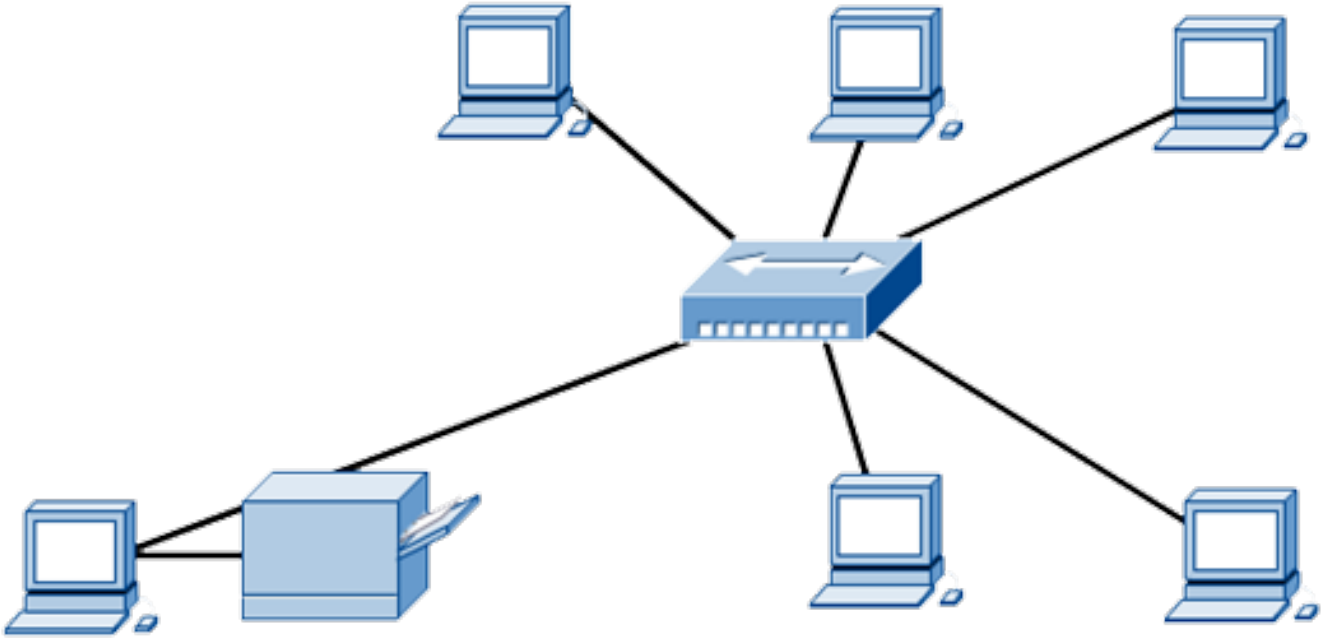
Network Fundamentals and Cabling

TELECOMMUNICATION AND NETWORKING

Computer Networks

- Defined as having two or more devices (such as workstations, printers, or servers) that are linked together for the purpose of sharing information, resources, or both



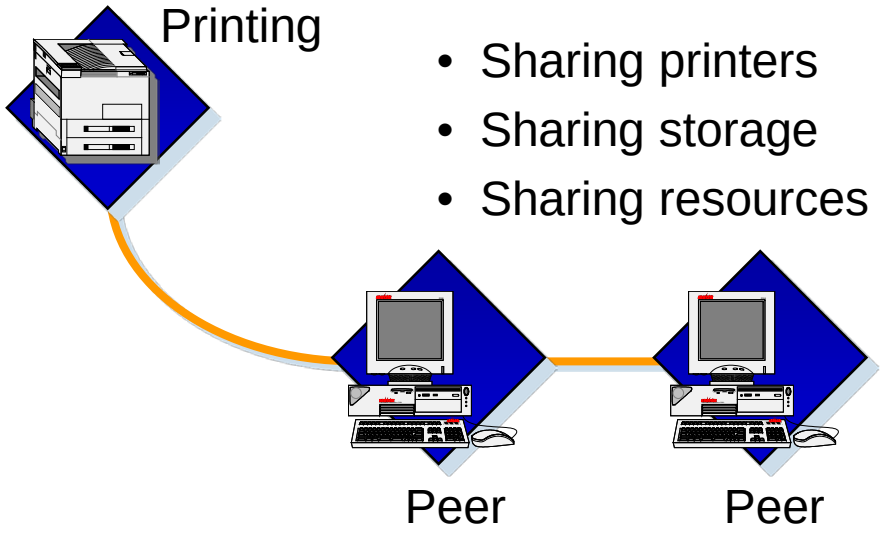
Why Do We Need Networking?

- Share printers
- Share Internet connection
- Access shared files
- Avoids duplication
- Allow multiple users
- Share resources

Networked computers may take on different roles or functions in relation to each other. They communicate using request/response protocols.

A Peer-to Peer Network (Workgroup)

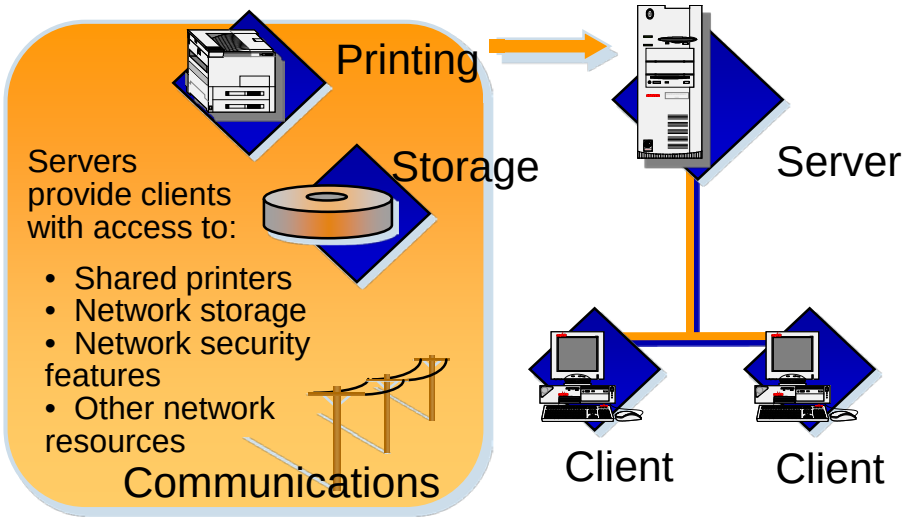
- Computers act as equal partners
- Individual users control their own resources
- Make their own decisions
- Works well in small numbers

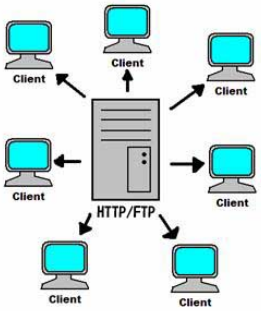


A Client/Server Network (Domain)

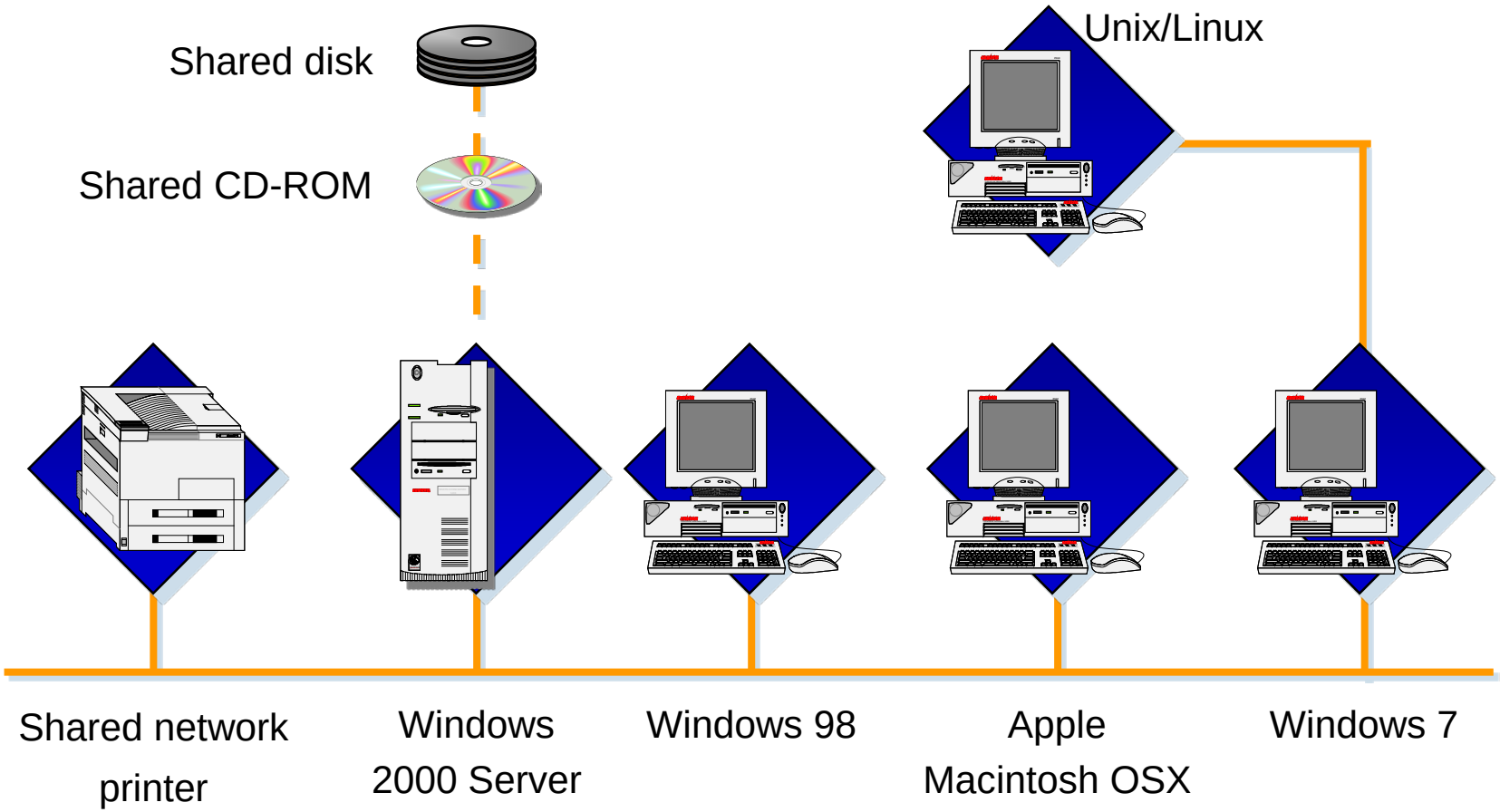
- Network services are located in a dedicated computer
- Serves many functions
- Share applications

- Server has:
  - Additional processing power
  - Additional memory
  - Specialized software





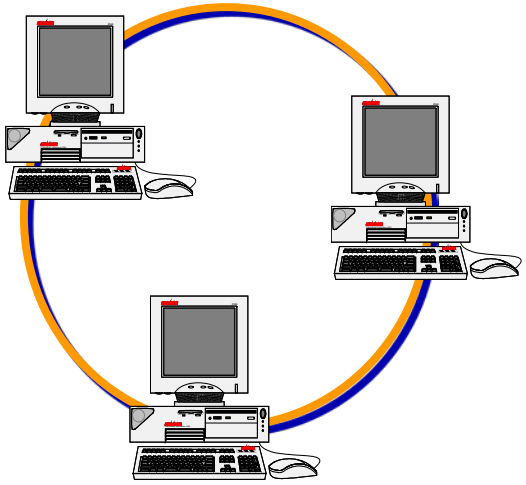
A Typical Network



Networks based on standard protocols, can communicate and share information from any OS

Local-Area Networks

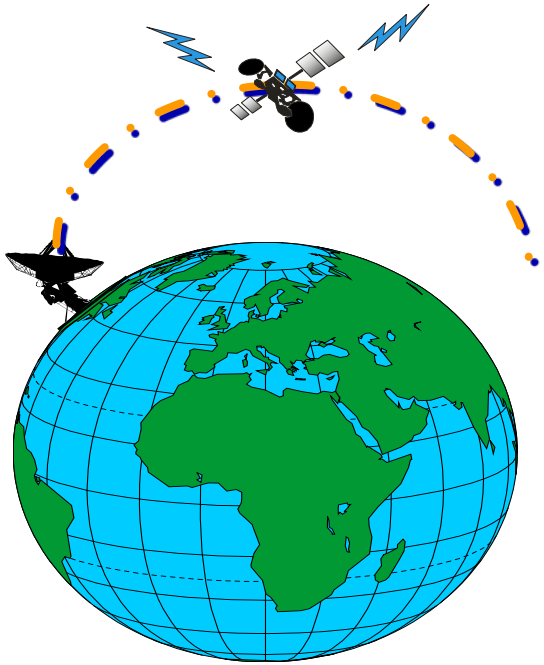
- **Topology**
  - Logical
  - Physical
- **Local Area Network (LAN)**
  - Small geographical area
  - Require shared communications channel
  - Medium



Local Area Network (LAN)
Small geographical area

Wide-Area Networks

- Large geographical area
- Use point-to-point, serial communications lines
- Use common carriers
- Connect fewer computers
- Operate at lower speeds
- Interconnect LANs
- Cover large distances



Wide Area Network (WAN)
Large geographical area

Other Types of Networks

- **MAN** (Metropolitan Area Network)
- **PAN** (Personal Area Network)
- **SAN** (Server Area Network)
- **NOS** (Network Attached Storage)

Circuit-switched vs. Packet-switched

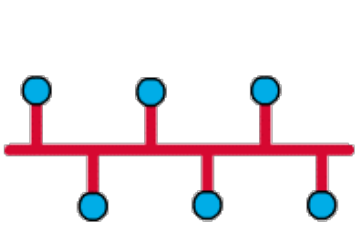
1. **Circuit-switched network**
   - Establishes connection
   - Transmits over that circuit
   - Modem
   - POTS
   - Any dial-up connection
2. **Packet-switched network**
   - Individual packets can take different paths
   - Always-on connection
   - Cable, DSL, T1
   - Internet traffic

Data Transmission

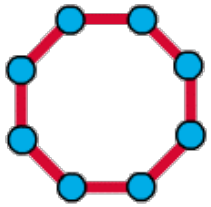
- Signals sent and received can operate in:
  - **Simplex**
  - **Half-duplex**
  - **Full-duplex**

Physical Topologies

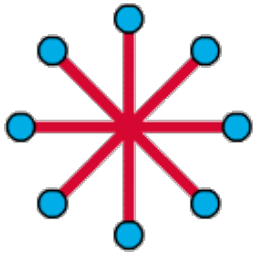
- Defines the way devices are connected



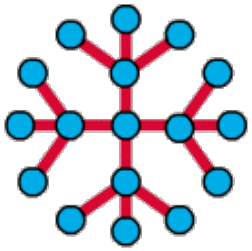
Bus Topology



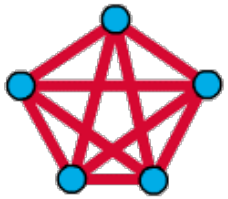
Ring Topology



Star Topology



Extended Star Topology



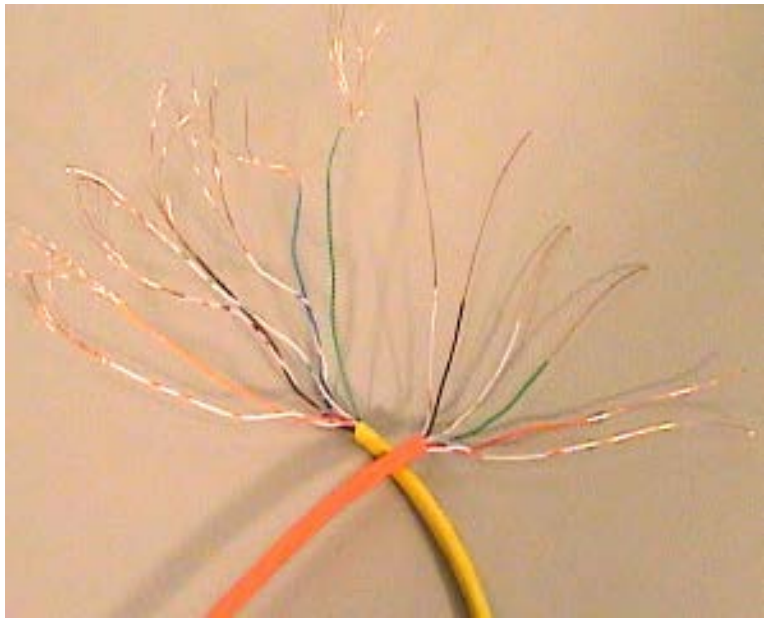
Mesh Topology

Copper Media

TELECOMMUNICATIONS AND NETWORKING

Copper Cable Components

- Copper wire
- Spacers to preserve the electrical properties of the cable
- Insulation to prevent short circuits between the individual conductors
- Kevlar strength member
- A sheath or jacket for protection

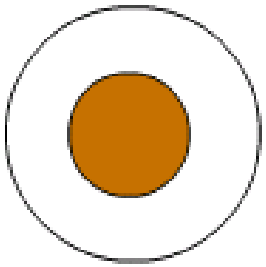


Copper Properties

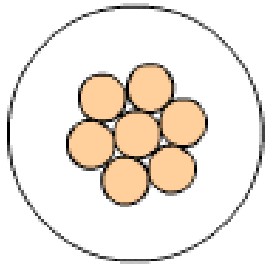
- **Conductivity**- Ability to conduct electrical current, excellent conductor of heat
- **Corrosion Resistance** – will not rust and is fairly resistant to corrosion
- **Ductility** - ability to be drawn into thin wires without breaking
- **Malleability** – easy to shape, does not crack and can be spun into unusual shapes
- **Strength** – Cold rolled copper has a tensile strength 3,500 to 4,900 kilograms per square centimeter. Copper keeps its strength and toughness up to about 400^{o}F (204^{o}C)

Stranded versus Solid

- The center conductor of each wire can be either solid or stranded
- Stranded wires are more flexible
  - They are used between wall jacks and computers
  - They are typically used in military and aviation applications
- Solid wires are more sturdy
  - Also used for patch cables that are plugged and unplugged frequently



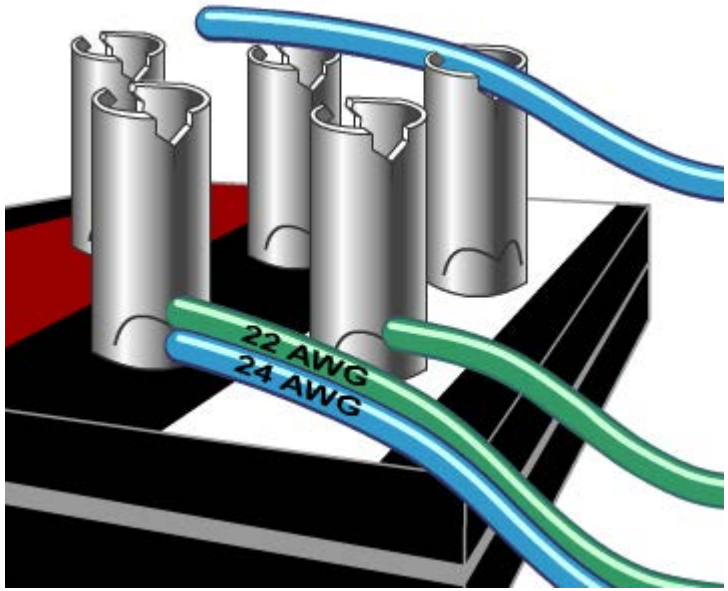
Solid Core

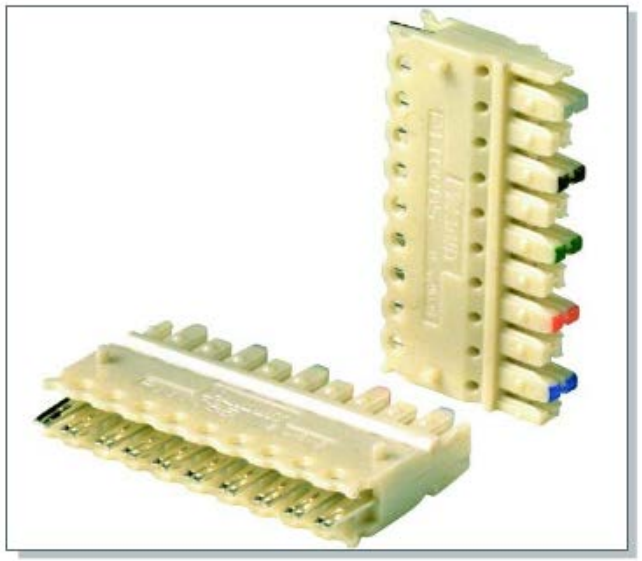


Stranded Core

Solid Wires

- More desirable when connections are to be made to standard insulation displacement connectors (IDCs).
- Connectors work by inserting the wire into grippers that have sharp internal edges. These grippers make contact by cutting through the insulation and biting into the copper conductor.
- This method works best when the conductor is solid.





Connector clips use IDCs to terminate copper conductors on 110-blocks.

Cable Insulation

- Used as a high resistance material that is coated on the conductor to resist the flow of current between conductors in the cable.
- Sometimes referred as the dielectric part of the cable.
- Several types of materials used for insulation, each having its advantages and disadvantages. The type of insulation used depends on the intended application of the cable.
- There are Three primary categories of insulators.
  - Thermoplastics - Polyvinylchloride (PVC), These are widely used and resist most sunlight, ozone, oil, and solvents
  - Flouropolymers (**fluorinated ethylene propylene)** - Halar and Teflon. These are used for high temperature applications
  - Elastomers - These are rubber like and return to shape after tension is released

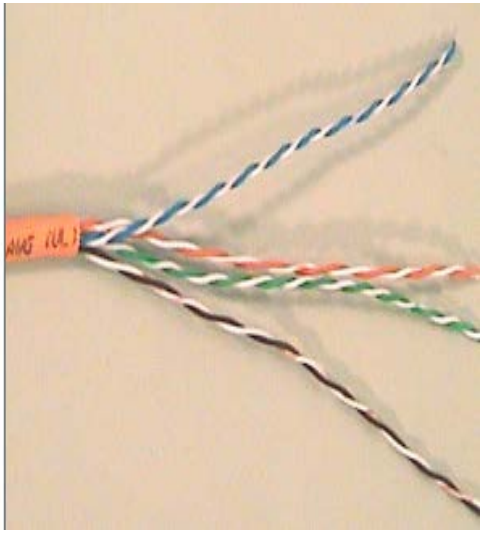
Flouropolymers - Plenum

- Cables often run in ventilation system return spaces above ceilings or below floors
- Such spaces, called plenums, must not quickly fill with toxic gasses should a small fire break out because the air conditioning system will spread the poisonous fumes to other areas of the building
- Plenum-rated cables have jackets made of materials that are slow burning and do not emit noxious fumes

Types of Cables

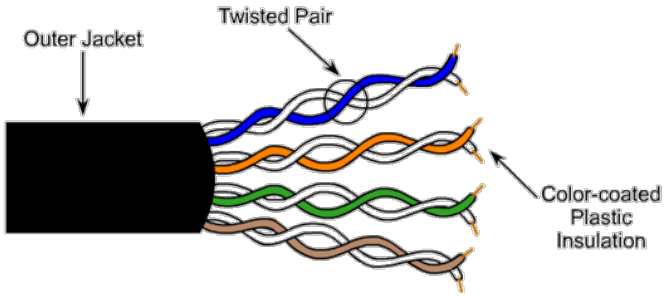
- **Twisted-pair** cabling consists of pairs of insulated copper wires that are twisted together and then housed in a protective sheath.
  - UTP – Unshielded Twisted Pair
  - STP – Shielded Twisted Pair
- **Coaxial cable** consists of a copper center conductor, either stranded or solid, which is wrapped in insulation and covered with one or more layers of braid and foil. The cable is encased in a durable outer jacket.

Twisted Pair Cable Overview



- Precision system for conveying electronic signals
- Consist of 4 or more pairs of insulated copper wires that are twisted together
- 8-position, 8-contact (8P8C) modular connector, also known as the Registered Jack 45 (RJ-45) connector
- Sometimes the wires in a twisted-pair cable are mounted to connectors in an array called a patch panel

Benefits of Twisted-Pair Cables



- The twisting of each pair of wires provides a ***cancellation effect*** that helps neutralize noise and null out interference.
- Because the signals in each wire of the pair are going opposite directions, the interference adds to the signal in one wire as it resists the signal in the other wire. The result is that in twisted-pairs, interference such as EMI and RFI tends to be canceled out.

Issues that affect cabling performance

- Signal reconstruction – higher frequencies could cause signal degradation
- Manufacturing tolerances – some fuse each pair to keep wires from shifting
- Optimum twist ratios
- Reducing twist-induced skew
- Separating pairs physically – to keep pair separation constant

Category Improvements

- The TIA/EIA/ANSI standards evolve through an interactive committee process so change is constant.
- Most improvements are a result of improved manufacturing.
  - For instance, the gauge of the center conductors is more consistent than in the past.
  - The insulation covering wires has uniform chemical properties and thickness.
- These improvements result in a more uniform cable, which helps eliminate signal problems as operating frequencies increase.

Category 1 Cable

- Typically 22 American Wire Gauge (AWG) or 24 AWG untwisted wire, with a wide range of impedance and attenuation values.
- Not recommended for data in general and certainly not for any signaling with speeds over 1Mbps.
- Not recognized as part of ANSI/TIA/EIA-568-B.1 and ANSI/TIA/EIA-568-B.2, therefore it is not part of modern structured cabling systems
- Telephones and doorbells

Category 2 Cable

- Maximum data rate of up to 4Mbps
- 22AWG – 24AWG solid wire in twisted pairs
- Maximum bandwidth of 1MHz, but not tested for crosstalk
- Not recognized as ANSI/TIA/EIA-568B.1 and B.2

Category 3 Cable

- 100 Ohm UTP cables with 4 pairs
- 24 AWG solid copper wire in twisted-pairs
- Tested for attenuation and crosstalk through 16 MHz
- Popular for telephone wiring

Category 4 Cable

- Primarily used for Token Ring networks
- 4 pairs of 22-24 AWG wire
- 100 ohm
- Performance bandwidth of 20MHz
- Not recognized as ANSI/TIA/EIA-568-B.1 or B.2

Category 5

- 100 ohm
- Transmission up to 100 MHz
- Operates under the 100BaseT specification, needs multiple wire pairs within the same cable to split the data stream

Category 5e

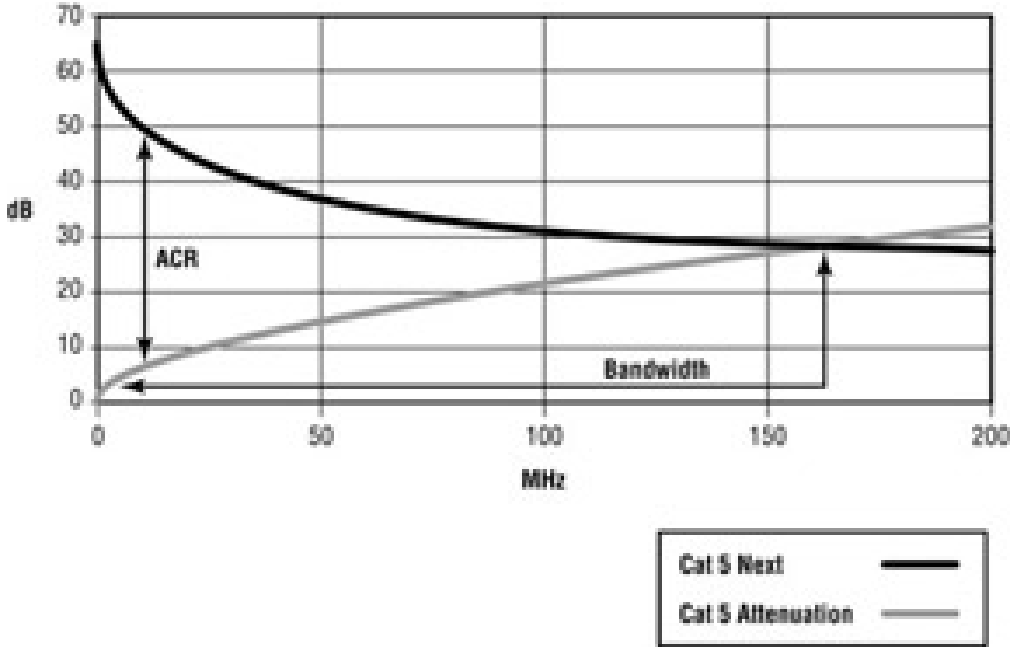
- e = enhanced
- More twists than Category 5
- Extra twists improve performance by resisting interference
- Tighter twisting allows cables to resist separation and bunching during installation
- Made for 100Mb installations
- Limited 1000Mb
- Most widely used cable

Category 6

- Latest wiring type available for installation and use
- 4 pairs of 24 AWG copper wires
- More twists than Category 5e
- Reduction of crosstalk forms a more reliable medium for 1000Base-TX
- Currently the fastest approved standard for UTP
- More expensive

Attenuation-to-Crosstalk Ratio (ACR)

- A mathematical formula that calculates the ratio of attenuation to near-end crosstalk for each combination of cable pairs.
- ACR can be used to define a signal bandwidth
- TIA standard defines performance in categories (Cat 3, Cat 5e, Cat 6) and the ISO defines classes (Class C, D, E, and F)

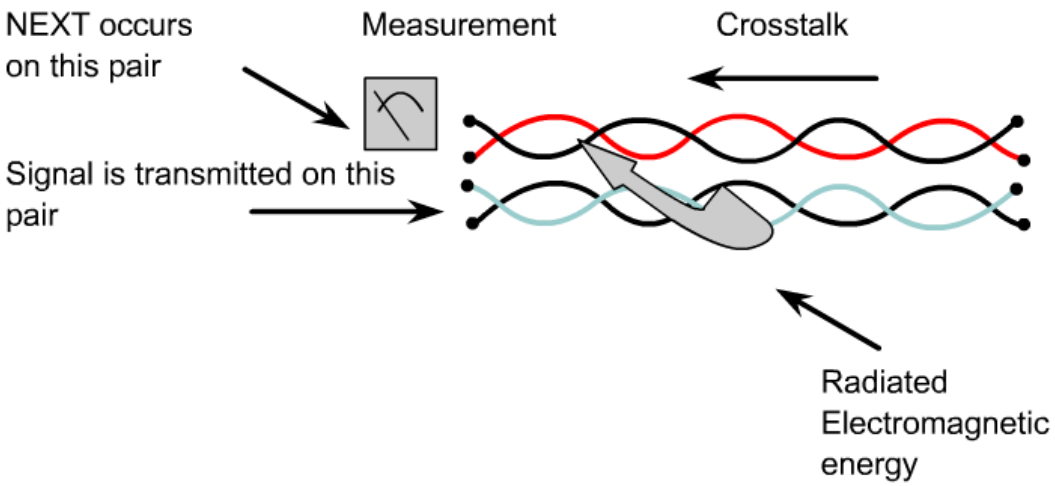


Attenuation-to-Crosstalk Ratio (ACR)

Parameter	Cat 5e	Cat 6
Frequency Range	1 – 100 MHz	1 – 250 MHz
Propagation Delay	548 ns @ 100 MHz	548 ns @ 100 MHz 546 ns @ 250 MHz
Delay Skew	50 ns	50ns
Insertion Loss	24 dB	21.3 dB @ 100 MHz 36 dB @ 250 MHz
NEXT Near End CrossTalk	30.1 dB	39.9 dB @ 100 MHz 33.1 dB @ 250 MHz
PSNEXT Power Sum	27.1 dB	37.1 dB @ 100 MHz 30.2 dB @ 250 MHz
ELFEXT Equal Level Far End CrossTalk	17.4 dB	23.2 dB @ 100 MHz 15.3 dB @ 250 MHz
PS-ELFEXT	14.4 dB	20.2 dB @ 100 MHz 12.3 dB @ 250 MHz
Return Loss	10 dB	18.6 dB @ 100 MHz 8 dB @ 250 MHz

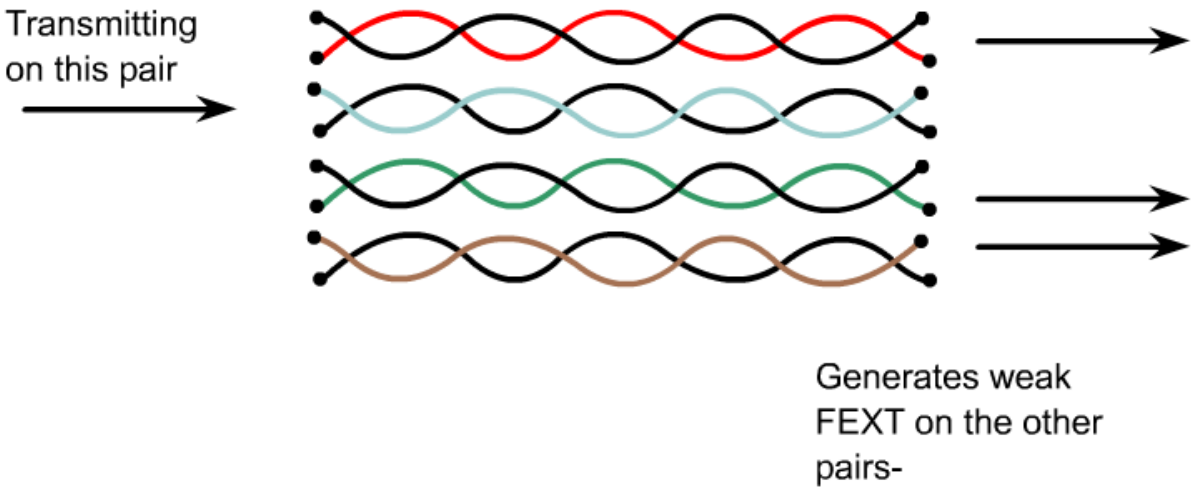
CAT5e – 100MHz CAT6 – 250MHz CAT6a – 750MHz

Near-end Crosstalk (NEXT)



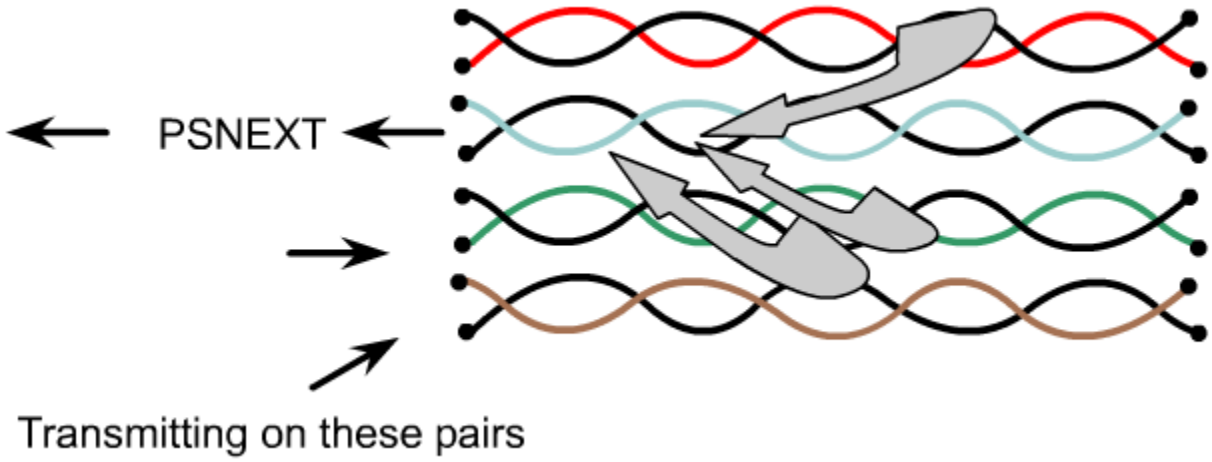
- **Near-end crosstalk (NEXT)** is computed as the ratio of voltage amplitude between the test signal and the crosstalk signal when measured from the same end of the link.

Far-end Crosstalk (FEXT)



- Due to attenuation, crosstalk occurring further away from the transmitter creates less noise on a cable than NEXT.
- This is called **far-end crosstalk, or FEXT.**
- The noise caused by FEXT still travels back to the source, but it is attenuated as it returns.
- Thus, FEXT is not as significant a problem as NEXT.

Power Sum Near-end Crosstalk (PSNEXT)



- **Power Sum NEXT (PSNEXT)** measures the cumulative effect of NEXT from all wire pairs in the cable.
- PSNEXT is computed for each wire pair based on the NEXT effects of the other three pairs.
- The combined effect of crosstalk from multiple simultaneous transmission sources can be very detrimental to the signal.

Cable Testing Standards

- The ten primary test parameters that must be verified for a cable link to meet TIA/EIA standards are:
  - Wire map
  - Insertion loss
  - Near-end crosstalk (NEXT)
  - Power sum near-end crosstalk (PSNEXT)
  - Equal-level far-end crosstalk (ELFEXT)
  - Power sum equal-level far-end crosstalk (PSELFEXT)
  - Return loss
  - Propagation delay
  - Cable length
  - Delay skew

Future Categories

- Cables that can move traffic at 1000 Megabit per second (Gigabit Ethernet) are available and many leading firms have already installed them.
- Speeds of 10 Gbps or even 40 Gbps are in development. Such data rates could allow twisted-pair cable to provide all the functions of the wired desktop such as phones, faxes, networked computers, and even video conferencing.
- Advanced cabling is a key consideration in the design and implementation of next generation networks

Things that can go wrong with Twisted Pair

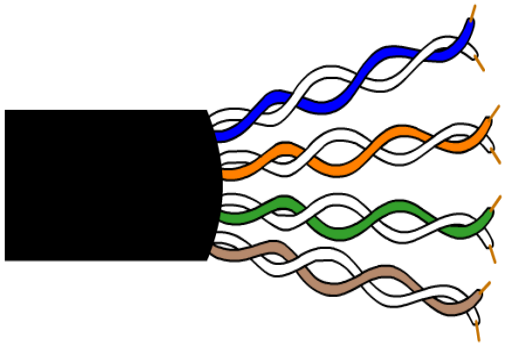
- Conductors are not the same diameter (AWG), length or same resistance. This is called resistance unbalance.
- Conductors that are not in the center of their insulation or vary in distance between them. This is called capacitance unbalance.
- Each pair has the same number of twists.
- Pairs forced together or apart by bending the cable, increasing crosstalk.
- Cables untwisted excessively at the point of termination.

Note: While the manufacturer controls some of these things, most of them are caused or contributed to by careless installation.

Cancellation Effect

- The interwoven nature of each pair of wires provides a ***cancellation effect*** that helps neutralize noise and null out interference.
- Installers must preserve the twisting nature of the pairs in these cables to avoid introducing performance-degrading problems into the wiring.
- The proximity of wires may allow them to cancel out each other's fields, but they still emit magnetic lines of force that can affect other wires near them.
- The result is that in twisted-pairs, interference such as EMI and RFI tends to be canceled out.

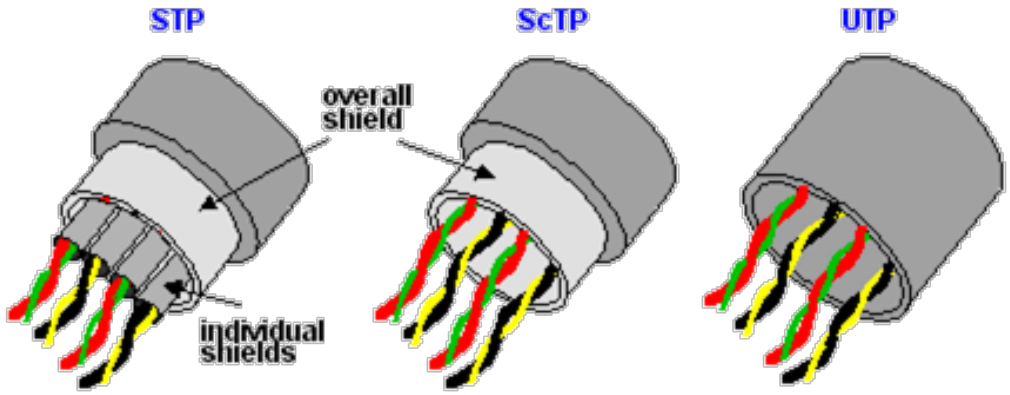
UTP (Unshielded Twisted Pair)



- Type of twisted-pair cable that relies solely on the cancellation effect produced by the twisted wire pairs to limit signal degradation caused by:
  - EMI (Electromagnetic Interference)
  - RFI (Radio Frequency Interference).
- UTP cable must follow precise specifications as to how many twists are permitted.
- More twists result in fewer problems with signal degradation.
- It also means that the path the electrons travel is longer. Since the number of twists varies between pairs in the same cable, cables with more twists have a higher incidence of bits traveling in different pairs arriving at slightly different intervals due to the longer cable. When this problem occurs, it is called **skew**.

Shielded (STP) & variations

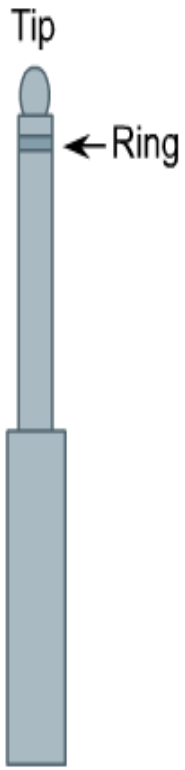
- Shielded twisted-pair (STP) has shielding around each pair to prevent EMI and crosstalk.
- Used in noisy environments where the shield around each of the wire pairs, plus an overall shield, protects against excessive electromagnetic interference
- Screened twisted-pair (ScTP) is simply a variation of STP and uses only the overall shield and provides more protection than UTP, but not as much as STP.



STP precautions

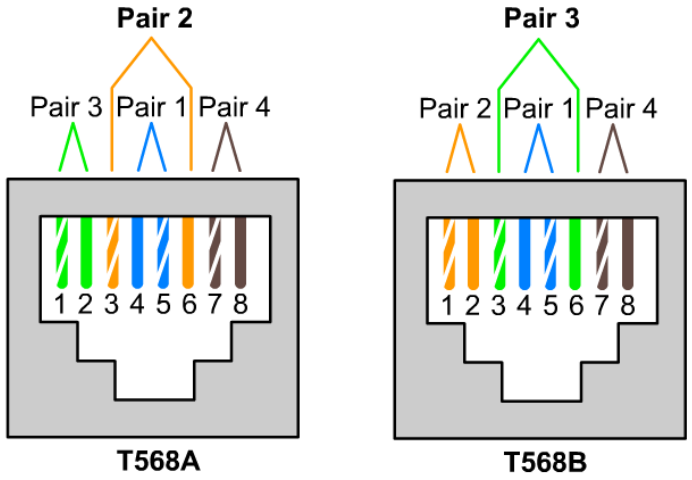
- The ground wire should be attached to the metallic band around every RJ-45 connector.
- The screen or drain wire should always be connected to the equipment bonding system at the patch panel.

Color Codes for Twisted Pair



- Old-time patch panel switchboards used in phone telephone offices are the source of some of the unique terminology of wiring.
- Each of the wires in a pair has a unique name: **tip or ring**.
- Operators inserted probes, called *plugs*, into receptacles, called *jacks*. One conductor fastened to the tip of the plug. The other conductor was fastened to a ring around the plug. In time, these wires came to be known as tip and ring, a designation that continues to this day.

Cable Standards



- The Ethernet standard specifies that each of the pins on an RJ-45 connector have a particular purpose.
- The wires in UTP cable must be connected to the proper pins at each end of a cable.

Color Code for 4-pair

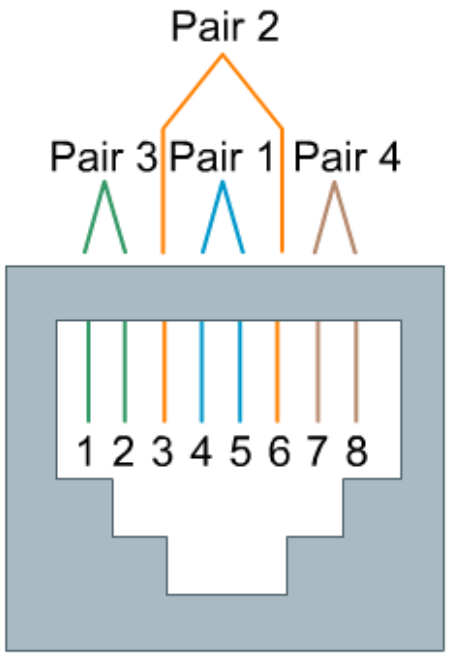
- Each of the wires in a pair has a unique color assigned to the tip and ring
  - Tip always denotes the striped wire
  - Ring always denotes the solid colored wire

Pair	Tip	Ring
Pair 1	**White/Blue**	**Blue**
Pair 2	**White/Orange**	**Orange**
Pair 3	**White/Green**	**Green**
Pair 4	**White/Brown**	**Brown**

ANSI/TIA/EIA 568A & 568B Standards

- Bell Telephone Universal Service Order Code (USOC) established the technique for organizing wires in a modular plug for twisted-pair – but because of separation of the data wires it can lead to crosstalk.
- There are two patterns for wiring called T568-A and T568-B that keep the pairs closer together.
- In most cases, either wiring scheme can be chosen for the majority of new cabling jobs. If working on an existing network, use the wiring scheme already employed. Either way, make sure that the same wiring scheme is used for every termination in that project.
- There are certain occasions in which a crossover cable will need to be made. For this, use T568A on one end and T568B on the other. It is important to master terminating wires using both schemes.

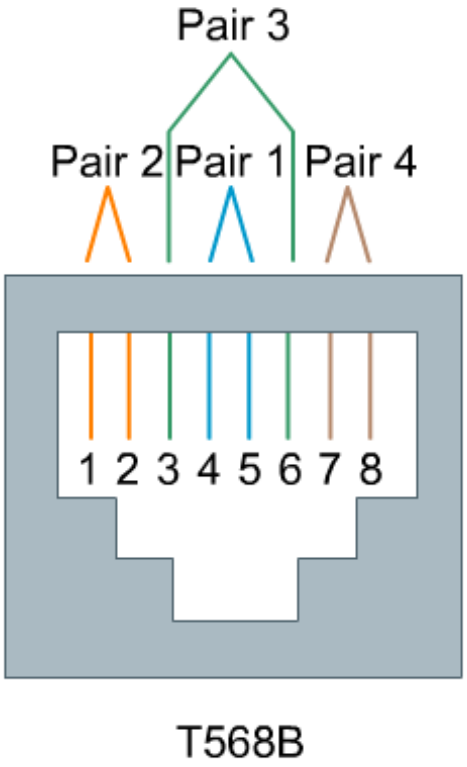
ANSI/TIA/EIA 568A



T568A

- Order
  - White/Green
  - Green
  - White/Orange
  - Blue
  - White/Blue
  - Orange
  - White/Brown
  - Brown
- Split the Orange, reverse the blue.

ANSI/TIA/EIA 568B



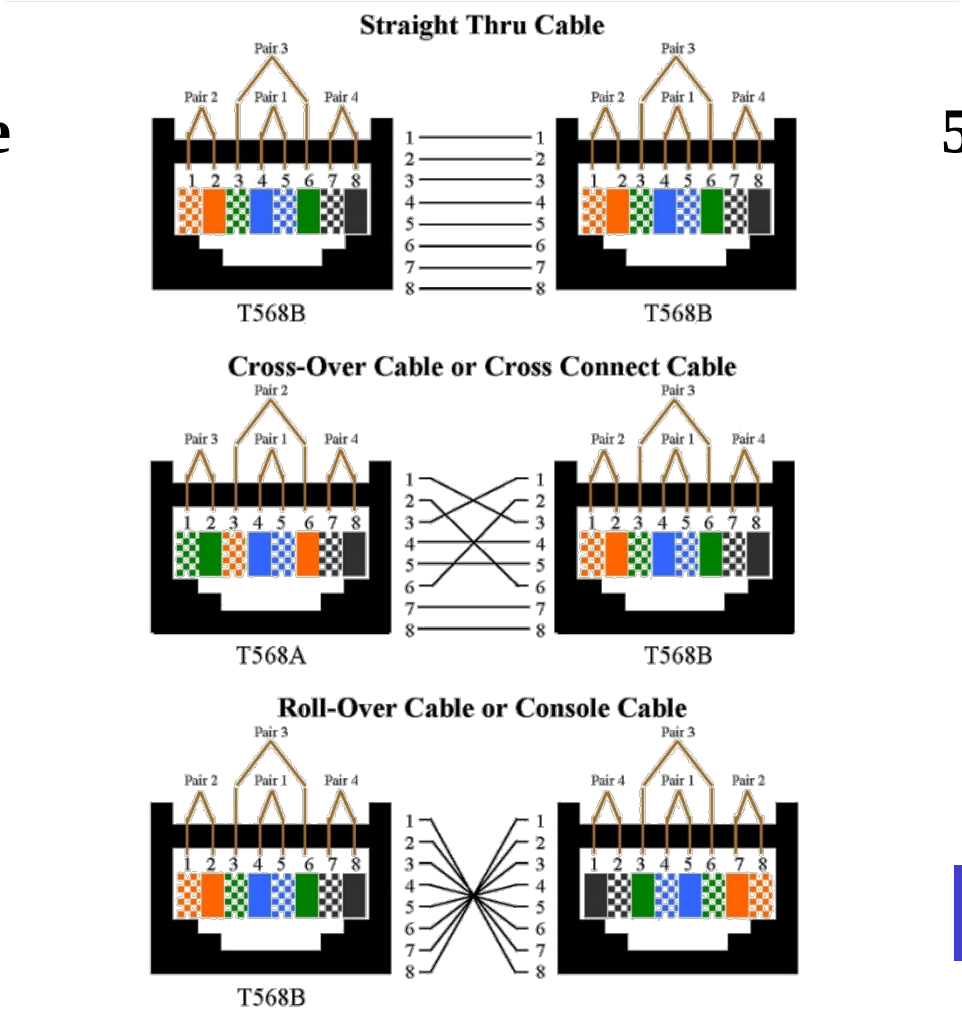
T568B

- Order
  - White/Orange
  - Orange
  - White/Green
  - Blue
  - White/Blue
  - Green
  - White/Brown
  - Brown
- Split the Green, reverse the blue

RJ-45 Pinouts

568A Scheme

G/W
G
O/W
B
B/W
O
Br/W
Br

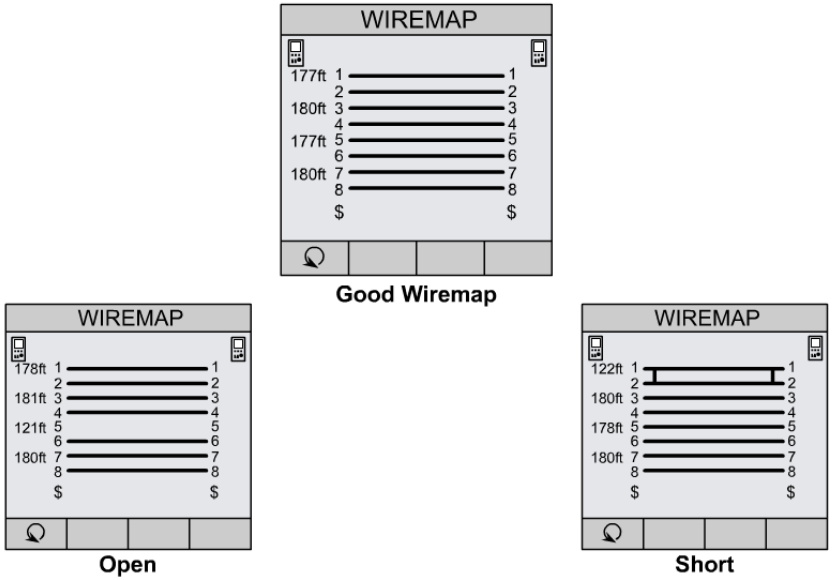


568B Scheme

O/W
O
G/W
B
B/W
G
Br/W
Br

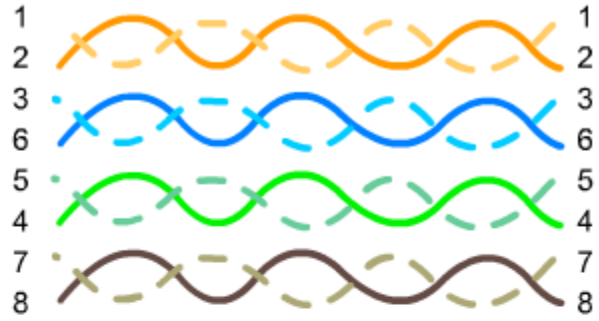
STANDARD

Cable Testing Standards

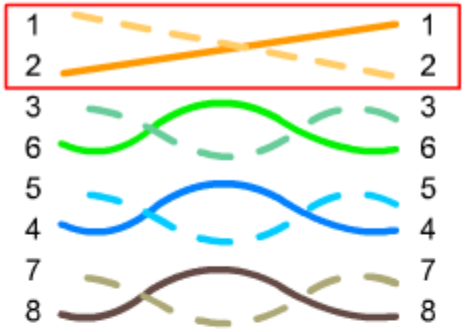


- The **wire map** test insures that no open or short circuits exist on the cable.
- An **open circuit** occurs if the wire does not attach properly at the connector.
- A **short circuit** occurs if two wires are connected to each other.

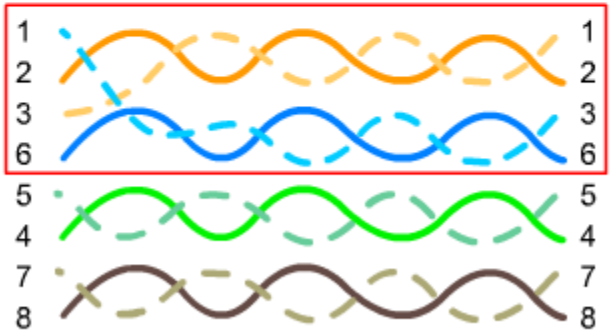
Cable Testing Standards



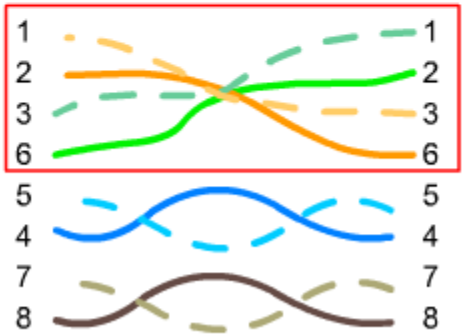
Correct T568B Wiring



Reversed-pair wiring fault



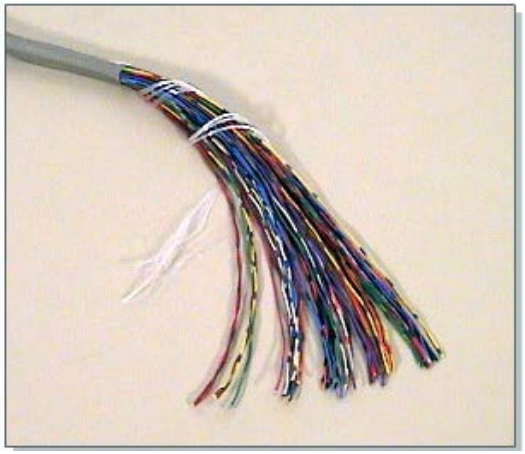
Split-pair Wiring Fault



Transposed-pair Wiring Fault

- The wire map test also verifies that all eight wires are connected to the correct pins on both ends of the cable.
- There are several different wiring faults that the wire map test can detect.

Multi-pair cables



- Telecommunications cable comes in many sizes, starting with a single pair of wires to 4200 pairs of wires.
- A standard color coding scheme is used for each 25 pairs of wires.
- When a cable has more than 25 pair groups, each group is wrapped with colored tape to form binder groups.
- 900 – pair should not be exceeded because of the space required for surge-protecting devices – fiber should be used in this case.

Color Codes for 25-pair Cables

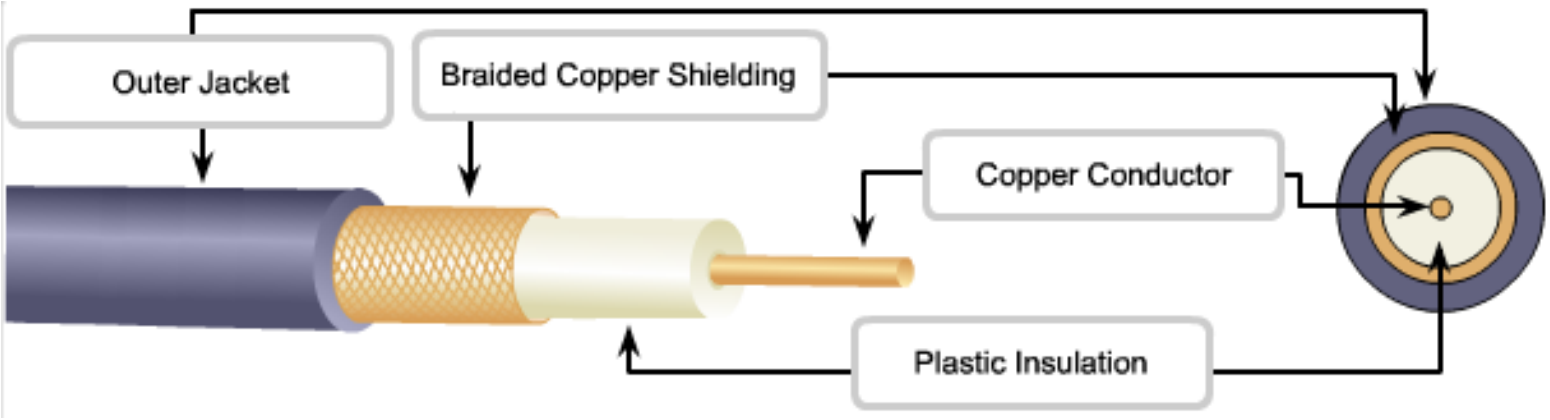
- The standard four-pair cable colors are a subset of a large scheme of colors. Pairs 1-4 of a four-pair cable use the same color system that is used in a 25-pair cable. One wire from each pair is the tip, and the other is the ring. The colors alternate for each. The tip wire has a stripe of the ring color in it. (Sometimes the stripes are actually rings or color bands; other times they are smudges.)
- When indicating colors for a pair, the tip colors come first, because that is the order in which the cables are punched on a punch block. Ring colors are just the opposite, that is, if Pair 22 has tip colors Violet-Orange, then Orange-Violet would be the ring colors for that pair.

The 25-Pair Color Code

- The tip wire has a stripe of the ring color in it and the ring wire has a stripe of the tip color in it

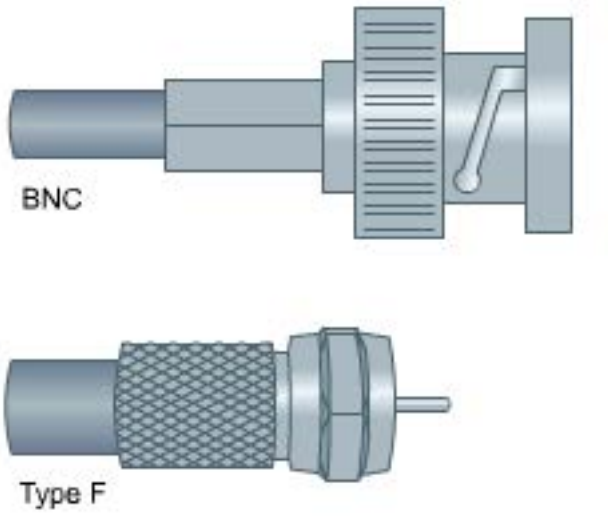
Coaxial Cable Overview

- Coaxial cable has a central copper conductor encircled by a layer of insulation, then a layer of shielding, and finally an outer jacket layer. (Impedence, typically 50 ohms for radio and networking)
- Types of Coaxial Cable
  - Thicknet
  - Thinnet



Coaxial Connectors

- The most common types of connectors used with coaxial cables are the BNC connector and the Type F connector.
- The BNC is used for networking and video applications.
- The F-series connector is used for modulated radio frequency applications, such as cable-TV and home entertainment systems.

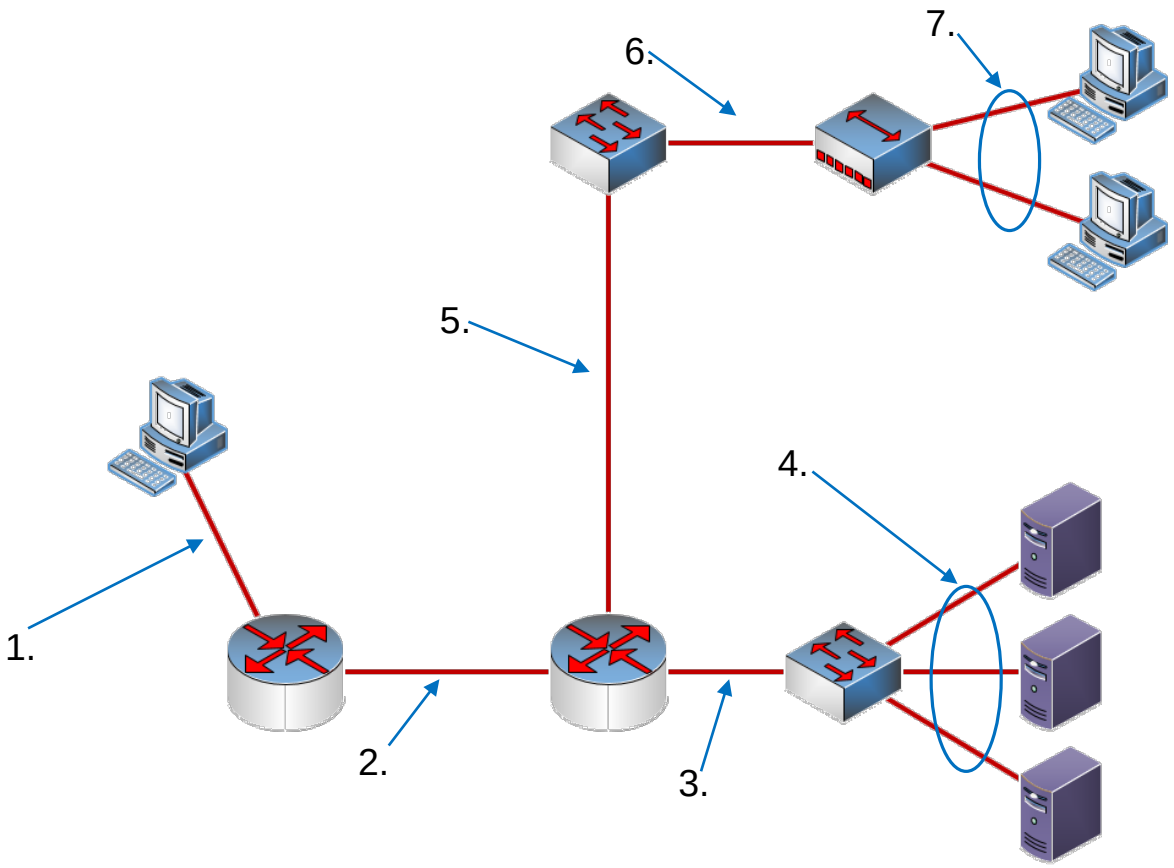


Network Cabling

Cable System	Speed	Cables and Connectors	Maximum Cable Length
10Base2 (ThinNet)	10 Mbps	Coaxial uses a BNC or F connector. RG-6 cable	185 Meters (607 ft)
10Base5 (ThickNet)	10Mbps	Coaxial uses an AUI 15-pin D-shaped connector	500 Meters (1640 ft)
10BaseT (Twisted-Pair)	10 Mbps	UTP uses an RJ-45 connector	100 Meters (328 ft)
100BaseTX (Twisted-Pair)	100 Mbps	UTP uses an RJ-45 connector	100 Meters (328 ft)
1000BaseTX (Twisted-Pair)	1000 Mbps	UTP uses an RJ-45 connector	100 Meters (328 ft)

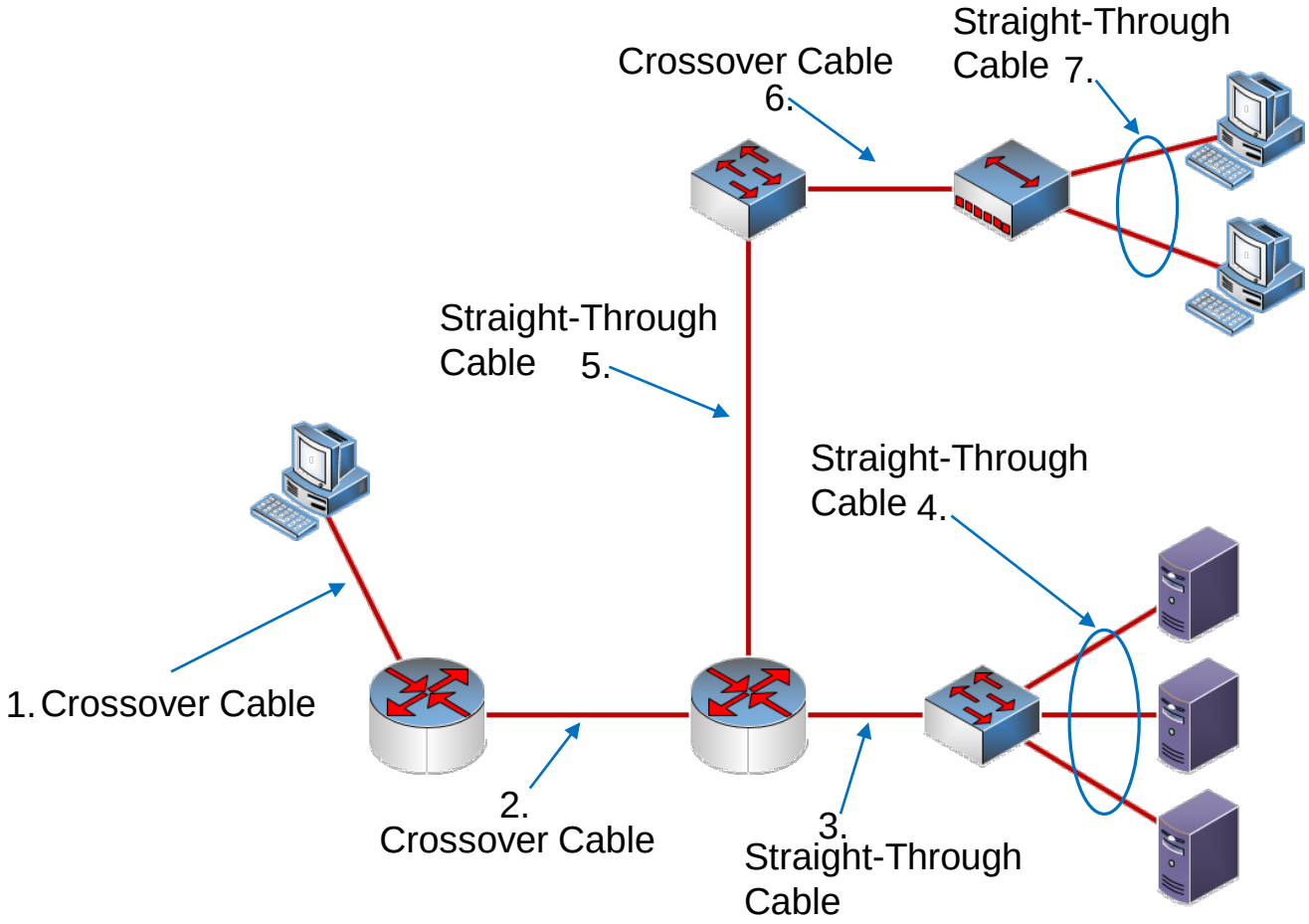
Types of Connections in a LAN

Identify the correct cable to use in connecting intermediate and end devices in a LAN.



Types of Connections in a LAN

Identify the correct cable to use in connecting intermediate and end devices in a LAN.

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