Mod 3 – Networking Media

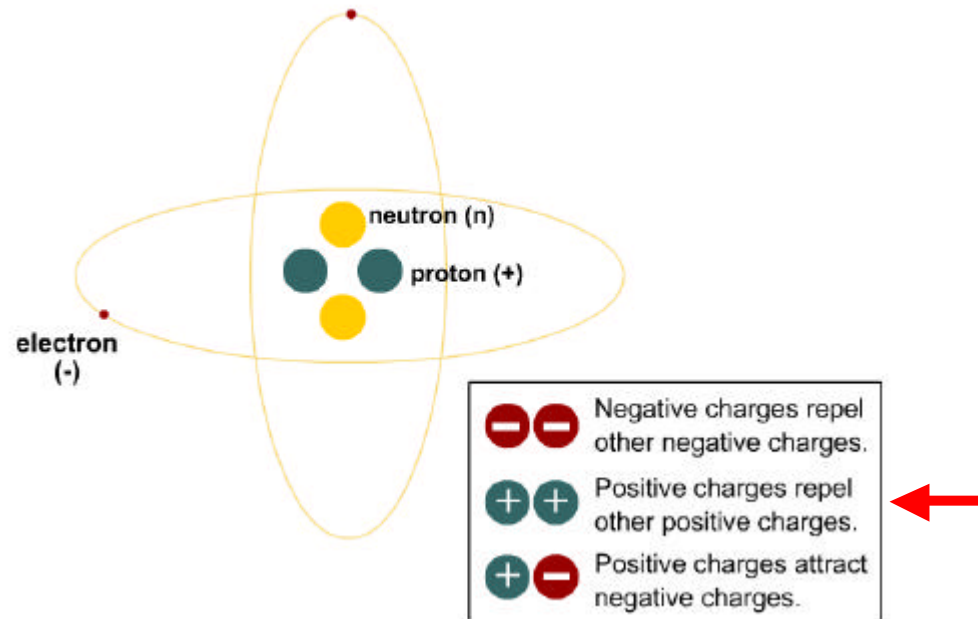CCNA 1 version 3.0

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Objectives

- Discuss the electrical properties of matter.
- Define voltage, resistance, impedance, current, and circuits.
- 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.
- 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.

Basic of Electricity

- Discuss the electrical properties of matter.
- Define voltage, resistance, impedance, current, and circuits.

Atoms and electrons

neutron (n)

proton (+)

electron
(-)

Negative charges repel
other negative charges.

Positive charges repel
other positive charges.

Positive charges attract
negative charges.

- **Electrons** – Particles with a negative charge that orbit the nucleus
- **Nucleus** – The center part of the atom, composed of protons and neutrons
- **Protons** – Particles with a positive charge
- **Neutrons** – Particles with no charge (neutral)
- Electrons stay in orbit, even though the protons attract the electrons.
- The electrons have just enough velocity to keep orbiting and not be pulled into the nucleus, just like the moon around the Earth.

Atoms and electrons
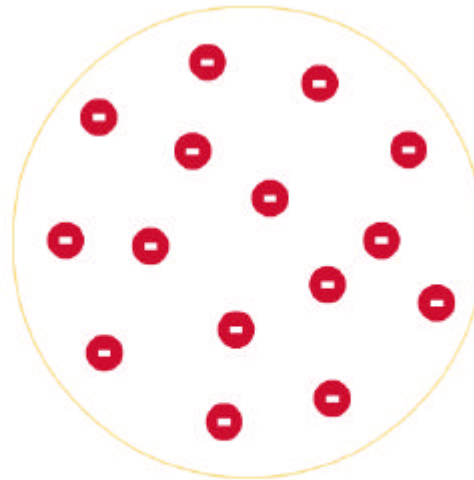
Electrons that have gathered close to each other do not move because the electrical fields repelling electrons balance out. The result is a net electrical force of zero.

- Loosened electrons that stay in one place, without moving, and with a negative charge, are called static electricity.
- If these static electrons have an opportunity to jump to a conductor, this can lead to electrostatic discharge (ESD).
- ESD, though usually harmless to people, can create serious problems for sensitive electronic equipment.
- The basis for all electronic devices is the knowledge of how insulators, conductors and semiconductors control the flow of electrons and work together in various combinations.

Voltage (force or speed)

- Voltage is sometimes referred to as electromotive force (EMF)
- Voltage is represented by the letter V, and sometimes by the letter E, for electromotive force.
- The unit of measurement for voltage is volt (V)

- Because electrons and protons have opposite charges, they are attracted to each other.
  - Similar to north and south poles of two magnets
- When charges are separated, causes a force or pressure field between the charges.
- This force is voltage.
- Voltage can be considered as, *the speed of the electron traffic*.

Voltage (force or speed)
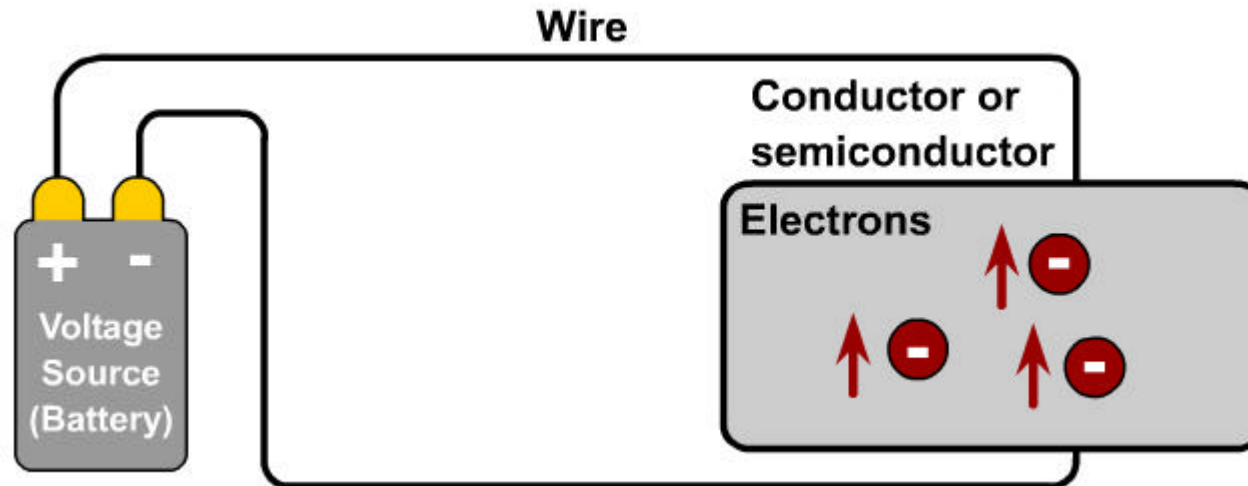
- This process occurs in a battery, where chemical action causes electrons to be freed from the negative terminal of the battery.
- The electrons then travel to the opposite, or positive, terminal through an EXTERNAL circuit.
- The electrons do not travel through the battery itself.
- Remember that the flow of electricity is really the flow of electrons.

Voltage (force or speed)

DC

AC
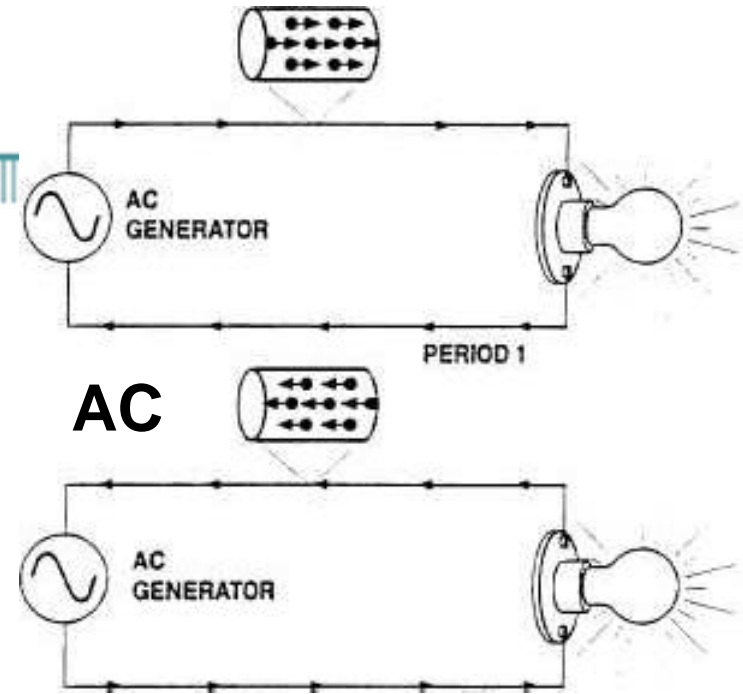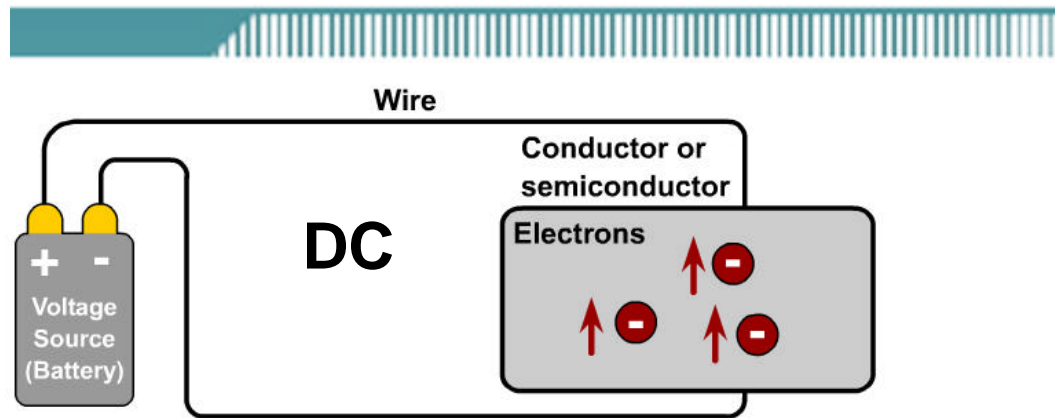
- **Direct-current (DC) voltage**
  - Example: battery
  - Te movement of electrons in a DC circuit is always in the same direction, from negative to positive.
- **Alternating-current (AC) voltage**
  - The positive and negative terminals of the AC voltage source regulary change to negative and positive and back again.
  - The change makes the direction of electron movement change, or anternate with respect to time.
  - Alternating current is the more common type of electricity as permanent supply to commercial and industrial buildings and domestic premises..

Voltage - AC
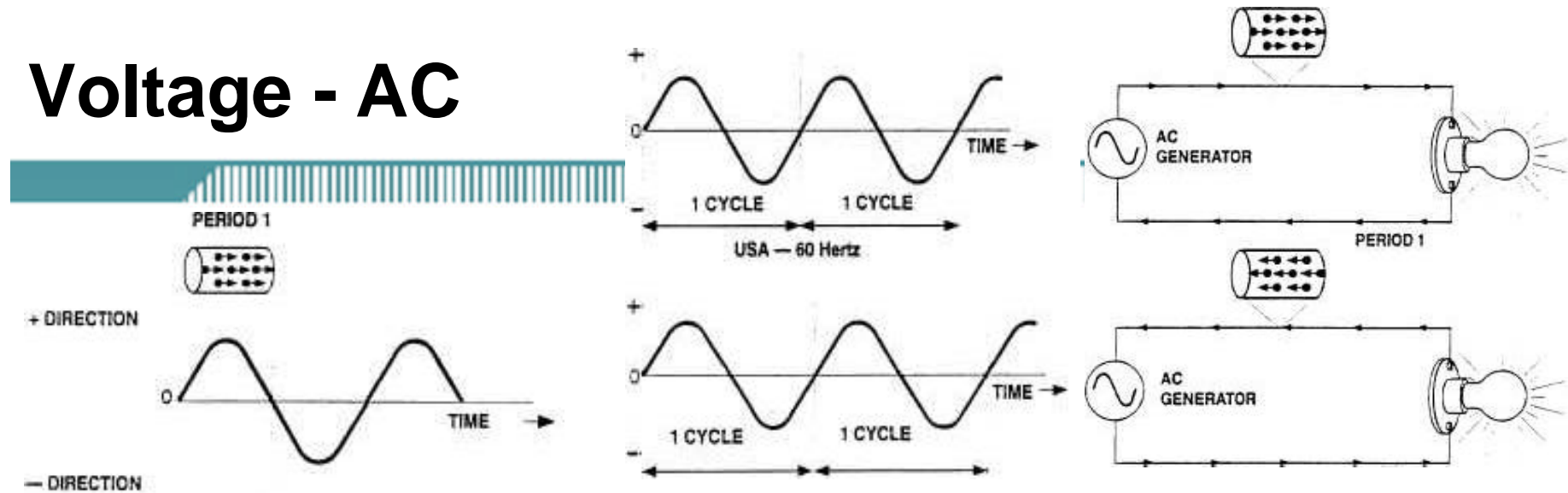
- This is a graphical representation of alternating current called a sine wave. Note the two axes.

- The vertical axis represents the direction and magnitude of the current; the horizontal axis represents time.

- When the wave form is above the time axis, current is flowing in what is called the positive (+) direction.

- When the wave for is below the time axis, the current is flowing in the opposite, or what is called the negative (-) direction.

- In period 1, current starts at zero magnitude, increases to a maximum magnitude, and diminishes back to zero.

- In period 2 shown in current flow reverses direction and immediately begins to increase in the negative direction.

- When current flow reaches maximum magnitude, it diminishes until it reaches zero again.

- The pattern of alternating current flowing first in the positive direction (period 1) and then in the negative direction (period 2), is called one cycle (periods 1 + 2).

Current (Amperage)

- The action of electricity flowing in a conductor is called "current flow".
- **Current** is the flow of charges that is created when electrons move.
- When voltage, electrical pressure, is applied and a path for the current exists, electrons move from the negative terminal to the positive terminal.
- The symbol for current is the capital letter "I".
- Measured in **amperes**, or amp, "A"
- **Amp** = *Number of charges per second that pass by a point along a path.*
    - The amount of electron traffic.
    - More electron traffic that is flowing through a circuit, the higher the current.
- DC current is one direction, AC current is two directions.
- You can compare water flow to electron flow.
- A flow meter can be used to measure the quantity of water flowing in a pipe, measured in litres per second.
- An ampmeter can be used to measure current flow through a conductor.

Wattage

- If **current** (amperage) is the *amount* or volume of electron traffic that is flow, …
- Then **voltage** can be thought of as the *speed* of electron traffic.
- Current (amps) times Voltage = Wattage (W)
  - W = V x I
- A watt (W) is the basic unit of electrical power.
- Wattage is how much power electrical devices consume or produce.
  - **Static electricity** has very high voltage (jumping a gap of over an inch), but very low amperage, which means can create a shock, but no injury.
  - A **starter motor** relatively low 12 volts, but requires high enough amperage to turn over the engine.
  - **Lightening**, has both high voltage and high amperage, an can cause severe injury or damage.

Resistance (DC) and Impedance (AC)

Insulators	Conductors	Semiconductors
Electrons flow poorly	Electrons flow well	Electron flow can be precisely controlled
Plastic Rubber Air Paper Dry Wood Glass	Copper (Cu) Silver (Ag) Gold (Au) Solder Water w/Ions Humans	Carbon (C) Germanium (Ge) Gallium Arsenide (GaAs) Silicon (Si)

- The materials through which current flows offer varying amounts of opposition, or resistance to the movement of the electrons.
- The materials that offer very little, or no, resistance, are called **conductors**.
- Those materials that do not allow the current to flow, or severely restrict its flow, are called **insulators**.
- **Semiconductors** are materials where the amount of electricity they conduct can be precisely controlled.
- The amount of resistance depends on the chemical composition of the materials.

Resistance (DC) and Impedance (AC)

Insulators	Conductors	Semiconductors
Electrons flow poorly	Electrons flow well	Electron flow can be precisely controlled
Plastic Rubber Air Paper Dry Wood Glass	Copper (Cu) Silver (Ag) Gold (Au) Solder Water w/Ions Humans	Carbon (C) Germanium (Ge) Gallium Arsenide (GaAs) Silicon (Si)

- **Resistance (R)** is the property of material that resists electron movement.
    - Generally refers to DC circuits
    - Conductors - low resistance
    - Insulators - high resistance
- **Impedance (Z)** is the resistance to the movement of electrons in an AC circuit.
- **Ohm (W, omega)** – unit of measurement for resistance and impedance
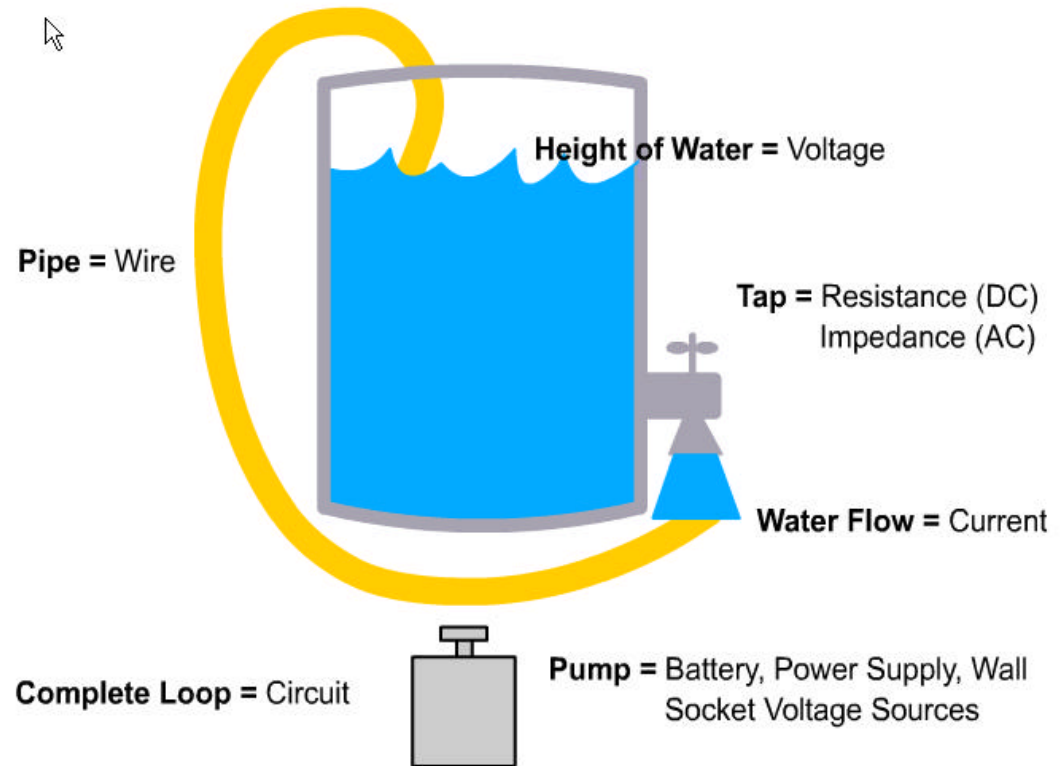
Resistance (DC) and Impedance (AC)

- All materials that conduct electricity have a measure of **resistance** to the flow of electrons through them.

- These materials also have other effects called **capacitance** and **inductance** associated with the flow of electrons.

  - **capacitance**

    - A **capacitor** is a passive electronic component that stores energy in the form of an electrostatic field.

    - The number of electrons it can hold under a given electrical pressure (voltage) is called its **capacitance or capacity**.

  - **inductance**

    - An inductor is a passive electronic component that stores energy in the form of a magnetic field.

    - In its simplest form, an inductor consists of a wire loop or coil.

    - **inductance** is the property of a circuit by which energy is stored in the form of an electromagnetic field.

- The three characteristics, **resistance, capacitance, and inductance, comprise impedance**, which is similar to and includes resistance.
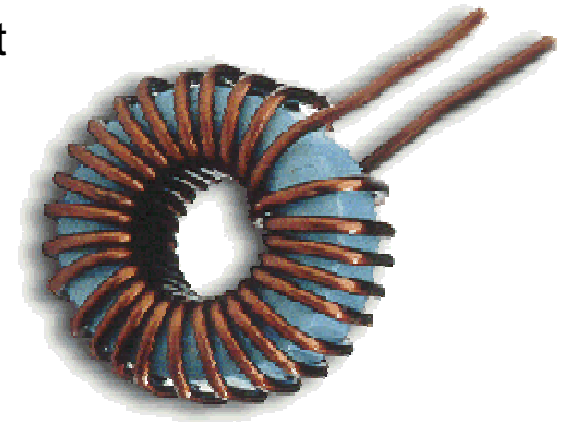
Circuits

- The relationship among voltage, resistance, and current is:
- voltage (V) = current (I) multiplied by resistance (R).
- **Ohm's law**, $V=I*R$

Height of Water = Voltage

Pipe = Wire

Tap = Resistance (DC)
Impedance (AC)

Water Flow = Current

Pump = Battery, Power Supply, Wall Socket Voltage Sources

Complete Loop = Circuit

- Current flows in closed loops called **circuits**.
- These circuits must be **composed of conducting materials**, and must have **sources of voltage**.
- **Voltage** causes current to flow, while **resistance** and **impedance** oppose it.
- **Current** consists of electrons flowing away from **negative** terminals and towards **positive** terminals.
- Knowing these facts allows people to control a flow of current.

Circuits

- *Electrons flow in closed circuits, or complete loops*.
- The chemical processes in the battery cause charges to build up.
- This provides a voltage, or electrical pressure, that enables electrons to flow through various devices.

Switch "Off"
Open Circuit
Broken Loop
No Current
No Continuity

Provides Resistance

6V Lantern

Switch "On"
Closed Circuit
Closed Loop
Some Current
Continuity

6V Lantern

Wire is Conductor

- The lines represent a conductor, which is usually copper wire.
- Think of a **switch** as *two ends of a single wire that can be opened or broken to prevent electrons from flowing*.
- When the two ends are closed, fixed, or shorted, electrons are allowed to flow.
- Finally, a light bulb provides resistance to the flow of electrons, causing the electrons to release energy in the form of light.
- The circuits involved in networking use a much more complex version of this very simple circuit.
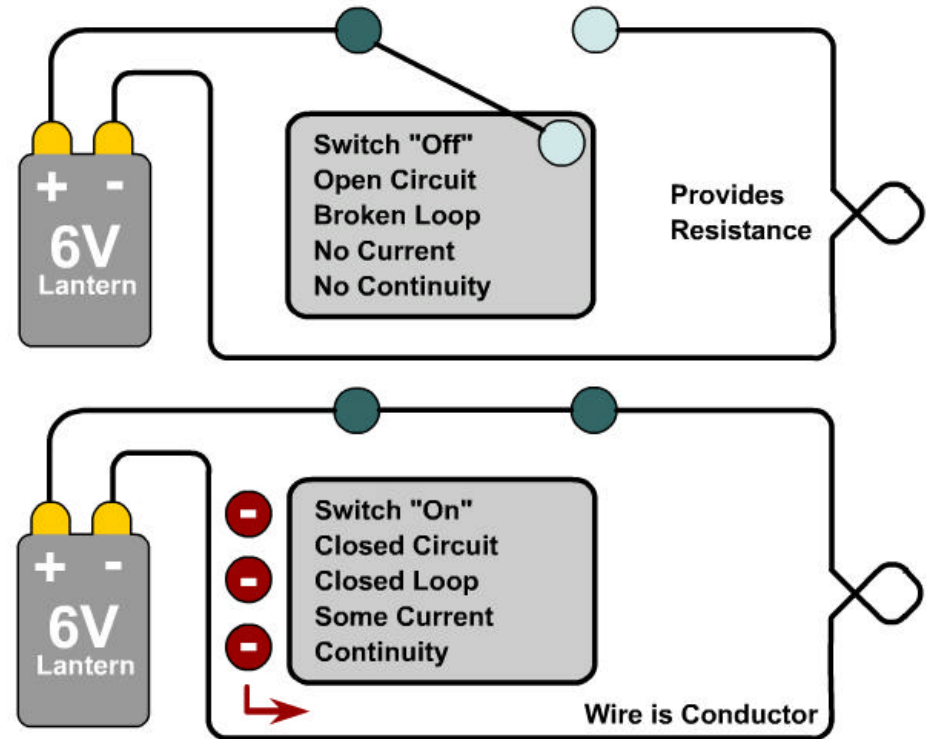
Copper Media

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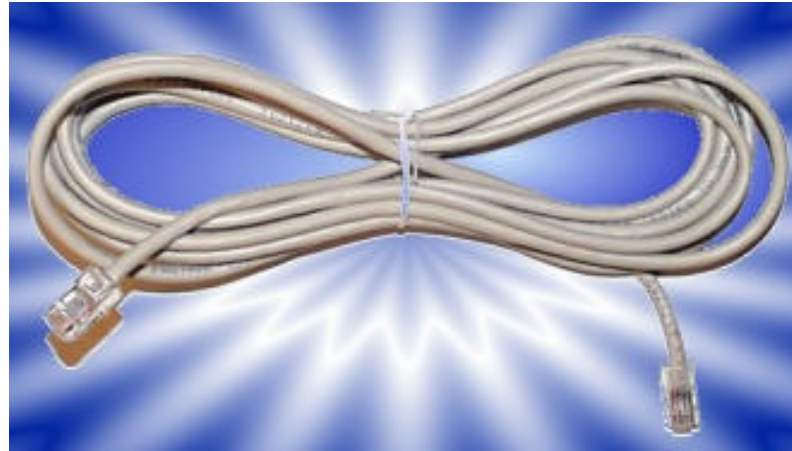
Cable Specifications

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
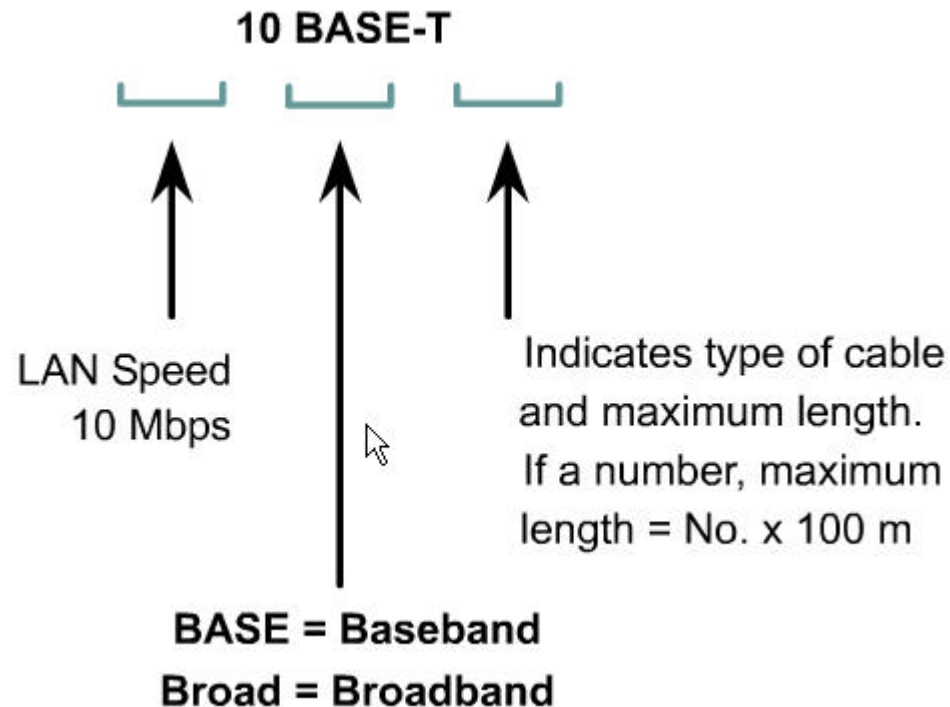
- Cables have different specifications and expectations pertaining to performance.

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.

Cable Specifications

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

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**

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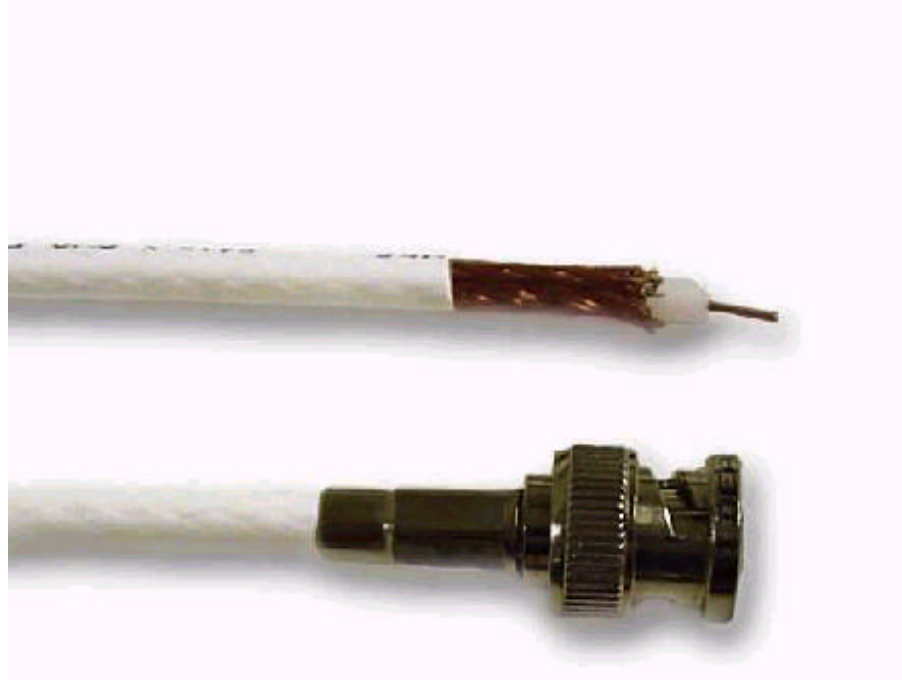
- **10BASE2**
  - speed of transmission at 10 Mbps
  - type of transmission is baseband
  - The 2, in 10BASE2, represents the capability of the cable to allow the signal to travel for approximately 200 meters, before attenuation could disrupt the ability of the receiver to appropriately interpret the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

Coaxial Cable

Outer Jacket

Braided Copper Shielding

Copper Conductor

Plastic Insulation
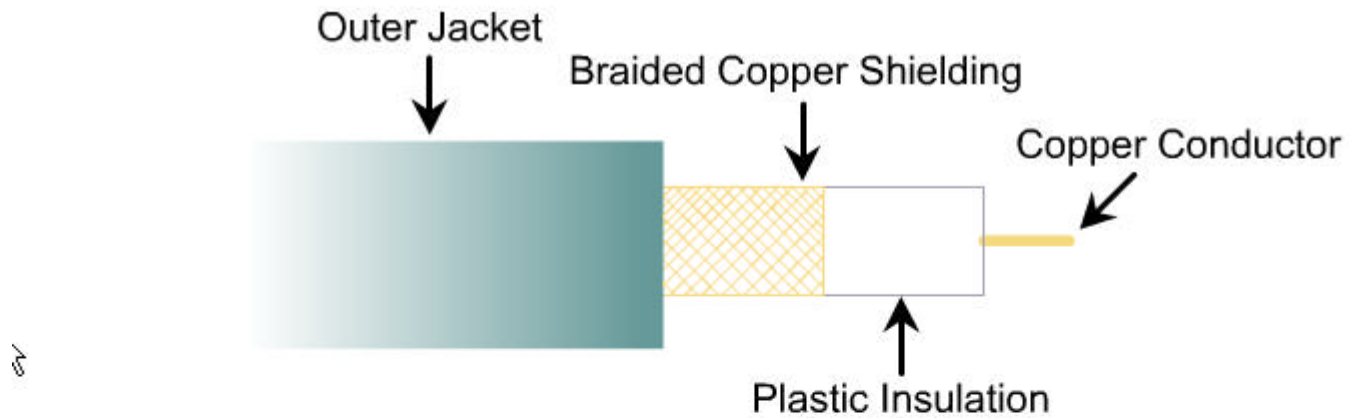
BNC Connector →

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

Coaxial Cable

Outer Jacket

Braided Copper Shielding

Copper Conductor

Plastic Insulation

BNC Connector →
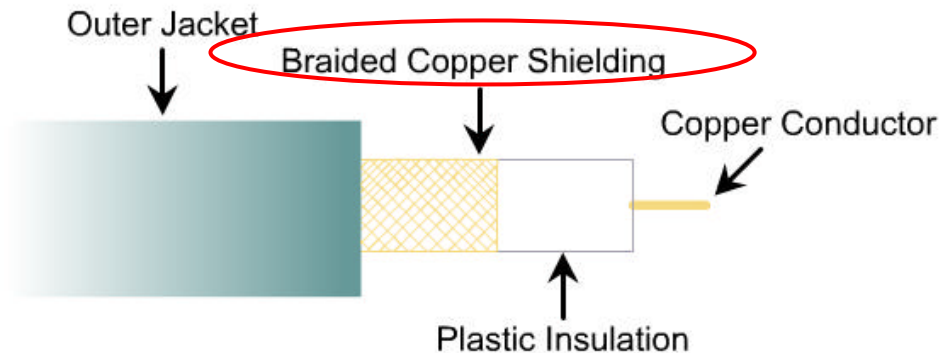
- Woven copper braid or metallic foil
  - Acts as the second wire in the circuit
  - Acts as a shield for the inner conductor.
  - Reduces the amount of outside electro-magnetic interference.
  - Comprises half the electric circuit
  - Special care must be taken to ensure a solid electrical connection 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.

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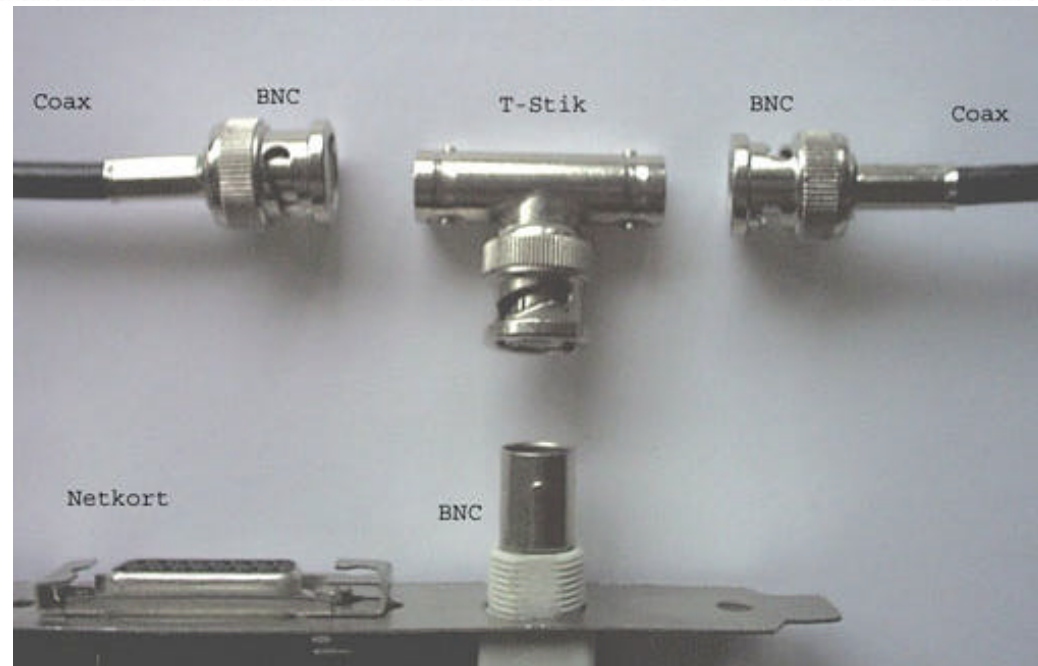
- **Advantages**:
  - Requires fewer repeaters than twisted pair
  - Less expensive than fiber
  - It has been used for many years for many types of data communication, including cable television
- **Disadvantages**:
  - More expensive and more difficult to install than twisted pair
  - Needs more room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

Shielded Twisted Pair (STP and ScTP)

STP – Shielded Twisted Pair
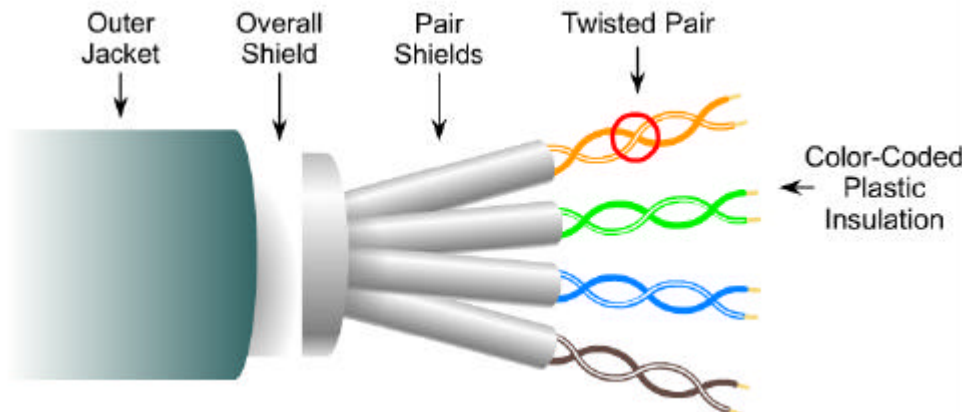
ScTP – Screened Twisted Pair
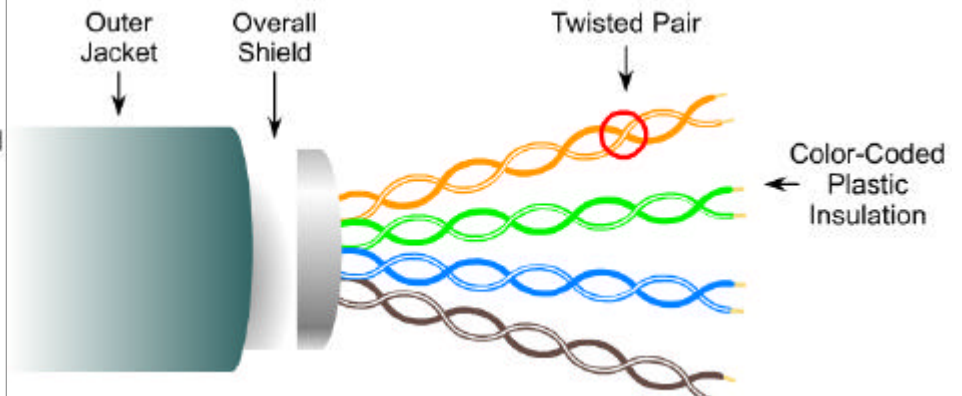
- Speed and throughput: 10 - 100 Mbps
- Average $ per node: Moderately Expensive
- Media and connector size: Medium to Large
- Maximum cable length: 100m

- **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.

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

Unshielded Twisted Pair (UTP)

Outer Jacket

Twisted Pair

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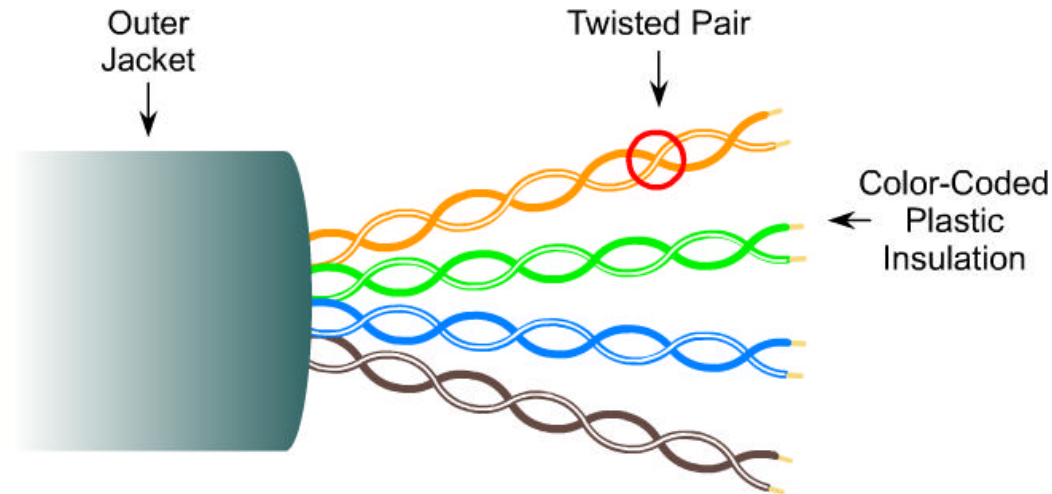
- Unshielded twisted-pair cable (UTP) is a four-pair wire medium used in a variety of networks.
- TIA/EIA-568-A contains specifications governing cable performance.
- RJ-45 connector
- When communication occurs, the signal that is transmitted by the source needs to be understood by the destination.
-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

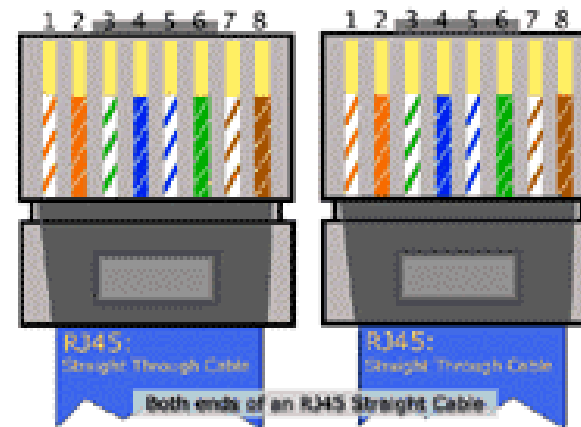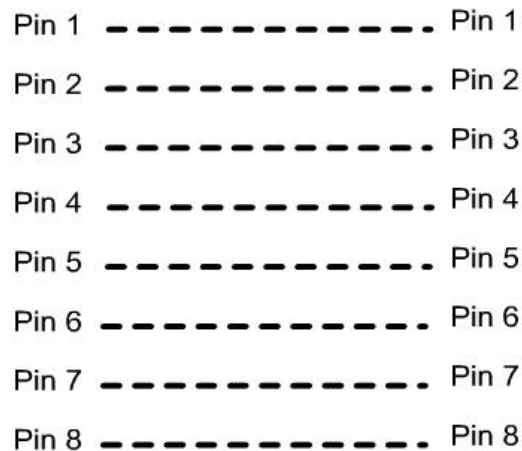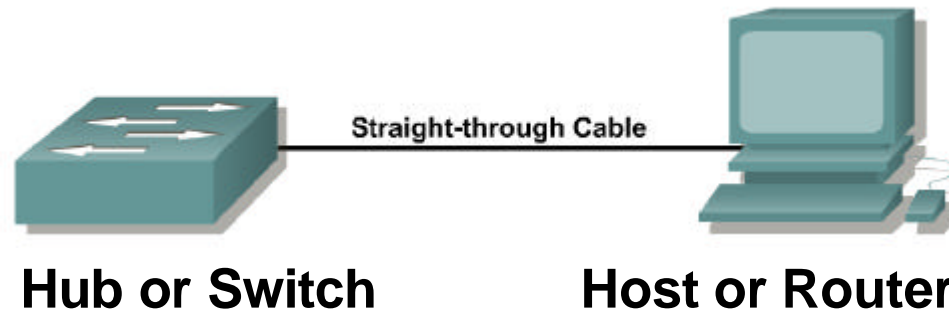# Unshielded Twisted Pair (UTP)
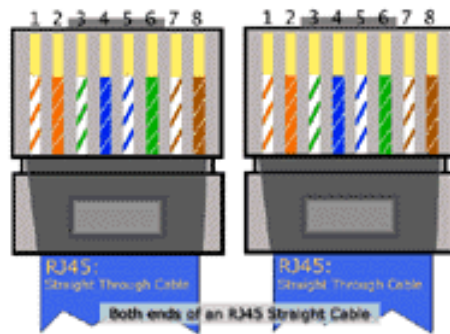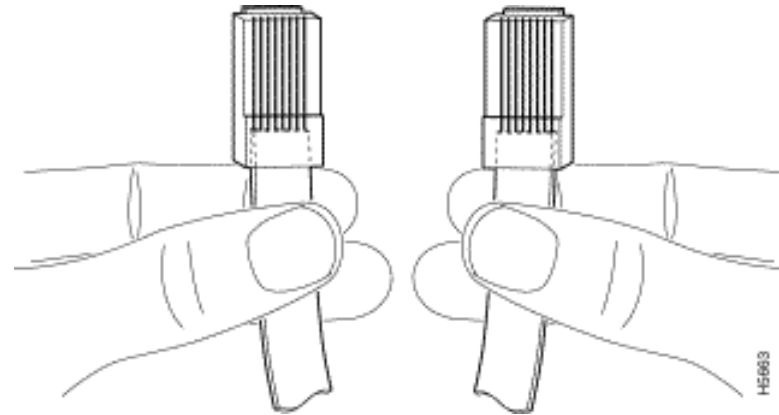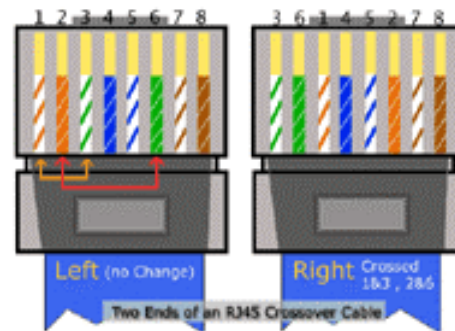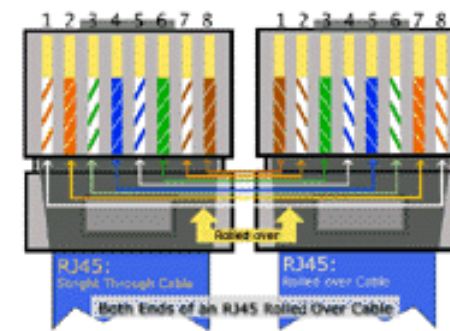
Straight-through   **Cross-over**   **Rollover**

www.cisco.com/warp/ public/701/14.html

UTP Straight-through Cable

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

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

RJ45: Straight Through Cable   RJ45: Straight Through Cable
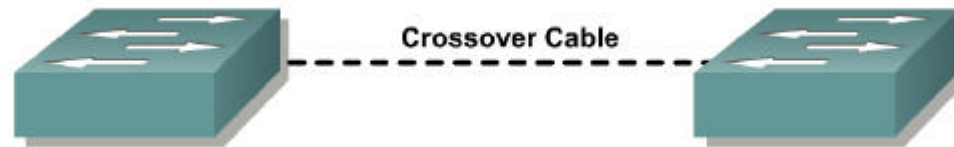
Both ends of an RJ45 Straight Cable

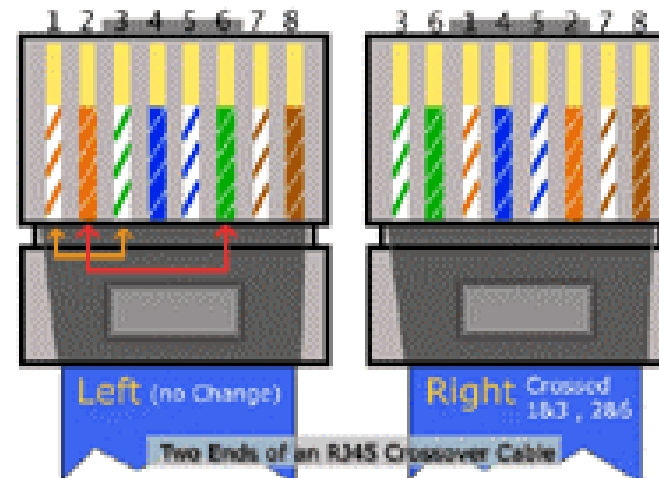- The cable that connects from the switch port to the computer NIC port is called a straight-through cable.

UTP Straight-through Cable

Hub or Switch   **Host or Router**

Straight-through Cable
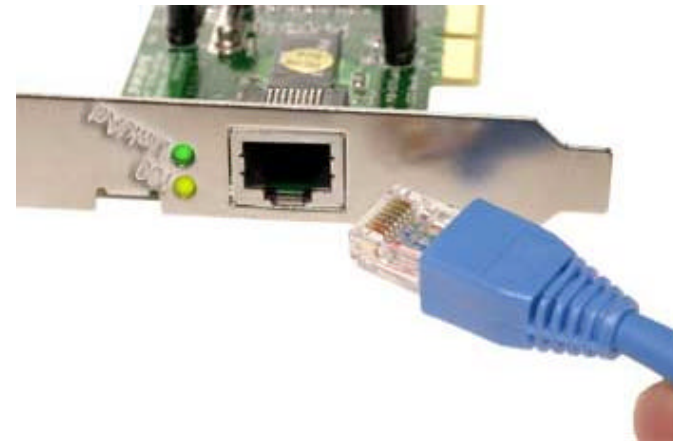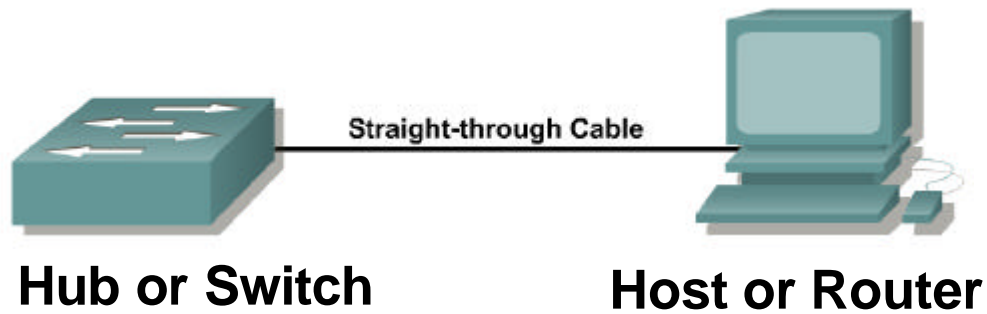
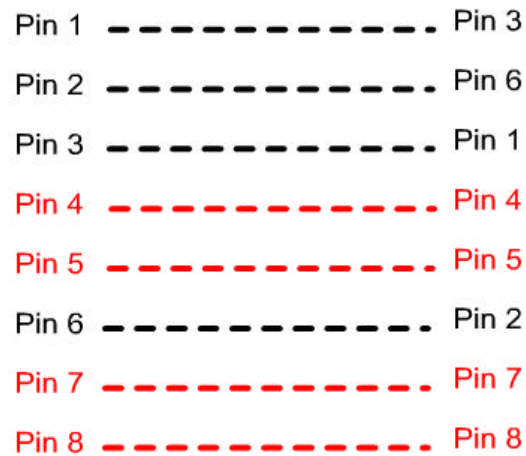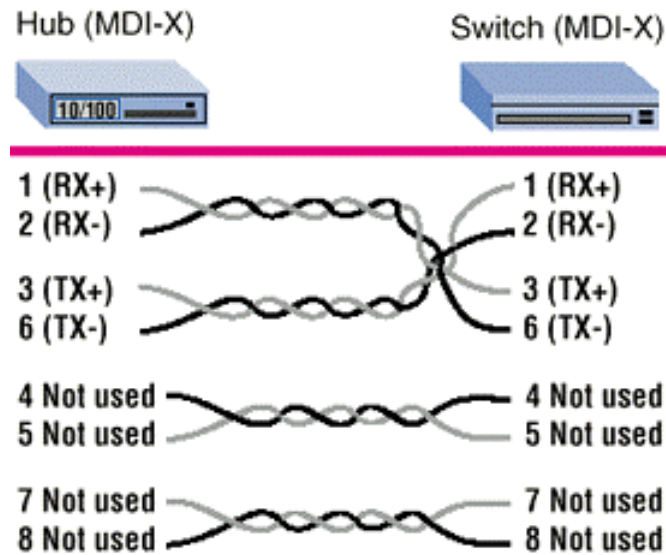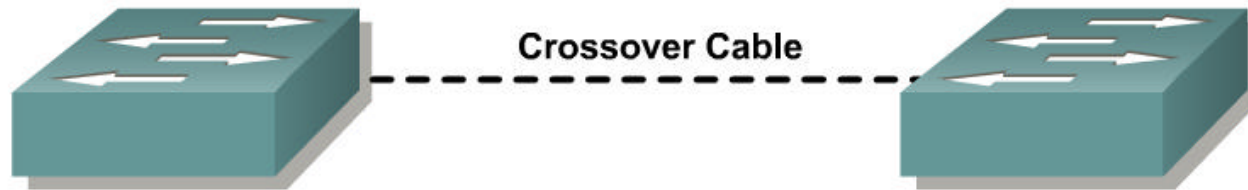# UTP Cross-over Cable

Crossover 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

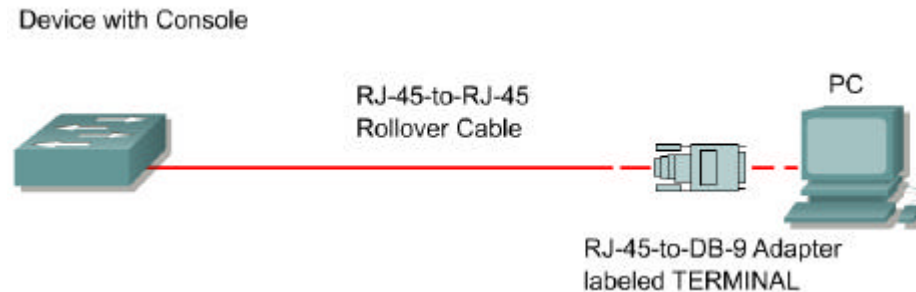Left (no Change)   Right Crossed 1&3 , 2&6

Two Ends of an RJ45 Crossover Cable

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

UTP Cross-over Cable

Crossover Cable

Hub (MDI-X)   Switch (MDI-X)

10/100

1 (RX+)   1 (RX+)
2 (RX-)   2 (RX-)

3 (TX+)   3 (TX+)
6 (TX-)   6 (TX-)

4 Not used   4 Not used
5 Not used   5 Not used

7 Not used   7 Not used
8 Not used   8 Not used

UTP Rollover Cable

Device with Console

RJ-45-to-RJ-45
Rollover Cable

PC

RJ-45-to-DB-9 Adapter
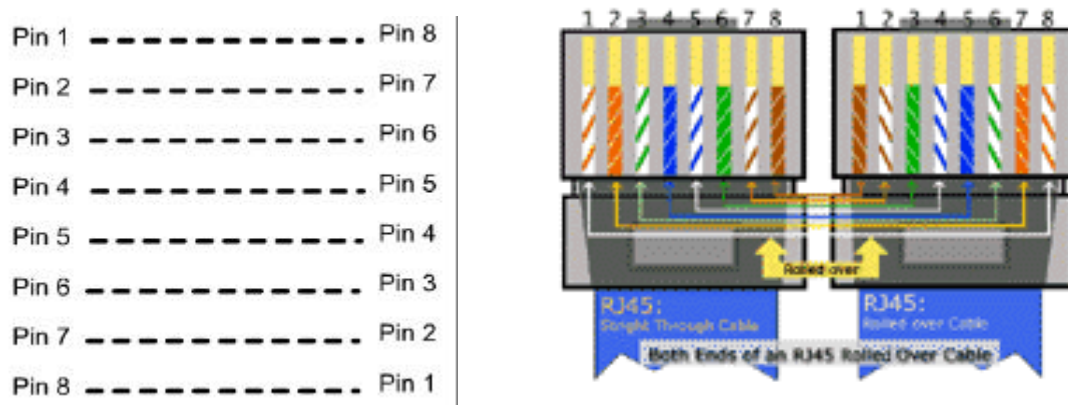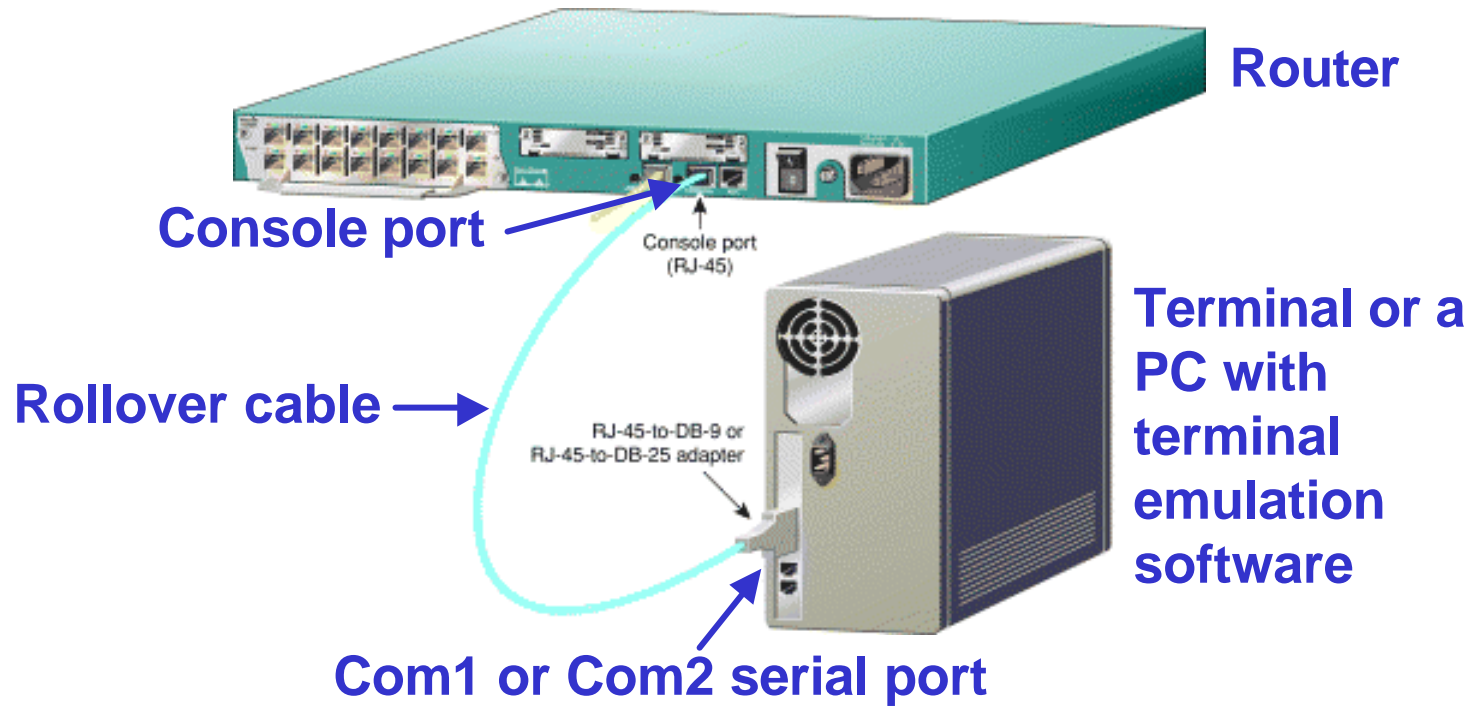labeled TERMINAL

- 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.

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

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

Rolled over

RJ45:
Straight Through Cable

RJ45:
Rolled over Cable

Both Ends of an RJ45 Rolled Over Cable

- 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.

UTP Rollover Cable

Router

Console port

Console port
(RJ-45)

Terminal or a PC with terminal emulation software

Rollover cable

RJ-45-to-DB-9 or
RJ-45-to-DB-25 adapter
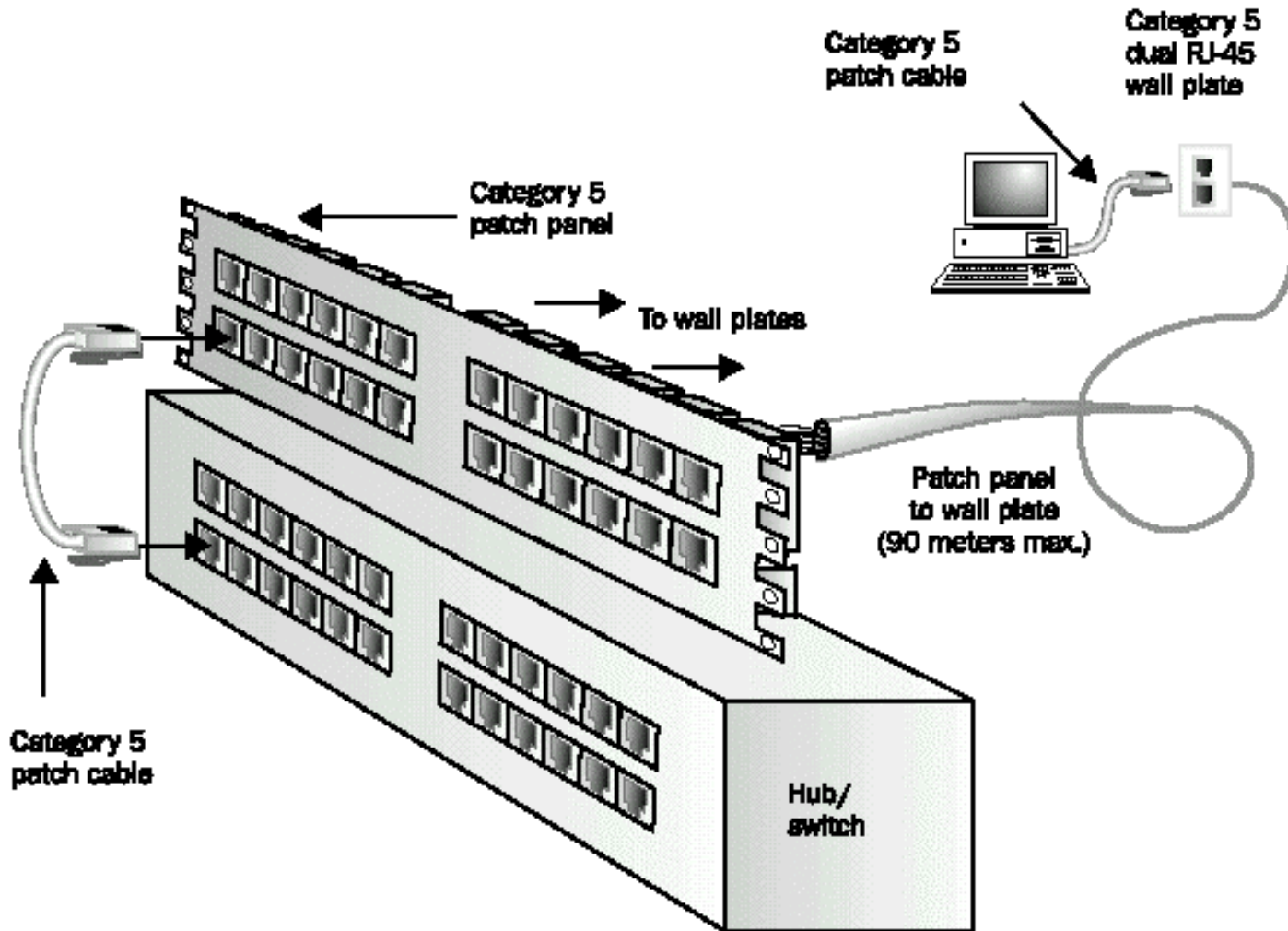
Com1 or Com2 serial port

Lab Activities

- Lab Exercise: Fluke 620 Basic Cable Testing
- In this lab, the student will use a simple cable tester to verify whether a straight-through or crossover cable is good or bad.

- Lab Exercise: Straight-Through Cable Construction
- In this lab, the student will build a Category 5 or Category 5e (CAT 5 or 5e) unshielded twisted pair (UTP) Ethernet network patch cable or patch cord and test the cable for continuity and correct pinouts, the correct color of wire on the right pin.

- Lab Exercise: Rollover Cable Construction
- In this lab, the student will build a Category 5 or Category 5e (CAT 5 or 5e) unshielded twisted pair (UTP) console rollover cable and test the cable for continuity and correct pin-outs, the correct wire on the right pin.

- Lab Exercise: Crossover Cable Construction
- In this lab, the student will build a Category 5 or Category 5e (CAT 5 or 5e) unshielded twisted pair (UTP) Ethernet crossover cable to T568-B and T-568-A standards and test the cable for continuity and correct pin-outs, correct wire on the right pin.
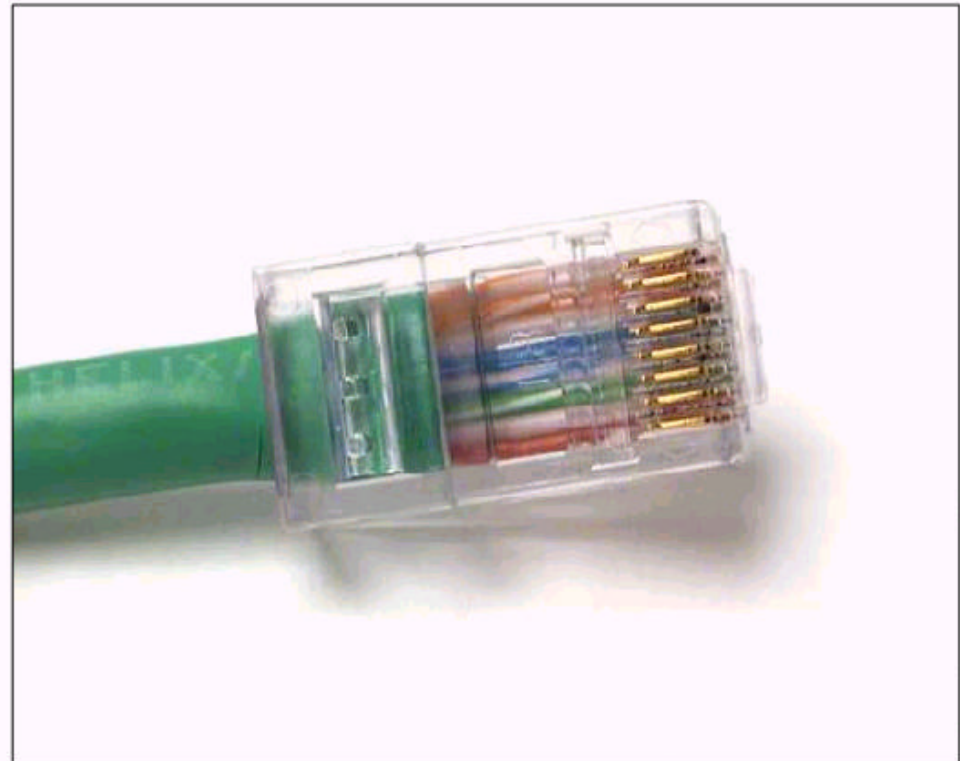
- Lab Exercise: UTP Cable Purchase
- This lab will introduce the variety and prices of network cabling and components in the market. The student will gather pricing information for UTP patch cables and bulk cable.
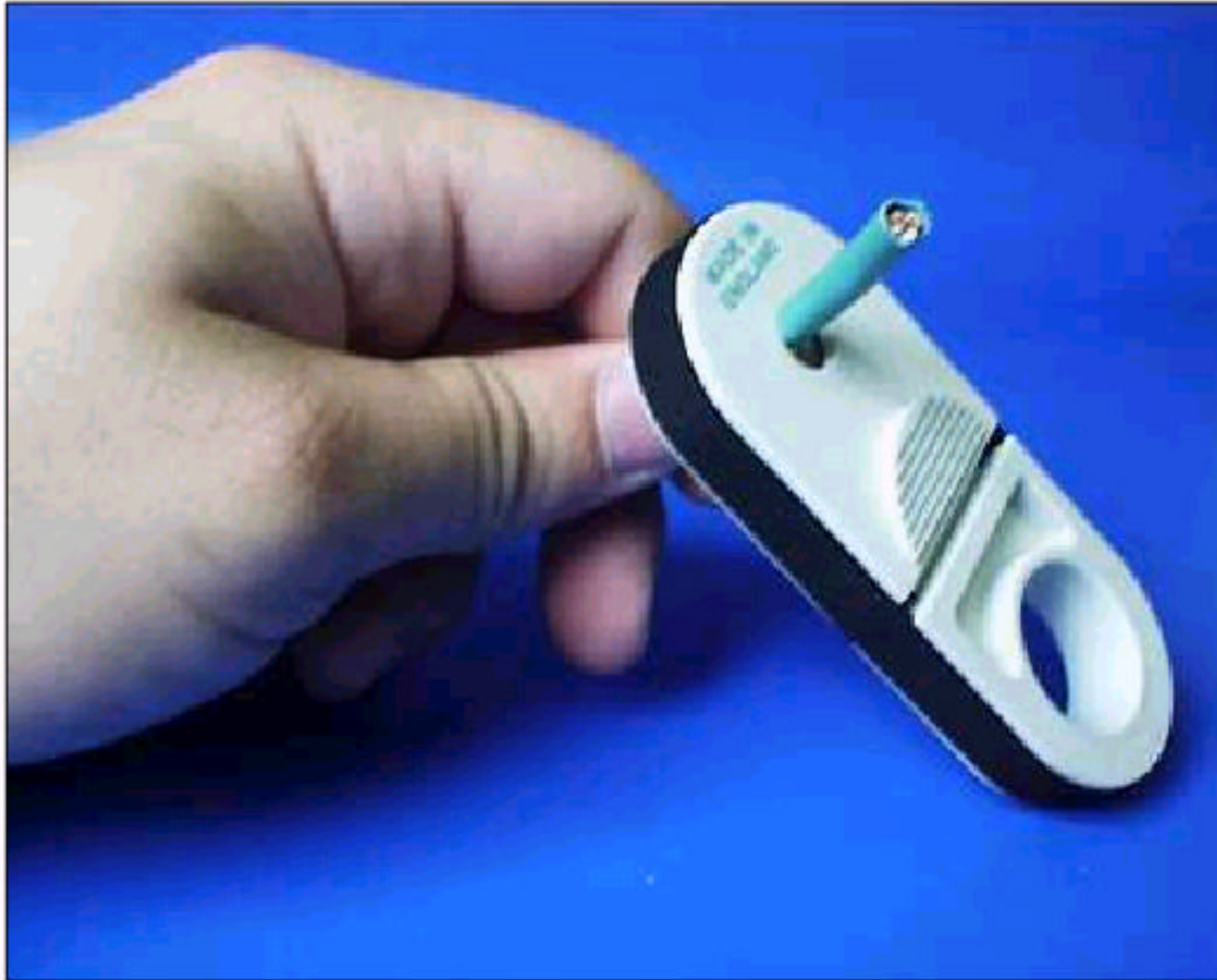
Category 5
patch cable

Category 5
dual RJ-45
wall plate

Category 5
patch panel

To wall plates

Patch panel
to wall plate
(90 meters max.)

Category 5
patch cable

Hub/
switch
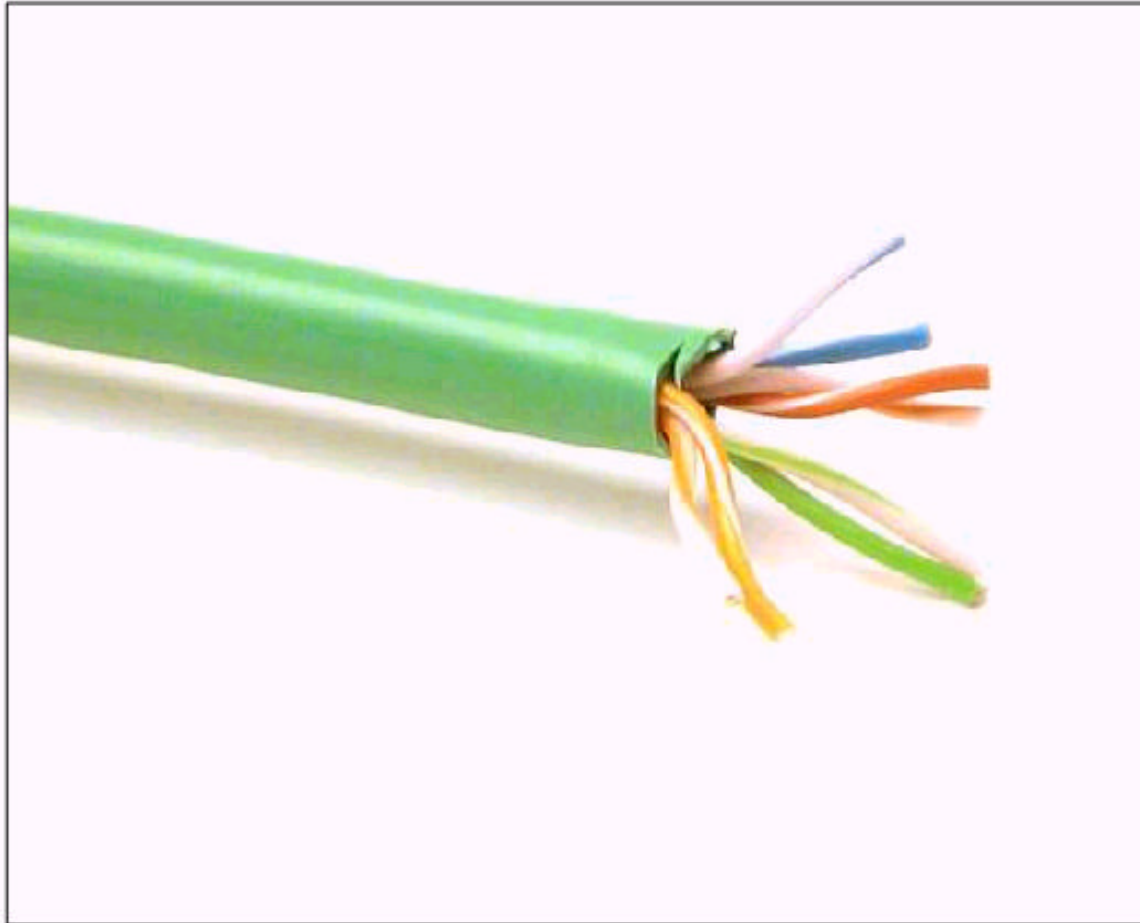
Making a Cable

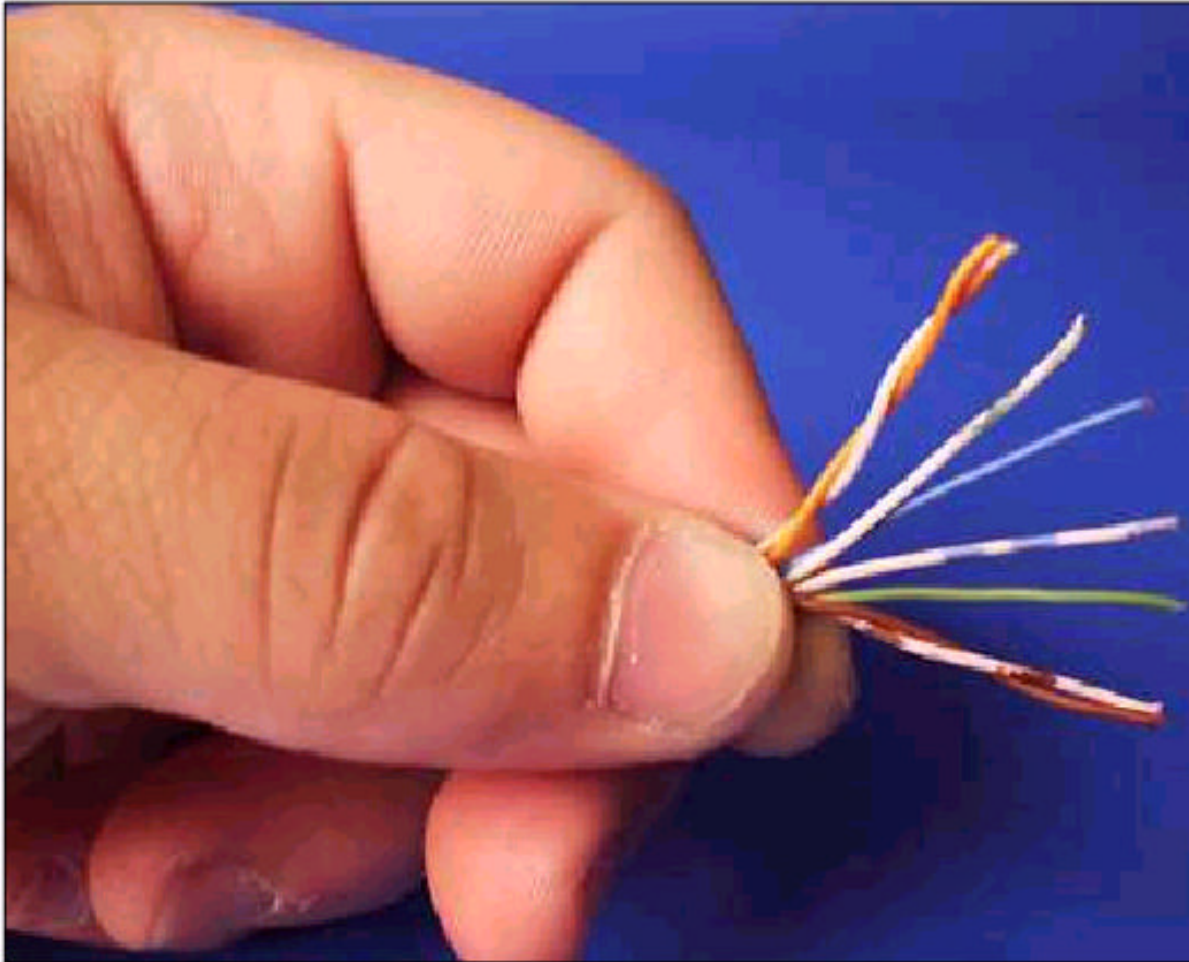We will have a lab on this later.
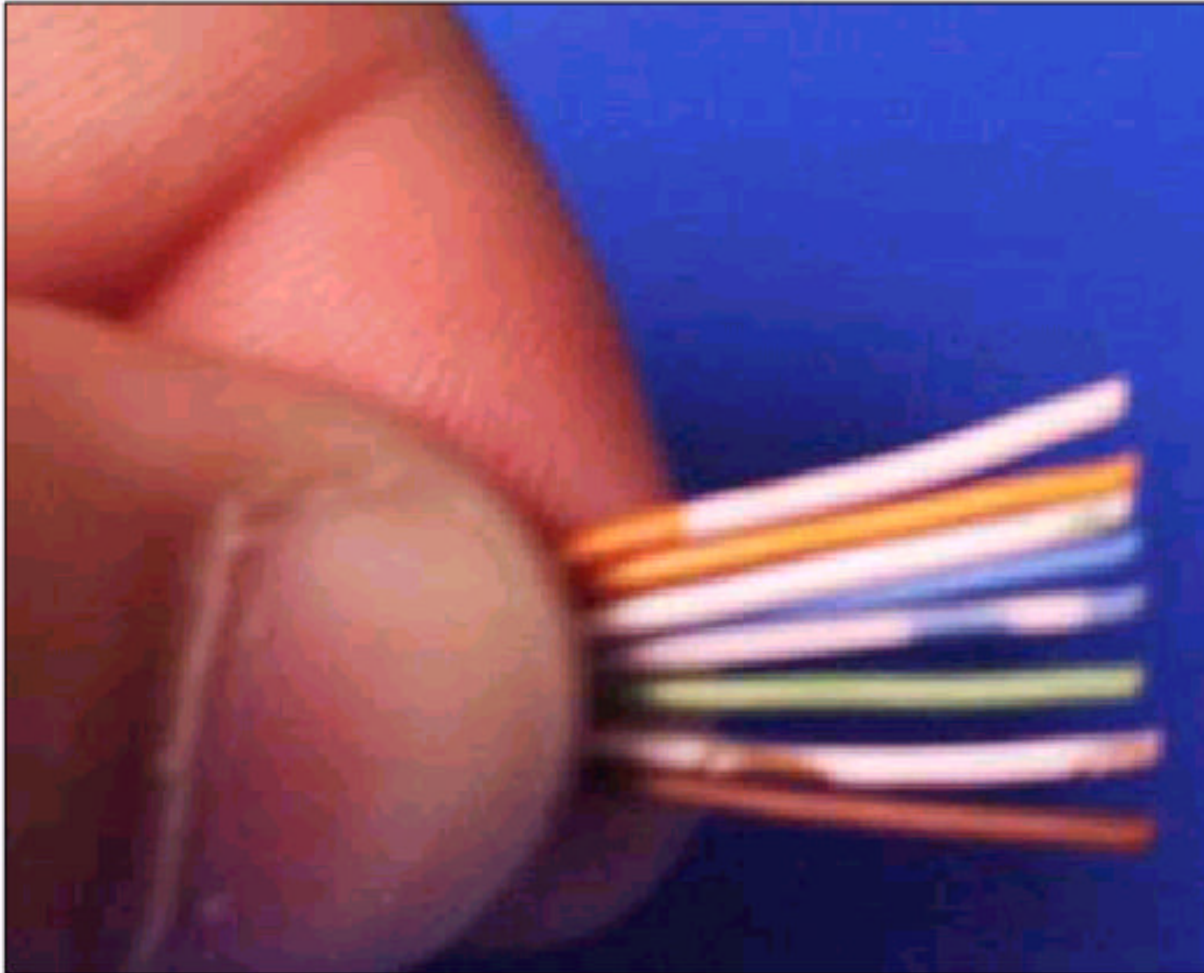
Cut a Length of Cable

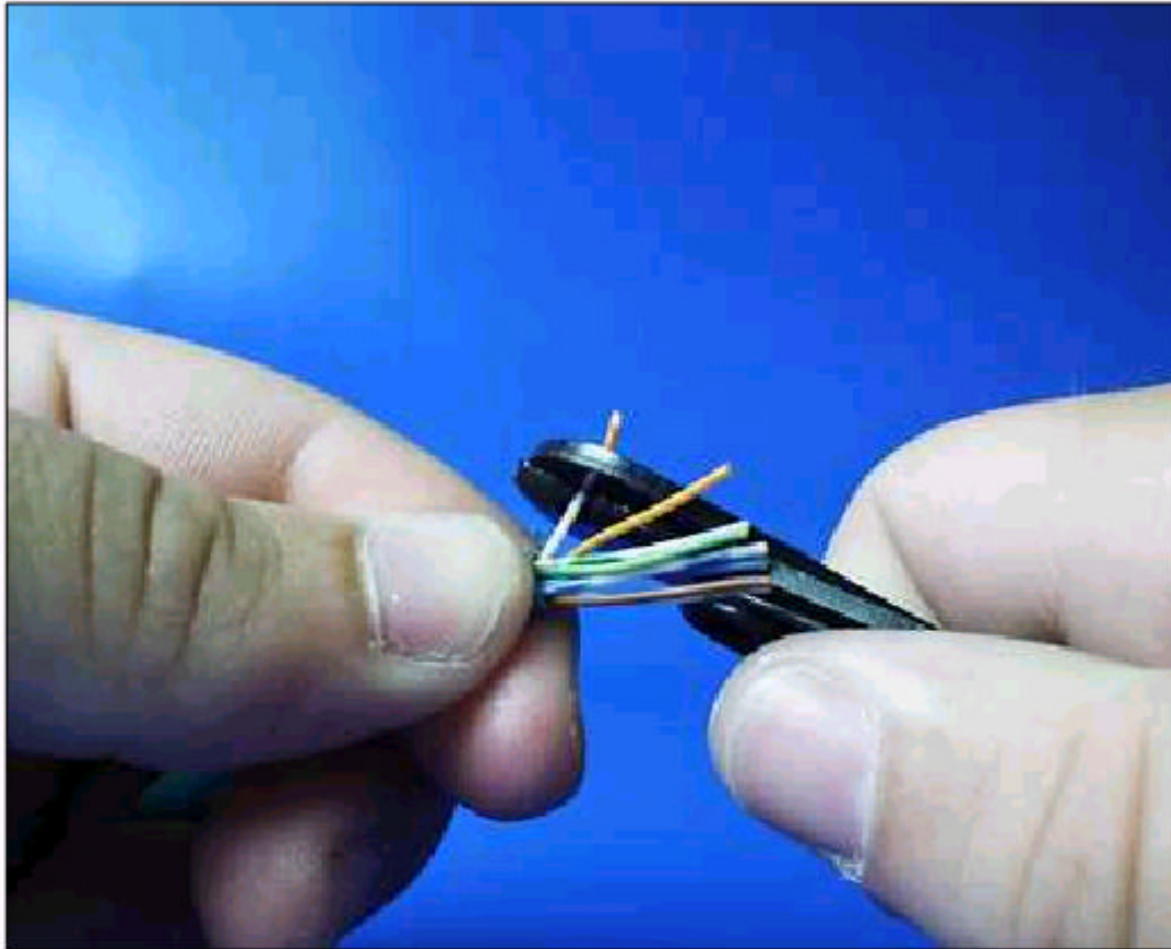# Strip off the Jacket
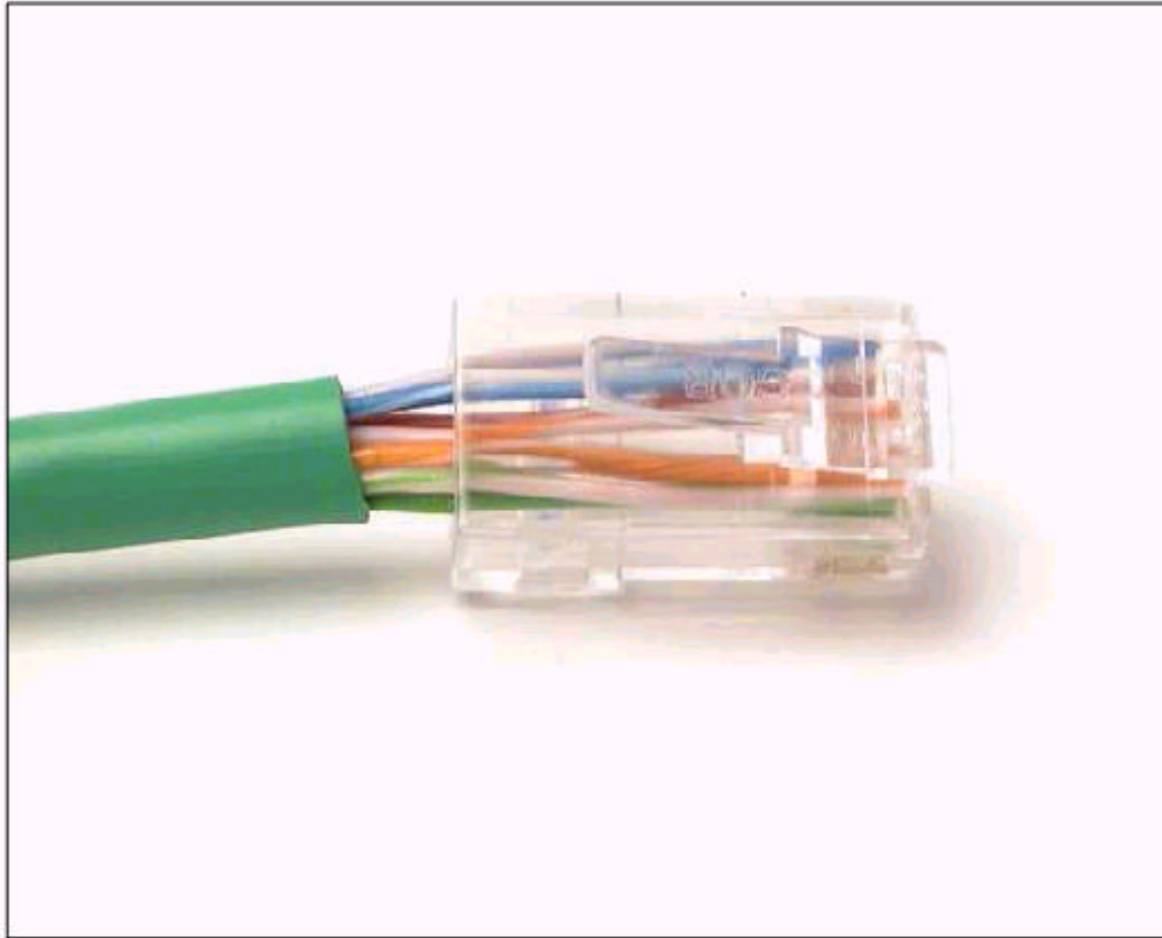
Separate the Wires

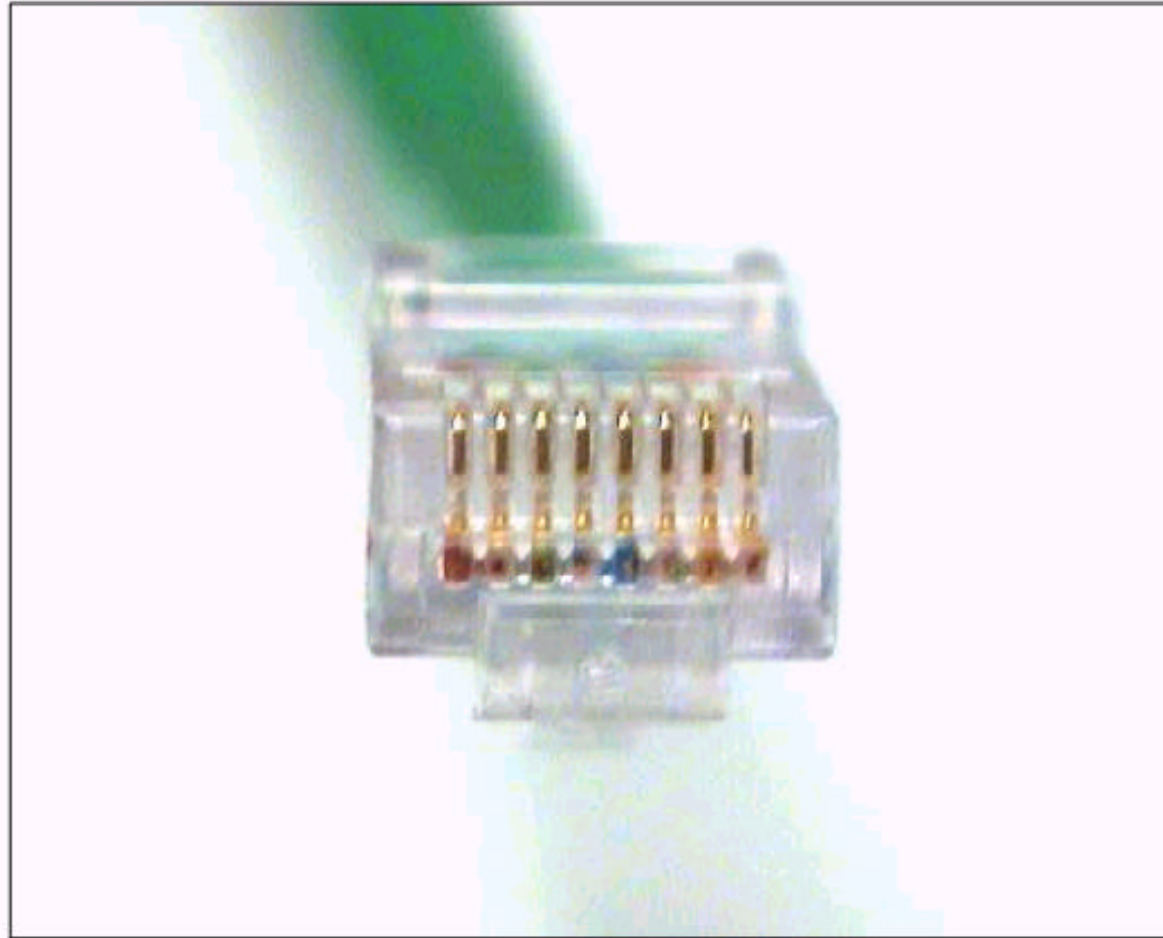# Untwist the Wires

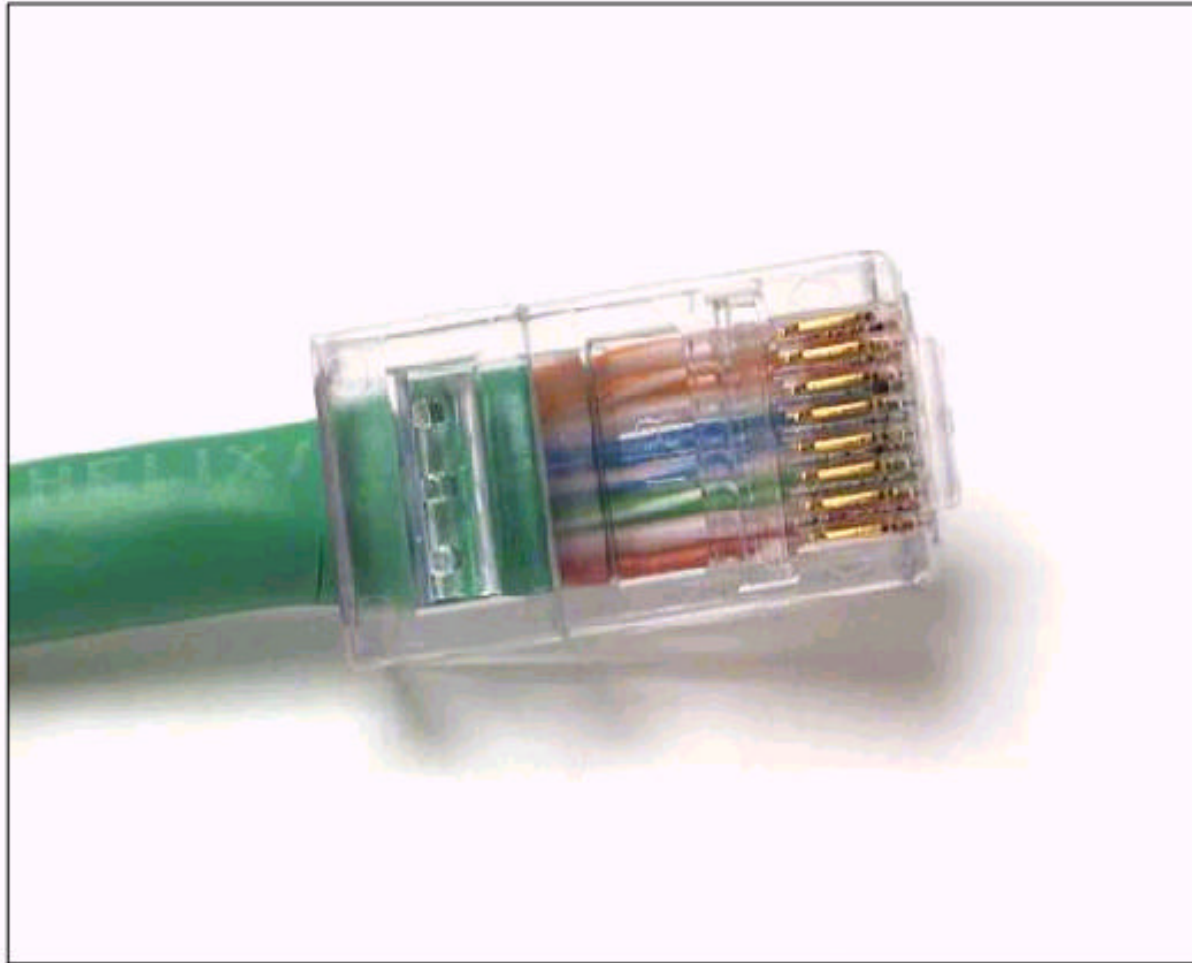# Organize and Flatten Wires

Clip the Wires

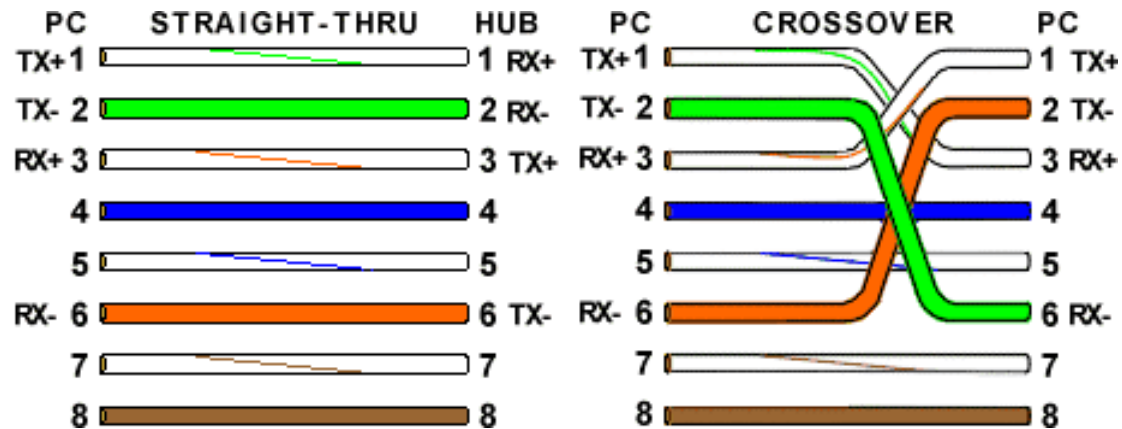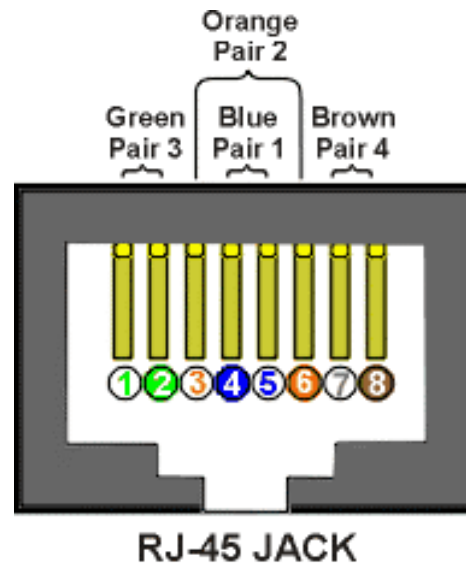# Insert Wires into RJ-45 Plug
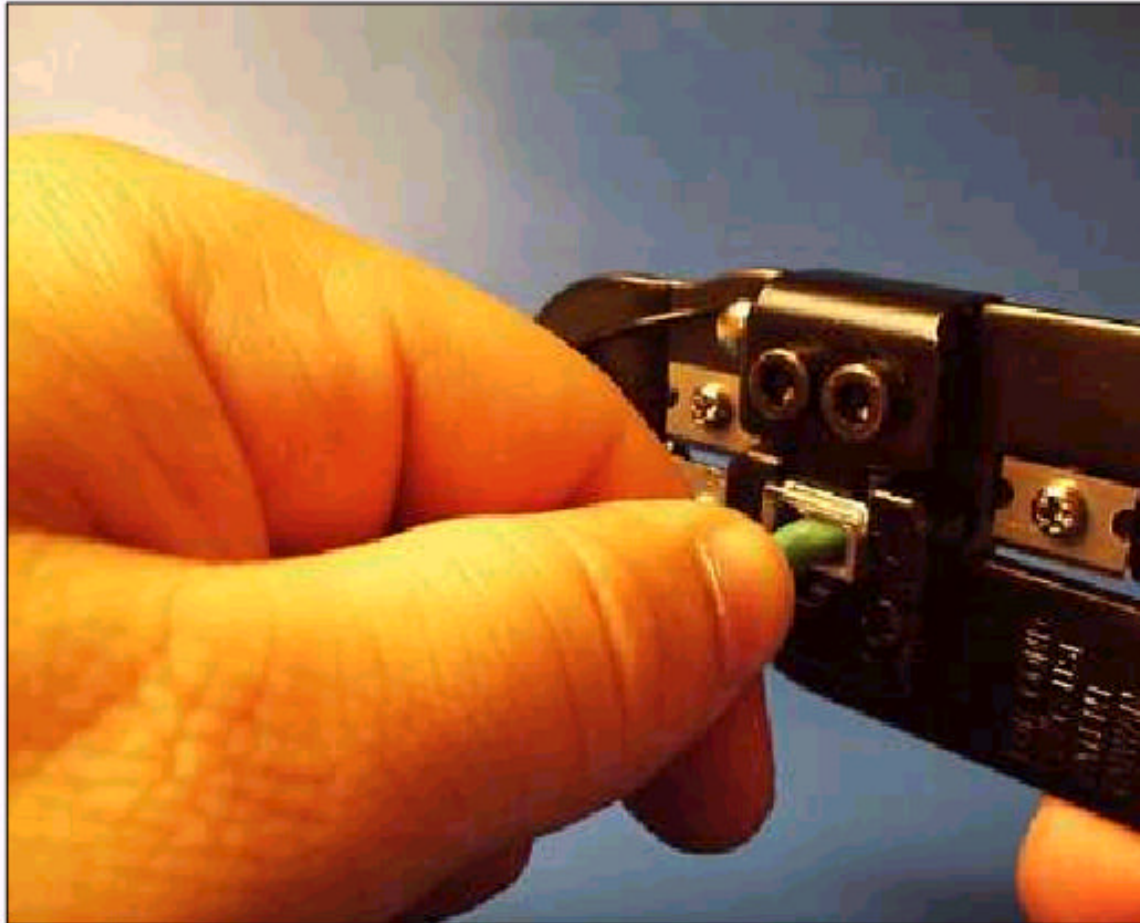
Push the Wires In

Inspect the Color Code

CAT5 Termination (568A)

Crimp Down the Wires

Inspect Both Ends
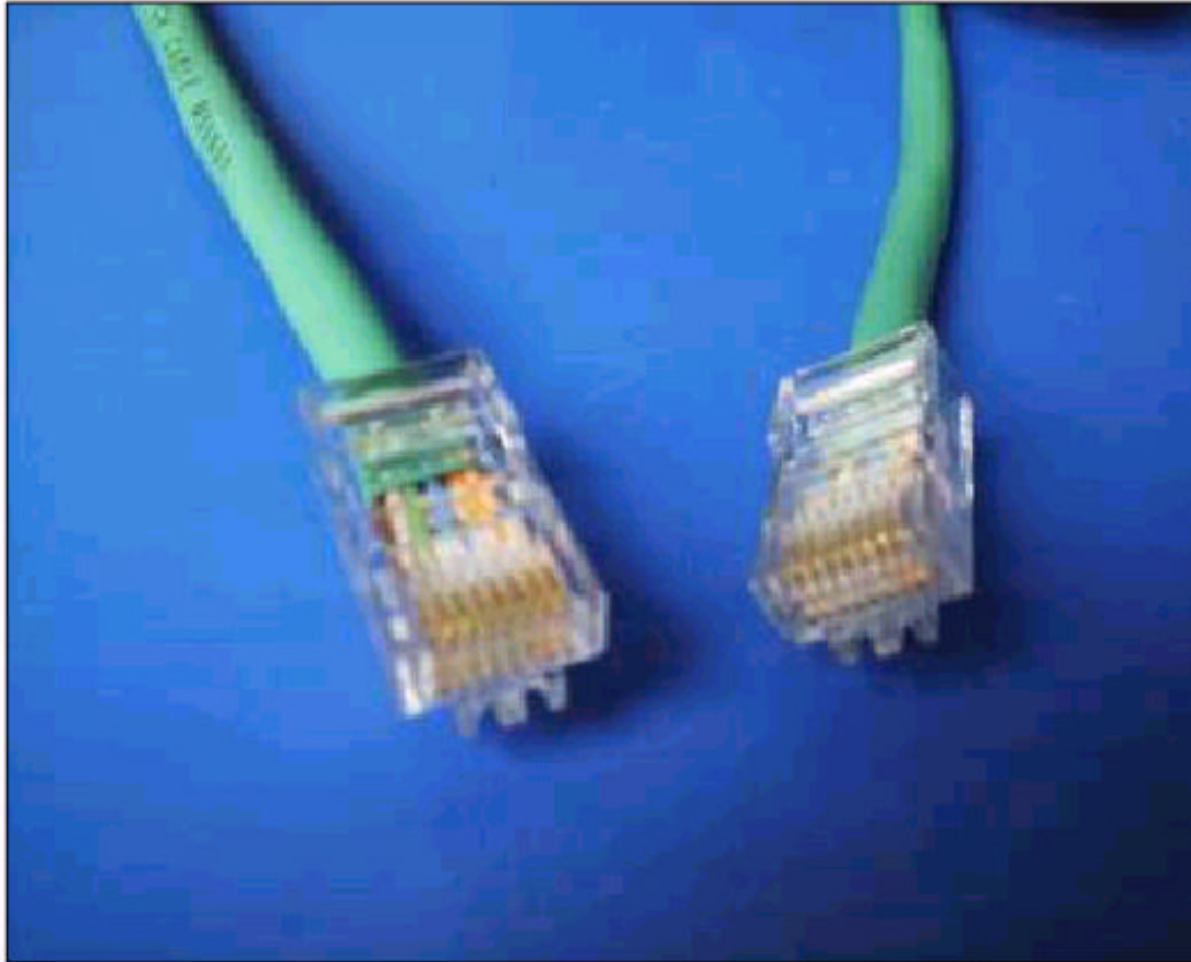
Test the Quality of Cable

Then say, 'The heck with it', and go buy a cable!

← Legal purchase

Blackmarket cable purchase

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.

The electromagnetic spectrum

Wavelength

- The light used in optical fiber networks is one type of electromagnetic energy.

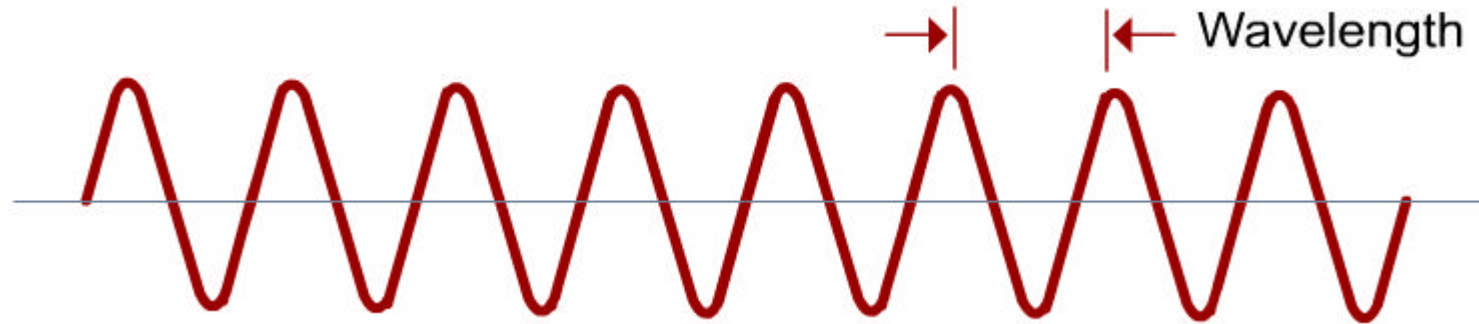- When an electric charge moves back and forth, or accelerates, a type of energy called electromagnetic energy is produced.

- This energy in the form of waves can travel through a vacuum, the air, and through some materials like glass.

- An important property of any energy wave is the wavelength.

- Radio, microwaves, radar, visible light, x-rays are all types of electromagnetic energy.

The electromagnetic spectrum
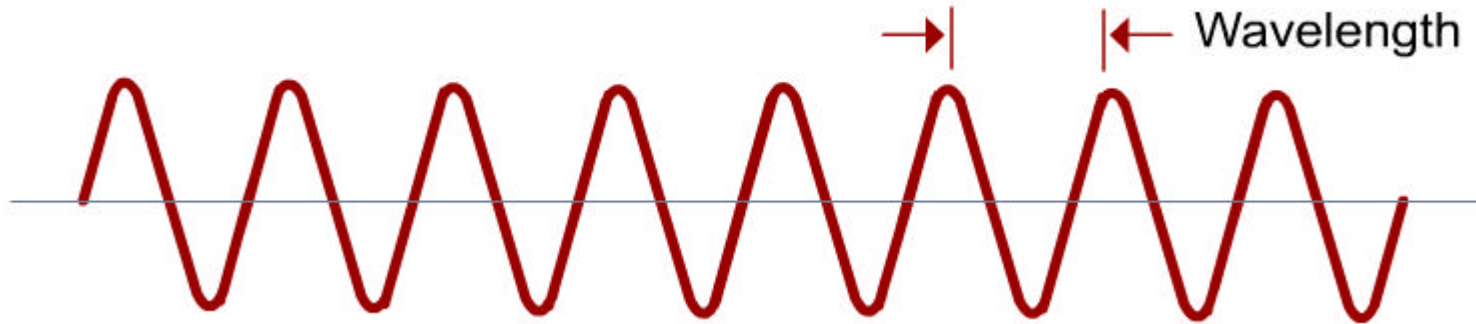
→| |← Wavelength

- The wavelength of an electromagnetic wave is determined by how frequently the electric charge that generates the wave moves back and forth.
- If the charge moves back and forth slowly, the wavelength it generates is a long wavelength.
- Visualize the movement of the electric charge as like that of a stick in a pool of water.
- If the stick is moved back and forth slowly, it will generate ripples in the water with a long wavelength between the tops of the ripples.
- If the stick is moved back and forth more rapidly, the ripples will have a shorter wavelength.

The electromagnetic spectrum
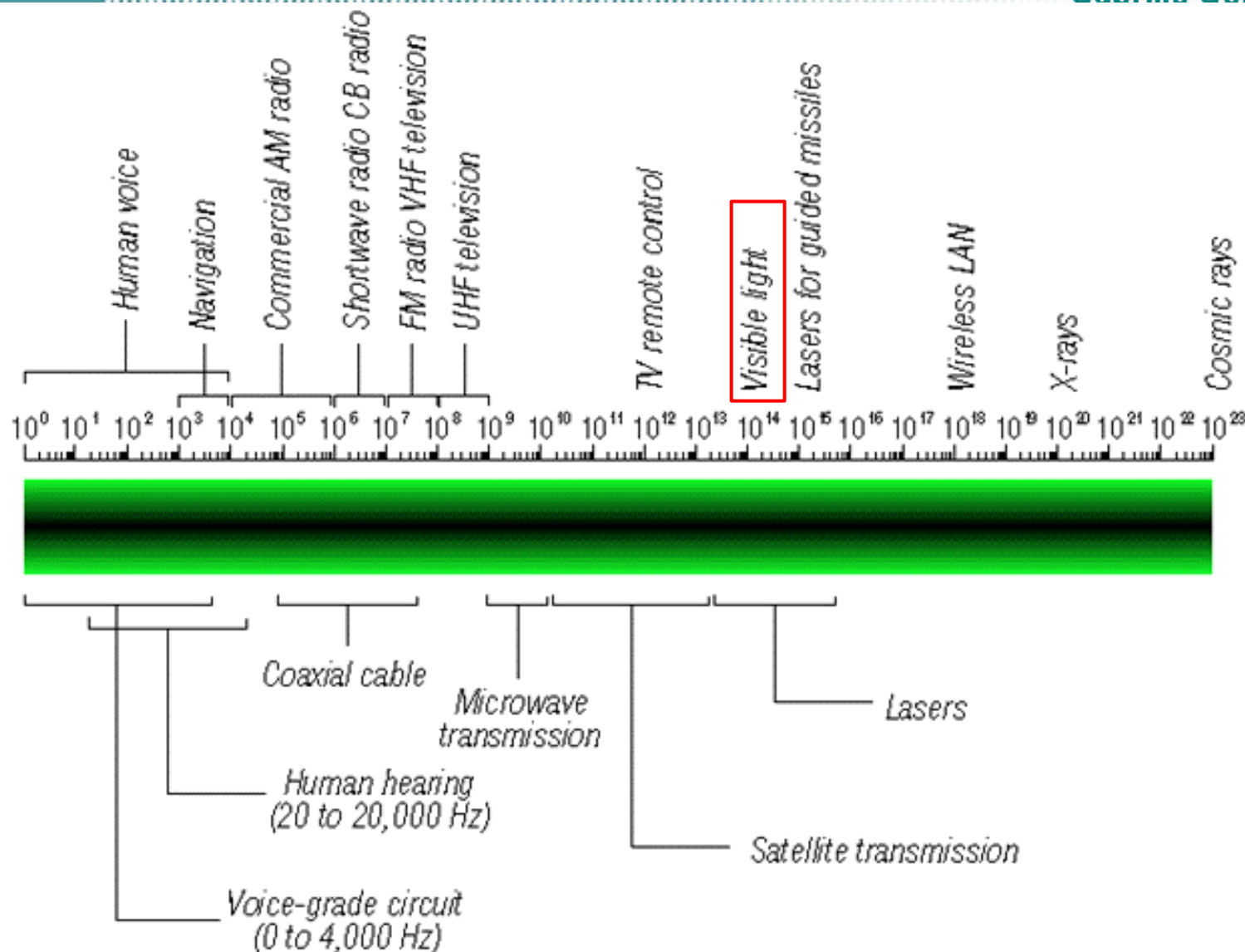
The electromagnetic spectrum
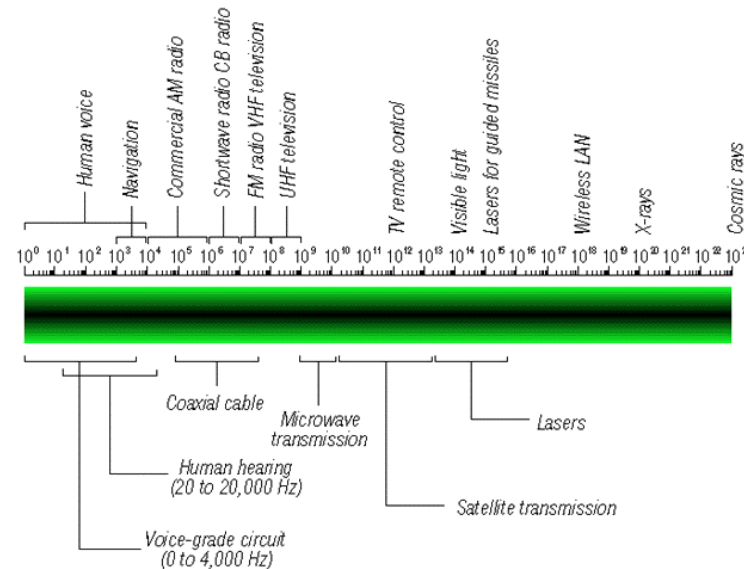
- Wavelengths that are not visible to the human eye are used to transmit data over optical fiber.

- *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.

Ray model of light

Light Rays

Lightbulb

Laser

$$\text{Index of Refraction} = n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in material}}$$
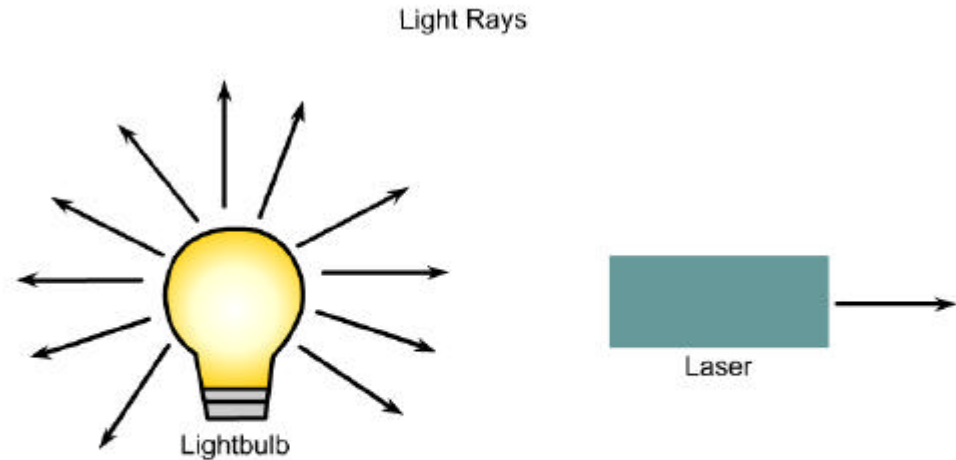
- When electromagnetic waves travel out from a source, they travel in straight lines.
- These straight lines pointing out from the source are called **rays**.
- Think of light rays as narrow beams of light like those produced by lasers.
- In the vacuum of empty space, light travels continuously in a straight line at *300,000 kilometers per second*.
- 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.
- That is why you can see yourself in window glass.
- The light that is reflected back is called the **reflected ray**.

Ray model of light

- The light energy in the incident ray that is not reflected will enter the glass.

- **refracted ray** - *The entering ray will be bent at an angle from its original path*.

- How much the incident light ray is bent depends on the angle at which the incident ray strikes the surface of the glass and the different rates of speed at which light travels through the two substances

- The **optical density** of the glass determines how much the rays of light in the glass bends.

- Optical density refers to how much a light ray slows down when it passes through a substance.

- The greater the optical density of a material, the more it slows light down from its speed in a vacuum.

- *The ratio of the speed of light in a material to the speed of light in a vacuum* is called the **Index of Refraction**.

Reflection

Normal

These angles have to be the same for each pair of rays.

θ_1 θ_2

1   2

Air

Glass

Air
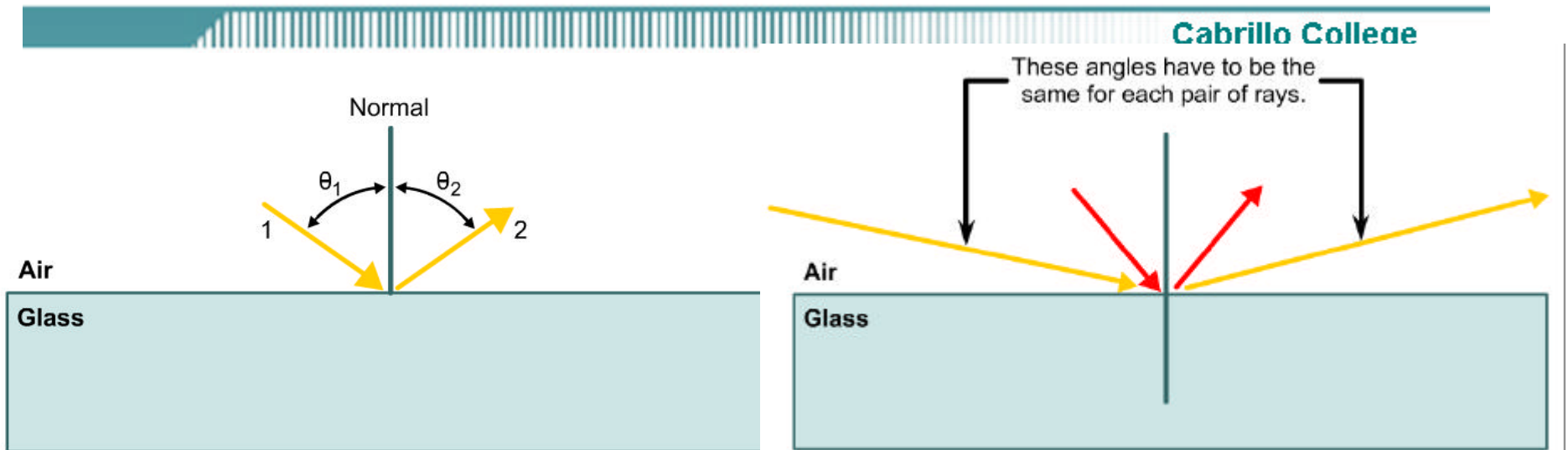
Glass

Ray 1: Incident ray, measured θ_1 degrees from the normal
Ray 2: Reflected ray, measured θ_2 degrees from the normal
Law of Reflection: $\theta_1 = \theta_2$

Interactive Media Activity

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**.

- The angle at which a light ray strikes a reflective surface determines the angle that the ray will reflect off the surface.

Refraction
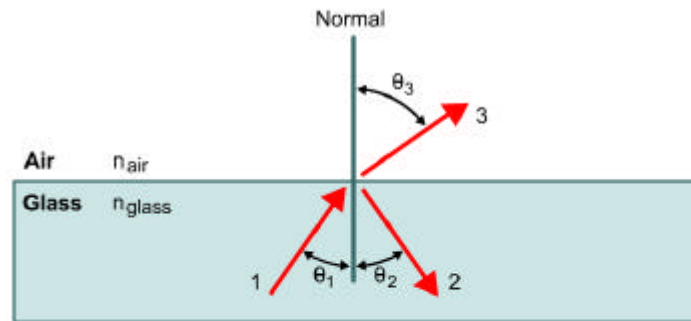
Normal

θ_3

3

Air n_{air}

Glass n_{glass}

1   θ_1 θ_2 2

Ray 1: Incident ray
Ray 2: Reflected ray
Ray 3: Refracted ray
Law of Reflection: $\theta_1 = \theta_2$
Law of Refraction: since $n_{glass} > n_{air}$, $\theta_3 > \theta_1$

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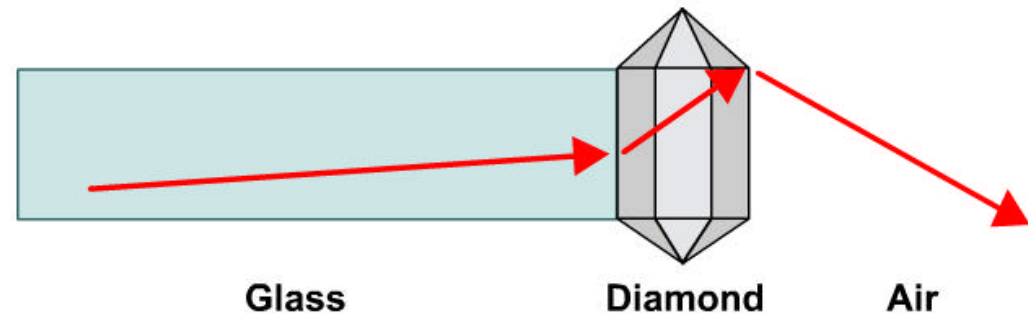
- When a light strikes the interface between two transparent materials, the light divides into two parts.
- Part of the light ray is reflected back into the first substance, with the angle of reflection equaling the angle of incidence.
- The remaining energy in the light ray crosses the interface and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

Refraction

Normal

θ_3

3

Air n_{air}

Glass n_{glass}

1   θ_1 θ_2 2
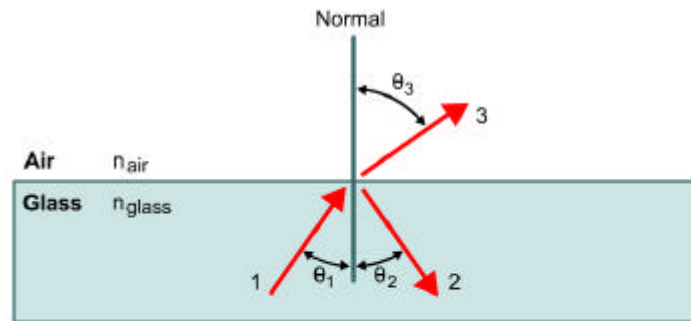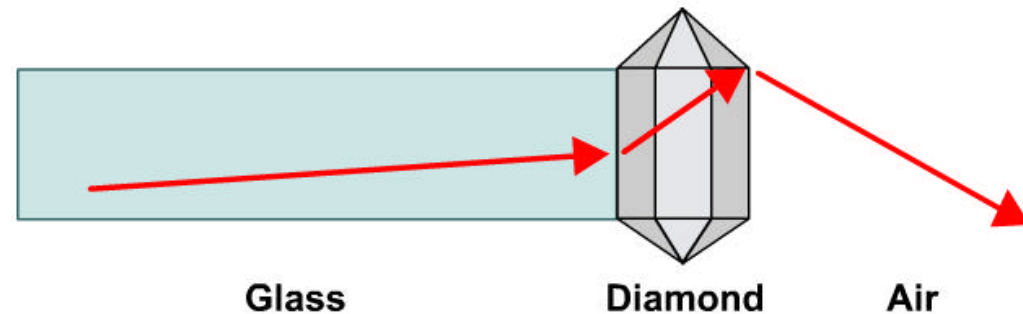
Ray 1: Incident ray
Ray 2: Reflected ray
Ray 3: Refracted ray
Law of Reflection: $\theta_1 = \theta_2$
Law of Refraction: since $n_{glass} > n_{air}$, $\theta_3 > \theta_1$

Glass   Diamond   Air

- 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.
- **Interactive Media Activity**

Total internal reflection
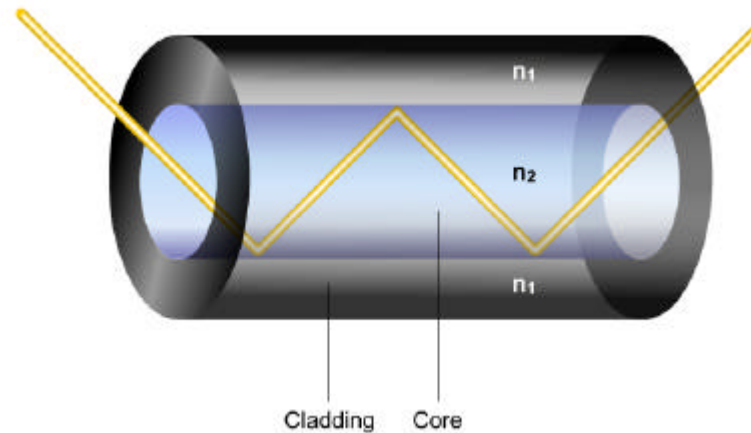
- A light ray that is being turned on and off to send data (1s and 0s) into an optical fiber must stay inside the fiber until it reaches the far end.
- The ray must not refract into the material wrapped around the outside of the fiber.
- The refraction would cause the loss of part of the light energy of the ray.
- A design must be achieved for the fiber that will make the outside surface of the fiber act like a mirror to the light ray moving through the fiber.
- If any light ray that tries to move out through the side of the fiber were reflected back into the fiber at an angle that sends it towards the far end of the fiber, this would be a good "pipe" or "wave guide" for the light waves.
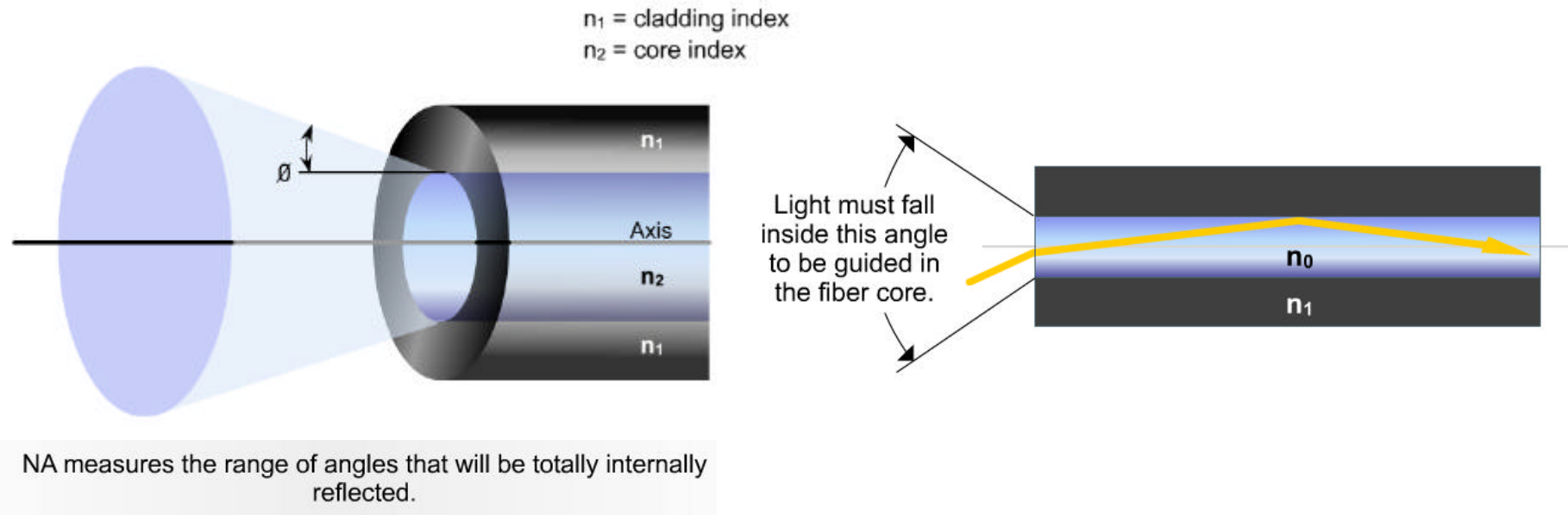
Total internal reflection

Light incident at any angle smaller than or equal to the critical angle is not totally reflected. Some of the energy in the incident ray exits the glass.

Light incident at any angle greater than the critical angle is totally reflected. All of the energy of the incident ray stays in the glass.

Air

Glass

θ_1 θ_2 θ_3

1

2

3

Light Source

Critical Angle for Glass-to-Air

$\theta_C = 41.8°$
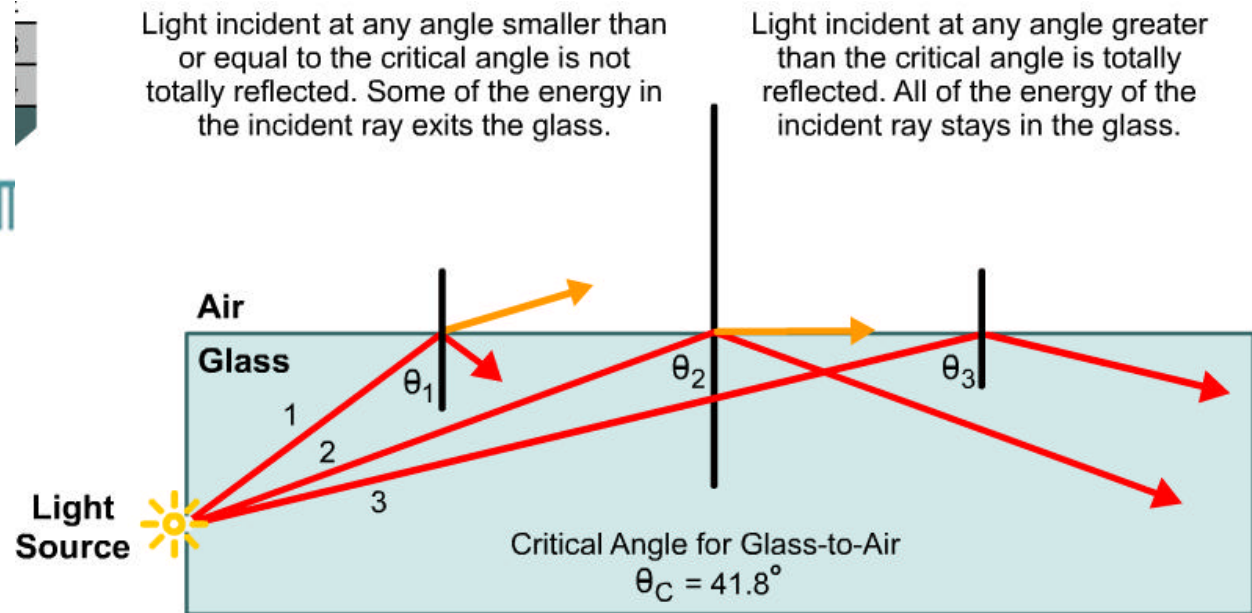
Ray 1: $\theta_1 < \theta_C$, so ray reflects and refracts
Ray 2: $\theta_2 = \theta_C$, so ray reflects and refracts
Ray 3: $\theta_3 > \theta_C$, so ray is totally internally reflected

- The laws of reflection and refraction illustrate how to design a fiber that guides the light waves through the fiber with a minimum energy loss.
- **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

n_1 = cladding index
n_2 = core index

n_1

Axis

n_2

n_1

Light must fall
inside this angle
to be guided in
the fiber core.

n_0

n_1

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.

Fiber Optic Cabling

Cabrillo College

- Coating or Buffer
- Cladding
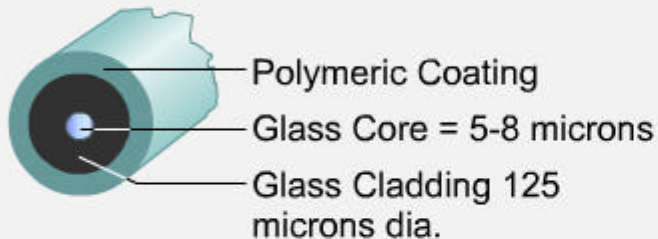- Core

- Jacket
- Aramid Yarn
- Buffer
- Cladding
- Core
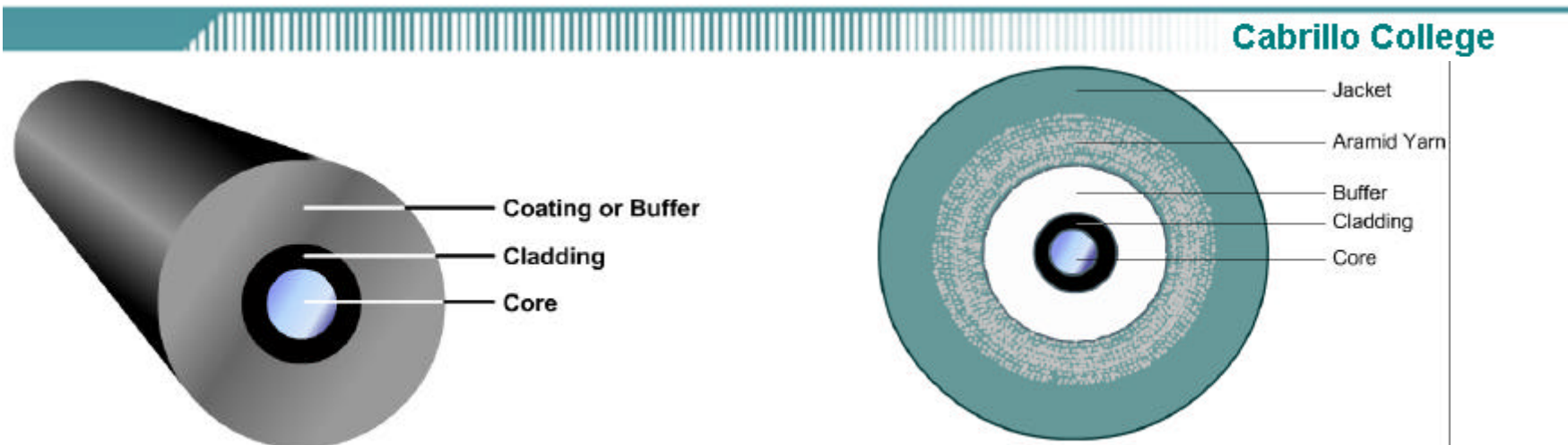
- The **core** is the light transmission element at the center of the optical fiber. All the light signals travel through the core.
- **Cladding** is also made of silica but with a lower index of refraction than the core. Light rays traveling through the fiber core reflect off this core-to-cladding interface 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.

Fiber Optic Cabling

Single-mode
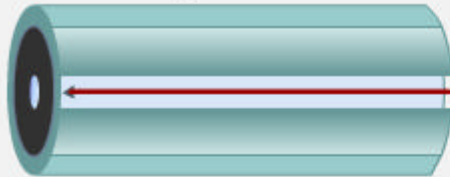
Requires very straight path

- Polymeric Coating
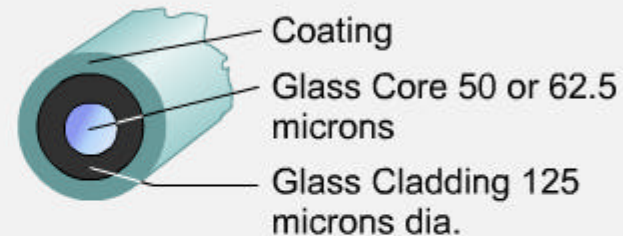- Glass Core = 5-8 microns
- Glass Cladding 125 microns dia.

• 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

Multiple paths-sloppy

- Coating
- Glass Core 50 or 62.5 microns
- Glass Cladding 125 microns dia.
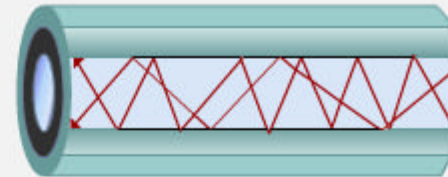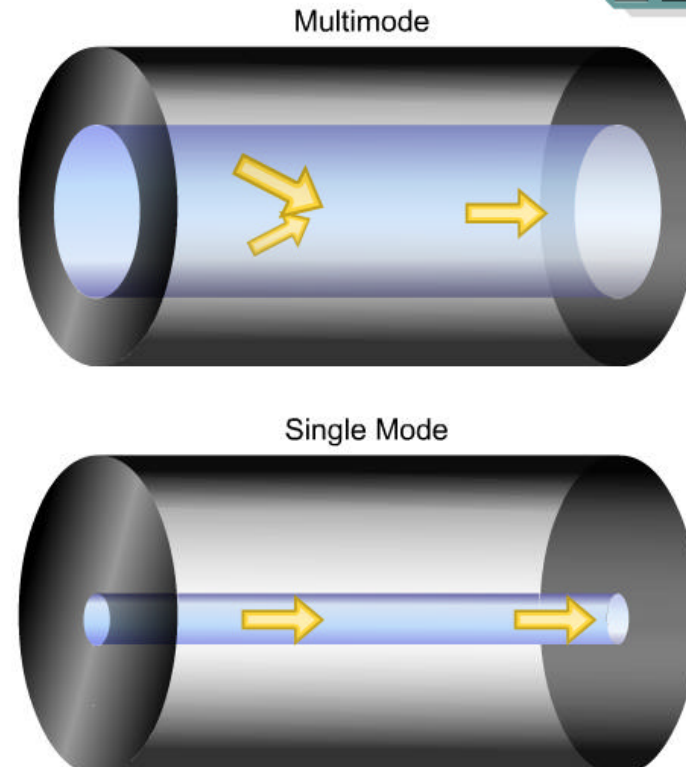
• Larger core than single-mode cable (50 or 62.5 microns or greater)

• 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

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.

Fiber Optic Cabling
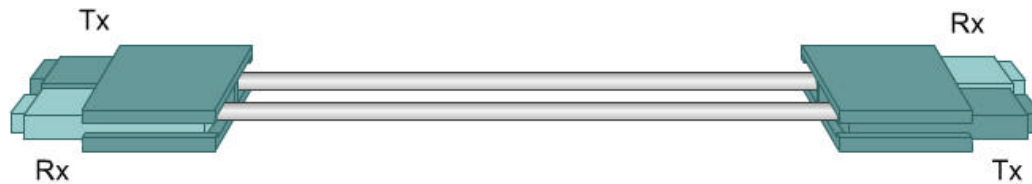
- Every fiber-optic cable used for networking consists of two glass fibers encased in separate sheaths.

- 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

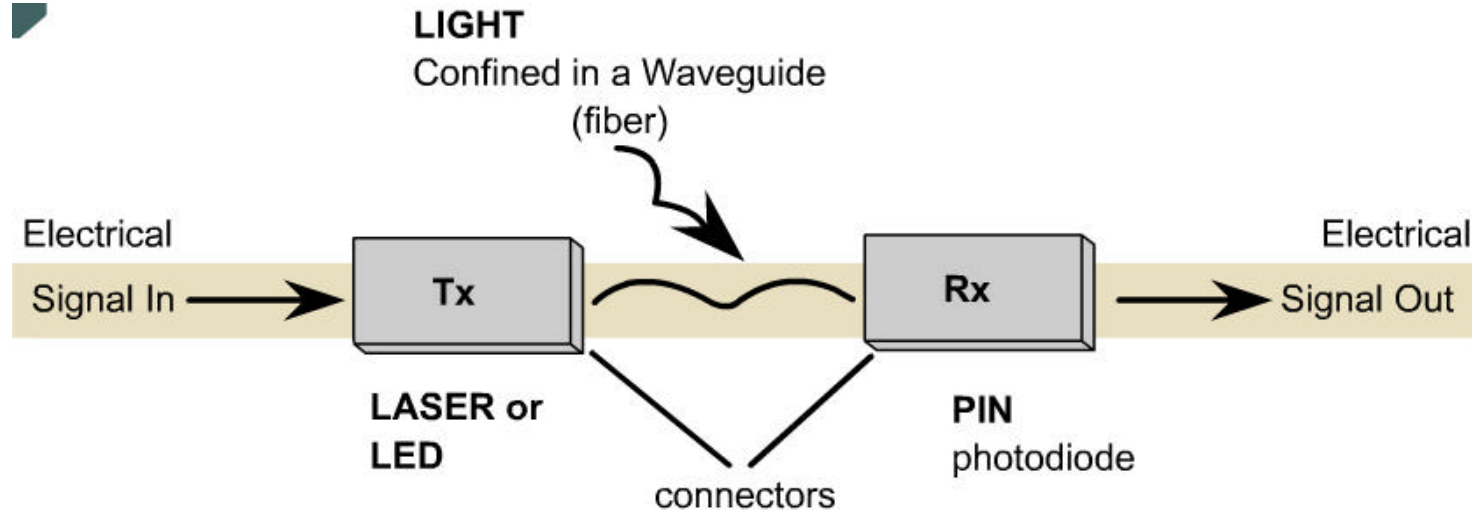| Multimode	Multimode	Multimode	Single-mode
100-140 microns	62.5-125 microns	50-125 microns	10-125 microns

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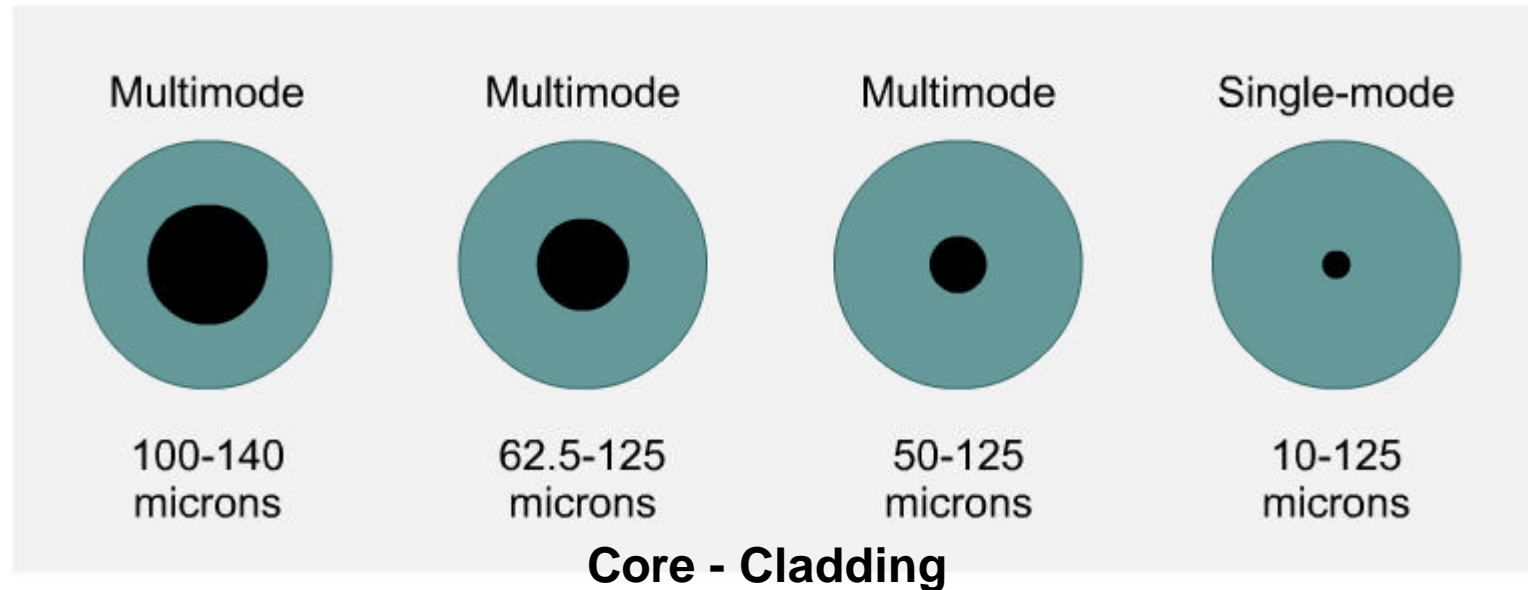
- **Warning:** The laser light used with single-mode has a longer wavelength than can be seen.
- The laser is so strong that it can seriously damage eyes.
- **Never** look at the near end of a fiber that is connected to a device at the far end.
- **Never** look into the transmit port on a NIC, switch,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

Transmitting Devices

LIGHT
Confined in a Waveguide
(fiber)

Electrical
Signal In → Tx ∿ Rx → Signal Out Electrical

LASER or
LED

connectors

PIN
photodiode

- The transmitter converts the electronic signals into their equivalent light pulses.
- There are two types of light sources used to encode and transmit the data through the cable:
  - A light emitting diode (**LED**) producing infrared light.
  - Light amplification by stimulated emission radiation (**LASER**) a light source producing a thin beam of intense infrared light usually with wavelengths of 1310nm or 1550 nm.
  - Lasers are used with single-mode fiber over the longer distances involved in WANs or campus backbones.

Receiving Devices

LIGHT
Confined in a Waveguide
(fiber)

Electrical
Signal In → Tx

LASER or
LED

connectors

Rx

PIN
photodiode

Electrical
Signal Out
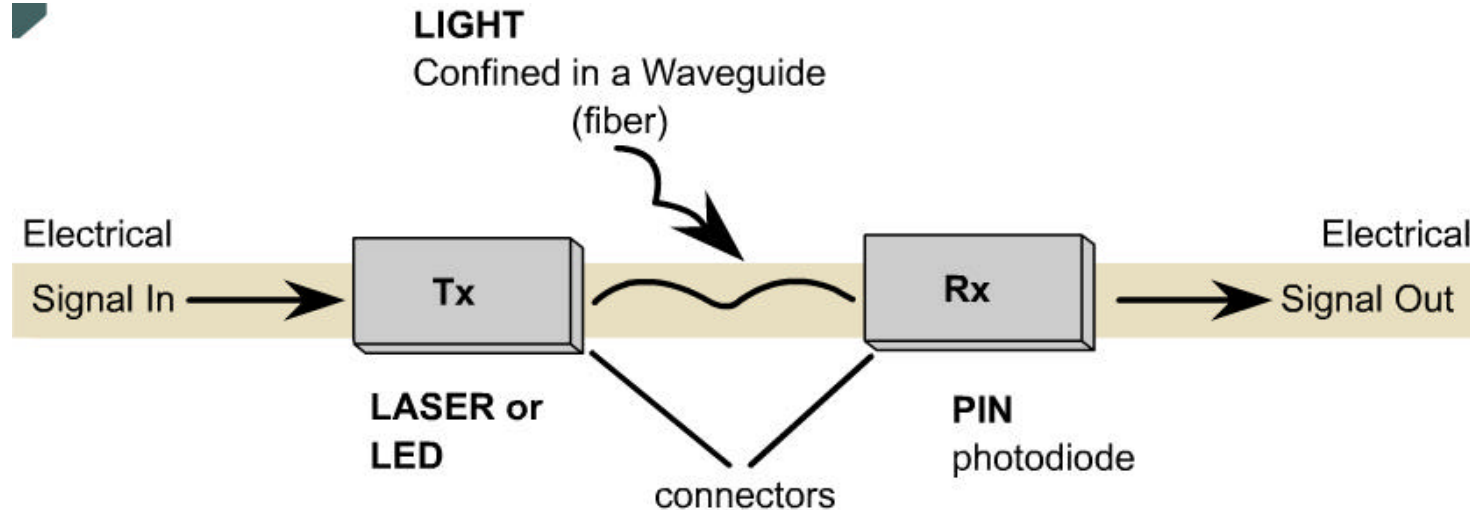
- The receiver functions something like the photoelectric cell in a solar powered calculator.
- When light strikes the receiver, it produces electricity.
- The semiconductor devices that are usually used as receivers with fiber-optic links are called **p-intrinsic-n diodes (PIN photodiodes).**
- *When struck by a pulse of light at the proper wavelength, the PIN photodiode quickly produces an electric current of the proper voltage for the network.*
- It instantly stops producing the voltage when no light strikes the PIN photodiode.
- This generates the voltage changes that represent the data 1s and 0s on a copper cable.

ST and SC Connectors

ST Connector
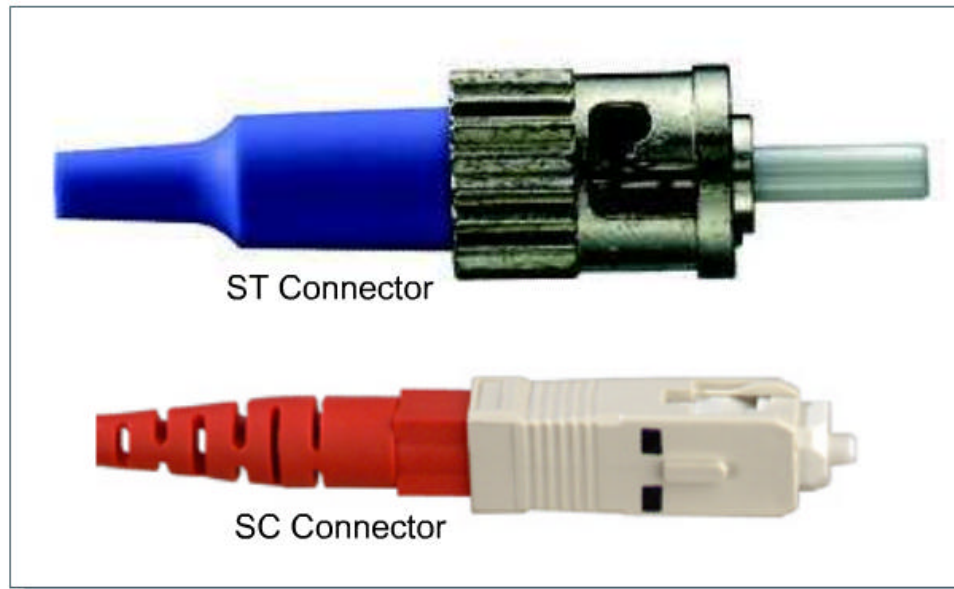
SC Connector

- 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.

Fiber Optic Patch Panel
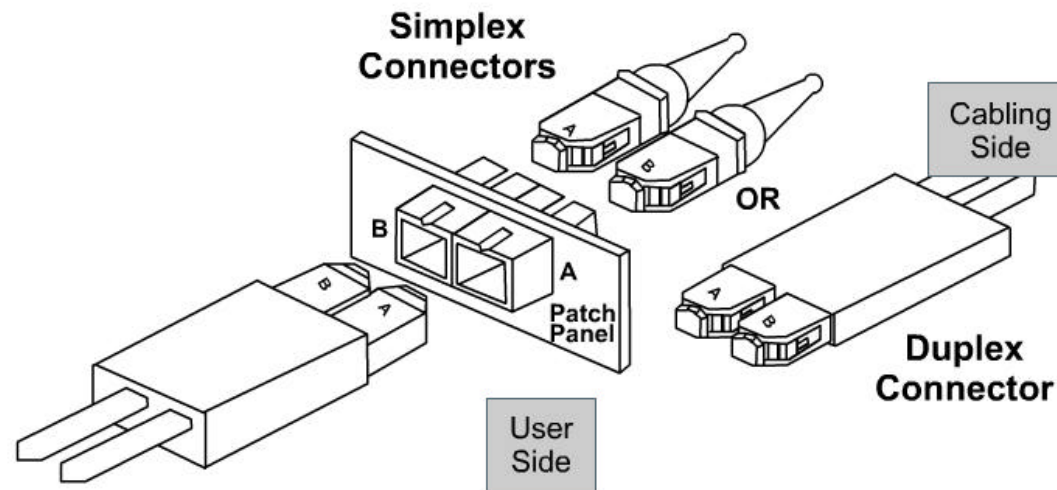
Fiber Optic Patch Panel
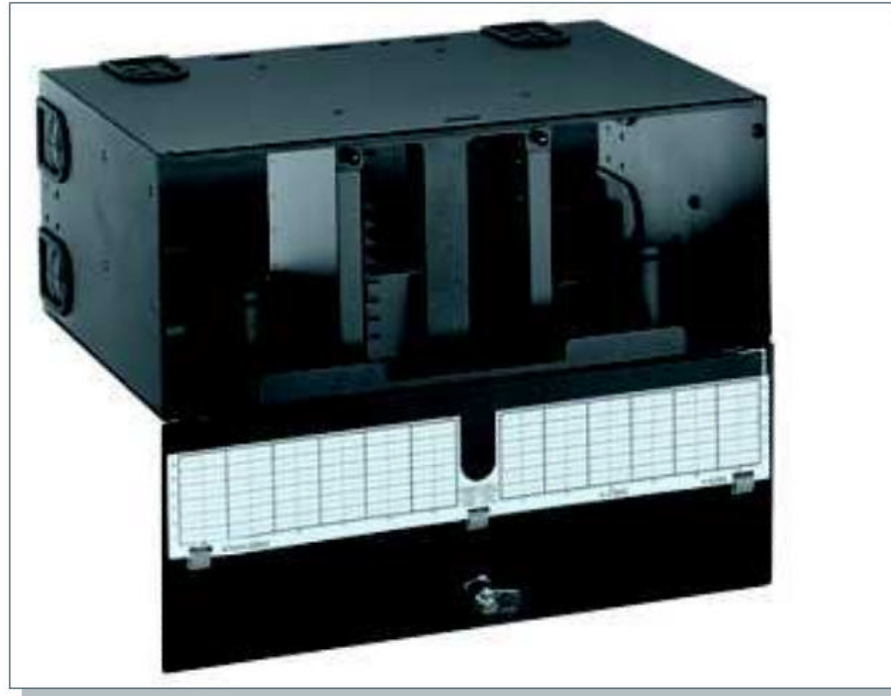
- Fiber patch panels similar to the patch panels used with copper cable.
- These panels increase the flexibility of an optical network by allowing quick changes to the connection of devices like switches or routers with various available fiber runs, or cable links.

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.
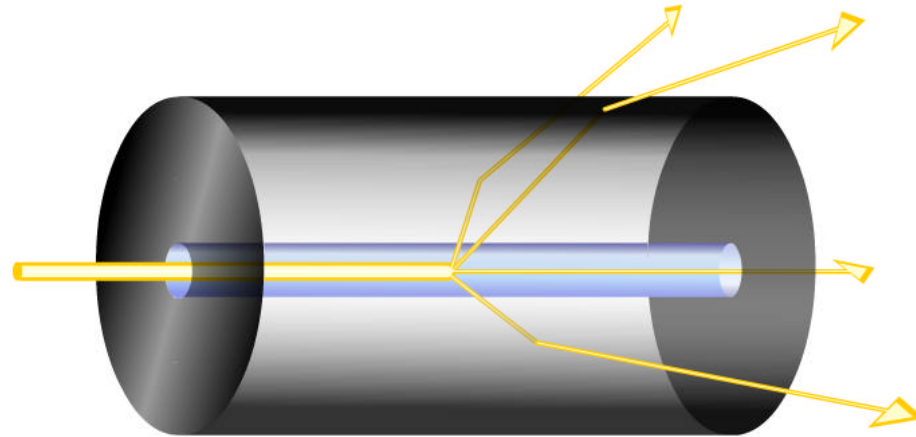
- Although fiber is the best of all the transmission media at carrying large amounts of data over long distances, fiber is not without problems. When light travels through fiber, some of the light energy is lost.

- 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.

Signals and noise in optical fibers
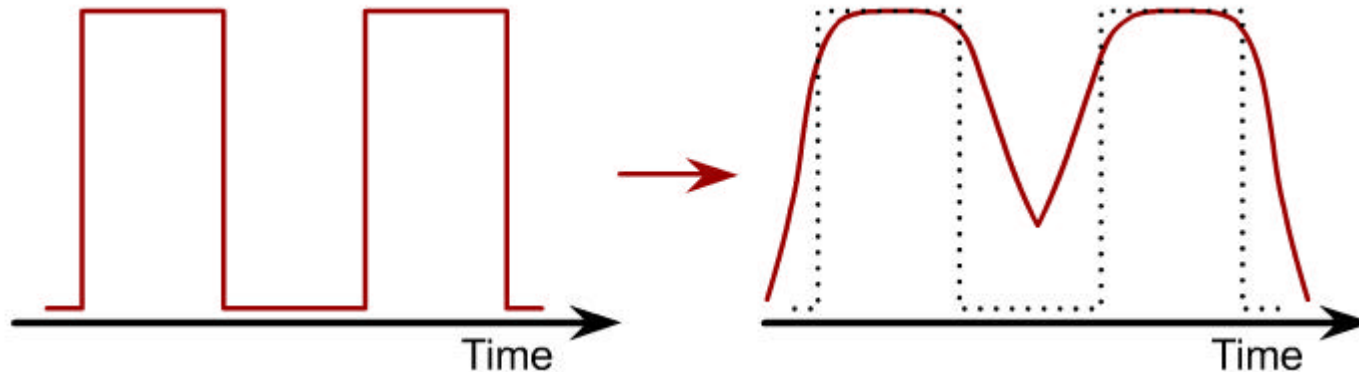
- **Absorption** is another cause of light energy loss.
  - When a light ray strikes some types of chemical impurities in a fiber, the impurities absorb part of the energy.
  - This light energy is converted to a small amount of heat energy.
  - Absorption makes the light signal a little dimmer.
- Another factor that causes attenuation of the light signal is **manufacturing irregularities** or roughness in the core-to-cladding boundary.
  - Any microscopic imperfections in the thickness or symmetry of the fiber will cut down on total internal reflection and the cladding will absorb some light energy.

Signals and noise in optical fibers
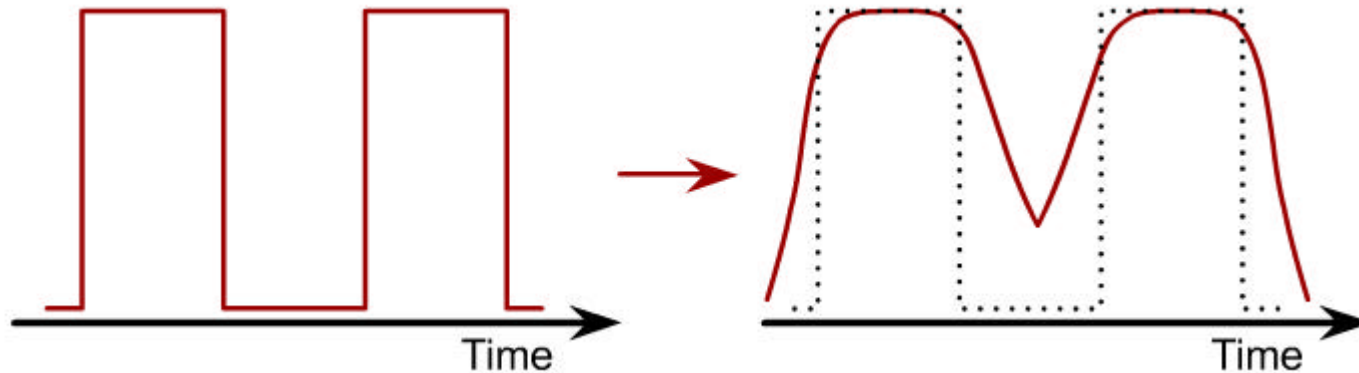
- **Dispersion** of a light flash also limits transmission distances on a fiber.
  - Dispersion is the technical term for the spreading of pulses of light as they travel down the fiber

Installation, care, and testing of optical fiber

- Once the fiber-optic cable and connectors have been installed, the connectors and the ends of the fibers must be kept spotlessly clean.

- The ends of the fibers should be covered with protective covers to prevent damage to the fiber ends.

- When these covers are removed prior to connecting the fiber to a port on a switch or a router, the fiber ends must be cleaned.

- Clean the fiber ends with lint free lens tissue moistened with pure isopropyl alcohol.

- The fiber ports on a switch or router should also be kept covered when not in use and cleaned with lens tissue and isopropyl alcohol before a connection is made.

- Dirty ends on a fiber will cause a big drop in the amount of light that reaches the receiver.

Installation, care, and testing of optical fiber

- When a fiber-optic link is being planned, the amount of signal power loss that can be tolerated must be calculated.
- This is referred to as the **optical link loss budget**.
- The **decibel (dB)** is the unit used to measure the amount of power loss.
  - It tells what percent of the power that leaves the transmitter actually enters the receiver.
- Testing fiber links is extremely important and records of the results of these tests must be kept.
- Two of the most important instruments are
  - Optical Loss Meters
 - Optical Time Domain Reflectometers (OTDRs).

Wireless Media

- Wireless LAN organizations and standards

- Wireless devices and topologies

- How wireless LANs communicate

- Authentication and association

- The radio wave and microwave spectrums

- Signals and noise on a WLANs

- Wireless security

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 throughout as 802.11a but with backwards compatibility for 802.11b devices.

Wireless devices and topologies
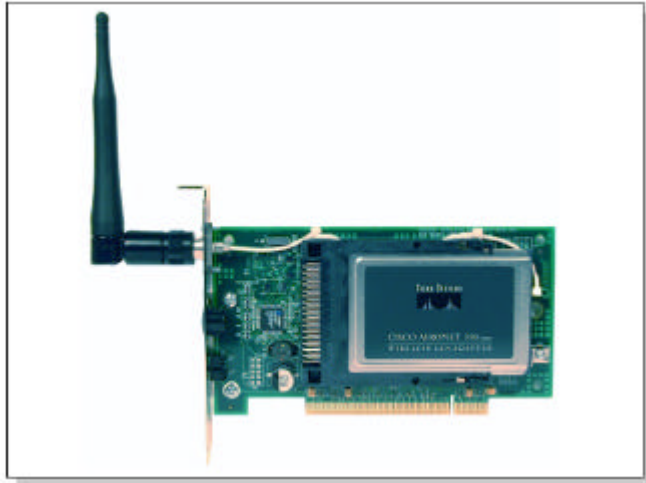
Wireless devices and topologies

- **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).

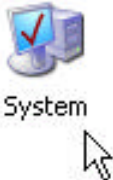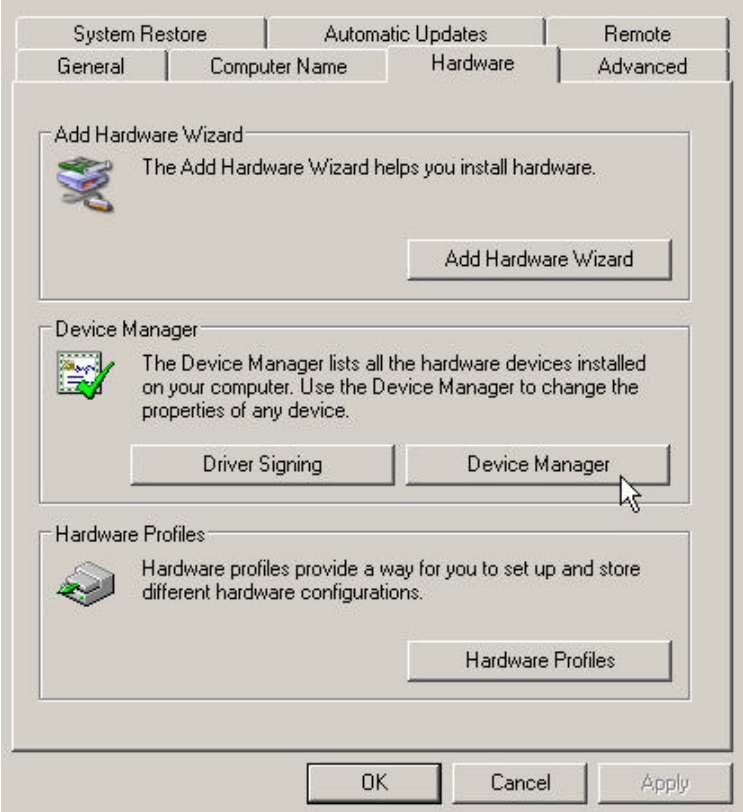# Wireless devices and topologies
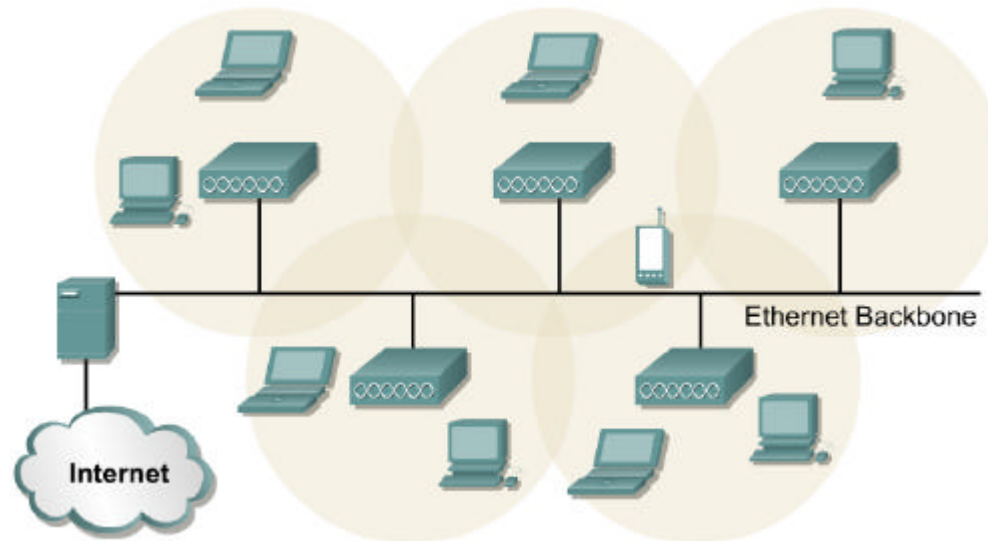
- Overlap, on multiple AP networks, is critical to allow for movement of devices within the WLAN.

- 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.
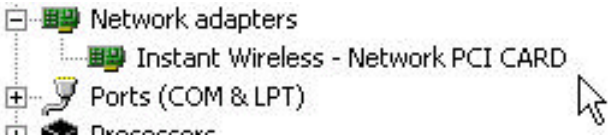
Wireless devices and topologies
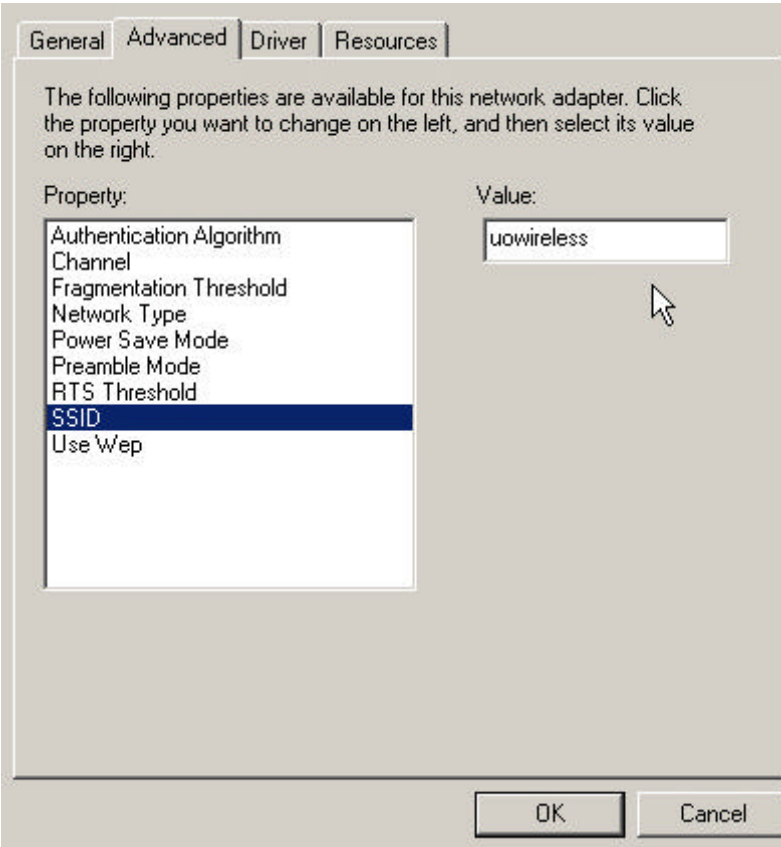
- When a client is activated within the WLAN, it will start "listening" for a compatible device with which to "associate".

- This is referred to as "**scanning**" and may be active or passive.

- Active scanning causes a probe request to be sent from the wireless node seeking to join the network.

- The probe request will contain the **Service Set Identifier (SSID)** of the network it wishes to join.

- When an AP with the same SSID is found, the AP will issue a probe response.

- The **authentication and association** steps are completed.

- From webpedia.com

  - Short for Service Set Identifier, a 32-character unique identifier attached to the header of packets sent over a WLAN that acts as a password when a mobile device tries to connect to the BSS. The SSID differentiates one WLAN from another, so all access points and all devices attempting to connect to a specific WLAN must use the same SSID. A device will not be permitted to join the BSS unless it can provide the unique SSID. Because an SSID can be sniffed in plain text from a packet it does not supply any security to the network.

Configuring the SSID on the PC

1
- Control Panel
- Network Connections
- Printers and Faxes
- Taskbar and Start Menu

2 System

4
- Network adapters
  - Instant Wireless - Network PCI CARD
- Ports (COM & LPT)
- Processors

3

Tabs: System Restore | Automatic Updates | Remote | General | Computer Name | Hardware | Advanced

Add Hardware Wizard
The Add Hardware Wizard helps you install hardware.
[Add Hardware Wizard]

Device Manager
The Device Manager lists all the hardware devices installed on your computer. Use the Device Manager to change the properties of any device.
[Driver Signing] [Device Manager]

Hardware Profiles
Hardware profiles provide a way for you to set up and store different hardware configurations.
[Hardware Profiles]

[OK] [Cancel] [Apply]

5

Tabs: General | Advanced | Driver | Resources

The following properties are available for this network adapter. Click the property you want to change on the left, and then select its value on the right.

Property:
- Authentication Algorithm
- Channel
- Fragmentation Threshold
- Network Type
- Power Save Mode
- Preamble Mode
- RTS Threshold
- SSID
- Use Wep

Value:
uowireless

[OK] [Cancel]

micro.uoregon.edu/ wireless/windows/

Configuring the SSID on the AP

How wireless LANs communicate

Management Frames
- Association request frame
- Association response frame
- Probe request frame
- Probe response frame
- Beacon frame
- Authentication frame

Control Frames
- Request to send (RTS)
- Clear to send (CTS)
- Acknowledgment

Data Frames

- After establishing connectivity to the WLAN, a node will pass frames in the same manner as on any other 802.x network.

- WLANs do not use a standard 802.3 frame.

- Therefore, using the term wireless Ethernet is misleading.

- There are three types of frames: control, management, and data.

- Only the data frame type is similar to 802.3 frames.

How wireless LANs communicate
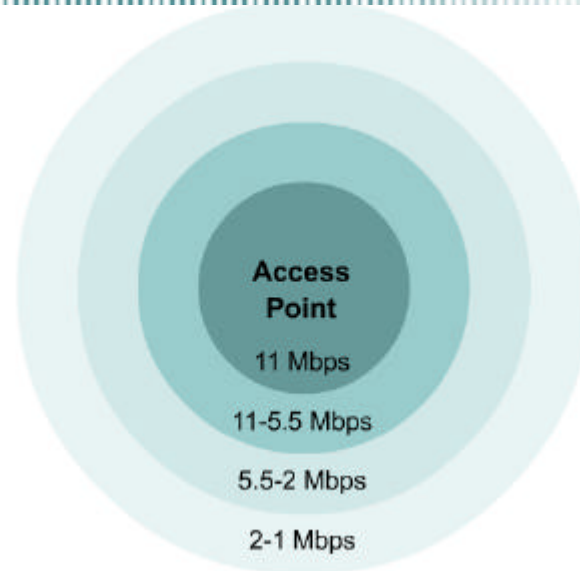
- Since radio frequency (RF) is a shared medium, collisions can occur just as they do on wired shared medium.

- The major difference is that there is no method by which the source node is able to detect that a collision occurred.

- For that reason WLANs use Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA).

- This is somewhat like Ethernet CSMA/CD.

How wireless LANs communicate

- When a source node sends a frame, the receiving node returns a *positive acknowledgment (ACK).*

- This can cause *consumption of 50% of the available bandwidth.*

- This overhead when combined with the collision avoidance protocol overhead reduces the *actual data throughput to a maximum of 5.0 to 5.5 Mbps* on an 802.11b wireless LAN rated at 11 Mbps.

- Performance of the network will also be affected by signal strength and degradation in signal quality due to distance or interference.

- As the signal becomes weaker, Adaptive Rate Selection (ARS) may be invoked.

- The transmitting unit will drop the data rate from 11 Mbps to 5.5 Mbps, from 5.5 Mbps to 2 Mbps or 2 Mbps to 1 Mbps.

Authentication and association

- Unauthenticated and unassociated
- Authenticated and unassociated
- Authenticated and associated

- Unauthenticated and unassociated
  - The node is disconnected from the network and not associated to an access point.

- Authenticated and unassociated
  - The node has been authenticated on the network but has not yet associated with the access point.

- Authenticated and associated
  - The node is connected to the network and able to transmit and receive data through the access point.

Methods of Authentication

- IEEE 802.11 lists two types of authentication processes.
- The first authentication process is the **open system**.
  - This is an open connectivity standard in which only the **SSID** must match.
  - This may be used in a secure or non-secure environment although the ability of low level network 'sniffers' to discover the SSID of the WLAN is high.
- The second process is the **shared key**.
  - This process requires the use of **Wireless Equivalency Protocol (WEP) encryption**.
  - WEP is a fairly simple algorithm using 64 and 128 bit keys.
  - The AP is configured with an encrypted key and nodes attempting to access the network through the AP must have a matching key.
  - Statically assigned WEP keys provide a higher level of security than the open system but are *definitely not hack proof*.
- The problem of unauthorized entry into WLANs is being addressed by a number of new security solution technologies.

The radio wave and microwave spectrums
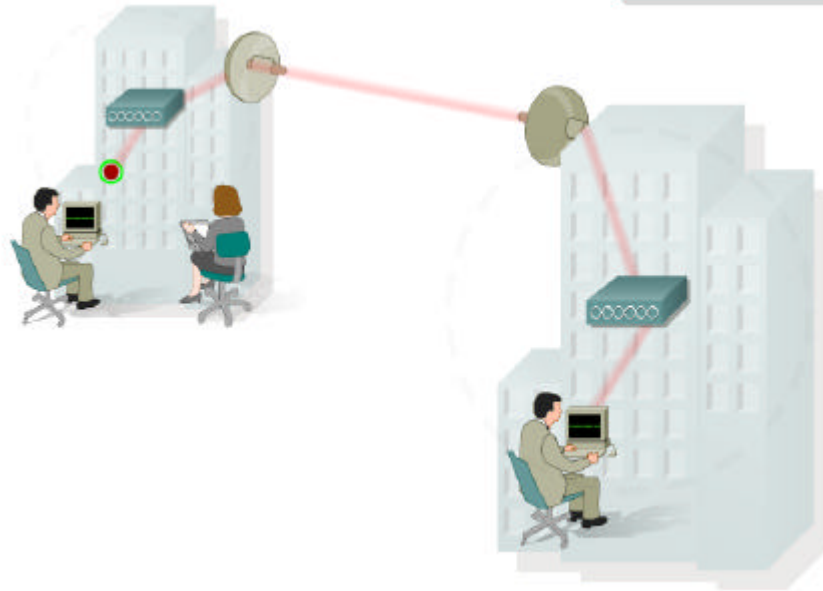
- Computers send data signals electronically.
- Radio transmitters convert these electrical signals to radio waves.
- Changing electric currents in the antenna of a transmitter generates the radio waves.
- However, radio waves attenuate as they move out from the transmitting antenna.
- In a WLAN, a radio signal measured at a distance of just 10 meters (30 feet) from the transmitting antenna would be only 1/100th of its original strength.

Modulation
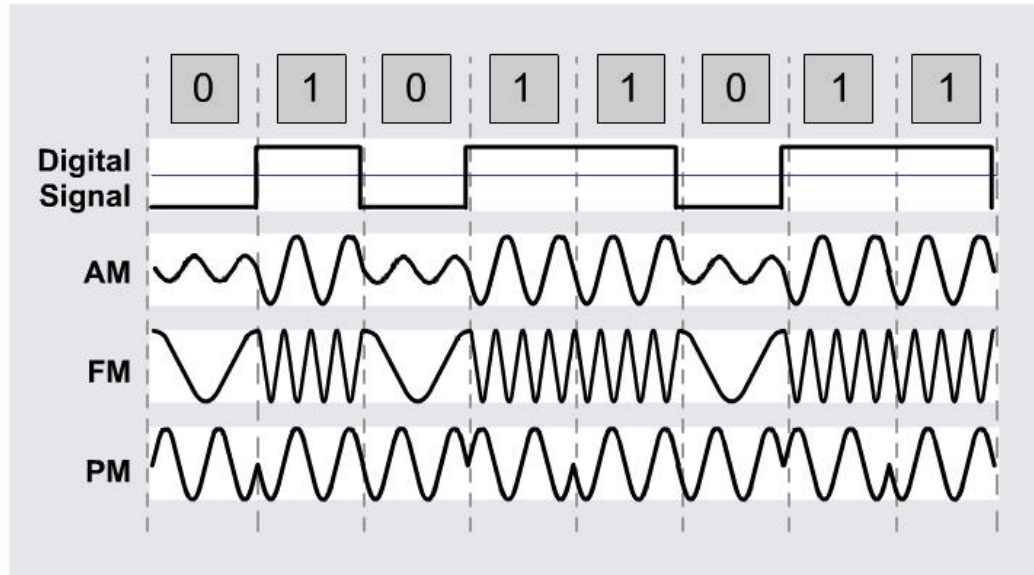
- The process of altering the carrier signal that will enter the antenna of the transmitter is called modulation.
- There are three basic ways in which a radio carrier signal can be modulated.
- For example, **Amplitude Modulated (AM)** radio stations modulate the *height (amplitude) of the carrier signal*.
- **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.

Signals and noise on a WLAN
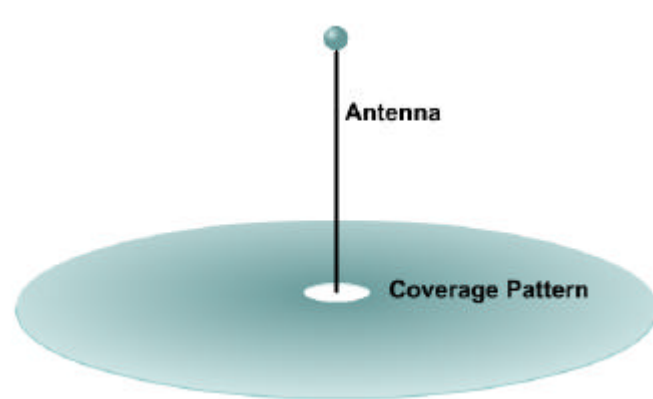
- When using RF technology many kinds of interference must be taken into consideration.
- In homes and offices, a device that is often overlooked as causing interference is the standard microwave oven.
- Leakage from a microwave of as little as one watt into the RF spectrum can cause major network disruption.
- Wireless phones operating in the 2.4GHZ spectrum can also cause network disorder.
- Generally the RF signal will not be affected by even the most extreme weather conditions. However, fog or very high moisture conditions can and do affect wireless networks. Lightning can also charge the atmosphere and alter the path of a transmitted signal.

Wireless security

- A number of new security solutions and protocols, such as Virtual Private Networking (VPN) and Extensible Authentication Protocol (EAP) are emerging.

- With EAP, the access point does not provide authentication to the client, but passes the duties to a more sophisticated device, possibly a dedicated server, designed for that purpose.

- **EAP-MD5 Challenge** – Extensible Authentication Protocol is the earliest authentication type, which is very similar to CHAP password protection on a wired network.

- **LEAP (Cisco)** – Lightweight Extensible Authentication Protocol is the type primarily used on Cisco WLAN access points. LEAP provides security during credential exchange, encrypts using dynamic WEP keys, and supports mutual authentication.

- **User authentication** – Allows only authorized users to connect, send and receive data over the wireless network.

- **Encryption** – Provides encryption services further protecting the data from intruders.

- **Data authentication** – Ensures the integrity of the data, authenticating source and destination devices.

Summary 1 of 3

An understanding of the following key points should have been achieved:

- All matter is composed of atoms, and the three main parts of an atom are: protons, neutrons, and electrons. The protons and neutrons are located in the center part of the atom (nucleus)

- Electrostatic discharge (ESD) can create serious problems for sensitive electronic equipment

- Attenuation refers to the resistance to the flow of electrons and why a signal becomes degraded as it travels

- Currents flow in closed loops called circuits, which must be composed of conducting materials and must have sources of voltage

- A multimeter is used to measure voltage, current, resistance, and other electrical quantities expressed in numeric form

- Three types of copper cables used in networking are: straight-through, crossover, and rollover

- Coaxial cable consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor

- UTP cable is a four-pair wire medium used in a variety of networks

- STP cable combines the techniques of shielding, cancellation, and twisting of wires

Summary 2 of 3

- Optical fiber is a very good transmission medium when it is properly installed, tested, and maintained
- Light energy, a type of electromagnetic energy wave, is used to transmit large amounts of data securely over relatively long distances
- The light signal carried by a fiber is produced by a transmitter that converts an electrical signal into a light signal
- The light that arrives at the far end of the cable is converted back to the original electrical signal by the receiver
- Fibers are used in pairs to provide full duplex communications
- Light rays obey the laws of reflection and refraction as they travel through a glass fiber, which allows fibers with the property of total internal reflection to be manufactured
- Total internal reflection makes light signals stay inside the fiber, even if the fiber is not straight
- Attenuation of a light signal becomes a problem over long cables especially if sections of cable are connected at patch panels or spliced
- Cable and connectors must be properly installed and thoroughly tested with high quality optical test equipment before their use
- Cable links must be tested periodically with high quality optical test instruments to check whether the link has deteriorated in any way
- Care must always be taken to protect eyes when intense light sources like lasers are used

Summary 3 of 3

- Understanding the regulations and standards that apply to wireless technology will ensure that deployed networks will be interoperable and in compliance
- Compatibility problems with NICs are solved by installing an access point (AP) to act as a central hub for the WLAN
- Three types of frames are used in wireless communication: control, management, and data
- WLANs use Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)
- WLAN authentication is a process that authenticates the device, not the user