THE PHYSICAL LAYER

The physical layer of the network focuses on hardware elements, such as cables, repeaters, and network interface cards. By far the most common protocol used at the physical layer is Ethernet. For example, an Ethernet network (such as 10BaseT or 100BaseTX) specifies the type of cables that can be used, the optimal topology (star vs. bus, etc.), the maximum length of cables, etc.

Protocol:

- **Ethernet:** (while considered a Layer 2 protocol) Ethernet also operates at the physical layer.
- EIA/TIA 232 (serial signaling)
- V.35 (modem signaling)
- Cat6
- RJ45

Device

A Layer One device merely repeats the signal across all ports without looking at the contents of the frame. Hubs and repeaters operate at the Physical layer--they simply repeat packets without regard to addresses.

- **Media Converters:** Media converters are Layer 1 devices. They operate at the Physical layer in the OSI Model and can only convert one type of transmission signal into another.
- **Network Adapters:** Network adapters are Layer 1 devices because they send and receive signals on the network medium. They are also Layer 2 devices because they must follow the rules for media access and because they read the physical address in a frame.
- **Transceivers:** The network adapter's transceiver operates at layer 1. It accepts the digital data represented by zeroes and ones and converts it into an electrical signal by converting zeroes and ones into negative and positive charges on the cable.
- **Hubs:** Sometimes called repeaters. Because a hub only sends electrical signals and doesn't examine the contents of a frame or packet, it operates at the physical layer, or Layer One, of the OSI model.
- **Line Status (status of interface itself):** Layer one function. You can determine the line status by running “show interfaces command” - it will display whether the interface status is up or down.

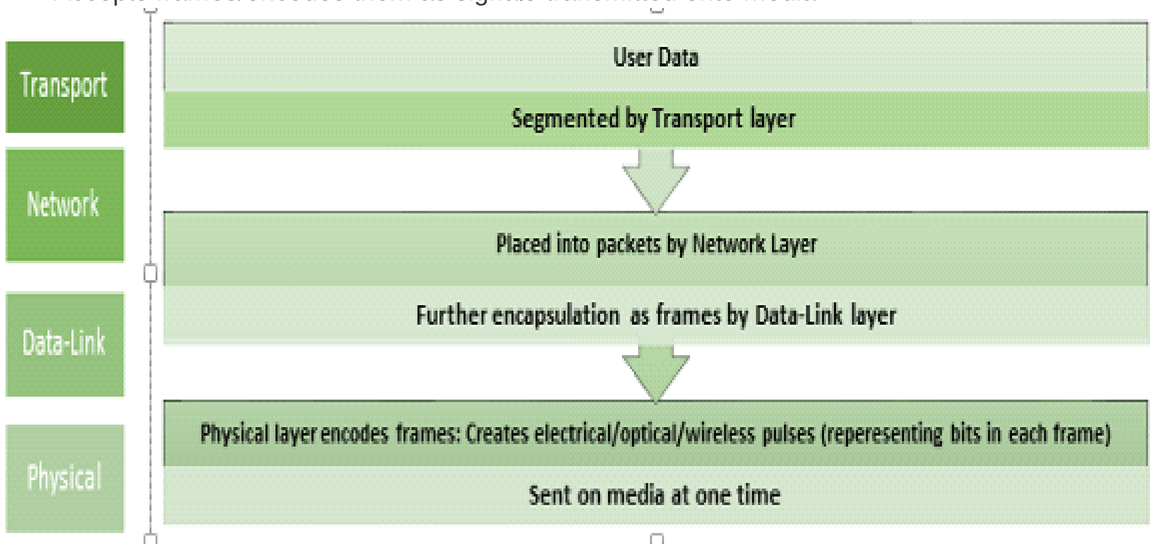
Functions:

- Moves bits across the media.
- Defines cables, connectors, and pin positions.
- Specifies electrical signals (voltage, bit synchronization).
- Defines the physical topology (network layout).
- Sets standards for sending and receiving electrical signals between devices. It describes how digital data (bits) are converted to electric pulses, radio waves, or pulses of lights. Devices that operate at the physical layer send and
- receive a stream of bits.

THE PHYSICAL LAYER

Physical: The way bits are transported: Makes up a link layer frame across media

- Accepts frames/encodes them as signals transmitted onto media



3 media forms: Governed by: **IETF/ISO/IEEE/TIA/EIA/ITU/ANSI**

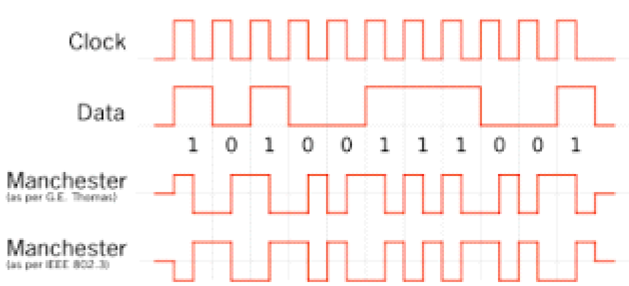
1. **Copper:** Electrical
2. **Fiber:** Light
3. **Wireless:** Radio transmission

The physical layer standards address 3 areas:

1. **Components**
2. **Encoding**
3. **Signaling**

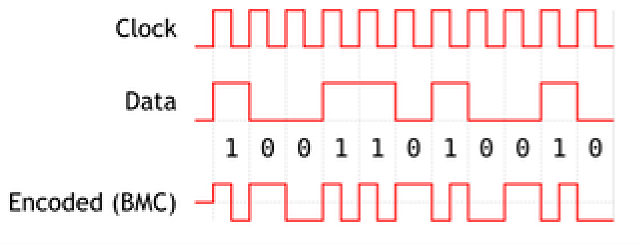
Components	Hardware/connectors (transmits signals to represent bits)
Encoding	Conversion of streaming bits into predefined codes
Code	Groupings of bits: Provides patterns recognized by sender/receiver
Encoding	Pattern of voltage/current used to represent bits: 0 | 1

Manchester encoding: Used in versions of Ethernet/RFID/NFC



0 == High-to-low voltage transition
1 == Low-to-high voltage transition

NRZ: Non-Return to Zero: Encoded data has 0 and 1 but no neutral or rest position



0 == One voltage level on media
1 == Different voltage

Signal transmission done one of 2 ways:

1. **Asynchronous:** Signals transmitted without an associated clock signal
    - **Time spacing between characters/blocks can be arbitrary**
    - **Frames require START/STOP indicator flags**
2. **Synchronous:** Signals sent along a clock signal that occurs at bit time
    - **Bit time: Evenly spaced duration**

Modulation: Process which characteristics of 1 wave (signal) modifies another (carrier)
Modulation techniques widely used in transmitting data:

FM	**Frequency Modulation:** Carrier frequency varies in accordance w/signal
AM	**Amplitude Modulation:** Amplitude varies in accordance with signal
PCM	**Pulse-Coded Modulation:** • Analog signals (voice) converted to digital by sampling amplitude/expressing diff amplitudes as bin nums • Sampling rate must be at least 2x highest frequency

Nature of signals representing bits depends on signaling method:

- Some may use one attribute of signaling to represent a 0: Another to represent 1

Bandwidth: The capacity of a medium to carry data:

- Measures data flow from one place to another in a given time

Bandwidth determined partially by:

1. Media properties
2. Tech chosen for signaling/detecting signals

Throughput/Goodput: Measures transfer of bits across media in given time

Factors that influence throughput: <u>Amount of traffic</u> || <u>Type of traffic</u>

- Latency created by num of devices encountered bet source/dest
- Throughput can't be faster than slowest link from source/dest
- Even if segments have high bandwidth:
    - Creates bottleneck via 1 segment in path with low throughput

Goodput: Measures usable data transferred over given period of time
Throughput: Overhead (established sessions/acknowledgements, encapsulations)
Copper Media: Low resistance to current (limited by distance/interference)

- Data transmitted as electrical pulses can successfully decode to match sent signals

Attenuation: The longer a signal travels, the more it deteriorates
Interference from 2 sources:

1. **EMI: Electromagnetic Interference**
2. **RFI: Radio Frequency Interference**

EMI/RFI: Distorts/corrupts signals carried by copper

- Radio waves/electromagnetic devices/fluorescent lights etc..

Crosstalk: Disturbance caused by electric/magnetic fields of a signal on one wire to another

- Current/circular magnetic fields created around wires that can be picked up by other wires

Countering:

EMI/RFI	Copper cables: Wrapped in metallic shielding that require groundings
Crosstalk	Copper cables: Opposing circuit wire pairs twisted together (cancels)

Electronic noise reduction:

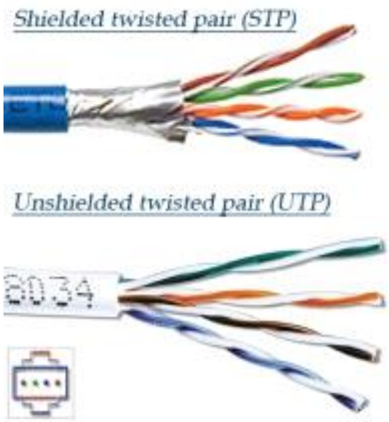
- Cable/category most suited to network environment
- Design infrastructure to avoid potential sources of interference
- Use cabling techniques that include proper handling/termination

Copper Media:

- Interconnects nodes on LAN/devices (switches/routers/access points)
- Each type/device has requirements stipulated by physical standards
- A single physical connector may be used for many types of connections

UTP: Unshielded Twisted Pair	**STP: Shielded twisted pair**	**Coaxial**

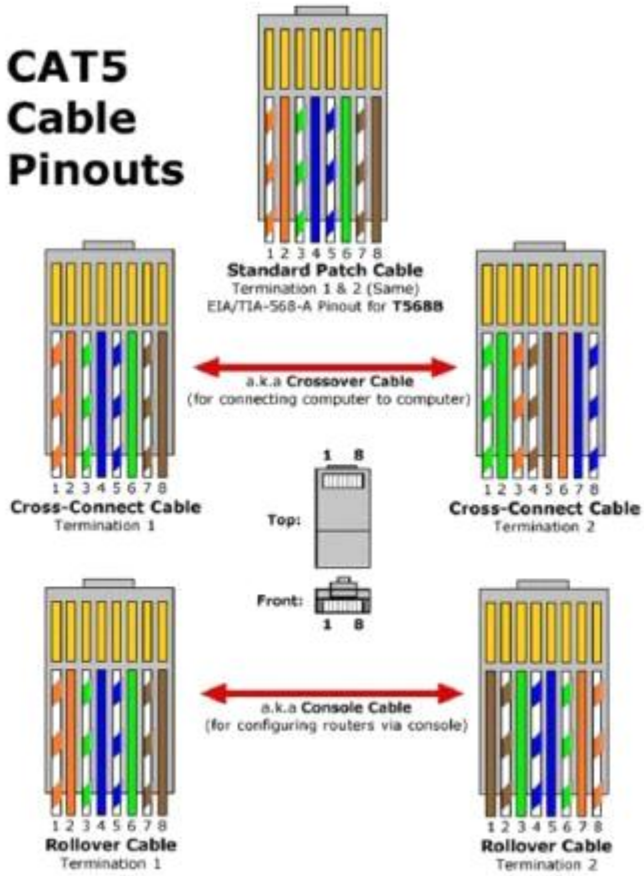
UTP Unshielded Twisted-Pair Cable:

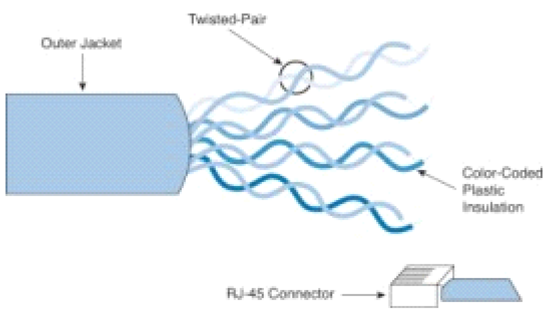


- Terminated with ISO 8877 RJ-45's
- Interconnects network hosts with intermediate devices (switches/routers)
- 4 pairs of color-coded wires twisted together/encased in plastic sheath
- Twisting wires helps protect against signal interference
- 22 or 24 gauge copper wire
- External diameter of approximately .43cm or .17in

Color coding:

Orange-white	Orange	Blue-White	Blue	Green-white	Green	Brown-white	Brown





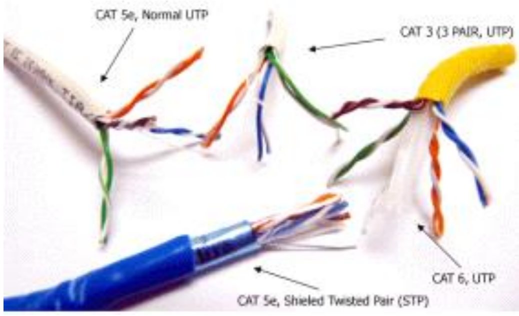
UTP Cabling/Cabling Standards: Crosstalk limited by:

Cancellation	Wires paired in a circuit
Number of twists per pair	<u>Twists of each pair vary:</u> • O/orange-white less than b/white-blue pairs

TIA/EIA-568A stipulates commercial cabling standards for LAN installations
<u>Some elements defined</u>: Types/lengths/connectors/terminations/methods of testing
IEEE: Characteristics of copper cabling/placed into categories based on ability to carry bandwidth

Cat3	• Voice communication/phone lines
Cat5/5e	• Data transmission: 568 standard • Supports: 100 Mbps & 1000 Mbps (Gigabit)
Cat6	• Data transmission: 568 standard • Separator added bet each pair of wires: Allows higher speeds • Supports 1000 Mbps & up to 10 Gbps
Cat7 (ScTP)	• Individual pairs wrapped in shield: 4 pairs wrapped in another shield

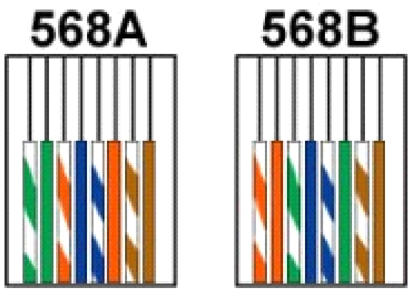
UTP Connectors:



- TIA/EIA 568 standard describes wire colors to pin-outs for Ethernet
- Male component: RJ-45 (socket female)
- Each time cabling terminated: Chance of signal loss/introduction of noise

Cable types for specific wiring conventions:

Straight-Through	• Connect a host to switch/switch to router • Both ends: Either 568A/568B
Crossover	• Connect similar devices: Switch to switch/host to host/router to router • Also used to directly connect host to router • One end: 568A • One end: 568B
Rollover	• Cisco-proprietary cable: Router/switch console port • Pin 1 is Pin 6 on other end



Testing UTP Cables: Wire map/length/sig loss b/c of attenuation/crosstalk
STP Shielded Twisted-Pair Cable:

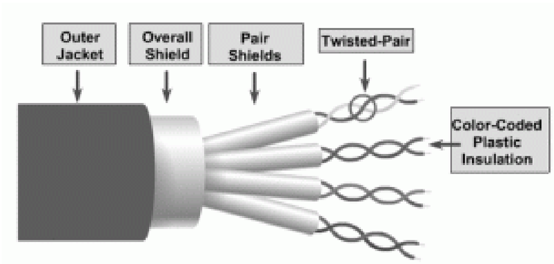
- Better noise protection than UTP: More expensive: Diff to install
- Combines shielding to counter EMI/RFI: Wire twisting to counter crosstalk
- Gain benefit: STP cables terminated with shielded STP data connectors
- Improperly grounded shields: Can act like antennas/pick up unwanted signals

<u>Uses 4 pairs of wires:</u>

- Each wrapped in foil shield: Then wrapped in overall metallic braid/foil
- 10GB: Standard Ethernet has provision for STP

2 most common variations of STP cables:

1. Cable shields entire bundle of wires with foil (no interference)
2. Cable shields entire bundle of wires and individual pairs with foil (no interference)



Coaxial: Derived name because 2 conductors share the same axis

- Copper conductor transmits electronic signals and is surrounded by plastic insulation

Insulating material woven copper braid/metallic foil:

- Acts as second wire in circuit/shield for inner conductor

- Second layer/shield reduces electromagnetic interference
- Different connector types: F//N types/BNC

UTP: Mostly replaced coax in modern Ethernet installations: Still adapted for:

Wireless	Cables attached to antennas/wireless devices: • RF's between antennas/radio equipment
Cable	Portions of coax/elements replaced w/fiber: Final connections coax • **HFC: Hybrid Fiber Coax:** Combined use of fiber/coax

Copper safety: All types susceptible to fire/electrical hazards
Cable insulation/sheaths: Flammable/produce toxic fumes/conduct electricity in bad ways
Cabling practices to avoid hazards:
1. Maintain separation of data/electrical power
2. Connect cables properly/Inspect for damage
3. Properly ground equipment

Fiber-Optic Cabling
- Flexible/extremely thin transparent strands of glass (silica): Like human hair
- Bits encoded as light impulses
- Cable acts as wave guide to transmit light between 2 ends with minimal loss of signal
- Less attenuation/immunity to EFI/RFI

Fiber-optic cabling now used in 4 industry network types:

Enterprise	Backbone cabling applications/interconnecting infrastructure
FTTH	**Fiber-to-the-home** • Provide networks to connect countries/cities • Networks range from few dozen-thousand kilos • Up to 10Gbps-based systems
Submarine	High-speed/capacity solutions capable of surviving harsh undersea environments

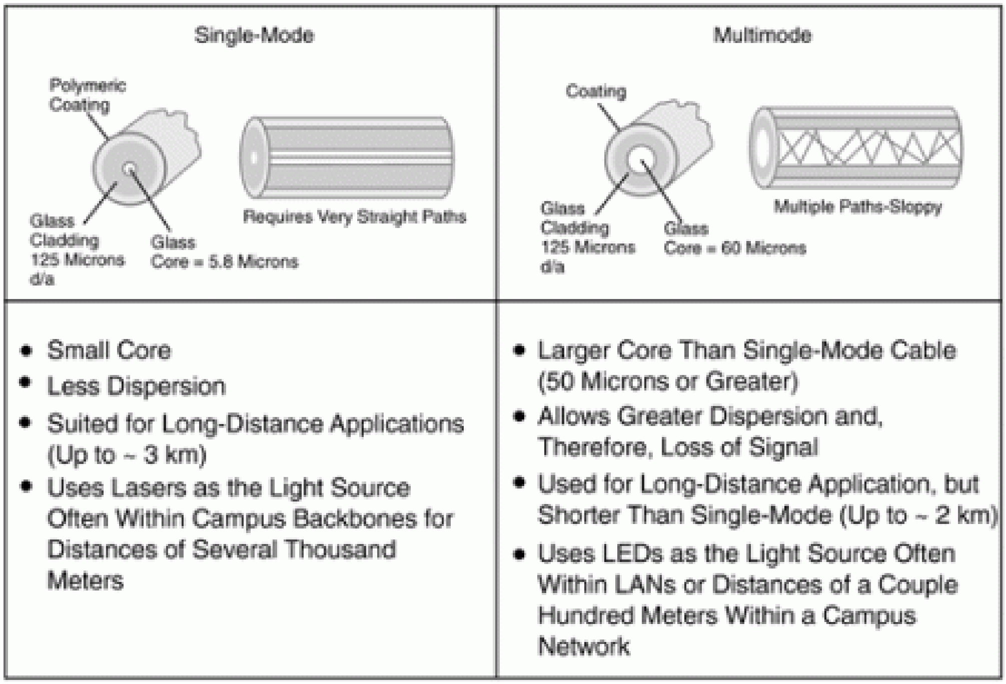
Cable Design:

Core	Pure glass/where light carried
Cladding	Glass that surrounds core: Acts as mirror • Light pulses propagate down core: Cladding reflects pulses • Keeps pulses contained in core: **Total internal reflection**
Jacket	PVC jacket protects core/cladding • Can include strengthening materials/buffer (coating) to protect glass from scratches/moisture

Types of fiber media:
1. Lasers
2. LED: Light Emitting Diodes
- Photodiodes (electronic semiconductors) detect light pulses/convert them to voltages
- These voltages can be reconstructed into data frames

Fiber broadly classified into 2 types: SMF/MMF

Single-Mode	Single light beam down center • Small core: Uses expensive laser tech to send ray of light • Good: Long-distance spanning 100's of kilometers (telephony/ cable TV applications)
Multimode	Reflection of light bouncing inside fiber (many paths/modes) • Larger core: Uses LED emitters to send light pulses • Light from LED enters MMF at different angles • Good for LANS: Can be powered by low cost LEDS • Bandwidth up to 10Gbps over lengths up to 550 meters



Dispersion: Spreading out of a light pulse over time
The major difference between SMF/MMF cabling

- Use of 1 laser in SMF: Less dispersion
- The more dispersion: The greater signal loss/less distance of signal over fiber

Network Fiber Connectors: Connector terminates end of optical fiber

- Main diff among connector types: Dimensions/methods of mechanical coupling

3 most popular network fiber connectors

ST: Straight-tip	Older bayonet style connector: MMF/SMF
SC: Subscriber Connector	Square/standard connector: MMF/SMF • LAN/WAN uses push-pull mechanism for positive insertion
LC: Lucent Connector	Little/local connector: SMF/supports MMF

Other connectors:

- FC: Ferrule Connector
- SMA: Sub Miniature A

Obsolete connectors: Biconic, D4

- Light tends to travel in 1 direction over fiber: 2 fibers required to support full-duplex
- Cables bundle together: Terminate with pair of standard single fiber connectors
- Some connectors accept both transmitting/receiving fibers: **Duplex connector**

Simplex: 1 strand: 1 way communication (telephony)
Full duplex: Both parties communicate with each other simultaneously
Half duplex: Transmission of signals in both directions: Not simultaneously

Common patch cords:

- SC-SC (multimode), LC-LC (single-mode), ST-LC (multimode), SC-ST (single-mode)
- Cables should be protected with plastic cap when not in use
- TIA-598 standard is yellow jackets for SMF and orange (or aqua) for MMF cables

3 most common types of fiber termination/splicing errors:

Misalignment	Fiber-optic media isn't aligned to one another when joined
End Gap	Media doesn't completely touch at the splice/connection
End Finish	Media ends aren't well polished/Dirt is present at the termination

OTDR: Optical Time Domain Reflectometer: Used to test fiber-optic cable segments
Flashlight: Can also be used
Fiber vs. Copper

- Fiber: More expensive over the same distance: Higher capacity
- Different skills/equipment required to terminate/splice
- More careful handling than copper

Wireless Media: Carries electromagnetic signals that represent binary digits of data using radio/microwave frequencies

- Not restricted to conductors or pathways, as copper/fiber

Areas of concern in wireless:

Coverage	Good in open environments/Certain materials can limit coverage
Interference	Susceptible to interference/can be disrupted by common devices
Security	Fairly open/unauthorized users can gain access to transmissions

Types of wireless media (IEEE):

802.11	**WLAN:** Wi-Fi: Contention/nondeterministic system with • **Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)**
802.15	**WPAN:** Wireless Personal Area Network: BT: • Device pairing processes to communicate over distances 1-100 meters
802.16	**WiMAX:** Worldwide Interoperability for Microwave Access: • Point-to-multipoint topology to provide wireless broadband access

Physical layer specifications applied to areas include:

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

WiFi Standards:

Standard	Max Speed	Frequency	Backward Compatibility
802.11a	54Mbps	5Ghz	No
802.11b	11Mbps	2.4Ghz	No
802.11g	54Mbps	2.4Ghz	802.11b
802.11n	600Mbps	2.4Ghz/5Ghz	802.11a/b/g
802.11ac	1.3Gbps	2.4Ghz/5Ghz	802.11a/b/g/n
802.11ad	7Gbps	2.4Ghz/5Ghz/60Ghz	802.11a/b/g/n/ac