EECP0442 Computer Network

Week 3 Network Media and Physical Layer

Bandwidth

- Bandwidth is defined as the amount of information that can flow through a network connection in a given period of time. It is essential to understand the concept of bandwidth when studying networking for the following four reasons:

1. Bandwidth is finite
2. Bandwidth is not free
3. Bandwidth is a key factor in analyzing network performance, designing new networks, and understanding the Internet.
4. The demand for bandwidth is ever increasing.

Bandwidth is finite

- **1. Bandwidth is finite.**
  - In other words, regardless of the media used to build the network, there are limits on the capacity of that network to carry information. Bandwidth is limited by the laws of physics and by the technologies used to place information on the media.

- For example, the bandwidth of a conventional modem is limited to about 56 kbps by both the physical properties of twisted-pair phone wires and by modem technology. However, the technologies employed by DSL also use the same twisted-pair phone wires, yet DSL provides much greater bandwidth than is available with conventional modems

- So, even the limits imposed by the laws of physics are sometimes difficult to define. Optical fiber has the physical potential to provide virtually limitless bandwidth. Even so, the bandwidth of optical fiber cannot be fully realized until technologies are developed to take full advantage of its potential.

Bandwidth is not free

- It is possible to buy equipment for a local-area network (LAN) that will provide nearly unlimited bandwidth over a long period of time. For wide-area network (WAN) connections, it is almost always necessary to buy bandwidth from a service provider.

- In either case, an understanding of bandwidth and changes in demand for bandwidth over a given time can save an individual or a business a significant amount of money. A network manager needs to make the right decisions about the kinds of equipment and services to buy.

Bandwidth is a key factor in analyzing network

- A networking professional must understand the tremendous impact of bandwidth and throughput on network performance and design. Information flows as a string of bits from computer to computer throughout the world.

- These bits represent massive amounts of information flowing back and forth across the globe in seconds or less. In a sense, it may be appropriate to say that the Internet is bandwidth.

The demand for bandwidth is ever increasing

- As soon as new network technologies and infrastructures are built to provide greater bandwidth, new applications are created to take advantage of the greater capacity. The delivery over the network of rich media content, including streaming video and audio, requires tremendous amounts of bandwidth.

- IP telephony systems are now commonly installed in place of traditional voice systems, which further adds to the need for bandwidth. The successful networking professional must anticipate the need for increased bandwidth and act accordingly.

Bandwidth Analogy

- **Bandwidth**

- Bandwidth is defined as the speed at which data flows through a specific transmission line. In the case of streaming media, bandwidth is more specifically defined as how fast the streaming data can flow through our network of computers.

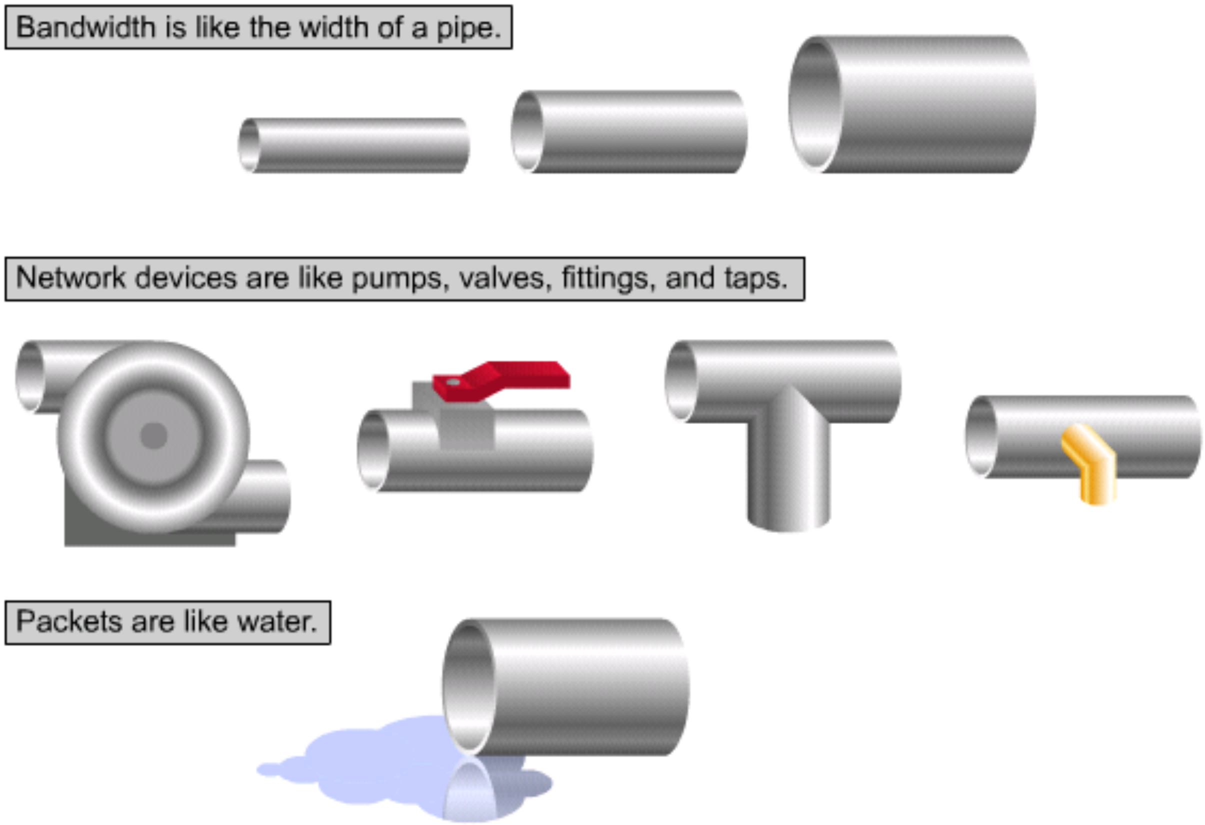
- The easiest way to think of bandwidth is in terms of a river. A wider river will allow a larger amount of water to flow down the river. Computer connection lines are like that river in that the higher data transfer rate through those lines, the higher the bandwidth. A higher transfer rate will allow more data to flow faster through the line.

- Different file formats require different amounts of data rate and bandwidth. A simple text file requires the least amount of bandwidth to view it in comparison to a video streaming file that requires the largest amount of bandwidth to provide good video quality. Another analogy will help to illustrate these different media types and their bandwidth requirements.

- Take the following four media types: Text, Graphics, Audio, and Video. Picture these data types as the following vehicles:

- **Text = Super-fast Sports Car**
- **Graphics = Normal Midsize Car**
- **Audio = Slow Fullsize Van**
- **Video = Super-slow "Oversized Load" truck**

- Now think of bandwidth as the roadway that these four vehicles need to drive on. You can see that the Super-fast Sports car (Text) will be able to travel the same roadway but just at a much faster speed and will take up much less of the road than any of the other vehicles. The Super-slow "Oversized Load" truck (Video) will travel at a much slower speed than the rest of them and will take up the entire road plus more.
- Two solutions to this problem exist. The first idea is to make the roadway larger (increasing bandwidth), which would allow the vehicles more room to drive (a larger pathway to transfer data through.) The second idea would involve reducing the size of the vehicles (compressing the files into smaller versions), which would speed up data transfer. In conclusion, bandwidth solutions are currently in place today and are constantly being improved upon.


Bandwidth is like the width of a pipe.
Network devices are like pumps, valves, fittings, and taps.
Packets are like water.

Bandwidth Measurement

- In digital systems, the basic unit of bandwidth is **bits per second (bps).** Bandwidth is the measure of how much information, or bits, can flow from one place to another in a given amount of time, or seconds. Although bandwidth can be described in bits per second, usually some multiple of bits per second is used. In other words, network bandwidth is typically described as thousands of bits per second (kbps), millions of bits per second (Mbps), and billions of bits per second (Gbps) and trillions of bits per second (Tbps).

Throughput

- Bandwidth is the measure of the amount of information that can move through the network in a given period of time. Therefore, the amount of available bandwidth is a critical part of the specification of the network. A typical LAN might be built to provide 100 Mbps to every desktop workstation, but this does not mean that each user is actually able to move one hundred megabits of data through the network for every second of use. This would be true only under the most ideal circumstances. The concept of throughput can help explain why this is so.

- Throughput refers to actual measured bandwidth, at a specific time of day, using specific Internet routes, and while a specific set of data is transmitted on the network. Unfortunately, for many reasons, throughput is often far less than the maximum possible digital bandwidth of the medium that is being used

- The following are some of the factors that determine throughput:
  - Internetworking devices
  - Type of data being transferred
  - Network topology
  - Number of users on the network
  - User computer
  - Server computer
  - Power conditions

Data Transfer time calculation

- Best Download T=S/BW
- Actual Download T=S/P
  - When T = Data Transfer Time
  - S = Size of Data
  - BW = Maximum theatrical bandwidth of the slowest like between end hosts
  - P = Actual throughput

3- Transmission Media

- Copper Media
- Optical Media
- Wireless Media

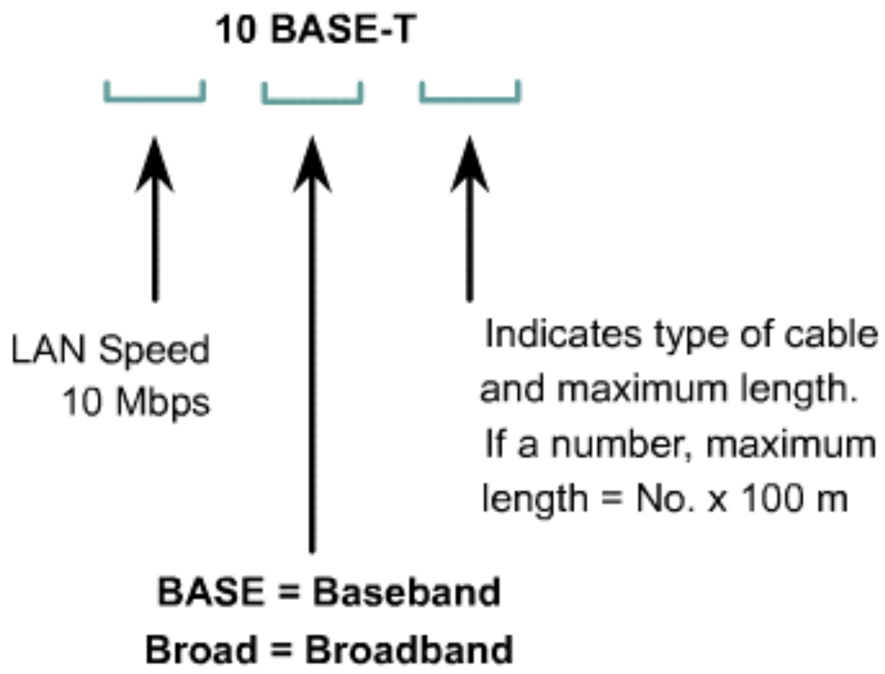
3.1 Copper Media

- Copper cable is used in almost every LAN. Many different types of copper cable are available, with each type having advantages and disadvantages. Proper selection of cabling is key to efficient network operation. Because copper carries information using electrical current, it is important to understand some basics of electricity when planning and installing a network.

Cable Specification

- Cables have different specifications and expectations pertaining to performance:
  - What speeds for data transmission can be achieved using a particular type of cable? The speed of bit transmission through the cable is extremely important. The speed of transmission is affected by the kind of conduit used.

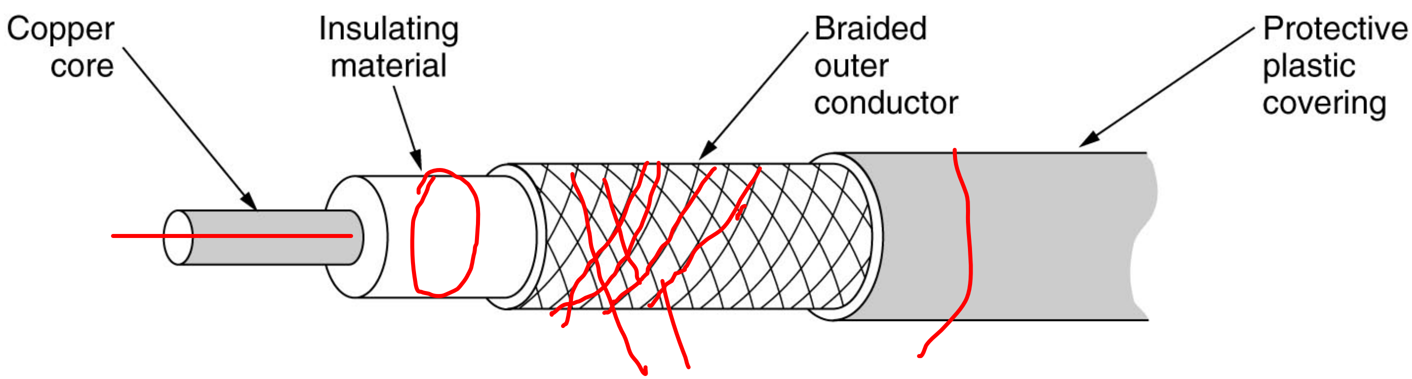
- What kind of transmission is being considered? Will the transmissions be digital or will they be analog-based? Digital or baseband transmission and analog-based or broadband transmission are the two choices.
- How far can a signal travel through a particular type of cable before attenuation of that signal becomes a concern? In other words, will the signal become so degraded that the recipient device might not be able to accurately receive and interpret the signal by the time the signal reaches that device? The distance the signal travels through the cable directly affects attenuation of the signal. Degradation of the signal is directly related to the distance the signal travels and the type of cable used.


10 BASE-T
LAN Speed
10 Mbps
Indicates type of cable
and maximum length.
If a number, maximum
length = No. x 100 m
BASE = Baseband
Broad = Broadband

- 10BASE-T
- 10BASE5
- 10BASE2

Coaxial cable

- Some call it “Coax”
- Coaxial cable consists of a hollow outer cylindrical conductor that surrounds a single inner wire made of two conducting elements. One of these elements, located in the center of the cable, is a copper conductor. Surrounding the copper conductor is a layer of flexible insulation. Over this insulating material is a woven copper braid or metallic foil that acts as the second wire in the circuit and as a shield for the inner conductor. This second layer, or shield reduces the amount of outside electro-magnetic interference. Covering this shield is the cable jacket.

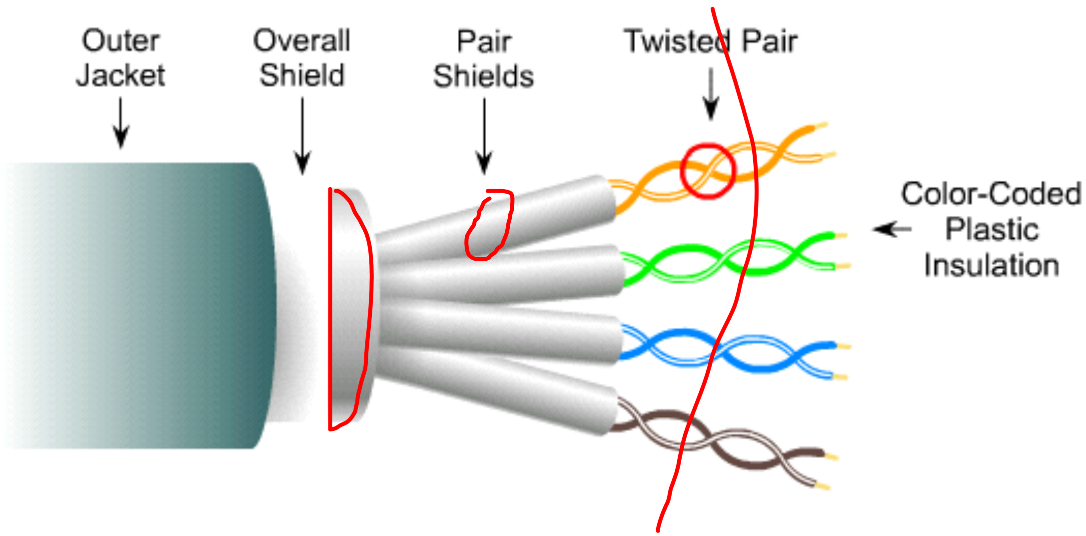


Coaxial Cable

- Speed and Throughput 10-100 Mbps
- Max Cable length 500M

STP (Shielded Twisted-pair Cable)

- Shielded twisted-pair cable (STP) combines the techniques of shielding, cancellation, and twisting of wires. Each pair of wires is wrapped in metallic foil. The four pairs of wires are wrapped in an overall metallic braid or foil. It is usually 150-Ohm cable. As specified for use in Ethernet network installations, STP reduces electrical noise within the cable such as pair to pair coupling and crosstalk. STP also reduces electronic noise from outside the cable, for example electromagnetic interference (EMI) and radio frequency interference (RFI). Shielded twisted-pair cable shares many of the advantages and disadvantages of unshielded twisted-pair cable (UTP). STP affords greater protection from all types of external interference, but is more expensive and difficult to install than UTP.


Outer Jacket
Overall Shield
Pair Shields
Twisted Pair
Color-Coded Plastic Insulation

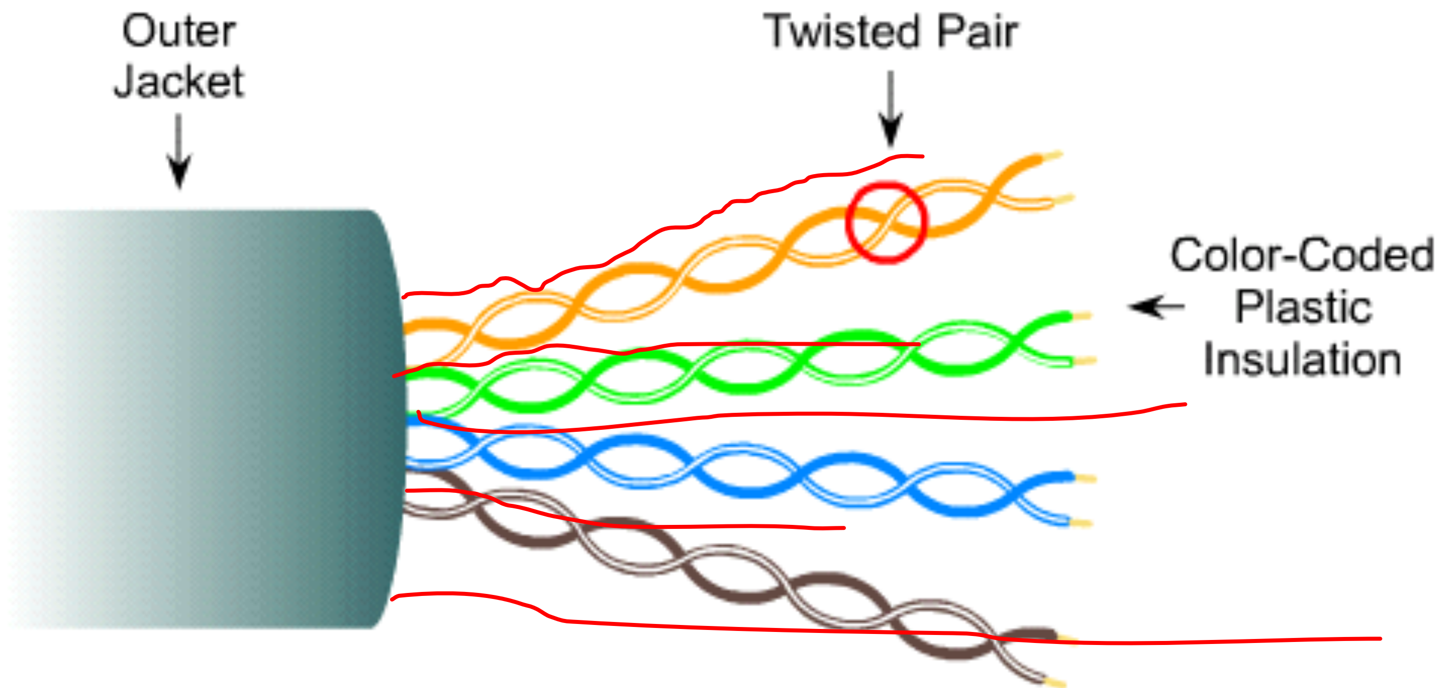
STP

- Speed and Throughput 10 – 100 - 1000 Mbps
- Max Length 100M

UTP (Unshielded Twist-Pair Cable)

- Unshielded twisted-pair cable (UTP) is a four-pair wire medium used in a variety of networks. Each of the 8 individual copper wires in the UTP cable is covered by insulating material. In addition, each pair of wires is twisted around each other. This type of cable relies solely on the cancellation effect produced by the twisted wire pairs, to limit signal degradation caused by EMI and RFI. To further reduce **crosstalk between the pairs in UTP cable**, the number of twists in the wire pairs varies.

EMI = electromagnetic interference. Interference by electromagnetic signals that can cause reduced data integrity and increased error rates on transmission channels.
RFI = radio frequency interference. Radio frequencies that create noise that interferes with information being transmitted across unshielded copper cabling.


Outer Jacket
Twisted Pair
Color-Coded Plastic Insulation

- Speed and throughput: 10 - 100 - 1000 Mbps (depending on the quality/category of cable)
- Average $ per node: Least Expensive
- Media and connector size: Small
- Maximum cable length: 100m

- TIA/EIA-568-A contains specifications governing cable performance. It calls for running two cables, one for voice and one for data, to each outlet. Of the two cables, the one for voice must be four-pair UTP. **CAT 5** is the one most frequently recommended and implemented in installations today.

- Unshielded twisted-pair cable has many advantages. It is easy to install and is less expensive than other types of networking media. In fact, UTP costs less per meter than any other type of LAN cabling. However, the real advantage is the size. Since it has such a small external diameter, UTP does not fill up wiring ducts as rapidly as other types of cable. This can be an extremely important factor to consider, particularly when installing a network in an older building. In addition, when UTP cable is installed using an RJ-45 connector, potential sources of network noise are greatly reduced and a good solid connection is practically guaranteed. There are disadvantages in using twisted-pair cabling. UTP cable is more prone to electrical noise and interference than other types of networking media, and the distance between signal boosts is shorter for UTP than it is for coaxial and fiber optic cables.

- UTP was once considered slower at transmitting data than other types of cable. This is no longer true. In fact, today, UTP is considered the fastest copper-based media.

Straight Through Cable

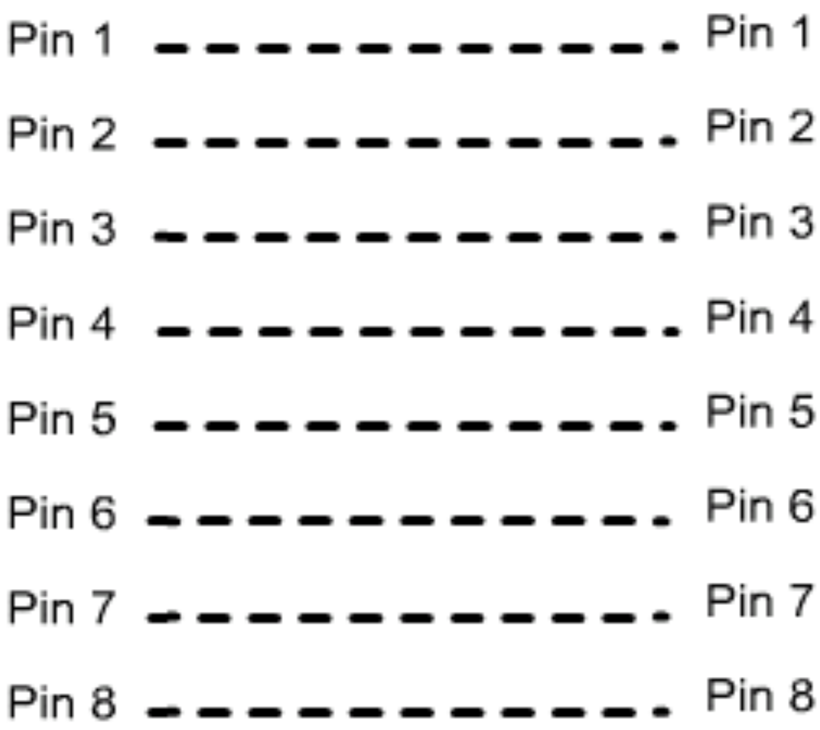
- When communication occurs, the signal that is transmitted by the source needs to be understood by the destination. This is true from both a software and physical perspective. The transmitted signal needs to be properly received by the circuit connection designed to receive signals. The transmit pin of the source needs to ultimately connect to the receiving pin of the destination. The following are the types of cable connections used between internetwork devices.


Straight-through Cable

Straight-Through Cables

- Maintain the pin connection all the way through the cable.
- Wire connected to pin 1 is the same on both ends.
- Used to connect such devices as PCs or routers to other devices such as hubs or switches.

Straight-Through Cables

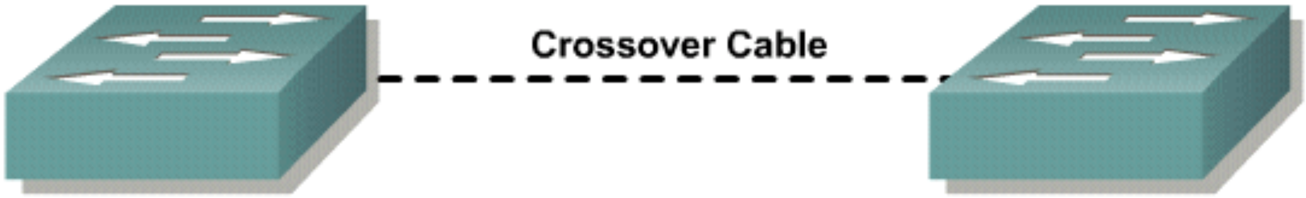


Crossover or Rollover Cables

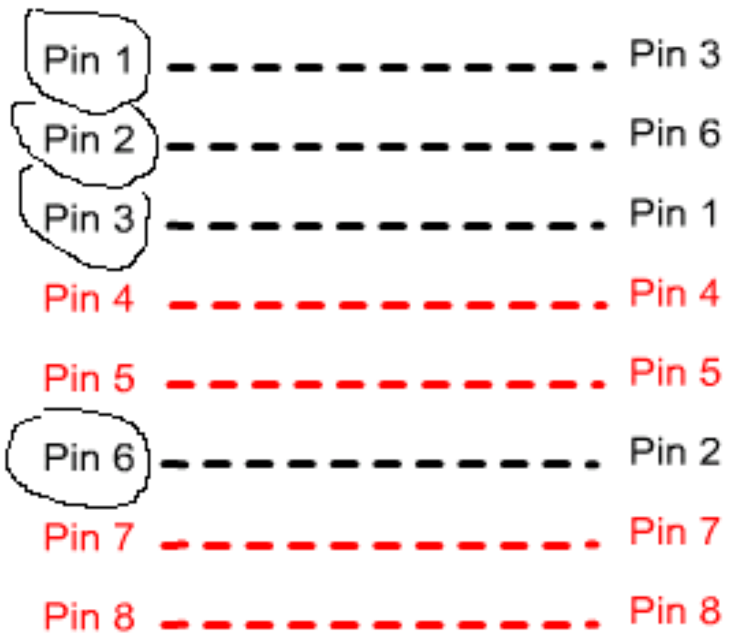
- When two switches are connected together, the cable that connects from one switch port to another switch port is called a crossover cable.

Crossover or Rollover Cables

- Cross the critical pair to properly align, transmit, and receive signals on devices with like connections.
- Pin 1 connected to pin 3, pin 2 connected to pin 6.
- Used to connect similar devices: switch to switch, switch to hub, hub to hub, router to router, PC to PC.


Crossover Cable

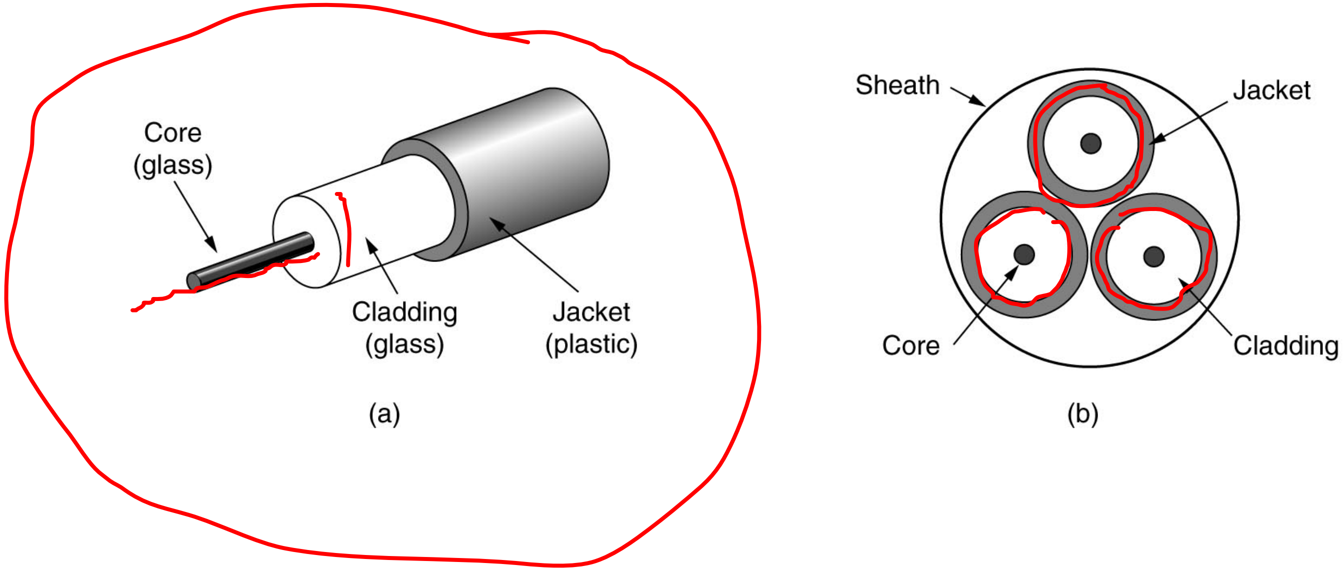
Crossover or Rollover Cables



Optical Media

- Optical transmission system has three components:
  - The light source
  - The transmission media
  - The detector
    - A pulse of light indicate 1 bit and the absent of light indicate a 0 bit The transmission medium is an ultra-thin fiber of glass. The detector generates an electrical pules when light falls on it.

Fiber Cable


Core
(glass)
Cladding
(glass)
Jacket
(plastic)
(a)
Sheath
Jacket
Core
Cladding
(b)

Multimode vs Single Mode

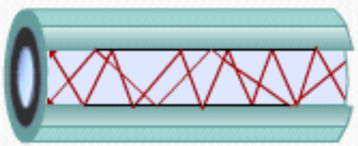
- If the diameter of the core of the fiber is large enough so that there are many paths that light can take through the fiber, the fiber is called "multimode" fiber. Single-mode fiber has a much smaller core that only allows light rays to travel along one mode inside the fiber

Single-mode

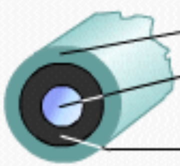
Requires very straight path

- Small core
- Less dispersion
- Suited for long distance applications (up to ~3km, 9,840 ft)
- Uses lasers as the light source often within campus backbones for distances of several thousand meters

Multimode



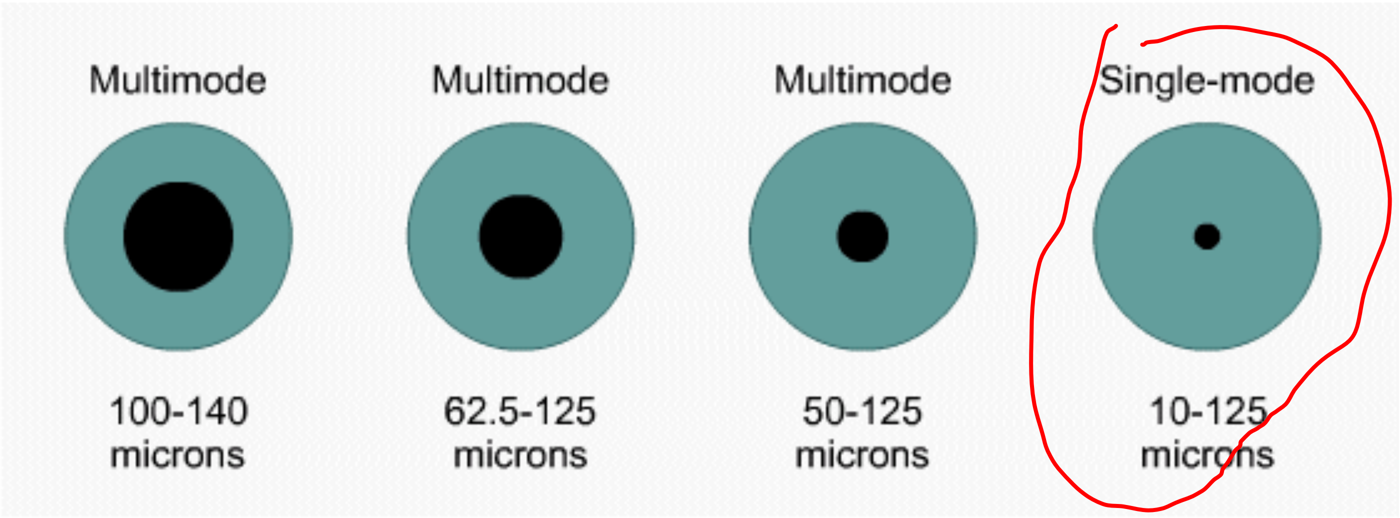
Multiple paths-sloppy



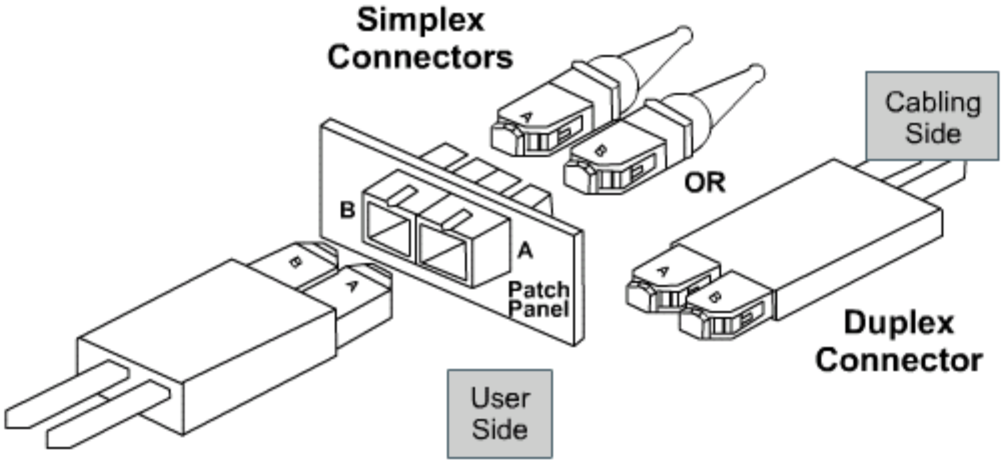
- Larger core than single-mode cable (50 or 62.5 microns or greater)
- Allows greater dipersion and therefore, loss of signal
- Used for long distance application, but shorter than single-mode (up to ~2km, 6,560 ft)
- Uses LEDs as the light source often within LANs or distances of a couple hundred meters within a campus network

- In optical fiber technology, multimode fiber is optical fiber that is designed to carry multiple light rays or modes concurrently, each at a slightly different reflection angle within the optical fiber core. Multimode fiber transmission is used for relatively short distances because the modes tend to disperse over longer lengths (this is called *modal dispersion*) . For longer distances, single mode fiber (sometimes called *monomode*) fiber is used.

- Single-mode fiber consists of the same parts as multimode. The outer jacket of single-mode fiber is usually yellow. The major difference between multimode and single-mode fiber is that single-mode allows only one mode of light to propagate through the smaller, fiber-optic core. The single-mode core is eight to ten microns in diameter. Nine-micron cores are the most common. A 9/125 marking on the jacket of the single-mode fiber indicates that the core fiber has a diameter of 9 microns and the surrounding cladding is 125 microns in diameter. An infrared laser is used as the light source in single-mode fiber. The ray of light it generates enters the core at a 90-degree angle. As a result, the data carrying light ray pulses in single-mode fiber are essentially transmitted in a straight line right down the middle of the core. This greatly increases both the speed and the distance that data can be transmitted.


Multimode
Multimode
Multimode
Single-mode
100-140 microns
62.5-125 microns
50-125 microns
10-125 microns

Optic Fiber Connectors



Wireless Media

- **Wireless LAN organizations and standards**
  - An understanding of the regulations and standards that apply to wireless technology will ensure that deployed networks will be interoperable and in compliance. Just as in cabled networks, IEEE is the prime issuer of standards for wireless networks. The standards have been created within the framework of the regulations created by the Federal Communications Commission (FCC).
  - IEEE 802.11, 802.11b, 802.11a, 802.11gui

802.11

- A key technology contained within the 802.11 standard is Direct Sequence Spread Spectrum (DSSS). DSSS applies to wireless devices operating within a 1 to 2 Mbps range. A DSSS system may operate at up to 11 Mbps but will not be considered compliant above 2 Mbps. The next standard approved was 802.11b, which increased transmission capabilities to 11 Mbps. Even though DSSS WLANs were able to interoperate with the Frequency Hopping Spread Spectrum (FHSS) WLANs, problems developed prompting design changes by the manufacturers. In this case, IEEE's task was simply to create a standard that matched the manufacturer's solution.

802.11b

- 802.11b may also be called Wi-Fi™ or high-speed wireless and refers to DSSS systems that operate at 1, 2, 5.5 and 11 Mbps. All 802.11b systems are backward compliant in that they also support 802.11 for 1 and 2 Mbps data rates for DSSS only. This backward compatibility is extremely important as it allows upgrading of the wireless network without replacing the NICs or access points.

- 802.11b devices achieve the higher data throughput rate by using a different coding technique from 802.11, allowing for a greater amount of data to be transferred in the same time frame. The majority of 802.11b devices still fail to match the 11 Mbps throughput and generally function in the 2 to 4 Mbps range.

802.11a

- 802.11a covers WLAN devices operating in the 5 GHZ transmission band. Using the 5 GHZ range disallows interoperability of 802.11b devices as they operate within 2.4 GHZ. 802.11a is capable of supplying data throughput of 54 Mbps and with proprietary technology known as "rate doubling" has achieved 108 Mbps. In production networks, a more standard rating is 20-26 Mbps.

802.11g

- 802.11g provides the same throughout as 802.11a but with backwards compatibility for 802.11b devices using Orthogonal Frequency Division Multiplexing (OFDM) modulation technology. Cisco has developed an access point that permits 802.11b and 802.11a devices to coexist on the same WLAN. The access point supplies ‘gateway’ services allowing these otherwise incompatible devices to communicate.