

**ACADEMIC PROGRAMME: BACHELOR OF SCIENCE IN COMPUTER SCIENCE**

**COURSE CODE AND TITLE: BSCS 302 – DATA COMMUNICATION AND NETWORKS**

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## **BSCS 302: DATA COMMUNICATIONS AND NETWORKS – LECTURE NOTES**

### **OVERVIEW DATA COMMUNICATIONS AND NETWORKING**

#### **DATA COMMUNICATIONS**

- Data communications are the exchange of data between two devices via some form of transmission medium such as a wired or wireless.
  - For data communications to occur, the communicating devices must be part of a communication system made up of combination of hardware and software.
  - The effectiveness of a data communications system depends on four fundamental characteristics: delivery, accuracy and timeliness.
1. **Delivery:** The system must deliver data to the correct destination. Data must be received by the intended device or user and only by that device or user.
  2. **Accuracy:** The system must deliver the data accurately. Data that have been altered in transmission and left uncorrected are unusable.
  3. **Timeliness:** The system must deliver data in a timely manner. Data delivered late are useless. Data delivering in the same order that they are produced, and without significant delay. This kind of delivery is called realtime transmission.

#### **COMPONENTS OF A DATA COMMUNICATIONS SYSTEM**

A data communications system has five components as follows;

1. **Message.** The message is the information (data) to be communicated. Popular forms of information include text, numbers, pictures, audio, and video.
2. **Sender.** The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.
3. **Receiver.** The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.
4. **Transmission medium.** The transmission medium is the physical path/air by which a message travels from sender to receiver. Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves.
5. **Protocol.** A protocol is a set of rules that govern data communications. It represents an agreement between the communicating devices. It defines how it is communicated, when communicated and what communicated. Key elements of protocols are timing, syntax and semantics. Without a protocol, two devices may be connected but not communicating.

#### **DATA REPRESENTATION**

Information today comes in different forms such as text, numbers, images, audio, and video.

1. **Text:** In data communications, text is represented as a bit pattern, a sequence of bits (0s or 1s).

2. **Numbers:** Numbers are also represented by bit patterns. However, a code such as ASCII is not used to represent number; the number is directly converted to a binary number to simplify mathematical operations.
3. **Images:** Images are also represented by bit patterns. In its simplest form, an image is composed of matrix of pixels (picture elements), where each pixel is a small dot.
4. **Audio:** Audio refers to the recording or broadcasting of sound or music.
5. **Video:** Video refers to the recording or broadcasting of a picture or movie.

## **COMPUTER NETWORKS**

- A **network** is a set of devices/node connected by communication links.
- Computers/devices on network are called nodes. Connecting medium are either physical medium i.e. wire/cable or wireless medium (i.e. through radio waves).
- Best known computer network is Internet.

## **NETWORK CRITERIA**

A network must be able to meet a certain number of criteria. The most important of these are performance, reliability and security.

□ **Performance:** Performance can be measured in many ways, including transit time and response time.

□ **Reliability:** In addition to accuracy of delivery, network reliability is measured by the frequency of failure, the time it takes a link to recover from a failure, and the network's robustness in a catastrophe.

□ **Security:** Network security issues include protecting data from unauthorized access, protecting, from damage and development, and implementing policies and procedures for recovery from breaches and lost data.

## **SIGNALS**

One of the major concerns of the physical layer lies in moving data in the form of electromagnetic signals across a transmission medium.

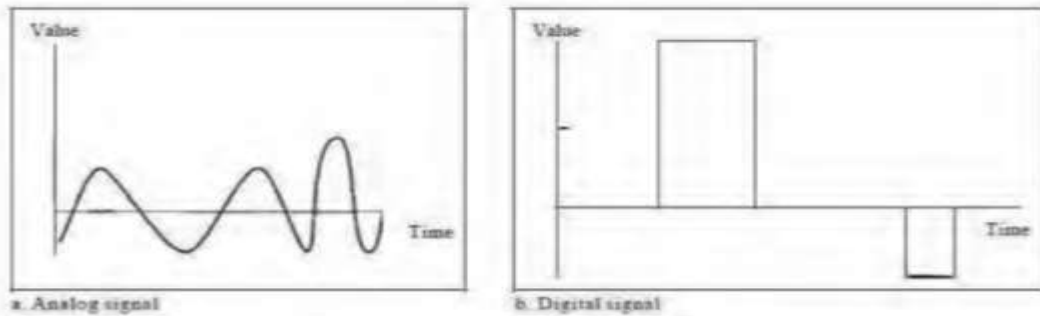
### **Analog and Digital**

**An analog signal** is any continuous signal for which the time varying feature (variable) of the signal is a representation of some other time varying quantity.

**A digital signal** is a chemical signal that is a representation of a sequence of discrete values (a quantified discrete-time signal), for example of arbitrary bit stream.

A digital signal that is generated by means of a digital modulation method (digital pass band transmission), produced by a modem.

Analog data, such as the sounds made by a human voice, take on continuous values. When someone speaks, an analog wave is created in the air. This can be captured by a microphone and converted to an




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Data can be analog or digital. Analog data are continuous and take continuous values.  
 Digital data have discrete states and take discrete values.

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analog  
 signal or  
 sampled  
 and  
 converted  
 to a  
 digital  
 signal.  
 Digital  
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 on  
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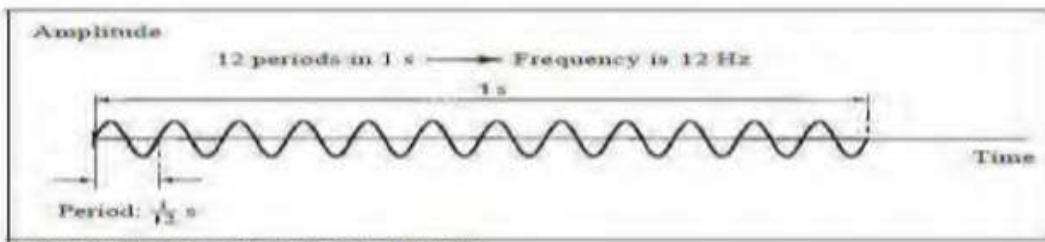
## Periodic and Non-periodic Signals

Both analog and digital signals can take one of two forms: periodic or non-periodic. In data communications, we commonly use periodic analog signals

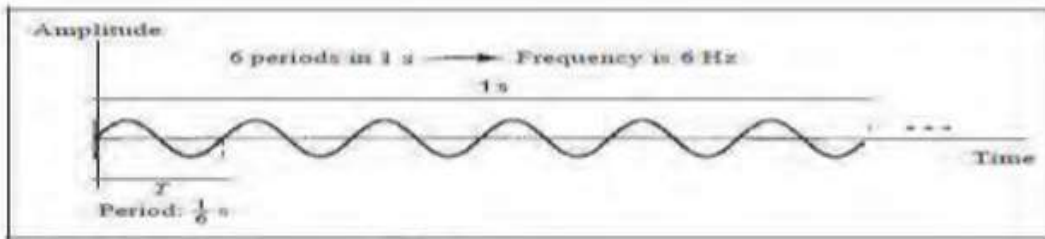
### Periodic Analog Signals

- ✓ Periodic Signals are signals that repeat themselves after a certain amount of time.
- ✓ A periodic signal completes a pattern within a measurable time frame, called a **period**, and repeats that pattern over subsequent identical periods.
- ✓ The completion of one full pattern is called a **cycle**
- ✓ The **sine wave** is the most fundamental form of a periodic analog signal.
- ✓ The **peak amplitude** of a signal is the absolute value of its highest intensity.
- ✓ **Period** refers to the amount of time, in seconds, a signal needs to complete 1 cycle.
- ✓ **Frequency** refers to the number of periods in 1 s.

*Two signals with the same amplitude and phase, but different frequencies*



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

## PHASE

- ☐ The term phase describes the position of the waveform relative to time 0.
- ☐ A complete cycle is defined as 360 degrees of phase.
- ☐ Phase can also be an expression of relative displacement between or among waves having the same frequency.

## BIT RATE

Most digital signals are non-periodic, and thus period and frequency are not appropriate characteristics. Another term-bit rate (instead frequency)-is used to describe digital signals, so bandwidth of the digital signal is measured in bit rate. The **bit rate** is the number of bits sent in 1s, expressed in bits per second (bps).

### Example 1

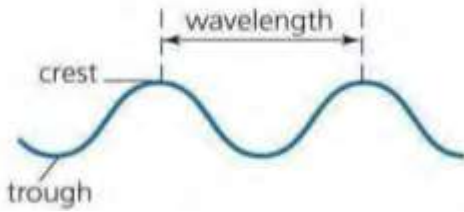
Assume we need to download text documents at the rate of 100 pages per minute. What is the required bit rate of the channel?

### Solution

A page is an average of 24 lines with 80 characters in each line. If we assume that one Character requires 8 bits, the bit rate is

$$100 \times 24 \times 80 \times 8 = 1,636,000 \text{ bps} = 1.636 \text{ Mbps}$$

## WAVELENGTH



Wavelength is the distance between identical points in the adjacent cycles of a waveform signal propagated in space or along a wire.

Or it is the distance between one peak of a wave to the next corresponding peak, or between any two adjacent corresponding points.

Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium.

**Wavelength = propagation speed x period = propagation speed / frequency**

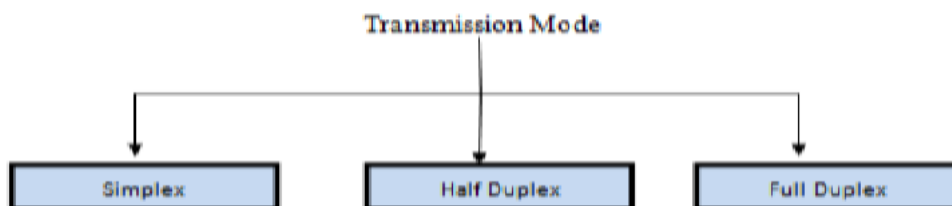
### **Bandwidth**

- ✖ The term Bandwidth defines the net bit rate, channel capacity, or the maximum throughput of a logical or physical communication path in a communication system.
- ✖ The bandwidth in analog signal is normally a difference between two numbers i.e the difference between the highest and the lowest frequencies contained in that signal.

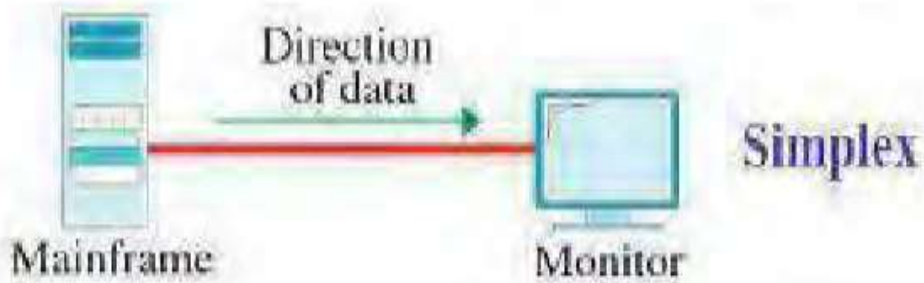
### **MODE OF DATA FLOW OR TRANSMISSION MODE**

The transmission mode is the direction of the exchanges where the number of bits sent simultaneously.

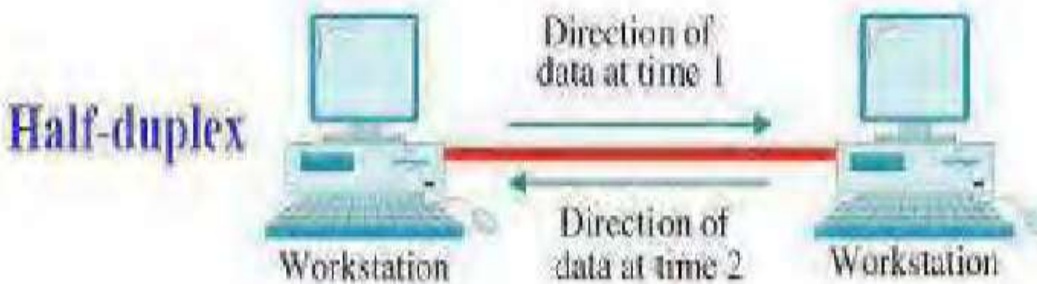
Communication between two devices can be a mode of **simplex, half-duplex, or full-duplex**.



□ **Simplex:** In simplex mode, the communication is unidirectional, as on a one-way street. One of the simplest examples is monitor keyboard communication, where keyboard only introduce input and monitor can only display output



□ **Half-Duplex:** In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, other can only receive and vice versa. Its examples are walkie-talkies



□ **Full-Duplex**  
: In full-duplex mode both stations can transmit and receive simultaneously.

The full-duplex mode is like a two-way street with traffic flowing in both directions at the same time. Common example is the telephone network where both talk and listen possible at same time



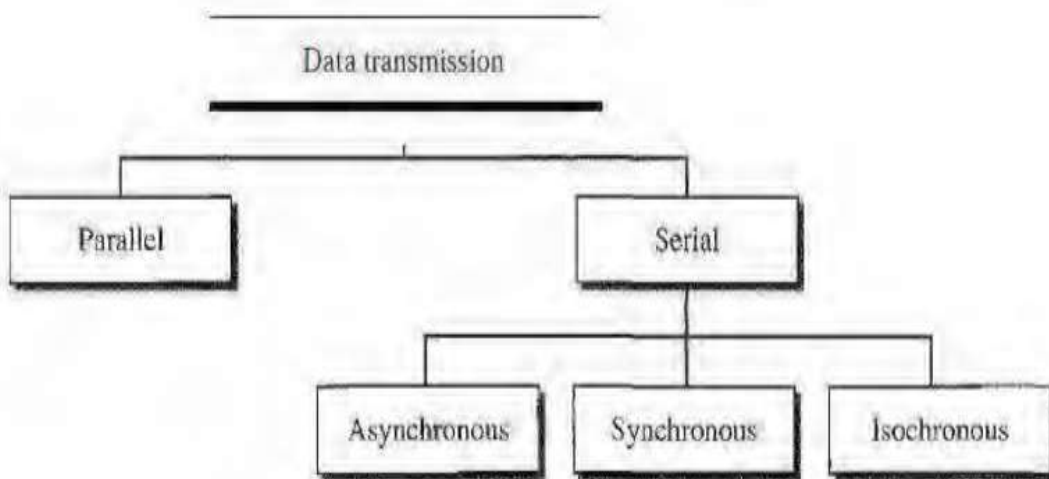
## DIGITAL TRANSMISSION

- A computer network is designed to send information from one point to another.
- This information needs to be converted to either a digital signal or an analog signal for transmission.

### **TRANSMISSION MODE**

The transmission of data from one device to another is the wiring, and of primary concern when we are considering the wiring is the data stream. The transmission of binary data (0 and 1) across a link can be accomplished in either parallel or serial mode.

- **In parallel mode**, multiple bits are sent with each clock tick.
- **In serial mode**, 1 bit is sent with each clock tick. While there is only one way to send parallel data, there are three sub classes of serial transmission: asynchronous, synchronous, and isochronous.

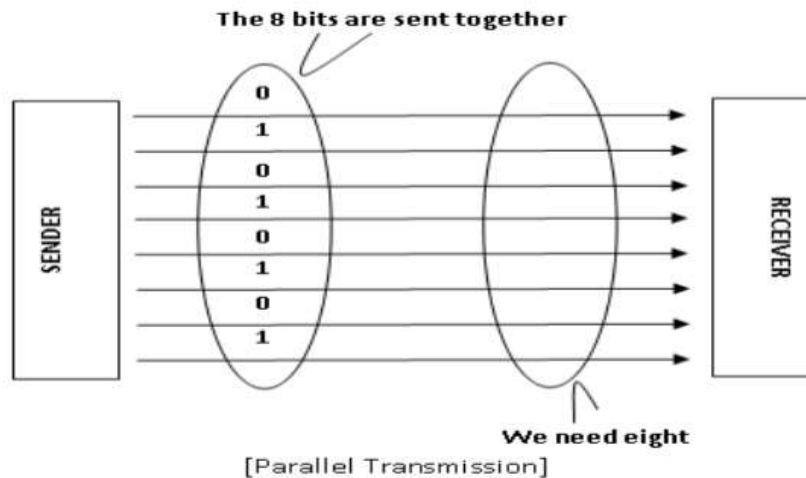


### **PARALLEL TRANSMISSION**

Binary data, consisting of 1s and 0s, may be organized into groups of n bits

each. Computers produce and consume data in groups of bits. By grouping, we can send data n bits at a time instead of 1. This is called parallel transmission.

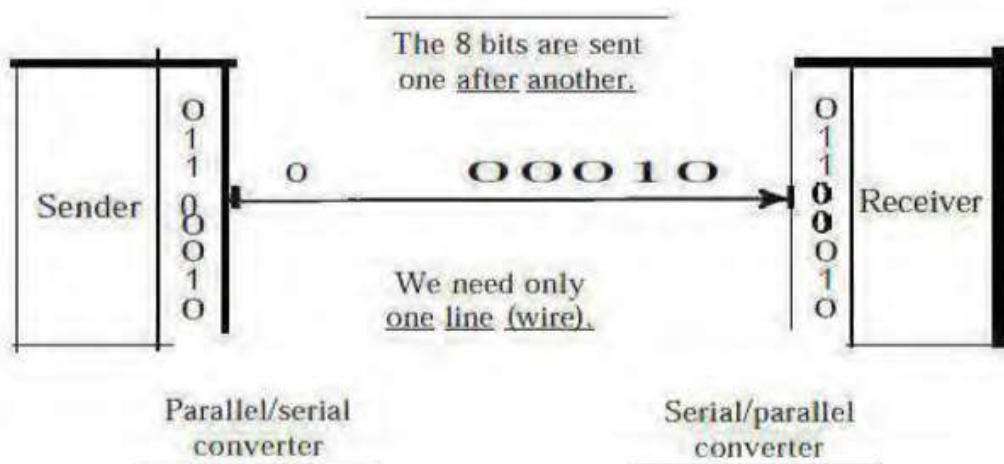




- The mechanism for parallel transmission is a conceptually simple one: Use  $n$  lines to send  $n$  bits at one time.
- That way each bit has its own wire, and all  $n$  bits of one group can be transmitted with each clock tick from one device to another.
- The advantage of parallel transmission is speed.
- That is parallel transmission can increase the transfer speed by a factor of  $n$  over serial transmission.

□ But there is a significant disadvantage is cost: Parallel transmission requires  $n$  communication lines just to transmit the data stream. Because this is expensive, parallel transmission is usually limited to short distances.

### SERIAL TRANSMISSION



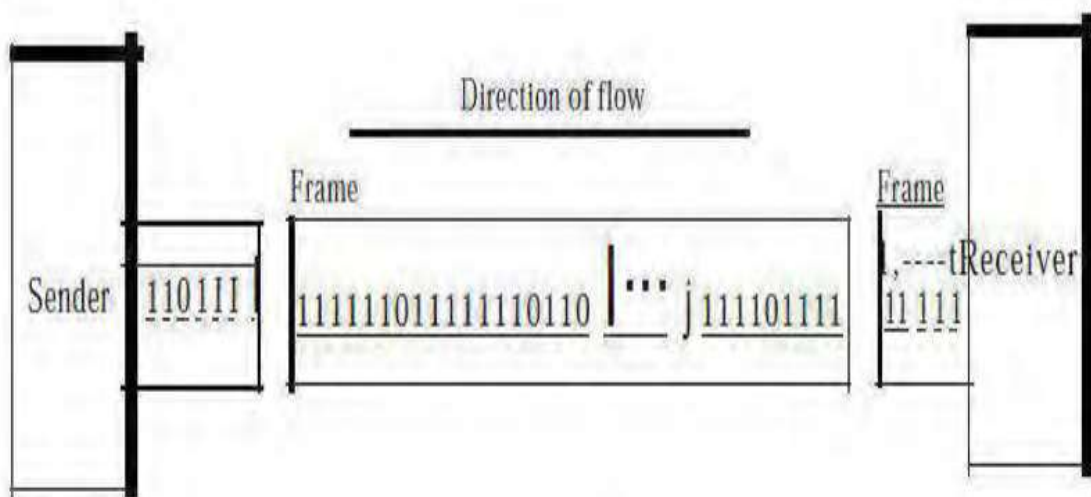
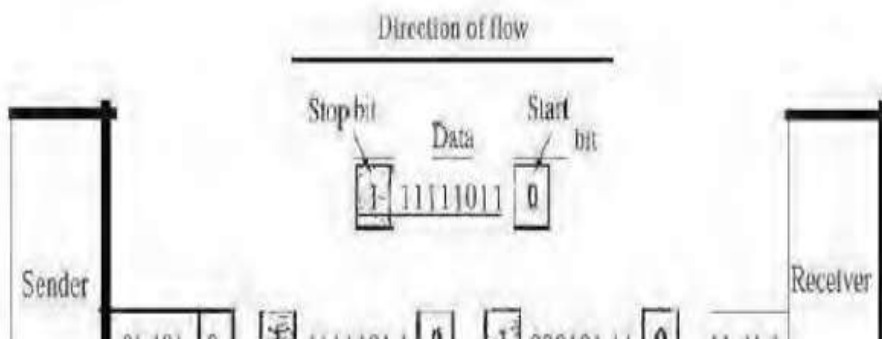
□ In serial transmission one bit follows another, so we need only one communication channel rather than  $n$  to transmit data between two communicating devices.



- The advantage of serial over parallel transmission is that with only one communication channel, serial transmission reduces the cost of transmission over parallel by roughly a factor of  $n$ . Since communication within devices is parallel, conversion devices are required at the interface between the sender and the line (parallel-to-serial) and between the line and the receiver (serial-to-parallel).
- Serial transmission occurs in one of two ways: asynchronous and synchronous.

## ASYNCHRONOUS

- ∞ Asynchronous transmission is so named because the timing of a signal is not important. Instead, information is received and translated by agreed upon patterns.
- ∞ Patterns are based on grouping the bit stream into bytes.
- ∞ Each group, usually 8 bits, is sent along the link as a unit.
- ∞ The sending system handles each group independently, relaying it to the link whenever ready, without regard to a timer. Without synchronization, the receiver cannot use timing to predict when the next group will arrive.
- ∞ To alert the receiver to the arrival of a new group, therefore, an extra bit is added to the beginning of each byte.
- ∞ This bit, usually a 0, is called the start bit. To let the receiver know that the byte is finished, 1 or more additional bits are appended to the end of the byte. These bits, usually 1s, are called stop bits.
- ∞ The start and stop bits and the gap alert the receiver to the beginning and end of each byte allow it to synchronize with the data stream.
- ∞ This mechanism is called asynchronous because, at the byte level, the sender and receiver do not have to be synchronized.
- ∞ But within each byte, the receiver must still be synchronized with the incoming bit stream.



## **SYNCHRONOUS TRANSMISSION**

- ∞ In synchronous transmission, the bit stream is combined into longer "frames," which may contain multiple bytes.
- ∞ Each byte is introduced onto the transmission link without a gap between it and the next one.
- ∞ It is left to the receiver to separate the bit stream into bytes for decoding purposes.
- ∞ In other words, data are transmitted as an unbroken string of 1s and 0s, and the receiver separates that string into the bytes, or characters, it needs to reconstruct the information.
- ∞ The advantage of synchronous transmission is speed.
- ∞ With no extra bits or gaps to introduce at the sending end and remove at the receiving end, and, by extension, with fewer bits to move across the link.
- ∞ Synchronous transmission is faster than asynchronous transmission.
- ∞ For this reason, it is more useful for high-speed applications such as the transmission of data from one computer to another.

## **TRANSMISSION IMPAIRMENT**

- ☐ Signals travel through transmission media, which are not perfect.
- ☐ The imperfection causes signal impairment.
- ☐ This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium.
- ☐ What is sent is not what is received is because of impairment (unwanted interruption).

Three causes of impairment are:

- **Attenuation,**
- **Distortion,**
- **Noise**

### **Attenuation:**

- ☐ Attenuation means a loss of energy or strength.
- ☐ That is why a wire carrying electric signals gets warm, if not hot, after a while. Some of the electrical energy in the signal is converted to heat.
- ☐ To compensate for this loss, amplifiers are used to amplify the signal.

### **Distortion**

- ☐ Distortion means that the signal changes its form or shape.
- ☐ Distortion can occur in a signal made of different frequencies.

Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration.

### **Noise**

- ☐ Noise is another cause of impairment.

□ Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal. Below figure shows the effect of noise on a signal.

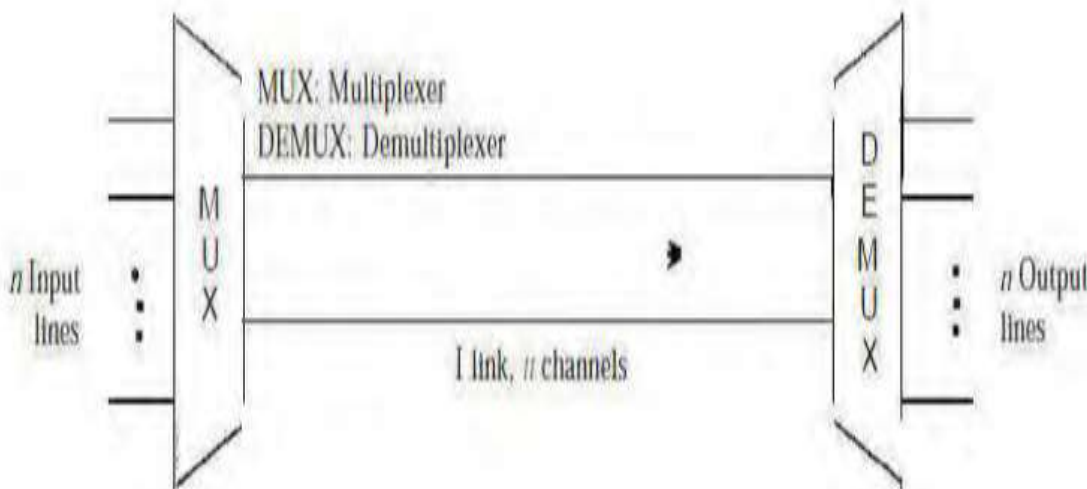
## MULTIPLEXING

There are two broad categories of bandwidth utilization (wise use of given bandwidths): multiplexing and spreading.

In **multiplexing**, our goal is efficiency where, we combine several channels with low bandwidth together into one with large bandwidth.

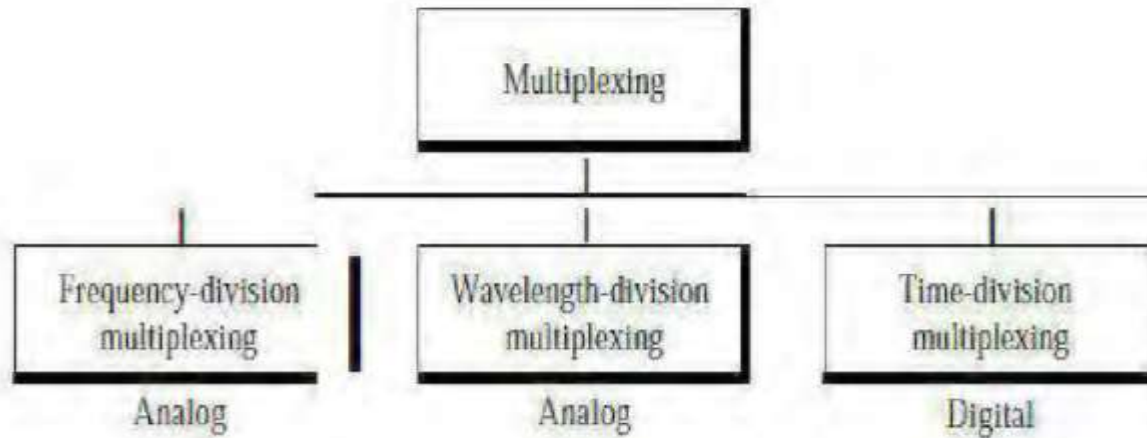
In **spreading**, our goals are privacy and anti-jamming where, we expand the bandwidth of a channel to insert redundancy, which is necessary to achieve these goals of accuracy.

- ❖ It combines multiple signals (analog or digital) for transmission over a single line or media.
- ❖ A common type of multiplexing combines several low-speed signals for transmission over a single high-speed connection.
- ❖ Multiplexing is done by using a device called multiplexer (MUX) that combines  $n$  input lines to generate one output line i.e. (many to one). Therefore multiplexer (MUX) has several inputs and one output.
- ❖ At the receiving end, a device called demultiplexer (DEMUX) is used that separates signal into its component signals. So DEMUX has one input and several outputs.
- ❖ Multiplexers and de-multiplexers are used to convert multiple signals into one signal.



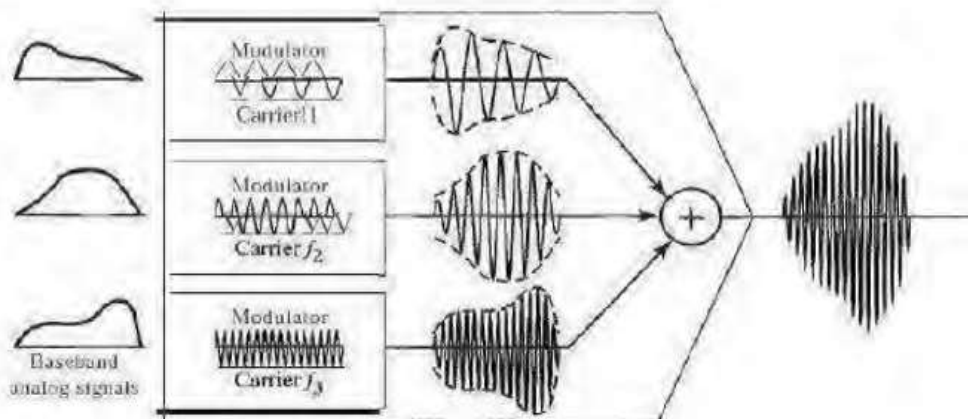
□ In the figure, the word **link** refers to the physical path. The word **channel** refers to the portion of a link that carries a transmission between a given pair of lines. **One link** can have many ( $n$ ) **channels**.

Multiplexing techniques can be categorized into the following three types:



### **Frequency-division multiplexing (FDM)**

**Example:** A very common application of FDM is AM and FM radio broadcasting. Radio uses the air as the transmission medium. A special band from 530 to 1700 kHz is assigned to AM radio.

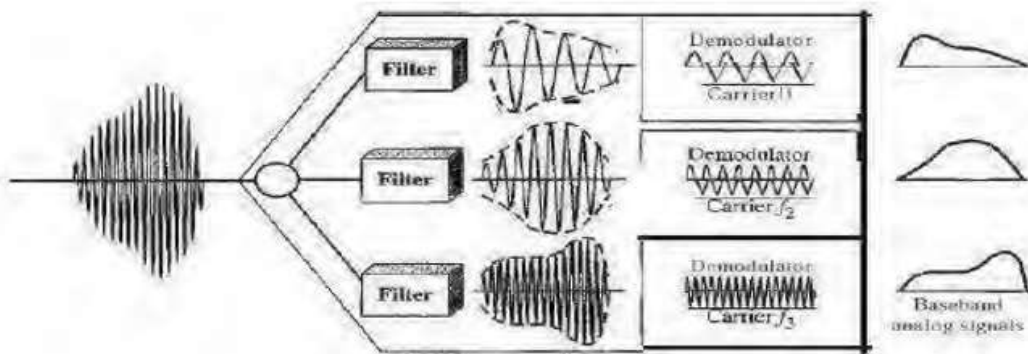


- Signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link.
- Channels can be separated by strips of unused bandwidth called guard bands to prevent signals from overlapping.

#### **Multiplexing Process**

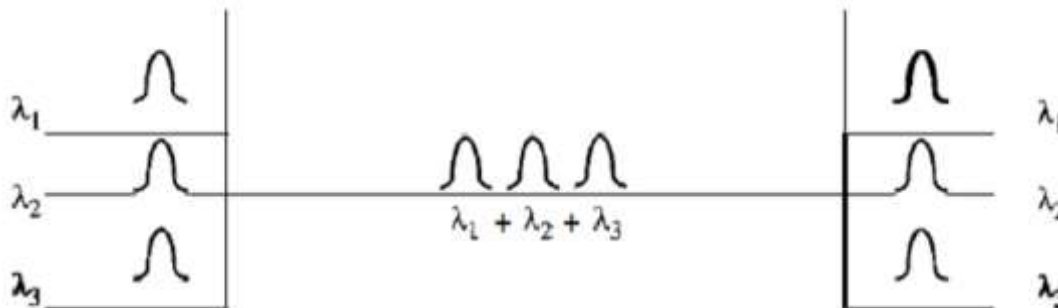
- ✗ Each source generates a signal of a similar frequency range.
- ✗ Inside the multiplexer, these similar signals modulates different carrier frequencies ( $f_1, f_2$  and  $f_3$ ).
- ✗ The resulting modulated signals are then combined into a single composite signal that is sent out over a media link that has enough bandwidth to accommodate it.

## DE MULTIPLEXING PROCESS



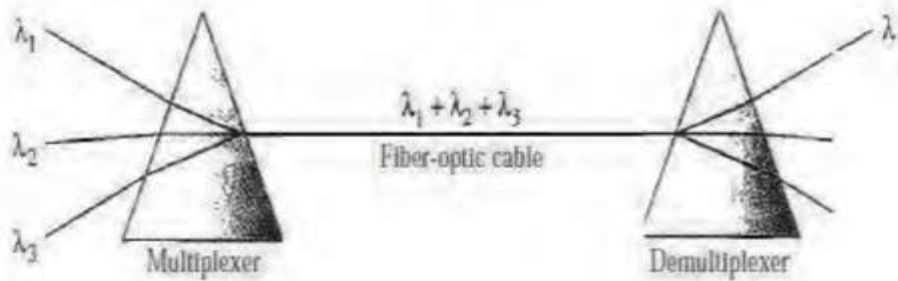
### Wavelength-Division Multiplexing

- The basic idea is that combine multiple light sources into one single light at the multiplexer and do the reverse at the de multiplexer.
- Wavelength-division multiplexing (WDM) is designed to use the high-data rate capability of fiber-optic cable.
- The optical fiber data rate is higher than the data rate of other metallic transmission cable.
- Using a fiber-optic cable for one single line wastes the available bandwidth.
- Concept of WDM is same as FDM, except that the multiplexing and de multiplexing, here involve optical signals transmitted through fiber-optic channels.



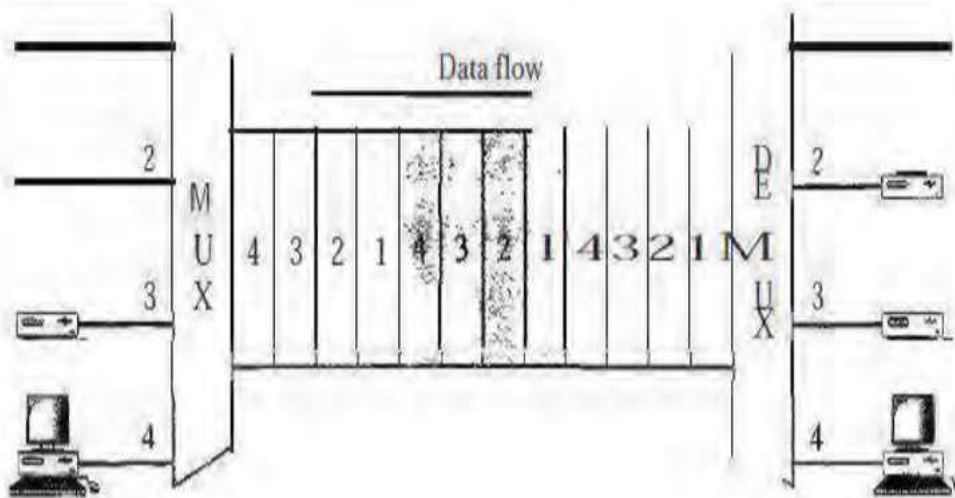
Very narrow bands of light from different sources are combined to make a wider band of light.

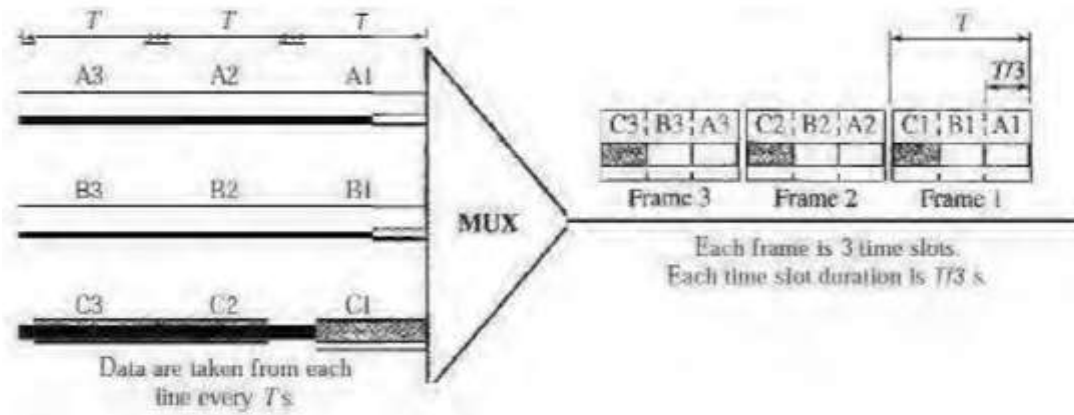
## *Prisms in wavelength-division multiplexing and de multiplexing*



## **TIME-DIVISION MULTIPLEXING (TDM)**

- It is also called synchronous TDM, which is commonly used for multiplexing digitized voice stream.
- The users take turns using the entire channel for short burst of time and that allows several connections to share the high bandwidth of a line.
- Each connection occupies a portion of time in the link.





In synchronous TDM, the data flow of each input connection is divided into units, where each input occupies one input time slot.