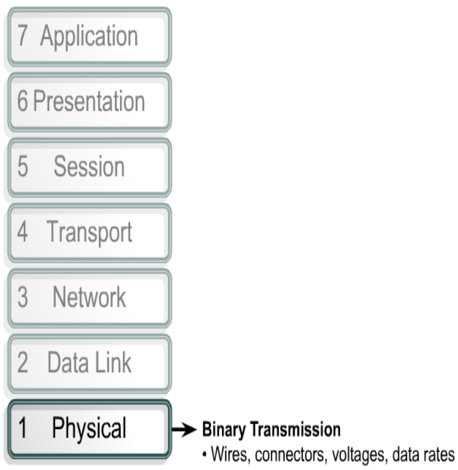
Chapter 2
Physical Layer and Media

Content

- Overview
- Data Communications Summary
- Network Media
- Actual Networks

Layer 1 overview



- Bottom-most layer
- Interact with layer 2 & pasive entity (media)
- Move data in the form of electronics signals across transmission medium

Digital communication feature

Advantages:

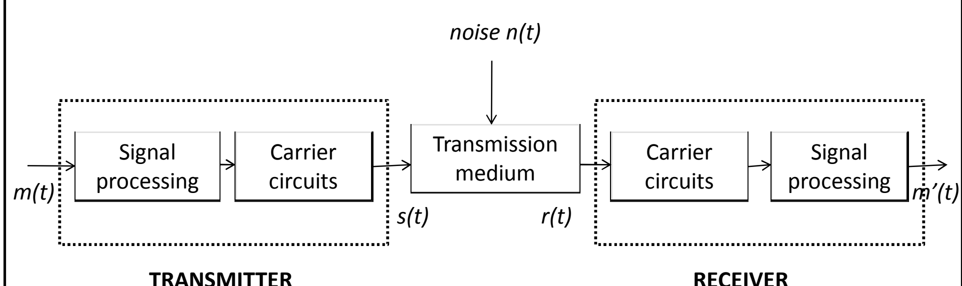
- Relatively inexpensive ditital circuits may be used
- Privacy is preserved by using data encryption
- Greater dynamic range is possible.
- Data from voice, video, and data sources may be merged and transmitted over a common digital transmission system.
- In long-distance systems, noise does not accumulate from repeater to repeater.
- Errors in detected data may be small, even when there is a large amount of noise on the received signal.
- Errors may often be corrected by the use of coding.

Digital communication feature (cont…)

Disadvantages:

- Generally, more bandwidth is required than that for analog systems.
- Synchronization is required.

A communication system



Frequency allocations

International Telecommunications Union (ITU)

Frequency band	Designation	Propagation Characteristics	Typical Uses
3-30 kHz	Very low frequency (VLF)	Ground wave, low attenuation day and night; high atmospheric noise level	Long-range navigation submarine communication
30-300 kHz	Low frequency (LF)	Similar to VLF, slightly less reliable; absorption in day time	Long-range navigation and marine communication radio becons
300-3000 kHz	Medium frequency (MF)	Ground wave and night sky wave, attenuation low at night and high in day, atmospheric noise	Maritime radio, direction finding and AM broadcasting
3-30 MHz	High frequency (HF)	Ionospheric reflection varies with time of day	Amateur radio, military comm, telephone, telegraph

Frequency band	Designation	Propagation Characteristics	Typical Uses
30-300 MHz	Very high frequency (VHF)	Nearly LOS propagation	VHF television, FM radio, AM aircraft communicaiton
0.3-3 GHz	Ultrahigh frequency (UHF)	LOS propagation	UHF television, cellular telephone, navigational aids, radar, GPS, microwave links, personal communication systems
1.0 – 2.0 2.0 – 4.0 3 – 30 GHz	L S Superhigh frequency (SHF)	LOS propagation	Satellite communication, radar microwave links
2.0 – 4.0 4.0 – 8.0 8.0 – 12.0 12.0 – 18.0 18.0 – 27.0 27.0 – 40.0 26.5 – 40.0 30 – 300 GHz	S C X Ku K Ka R (EHF)		

Frequency band	Designation	Propagation Characteristics	Typical Uses
27.0 – 40.0 26.5 – 40.0 33.0 – 50.0 40.0 – 75.0 75.0 – 110.0 110 – 300 10^3 – 10^7 Ghz	Ka R Q V W mm Infrared, visible light, and ultraviolet	LOS	Optical communications

Information measure

The information sent from a digital source when the jth message is transmitted is given by

$$I_j = \log 2\left(\frac{1}{P_j}\right) \text{ bits}$$

where P_j is the probability of transmitting the j^{th} message

Average information

$$H = \sum_{j=1}^{m} P_j I_j = \sum_{j=1}^{m} P_j \log_2\left(\frac{1}{P_j}\right) \text{ bits}$$

m is the number of possible different source messages

Pj is the probability of sending the jth message

The average information is called ***<u>entropy</u>***

Source rate

$$R = \frac{H}{T}$$

T is the time required to send a message.

The definitions previously given apply to digital sources.

Channel capacity

- Claude Shannon (1948):

If R < C

$$C = B\ log_2 \left(1 + \frac{S}{N}\right)$$

C is channel capacity (bits/s)

B is the channel bandwidth (Hz)

Network Media

Copper Media

- Describe the specifications and performances of different types of cable.
- Describe coaxial cable and its advantages and disadvantages over other types of cable.
- Describe shielded twisted-pair (STP) cable and its uses.
- Describe unshielded twisted-pair cable (UTP) and its uses.
- Discuss the characteristics of straight-through, crossover, and rollover cables and where each is used.

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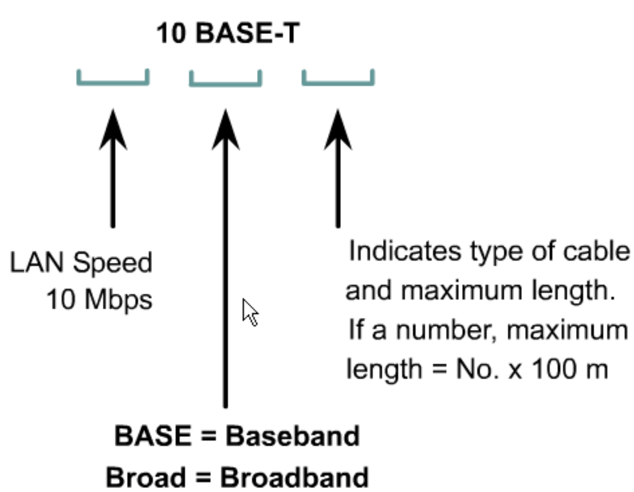
Cable Specifications



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Cable Specifications

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.

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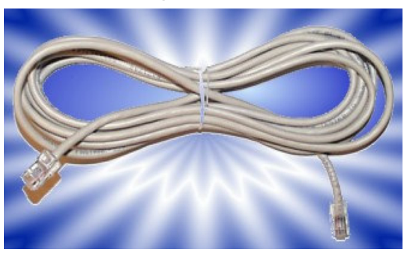
Cable Specifications



- **10BASE-T**
  - speed of transmission at 10 Mbps
  - type of transmission is baseband, or digitally interpreted
  - T stands for twisted pair

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Cable Specifications

- **10BASE5**
  - speed of transmission at 10 Mbps
  - type of transmission is baseband
  - 5 represents the capability of the cable to allow the signal to travel for approximately 500 meters before attenuation could disrupt the ability of the receiver to appropriately interpret the signal being received.
  - often referred to as **Thicknet**

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Cable Specifications

- **10BASE2**
  - speed of transmission at 10 Mbps
  - type of transmission is baseband
  - The 2, in 10BASE2, represents the capability of the cable to allow the signal to travel for approximately 200 meters, before attenuation could disrupt the ability of the receiver to appropriately interpret the signal being received. 10BASE2 is often referred to as **Thinnet**.

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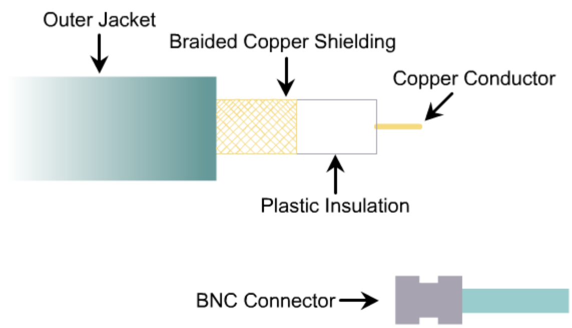
Coaxial Cable



- Speed and throughput: 10 - 100 Mbps
- Average $ per node: Inexpensive
- Media and connector size: Medium
- Maximum cable length: 500m

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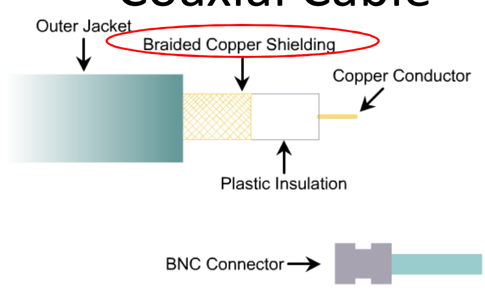
Coaxial Cable



- Copper braid or metallic foil
  - Acts as the second wire in the circuit
  - Acts as a shield for the inner conductor.
  - Reduces the amount of outside electro-magnetic interference.
  - Comprises half the electric circuit
  - Special care must be taken to ensure a solid electrical connection a both ends resulting in proper grounding
  - Poor shield connection is one of the biggest sources of connection problems in the installation of coaxial cable.

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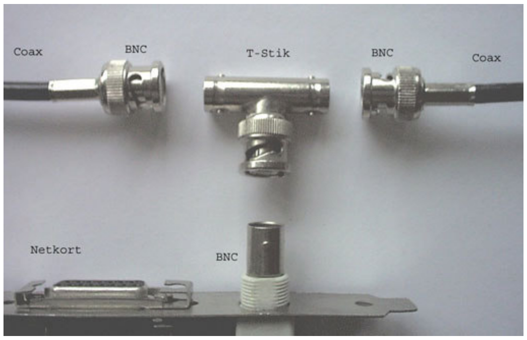
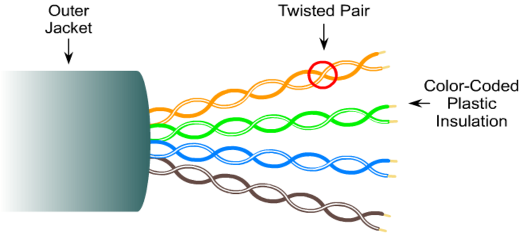
Coaxial Cable



- **Advantages**:
  - Requires fewer repeaters than twisted pair
  - Less expensive than fiber
  - It has been used for many years for many types of data communication, including cable television
- **Disadvantages**:
  - More expensive and more difficult to install than twisted pair
  - Needs more room in wiring ducts than twisted pair

Unshielded Twisted Pair (UTP)

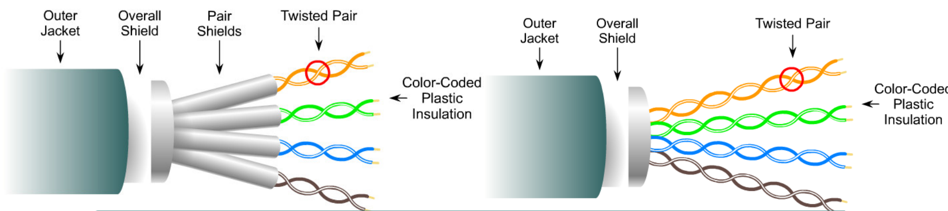


- Unshielded twisted-pair cable (UTP) is a four-pair wire medium used in a variety of networks.
- TIA/EIA-568-A contains specifications governing cable performance.
- RJ-45 connector
- When communication occurs, the signal that is transmitted by the source needs to be understood by the destination.
- 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.

Shielded Twisted Pair (STP and ScTP)

STP – Shielded Twisted Pair

ScTP – Screened Twisted Pair



- Speed and throughput: 10 - 100 Mbps
- Average $ per node: Moderately Expensive
- Media and connector size: Medium to Large
- Maximum cable length: 100m

- **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.
- A new hybrid of UTP with traditional STP is **Screened UTP (ScTP),** also known as **Foil Twisted Pair (FTP).**
  - ScTP is essentially UTP wrapped in a metallic foil shield, or screen.

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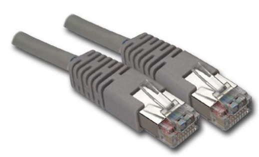
Shielded Twisted Pair (STP and ScTP)



- Greater protection from all types of external and internal interference than UTP.
  - Reduces electrical noise within the cable such as pair to pair coupling and crosstalk.
  - Reduces electronic noise from outside the cable, for example electromagnetic interference (EMI) and radio frequency interference (RFI).
- More expensive and difficult to install than UTP.
- Needs to be grounded at both ends

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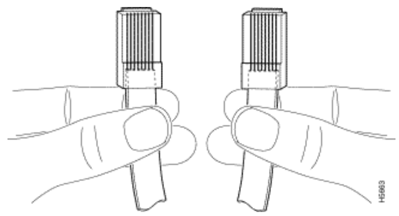
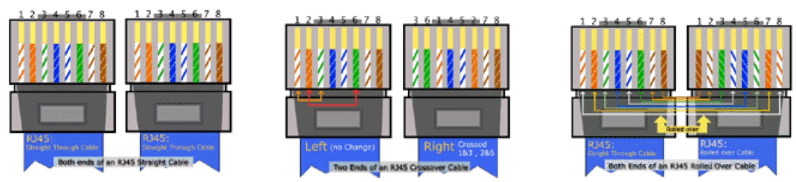
Unshielded Twisted Pair (UTP)



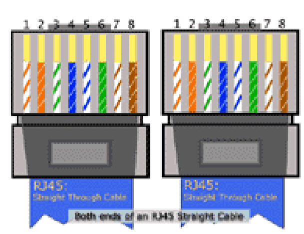


Straight-through | Cross-over | Rollover

UTP Straight-through Cable

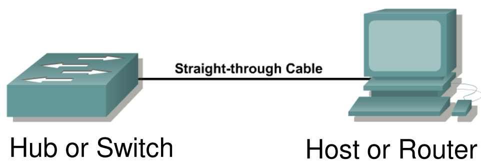
Hub or Switch | Host or Router

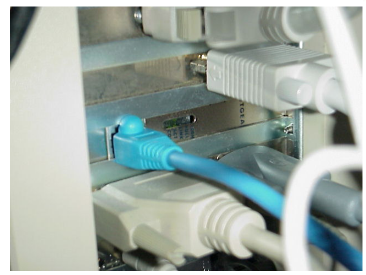
Pin 1	Pin 1
Pin 2	Pin 2
Pin 3	Pin 3
Pin 4	Pin 4
Pin 5	Pin 5
Pin 6	Pin 6
Pin 7	Pin 7
Pin 8	Pin 8



- The cable that connects from the switch port to the computer NIC port is called a straight-through cable.

UTP Straight-through Cable





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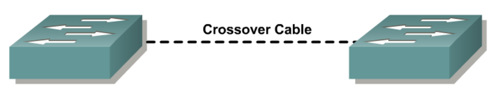
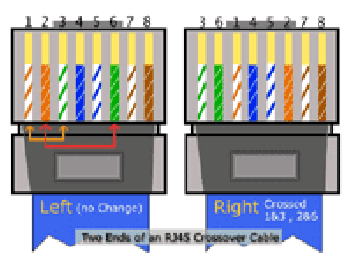
UTP Cross-over Cable



An Ethernet (10BASE-T and 100BASE-TX) cross-connect cable has only four active wires 1, 2, 3, and 6

Pin 1	Pin 3
Pin 2	Pin 6
Pin 3	Pin 1
Pin 4	Pin 4
Pin 5	Pin 5
Pin 6	Pin 2
Pin 7	Pin 7
Pin 8	Pin 8



- The cable that connects from one switch port to another switch port is called a crossover cable.

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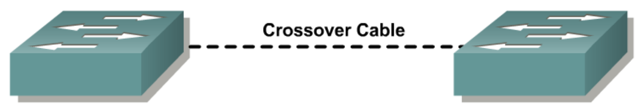
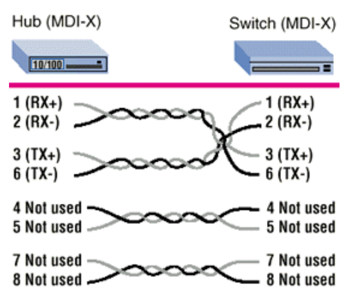
UTP Cross-over Cable





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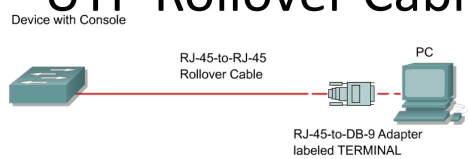
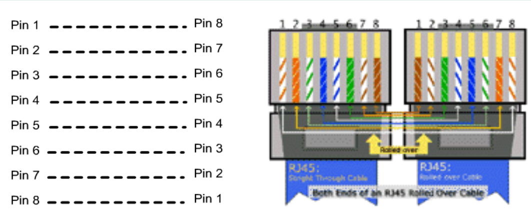
UTP Rollover Cable



- PCs require an RJ-45 to DB-9 or RJ-45 to DB-25 adapter.
- COM port settings are 9600 bps, 8 data bits, no parity, 1 stop bit, no flow control.
- This provides out-of-band console access.
- AUX switch port may be used for a modem-connected console.



- The cable that connects the RJ-45 adapter on the com port of the computer to the console port of the router or switch is called a rollover cable.

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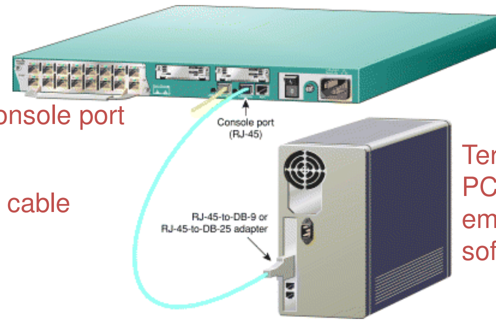
UTP Rollover Cable



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Optical Media

- Explain the basics of fiber-optic cable.
- Describe how fibers can guide light for long distances.
- Describe multimode and single-mode fiber.
- Describe how fiber is installed.
- Describe the type of connectors and equipment used with fiber-optic cable.
- Explain how fiber is tested to ensure that it will function properly.
- Discuss safety issues dealing with fiber-optics.

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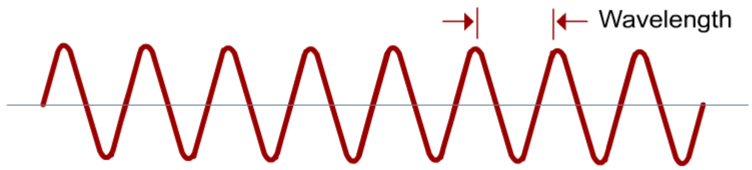
The electromagnetic spectrum



- The light used in optical fiber networks is one type of electromagnetic energy.
- When an electric charge moves back and forth, or accelerates, a type of energy called electromagnetic energy is produced.
- An important property of any energy wave is the wavelength.
- Radio, microwaves, radar, visible light, x-rays are all types of electromagnetic energy.

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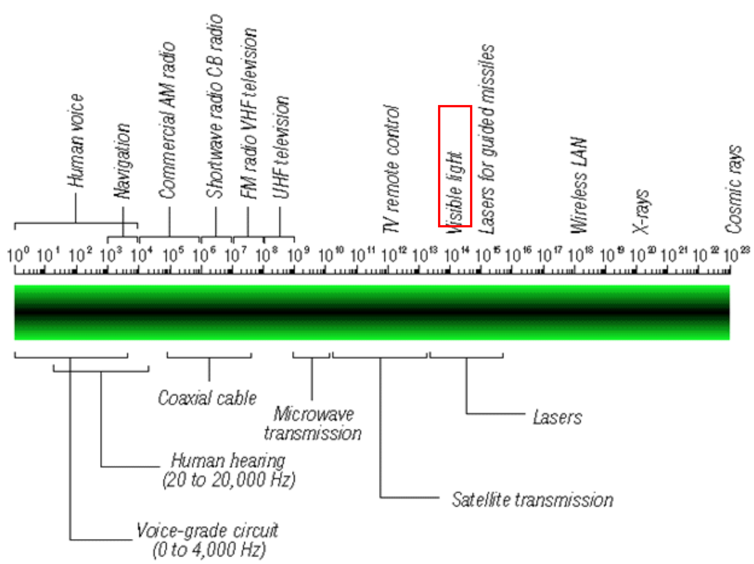
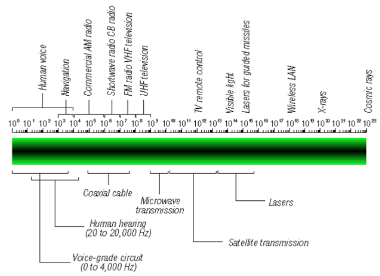
The electromagnetic spectrum



The electromagnetic spectrum



- Wavelengths that are not visible to the human eye are used to transmit data over optical fiber.
- *These wavelengths are slightly longer than red light and are called* **infrared light.**
- Infrared light is used in TV remote controls.
- These wavelengths were selected because they travel through optical fiber better than other wavelengths.

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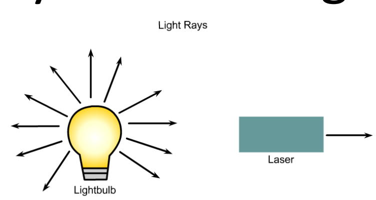
Ray model of light



$$\textbf{Index of Refraction} = n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in material}}$$

- When electromagnetic waves travel out from a source, they travel in straight lines.
- These straight lines pointing out from the source are called **rays**.
- However, light travels at different, slower speeds through other materials like air, water, and glass.
- When a light ray called the incident ray, crosses the boundary from one material to another, some of the light energy in the ray will be reflected back.
- The light that is reflected back is called the **reflected ray**.

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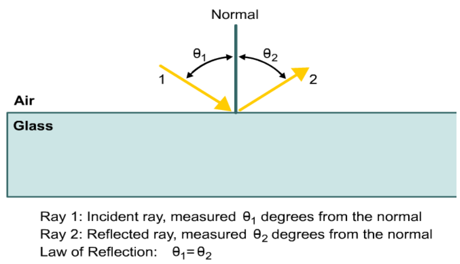
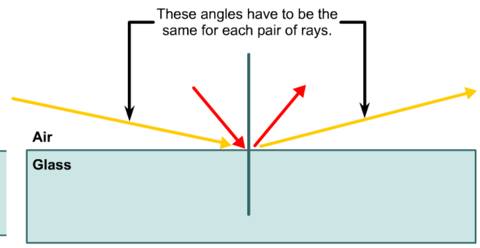
Reflection



Light traveling through the air is reflected off the surface of glass.



- When a ray of light (the incident ray) strikes the shiny surface of a flat piece of glass, some of the light energy in the ray is reflected.
- *The angle between the incident ray and a line perpendicular to the surface of the glass at the point where the incident ray strikes the glass* is called the **angle of incidence**.

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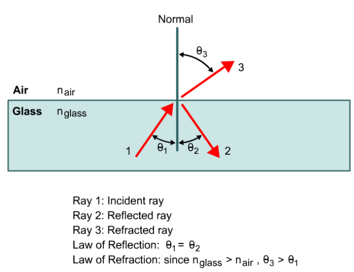
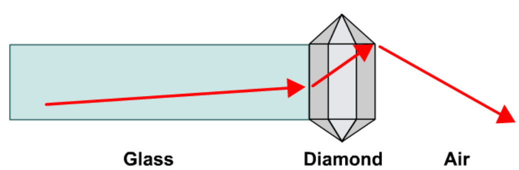
Refraction





- When a light strikes the interface between two transparent materials, the light divides into two parts.
- Part of the light ray is reflected back into the first substance, with the angle of reflection equaling the angle of incidence.
- The remaining energy in the light ray crosses the interface and enters into the second substance.

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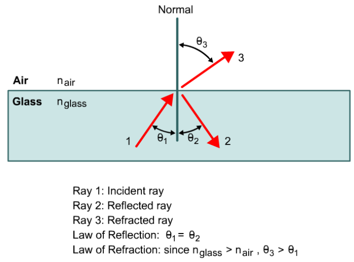
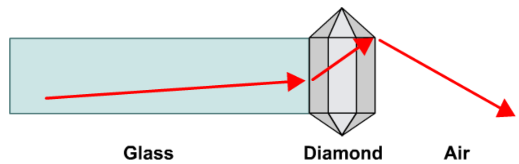
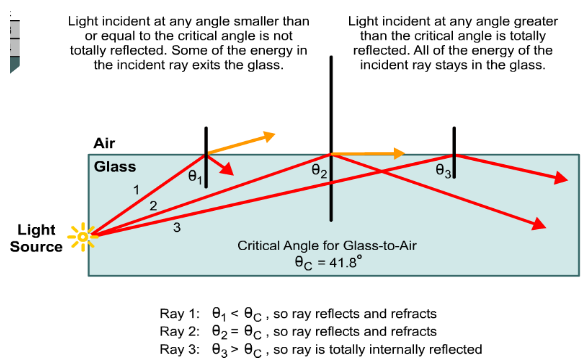
Refraction





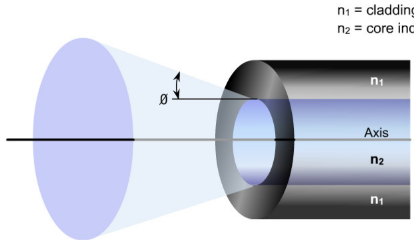
- If the incident ray strikes the glass surface at an exact 90-degree angle, the ray goes straight into the glass.
- The ray is not bent. However, if the incident ray is not at an exact 90-degree angle to the surface, then the transmitted ray that enters the glass is bent.
- The bending of the entering ray is called **refraction**.
- How much the ray is refracted depends on the index of refraction of the two transparent materials.

Total internal reflection

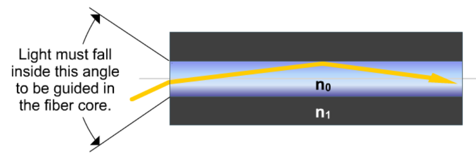


- **The following two conditions must be met for the light rays in a fiber to be reflected back into the fiber without any loss due to refraction**:
  - The core of the optical fiber has to have a larger index of refraction (n) than the material that surrounds it. The material that surrounds the core of the fiber is called the cladding.
  - The angle of incidence of the light ray is greater than the critical angle for the core and its cladding.

Total internal reflection



NA measures the range of angles that will be totally internally reflected.



- Restricting the following two factors controls the angle of incidence:
  - **The numerical aperture of the fiber** – The numerical aperture of a core is the range of angles of incident light rays entering the fiber that will be completely reflected.
  - **Modes** – The paths which a light ray can follow when traveling down a fiber.
- By controlling both conditions, the fiber run will have total internal reflection. This gives a light wave guide that can be used for data communications.

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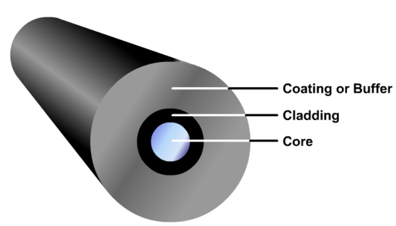
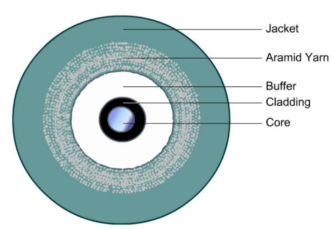
Fiber Optic Cabling





- The **core** is the light transmission element at the center of the optical fiber. All the light signals travel through the core.
- **Cladding** is also made of silica but with a lower index of refraction than the core. Light rays traveling through the fiber core reflect off this core-to-cladding interface as they move through the fiber by total internal reflection.
- Surrounding the cladding is a **buffer** material that is usually plastic. The buffer material helps shield the core and cladding from damage.
- The strength material surrounds the buffer, preventing the fiber cable from being stretched when installers pull it. The material used is often **Kevlar**, the same material used to produce bulletproof vests.
- The **outer jacket** surrounds the cable to protect the fiber against abrasion, solvents, and other contaminants.

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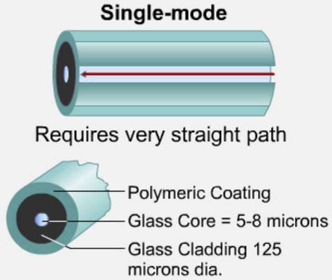
Fiber Optic Cabling

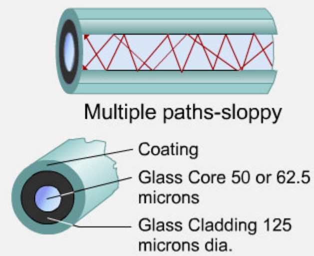
Single-mode



- 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

Higher bandwidth.

Multimode



- 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

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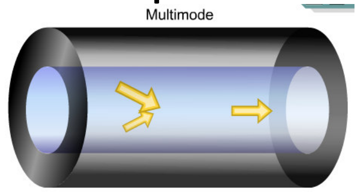
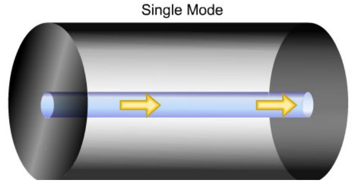
Fiber Optic Cabling

Multimode



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.

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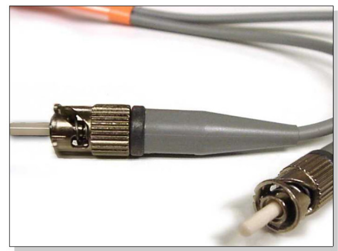
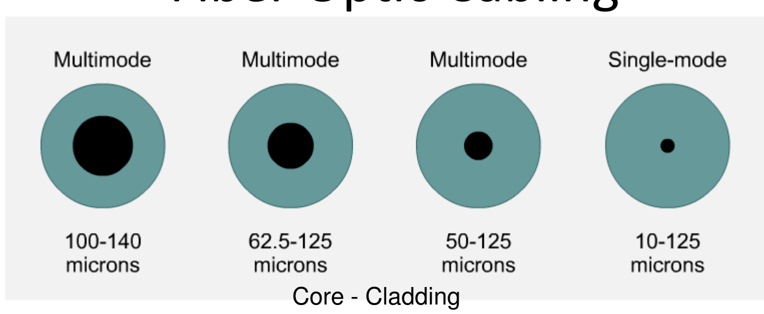
Fiber Optic Cabling



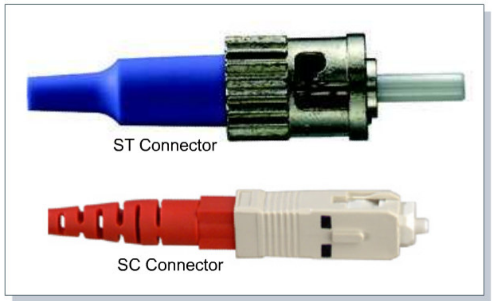
- Every fiber-optic cable used for networking consists of two glass fibers encased in separate sheaths.
- One fiber carries transmitted data from device A to device B.
- The second fiber carries data from device B to device A.
- This provides a full-duplex communication link.
- Typically, these two fiber cables will be in a single outer jacket until they reach the point at which connectors are attached.

Fiber Optic Cabling



- **Warning:** The laser light used with single-mode has a longer wavelength than can be seen.
- The laser is so strong that it can seriously damage eyes.
- **Never** look at the near end of a fiber that is connected to a device at the far end.
- **Never** look into the transmit port on a NIC, switch, or router.
- Remember to keep protective covers over the ends of fiber and inserted into the fiber-optic ports of switches and routers.

ST and SC Connectors



- The type of connector most commonly used with multimode fiber is the Subscriber Connector (SC connector).
- On single-mode fiber, the Straight Tip (ST) connector is frequently used

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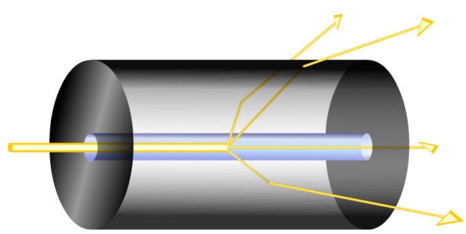
Signals and noise in optical fibers



- Fiber-optic cable is **not** affected by the sources of external noise that cause problems on copper media because external light cannot enter the fiber except at the transmitter end.
- Although fiber is the best of all the transmission media at carrying large amounts of data over long distances, fiber is not without problems. When light travels through fiber, some of the light energy is lost.
- The most important factor is **scattering**.
  - The scattering of light in a fiber is caused by microscopic non-uniformity (distortions) in the fiber that reflects and scatters some of the light energy.

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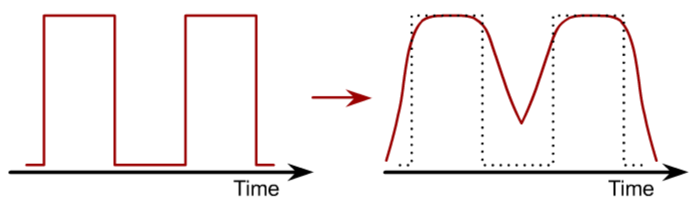
Signals and noise in optical fibers



- **Absorption** is another cause of light energy loss.
- Another factor that causes attenuation of the light signal is **manufacturing irregularities** or roughness in the core-to-cladding boundary.
- **Dispersion** of a light flash also limits transmission distances on a fiber.
  - Dispersion is the technical term for the spreading of pulses of light as they travel down the fiber

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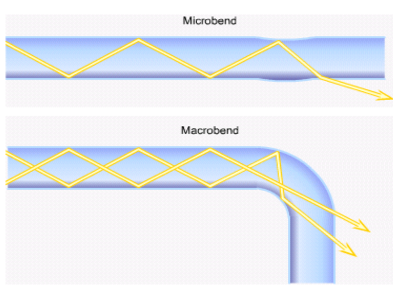
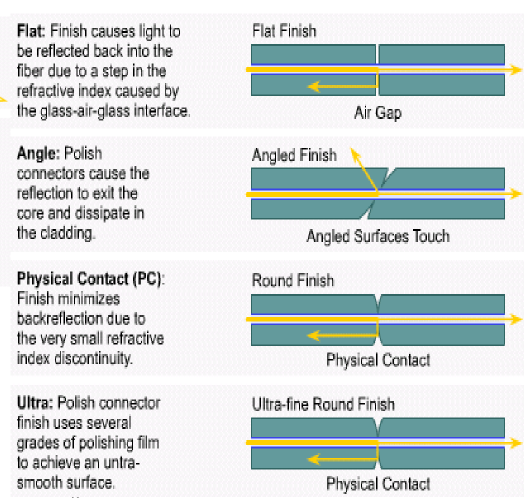
Installation, care, and testing of optical fiber

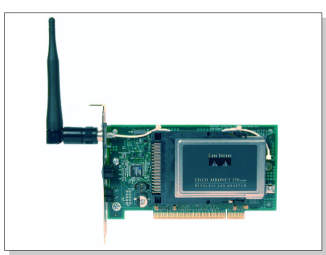




Wireless WAN Standards

- 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).
- **802.11** standard is Direct Sequence Spread Spectrum (DSSS).
  - DSSS applies to wireless devices operating within a *1 to 2 Mbps range*.
- **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*.
  - 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** covers WLAN devices operating in the 5 GHZ transmission band.
  - 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** provides the same throughput as 802.11a but with backwards compatibility for 802.11b devices.

Wireless devices and topologies



Wireless devices and topologies

- **Access point (AP)** is commonly installed to act as a central hub for the WLAN "infrastructure mode".
- The AP is hard wired to the cabled LAN to provide Internet access and connectivity to the wired network. APs are equipped with antennae and provide wireless connectivity over a specified area referred to as a cell.
- Depending on the structural composition of the location in which the AP is installed and the size and gain of the antennae, the size of the cell could greatly vary.
- Most commonly, the range will be from 91.44 to 152.4 meters (300 to 500 feet).

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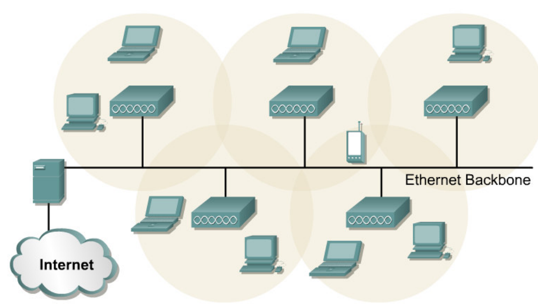
Wireless devices and topologies



- Overlap, on multiple AP networks, is critical to allow for movement of devices within the WLAN.
- Although not addressed in the IEEE standards, a 20-30% overlap is desirable.
- This rate of overlap will permit roaming between cells, allowing for the disconnect and reconnect activity to occur seamlessly without service interruption.

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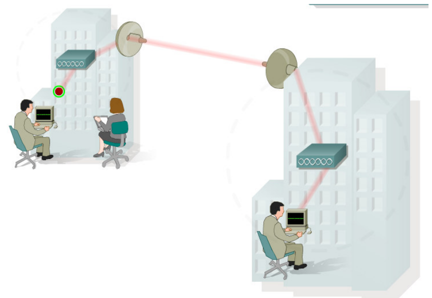
The radio wave and microwave spectrums



- Computers send data signals electronically.
- Radio transmitters convert these electrical signals to radio waves.
- Changing electric currents in the antenna of a transmitter generates the radio waves.
- However, radio waves attenuate as they move out from the transmitting antenna.

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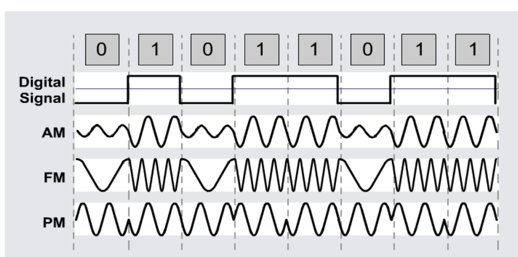
Modulation



- The process of altering the carrier signal that will enter the antenna of the transmitter is called modulation.
- There are three basic ways in which a radio carrier signal can be modulated.
- For example, **Amplitude Modulated (AM)** radio stations modulate the *height (amplitude) of the carrier signal*.
- **Frequency Modulated (FM)** radio stations modulate the *frequency of the carrier signal* as determined by the electrical signal from the microphone.
- In WLANs, a third type of modulation called **phase modulation** is used to *superimpose the data signal onto the carrier signal* that is broadcast by the transmitter.

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Actual Networks

- Apendix 3