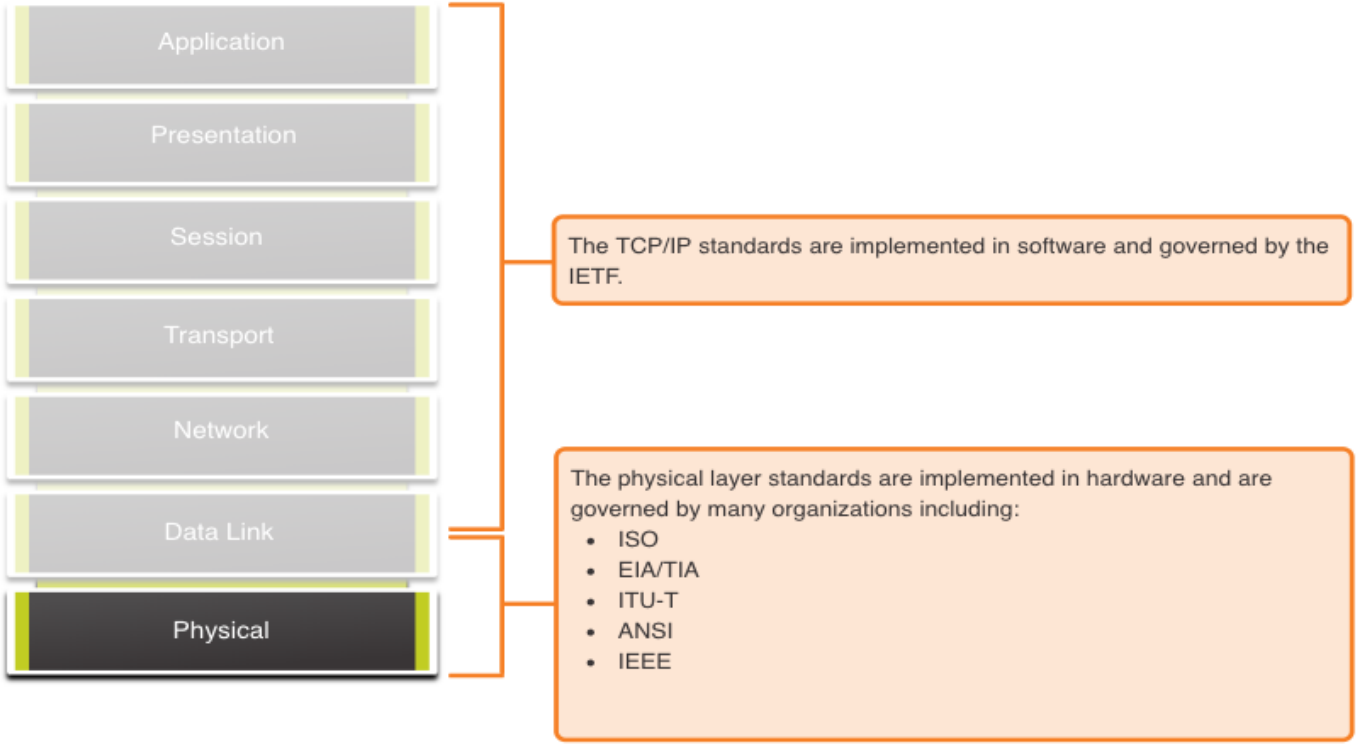
Physical Layer

Physical Layer Standards



Physical Components

Physical Layer Standards address three functional areas:

- Physical Components
- Encoding
- Signaling

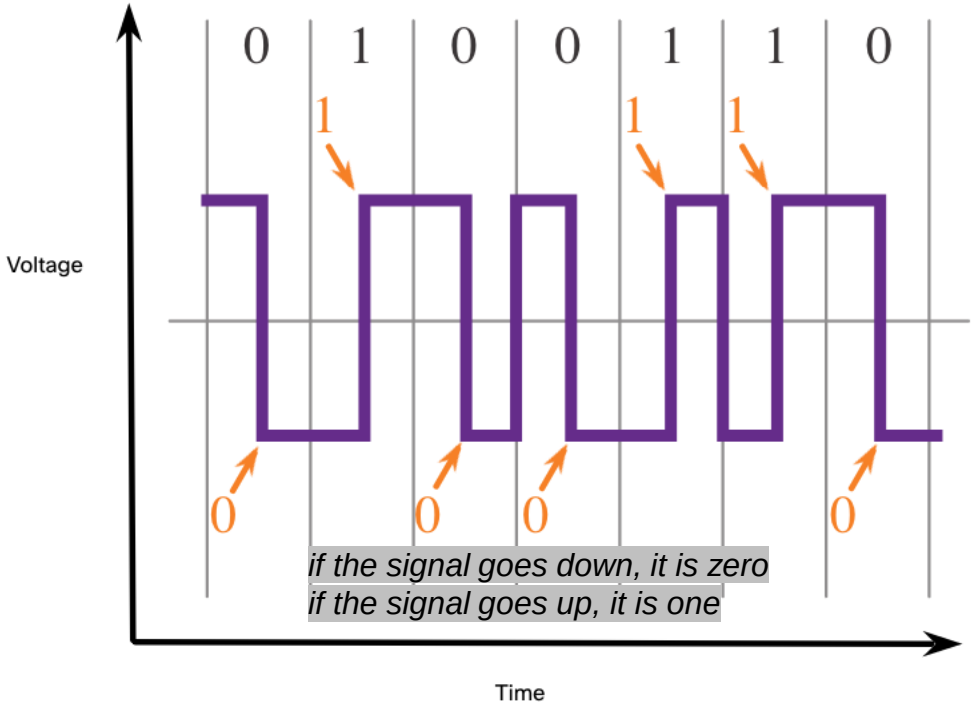
Physical Components

The Physical Components are e.g.

- Hardware devices, NICs
- Media (cables)
- Connectors

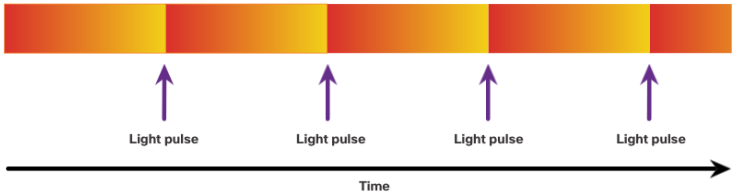
Encoding

- Encoding converts the stream of bits into a format recognizable by the next device in the network.
- This ‘coding’ provides patterns that can be recognized by the next device.

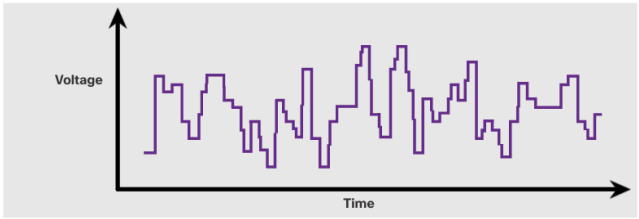


Signaling

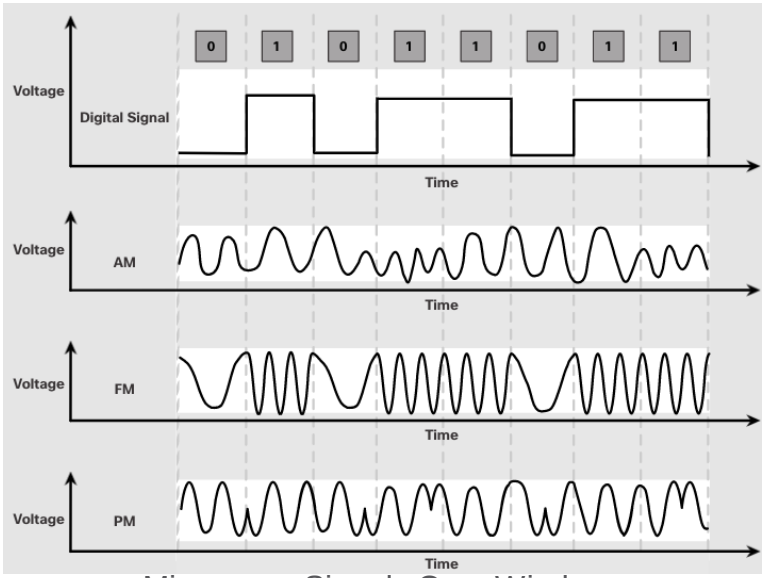
- The signaling method is how the bit values, “1” and “0” are represented on the physical medium.
- The method of signaling will vary based on the type of medium being used.



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

Notice difference between bit and Byte. 1B (byte) = 8bit

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

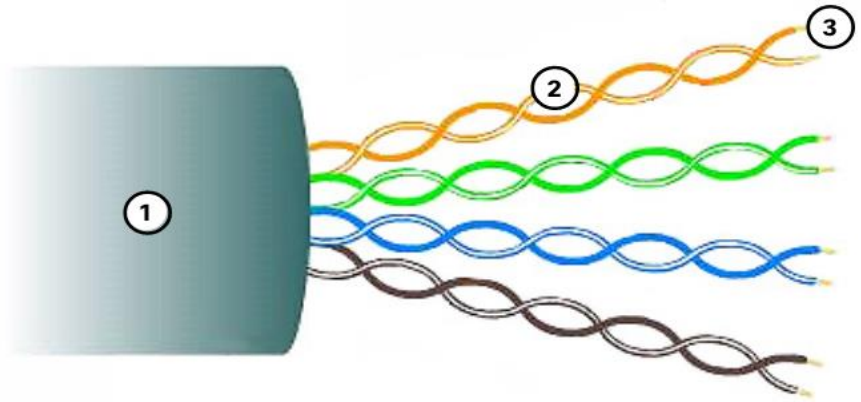
Types of Copper Cabling

Unshielded Twisted-Pair (UTP) Cable

Shielded Twisted-Pair (STP) Cable

Coaxial Cable

Unshielded Twisted Pair (UTP)

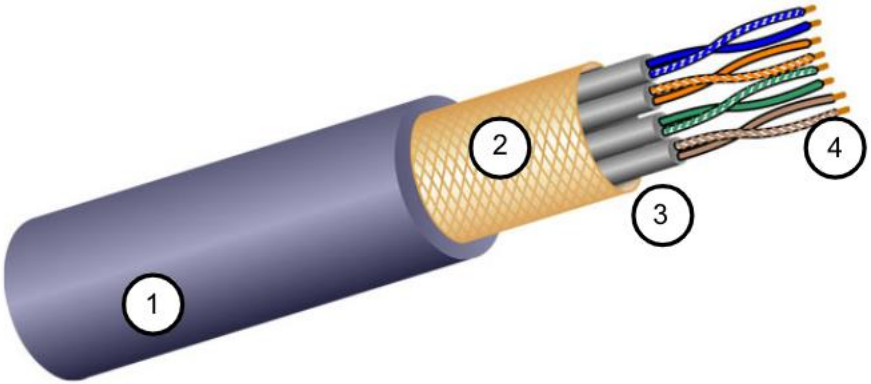


- UTP is the most common networking media.
- Terminated with RJ-45 connectors
- Interconnects hosts with intermediary network devices.

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
- Braided and foil shield provides EMI/RFI protection
- More expensive than UTP
- Harder to install than UTP
- Terminated with RJ-45 connectors
- Interconnects hosts with intermediary network devices

Key Characteristics of STP:

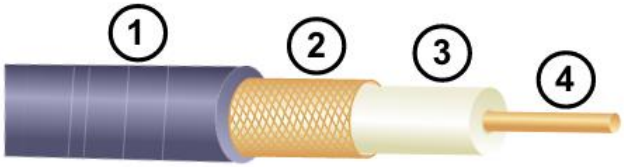
1. The outer jacket protects the copper wires from physical damage
2. Braided or foil shield provides EMI/RFI protection
3. Foil shield for each pair of wires provides EMI/RFI protection
4. Color-coded plastic insulation electrically isolates the wires from each other and identifies each pair

The shields of an STP cable is not always the same kind, depending on manufacturer.

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.

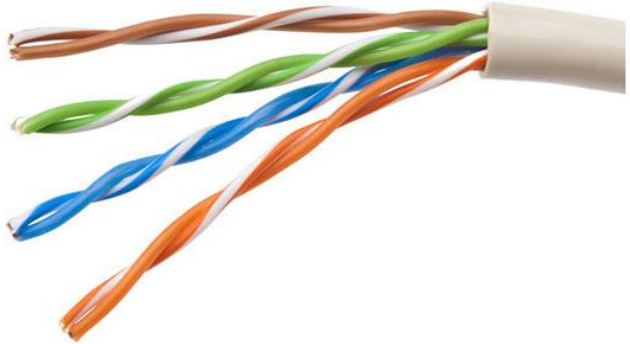
Commonly used in the following situations:

- Wireless installations - attach antennas to wireless devices
- Cable internet installations - customer premises wiring
- In measurement devices like oscilloscopes

More about UTP Cabling

Properties of UTP Cabling

- UTP has four pairs of color-coded copper wires twisted together
- No shielding is used.
- Each wire in a pair of wires uses opposite polarity. One wire is negative, the other wire is positive. This is to prevent EMI/RFI interference
- 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:

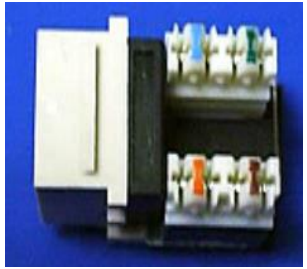
- Category 3
- Category 5 and 5e
- Category 6

Category	Maximum Speed	Max. Length	Frequency	SHIELDING
CAT 1	Up to 1Mbps(Carry only Voice)	--	1MHz	Unshielded
CAT 2	Up to 4Mbps	--	4MHz	Unshielded
CAT 3	Up to 10Mbps	100m	16MHz	Unshielded
CAT 4	Up to 16Mbps	100m	20MHz	Unshielded
CAT 5	Up to 100Mbps	100m	100MHz	Unshielded
CAT 5e	Up to 1Gbps	100m	100MHz	Unshielded or Shielded
CAT 6	Up to 10Gbps	100m	250MHz	Unshielded or Shielded
CAT 6a	Up to 10Gbps	100m	500MHz	Shielded
CAT 7	Up to 10Gbps	100m	600MHz	Shielded
CAT 8	Up to 40Gbps	100m	2000MHz	Shielded

UTP Cabling Standards and Connectors (Cont.)

RJ-45 Connector

Notice that connectors and sockets must be in same category than cables.



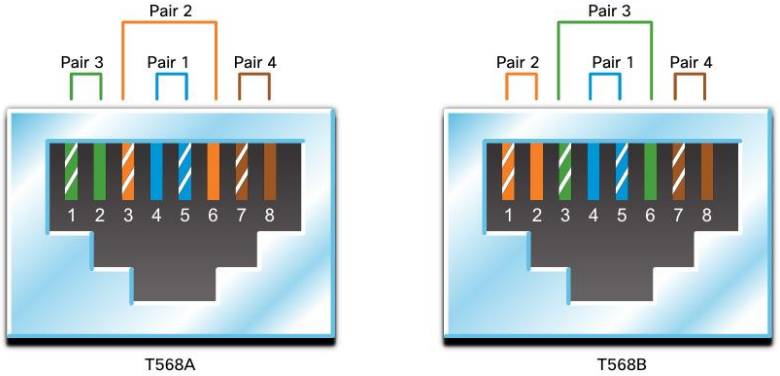
RJ-45 Socket

Poorly terminated UTP cable

Properly terminated UTP cable

Straight-through and Crossover UTP Cables

- T568A and T568B are the wiring standards that define the pinout (connection order)
- The purpose is to make a straight-through cable, where both ends are identical



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		

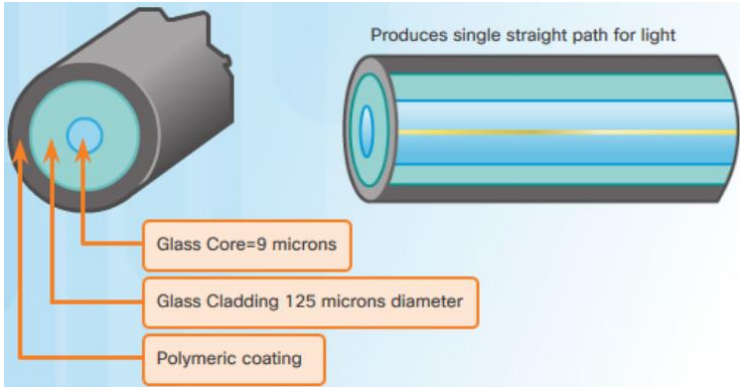
Fiber-Optic Cabling

Properties of Fiber-Optic Cabling

- Not as common as UTP because of the expense involved and difficulty of installation
- Transmits data over longer distances at higher bandwidth than any other networking media
- Less attenuation and immune to EMI/RFI
- Uses a laser or LED to encode bits as pulses of light

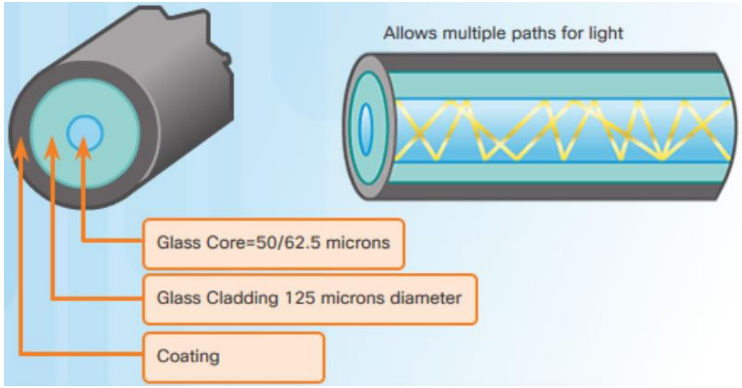
Types of Fiber Media

Single-Mode Fiber



- Very small core
- Uses expensive lasers
- Long-distance applications, tens of kilometers

Multimode Fiber



- Larger core
- Uses less expensive LEDs
- Up to 10 Gbps over 550 meters

The main difference between them is the way the signal is transmitted

- sm: moves linearly
- mm: moves by reflection

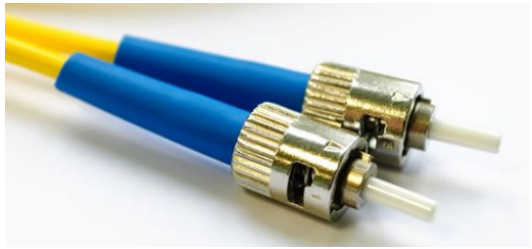
Fiber-Optic Cabling Usage

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.

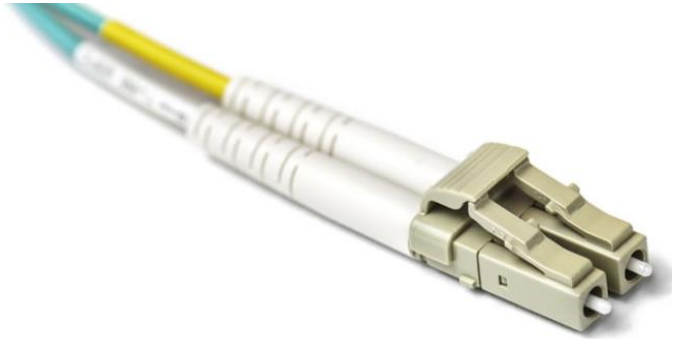
Fiber-Optic Connectors



Straight-Tip (ST) Connectors

Lucent Connector (LC) Simplex Connectors

Subscriber Connector (SC) Connectors



Duplex Multimode LC Connectors

Fiber Patch Cords

- Connection cable, used when, for example, switches are connected to a fixed fiber network

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 - 40 Gb/s	10 Mb/s - 400 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