



Module 4: Physical Layer

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Introduction to Networks v7.0
(ITN)



Module 4: Best Practices (Cont.)

Topic 4.3

- Ask the students or have a class discussion
 - What kinds of things do you think will generate EMI or RFI that could have an effect on UTP?
 - Why do you suppose copper is the conductor of choice?

Topic 4.4

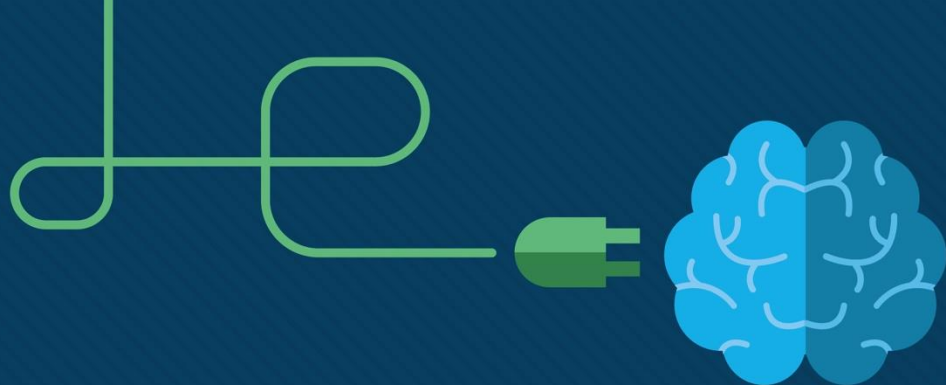
- Ask the students or have a class discussion
 - What would happen if you tried to use a cable that was terminated using different standards at each end?
 - What is it that makes the higher numbered categories of copper wire better?

Topic 4.5

- Ask the students or have a class discussion
 - Have you ever seen or dealt with a fiber optic connection?
 - If available, pass around some fiber optic patch cables with different connectors.

Topic 4.6

- Ask the students or have a class discussion
 - Have you ever used a wireless device other than 802.11 Wi-Fi?



Module 4: Physical Layer

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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.

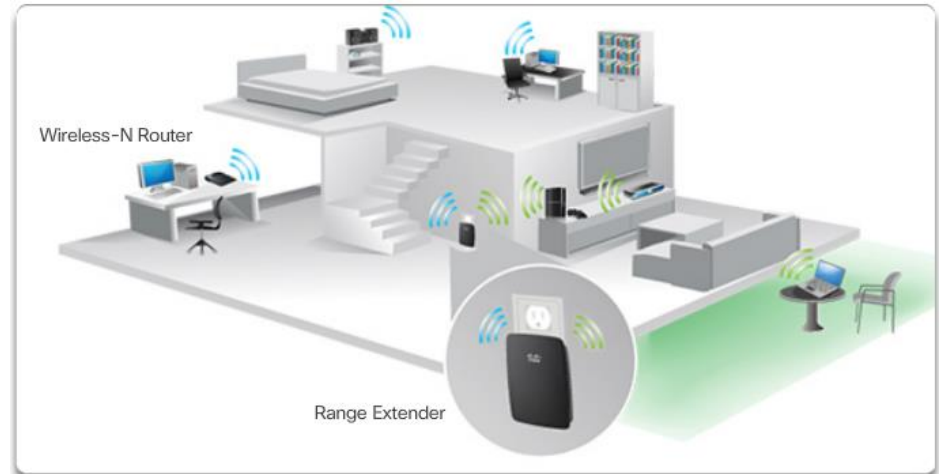
Physical Layer Connection

Network Interface Cards



- Wireless Local Area Network (WLAN) NICs are used for wireless connections.

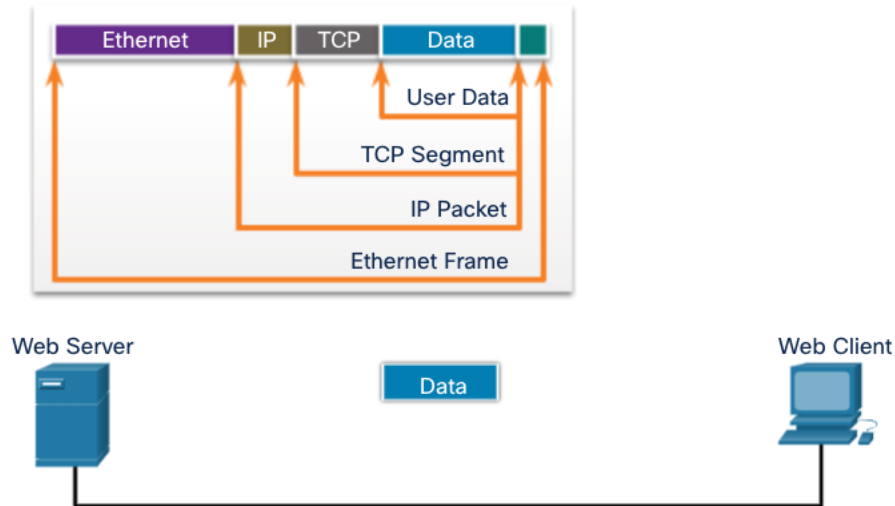
- Network Interface Cards (NICs) connect a device to a network.
- Used for a wired connection.



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.



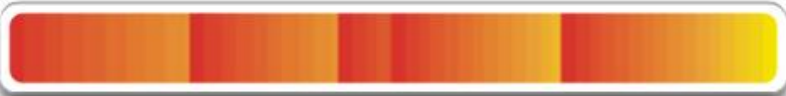
Purpose of the Physical Layer

Physical Layer Media

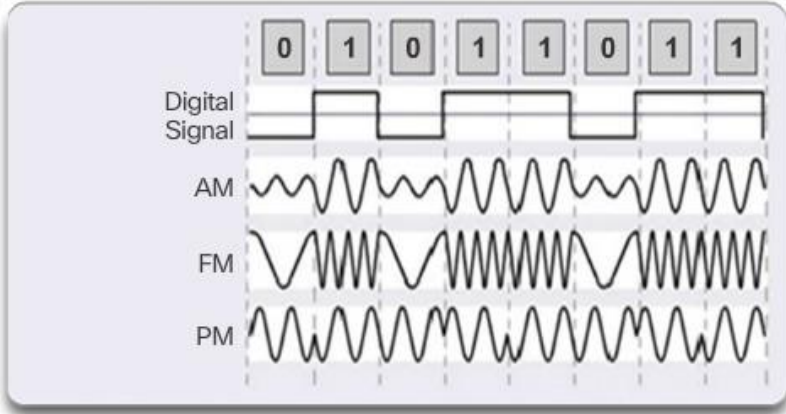
Three basic forms of network media



Electrical Signals -
Copper cable



Light Pulse -
Fiber-optic cable

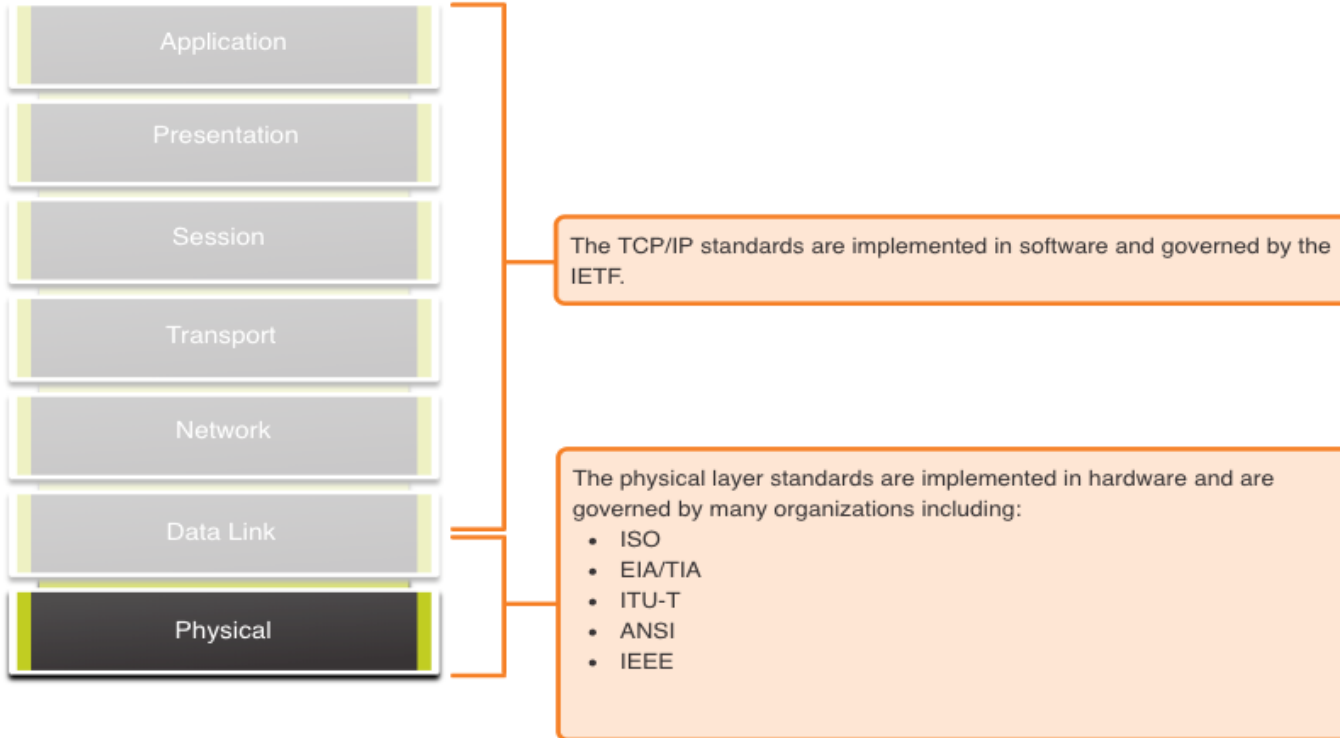


Microwave Signals -
Wireless

4.2 Physical Layer Characteristics

Physical Layer Characteristics

Physical Layer Standards



Physical Layer Characteristics

Physical Components

Physical Layer Standards address three functional areas:

- Physical Components
- Encoding
- Signaling

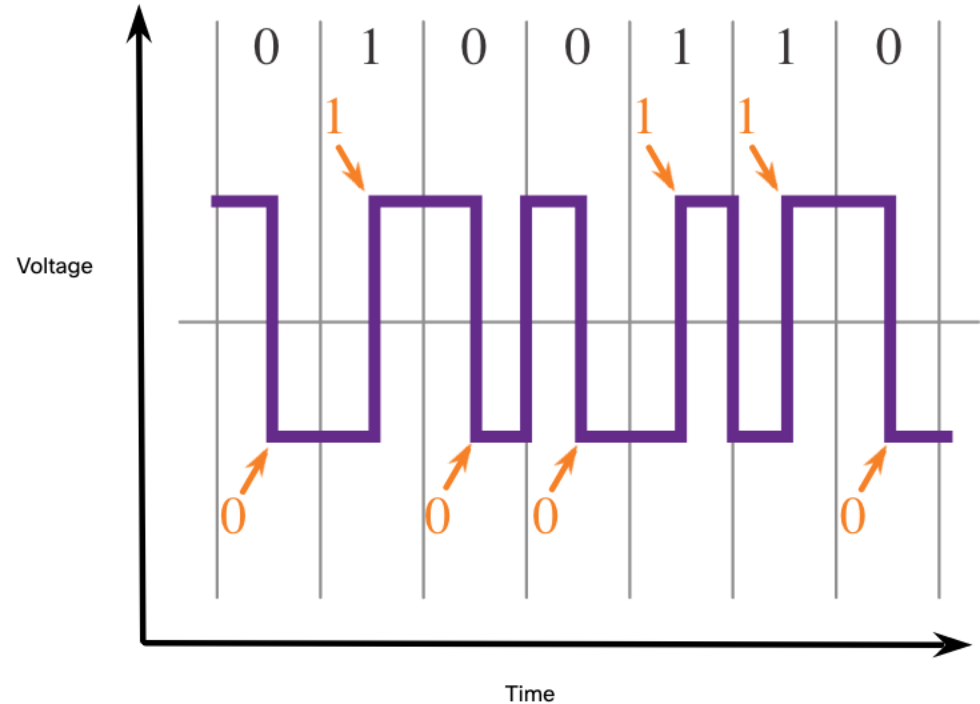
The Physical Components are the hardware devices, media, and other connectors that transmit the signals that represent the bits.

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

Physical Layer Characteristics

Encoding

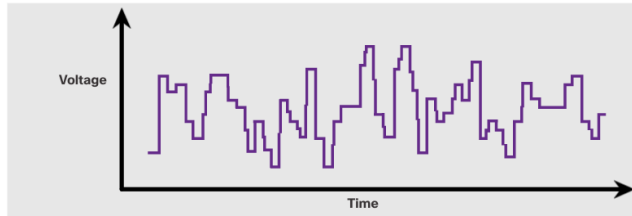
- Encoding converts the stream of bits into a format recognizable by the next device in the network path.
- This 'coding' provides predictable patterns that can be recognized by the next device.
- Examples of encoding methods include Manchester (shown in the figure), 4B/5B, and 8B/10B.



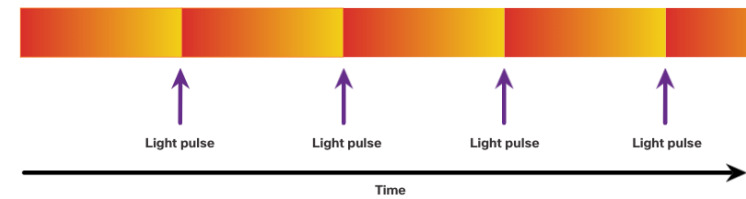
Physical Layer Characteristics

Signaling

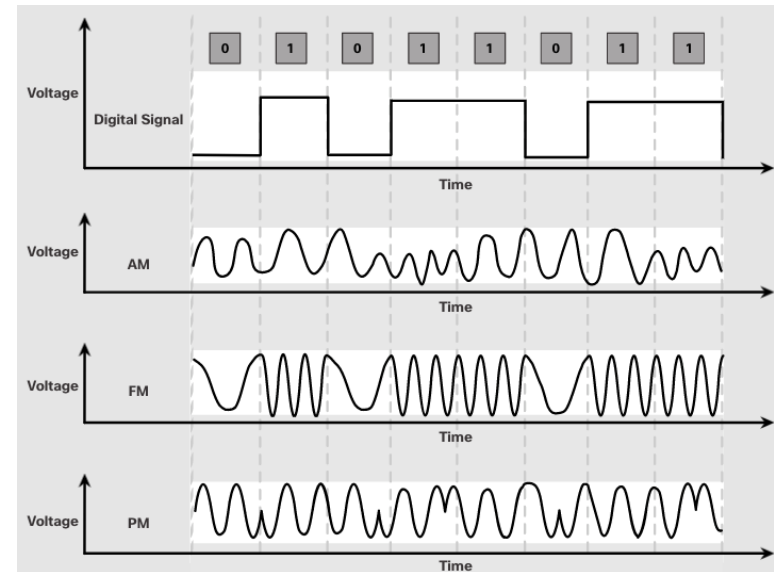
- The signaling method is how the bit values, “1” and “0” are represented on the physical medium.
- The method of signaling will vary based on the type of medium being used.



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

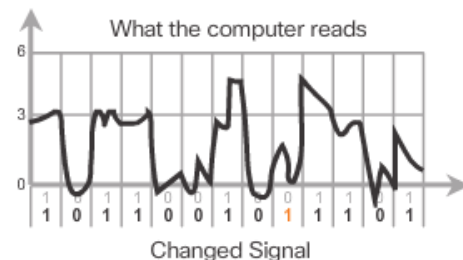
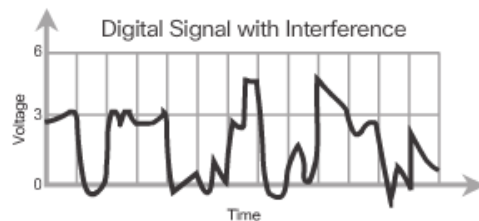
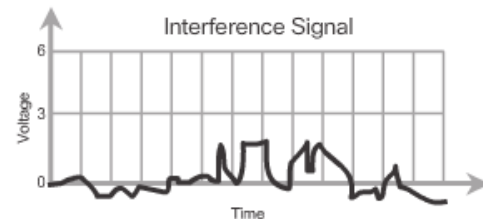
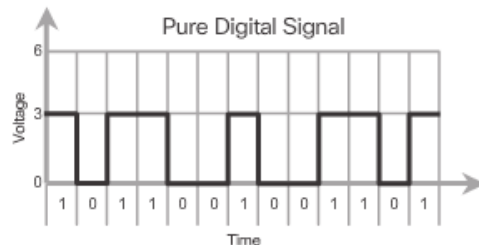
Goodput

- 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 Media

- Transmitted on copper cables as electrical pulses.
- Attenuation - the longer the signal travels, the more it deteriorates.
- All copper media must follow strict distance limitations.
- Electromagnetic interference (EMI) or radio frequency interference (RFI) - distorts and corrupts the data signals being carried by copper media.
 - To counter copper cables wrapped in shielding.
- Crosstalk - disturbance caused by the electric or magnetic fields of a signal on one wire to the signal in an adjacent wire.
 - To cancel crosstalk opposing circuit wire pairs twisted together.

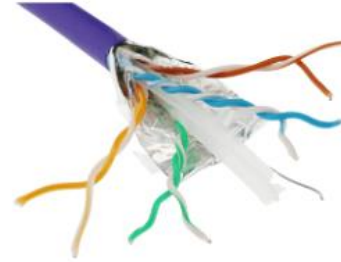


Copper Cabling

Types of Copper Cabling



Unshielded Twisted-Pair (UTP) Cable



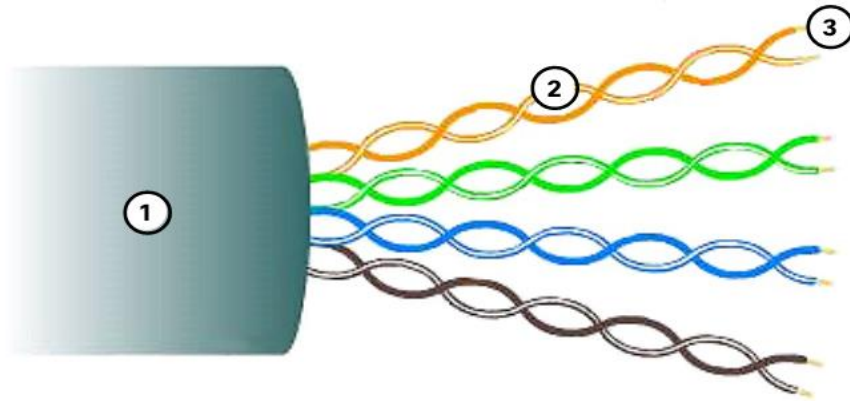
Shielded Twisted-Pair (STP) Cable



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.

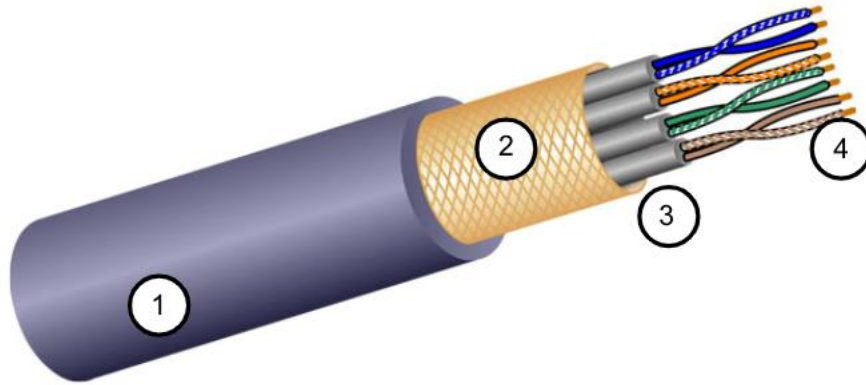
Key Characteristics of UTP

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

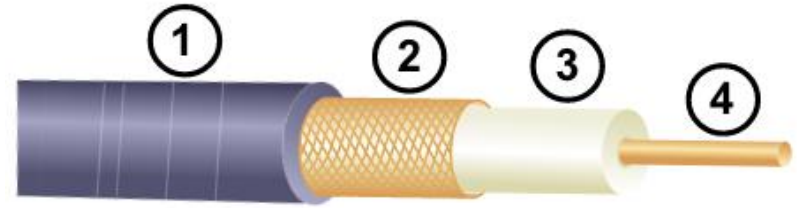
Consists of the following:

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



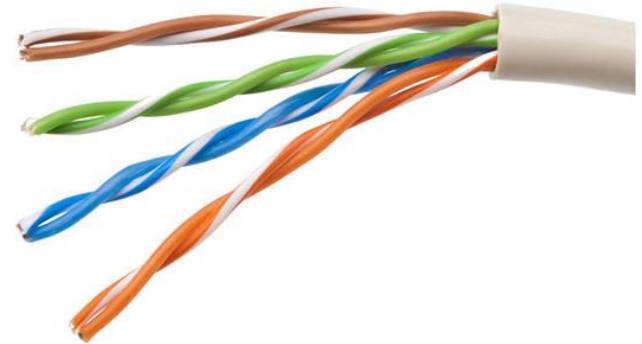
4.4 UTP Cabling

UTP Cabling

Properties of UTP Cabling

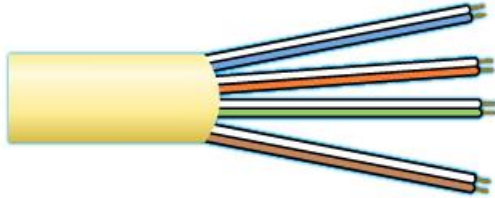
UTP has four pairs of color-coded copper wires twisted together and encased in a flexible plastic sheath. No shielding is used. UTP relies on the following properties to limit crosstalk:

- 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.

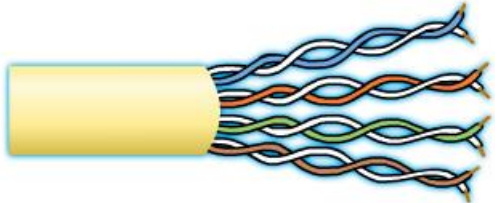


UTP Cabling

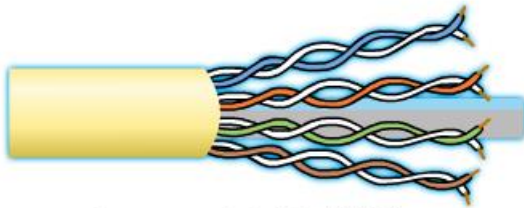
UTP Cabling Standards



Category 3 Cable (UTP)



Category 5 and 5e Cable (UTP)



Category 6 Cable (UTP)

- UTP cabling conforms to the standards established by TIA/EIA.
 - TIA/EIA-568 stipulates the cabling standards for LAN installations (Cable Types, Lengths, Connectors, Termination, Testing Methods)
- Cat 3 Cable
 - Used for voice communication
 - Most often used for phone lines
- Cat 5 and 5e Cable
 - Used for data transmission
 - Cat5 supports 100 Mb/s and can support 1000Mb/s, but it is not recommended
 - Cat5e supports 1000 Mb/s
- Cat 6 Cable
 - Used for data transmission
 - An added separator is between each pair of wires allowing it to function at higher speeds
 - Support 1000 Mb/s – 10 Gb/s, though 10 Gb/s is not recommended

UTP Cabling

UTP Cabling Standards and Connectors (Cont.)



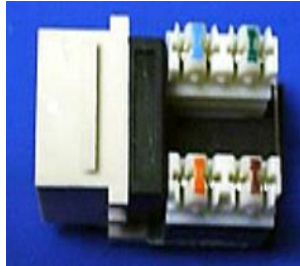
RJ-45 Connector



Poorly terminated UTP cable



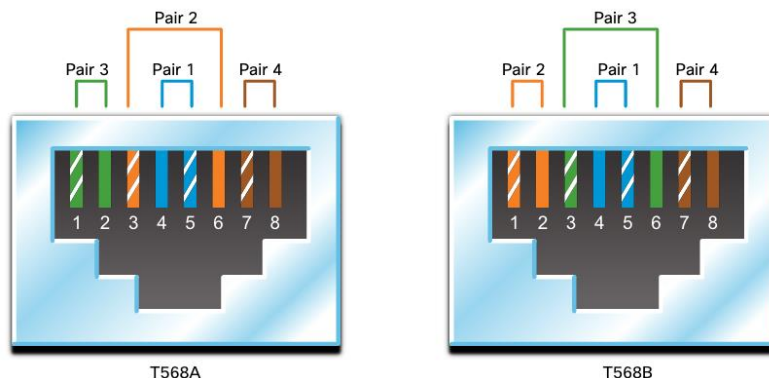
RJ-45 Socket



Properly terminated UTP cable

UTP Cabling

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

Fiber-Optic Cabling

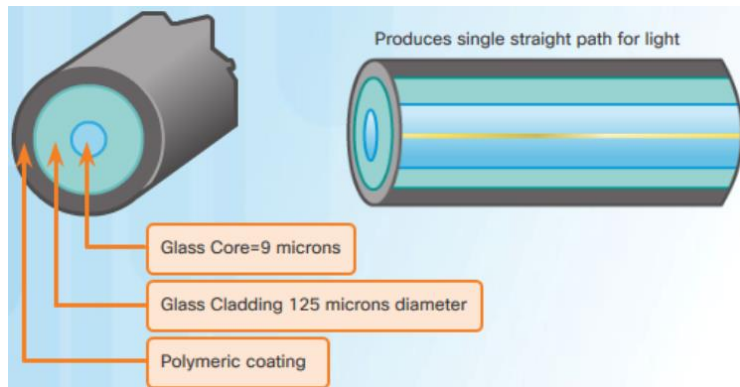
Properties of Fiber-Optic Cabling

- 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

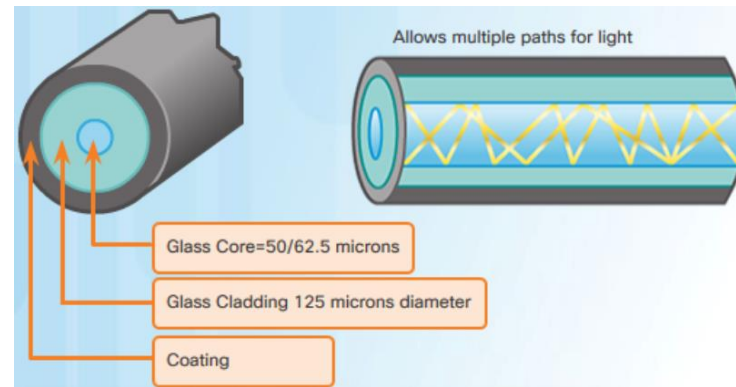
Types of Fiber Media

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 the maximum cable distance for MMF is 550 meters.

Fiber-Optic Cabling

Fiber-Optic Cabling Usage

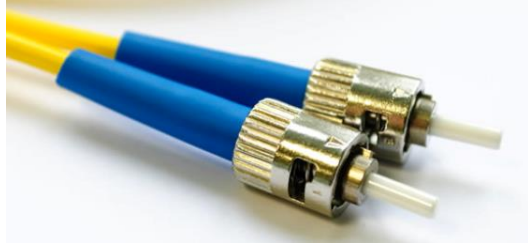
Fiber-optic cabling is now being used in four types of industry:

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



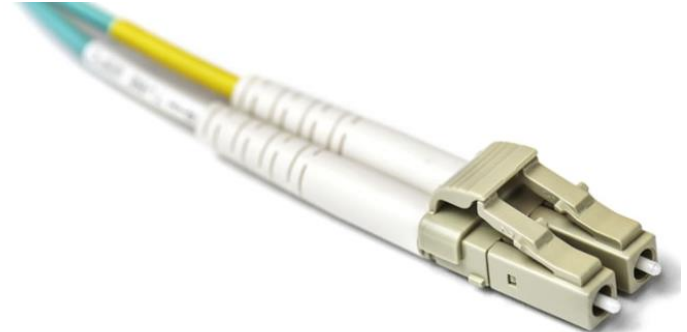
Straight-Tip (ST) Connectors



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.

