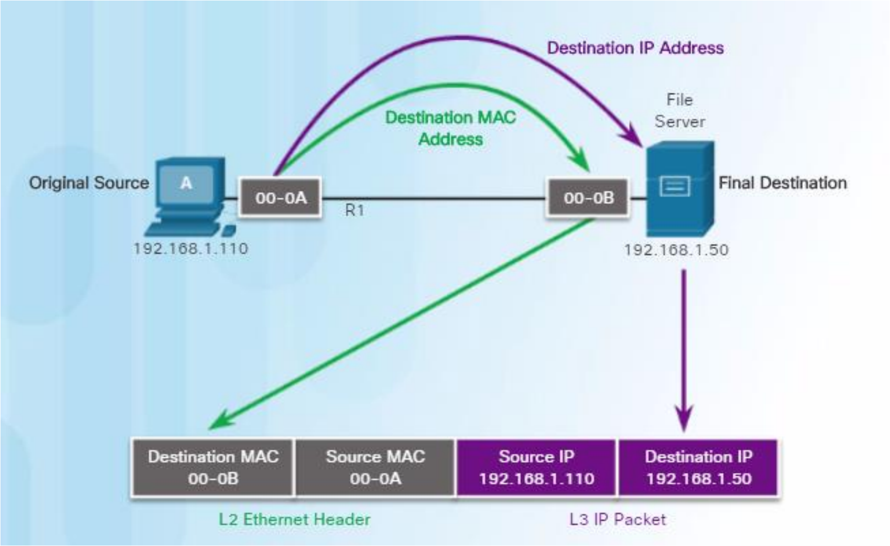


- Connections between specific devices such as switch-to-switch, switch-to-router, switch-to-host, and router-to-host devices, once **required the use of specific cable types** (**crossover** or **straight-through**).
- Most switch devices now support the **automatic medium-dependent interface crossover** (auto-MDIX) feature. This is enabled by default on switches since IOS 12.2(18)SE.
- When enabled using the **mdix auto** interface configuration command, the switch detects the type of cable attached to the port, and configures the interfaces accordingly.

5.3 Address Resolution Protocol

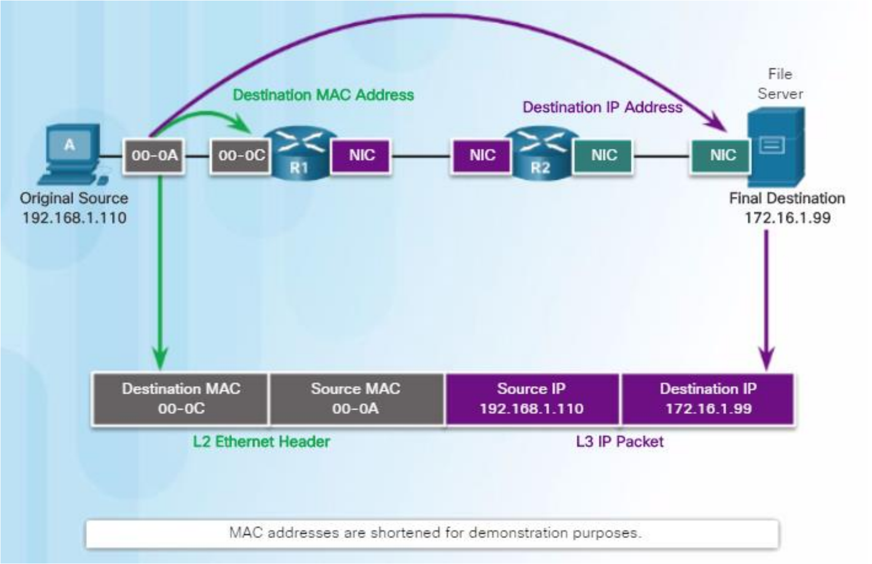
Destination on Same Network

- There are two primary addresses assigned to a device on an Ethernet LAN:
  - Physical address (the Ethernet **MAC** address)
  - Logical address (the **IP** address)
- As an example, PC-A sends an IP packet to the file server on the same network. The Layer 2 Ethernet frame contains:
  - Destination MAC address
  - Source MAC address
- The Layer 3 IP packet contains:
  - Source IP address
  - Destination IP address



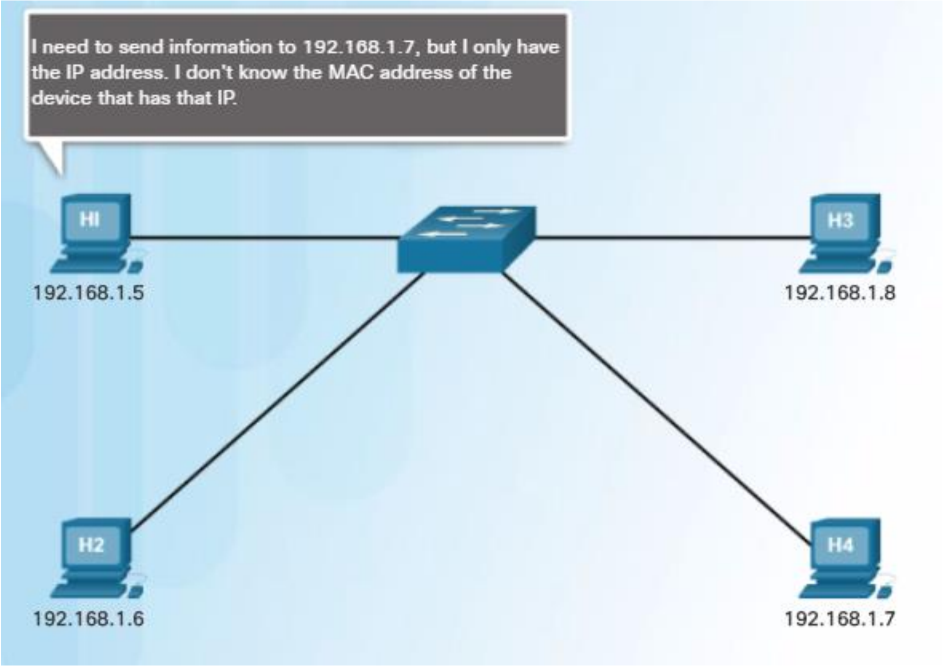
Destination on Remote Network

- When the destination IP address is on a remote network, the destination MAC address will be the address of the host's default gateway.
- In the figure, PC-A is sending an IP packet to a web server on a remote network.
  - The destination IP address is that of the File Server.
  - The destination MAC address is that of Ethernet interface of R1.



Introduction to ARP

- When a device sends an Ethernet frame, it contains these two addresses:
  - Destination MAC address
  - Source MAC address

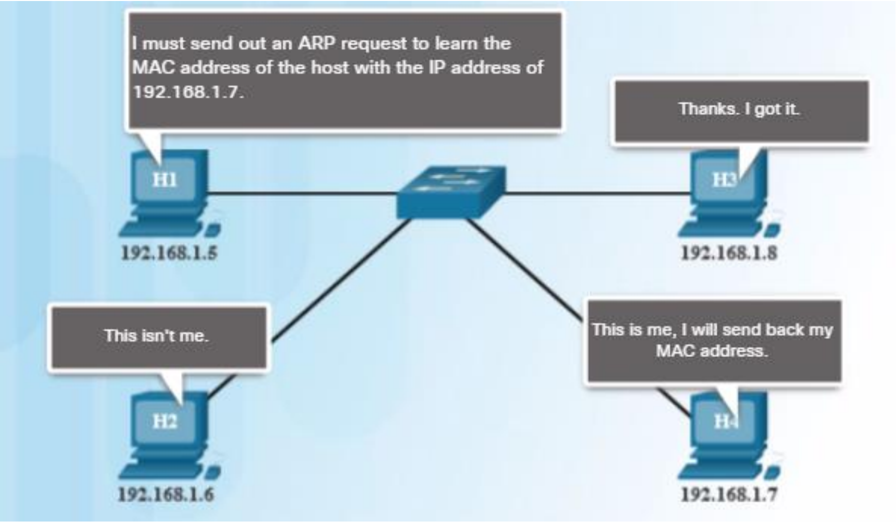


- To determine the destination MAC address, the device uses **ARP**.

- **ARP** provides two basic functions:
  - **Resolving IPv4 addresses to MAC addresses**
  - **Maintaining a table of mappings**

ARP Functions

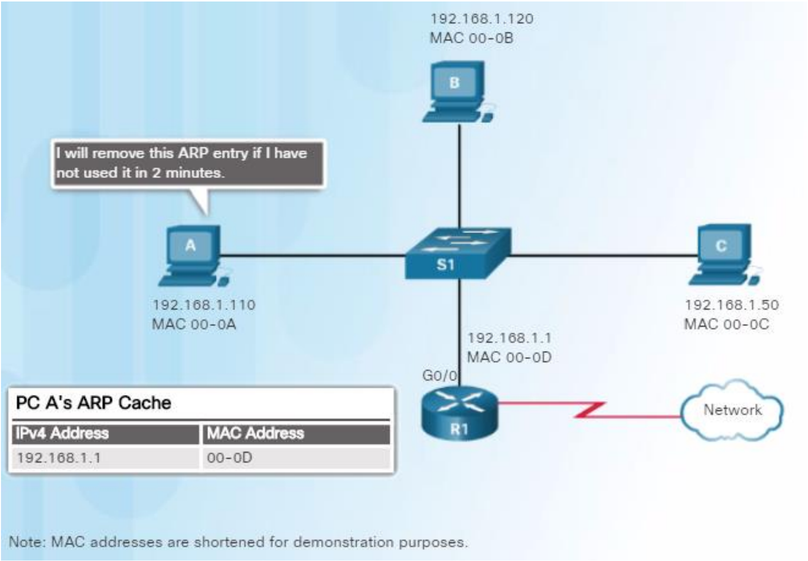
- Ethernet devices refer to an **ARP table** (or the **ARP cache**) in its memory (i.e., RAM) to find the MAC address that is mapped to the IPv4 address.
- A device will search its ARP table for a destination IPv4 address and a corresponding MAC address.
  - If the packet's destination IPv4 address is on the same network as the source IPv4 address, the device will search the ARP table for the destination IPv4 address.
  - If the destination IPv4 address is on a different network than the source IPv4 address, the device will search the ARP table for the IPv4 address of the default gateway.



Removing Entries from an ARP Table

- Every device has an ARP cache timer that **removes** ARP **entries** that **have not been used** for a specified period of time.

- **The times differ** depending on the device's operating system. As shown in the figure, some Windows operating systems store ARP cache entries for **2 minutes.**



- You can also manually remove all or some of the entries in the ARP table.

ARP Tables

On a Router	On a Windows Host
On a Cisco router, the **show ip arp** command is used to display the ARP table.	On a Windows 7 PC, the **arp –a** command is used to display the ARP table.

```
Router# show ip arp
Protocol  Address          Age (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
Router#
```

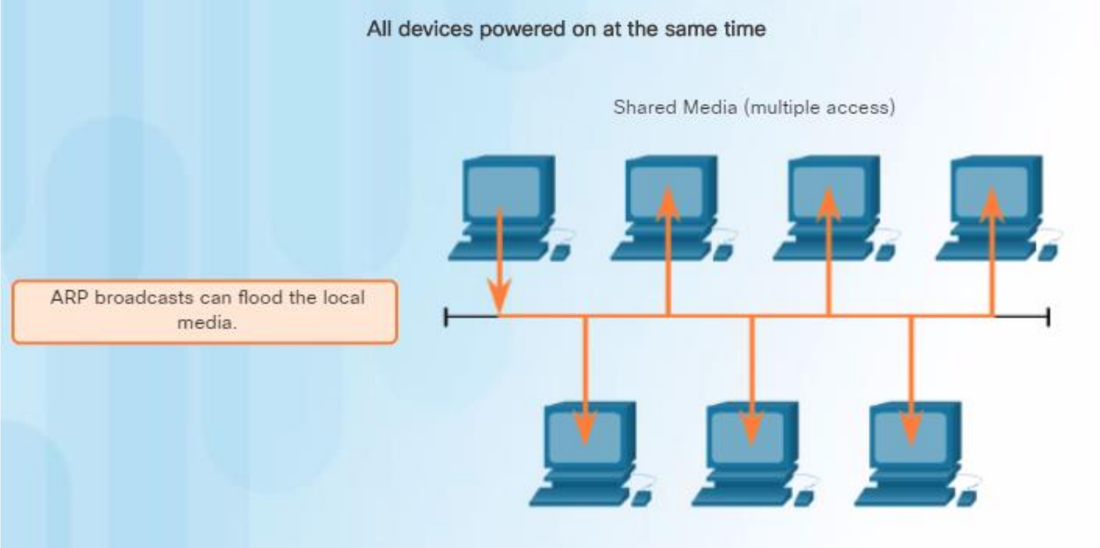
```
C:\> arp -a

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

Interface: 10.82.253.91 --- 0x10
  Internet Address      Physical Address      Type
  10.82.253.92          64-0f-29-0d-36-91     dynamic
  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
```

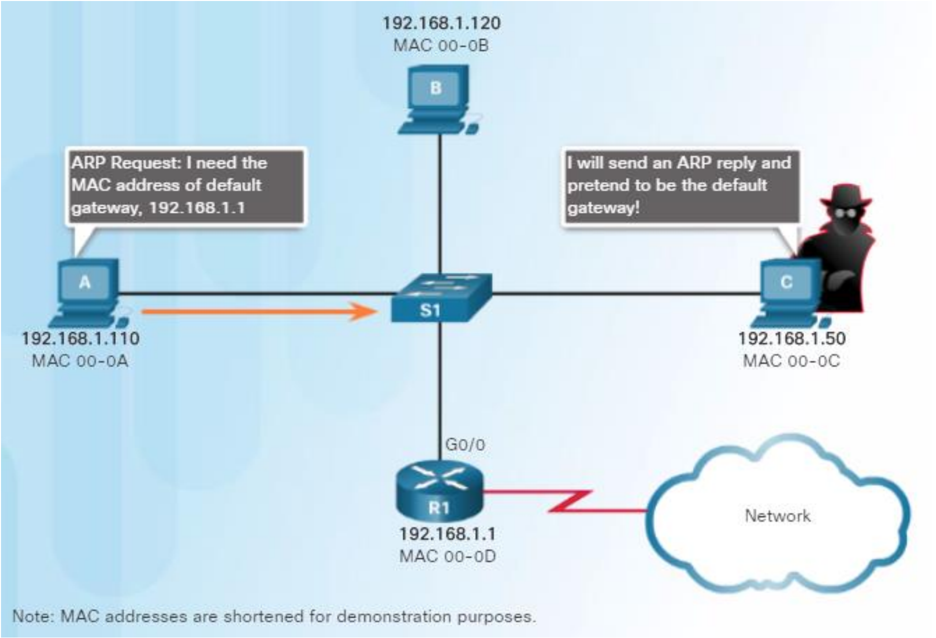
ARP Broadcasts

- As a broadcast frame, an **ARP request is received and processed by every device on the local network**.
- ARP requests can flood the local segment if a large number of devices were to be powered up and all start accessing network services at the same time.



ARP Spoofing

- Attackers can respond to requests and pretend to be providers of services.
- One type of ARP spoofing attack used by attackers is to **reply to an ARP request for the default gateway**. In the figure, host A requests the MAC address of the default gateway. Host C replies to the ARP request. Host A receives the reply and updates its ARP table. It now sends packets destined to the default gateway to the attacker host C.
- Enterprise level switches include mitigation techniques known as dynamic ARP inspection (DAI).



5.4 Chapter Summary

Conclusion

Chapter 5: Ethernet

- Explain the operation of Ethernet.
- Explain how a switch operates.
- Explain how the address resolution protocol enables communication on a network.