Wollo University

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Data Communication and Computer Networks()

Chapter 2:

DATA COMMUNICATIONS

2.1 What is Communication

- Communication is simply the act of transferring information from one place to another.
- There are various categories of communication and more than one may occur at any time.
- The different categories of communication are:
  - **Spoken** or verbal communication:

    face-to-face, telephone, radio or television or other media.
  - **Non-verbal communication:**

    body language, gestures, how we dress or act – even our scent.
  - **Written communication**
    - **letters, e-mails, books, magazines, the Internet or via other media.**
  - **Visualizations**:

    graphs, charts, maps, logos and other visualizations can communicate

Cont…

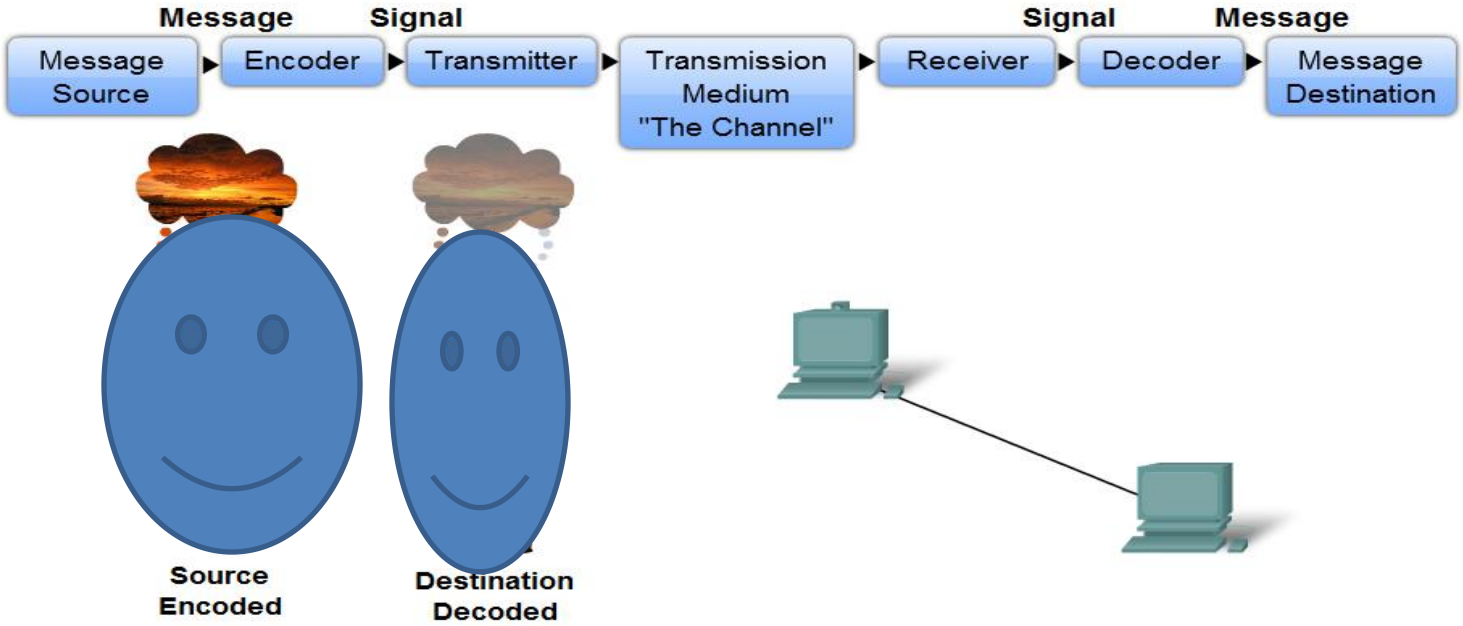
- Communication theory states that communication involves a sender and a receiver (or receivers) conveying information through a communication channel.
- **The desired outcome or goal of any communication process is understanding.**
- The process of **interpersonal communication** cannot be regarded as a phenomena which simply 'happens', but should be seen as a process which involves participants negotiating their role in this process, whether consciously or unconsciously.

Data communication…

- Communication is the act of conveying meaningful information
  - ✓ Requires a Sender, a Message, and an intended Recipient
- Establishing the Rules
  - ✓ Communication is successful when the intended message has been received & confirmed
- **Data communication** is the exchange of information between two agents

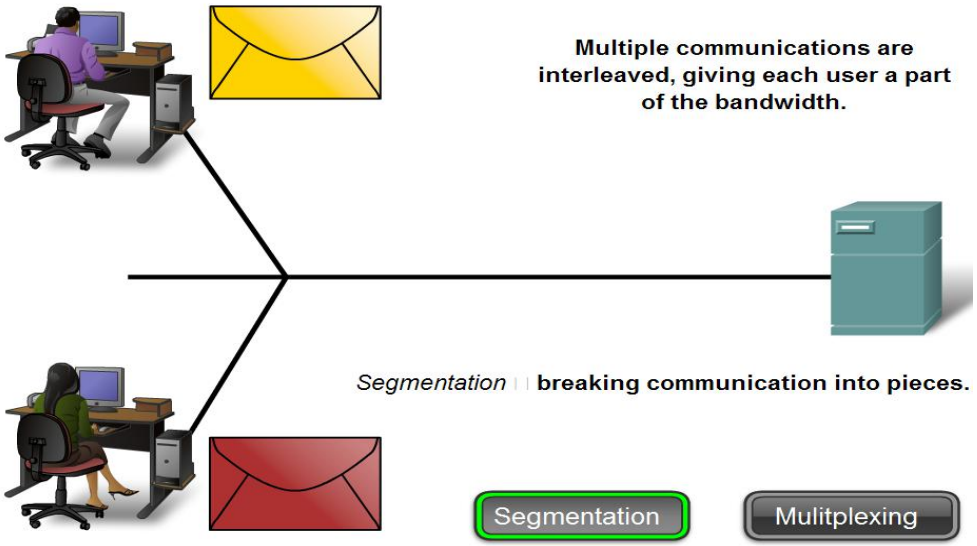
The Platform for Communication

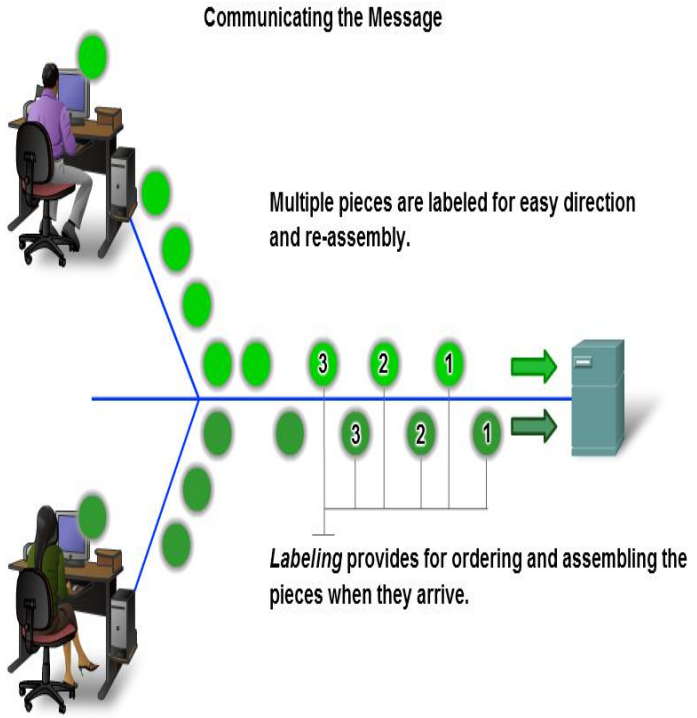
- Elements of communication
  - ✓ 3 common elements of communication
    - Message source
    - The channel
    - Message destination



Communicating the message

- Data is sent across a network in small "chunks" called segments, it advantages are:
  - Multiplexing
  - Reliability





Data Transmission

- Computers encode and transmit data, voice, and video over networks via various transmission media.
- Encoding is the process of transforming information into digital and analog signals
- Data is transmitted over networks using signals, which are transformed, or encoded, by computers into the voice, video, graphics, and/or the print we see on our computer screens.
- Transmission is communication of data by propagation and processing of signals

Data Transmission…

- The successful transmission of data depends on two factors:
  I. Quality of the signal being transmitted
  II. Characteristics of the transmission medium
- Data transmission is the process of sending digital or analog data over a communication medium to one or more computing, network, communication or electronic devices.

2.2 Concepts and Terminology

Transmission Terminology

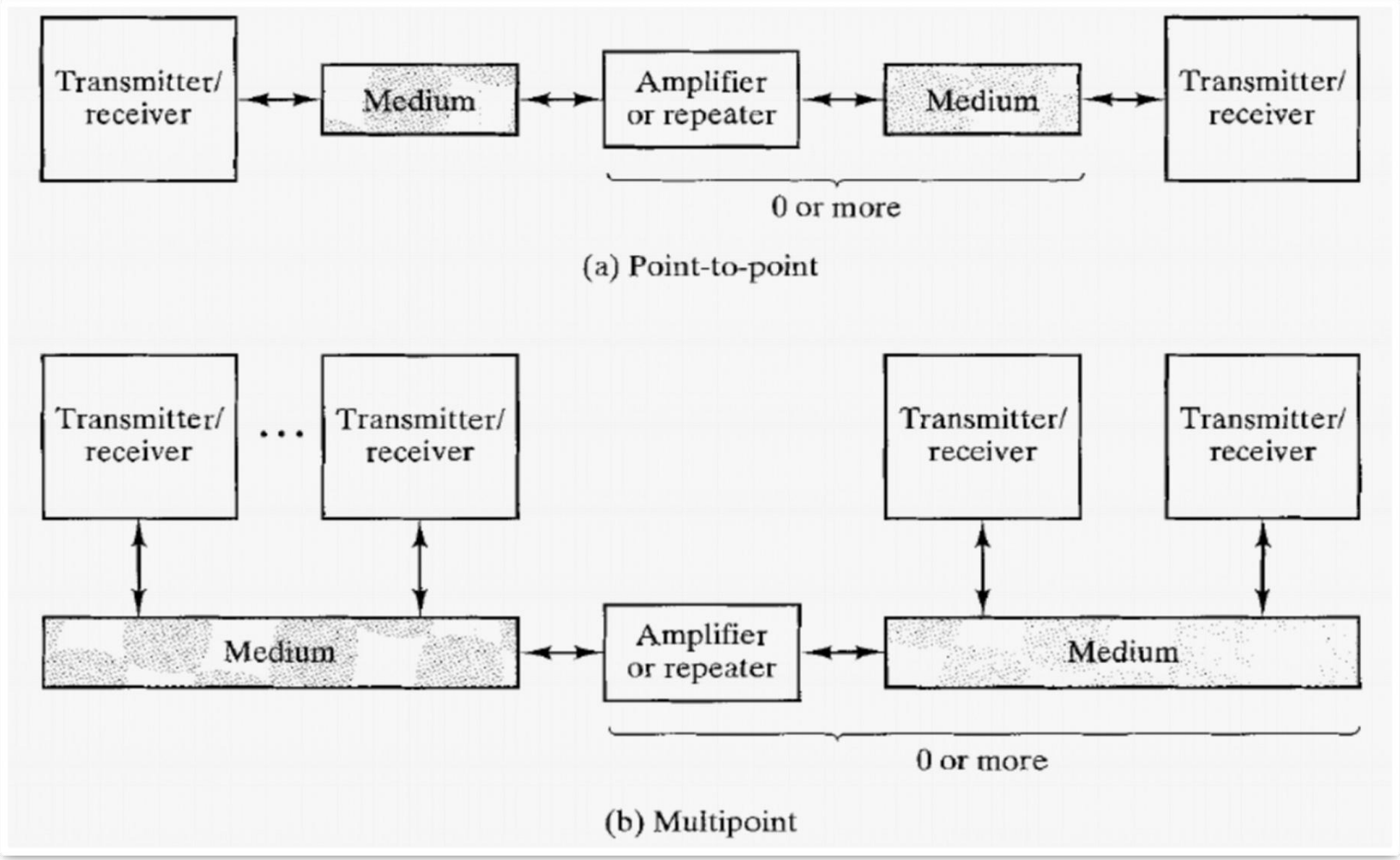
- ✓ Data transmission occurs between transmitter and receiver over some transmission medium.
- ✓ Transmission media may be classified as guided or unguided.
- ✓ In both cases, communication is in the form of electromagnetic waves. With guided media, the waves are guided along a physical path; examples of guided media are twisted pair, coaxial cable, and optical fiber.
- ✓ Unguided media provide a means for transmitting electromagnetic waves but do not guide them examples are propagation through air, vacuum, and sea water

Transmission Terminology…

Types of Connection

- The term *direct link* is used to refer to the transmission path between two devices in which signals propagate directly from transmitter to receiver with no intermediate devices, other than amplifiers or repeaters used to increase signal strength.
- Both parts of figure below depict a direct link. Note that this term can apply to both guided and unguided media.
- A guided transmission medium is point-to-point if, first, it provides a direct link between two devices and, second, those are the only two devices sharing the medium (Figure a).
- In a multipoint guided configuration, more than two devices share the same medium (b).

Types of connection…



Mode of Transmission

- Based on the direction of transmission, transmission may be simplex, half-duplex, or full-duplex.
- In **simplex** transmission, signals are transmitted in only one direction; one station is the transmitter and the other is the receiver.

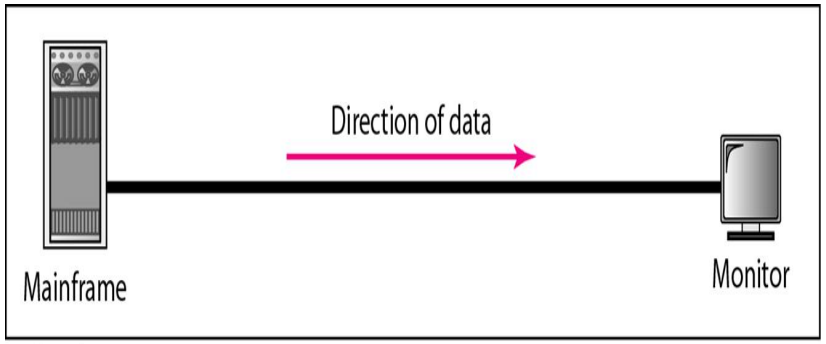
Eg. E.g. from the computer to the printer, remote

- In **half-duplex** operation, both stations may transmit, but only one at a time.

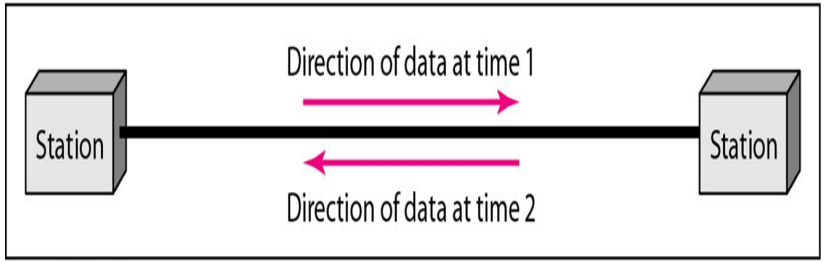
Eg. Walky talky (wakie talkie)

- In **full-duplex** operation, both stations may transmit simultaneously.
- In the latter case, the medium is carrying signals in both directions at the same time.

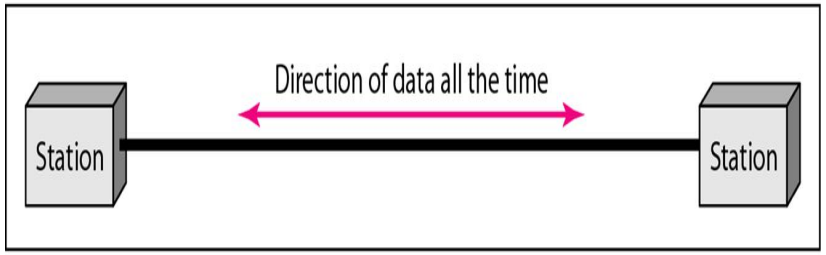
Eg. Telephone



a. Simplex



b. Half-duplex



c. Full-duplex

Transmission Modes

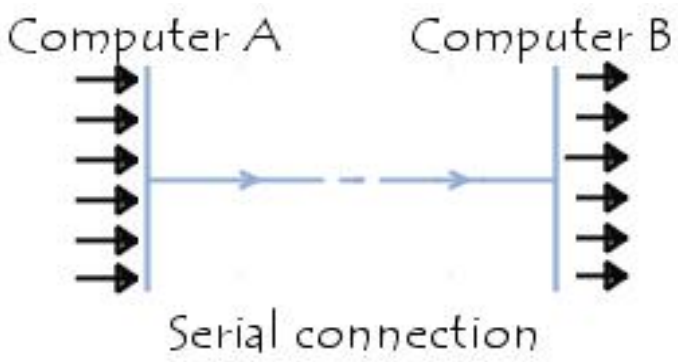
Transmission modes based on number of bits sent simultaneously

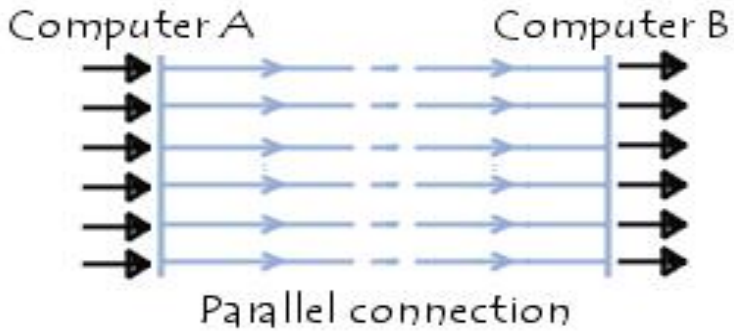
Parallel connection

- Simultaneous transmission of N bits
- These bits are sent simultaneously over N different channels
- The type of transmission mode most computers use is parallel connection

Serial connection

- the data are sent one bit at a time





- When we talk of data communication we are primarily concerned with serial transmission.
- In serial transmission the data is transmitted bit by bit as a stream of 0s and 1s.
- Protocols are implemented for these types of transmissions so that the communication takes place in a well-defined manner.
- Protocols are mutually agreed set of rules and are necessary because the format of transmission should be understood by the receiver
- The following key factors have to be observed regarding serial transmission:
  - *Timing Problem*
  - *Error Detection*
  - *Error Correction*

Cont…

- Timing problems require a mechanism to synchronize the transmitter and receiver.
- There are two approaches regarding transmission of serial data.

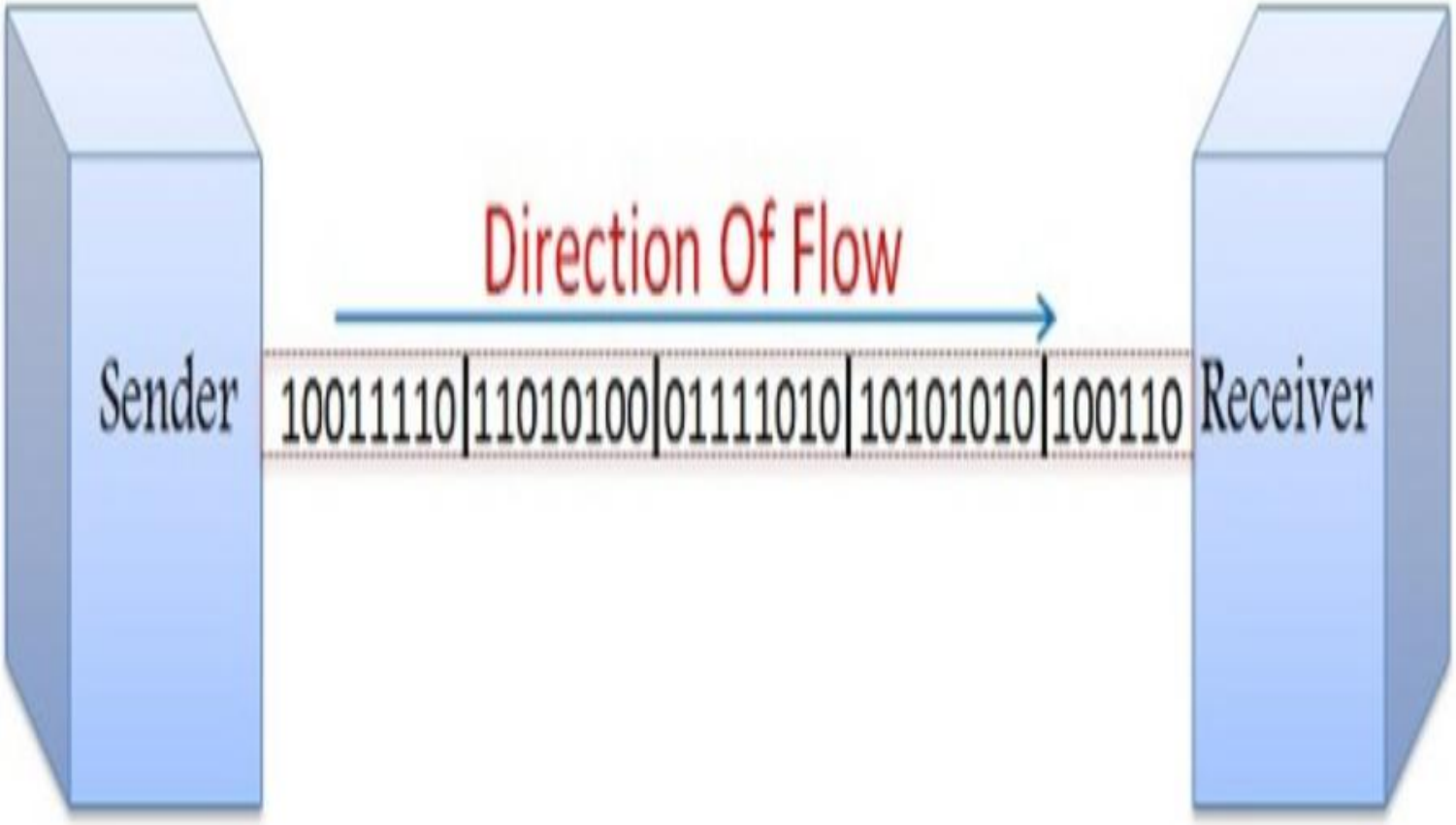
1. **Synchronous Transmission**

- In Synchronous Transmission, data flows in a full duplex mode in the form of blocks or frames.
- Synchronization between the sender and receiver is necessary so that the sender know where the new byte starts (since there is no gap between the data).

  Synchronous Transmission is efficient, reliable and is used for transferring a large amount of data.
- It provides real-time communication between connected devices.
- Eg. Chat Rooms, Video Conferencing, telephonic conversations, as well as face to face interactions

Cont…

Synchronous Transmission



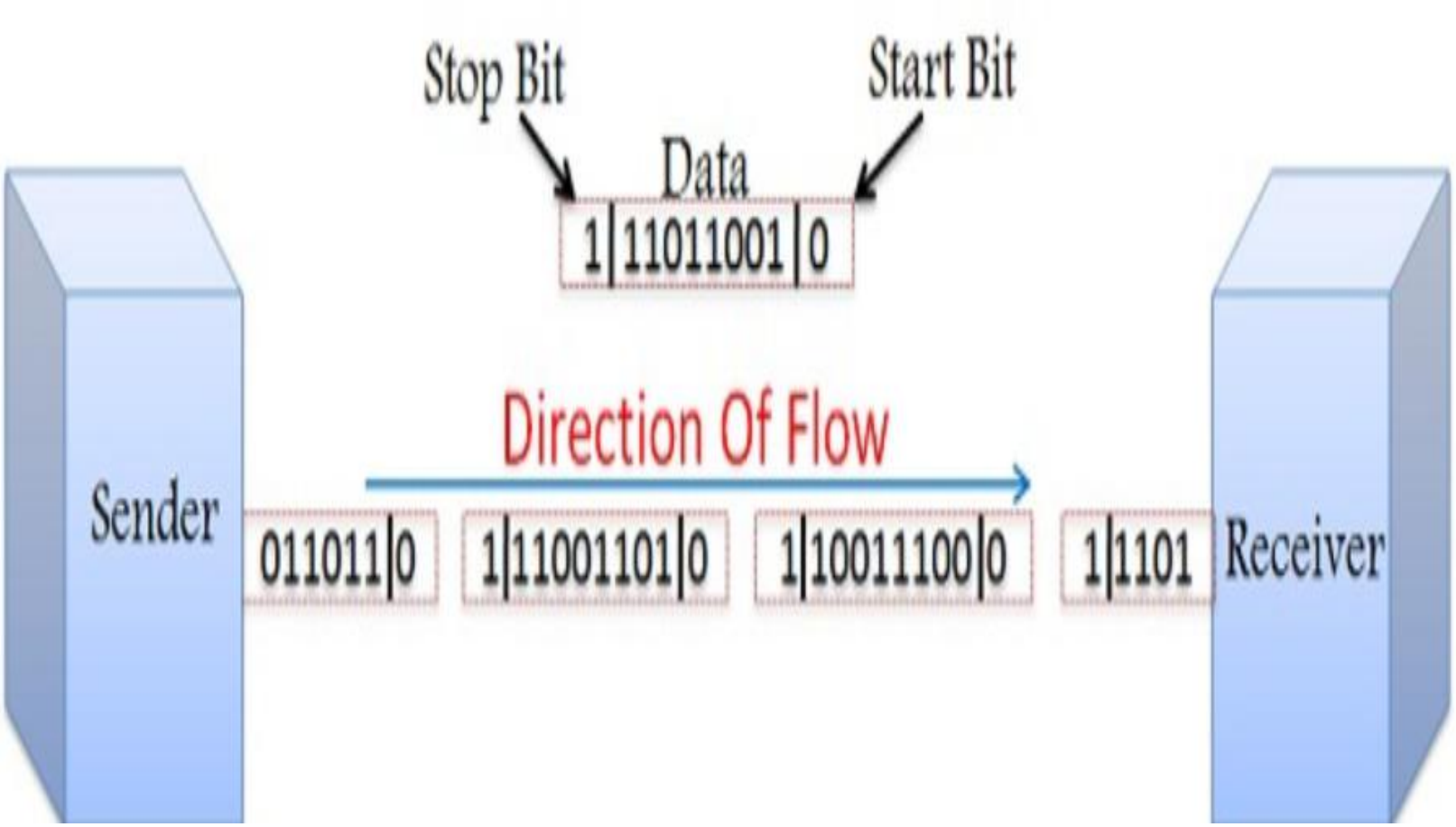
Cont…

2. Asynchronous Transmission

- data flows in a half duplex mode, 1 byte or a character at a time.
- It transmits the data in a continuous stream of bytes. In general, the size of a character sent is 8 bits to which a parity bit is added i.e. a start and a stop bit that gives the total of 10 bits.
- It does not require a clock for synchronization; rather it uses the parity bits to tell the receiver how to interpret the data.
- It is simple, fast, economical and does not require a 2-way communication.
- Eg. Letters, emails, forums, televisions and radios

Cont…

ASynchronous Transmission



Key Differences Between Synchronous and Asynchronous Transmission

- In Synchronous Transmission data is transferred in the form of frames on the other hand in Asynchronous Transmission data is transmitted 1 byte at a time.
- Synchronous Transmission requires a clock signal between the sender and receiver so as to inform the receiver about the new byte. Whereas, in Asynchronous Transmission sender and receiver does not require a clock signal as the data sent here has a parity bit attached to it which indicates the start of the new byte.
- Data transfer rate of Asynchronous Transmission is slower than that of Synchronous Transmission.
- Asynchronous Transmission is simple and economic whereas, Synchronous Transmission is complex and expensive.
- Synchronous Transmission is efficient and has lower overhead as compared to the Asynchronous Transmission.

2.3 Analog and Digital Data Transmission

In transmitting data from a source to a destination, one must be concerned with

- **the nature of the data,**
- **the actual physical means used to propagate the data, and**
- **What processing or adjustments may be required along the way to assure that the received data are intelligible.**

- The terms *analog* and *digital* correspond, roughly, to *continuous* and *discrete,* respectively.
- These two terms are used frequently in data communications in at least three contexts:
  - ✓ **Data**
  - ✓ **Signaling**
  - ✓ **Transmission**

Analog and Digital Data Transmission…

1. **Data:** can be define as entities that convey meaning or information (data ≠ info)

- ***Analog data*** take on continuous values on some interval.
  - ✓ Example, voice or sound and video
- Most data collected by sensors, such as temperature and pressure, are continuous-valued.
- The most familiar example of analog data is audio or acoustic data, which, in the form of sound waves, can be perceived directly by human beings.

- ***Digital Data*** *is discrete values rather than* continuous.
  - ✓ Example, text, integers

- While textual data are most convenient for human beings, they cannot, in character form, be easily stored or transmitted by data processing and communications systems.
- Such systems are designed for binary data. Thus, a number of codes have been devised by which characters are represented by a sequence of bits.

Signals

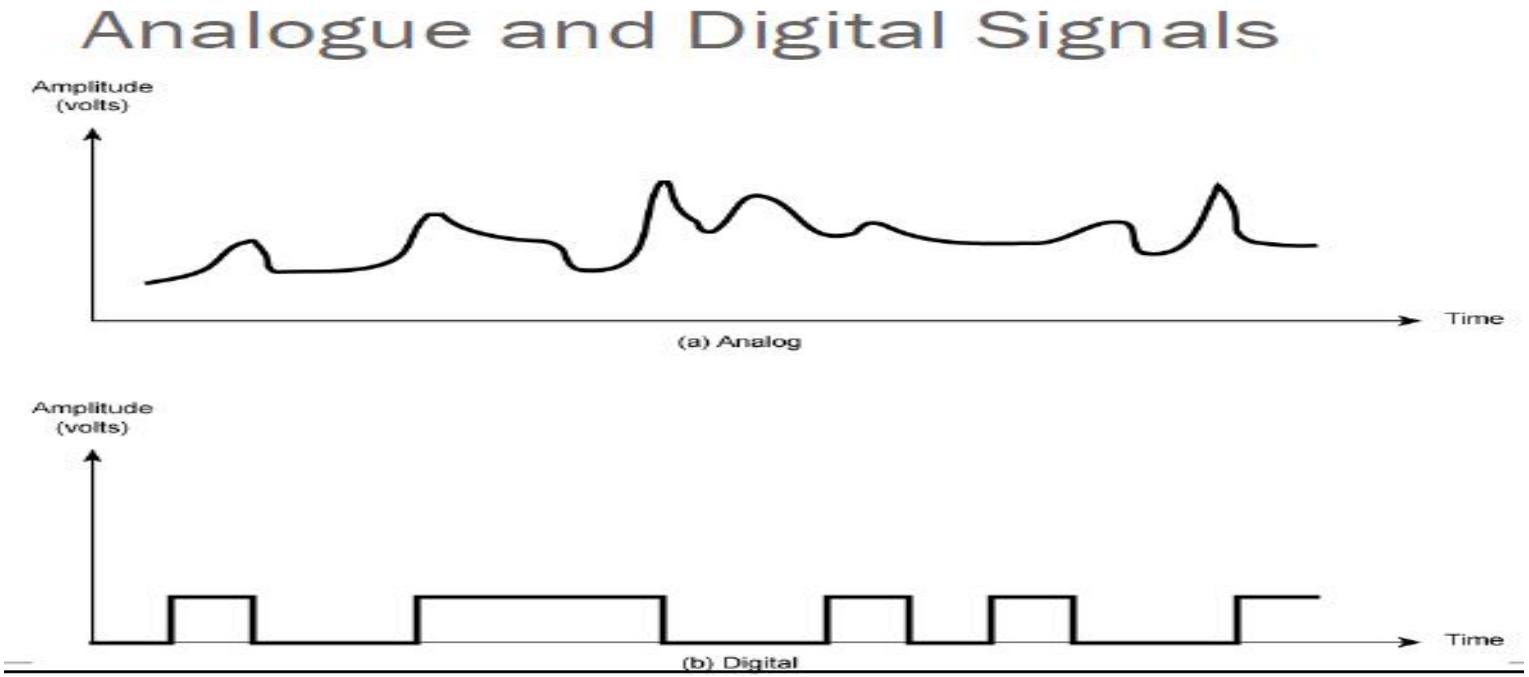
- Signals are electric or electromagnetic encoding of data.
- Signaling is the act of propagating the signal along a suitable medium
- In a communications system, data are propagated from one point to another by means of electric signals.

- **An analog signal** is a continuously varying electromagnetic wave that may be propagated over a variety of media, depending on spectrum.
- Examples are wire media, such as
  - twisted pair, coaxial cable and fiber optic cable, and
  - atmosphere or space propagation

Signals…

A digital signal is a sequence of voltage pulses that may be transmitted over a wire medium;

for example, a constant positive voltage level may represent binary 1, and a constant negative voltage level may represent binary 0.

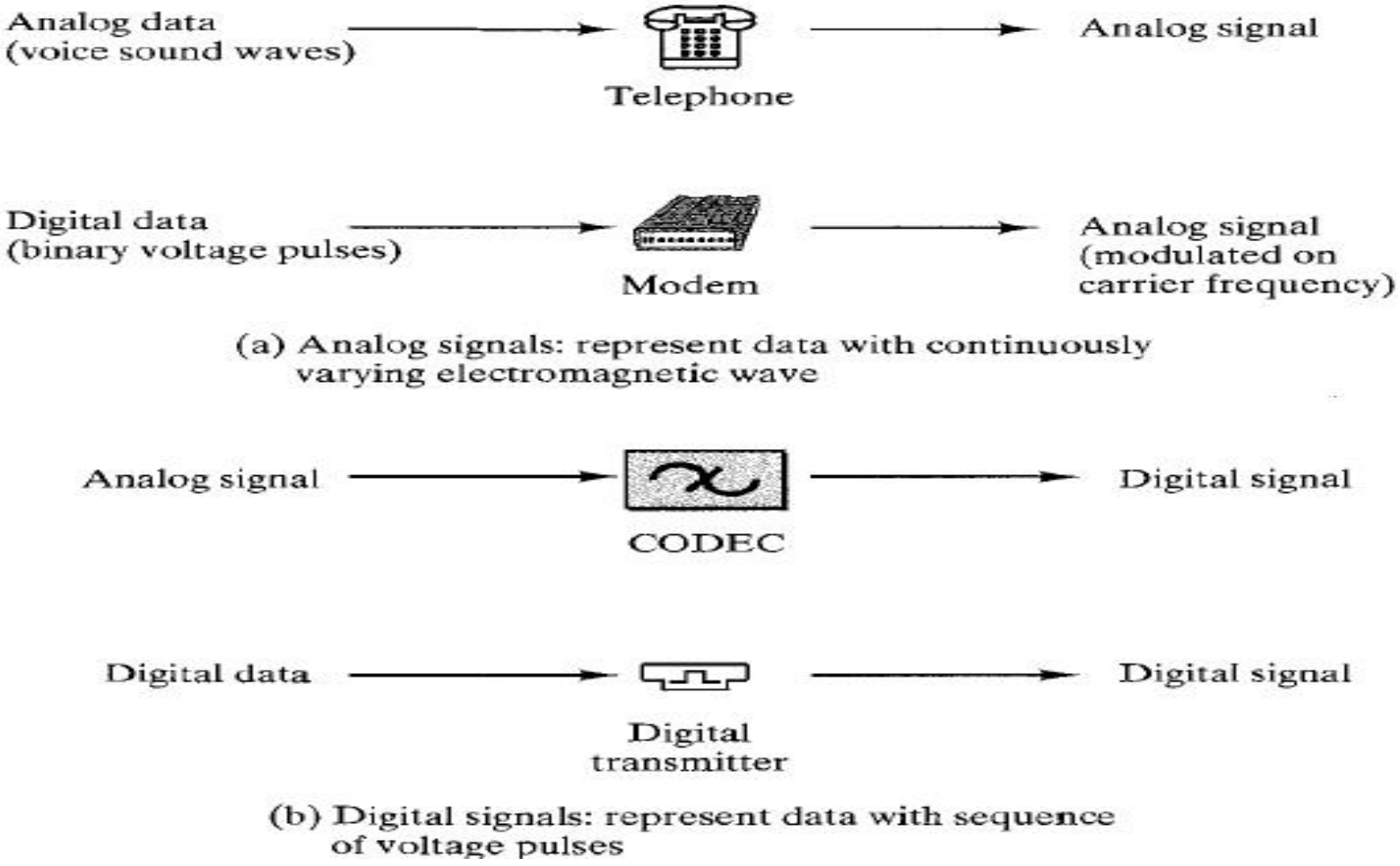


Data and Signals

In the foregoing discussion, we have looked at analog signals used to represent analog data and digital signals used to represent digital data.

- Generally, analog data are a function of time and occupy a limited frequency spectrum; such data can be represented by an electromagnetic signal occupying the same spectrum.
- Digital data can be represented by digital signals, with a different voltage level for each of the two binary digits.

Data and Signals…



Analog and digital signaling of analog and digital data

Transmission

Transmission is the communication of data by the propagation and processing of signals.

- Both analog and digital signals may be transmitted on suitable transmission media.
- The way these signals are treated is a function of the transmission system

Analog transmission is a means of transmitting analog signals without regard to their content; the signals may represent analog data (e.g., voice) or digital data (e.g., binary data that pass through a modem).

- In either case, the analog signal will become weaker (attenuated) after a certain distance.
- To achieve longer distances, the analog transmission system includes amplifiers that boost the energy in the signal

Transmission…

Digital transmission, in contrast, is concerned with the content of the signal.

- Digital signal can be transmitted only a limited distance before attenuation endangers the integrity of the data.
- To achieve greater distances, repeaters are used.
- A repeater receives the digital signal, recovers the pattern of 1s and 0s, and retransmits a new signal, thereby overcoming the attenuation.

2.4 Transmission Impairments

With any communications system, it must be recognized that the received signal will differ from the transmitted signal due to various transmission impairments.

- **For analog signals**, these impairments can degrade the signal quality.
- **For digital signals**, bit errors may be introduced, such that a binary 1 is transformed into a binary 0 or vice versa.

The most significant impairments are

- Attenuation and attenuation distortion
- Delay distortion
- Noise

1. Attenuation

- The strength of a signal falls off with distance over any transmission medium.
- For guided media, this reduction in strength, or attenuation, is generally exponential and thus is typically expressed as a constant number of decibels per unit distance.
- For unguided media, attenuation is a more complex function of distance and the makeup of the atmosphere.
- Attenuation introduces three considerations for the transmission engineer.
  - ✓ First, a received signal must have sufficient strength so that the electronic circuitry in the receiver can detect the signal.
  - ✓ Second, the signal must maintain a level sufficiently higher than noise to be received without error.
  - ✓ Third, attenuation varies with frequency.

Attenuation…

- The first and second problems are dealt with by attention to signal strength and the use of amplifiers or repeaters.
- For a point-to-point link, the signal strength of the transmitter must be strong enough to be received intelligibly, but not so strong as to overload the circuitry of the transmitter or receiver, which would cause distortion.
- Beyond a certain distance, the attenuation becomes unacceptably great, and repeaters or amplifiers are used to boost the signal at regular intervals. These problems are more complex for multipoint lines where the distance from transmitter to receiver is variable.

Attenuation…

- The third problem is particularly noticeable for analog signals. Because the attenuation varies as a function of frequency, the received signal is distorted, reducing intelligibility.
- To overcome this problem, techniques are available for equalizing attenuation across a band of frequencies. This is commonly done for voice-grade telephone lines by using loading coils that change the electrical properties of the line; the result is to smooth out attenuation effects.
- Another approach is to use amplifiers that amplify high frequencies more than lower frequencies.

2. Delay Distortion

- Delay distortion occurs because the velocity of propagation of a signal through a guided medium varies with frequency.
- For a band limited signal, the velocity tends to be highest near the center frequency and fall off toward the two edges of the band.
- Thus various frequency components of a signal will arrive at the receiver at different times, resulting in phase shifts between the different frequencies.
- This effect is referred to as delay distortion because the received signal is distorted due to varying delays experienced at its constituent frequencies.

Delay Distortion…

- Delay distortion is particularly critical for digital data. Consider that a sequence of bits is being transmitted, using either analog or digital signals. Because of delay distortion, some of the signal components of one bit position will spill over into other bit positions, causing **inter symbol interference**, which is a major limitation to maximum bit rate over a transmission channel.

3. Noise

- For any data transmission event, the received signal will consist of the transmitted signal, modified by the various distortions imposed by
  - the transmission system, plus
  - additional unwanted signals that are inserted somewhere between transmission and reception.
- The latter, undesired signals are referred to as noise.
- Noise is the major limiting factor in communications system performance.
- Noise may be divided into four categories:

1. Thermal Noise: is due to thermal agitation of electrons.

It is present in all electronic devices and transmission media and is a function of temperature.

Noise…

- Thermal noise is uniformly distributed across the bandwidths typically used in communications systems and hence is often referred to as **white noise**

2. Intermodulation noise: When signals at different frequencies share the same transmission medium, the result may be **intermodulation noise**.

The effect of intermodulation noise is to

- produce signals at a frequency that is the sum or difference of the two original frequencies or multiples of those frequencies

3. Crosstalk: has been experienced by anyone who, while using the telephone, has been able to hear another conversation; it is an unwanted coupling between signal paths..

Noise…

It can occur by

- Electrical coupling between nearby twisted pairs or, rarely, coax cable lines carrying multiple signals.
- Crosstalk can also occur when microwave antennas pick up unwanted signals; although highly directional antennas are used, microwave energy does spread during propagation.

- All of the types of noise discussed so far have reasonably predictable and relatively constant magnitudes.

4. Impulse noise: is noncontiguous, consisting of irregular pulses or noise spikes of short duration and of relatively high amplitude. It is generated from a variety of causes, including external electromagnetic disturbances, such as lightning, and faults and flaws in the communications system. Impulse noise is generally only a minor annoyance for analog data.

2.5 Channel Capacity

- The maximum rate at which data can be transmitted over a given communication path, or channel, under given conditions, is referred to as the **channel capacity**.
- There are four concepts here that we are trying to relate to one another.

Data rate: The rate, in bits per second (bps), at which data can be communicated

Bandwidth: The bandwidth of the transmitted signal as constrained by the transmitter and the nature of the transmission medium, expressed in cycles per second, or Hertz

Noise: The average level of noise over the communications path

Error rate: The rate at which errors occur, where an error is the reception of a 1 when a 0 was transmitted or the reception of a 0 when a 1 was transmitted

2.6 Transmission Media

In a data transmission system,

- the **transmission medium** is the physical path between transmitter and receiver.
- In the case of guided media, the medium itself is more important in determining the limitations of transmission.
- For unguided media, the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics.
- One key property of signals transmitted by antenna is directionality.
- **In general, signals at lower frequencies are omnidirectional;** that is, the signal propagates in all directions from the antenna**.**
- **At higher frequencies, it is possible to focus the signal into a directional beam.**

Transmission Media…

- In considering the design of data transmission systems, key concerns are data rate and distance: the greater the data rate and distance the better.
- A number of design factors relating to the transmission medium and the signal determine the data rate and distance:

Bandwidth: All other factors remaining constant, the greater the bandwidth of a signal, the higher the data rate that can be achieved.

Transmission impairments: Impairments, such as attenuation, limit the distance.

- For guided media, twisted pair generally suffers more impairment than coaxial cable, which in turn suffers more than optical fiber.

Interference: Interference from competing signals in overlapping frequency bands can distort or wipe out a signal. Interference is of particular concern for unguided media, but is also a problem with guided media. For guided media, interference can be caused by emanations from nearby cables.

Number of receivers: A guided medium can be used to construct a point to-point link or a shared link with multiple attachments. In the latter case, each attachment introduces some attenuation and distortion on the line, limiting distance and/or data rate.

2.7 GUIDED TRANSMISSION MEDIA

- For guided transmission media, the transmission capacity, in terms of either data rate or bandwidth, depends critically on
- ✓ the distance and on whether the medium is point-to-point or multipoint.
- The three guided media commonly used for data transmission are
  - Twisted Pairs
  - Coaxial Cable, and
  - Optical Fiber

Twisted Pairs

- The least expensive and most widely used guided transmission medium is twisted pair.
- A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern.
- A wire pair acts as a single communication link.

Advantages

- Protect against cross talk & interference
- Easy to add computers to network
- Well understood technology
- Less expensive

Twisted Pairs…

Disadvantages

- Susceptibility to noise
- Least secure
- Distance limitations
  - For analog, repeaters needed every 5-6km
  - For digital, repeaters needed every 2-3km

➢ Two types

- Unshielded Twisted Pair (UTP)
- Shielded Twisted Pair (STP)

➢ For local area networks (LAN): 10 Mbps or 100 Mbps

Unshielded Twisted Pair (UTP)

- Pair of wires do not have the shielding against electrical interference
- Uses RJ 45 connectors

There are three types of UTP cables:

- Ethernet Straight-through Cable
- Ethernet Crossover Cable
- Rollover Cable

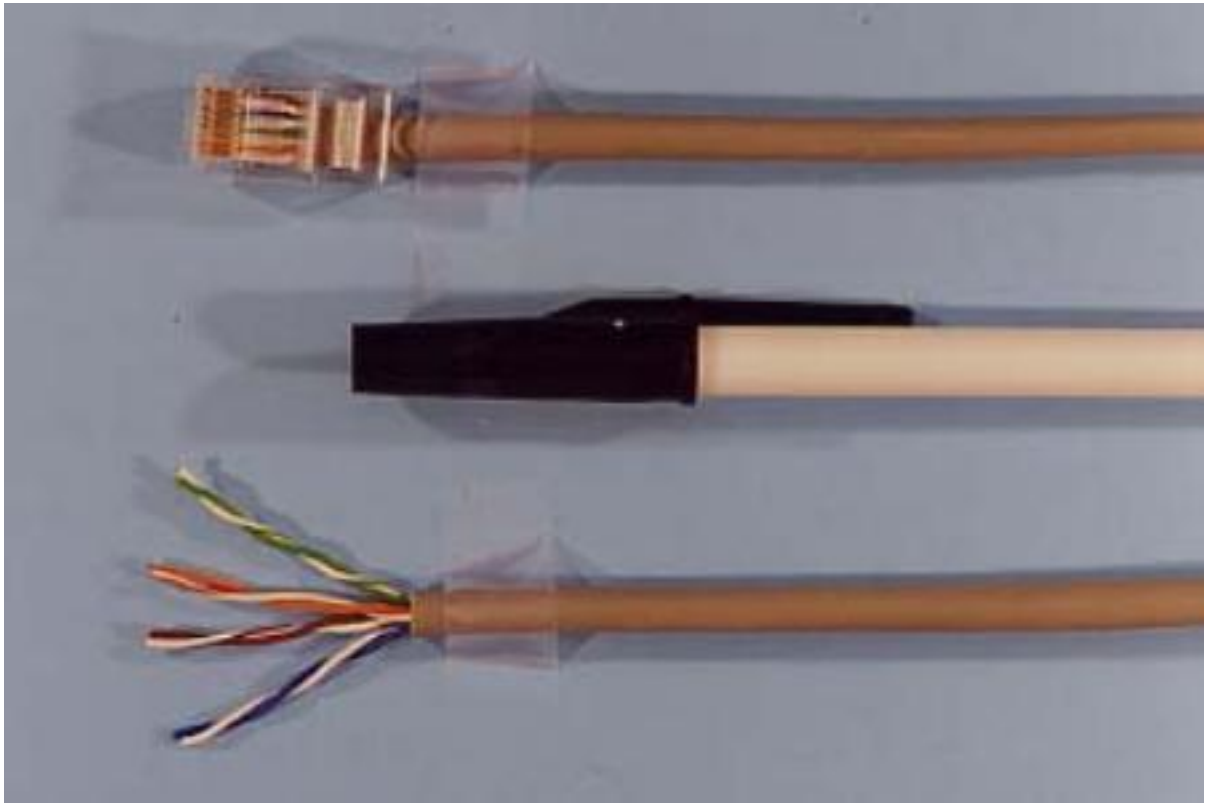
Advantages

- Less expensive
- Easy to install

Disadvantages

- Vulnerable to electromagnetic interference & crosstalk
- Subject to attenuation and electromagnetic interference

UTP Cable



Crimping UTP Cable

- Common Ethernet network cable are straight and crossover cable.
- This Ethernet network cable is made of 4 pair high performance cable that consists twisted pair conductors that used for data transmission.
- Both end of cable is called RJ-45 connector
- The cable can be categorized as **Cat 5, Cat 5e, Cat 6 UTP cable**.

  Cat 5 UTP cable can support 10/100 Mbps Ethernet network, whereas Cat 5e and Cat 6 UTP cable can support Ethernet network running at 10/100/1000 Mbps.
- Straight through and crossover cable can be Cat 5, Cat 5e or Cat 6 UTP cable, the only difference is each type will have different wire arrangement in the cable for serving different purposes.

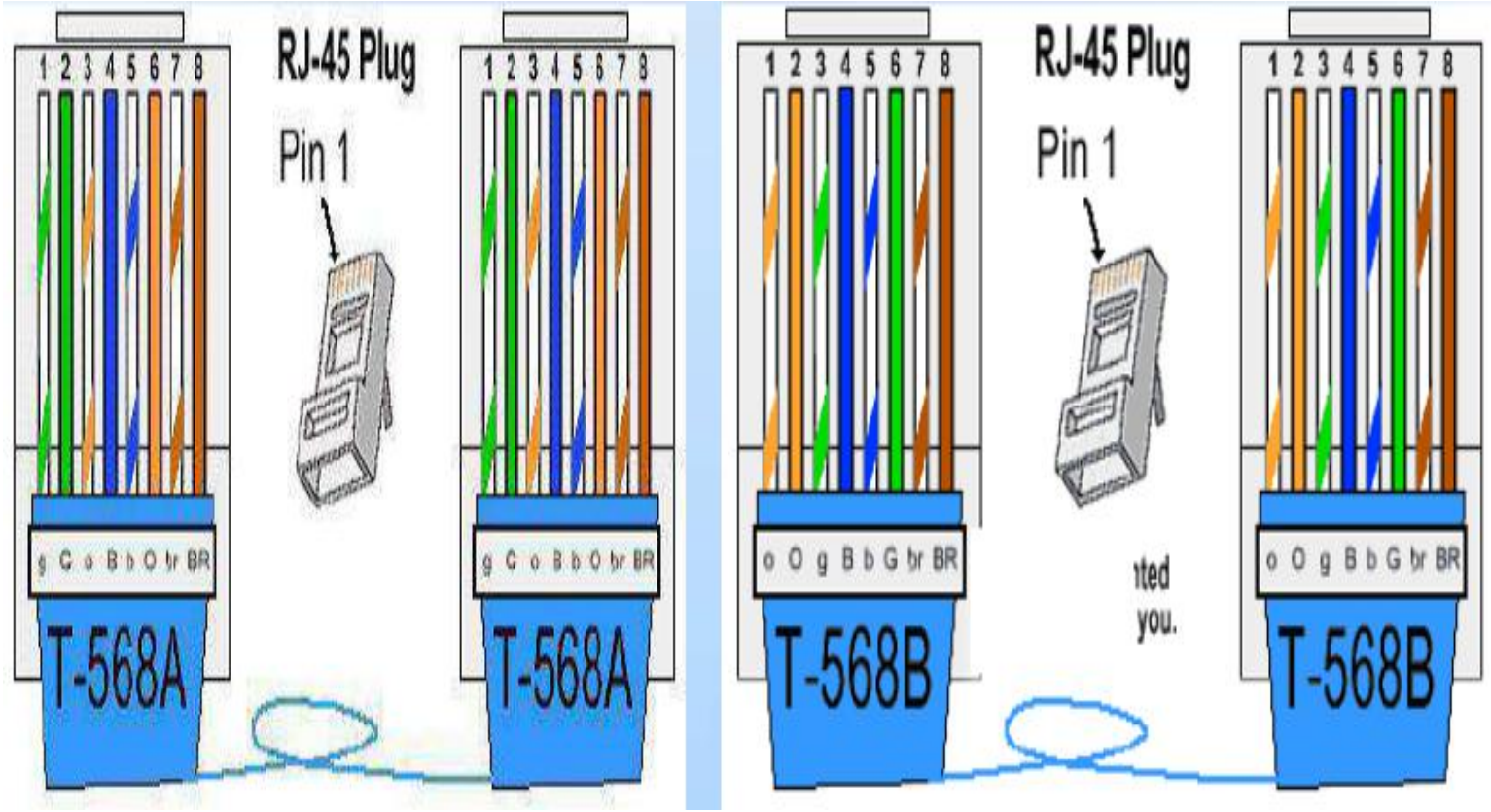
Straight through Cable

- You usually use straight through cable to connect different type of devices.
- This type of cable will be used most of the time and can be used to:
  1. Connect a computer to a switch/hub's normal port.
  2. Connect a computer to a cable/DSL modem's LAN port.
  3. Connect a router's WAN port to a cable/DSL modem's LAN port.
  4. Connect a router's LAN port to a switch/hub's uplink port. (normally used for expanding network)
  5. Connect 2 switches/hubs with one of the switch/hub using an uplink port and the other one using normal port.

Straight through cable crimping :

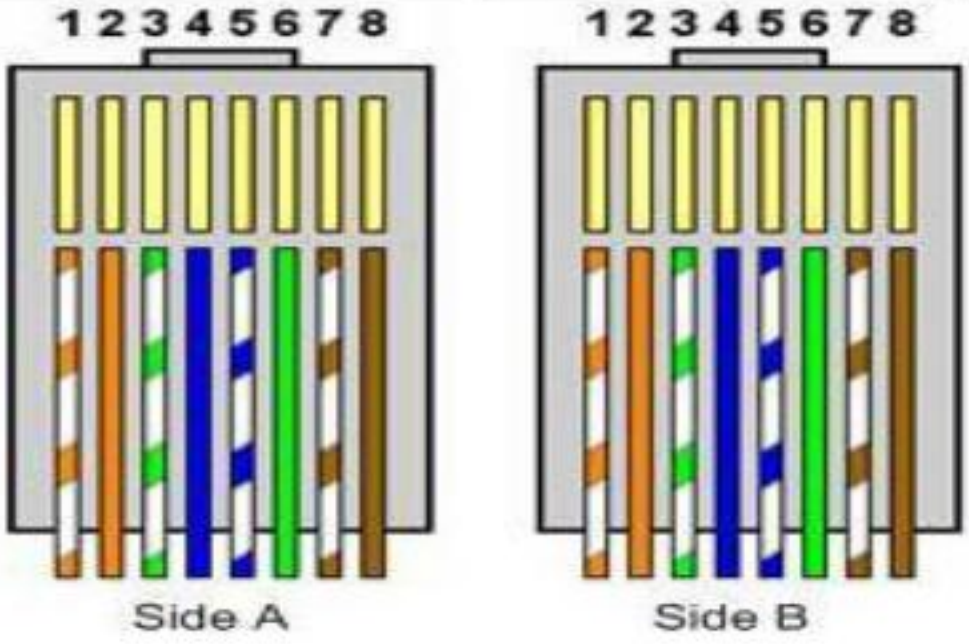
Straight through Cable…

- both ends standards which are **T568A or T568B.**



Straight through cable crimping :

Pin ID	Side A	Side B
1	Orange-white	Orange-white
2	Orange	Orange
3	Green-white	Green-white
4	Blue	Blue
5	Blue-white	Blue-white
6	Green	Green
7	Brown-white	Brown-white
8	Brown	Brown



Crossover Cable

- Sometimes you will use crossover cable, it's usually used to connect same type of devices. A crossover cable can be used to:

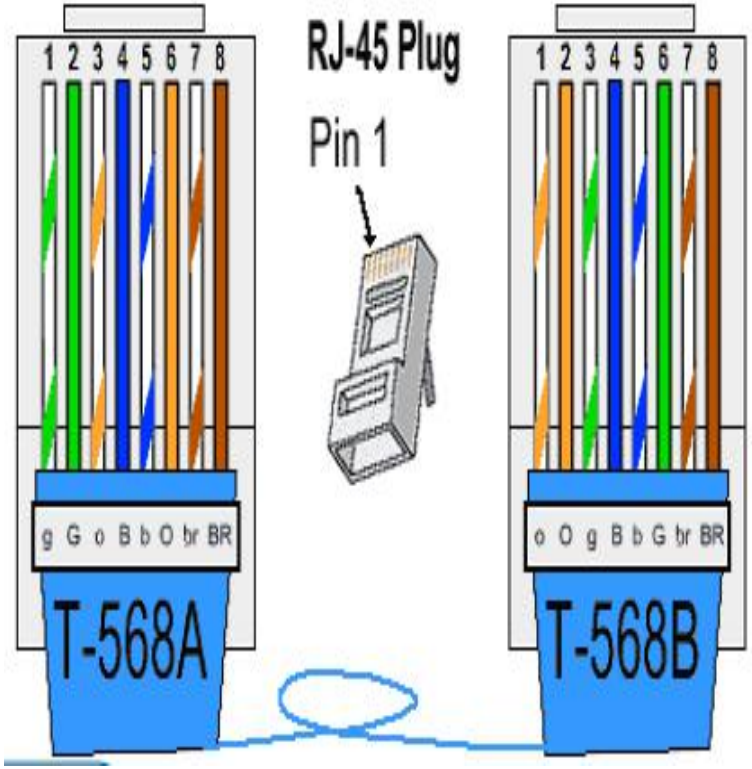
1) Connect 2 computers directly.
2) Connect a router's LAN port to a switch/hub's normal port. (normally used for expanding network)
3) Connect 2 switches/hubs by using normal port in both switches/hubs.

- In you need to check how crossover cable looks like.

Crossover Cable crimping:

PIN ID	SIDE A	SIDE B
1	Green-White	Orange-White
2	Green	Orange
3	Orange-White	Green-White
4	Blue	Blue
5	Blue-White	Blue-White
6	Orange	Green
7	Brown-White	Brown-White
8	Brown	Brown

Color Code



Shielded Twisted Pair (STP)

- An electrically grounded woven copper mesh wrapped around each twisted pair
- Shielded twisted pair is often used on networks using Token Ring topology
- Shielded twisted pair (STP) is suitable for environments with electrical interference; however, the extra shielding can make the cables quite bulky

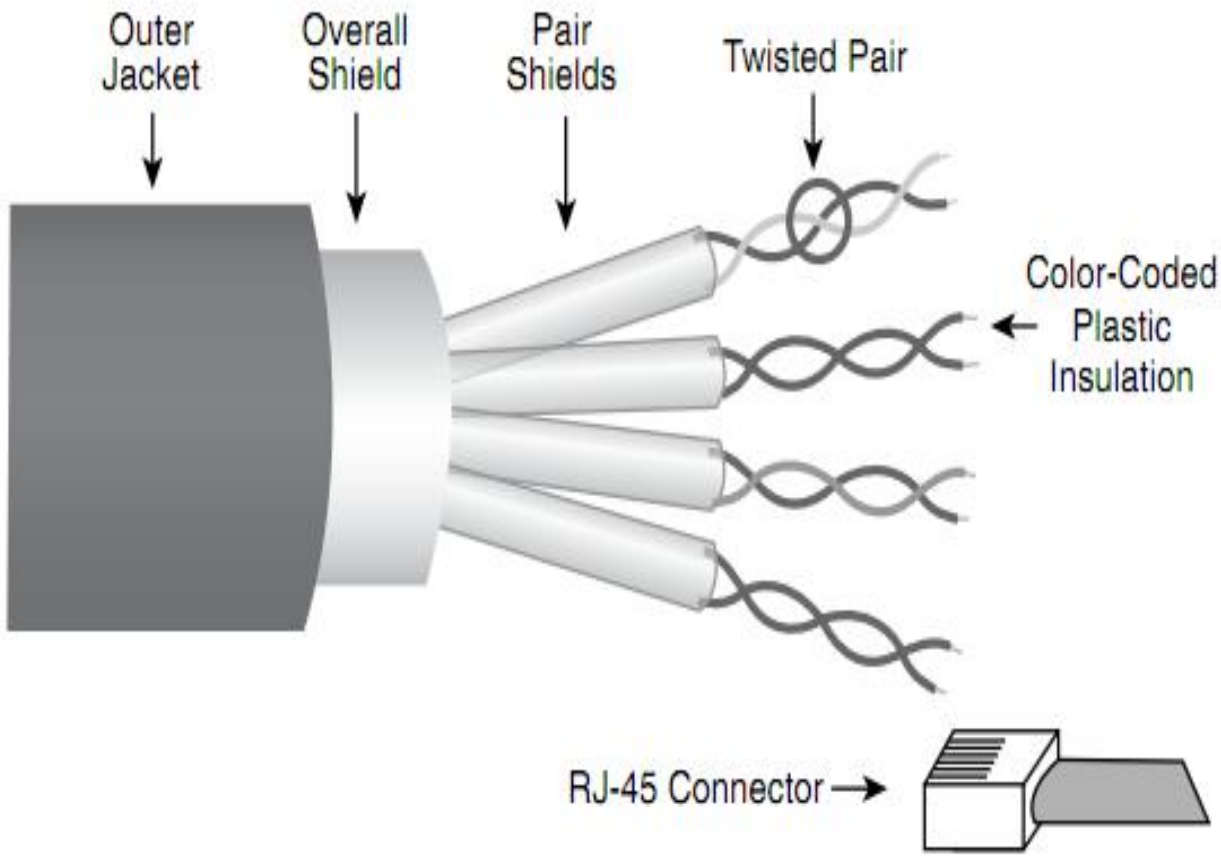
Advantage

- Reduces electromagnetic interference (EMI)

Disadvantage

- Makes the wiring thick and is difficult to maintain

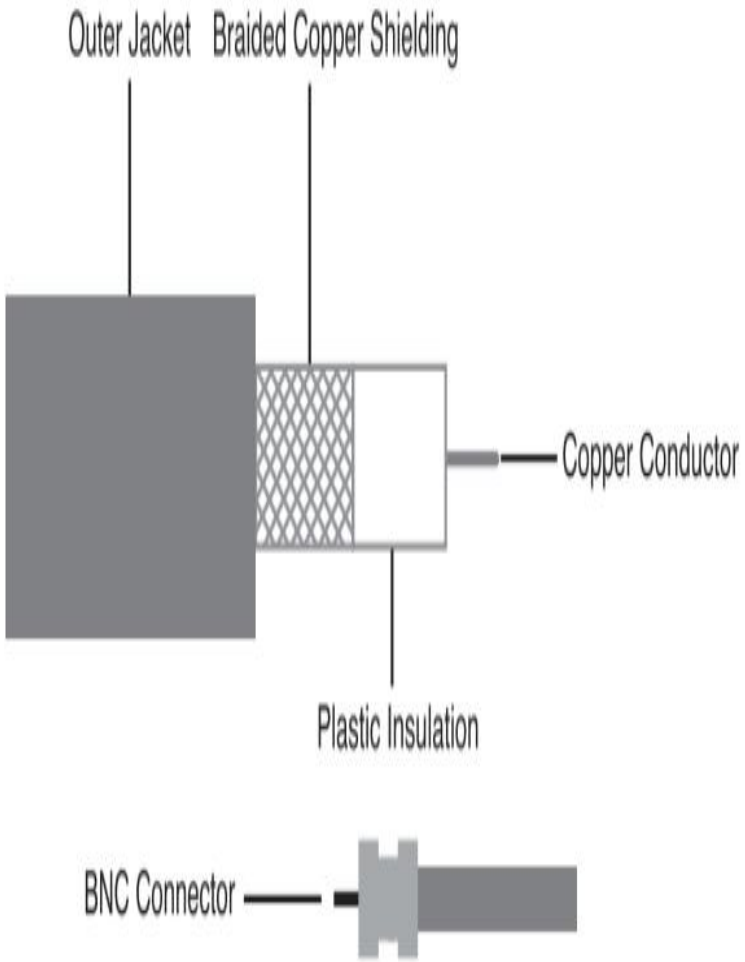
Shielded Twisted Pair (STP)…



Coaxial Cable

- Coaxial cable consists of four main parts:
  - ✓ Copper conductor
  - ✓ Plastic insulation
  - ✓ Braided copper shielding
  - ✓ Outer jacket
- At the center of the cable is a solid copper conductor. Surrounding that conductor is a layer of flexible plastic insulation.
- A plastic layer provides insulation between the center conductor and a braided metal shield
- The metal shield helps to block any outside interference from fluorescent lights, motors, and other computers.
- The connector used on coaxial cable is called a BNC, short for British Naval Connector or Bayonet Neill Concelman, connector.
- more expensive than UTP but less expensive than fiber-optic cable.

Coaxial Cable



Coaxial Cable Connectors

Coaxial Cable …

- Although coaxial cabling is difficult to install, it is highly resistant to signal interference. In addition, it can support greater cable lengths between network devices than twisted pair cable.
- The two types of coaxial cables

1.Thin coaxial cable is also referred to as thinnet.

  - 10Base2 refers to the specifications for thin coaxial cable carrying Ethernet signals.
  - The 2 refers to the approximate maximum segment length being 200 meters.
  - In actual fact the maximum segment length is 185 meters. Thin coaxial cable is popular in school networks, especially linear bus networks.

Coaxial Cable …

2.Thick coaxial cable is also referred to as thicknet.

- 10Base5 refers to the specifications for thick coaxial cable carrying Ethernet signals.
- The 5 refers to the maximum segment length being 500 meters. Thick coaxial cable has an extra protective plastic cover that helps keep moisture away from the center conductor.
- This makes thick coaxial a great choice when running longer lengths in a linear bus network.
- One disadvantage of thick coaxial is that it does not bend easily and is difficult to install.

Coaxial Cable Applications

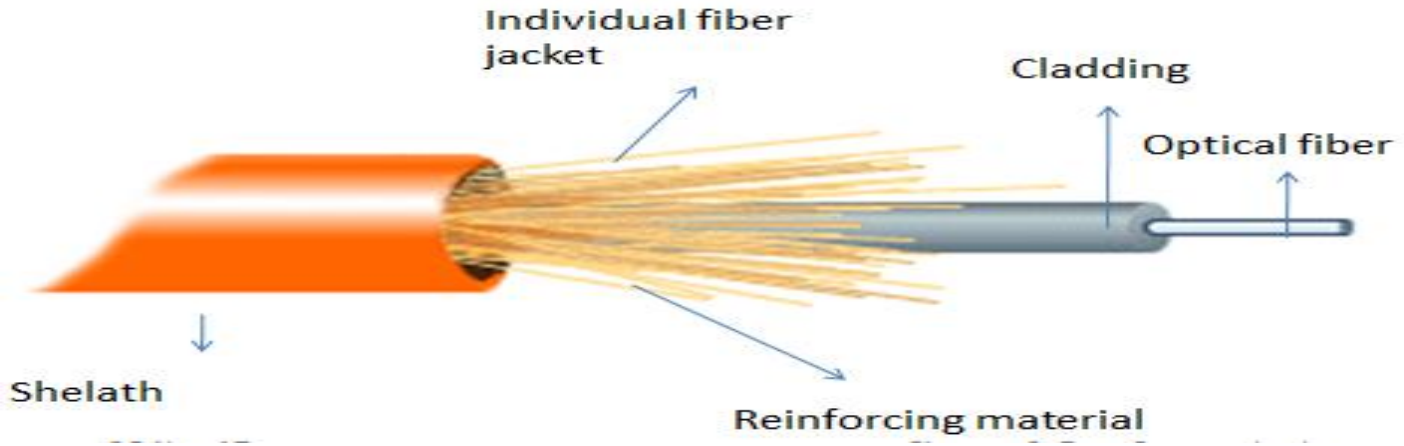
Coaxial cable is a versatile transmission medium, used in a wide variety of applications.

The most important of these are

- Television distribution
- Long-distance telephone transmission
- Short-run computer system links
- Local area networks

Fiber Optic Cable

Fiber optic cabling consists of a center glass core surrounded by several layers of protective materials.



Fiber Optic Cable…

- It transmits light rather than electronic signals eliminating the problem of electrical interference.
- It has also made it the standard for connecting networks between buildings, due to its immunity to the effects of moisture and lighting.
- Fiber optic cable has the ability to transmit signals over much longer distances than coaxial and twisted pair.
- It also has the capability to carry information at vastly greater speeds.
- This capacity broadens communication possibilities to include services such as video conferencing and interactive services.
- The cost of fiber optic cabling is a little bit higher; and, it is more difficult to install and modify.

Fiber Optic Cable…

Facts about fiber optic cables:

- Outer insulating jacket is made of Teflon or PVC.
- Kevlar fiber helps to strengthen the cable and prevent breakage.
- A plastic coating is used to cushion the fiber center.
- Center (core) is made of glass or plastic fibers.

Fiber Optic Cable Connector

- The most common connector used with fiber optic cable is an ST connector.
- It is barrel shaped, similar to a BNC connector.
- A newer connector, the SC, is becoming more popular.
- It has a squared face and is easier to connect in a confined space.
- ST connectors are more common than SC connectors

Fiber Optic Cable Applications

Five basic categories of application have become important for optical fiber:

- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- Local area networks

Installing Cable - Some Guidelines

- Always use more cable than you need. Leave plenty of cable.
- Test every part of a network as you install it. Even if it is brand new, it may have problems that will be difficult to isolate later.
- Stay at least 3 feet away from fluorescent light boxes and other sources of electrical interference.
- If it is necessary to run cable across the floor, cover the cable with cable protectors.
- Label both ends of each cable.
- Use cable ties to keep cables in the same location together.

2.8 Wireless (Unguided Media) Transmission

Transmission and reception are achieved by means of an antenna

- Directional
  - ✓ transmitting antenna puts out focused beam(ray)
  - ✓ transmitter and receiver must be aligned
- Omnidirectional
  - ✓ signal spreads out in all directions
  - ✓ can be received by many antennas

Wireless Transmission Media Types

We can divide wireless transmission into three broad groups:

- Radio Waves
- Microwaves
- Infrared Waves

Radio Waves

- Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz
- Radio waves use **omnidirectional** antennas that sendout signals in all directions.
- Radio waves can travel long distances. This makes radio waves a good candidate for long-distance broadcasting such as AM radio.
- One sender but many receivers. AM and FM radio, television, maritime and radios are examples of multicasting

Infrared

- Can be used for short-range communication
  - ✓ Remote controls for TVs, VCRs, and stereos
  - ✓ Indoor wireless LANs
- Do not pass through solid walls
  - ✓ Better security and no interference (with a similar system in adjacent rooms)
- Cannot be used outdoors (due to the sunshine)

Microwaves

- Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves.
- Microwaves are unidirectional
- Two types of antennas are used for microwave communications: the **parabolic dish** and the **horn**
- Microwaves are very useful when unicast (one-to-one) communication is needed between the sender and the receiver. They are used in **cellular phones**, **satellite networks**, and **wireless LANs**

CHAPTER END

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