

NETWORKING

Bandwidth

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

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

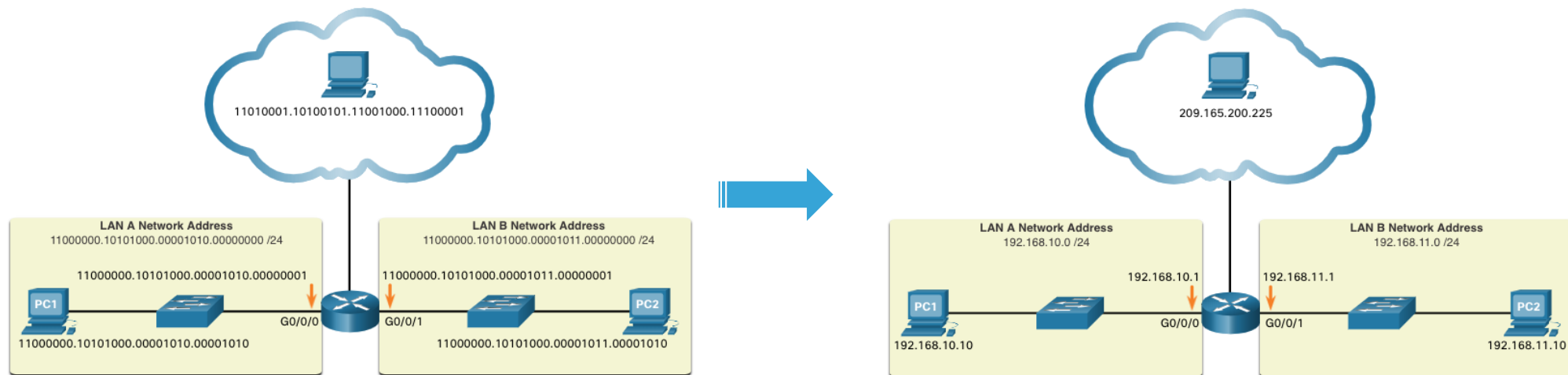
- The measure of usable data transferred over a given period of time
- $\text{Goodput} = \text{Throughput} - \text{traffic overhead}$

Binary Number System

Binary Number System

Binary and IPv4 Addresses

- Binary numbering system consists of 1s and 0s, called bits
- Decimal numbering system consists of digits 0 through 9
- Hosts, servers, and network equipment using binary addressing to identify each other.



Binary Number System

Convert Binary to Decimal

Convert 11000000.10101000.00001011.00001010 to decimal.

Positional Value	128	64	32	16	8	4	2	1
Binary Number (11000000)	1	1	0	0	0	0	0	0
Calculate	1x128	1x64	0x32	0x16	0x8	0x4	0x2	0x1
Add Them Up...	128	+ 64	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0
Binary Number (10101000)	1	0	1	0	1	0	0	0
Calculate	1x128	0x64	1x32	0x16	1x8	0x4	0x2	0x1
Add Them Up...	128	+ 0	+ 32	+ 0	+ 8	+ 0	+ 0	+ 0
Binary Number (00001011)	0	0	0	0	1	0	1	1
Calculate	0x128	0x64	0x32	0x16	1x8	0x4	1x2	1x1
Add Them Up...	0	+ 0	+ 0	+ 0	+ 8	+ 0	+ 2	+ 1
Binary Number (00001010)	0	0	0	0	1	0	1	0
Calculate	0x128	0x64	0x32	0x16	1x8	0x4	1x2	0x1
Add Them Up...	0	+ 0	+ 0	+ 0	+ 8	+ 0	+ 2	+ 0

➡ 192

➡ 168

➡ 11

➡ 10

192.168.11.10

Decimal to Binary Conversion Example

- Convert decimal 168 to binary

Is $168 > 128$?

- Yes, enter 1 in 128 position and subtract 128 ($168-128=40$)

Is $40 > 64$?

- No, enter 0 in 64 position and move on

Is $40 > 32$?

- Yes, enter 1 in 32 position and subtract 32 ($40-32=8$)

Is $8 > 16$?

- No, enter 0 in 16 position and move on

Is $8 > 8$?

- Equal. Enter 1 in 8 position and subtract 8 ($8-8=0$)

No values left. Enter 0 in remaining binary positions

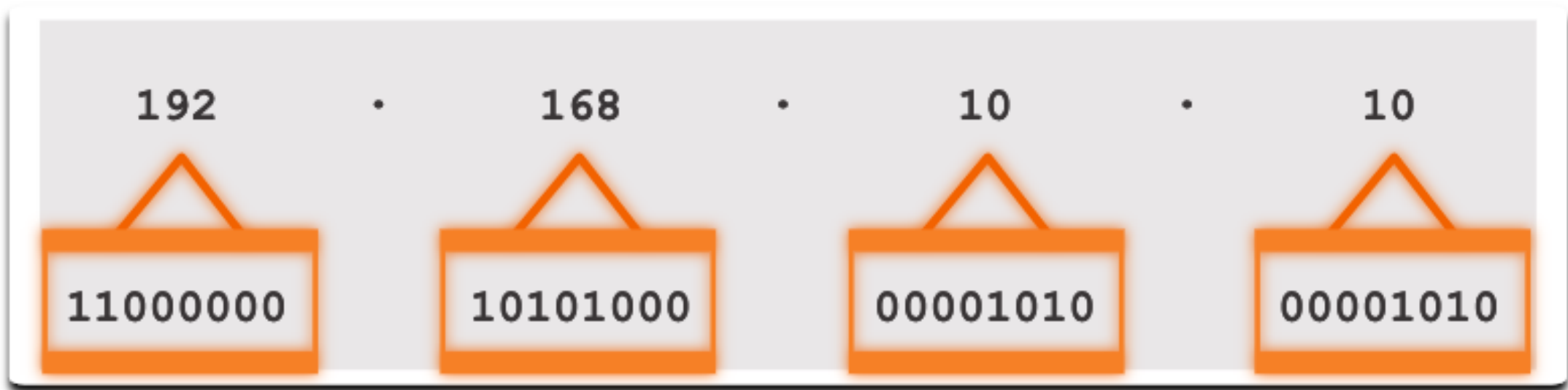
128	64	32	16	8	4	2	1
1	0	1	0	1	0	0	0

Decimal 168 is written as 10101000 in binary

Binary Number System

IPv4 Addresses

- Routers and computers only understand binary, while humans work in decimal. It is important for you to gain a thorough understanding of these two numbering systems and how they are used in networking.



Copper Cabling

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:

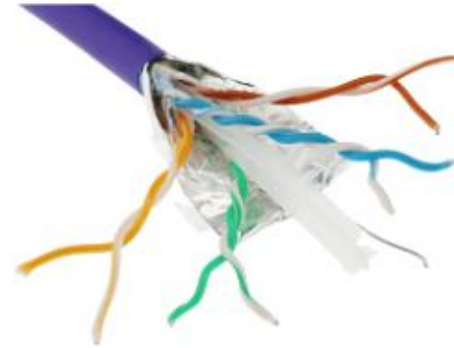
- Strict adherence to cable length limits will mitigate attenuation.
- Some kinds of copper cable mitigate EMI and RFI by using metallic shielding and grounding.
- Some kinds of copper cable mitigate crosstalk by twisting opposing circuit pair wires together.

Copper Cabling

Types of Copper Cabling



Unshielded Twisted-Pair (UTP) Cable



Shielded Twisted-Pair (STP) Cable



Coaxial Cable

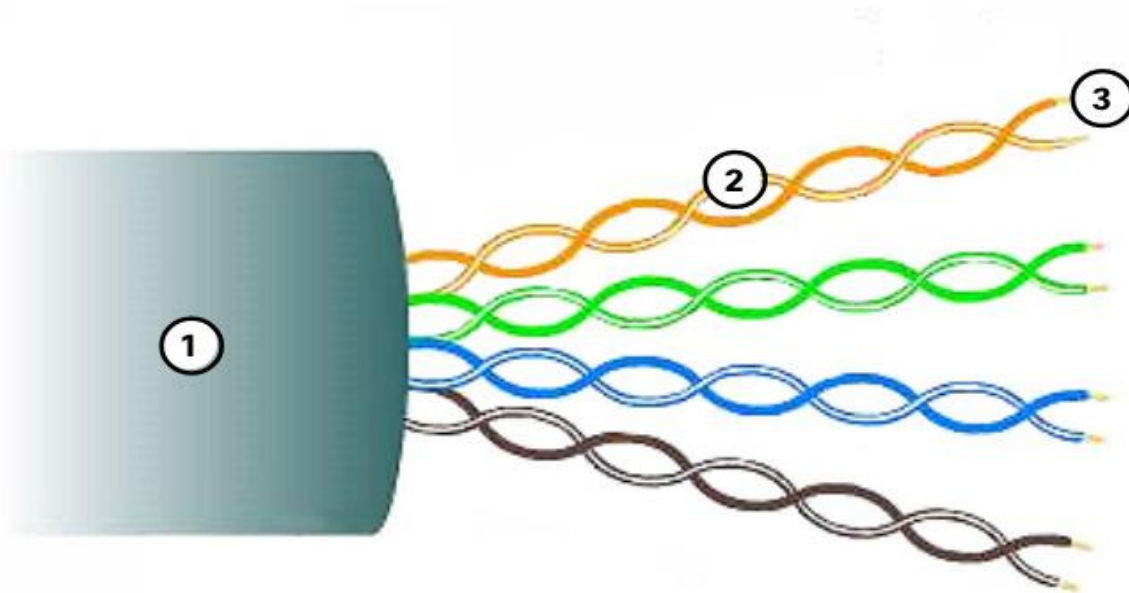
Copper Cabling

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.



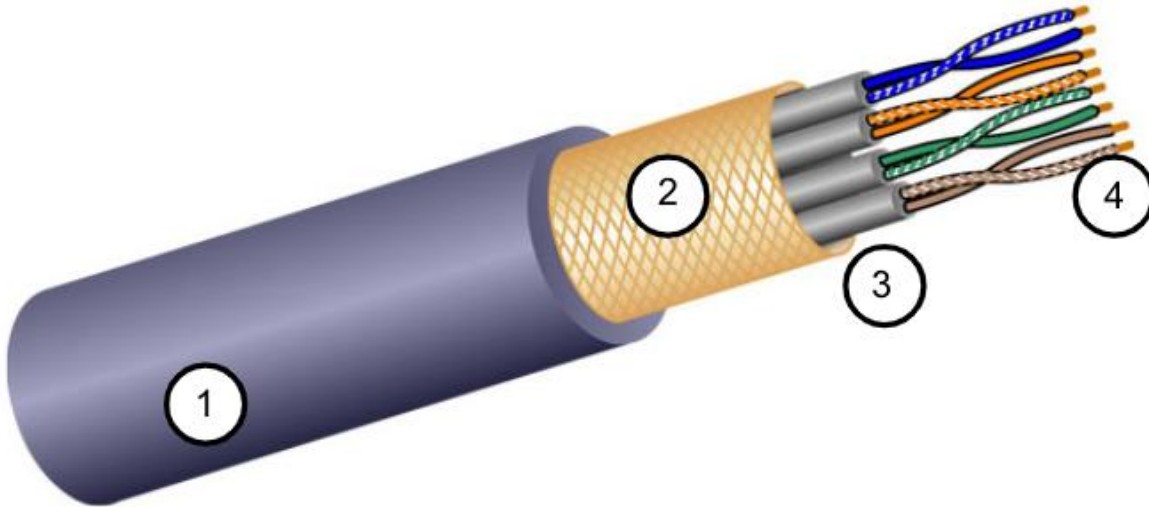
Copper Cabling

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

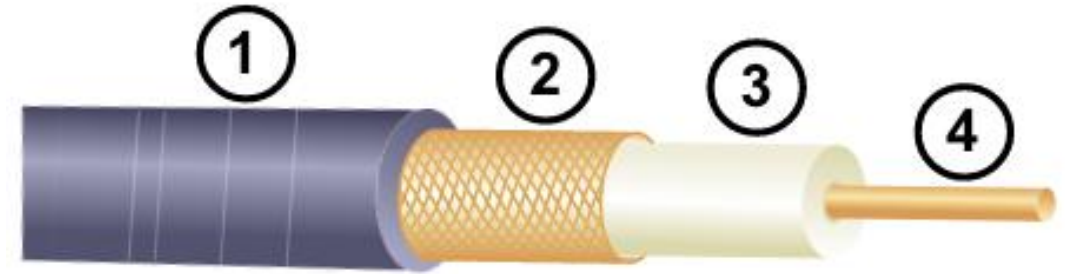


Copper Cabling

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



Fiber-Optic Cabling

Fiber-Optic Cabling

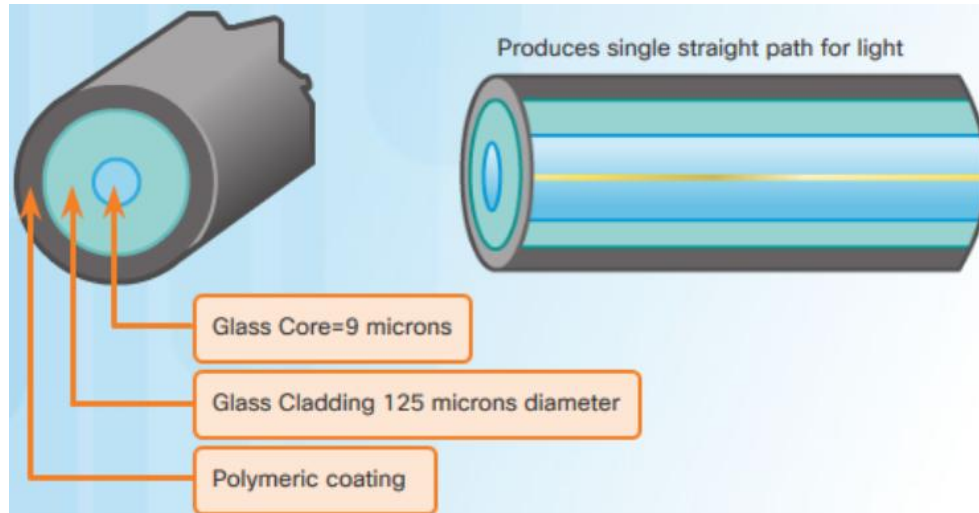
Properties of Fiber-Optic Cabling

- 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

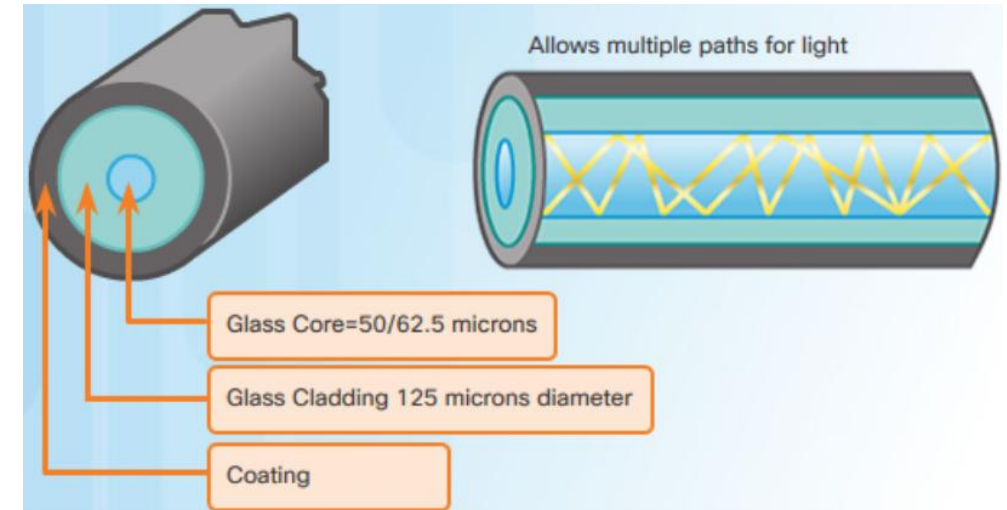
Types of Fiber Media

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.

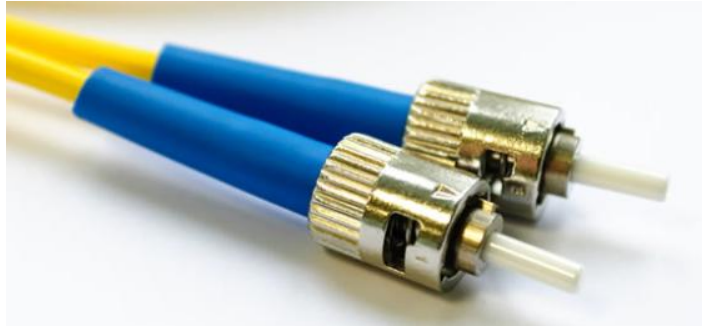
Fiber-Optic Cabling Usage

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.

Fiber-Optic Cabling

Fiber-Optic Connectors



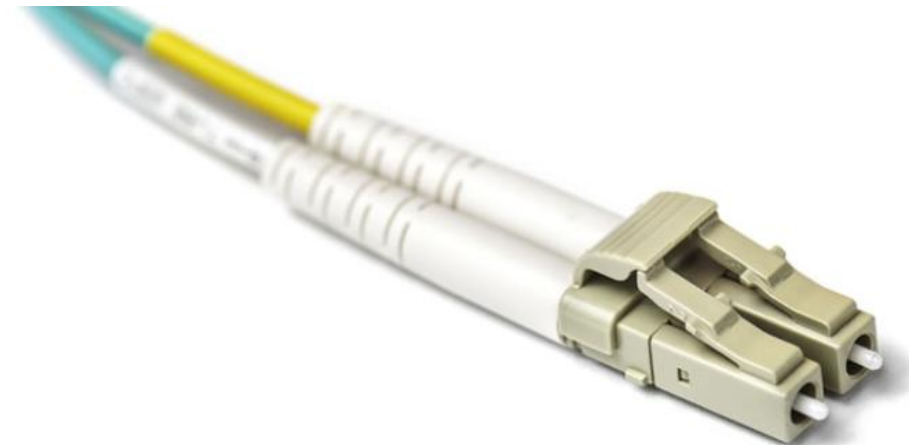
Straight-Tip (ST) Connectors



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

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

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

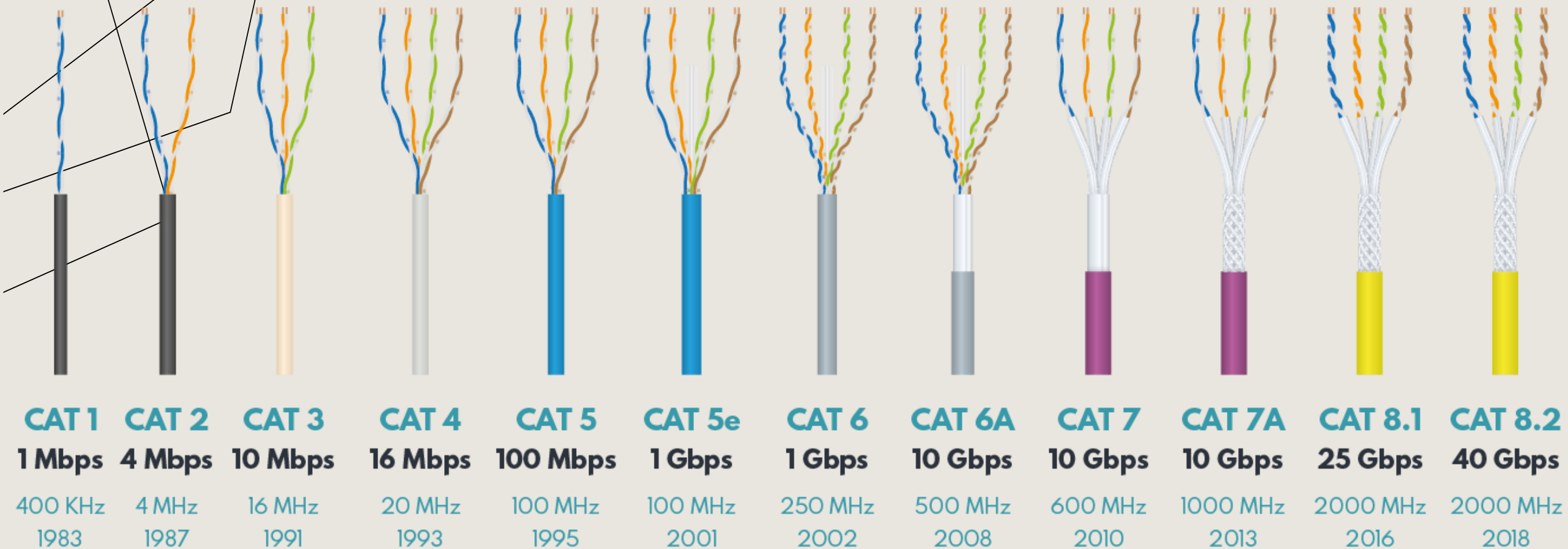
Wireless Standards:

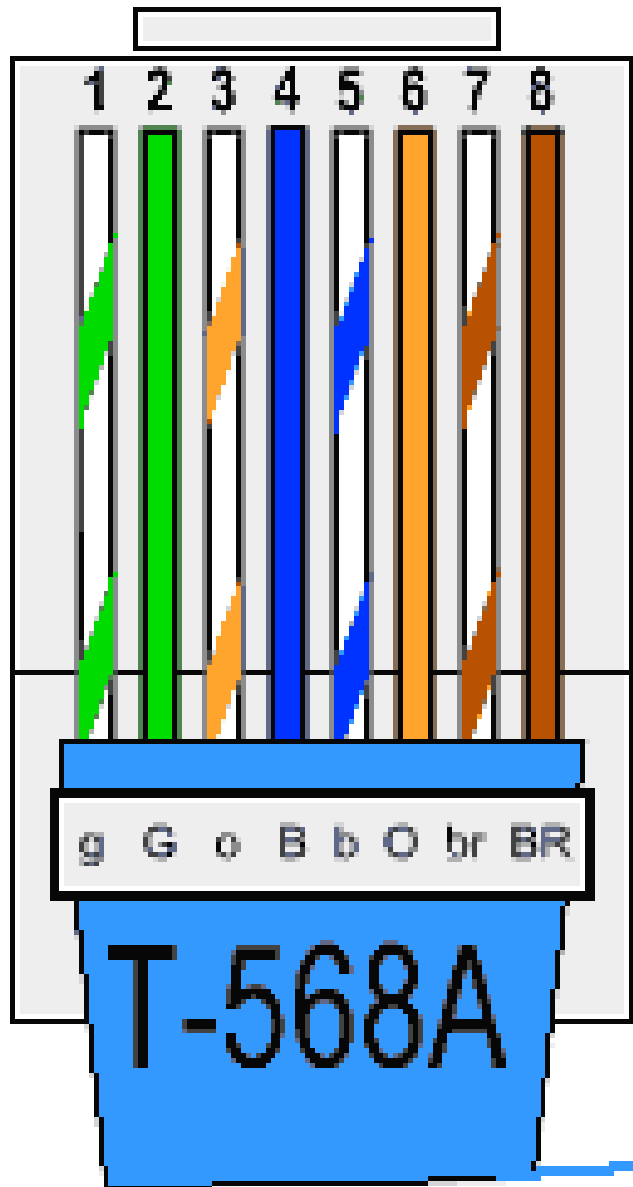
- **Wi-Fi (IEEE 802.11)** - Wireless LAN (WLAN) technology
- **Bluetooth (IEEE 802.15)** - Wireless Personal Area network (WPAN) standard
- **WiMAX (IEEE 802.16)** - Uses a point-to-multipoint topology to provide broadband wireless access
- **Zigbee (IEEE 802.15.4)** - Low data-rate, low power-consumption communications, primarily for Internet of Things (IoT) applications



LAN CABLE

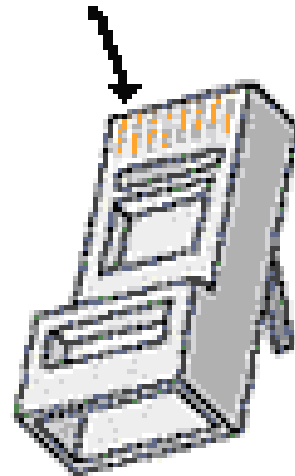
History of Ethernet LAN Cables' Categories



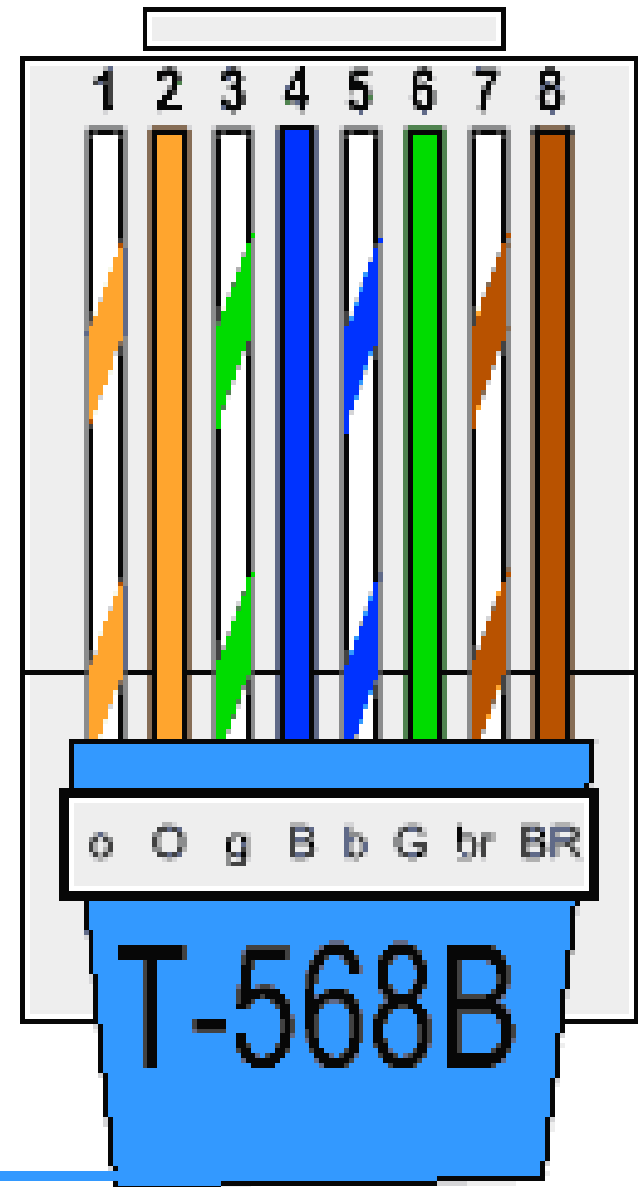


RJ-45 Plug

Pin 1



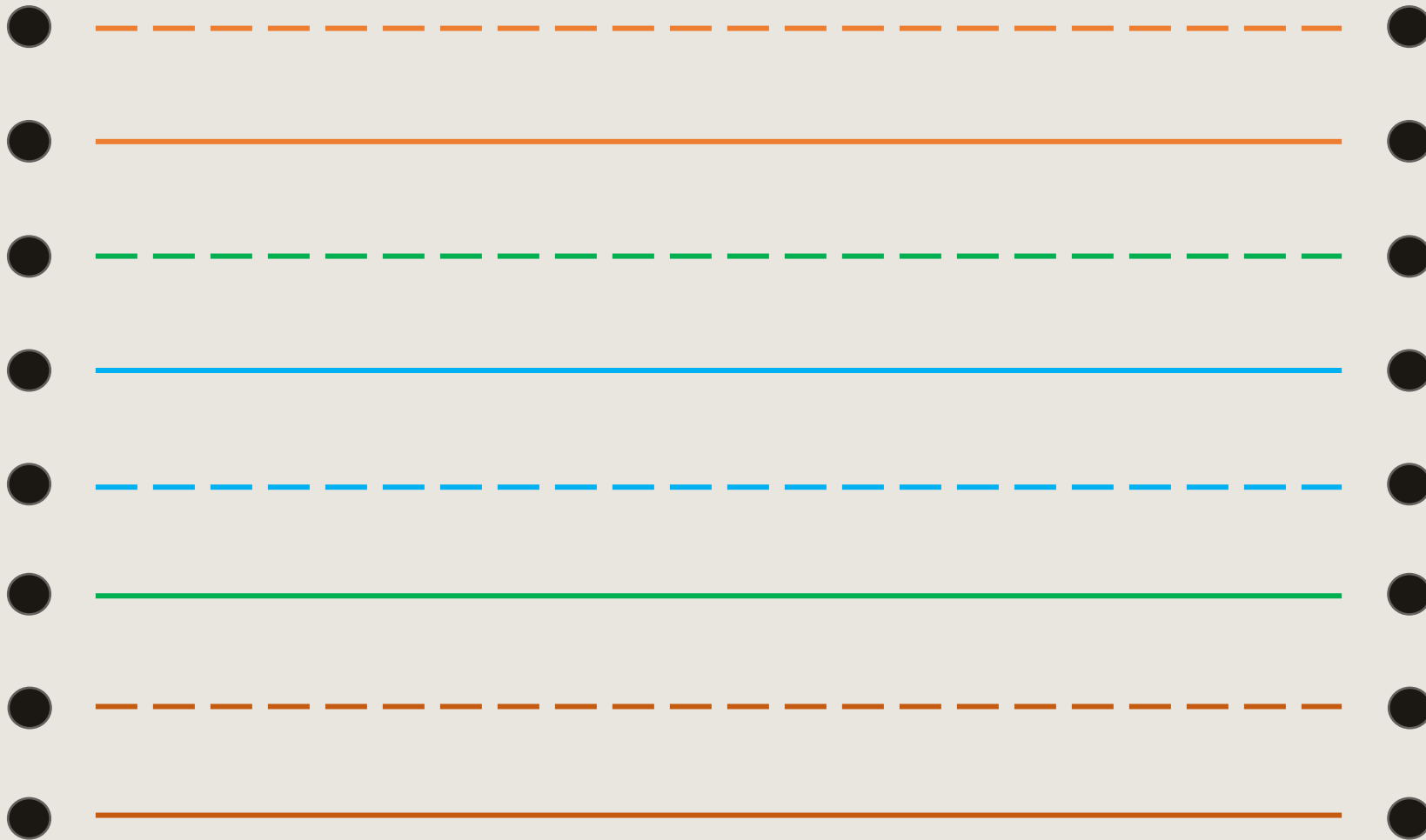
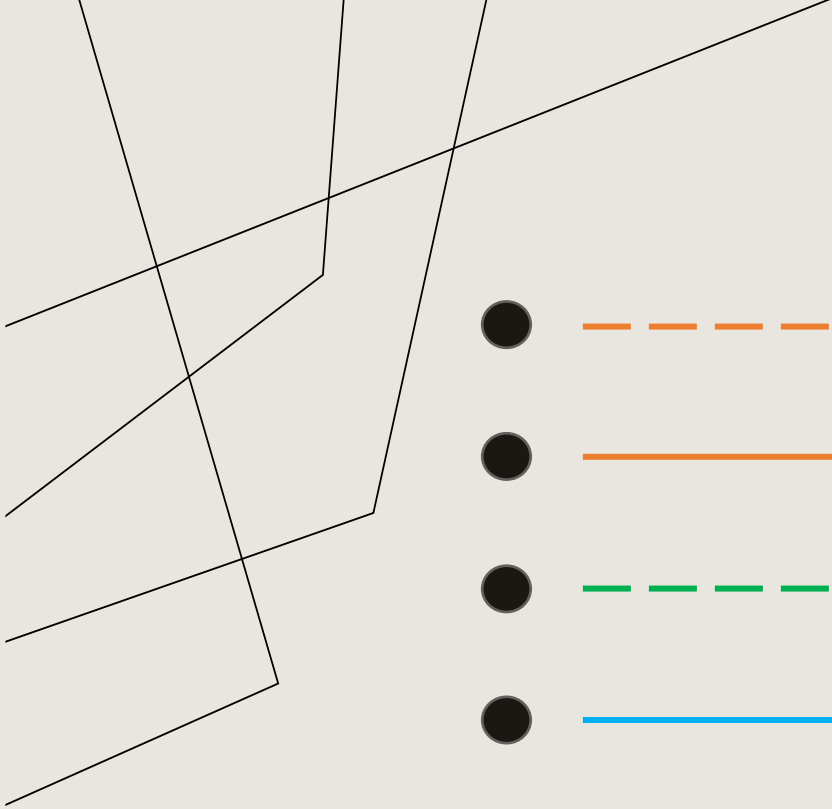
Clip is pointed
away from you.



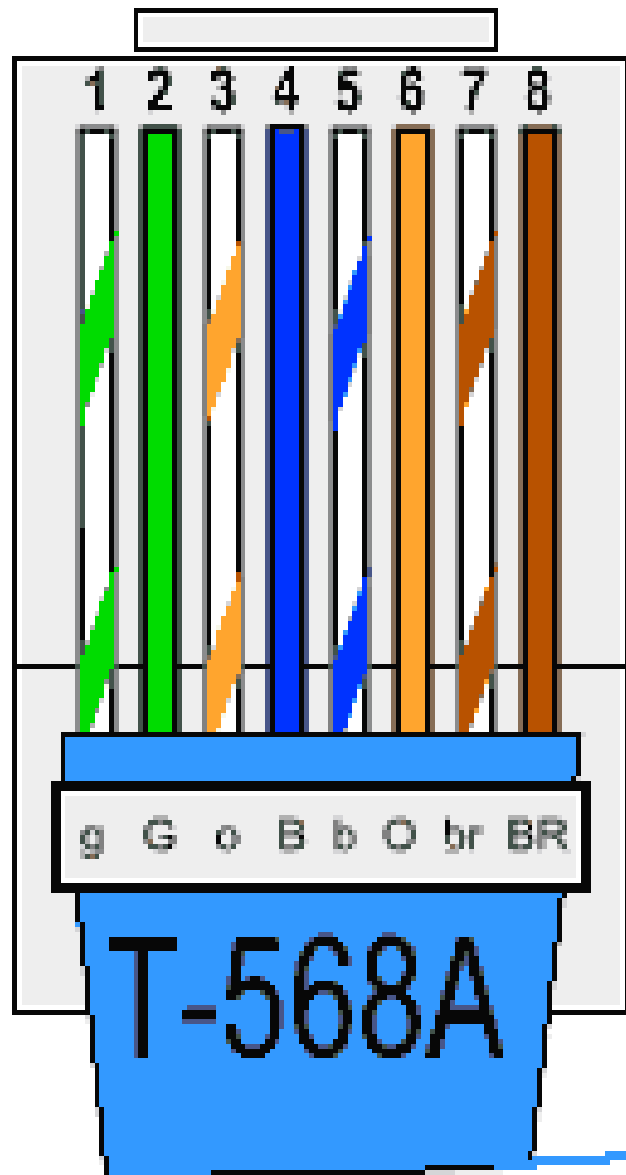


10BASE-T
100BASE-T = 2 pairs (4 wires)

1000BASE-T
10GBASE-t = 4 pairs (8 wires)

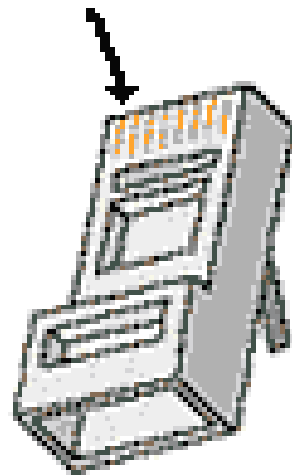


STRAIGHT-THROUGH

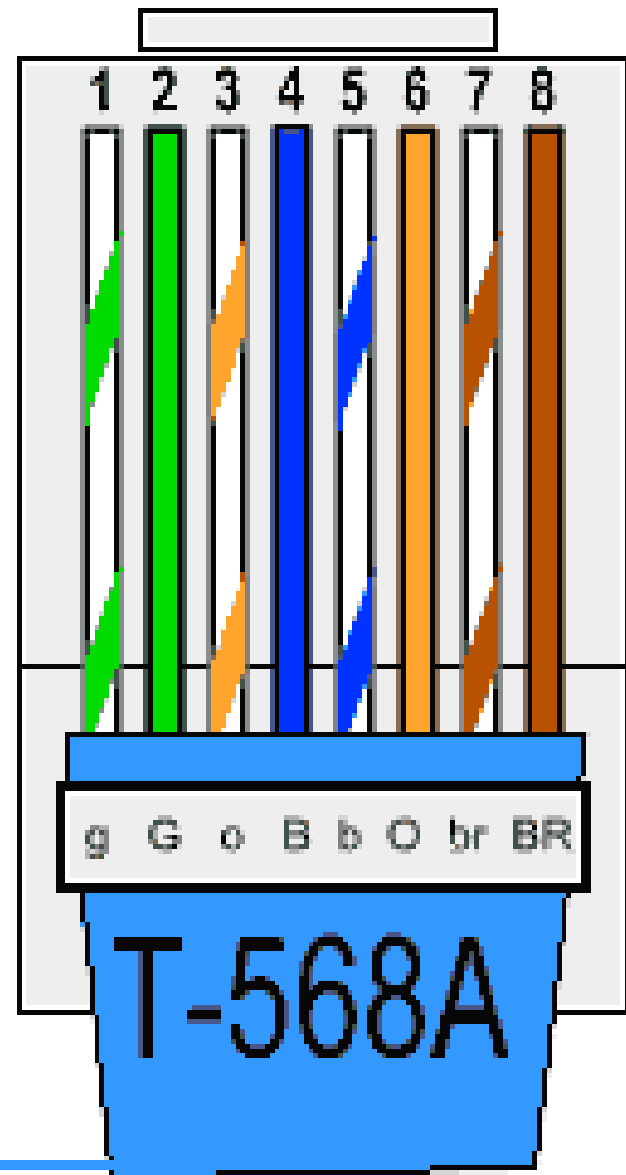


RJ-45 Plug

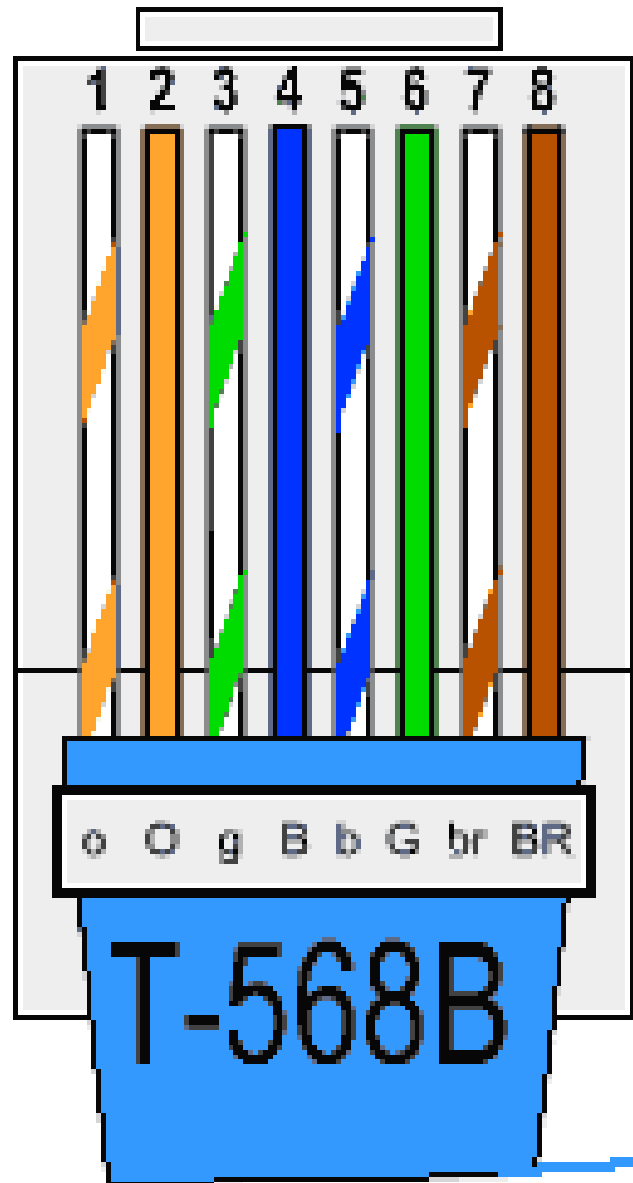
Pin 1



Clip is pointed away from you.

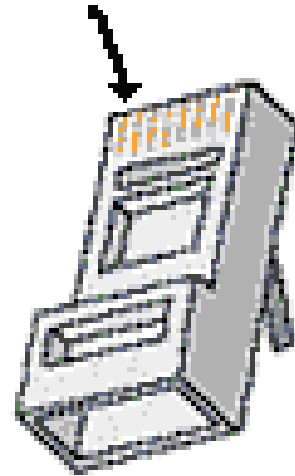


STRAIGHT-THROUGH

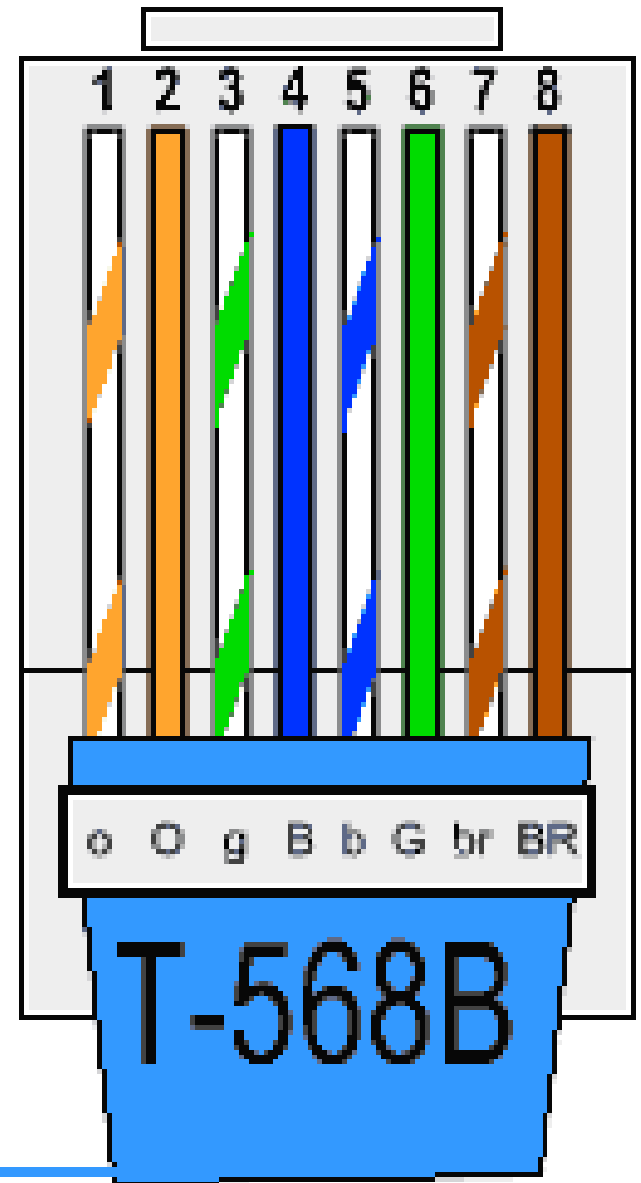


RJ-45 Plug

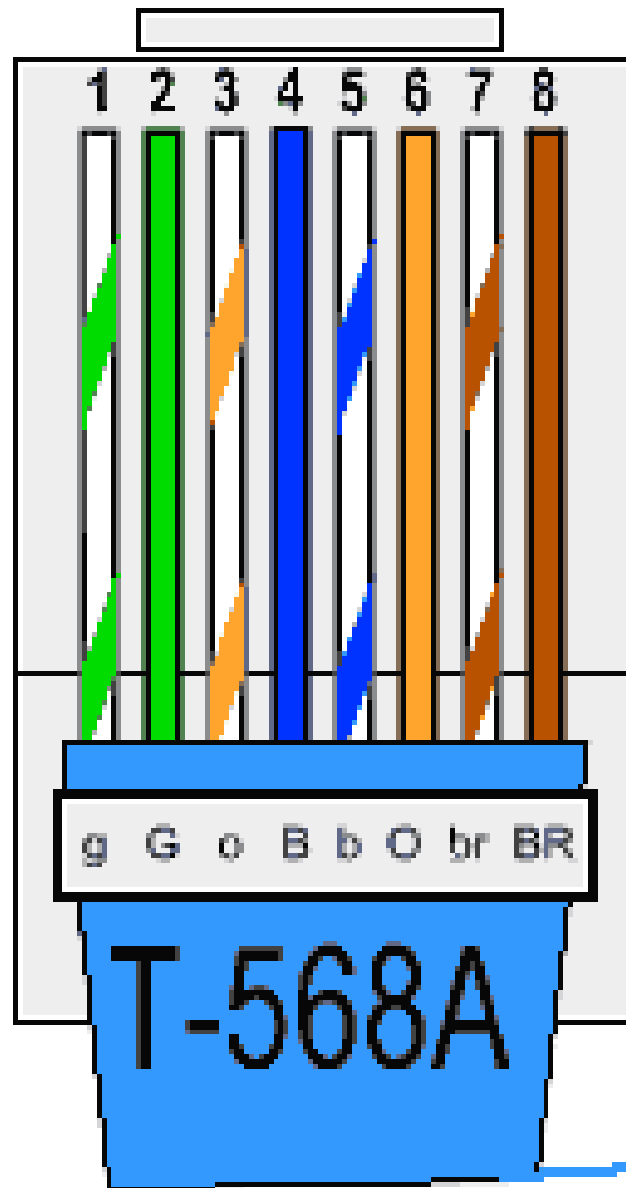
Pin 1



Clip is pointed
away from you.

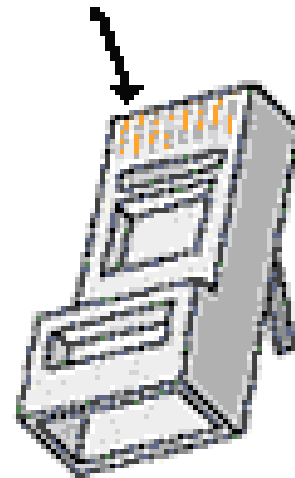


CROSSOVER

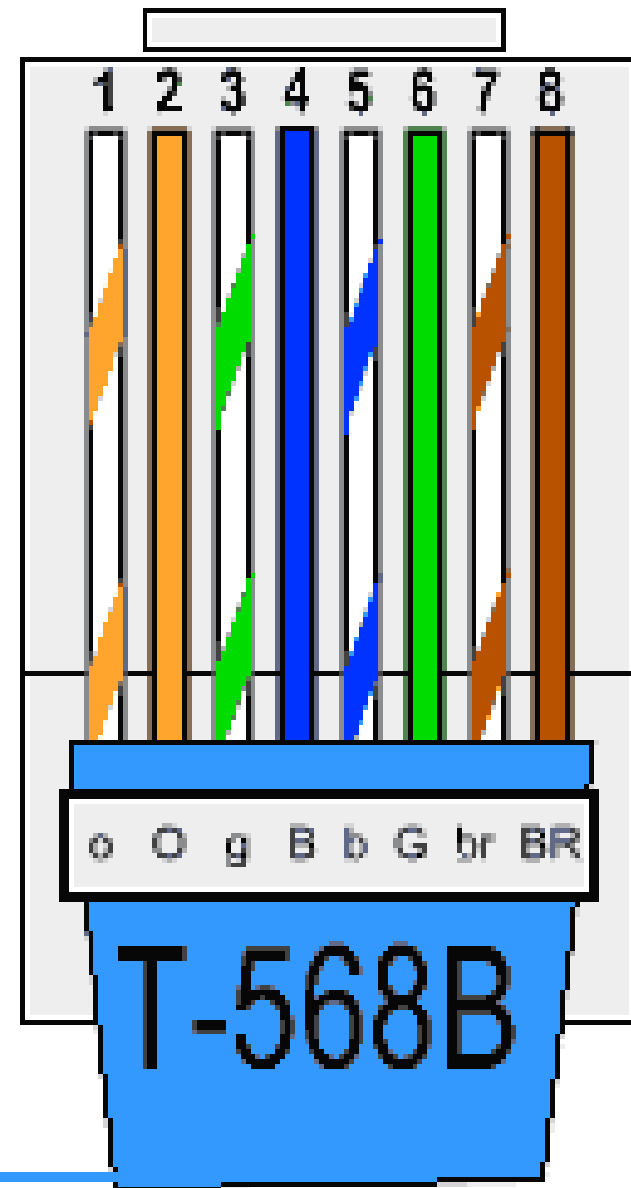






RJ-45 Plug

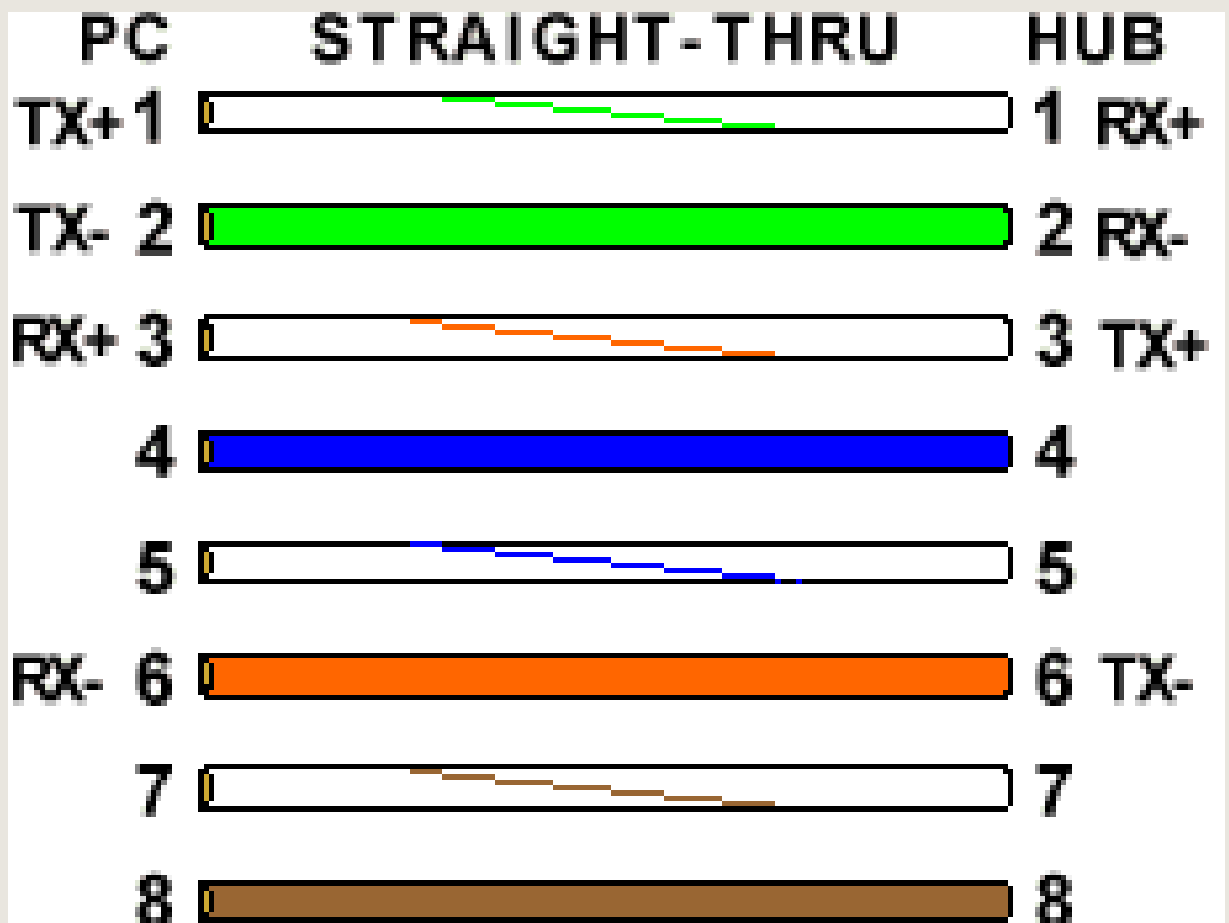
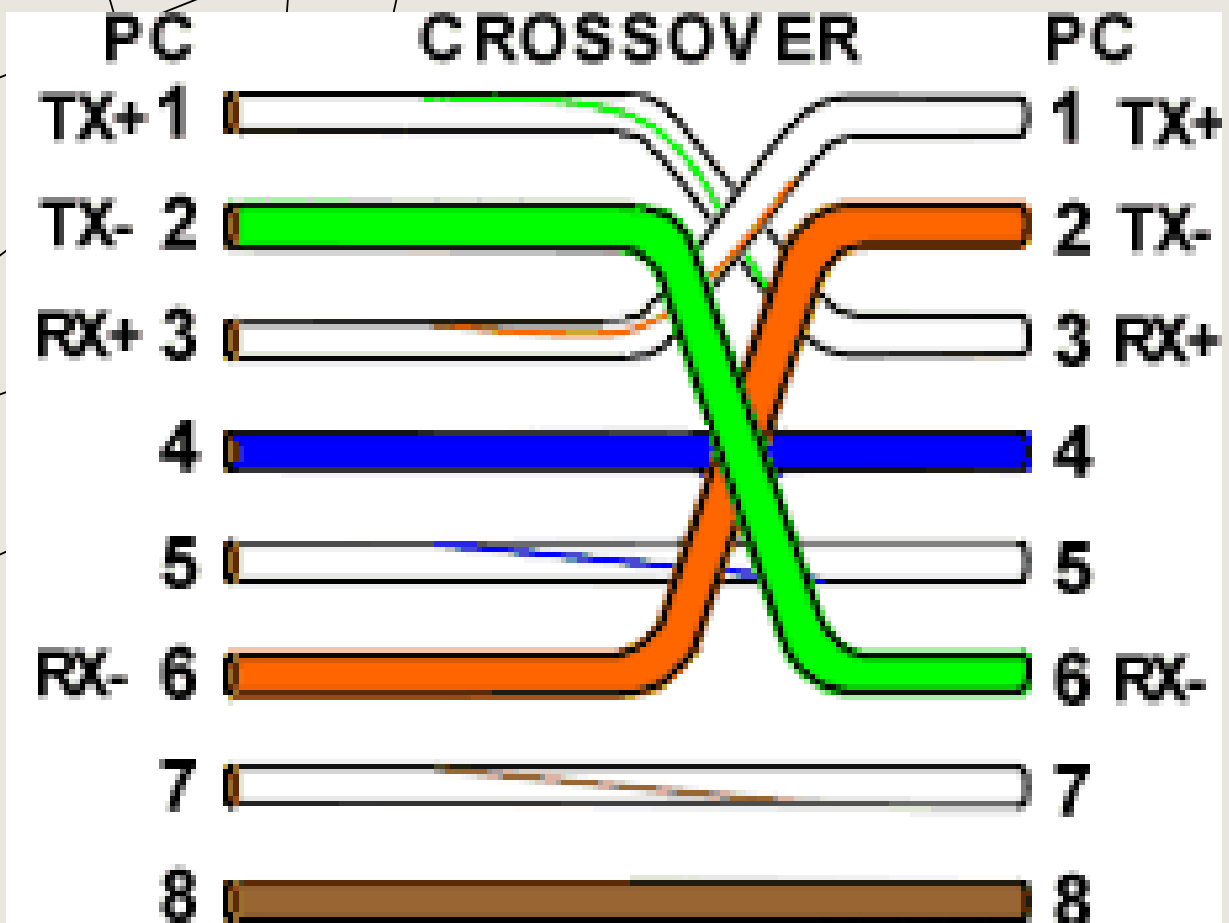
Pin 1



Clip is pointed
away from you.



Device Type		Transmit (Tx) Pins	Receive (Rx) Pins
Router		1 and 2	3 and 6
Firewall		1 and 2	3 and 6
PC		1 and 2	3 and 6
Switch		3 and 6	1 and 2



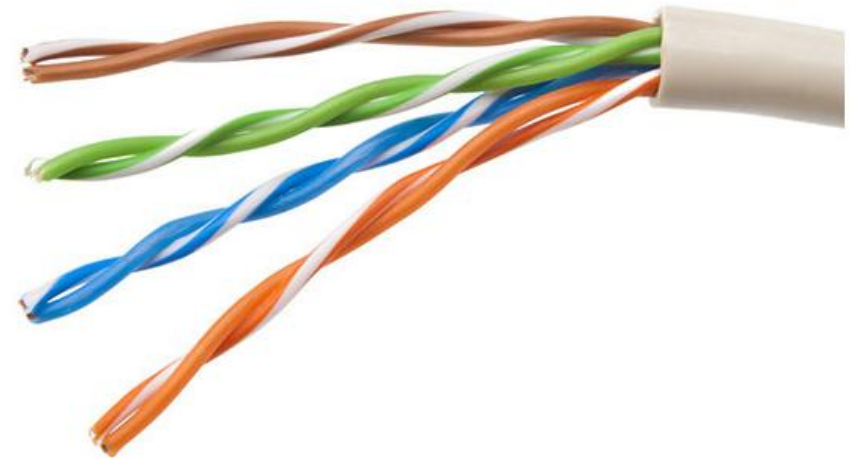
UTP Cabling

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

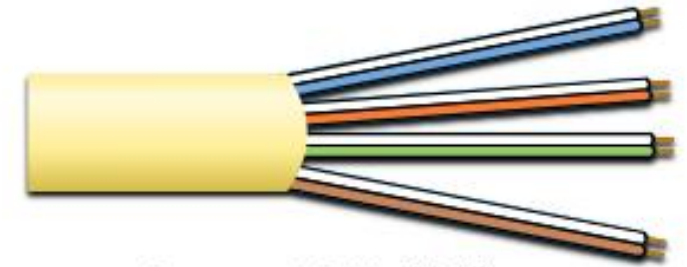
Standards for UTP are established by the TIA/EIA. TIA/EIA-568 standardizes elements like:

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

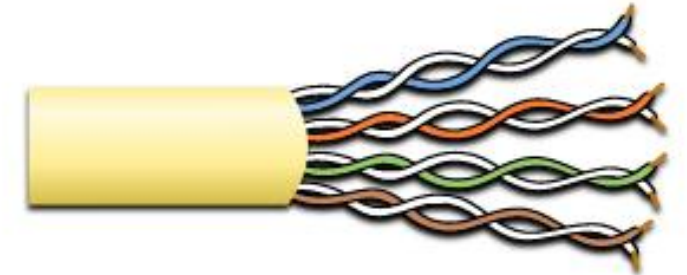
Electrical standards for copper cabling are established by the IEEE, which rates cable according to its performance.

Examples include:

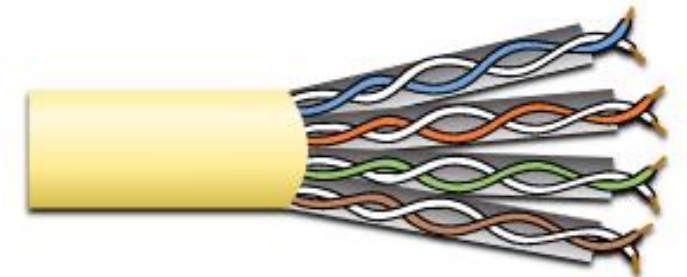
- Category 3
- Category 5 and 5e
- Category 6



Category 3 Cable (UTP)



Category 5 and 5e Cable (UTP)



Category 6 Cable (UTP)

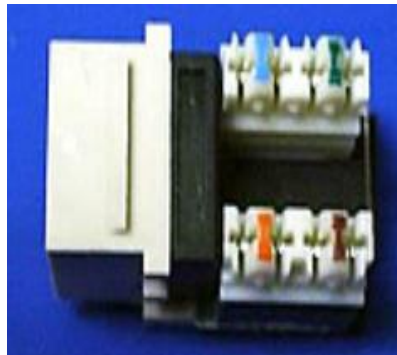
UTP Cabling Standards and Connectors (Cont.)



RJ-45 Connector



Poorly terminated UTP cable



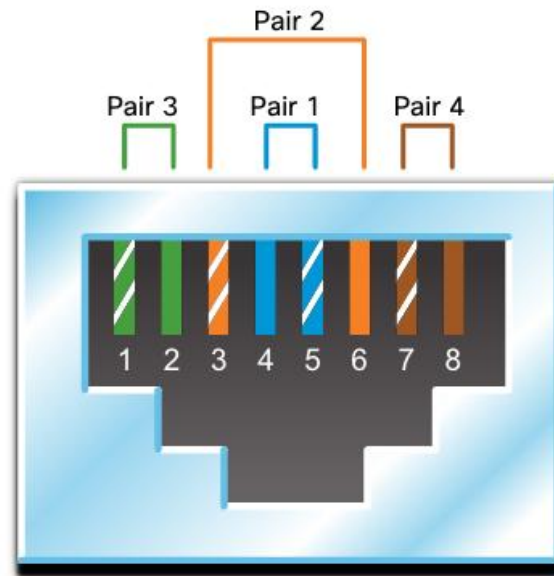
RJ-45 Socket



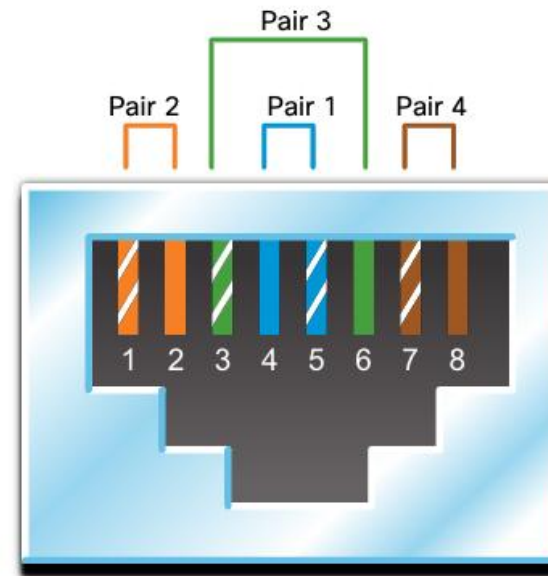
Properly terminated UTP cable

UTP Cabling

Straight-through and Crossover UTP Cables



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

UTP Cabling

Straight-through and Crossover UTP Cables

Prepare the following materials that will be used for the Practical #3

Materials	Quantity	Unit
Crimping Tool <ul style="list-style-type: none">• Crimper• UTP Cable Stripper• LAN Tester	1	set
RJ-45	30	pcs.
UTP Cable (CAT 5e / CAT 6)	10	meters

A series of white, thin, overlapping geometric lines on a black background, forming a complex, abstract shape on the left side of the slide.

THANK YOU