Introduction to Networking

CTO43-3-1 Version VD1

Network Access
(Physical Layer)

Physical Layer

Topics and Structure of the lesson

Topic Title	Topic Objective
Purpose of the Physical Layer	Describe the purpose and functions of the physical layer in the network.
Physical Layer Characteristics	Describe characteristics of the physical layer.
Copper Cabling	Identify the basic characteristics of copper cabling.
UTP Cabling	Explain how UTP cable is used in Ethernet networks.
Fiber-Optic Cabling	Describe fiber optic cabling and its main advantages over other media.
Wireless Media	Connect devices using wired and wireless media.

Key Terms You Must Be Able To Use

If you have mastered this topic, you should be able to use the following terms correctly in your exams:

- **Physical Connections and Standards**
- **Physical Component**
- **Encoding**
- **Signaling**
- **Bandwidth**
- **Copper Cabling**
- **UTP Cabling**
- **Wireless Media**

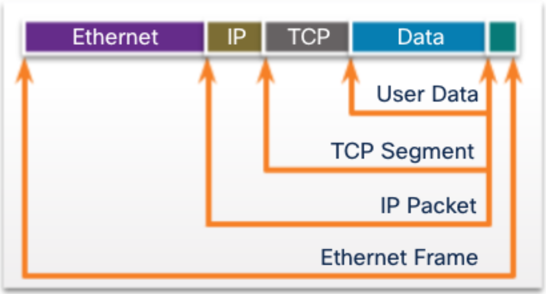
Purpose of the Physical Layer

The Physical Connection

- Before any network communications can occur, a physical connection to a local network must be established.
- This connection could be wired or wireless, depending on the setup of the network.
- This generally applies whether you are considering a corporate office or a home.
- A Network Interface Card (NIC) connects a device to the network.
- Some devices may have just one NIC, while others may have multiple NICs (Wired and/or Wireless, for example).
- Not all physical connections offer the same level of performance.

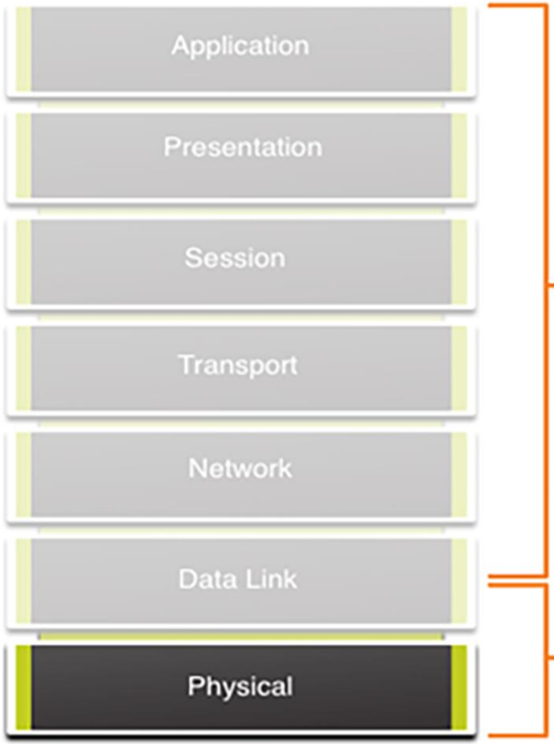
The Physical Layer

- Transports bits across the network media
- Accepts a complete frame from the Data Link Layer and encodes it as a series of signals that are transmitted to the local media
- This is the last step in the encapsulation process.
- The next device in the path to the destination receives the bits and re-encapsulates the frame, then decides what to do with it.



Physical Layer Characteristics

Physical Layer Standards



The TCP/IP standards are implemented in software and governed by the IETF.

The physical layer standards are implemented in hardware and are governed by many organizations including:

- International Organization for Standardization (ISO)
- Telecommunications Industry Association/Electronic Industries Association (TIA/EIA)
- International Telecommunication Union (ITU)
- American National Standards Institute (ANSI)
- Institute of Electrical and Electronics Engineers (IEEE)

Physical Components

Physical Layer Standards address three functional areas:

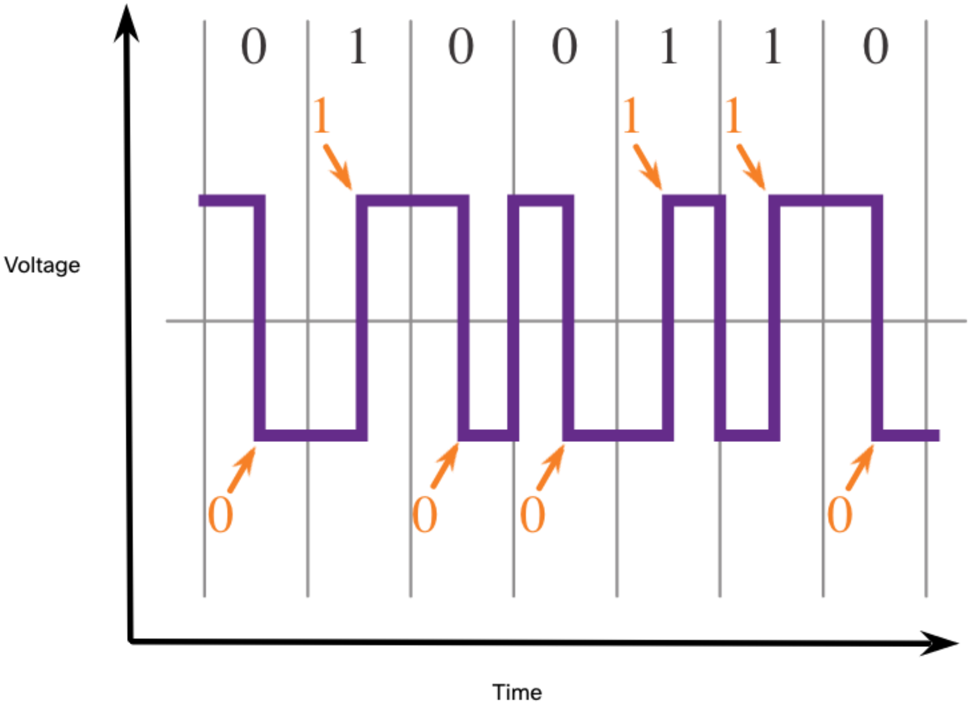
- Physical Components
- Encoding
- Signaling

The Physical Components are the hardware devices, media, and other connectors that transmit the signals that represent the bits.

- Hardware components like NICs, interfaces and connectors, cable materials, and cable designs are all specified in standards associated with the physical layer.

Encoding

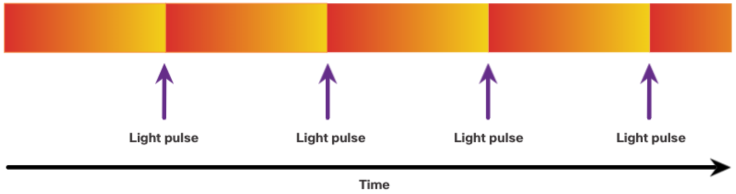
- Encoding converts the stream of bits into a format recognizable by the next device in the network path.
- This ‘coding’ provides predictable patterns that can be recognized by the next device.
- Examples of encoding methods include
  - Manchester (shown in the figure),
  - Block Coding
    - 4B/5B, and
    - 8B/10B.



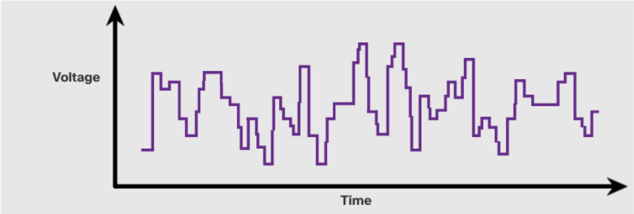
* 4B/5B – Here the 4 bit code is mapped with 5 bits, with the minimum number of 1 bits in the group

Physical Layer Characteristics
Signaling

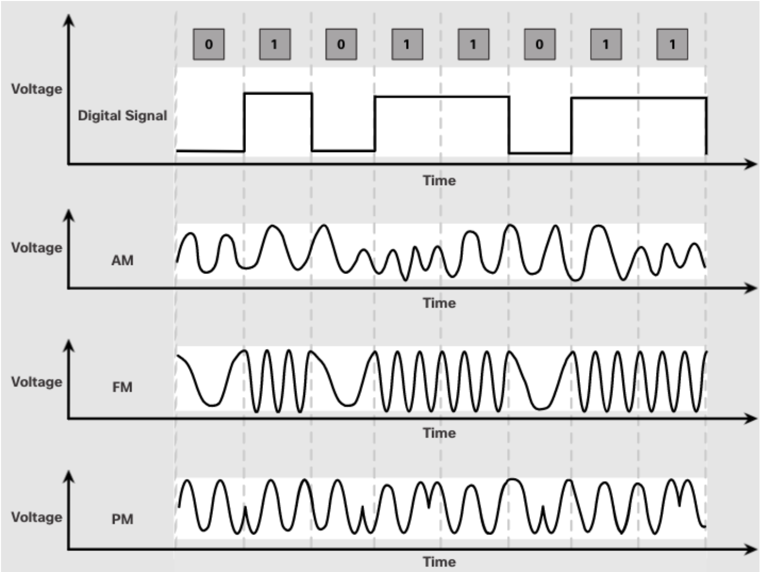
- The signaling method is how the bit values, “1” and “0” are represented on the physical medium.
- The method of signaling will vary based on the type of medium being used.



Light Pulses Over Fiber-Optic Cable



Electrical Signals Over Copper Cable



Microwave Signals Over Wireless

Bandwidth

- Bandwidth is the capacity at which a medium can carry data.
- Digital bandwidth measures the amount of data that can flow from one place to another in a given amount of time; how many bits can be transmitted in a second.
- Physical media properties, current technologies, and the laws of physics play a role in determining available 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

Bandwidth Terminology

Latency

- Amount of time, including delays, for data to travel from one given point to another

Throughput

- The measure of the transfer of bits across the media over a given period of time

Goodput

- The measure of usable data transferred over a given period of time
- Goodput = Throughput - traffic overhead

Copper Cabling

Characteristics of Copper Cabling

Copper cabling is the most common type of cabling used in networks today. It is inexpensive, easy to install, and has low resistance to electrical current flow.

Limitations:

- Attenuation – the longer the electrical signals have to travel, the weaker they get.
- The electrical signal is susceptible to interference from two sources, which can distort and corrupt the data signals (Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) and Crosstalk).

Mitigation:

- Strict adherence to cable length limits will mitigate attenuation.
- Some kinds of copper cable mitigate EMI and RFI by using metallic shielding and grounding.
- Some kinds of copper cable mitigate crosstalk by twisting opposing circuit pair wires together.

*EMI is an electromagnetic emission that causes a disturbance in another piece of electrical equipment RFI is the radiation or conduction of radio frequency energy or noise produced by electrical and electronic devices at levels that interfere with the operation of adjacent equipment. The difference is that EMI is any frequency of electrical noise where as RFI is a specific subset of electrical noise on the EMI spectrum.

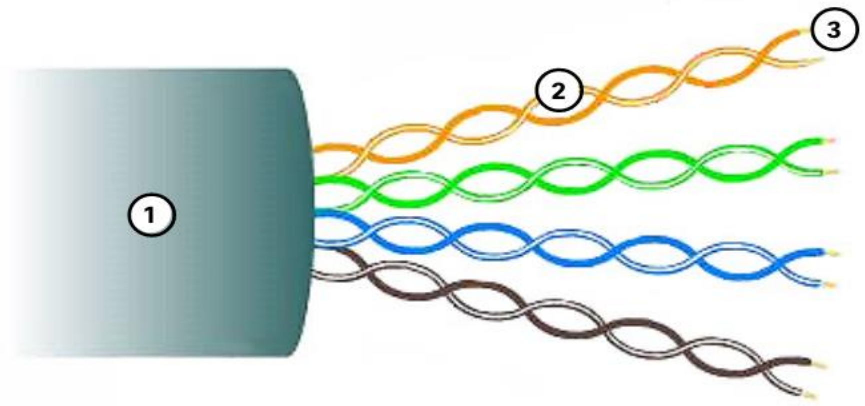
Types of Copper Cabling

Unshielded Twisted-Pair (UTP) Cable

Shielded Twisted-Pair (STP) Cable

Coaxial Cable

Unshielded Twisted Pair (UTP)

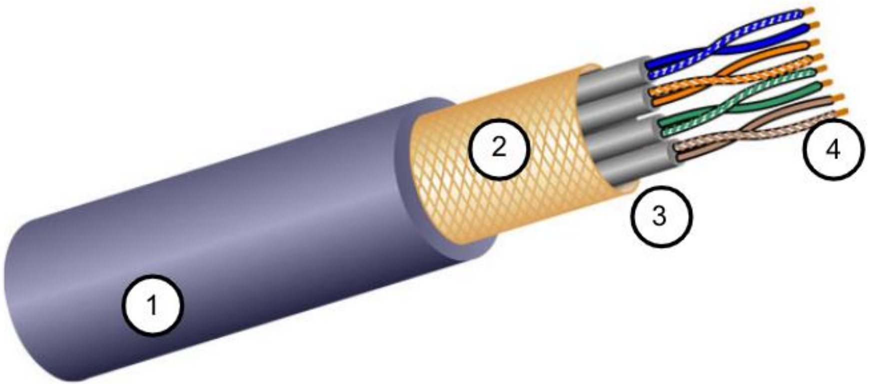


- UTP is the most common networking media.
- Terminated with RJ-45 connectors
- Interconnects hosts with intermediary network devices.

Key Characteristics of UTP

1. The outer jacket protects the copper wires from physical damage.
2. Twisted pairs protect the signal from interference.
3. Color-coded plastic insulation electrically isolates the wires from each other and identifies each pair.

Shielded Twisted Pair (STP)



- Better noise protection than UTP
- More expensive than UTP
- Harder to install than UTP
- Terminated with RJ-45 connectors
- Interconnects hosts with intermediary network devices

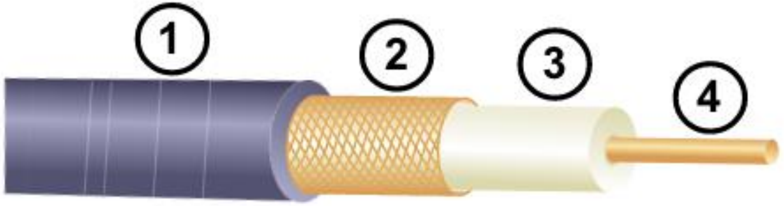
Key Characteristics of STP

1. The outer jacket protects the copper wires from physical damage
2. Braided or foil shield provides EMI/RFI protection
3. Foil shield for each pair of wires provides EMI/RFI protection
4. Color-coded plastic insulation electrically isolates the wires from each other and identifies each pair

Coaxial Cable

Consists of the following:

1. Outer cable jacket to prevent minor physical damage
2. A woven copper braid, or metallic foil, acts as the second wire in the circuit and as a shield for the inner conductor.
3. A layer of flexible plastic insulation
4. A copper conductor is used to transmit the electronic signals.



There are different types of connectors used with coax cable.

Commonly used in the following situations:

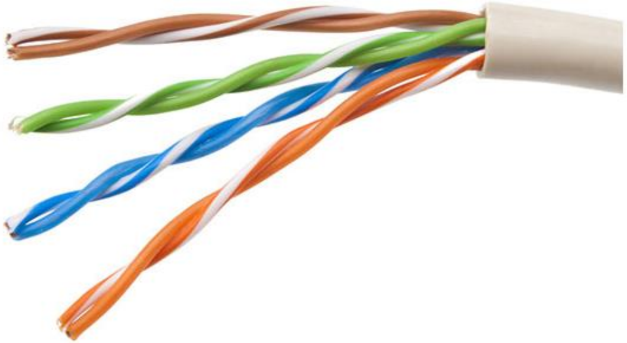
- Wireless installations - attach antennas to wireless devices
- Cable internet installations - customer premises wiring

UTP Cabling

Properties of UTP Cabling

UTP has four pairs of color-coded copper wires twisted together and encased in a flexible plastic sheath. No shielding is used. UTP relies on the following properties to limit crosstalk:

- Cancellation - Each wire in a pair of wires uses opposite polarity. One wire is negative, the other wire is positive. They are twisted together and the magnetic fields effectively cancel each other and outside EMI/RFI.
- Variation in twists per foot in each wire - Each wire is twisted a different amount, which helps prevent crosstalk amongst the wires in the cable.



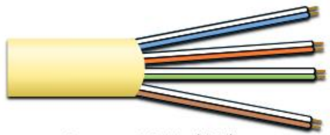
UTP Cabling Standards and Connectors

Standards for UTP are established by the TIA/EIA. TIA/EIA-568 standardizes elements like:

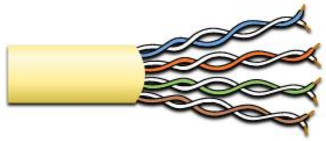
- Cable Types
- Cable Lengths
- Connectors
- Cable Termination
- Testing Methods

Electrical standards for copper cabling are established by the IEEE, which rates cable according to its performance. Examples include:

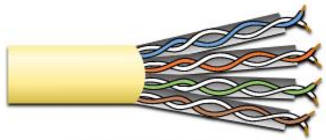
- Category 3
- Category 5 and 5e
- Category 6 (Popular, 250MHz frequency, 1-10 Gbps (35m) speed)
- Category 7 (600MHz frequency, 10 Gbps)
- Category 8 (2000MHz frequency, 40Gbps for 30m, Data Centers)



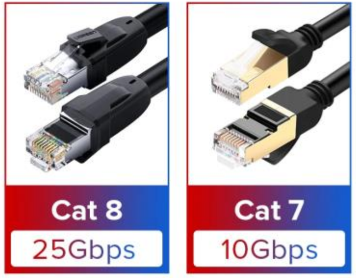
Category 3 Cable (UTP)



Category 5 and 5e Cable (UTP)



Category 6 Cable (UTP)

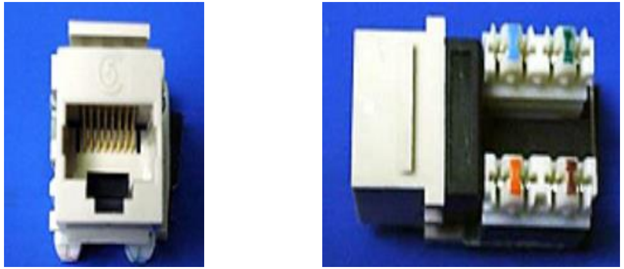


Cat 8/Cat 7 For Choice

UTP Cabling
UTP Cabling Standards and Connectors (Cont.)

RJ-45 Connector

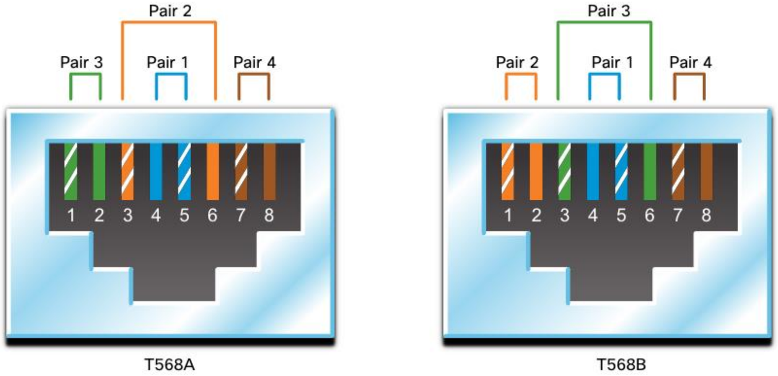
Poorly terminated UTP cable



RJ-45 Socket

Properly terminated UTP cable

Straight-through and Crossover UTP Cables



Cable Type	Standard	Application
Ethernet Straight-through	Both ends T568A or T568B	Host to Network Device
Ethernet Crossover *	One end T568A, other end T568B	Host-to-Host, Switch-to-Switch, Router-to-Router
* Considered Legacy due to most NICs using Auto-MDIX to sense cable type and complete connection		
Rollover	Cisco Proprietary	Host serial port to Router or Switch Console Port, using an adapter

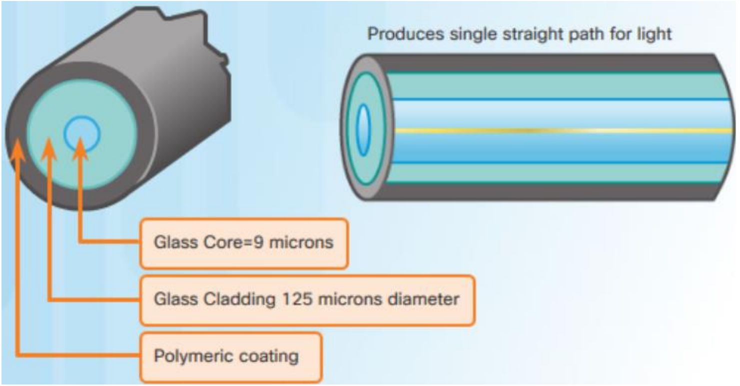
Fiber-Optic Cabling

Properties of Fiber-Optic Cabling

- Not as common as UTP because of the expense involved
- Ideal for some networking scenarios
- Transmits data over longer distances at higher bandwidth than any other networking media
- Less susceptible to attenuation, and completely immune to EMI/RFI
- Made of flexible, extremely thin strands of very pure glass
- Uses a laser or LED to encode bits as pulses of light
- The fiber-optic cable acts as a wave guide to transmit light between the two ends with minimal signal loss

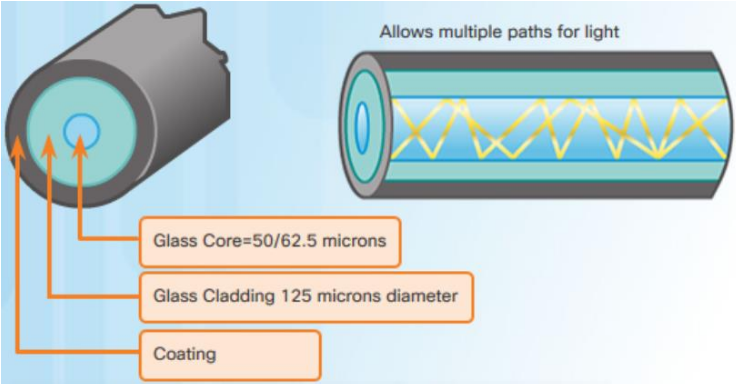
Types of Fiber Media

Single-Mode Fiber



- Very small core
- Uses expensive lasers
- Long-distance applications

Multimode Fiber



- Larger core
- Uses less expensive LEDs
- LEDs transmit at different angles
- Up to 10 Gbps over 550 meters

Dispersion refers to the spreading out of a light pulse over time. Increased dispersion means increased loss of signal strength. MMF has greater dispersion than SMF, with a the maximum cable distance for MMF is 550 meters.

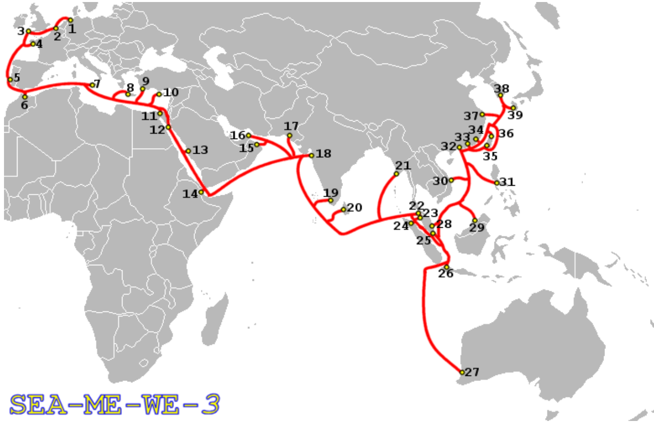
Fiber-Optic Cabling Usage

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

1. **Enterprise Networks -** Used for backbone cabling applications and interconnecting infrastructure devices
2. **Fiber-to-the-Home (FTTH) -** Used to provide always-on broadband services to homes and small businesses
3. **Long-Haul Networks -** Used by service providers to connect countries and cities

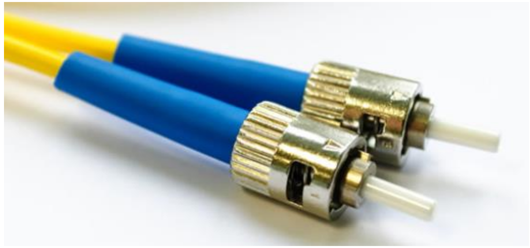
   These are collections of widely scattered computers connected by a common communication network which are relatively slow and unreliable and typically through telephone lines, microwave links, and satellite channels.

4. **Submarine Cable Networks -** Used to provide reliable high-speed, high-capacity solutions capable of surviving in harsh undersea environments at up to transoceanic distances.



SEA-ME-WE3 or South-East Asia - Middle East - Western Europe 3 is an optical submarine telecommunications cable linking those regions and is the longest in the world. Completed in late 2000, it is led by France Telecom and China Telecom, and is administered by Singtel, a telecommunications operator owned by the Government of Singapore. The Consortium is formed by 92 other investors from the telecom industry. It was commissioned in March 2000. It is 39,000 kilometres in length. It's capacity is 4.6 Tbps i.e 2.3 Tbit/s per pair (two fibre pairs)..

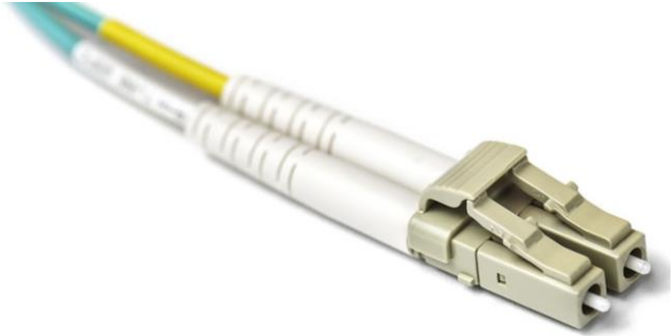
Fiber-Optic Connectors



Straight-Tip (ST) Connectors

Lucent Connector (LC) Simplex Connectors

Subscriber Connector (SC) Connectors



Duplex Multimode LC Connectors

Fiber-Optic Cabling

Fiber Patch Cords

SC-SC MM Patch Cord

LC-LC SM Patch Cord

ST-LC MM Patch Cord

ST-SC SM Patch Cord

A yellow jacket is for single-mode fiber cables and orange (or aqua) for multimode fiber cables.

Fiber versus Copper

Optical fiber is primarily used as backbone cabling for high-traffic, point-to-point connections between data distribution facilities and for the interconnection of buildings in multi-building campuses.

Implementation Issues	UTP Cabling	Fiber-Optic Cabling
Bandwidth supported	10 Mb/s - 10 Gb/s	10 Mb/s - 100 Gb/s
Distance	Relatively short (1 - 100 meters)	Relatively long (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

Wireless Media

Properties of Wireless Media

It carries electromagnetic signals representing binary digits using radio or microwave frequencies. This provides the greatest mobility option. Wireless connection numbers continue to increase.

Some of the limitations of wireless:

- **Coverage area** - Effective coverage can be significantly impacted by the physical characteristics of the deployment location.
- **Interference** - Wireless is susceptible to interference and can be disrupted by many common devices.
- **Security** - Wireless communication coverage requires no access to a physical strand of media, so anyone can gain access to the transmission.
- **Shared medium** - WLANs operate in half-duplex, which means only one device can send or receive at a time. Many users accessing the WLAN simultaneously results in reduced bandwidth for each user.

Types of Wireless Media

The IEEE and telecommunications industry standards for wireless data communications cover both the data link and physical layers. In each of these standards, physical layer specifications dictate:

- Data to radio signal encoding methods
- Frequency and power of transmission
- Signal reception and decoding requirements
- Antenna design and construction

Wireless Standards:

- **Wi-Fi (IEEE 802.11)** - Wireless LAN (WLAN) technology
- **Bluetooth (IEEE 802.15)** - Wireless Personal Area network (WPAN) standard
- **WiMAX (IEEE 802.16)** - Uses a point-to-multipoint topology to provide broadband wireless access
- **Zigbee (IEEE 802.15.4)** - The **name** "**Zigbee**" refers to the zig-zag dance of the honey bees. Low data-rate, low power-consumption communications, primarily for Internet of Things (IoT) applications. *Zigbee* is the only complete IoT solution — from mesh network to the universal language that allows smart objects to work together.

Wireless LAN

In general, a Wireless LAN (WLAN) requires the following devices:

- **Wireless Access Point (AP)** - Concentrate wireless signals from users and connect to the existing copper-based network infrastructure
- **Wireless NIC Adapters** - Provide wireless communications capability to network hosts

There are a number of WLAN standards. When purchasing WLAN equipment, ensure compatibility, and interoperability.

Network Administrators must develop and apply stringent security policies and processes to protect WLANs from unauthorized access and damage.

Summary

Summary of Main Teaching Points

- **Explain how physical layer protocols and services support communications across data networks.**

- **Build a simple network using the appropriate media**

Question and Answer Session

Q & A

What We Will Cover Next:

Data Link Layer