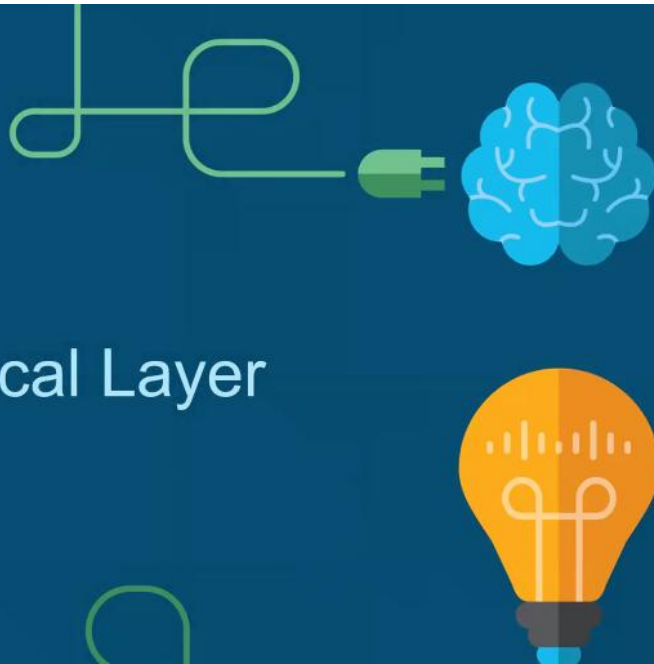**CISCO**

Module 4: Physical Layer

Instructor Materials

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.

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).
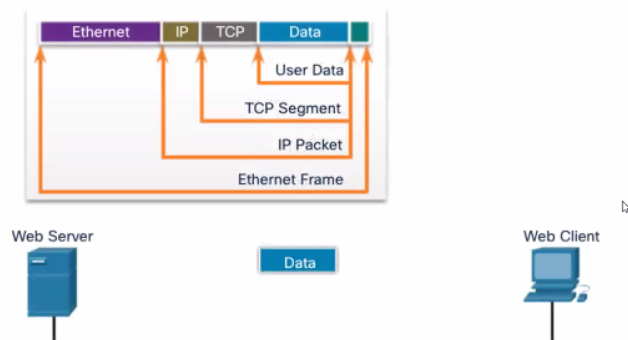- Not all physical connections offer the same level of performance.

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.
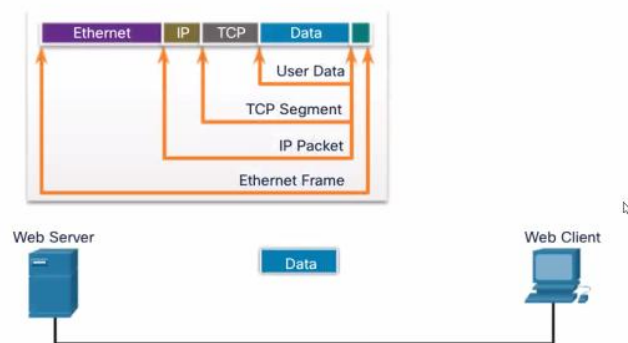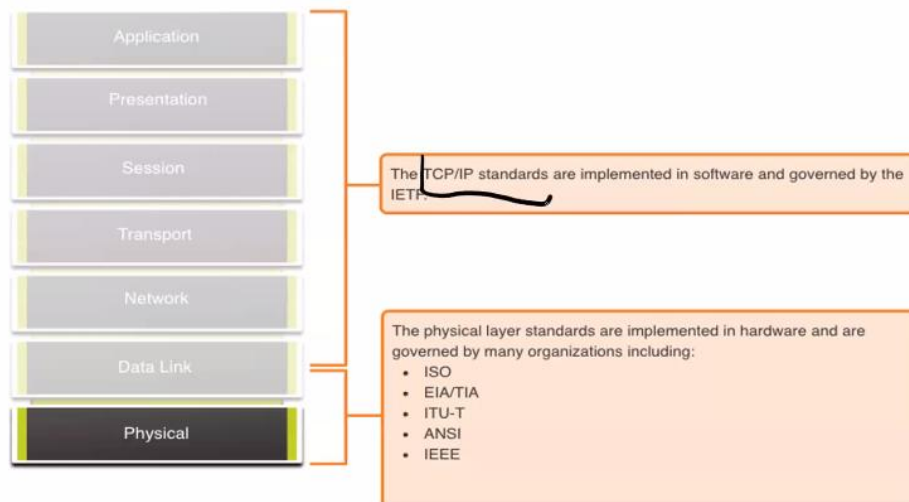
Purpose of the Physical Layer
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Ethernet	IP	TCP	Data	

User Data

TCP Segment

IP Packet

Ethernet Frame

Web Server

Data

Web Client

Physical Layer Characteristics
Physical Layer Standards

Application

Presentation

Session

Transport

Network

Data Link

Physical

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:
- ISO
- EIA/TIA
- ITU-T
- ANSI
- 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.
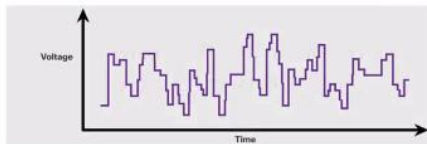
Encoding

- 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), 4B/5B, and 8B/10B.
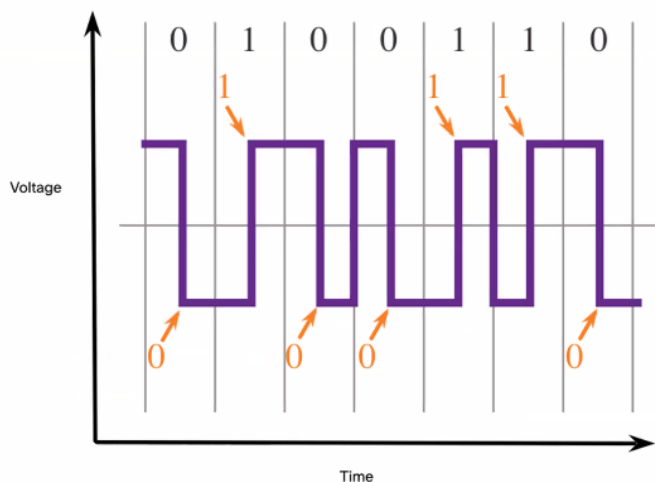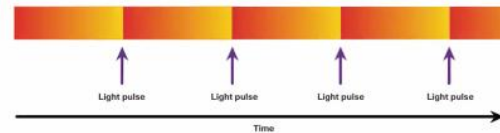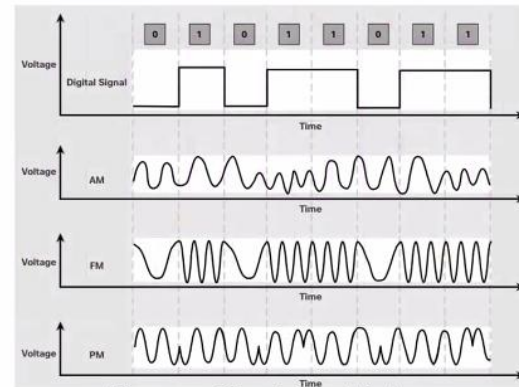
Physical Layer Characteristics
Signaling

- 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.

Light Pulses Over Fiber-Optic Cable

Electrical Signals Over Copper Cable

Microwave Signals Over Wireless

Physical Layer Characteristics
Bandwidth

Portata (quanti bit/s posso trasportare sul cavo) diverso da velocità che dipende dal medium (mezzo come cavo, luce) usato

- 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

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 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.

Types of Copper Cabling

ethernet

Unshielded Twisted-Pair (UTP) Cable
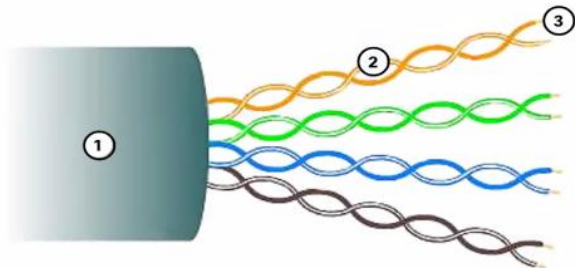
into schemature

Shielded Twisted-Pair (STP) Cable

.on schemature metellic

Coaxial Cable

Copper Cabling
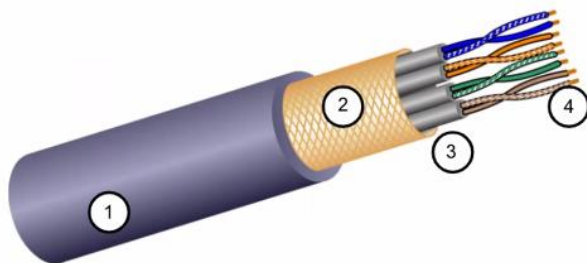# Unshielded Twisted Pair (UTP)

- 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
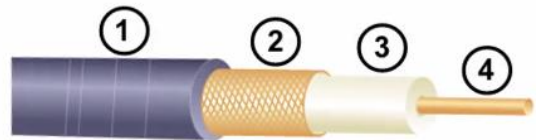
Coaxial Connectors

| BNC | N type | F type |

4.4 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.
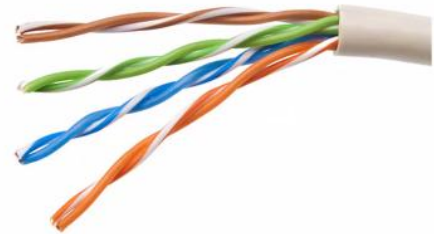
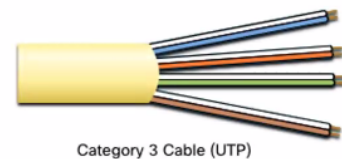# UTP Cabling Standards and Connectors

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

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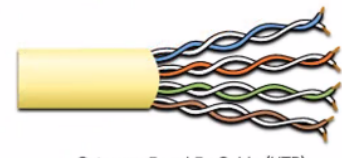- Cable Termination
- Testing Methods

Electrical standards for copper cabling are established by the IEEE, which rates cable according to its performance. Examples include:
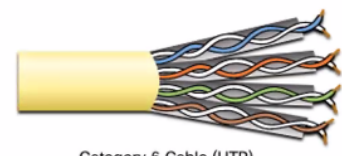
- Category 3
- Category 5 and 5e
- Category 6

Category 3 Cable (UTP)

Category 5 and 5e Cable (UTP)

Category 6 Cable (UTP)

UTP Cabling
UTP Cabling Standards and Connectors (Cont.)

RJ-45 Connector

Poorly terminated UTP cable

RJ-45 Socket

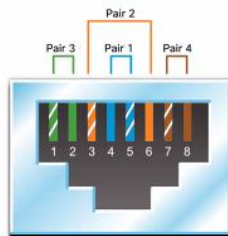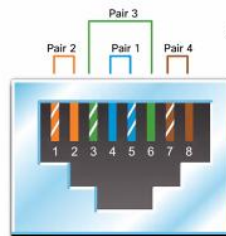Properly terminated UTP cable

UTP Cabling
Straight-through and Crossover UTP Cables

non a' interesse, oggi' le NIC hanno l'MIDx

T568A | T568B

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

Types of Fiber Media

Single-Mode Fiber

Produces single straight path for light

- Glass Core=9 microns
- Glass Cladding 125 microns diameter
- Polymeric coating

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

Multimode Fiber

Allows multiple paths for light

- Glass Core=50/62.5 microns
- Glass Cladding 125 microns diameter
- Coating

- Larger core
- Uses less expensive LEDs
- LEDs transmit at different angles
- Up to 10 Gbps over 550 meters
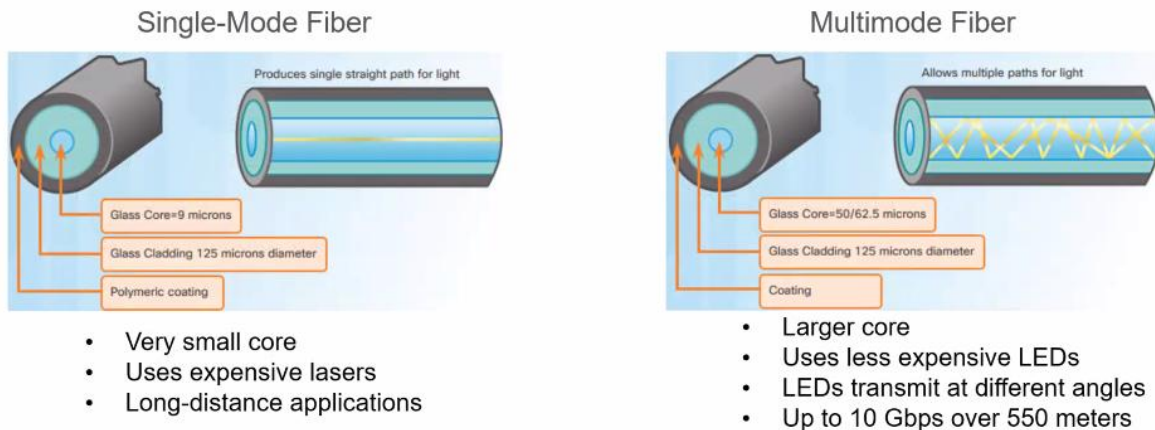
Dispersion refers to the spreading out of a light pulse over time. Increased dispersion means increased loss of signal strength. MMF has greater dispersion than SMF, with a the maximum cable distance for MMF is 550 meters.

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

Collegamento 1:1 con un dispositivo lontano

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 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

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.