Chapter 4:
Network Access

Introduction to Networks

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Chapter 4: Objectives

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

- Identify device connectivity options.
- Describe the purpose and functions of the physical layer in the network.
- Identify the basic characteristics of copper cabling, fiber-optic cabling and wireless media.
- Describe the purpose and function of the data link layer in preparing communication for transmission on specific media.
- Describe the basic characteristics of media control methods on WAN and LAN topologies.
- Describe the characteristics and functions of the data link frame.

4.1 Physical Layer Protocols

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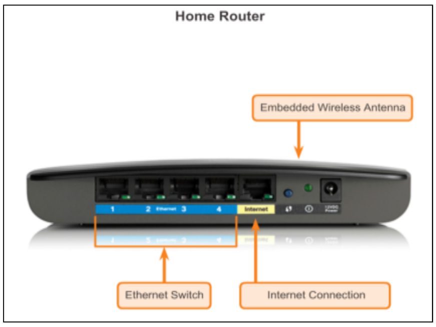
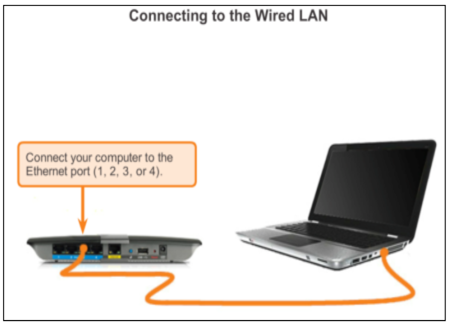
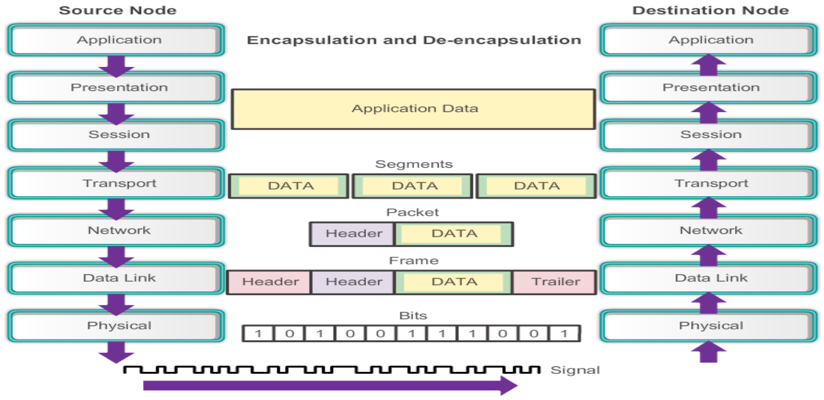
Getting it Connected – Connecting to the Network





- A physical connection can be a wired connection using a cable or a wireless connection using radio waves.
- For wireless connection, a network must incorporate a wireless access point (WAP) for devices to connect to.
- Switch devices and wireless access points are often two separate dedicated devices within a network implementation. However, there are also devices that offer both wired and wireless connectivity.

The Physical Layer



- The OSI physical layer provides the means to transport the bits that make up a data link layer frame across the network media.
- This layer accepts a complete frame from the data link layer and encodes it as a series of signals that are transmitted onto the local media.
- The encoded bits that comprise a frame are received by either an end device or an intermediate device.

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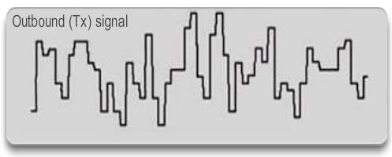
Physical Layer Media

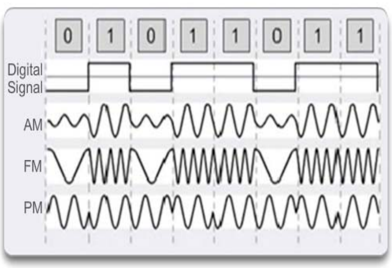


Electrical Signals - Copper cable

Copper cable: The signals are patterns of electrical pulses.

Light Pulse - Fiber-optic cable

Fiber-optic cable: The signals are patterns of light.



Microwave Signals - Wireless

Wireless: The signals are patterns of microwave transmissions.

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Physical Layer Fundamental Principles

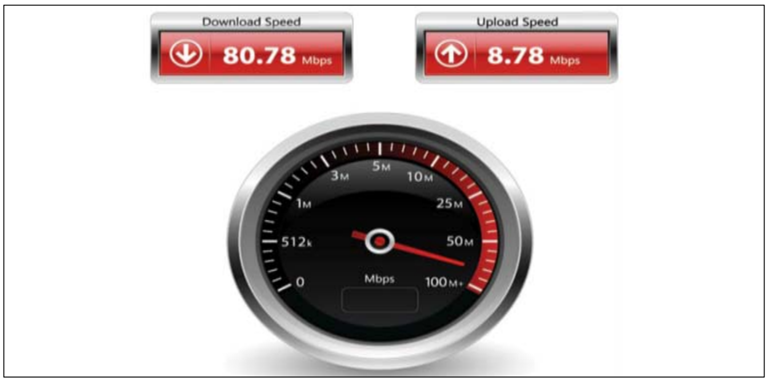
Media	Physical Components	Frame Encoding Technique	Signalling Method
Copper Cable	• UTP • Coaxial • Connectors • NICs • Ports • Interfaces	• Manchester Encoding • Non-Return to Zero (NRZ) techniques • 4B/5B codes are used with Multi-Level Transition Level 3 (MLT-3) signaling • 8B/10B • PAM5	• Changes in the electromagnetic field • Intensity of the electromagnetic field • Phase of the electromagnetic wave
Fiber Optic Cable	• Single-mode Fiber • Multimode Fiber • Connectors • NICs • Interfaces • Lasers and LEDs • Photoreceptors	• Pulses of light • Wavelength multiplexing using different colors	• A pulse equals 1. • No pulse is 0.
Wireless Media	• Access Points • NICs • Radio • Antennae	• DSSS (direct-sequence spread-spectrum) • OFDM (orthogonal frequency division multiplexing)	• Radio waves

Bandwidth

Unit of Bandwidth	Abbreviation	Equivalence
Bits per second	bps	1 bps = fundamental unit of bandwidth
Kilobits per second	kbps	1 kbps = 1,000 bps = 10^3 bps
Megabits per second	Mbps	1 Mbps = 1,000,000 bps = 10^6 bps
Gigabits per second	Gbps	1 Gbps = 1,000,000,000 bps = 10^9 bps
Terabits per second	Tbps	1 Tbps = 1,000,000,000,000 bps = 10^12 bps

- Different physical media support the transfer of bits at different speeds.
- Data transfer is usually discussed in terms of **bandwidth** and **throughput**.
- Bandwidth is the capacity of a medium to carry data. Digital bandwidth measures the amount of data that can flow from one place to another in a given amount of time.

Throughput & Goodput



- **Throughput** is the measure of the transfer of bits across the media over a given period of time.
- Due to a number of factors, throughput usually does not match the specified bandwidth in physical layer implementations.
- **Goodput** is the measure of usable data transferred over a given period of time.

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4.2 Network Media

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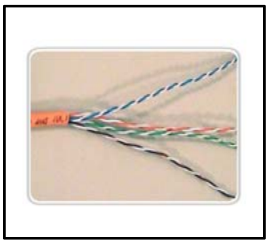
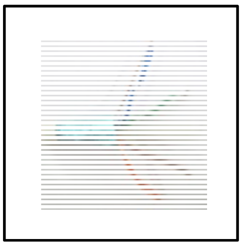
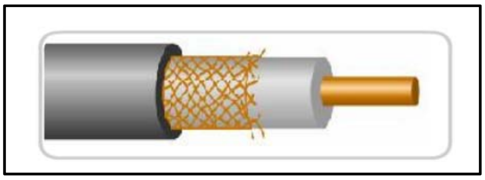
Copper Media



Unshielded Twisted Pair (UTP) Cable



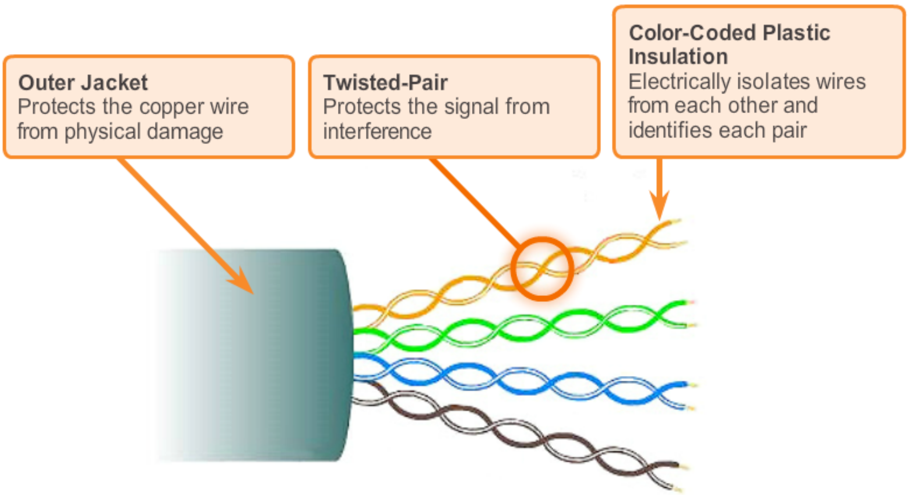
Shielded Twisted Pair (STP) Cable



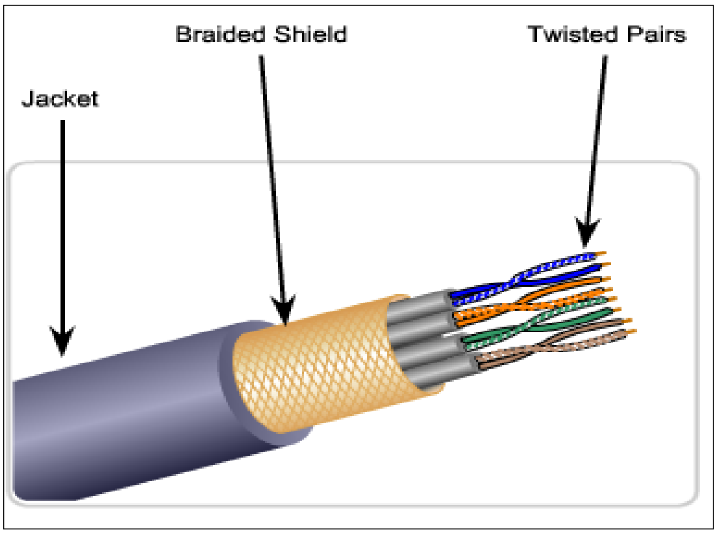
Coaxial Cable

- Data is transmitted on copper cables as electrical pulses.
- A detector in the network interface of a destination device must receive a signal that can be successfully decoded to match the signal sent.
- However, the longer the signal travels, the more it deteriorates in a phenomenon referred to as signal attenuation.
- For this reason, all copper media must follow strict distance limitations as specified by the guiding standards.

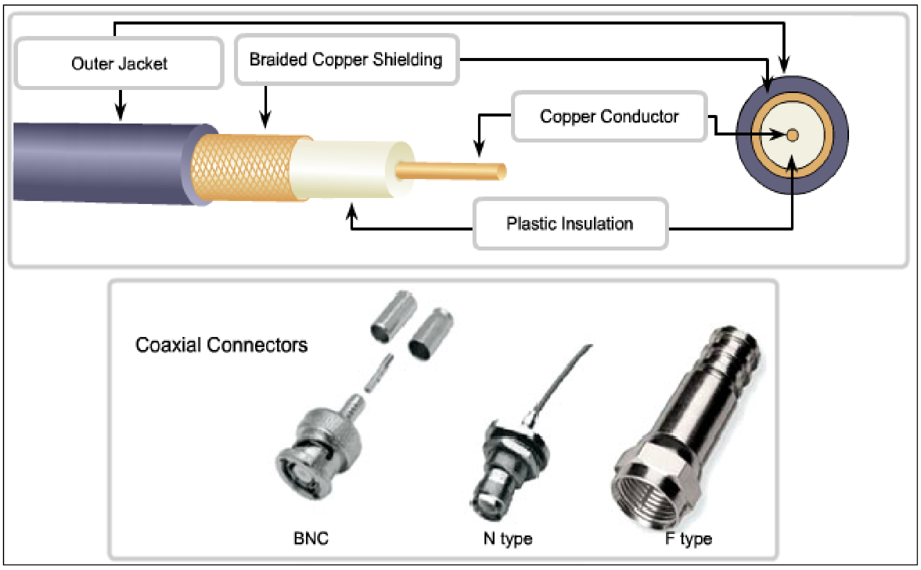
Unshielded Twisted Pair (UTP) Cable



Shielded Twisted Pair (STP) Cable



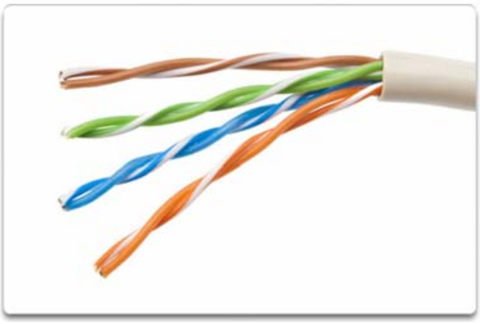
Coaxial Cable



Properties of UTP Cabling

UTP cable does not use shielding to counter the effects of interference such as EMI or RFI. Instead, cable designers have discovered that they can **limit the negative effect of crosstalk** by:

- Cancellation
- Varying the number of twists per wire pair



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UTP Connectors

RJ-45 UTP Plugs

RJ-45 UTP Socket

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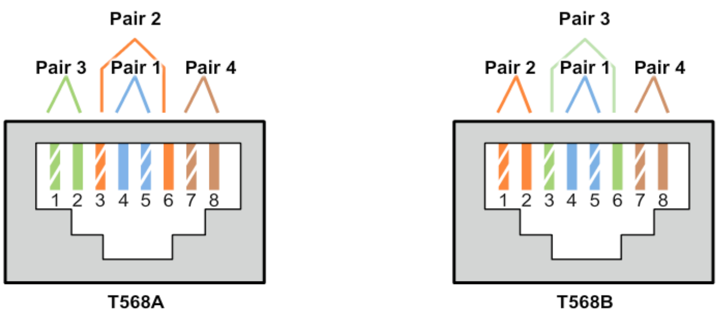
Types of UTP Cable

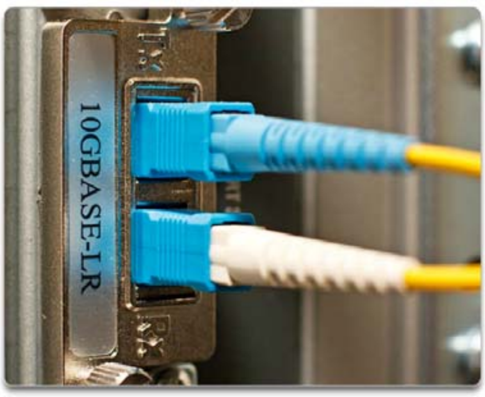


Cable Type	Standard	Application
Ethernet Straight-through	Both ends T568A or both ends T568B	Connects a network host to a network device such as a switch or hub.
Ethernet Crossover	One end T568A, other end T568B	• Connects two network hosts • Connects two network intermediary devices (switch to switch, or router to router)
Rollover	Cisco proprietary	Connects a workstation serial port to a router console port, using an adapter.

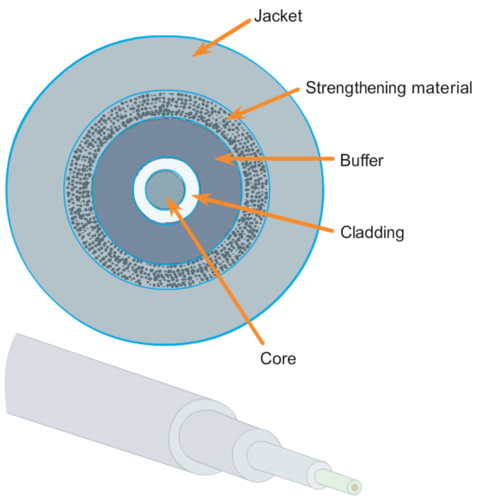
Properties of Fiber Optic Cabling

Fiber-optic cabling is now being used in four types of industry:

- Enterprise Networks
- Fiber-to-the-home (FTTH) and Access Networks
- Long-Haul Networks
- Submarine Networks



Fiber Media Cable Design



Although an optical fiber is very thin, it is composed of two kinds of glass and a protective outer shield. Specifically, these are the:

Core: Consists of pure glass and is the part of the fiber where light is carried.

Cladding: The glass that surrounds the core and acts as a mirror. The light pulses propagate down the core while the cladding reflects the light pulses.

Jacket: Typically a PVC jacket that protects the core and cladding.

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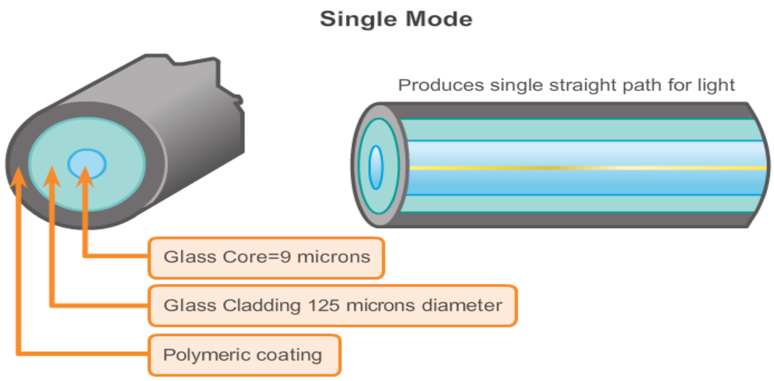
Types of Fiber Media



- Small core
- Less dispersion
- Suited for long distance applications
- Uses lasers as the light source
- Commonly used with campus backbones for distances of several thousand meters

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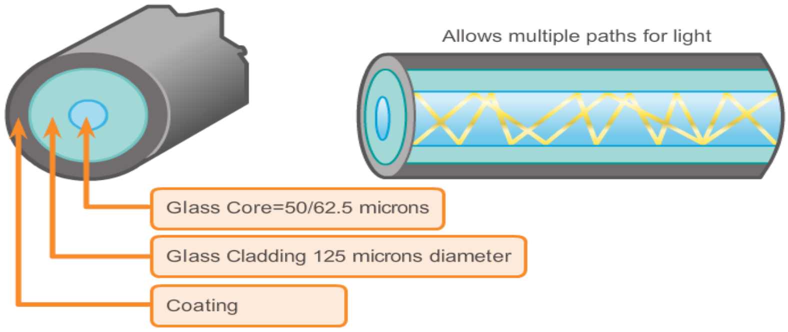
Types of Fiber Media

Multimode



- Larger core than single mode cable
- Allows greater dispersion and therefore, loss of signal
- Suited for long distance applications, but shorter than single mode
- Uses LEDs as the light source
- Commonly used with LANs or distances of a couple hundred meters within a campus network

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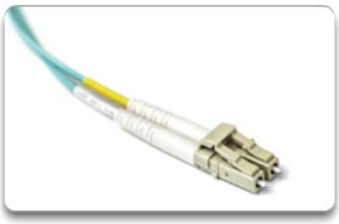
Network Fiber Connectors

ST Connectors

SC Connectors

LC Connector



Duplex Multimode LC Connectors

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Fiber versus Copper

Implementation Issues	Copper Media	Fibre Optic
Bandwidth Supported	10 Mbps – 10 Gbps	10 Mbps – 100 Gbps
Distance	Relatively short (1 – 100 meters)	Relatively High (1 – 100,000 meters)
Immunity To EMI And RFI	Low	High (Completely immune)
Immunity To Electrical Hazards	Low	High (Completely immune)
Media And Connector Costs	Lowest	Highest
Installation Skills Required	Lowest	Highest
Safety Precautions	Lowest	Highest

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Properties of Wireless Media

Wireless does have some areas of concern including:

- **Coverage area** - Wireless data communication technologies work well in open environments. However, certain construction materials used in buildings and structures, and the local terrain, will limit the effective coverage.
- **Interference** - Wireless is susceptible to interference and can be disrupted by such common devices as household cordless phones, some types of fluorescent lights, microwave ovens, and other wireless communications.
- **Security** - Wireless communication coverage requires no access to a physical media.
  - Therefore, devices and users who are not authorized for access to the network can gain access to the transmission.
  - Consequently, network security is a major concern of wireless network administration.

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Types of Wireless Media

Wi Fi	• IEEE 802.11 standards
	• Commonly referred to as Wi-Fi.
	• Uses CSMA/CA
	• Variations include:
	  • 802.11a: 54 Mbps, 5 GHz
	  • 802.11b: 11 Mbps, 2.4 GHz
	  • 802.11g: 54 Mbps, 2.4 GHz
	  • 802.11n: 600 Mbps, 2.4 and 5 GHz
	  • 802.11ac: 1 Gbps, 5 GHz
	  • 802.11ad: 7 Gbps, 2.4 GHz, 5 GHz, and 60 GHz

Bluetooth®	• IEEE 802.15 standard • Supports speeds up to 3 Mb/s • Provides device pairing over distances from 1 to 100 meters.
Wi MAX	• IEEE 802.16 standard • Provides speeds up to 1 Gbps • Uses a point-to-multipoint topology to provide wireless broadband access.

802.11 Wi-Fi Standards

Standard	Maximum Speed	Frequency	Backwards Compatible
802.11a	54 Mbps	5 GHz	No
802.11b	11 Mbps	2.4 GHz	No
802.11g	54 Mbps	2.4 GHz	802.11b
802.11n	600 Mbps	2.4 GHz or 5 GHz	802.11b/g
802.11ac	1.3 Gbps (1300 Mbps)	2.4 GHz and 5.5 GHz	802.11b/g/n
802.11ad	7 Gbps (7000 Mbps)	2.4 GHz, 5 GHz and 60 GHz	802.11b/g/n/ac

4.3 Data Link Layer Protocols

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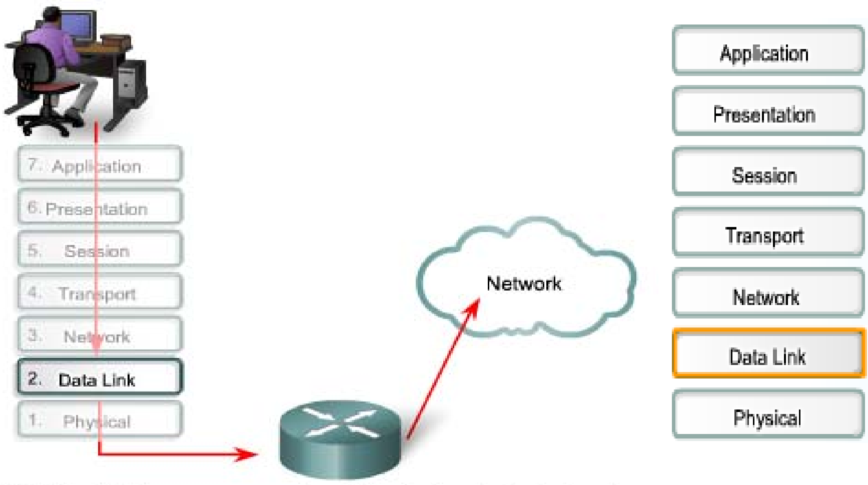
Data Link Layer



The Data Link layer prepares network data for the physical network.

The Data Link layer provides a means for exchanging data over a common local media.

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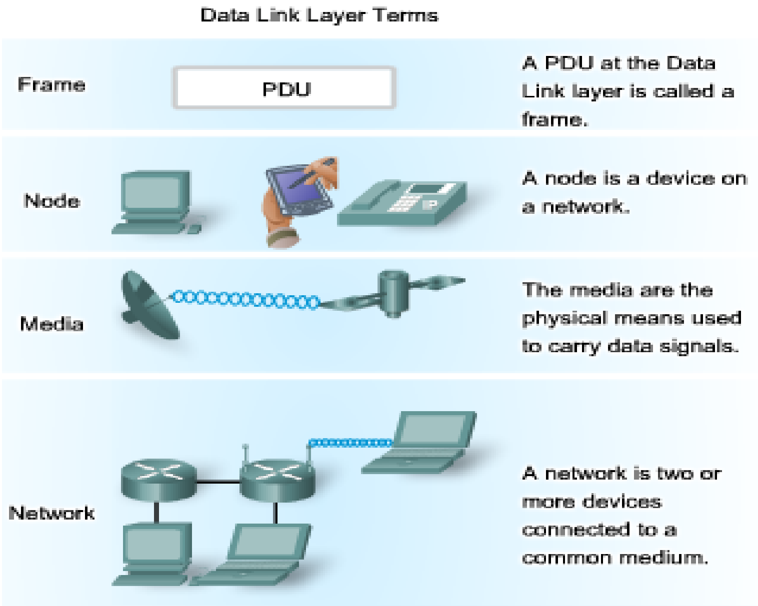
Data Link Layer

- The Data Link layer performs two basic services:
  - It accepts Layer 3 packets and packages them into data units called **frames**.
  - It controls media access control and performs error detection.
- The Data Link layer is responsible for the exchange of frames between nodes over the media of a physical network:
  - Frames - The Data Link layer PDU.
  - Nodes - Network devices connected to a common medium.
  - Media/medium - The physical means for the transfer of data between two nodes.
  - Network (physical) - Two or more nodes connected to a common medium.
  - The Data Link layer provides for the exchange of data over a common local media.

Data Link Layer

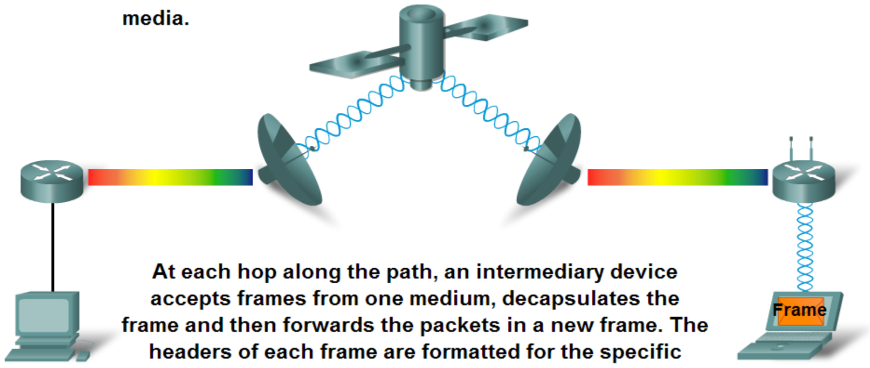


Data Link Layer – Accessing the Media

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, decapsulates 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.

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Data Link Layer – Accessing the Media

- The Data Link layer provides services to support the communication processes for each medium over which data is to be transmitted.
- Imagine a data conversation between two hosts, such as a **Laptop in Paris** with an Internet **Server in Japan**:
  - In this example, as the IP packet travels from Server (or PC) to laptop.

It will be encapsulated into Ethernet frame at the Server.

De-capsulated and then encapsulated into a new data link frame to cross the **satellite link**.

For the final link, the packet will use a **wireless** data link frame from the router to the laptop.

  - **As packet is received and directed to upper layer protocol (IPv4), the upper layer does not need to be aware of which media the communication will use.**

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Creating a Frame

- When data travels on the media, it is converted into a stream of bits,1s and 0s.
- Typical field types of a Frame include:
  - Start and stop indicator fields - The beginning and end limits of the frame
  - Naming or addressing fields
  - Type field - The type of PDU contained in the frame
  - Quality control fields
  - A data field -The frame payload (Network layer packet)
  - Fields at the end of the frame form the trailer. These fields are used for error detection and mark the end of the frame.

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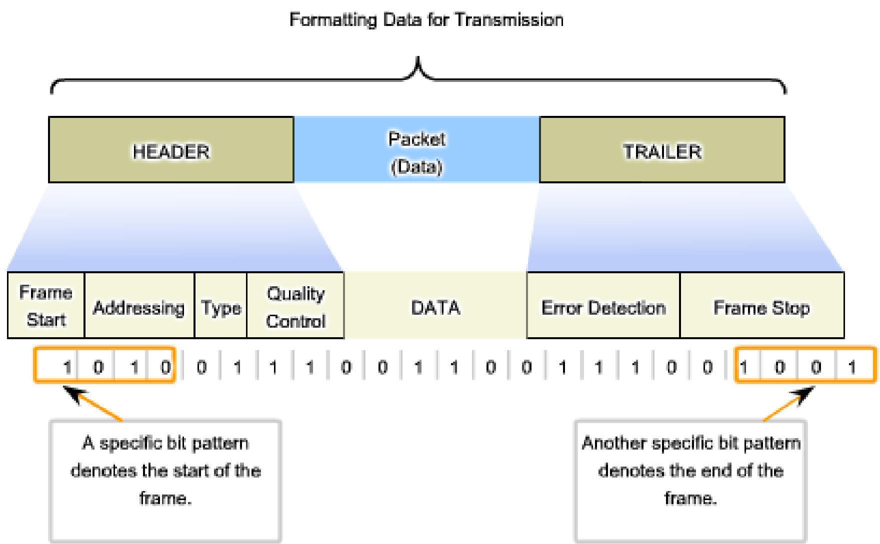
Creating a Frame



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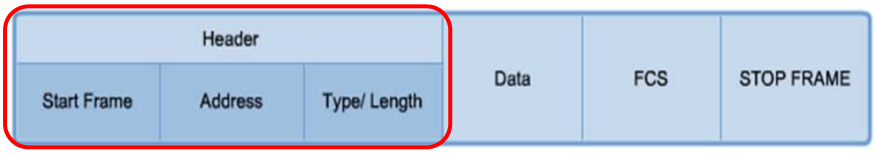
The Header



- **Start Frame field**: Indicates the beginning of the frame.
- **Source and Destination Address fields**: Indicates the source and destination nodes on the media.
- **Type field**: Indicates the upper layer service contained in the frame.

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The Trailer

Frame Check Sequence

This field is used for error checking. The source calculates a number based on the frame's data and places that number in the FCS field. The destination then recalculates the data to see if the FCS matches. If they don't match, the destination deletes the frame.

Stop Frame

This field, also called the Frame Trailer, is an optional field that is used when the length of the frame is not specified in the Type/Length field. It indicates the end of the frame when transmitted.

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Ethernet Frame

Ethernet Protocol

A Common Data Link Layer Protocol for LANs

Frame

Field name	Preamble	Destination	Source	Type	Data	Frame Check Sequence
Size	8 bytes	6 bytes	6 bytes	2 bytes	46 - 1500 bytes	4 bytes

Preamble - Used for synchronization; also contains a delimiter to mark the end of the timing information
Destination Address - 48-bit MAC address for the destination node
Source Address - 48-bit MAC address for the source node
Type - Value to indicate which upper layer protocol will receive the data after the Ethernet process is complete
Data or payload - This is the PDU, typically an IPv4 packet, that is to be transported over the media.
Frame Check Sequence (FCS) - A value used to check for damaged frames

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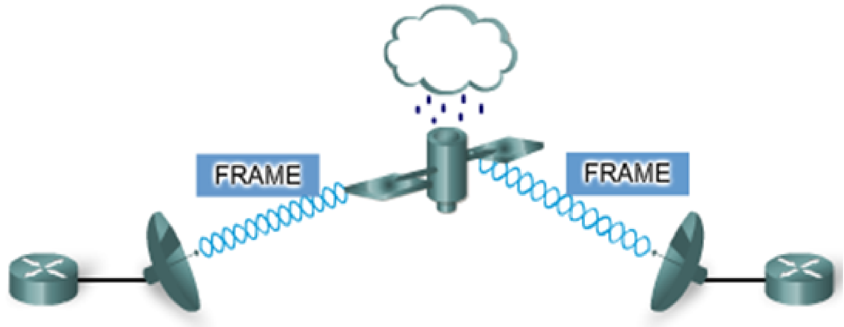
The Frame

In a fragile environment, more controls are needed to ensure delivery. The header and trailer fields are larger as more control information is needed.

Greater effort needed to ensure delivery = higher overhead = slower transmission rates



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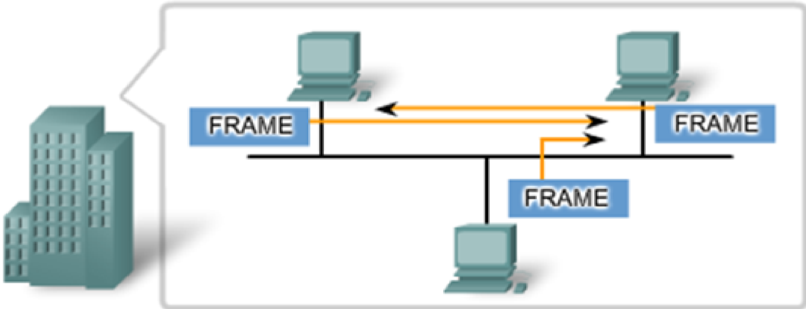
The Frame

In a protected environment, we can count on the frame arriving at its destination. Fewer controls are needed, resulting in smaller fields and smaller frames.

Less effort needed to ensure delivery = lower overhead = faster transmission rates



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Connecting Upper Layer Services to the Media

- The Data Link layer (Layer 2) is a connecting layer between the software processes of the layers above it and the Physical layer below it.
- It identify devices by physical addresses burned into the network card (permanent address that cannot be changed).
- Layer 2 address (Physical or MAC address):
  - Length of **48 bits** (binary digits).
  - Represented in **Hexadecimal** format.

  (Example: **6C - 62 - 6D - A2 - 35 - B7**)

  (In Binary: **01101100-01100010-01101101-10100010-00110101-10110111**)

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Connecting Upper Layer Services to the Media

- In many cases, the Data Link layer is embodied as a physical entity, such as an Ethernet NIC.
  - The NIC is not solely a physical entity.

  Software associated with the NIC enables the NIC to perform its intermediary functions of preparing data for transmission and encoding the data as signals to be sent on the associated media.
  - It prepares the Network layer packets for transmission across some form of media, be it copper, fiber, or the atmosphere (wireless).

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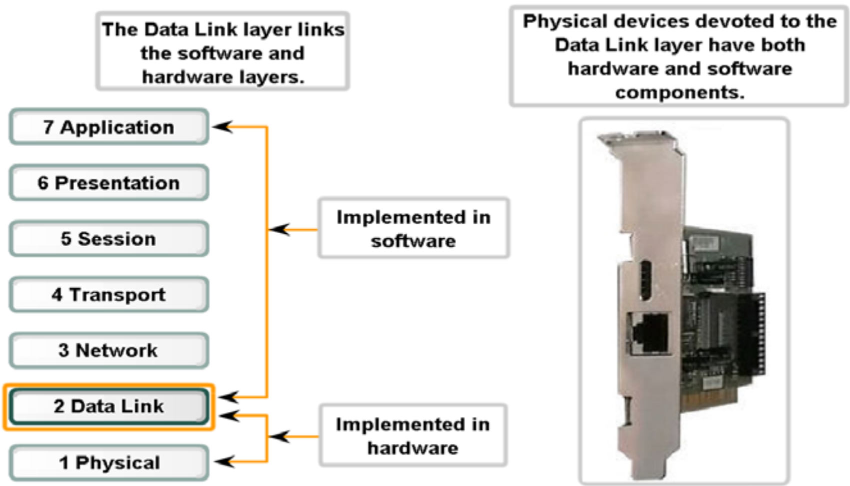
Connecting Upper Layer Services to the Media

Connecting Upper Layer Services to the Media



PC NIC

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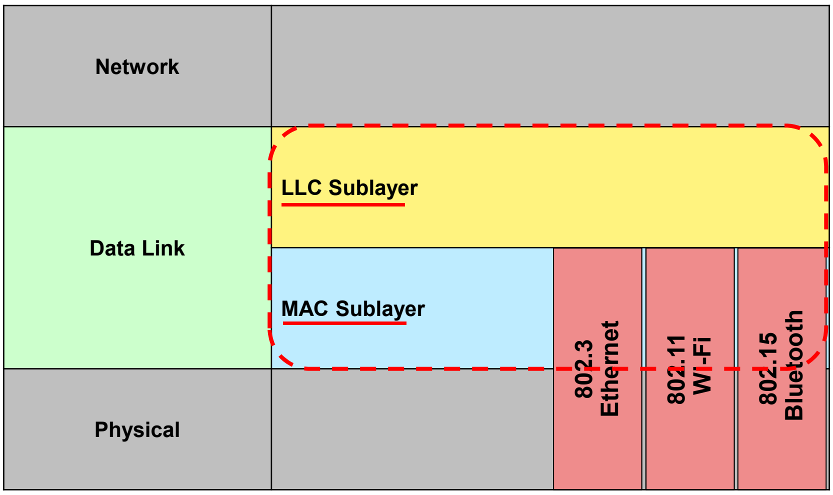
Data Link Sublayers



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Data Link Sublayers

- The Data Link layer is often **divided into two sublayers**.
  - **Logical Link Control** (**LLC**, The upper sublayer)
    - Defines the software processes that provide services to the Network layer protocols.
    - Identifying which Network layer protocol is being used for the frame.
    - This information allows multiple Layer 3 protocols, such as IP and IPX, to utilize the same network interface and media.
  - **Media Access Control** (**MAC**, The lower sublayer)
    - Provides Data Link layer addressing and delimiting of data according to the physical signaling requirements of the medium and the type of Data Link layer protocol in use.
    - Prepares the signal for transmission by the Physical layer.

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Media Access Control - MAC

The Data Link Layer

- As packets travel from source host to destination host, they typically traverse over different physical networks.
- These physical networks can consist of different types of physical media such as copper wires, optical fibers, and wireless consisting of electromagnetic signals, radio and microwave frequencies, and satellite links.
- The packets do not have a way to directly access these different media. It is the role of the **OSI data link layer** to prepare network layer packets for transmission and to control access to the physical media.

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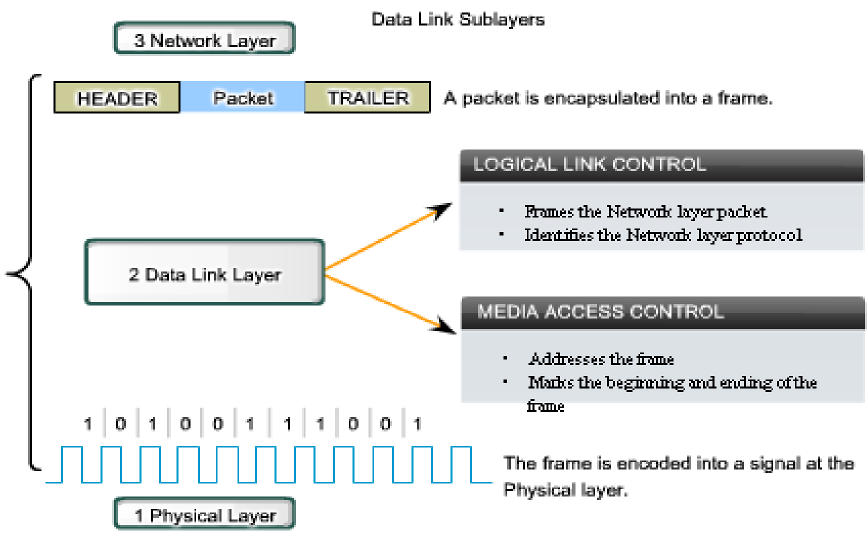
Data Link Sublayers



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Media Access Control

- There are 2 media access control methods for shared media:

  1) Controlled - Each node has its own time to use the medium.

  Network devices take turns, in sequence, to access the medium.

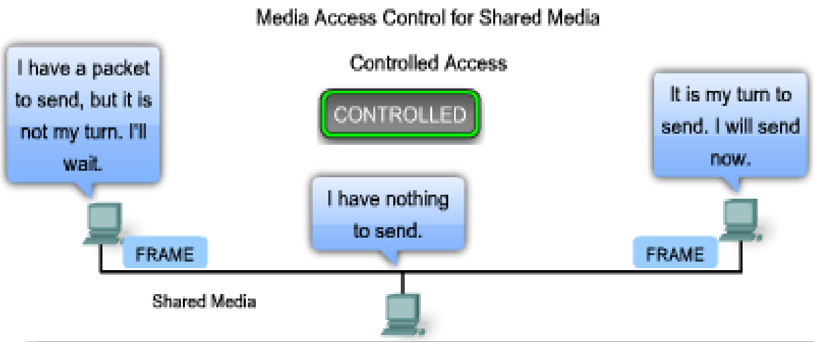
  This method is also known as scheduled access or deterministic.

  Although it is well-ordered, controlled method can be inefficient because a device has to wait for its turn before it can use the medium.

  For example: Token Ring

  2) Contention-based - All nodes compete for the use of the medium.

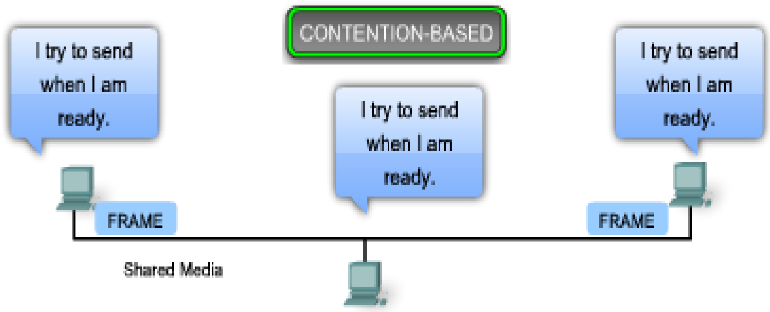
Media Access Control



Method	Characteristics	Example
Controlled Access	• Only one station transmits at a time • Devices wishing to transmit must wait their turn • No collisions • Some deterministic networks use token passing	• Token Ring • FDDI

Media Access Control

Media Access Control for Shared Media



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

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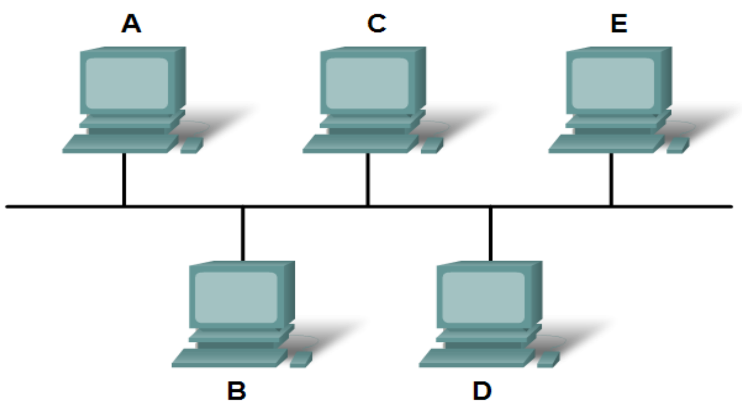
Media Access Control

- Multi-access topology - CSMA/CD

Logical Multi-Access Topology



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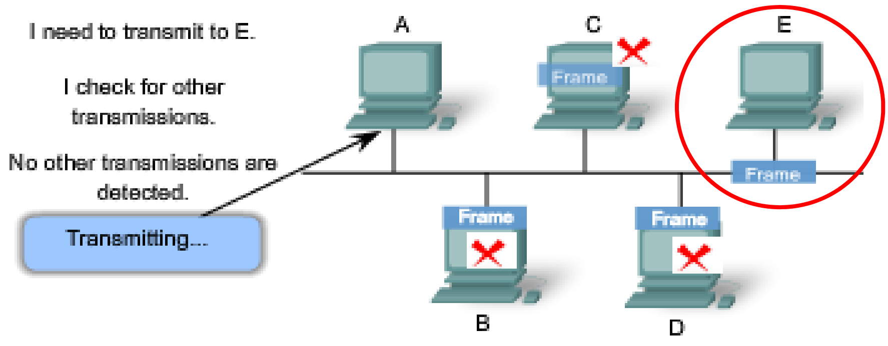
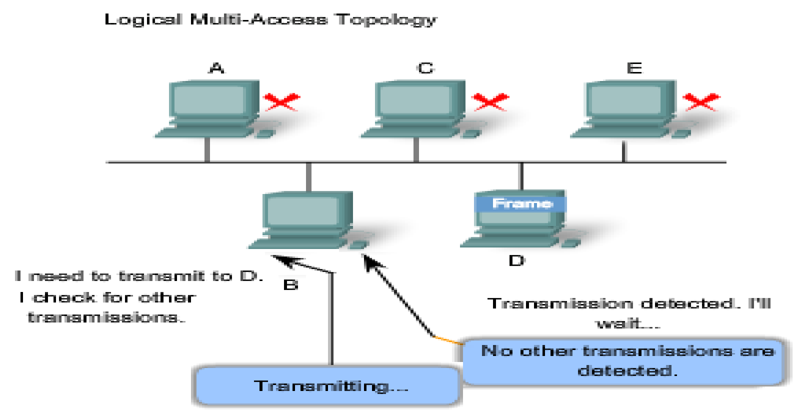
Logical Multi-Access Topology

- A logical multi-access topology enables a number of nodes to communicate by using the same shared media.
  - Data from only one node can be placed on the medium at any one time.
  - Every node sees all the frames that are on the medium, but only the node to which the frame is addressed processes the frame.



Logical Multi-Access Topology

- Having many nodes share access to the medium requires a media access control method to regulate the transmission of data and to reduce collisions between different signals.
  - The media access control methods used by logical multi-access topologies are typically **CSMA/CD or CSMA/CA**.



Media Access Control

- **Contention-based** - All nodes compete for the use of the medium.
  - **Carrier Sense Multiple Access/Collision Detection (CSMA/CD).**
  - The device monitors the media for the presence of a data signal.
  - If the media is free, the device transmits the data.
  - If more than one devices transmit at the same time, collision occurs and all devices stop sending and try again later.
  - Each device will wait a random amount of time before trying again.
- Ethernet make use this CSMA/CD method.

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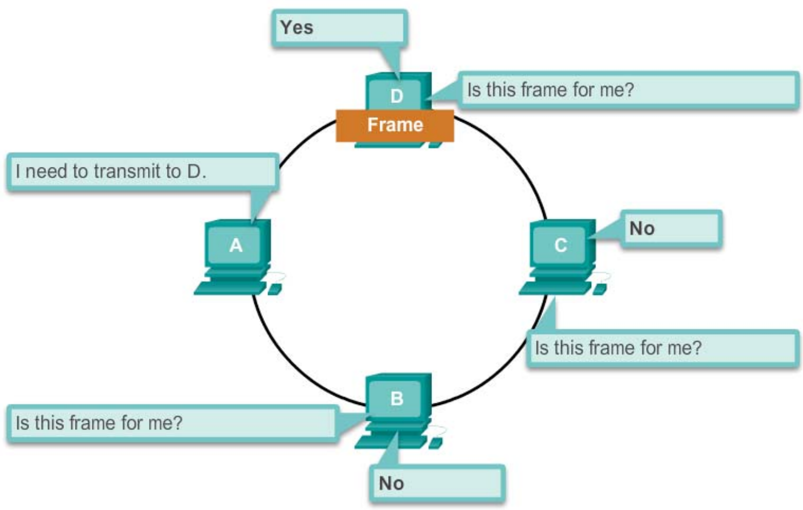
Ring Topology



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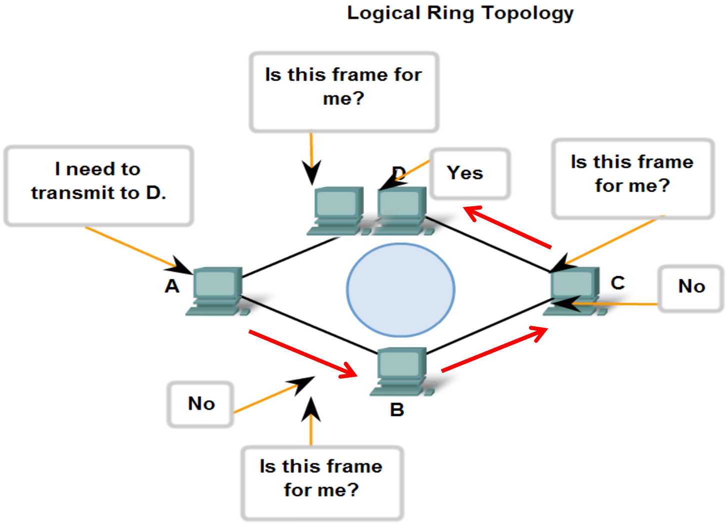
Media Access Control

- Logical ring topology using token passing method:



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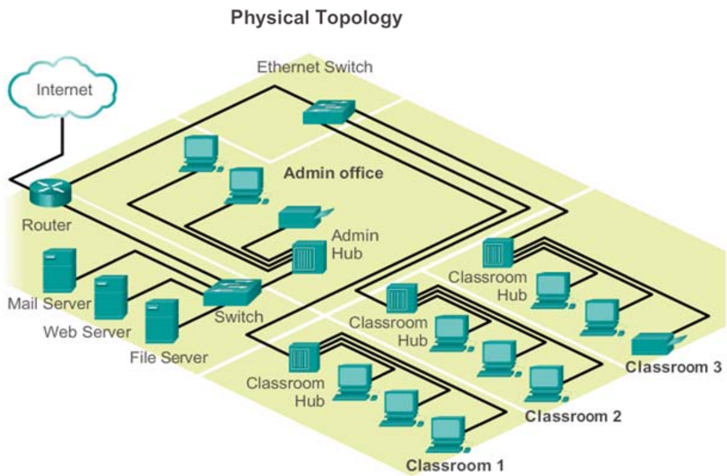
Physical and Logical Topologies



Physical topology: Refers to the physical connections and identifies how end devices and infrastructure devices such as routers, switches, and wireless access points are interconnected.

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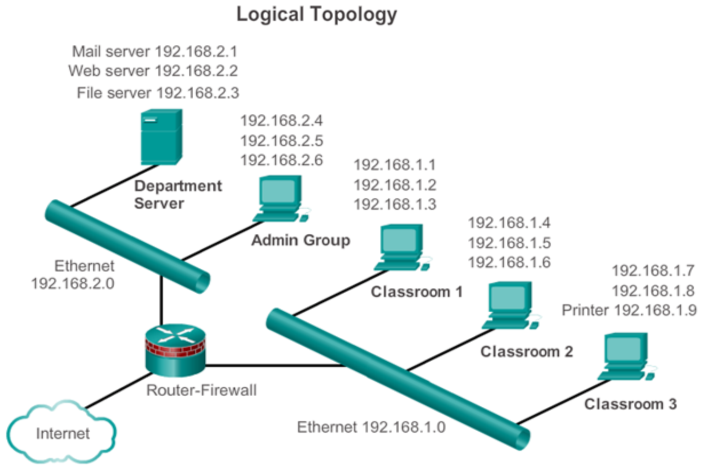
Physical and Logical Topologies



Logical topology: Refers to the way a network transfers frames from one node to the next. This arrangement consists of virtual connections between the nodes of a network. These logical signal paths are defined by data link layer protocols.

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Summary

- The physical layer standards address three functional areas: physical components, frame encoding technique, and signaling method.
- Wired communication consists of copper media and fiber cable.
- Wireless media carry electromagnetic signals that represent the binary digits of data communications using radio or microwave frequencies.
- The data link layer is responsible for the exchange of frames between nodes over a physical network media.
- It allows the upper layers to access the media and controls how data is placed and received on the media.

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