

Module 4: Physical Layer

Introduction to Networks v7.0
(ITN)





Module Objectives

Module Title: Physical Layer

Module Objective: Explain how physical layer protocols, services, and network media support communications across data networks.

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.



4.1 Purpose of the Physical Layer

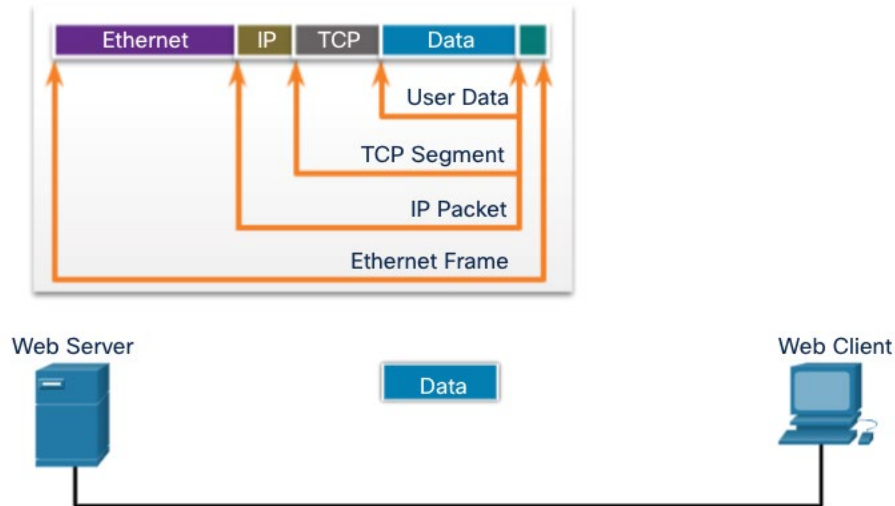
The Physical Connection

- 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.

Purpose of the Physical Layer

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.

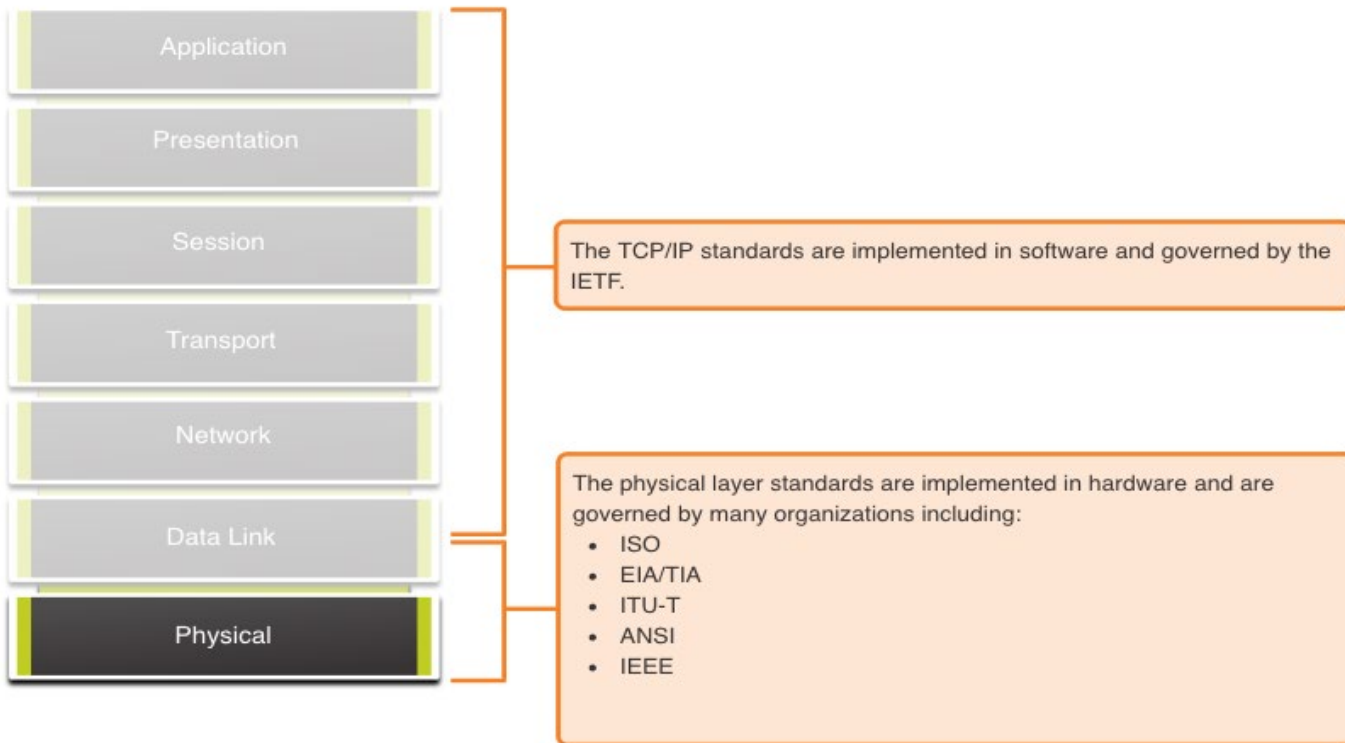




4.2 Physical Layer Characteristics

Physical Layer Characteristics

Physical Layer Standards



Physical Layer Standards address three functional areas:

- **Physical Components**
- **Encoding**
- **Signaling**

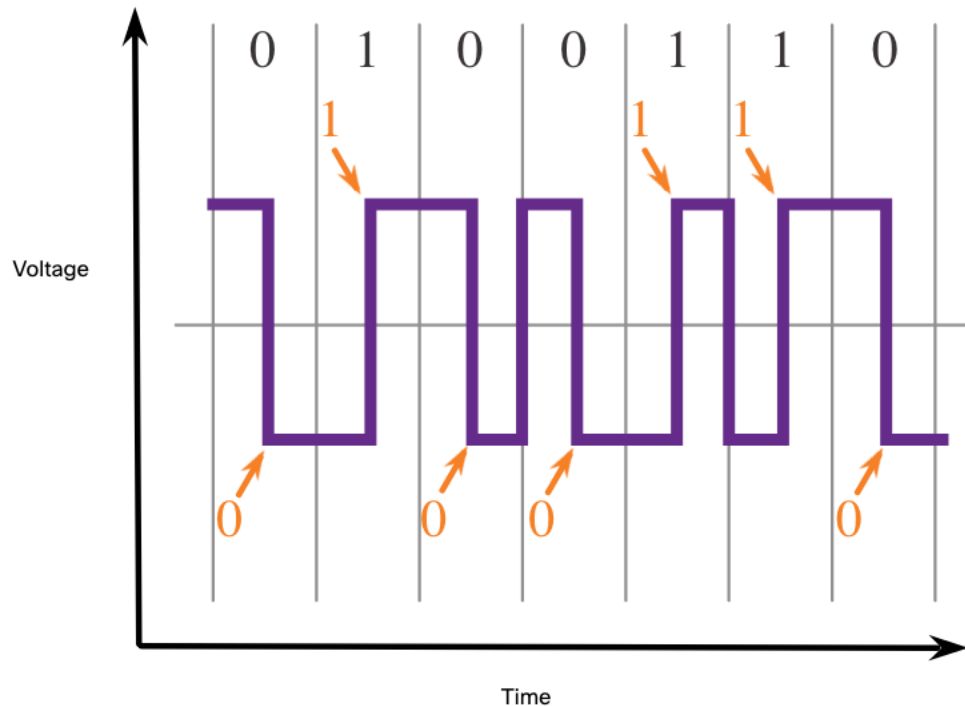
The **Physical Components are the hardware devices**, media, and other connectors that transmit the signals that represent the bits.

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

Physical Layer Characteristics

Encoding

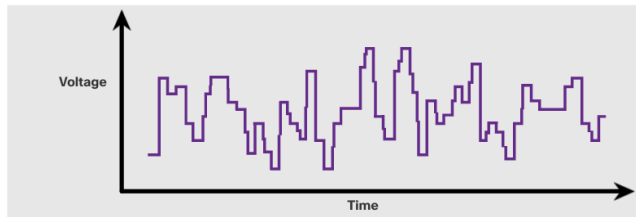
- Encoding converts the stream of bits into a format recognizable by the next device in the network path.
- This 'coding' provides predictable patterns that can be recognized by the next device.
- Examples of encoding methods include Manchester (shown in the figure), 4B/5B, and 8B/10B.



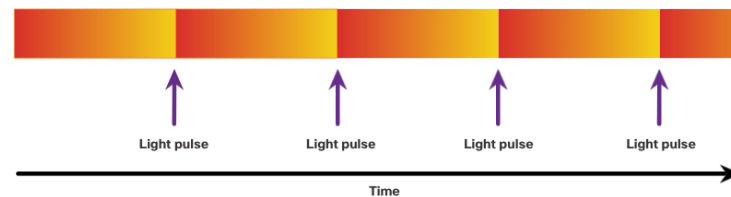
Physical Layer Characteristics

Signaling

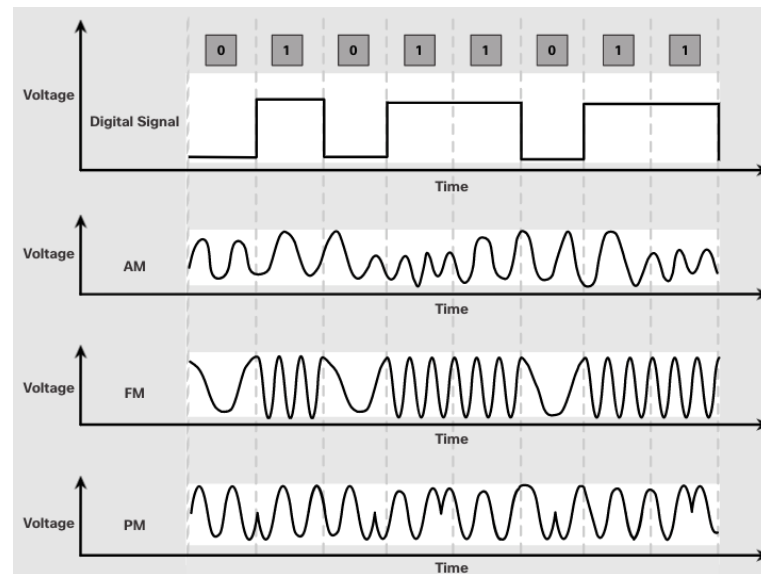
- The signaling method is how the **bit values**, “1” and “0” are **represented on the physical medium**.
- The method of signaling will vary based on the type of medium being used.



Electrical Signals Over Copper Cable



Light Pulses Over Fiber-Optic Cable



Microwave Signals Over Wireless

Physical Layer Characteristics

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

Physical Layer Characteristics

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
- $\text{Goodput} = \text{Throughput} - \text{traffic overhead}$



4.3 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 must 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:

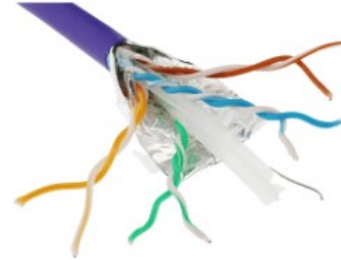
- Strict adherence to cable **length limits** will mitigate attenuation.
- Some kinds of copper cable mitigate EMI and RFI by using metallic **shielding** and **grounding**.
- Some kinds of copper cable mitigate crosstalk by **twisting** opposing circuit **pair** wires together.

Copper Cabling

Types of Copper Cabling



Unshielded Twisted-Pair (UTP) Cable



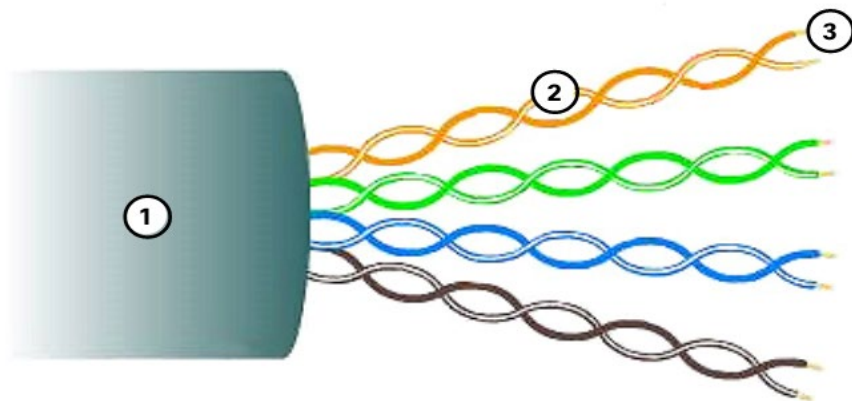
Shielded Twisted-Pair (STP) Cable



Coaxial Cable

Copper Cabling

Unshielded Twisted Pair (UTP)



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

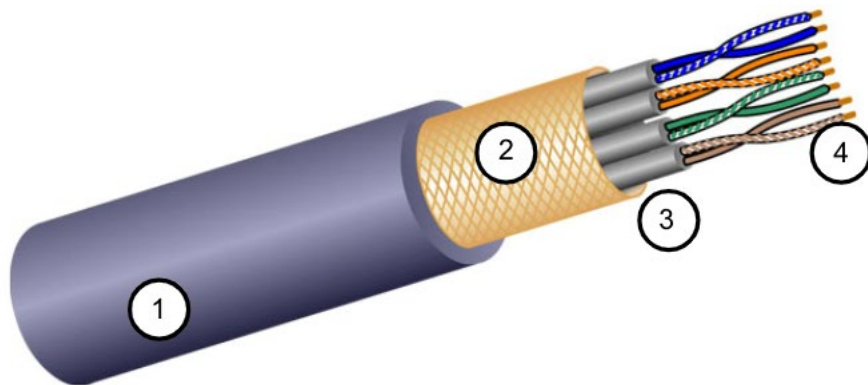
Key Characteristics of UTP

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.

Copper Cabling

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

Copper Cabling Coaxial Cable

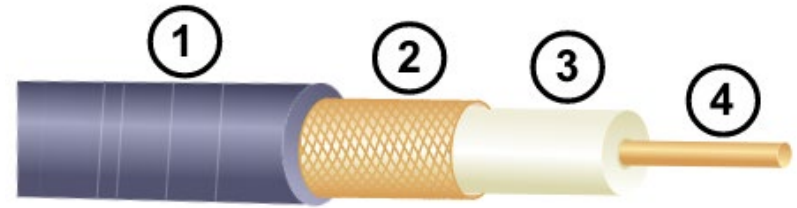
Consists of the following:

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





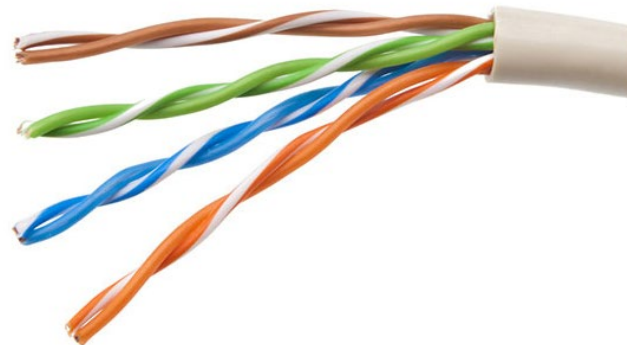
4.4 UTP Cabling

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

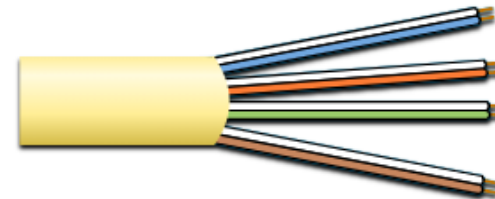
Standards for UTP are established by the TIA/EIA. TIA/EIA-568 standardizes elements like:

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

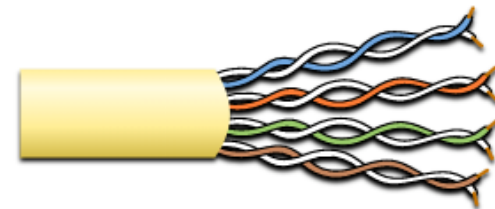
Electrical standards for copper cabling are established by the IEEE, which rates cable according to its performance.

Examples include:

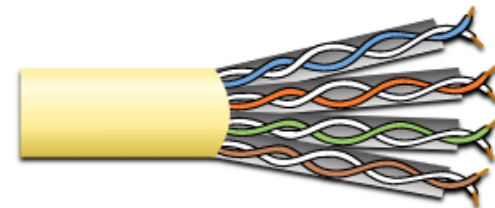
- Category 3
- Category 5 and 5e
- Category 6



Category 3 Cable (UTP)



Category 5 and 5e Cable (UTP)



Category 6 Cable (UTP)

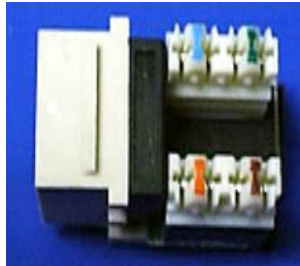
UTP Cabling Standards and Connectors (Cont.)



RJ-45 Connector



Poorly terminated UTP cable



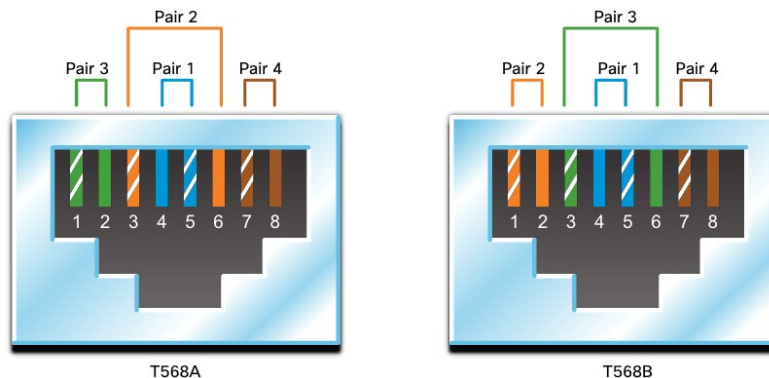
RJ-45 Socket



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



4.5 Fiber-Optic Cabling



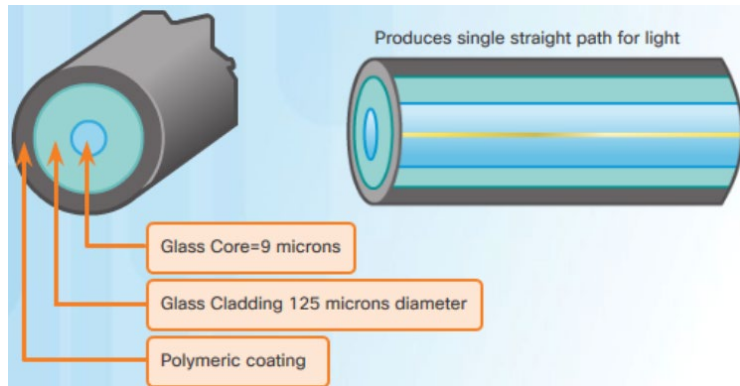
Properties of Fiber-Optic Cabling

- 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

Fiber-Optic Cabling

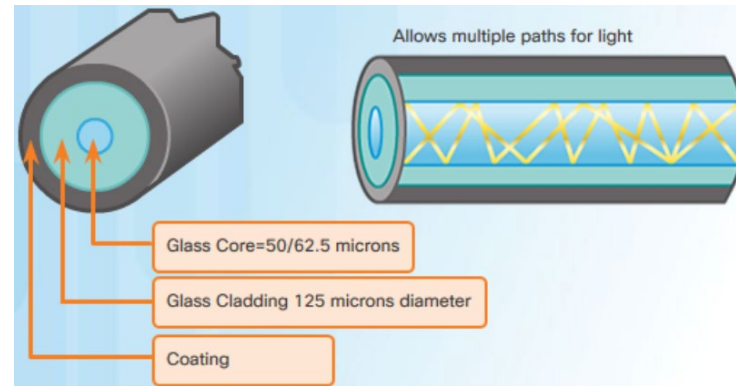
Types of Fiber Media

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 maximum cable distance for MMF is 550 meters.

Fiber-Optic Cabling Usage

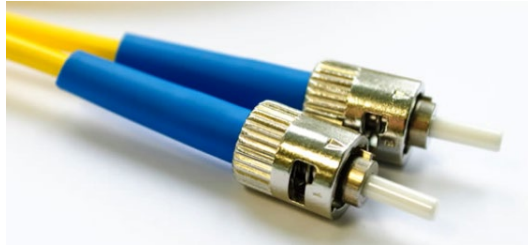
Fiber-optic cabling is now being used in four types of industry:

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
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.

Our focus in this course is the use of fiber within the enterprise.

Fiber-Optic Cabling

Fiber-Optic Connectors



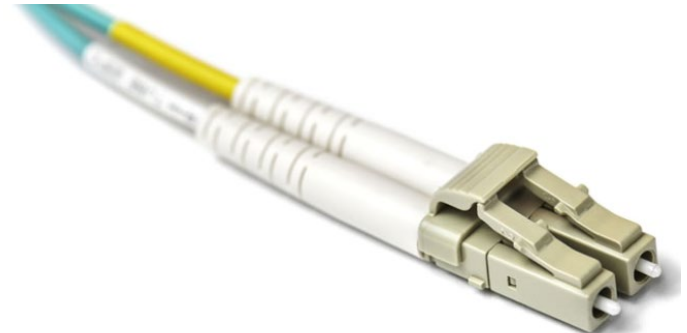
Straight-Tip (ST) Connectors



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-Optic Cabling

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



4.6 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)** - Low data-rate, low power-consumption communications, primarily for Internet of Things (IoT) applications

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.



4.7 Module Practice and Quiz



What did I learn in this module?

- Before any network communications can occur, a **physical connection** to a local network, either **wired or wireless**, must be established.
- The physical layer consists of **electronic circuitry, media, and connectors** developed by engineers.
- The physical layer standards address three functional areas: **physical components, encoding, and signaling**.
- Three types of copper cabling are: **UTP, STP, and coaxial cable (coax)**.
- UTP cabling conforms to the standards established jointly by the TIA/EIA. The electrical characteristics of copper cabling are defined by the Institute of Electrical and Electronics Engineers (IEEE).
- The main cable types that are obtained by using specific wiring conventions are **Ethernet Straight-through and Ethernet Crossover**.



What did I learn in this module (Cont.)?

- **Optical fiber** cable transmits data over **longer distances and at higher bandwidths** than any other networking media.
- There are four types of fiber-optic connectors: **ST, SC, LC, and duplex multimode LC**.
- Fiber-optic patch cords include SC-SC multimode, LC-LC single-mode, ST-LC multimode, and SC-ST single-mode.
- **Wireless** media carry **electromagnetic signals that represent the binary digits** of data communications using radio or microwave **frequencies**. Wireless does have some limitations, including **coverage area, interference, security**, and the problems that occur with any **shared medium**.
- Wireless standards include the following: **Wi-Fi (IEEE 802.11)**, Bluetooth (IEEE 802.15), WiMAX (IEEE 802.16), and Zigbee (IEEE 802.15.4).
- Wireless LAN (WLAN) requires a **wireless AP** and **wireless NIC adapters**.



4.8 Summary



Packet Tracer – Connect the Physical Layer

In this Packet Tracer, you will do the following:

- Identify Physical Characteristics of Internetworking Devices
- Select Correct Modules for Connectivity
- Connect Devices
- Check Connectivity

New Terms and Commands

- Telecommunications Industry Association/Electronic Industries Association (TIA/EIA)
- latency
- throughput
- goodput
- Electromagnetic interference (EMI)
- Radio frequency interference (RFI)
- Crosstalk
- Unshielded Twisted Pair (UTP)
- Shielded Twisted Pair (STP)
- Coaxial cable
- RJ-45
- Cancellation
- TIA/EIA-568

- Ethernet Straight-through
- Ethernet crossover
- Rollover
- Single-Mode Fiber (SMF)
- Multimode (MMF)
- Straight-tip (ST) Connectors
- Subscriber Connector (SC) Connectors
- Lucent Connector (LC) Simplex Connectors
- Duplex Multimode LC Connectors
- Bluetooth (IEEE 802.15)
- WiMAX (IEEE 802.16)
- Zigbee (IEEE 802.15.4)
- Wireless Access Point (AP)

