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## UNIT 2 DATA TRANSMISSION

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### 2.0 INTRODUCTION

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Communication from a source to a destination, that is, from one computer to another or from one device to another, involves the transfer of information from the sender to the receiver. The transfer of data from one machine to another machine such that, the sender and the receiver both interpret the data correctly is known as Data Communication.

All communication between devices requires that the devices agree on the format of the data. The set of rules defining a format is known as a protocol. At the very least, a communications protocol must define the following:

- Transmission media used.
- Rate of transmission (in baud or bps)
- Whether transmission is to be synchronous or asynchronous
- Whether data is to be transmitted in half-duplex or full-duplex mode

In order to understand this we need to learn about some of the basic concepts and terminologies related to data transmission, which we will be doing in this unit.

## 2.1 OBJECTIVES

After going through this unit, you should be able to:

- understand the concept of Transmission terminology;
- differentiate between Serial and Parallel communication;
- differentiate between Analog and Digital Data Transmission;
- have a broad idea about the different Transmission Impairments;
- compare the different Transmission Media and their characteristics, and
- understand Wireless Transmission and realise its importance.

## 2.2 DATA COMMUNICATION TERMINOLOGY

The transfer of data from one machine to another machine such that, the sender and the receiver both interpret the data correctly is known as Data Communication.

### 2.2.1 Channel

In communications, the term channel refers to a path of communications between two computers or devices. A communication channel provides everything that is needed for the transfer of electronic information from one location to another. It may refer to the physical medium, such as coaxial cable, or to a specific carrier frequency (sub-channel) within a larger channel or a wireless medium.

The channel capacity of a transmission system is the maximum rate at which information can be transferred reliably over a given period of time.

Two basic types of channels that are used in voice and data communication are Analog and Digital.

The Analog type of channel transmits signals generally using sinusoidal waves as shown in *Figure 6*. Non-sinusoidal waves can also be used for transmission. The commercial radio station and Public telephone system are examples of this type.

The Digital type of channel transmits pulsed wave signals, such as, those shown in *Figure 7*.

### 2.2.2 Baud

Pronounced bawd, Baud is the number of signaling elements that occur each second. The term is named after **J.M.E. Baudot**, the inventor of the Baudot telegraph code.

At slow speeds, only one bit of information (signaling element) is encoded in each electrical change. The baud, therefore, indicates the number of bits per second that are transmitted. For example, 300 baud means that 300 bits are transmitted each second (abbreviated 300 bps). Assuming asynchronous communication, which requires 10 bits per character, this translates in to 30 characters per second (cps). For slow rates (below 1,200 baud), you can divide the baud by 10 to see how many characters per second are sent.

At higher speeds, it is possible to encode more than one bit in each electrical change. 4,800 baud may allow 9,600 bits to be sent each second. At high data transfer speeds; therefore, data transmission rates are usually expressed in bits per second (bps) rather than baud. For example, a 9,600 bps modem may operate at only 2,400 baud.

### 2.2.3 Bandwidth

The amount of data or signals that the transmission media can carry in a fixed amount of time is called Bandwidth. The Bandwidth depends upon the length, media and

signaling technique used. A high bandwidth allows increased throughput and better performance. A medium that has a high capacity has a high bandwidth. A medium that has limited capacity has a low bandwidth. It is calculated using the difference between the highest and the lowest frequencies that the medium can carry. For digital devices, the bandwidth is usually expressed in bits per second (bps) or bytes per second. For analog devices, the bandwidth is expressed in cycles per second, or Hertz (Hz).

Bandwidth is particularly important for I/O devices. For example, a fast disk drive can be hampered by a bus with a low bandwidth.

#### 2.2.4 Frequency

Frequency is the number of cycles or periods a signal completes within one second. The unit of measuring frequency is called Hertz named after a German mathematician **Heinrich Hertz**. One Hz is one cycle/second. We use one KiloHertz or one kHz to mean 1000Hz and one Mega hertz or one MHz to mean 1000 kHz or 1000000Hz.

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## 2.3 MODES OF DATA TRANSMISSION

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Data can be transmitted from Source to Destination in a number of ways. The different modes of data transmission be outlined as follows:

- Parallel and Serial Communication.
- Asynchronous, Synchronous and Isochronous Communication.
- Simplex, Half duplex and Full duplex Communication.

#### 2.3.1 Serial and Parallel Communication

There is always a need to exchange commands, data and other control information between two communicating devices. There are mainly two options for transmitting data, commands and other control information from the sender to the receiver. These are:

- Serial communication.
- Parallel communication.

##### Serial Communication

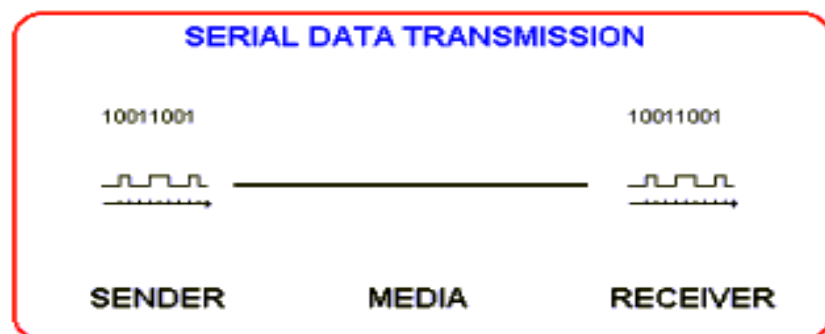


Figure 1: Serial Communication

In Serial data transmission, bits are transmitted serially, one after the other, as shown in *Figure 1*. The least significant bit (LSB) is usually transmitted first. While sending data serially, characters or bytes have to be separated and sent bit by bit. Thus, some hardware is required to convert the data from parallel to serial. At the destination, all the bits are collected, measured and put together as bytes in the memory of the destination. This requires conversion from serial to parallel.

As compared to parallel transmission, serial transmission requires only one circuit interconnecting the two devices. Therefore, serial transmission is suitable for transmission over long distances.

### Parallel Communication

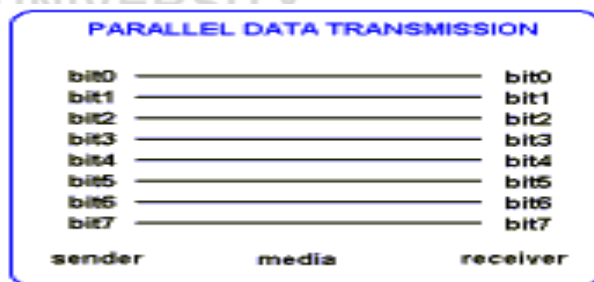


Figure 2: Parallel Data Transmission.

In Parallel transmission, all the bits of a byte are transmitted simultaneously on separate wires as shown in the *Figure 2*. Here, multiple connections between the two devices are therefore, required. This is a very fast method of transmitting data from one place to another.

The disadvantage of Parallel transmission is that it is very expensive, as it requires several wires for both sending, as well as receiving equipment. Secondly, it demands extraordinary accuracy that cannot be guaranteed over long distances.

### 2.3.2 Asynchronous, Synchronous and Isochronous Communication

One of the major difficulties in data transmission is that of synchronising the receiver (destination) with the sender (source). This is the main problem with serial communication. The receiver must be able to detect the beginning of each new character in the bit stream that is being presented to it and if it is not able to achieve this, it will not be able to interpret the incoming bit stream correctly.

The three mechanisms used for synchronisation are:

- Asynchronous Communication
- Synchronous Communication
- Isochronous Communication

#### Asynchronous Communication

Asynchronous communication sends individual characters one at a time framed by a start bit and 1 or 2 stop bits. Each frame begins with a start bit that enables the receiving device to adjust to the timing of the transmitted signal. The message can begin at any time. Here, messages are kept as short as possible because, the sending and receiving devices should not drift out of synchronisation, when the message is being transferred. Asynchronous communication is most frequently used to transmit character data and is ideally suited for characters that are transmitted at irregular intervals, such as, when users are typing in character data from the keyboard.

A typical frame used to transmit a character data has four components:

- 1) **A start bit:** Signals the starting a frame and enables the receiving device to synchronise itself with the message.
- 2) **Data Bits:** Consists of 7 or 8 bits when character data is being transmitted.
- 3) **Parity Bits:** Optionally used as a crude method for detecting transmission errors.

4) **A stop bit or bits:** Signals the end of the data frame.

Error detection in asynchronous transmission makes use of the parity bit. Parity techniques can detect errors that affect only one bit and if two or more bits are affected by errors, the parity techniques may not be able to detect them.

**Advantages of Asynchronous Communication**

- Asynchronous transmission is simple, inexpensive and is ideally suited for transmitting small frames at irregular intervals (e.g., Data entry from a keyboard).
- As each individual character is complete in itself, if a character is corrupted during transmission, its successor and predecessor will not be affected.

**Disadvantages of Asynchronous Communication**

- As start, stop and parity bits must be added to each character that is to be transmitted, this adds a high overhead to transmission. This wastes the bandwidth; as a result, asynchronous transmission is undesirable for transmitting large amounts of data.
- Successful transmission inevitably depends on the recognition of the start bits, hence, as these bits can be easily missed or occasionally spurious, as start bits can be generated by line interference, the transmission may be unsuccessful.
- Due to the effects of distortion the speed of asynchronous transmission is limited.

**Synchronous Communication**

In synchronous communication the whole block of data bits is transferred at once, instead of one character at a time. Here, transmission begins at a predetermined regular time instant. A sync signal is used to tell the receiving station that a new frame is arriving and to synchronise the receiving station.

Sync signals, generally utilise a bit pattern that cannot appear elsewhere in the messages, ensuring that they will always be distinct and easy for the receiver to recognise. As the transmitter and receiver remain in synchronisation for the duration of the transmission, frames can be of longer length.

As frames are longer the parity method of error detection is not suitable because, if multiple bits are affected, then, the parity technique will not report error accurately. Hence, the technique used with synchronous transmission is the Cyclic Redundancy Check (CRC).

The transmitter uses an algorithm to calculate a CRC value that summarises the entire value of data bits. This CRC value is appended to the data frame. The receiver uses the same algorithm, recalculates the CRC and compares the CRC in the frame to the value that it has calculated. If these values match then, it is sure that the frame was transmitted without error.

An end bit pattern indicates the end of the frame. Like sync the bit pattern for end is such that, it will not appear elsewhere in the messages, ensuring that they will always be distinct and easy for the receiver to recognise at the end of the frame.

Serial synchronous transmission is used for high-speed communication between computers. It is used when high volumes of data are to be transmitted.

### Advantages of Synchronous Communication

- Synchronous transmission is more efficient because, only 4 additional bytes (for start and end frames) are required to transmit upto 64 k bits.
- Synchronous transmission is not really prone to distortion, as a result, it can be used at high- speeds.

### Disadvantages of Synchronous Communication

- Synchronous transmission is expensive as complex circuitry is required and it is difficult to implement.
- If an error occurs during transmission, rather than just a single character the whole block of data is lost.
- The sender cannot transmit characters simply, as they occur, but has to store them until it has built up a block. Thus, this is not suitable where characters are generated at irregular intervals.

### Isochronous Communication

This method combines the approaches of asynchronous and synchronous communications. As in the asynchronous method, each character has both the start and stop bits. The idle period (where no transmission takes place) between the two characters is not random but an exact multiple of one character time interval. If, the time to transmit a character (Including its parity, start, stop bits) is  $t$ , the time interval between characters cannot be random as in the asynchronous method. It is also not 0 as in the synchronous method. It has to be  $t, 2t, 3t, \dots, nt$  where  $n$  is any positive integer. Here, the signal is expected to be received within certain delay bounds say  $T_{min}$  to  $T_{max}$ .

### Advantages of Isochronous Communication

- Isochronous transmission guarantees transmission rates, and it is almost deterministic.
- It has low overheads.
- It has high speed.

### Disadvantages of Isochronous Communication

- In isochronous transmission its necessary to ensure that the clocking device is fault tolerant.

### 2.3.3 Simplex, Half Duplex and Full Duplex Communication

This classification of data transmission is based on the which question of, communication can send data and at what point of time.

The three basic ways in which this can be done are:

- Simplex.
- Half Duplex
- Full Duplex, sometimes called Duplex.

#### Simplex

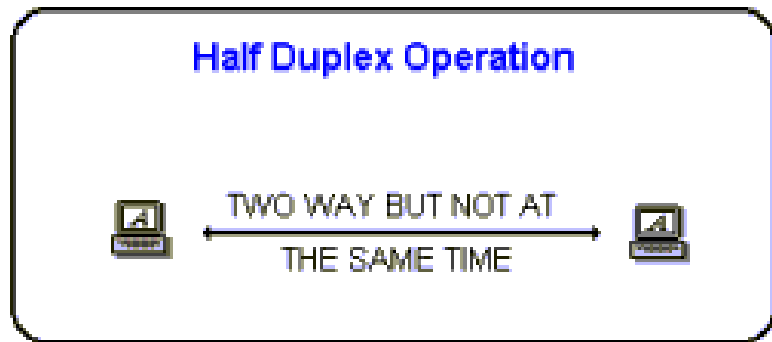
#### Simplex Channel Operation



**Figure 3: Simplex connection**

The simplest signal flow technique is the simplex configuration. In Simplex transmission, one of the communicating devices can only send data, whereas the other can only receive it. Here, communication is only in one direction (unidirectional) where one party is the transmitter and the other is the receiver as shown in the *Figure 3*. Examples of simplex communication are the simple radio, and Public broadcast television where, you can receive data from stations but can't transmit data back. The television station sends out electromagnetic signals. The station does not expect and does not monitor for a return signal from the television set. This type of channel design is easy and inexpensive to set up.

### Half Duplex



**Figure 4: Half duplex connection**

Half duplex refers to two-way communication where, only one party can transmit data at a time. Unlike, the Simplex mode here, both devices can transmit data though, not at the same time, that is Half duplex provides Simplex communication in both directions in a single channel as shown in *Figure 4*. When one device is sending data, the other device must only receive it and vice versa. Thus, both sides take turns at sending data. This requires a definite turn around time during which, the device changes from the receiving mode to the transmitting mode. Due to this delay, half duplex communication is slower than simplex communication. However, it is more convenient than simplex communication as both the devices can send and receive data.

Note, the difference between simplex and half-duplex. Half-duplex refers to two-way communication where, only one party can transmit data at a time. Simplex refers to one-way communication where, one party is the transmitter and the other is the receiver

For example, a walkie-talkie is a half-duplex device because only one party can talk at a time.

Most modems contain a switch that lets you select between half-duplex and full-duplex modes. The correct choice depends on which program you are using to transmit data through the modem.

## Full Duplex

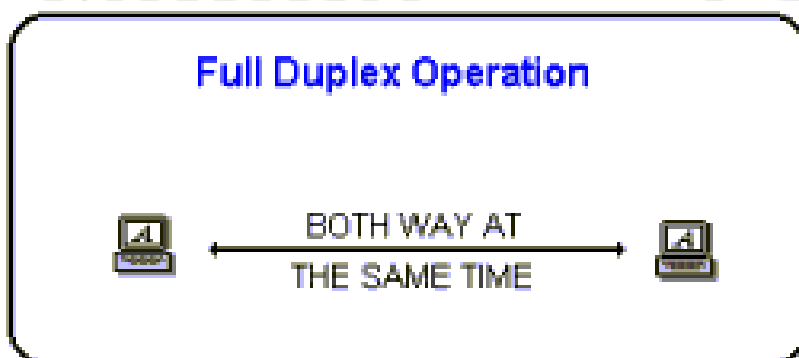


Figure 5: Full duplex connection

Full duplex refers to the transmission of data in two directions simultaneously. Here, both the devices are capable of sending as well as receiving data at the same time as shown in *Figure 5*. As you can see from *Figure 5*, that simultaneously bi-directional communication is possible, as a result, this configuration requires full and independent transmitting and receiving capabilities at both ends of the communication channel. Sharing the same channel and moving signals in both directions increases the channel throughput without increasing its bandwidth. For example, a telephone is a full-duplex device because both parties can talk to each other simultaneously. In contrast, a walkie-talkie is a half-duplex device because only one party can transmit at a time.

Most modems have a switch that lets you choose between full-duplex and half-duplex modes. The choice depends on which communications program you are running.

### Check Your Progress 1

- 1) What is Data Communication?

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- 2) Explain the term bandwidth. Why is bandwidth useful?

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- 3) If, a sine wave completes one cycle in 3 seconds, what is its frequency?

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- 4) Compare Parallel and Serial transmission methods and mention the situation where Parallel transmission is a better choice as compared to serial transmission.

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- .....
- .....
- 5) Give reasons as to why Full duplex is more challenging than simplex and half duplex transmission.
- .....
- .....
- .....
- 6) Bring out the difference between Synchronous, Asynchronous and Isochronous transmission.
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- .....
- .....

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## 2.4 ANALOG AND DIGITAL DATA TRANSMISSION

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We know that the two major types of signals are Analog and Digital. The manner in which these two types of signals can be transmitted from source to destination is of the same two types that is –

- Analog data transmission.
- Digital data transmission.

### Analog Signal

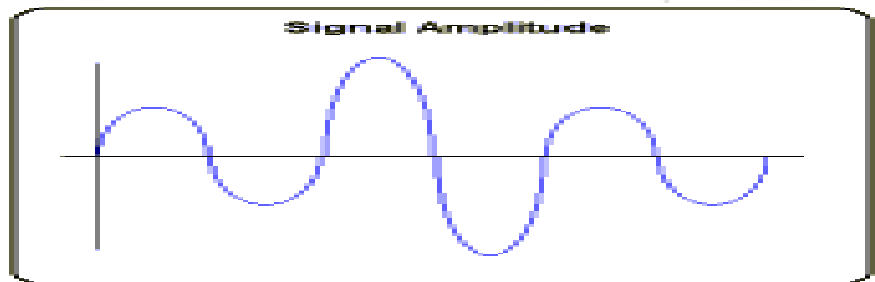


Figure 6: Analog signal

Analog signals vary constantly in one or more values; these changes in values can be used to represent data. An analog signal is continuous and can be represented by using sine waves. Human voice, video and music are all examples of analog signals, which vary in amplitude (volume) and frequency (pitch). Human voice generates an analog (continuously varying) signal containing multiple frequencies that is transmitted as an analog signal over the medium. Amplifiers are used to overcome the attenuation that the signal suffers on its way. The drawback is that amplifiers amplify noise along with the original signal and hence, if the signal gets distorted, it cannot be reconstructed and it is a permanent loss. Due to this reason, this type of transmission is not used where a high level of accuracy is needed. This is used in telephony where a slight distortion in human communication does not matter.

The ability to capture the subtle nature of the real world is the single advantage of analog techniques. However, once captured, modern electronic equipment, no matter

how advanced, cannot copy analog signals perfectly. Third and fourth generations of audio and video recordings show marked deterioration.

By converting analog signals into digital, the original audio or video data can be preserved indefinitely within the specified error bounds and copied over and over without deterioration. Once continuously varying analog signals are measured and converted into digital form, they can be stored and transmitted without loss of integrity due to the accuracy of digital methods.

### Digital Data Transmission

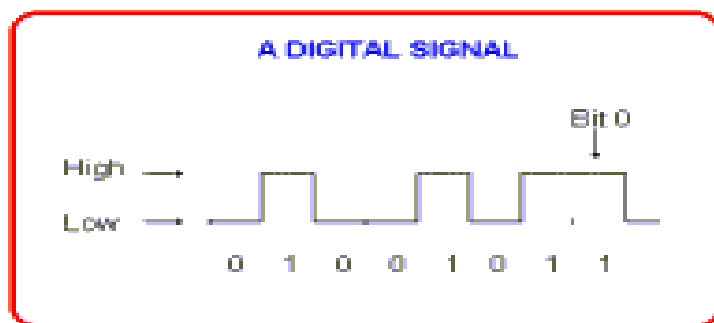


Figure 7: Digital Data Transmission

Digital data transmission describes any system based on discontinuous data or events. Computers are digital machines because at their most basic level they can distinguish between just two values, 0 and 1, or off and on. There is no simple way to represent all the values in between, such as 0.25. All data that a computer processes must be encoded digitally, as a series of zeroes and ones.

Information coming out of the computer is in the form of digital signals. The bandwidth of a digital signal is infinite as compared to any medium, which has a limited bandwidth. Therefore, as the signal is generated and enters the medium, at that point of entry, only limited frequencies are permissible on the medium and this depends upon the bandwidth. As the signal traverses over the medium it gets distorted and beyond a certain distance, the signal becomes unrecognisable from the original one. A hardware device called Repeater is used to regenerate the digital signal. The repeater measures the signal values at regular intervals to recognise the 0's and 1's in the signal and regenerates them. Hence, there is no loss of information. The number of repeaters to be used depends on the distance between the source and the destination. Any line with repeaters placed at appropriate distance is called a digital line.

When information, music, voice and video are turned into binary digital form, they can be electronically manipulated, preserved and regenerated perfectly at high speed. The millionth copy of a computer file is exactly the same as the original. This is, nevertheless, a major advantage of digital processing.

## 2.5 TRANSMISSION IMPAIRMENTS

When data is transmitted from a transmitter to receiver, there is scope for transmission errors. If, transmission media were perfect, the receiver would receive exactly the same signal that the transmitter sent. Unfortunately, media are not perfect, so the received signal may sometimes not be the same as the transmitted signal.

Transmission lines suffer from three major problems:

- Attenuation.
- Delay distortion.

- Noise.

### 2.5.1 Attenuation

Attenuation is the loss of energy as the signal propagates outwards. On guided media (e.g., wires and optical fibers), the signal falls off logarithmically with the distance. Attenuation is very small at short distances; therefore, the original signal can be recognised without too much distortion. Attenuation increases with distance as, some of the signal energy is absorbed by the medium. The loss is expressed in decibels per kilometer (db/km). The amount of energy lost depends on the frequency. Attenuation is also higher at higher frequencies.

If the attenuation is high, the receiver may not be able to detect the signal at all, or the signal may fall below the noise level. In many cases, the attenuation properties of a medium are known, so amplifiers can be put in place to try to compensate for the frequency-dependent attenuation. This approach helps but can never restore the signal exactly back to its original shape.

### 2.5.2 Delay Distortion

Delay distortion is caused by the fact that the signals of varying frequencies travel at different speeds along the medium. Any complex signal can be decomposed into different sinusoidal signals of different frequencies, resulting, in a frequency bandwidth for every signal.

One property of signal propagation is that the speed of travel of the frequency is the highest at the center of this bandwidth, and lowest at both ends. Therefore, at the receiving end, signals with different frequencies in a given bandwidth will arrive at different times. If, the signals received are measured at a specific time, they will not be exactly like the original signal resulting in its misinterpretation.

For digital data, fast components from one bit may catch up and overtake low components from the bit ahead, mixing the two bits and increasing the probability of incorrect reception.

### 2.5.3 Noise

Noise is unwanted energy from sources other than the transmitter. Thermal noise is caused by the random motion of the electrons in a wire and is unavoidable. Cross talk is caused by inductive coupling between two wires that are close to each other. Sometimes when talking on the telephone, you can hear another conversation in the background. That is crosstalk. Finally, there is impulse noise, caused by spikes on the power line or other causes. For digital data, impulse noise can wipe out one or more bits.

### 2.5.4 Concept of Delays

The average delay required to deliver a packet from source (origin) to destination has a large impact on the performance of a data network. Delay considerations strongly influence the choice and performance of network algorithms, such as routing and flow control. Because of these reasons, it is very important to understand the nature and mechanism of network delay, and the manner in which it depends on the characteristics of the network.

A large delay is disastrous for data transfer. The total delay can be categorised into two types. The first type is fixed delay. This is the total delay which is always present due to buffering, link capacity etc. The second type is variable delay. This is the delay component which is caused by packets queuing in the routers, congestions etc. Among the different types of delays, here, we shall discuss Transmission delay and Propagation delay.

### Transmission delay

Transmission delay is the delay, which is present due to link capacities. When resource reservation methods are supported in routers, transmission delays can probably be kept low enough to satisfy the overall delay constraint of 200 ms.

When data is transmitted, there is always a minimal amount of delay, due to the capacity of the links along which the data travels. But the most significant part of the delay of transmission is usually due to queuing of packets inside routers. This delay is highly variable and depends both on the number of routers along the path and the load of the routers.

### Propagation delay

Satellite microwave systems can reach remote places on the earth and can also communicate with mobile devices. As the signal travels a long distance (around 36,000 km), there is a delay of about 5 kms between, the transmission and the reception of the signal. This delay is known as the propagation delay. Such delays occur in all communication channels, however, small they may be.

Propagation delay is the time between the last bit transmitted at the head node of the link and the time the last bit is received at the tail node. This is proportional to the physical distance between the transmitter and the receiver; it can be relatively substantial, particularly for a satellite link or a very high-speed link.

The propagation delay depends on the physical characteristics of the link and is independent of the traffic carried by the link.

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## 2.6 TRANSMISSION MEDIA AND ITS CHARACTERISTICS

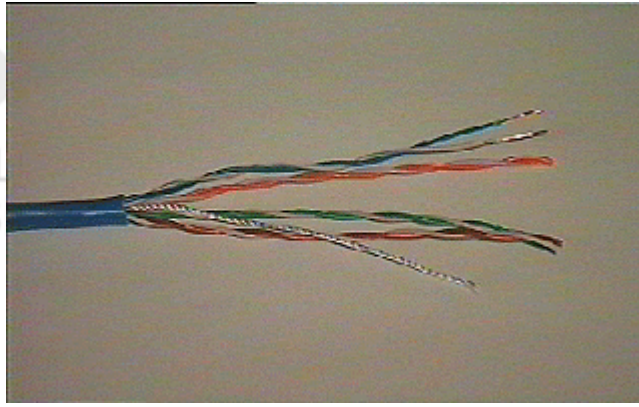
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Various physical media can be used for the actual transmission of information from one place to another. Each one has its own niche in terms of bandwidth, delay, cost, and ease of installation and maintenance. Transmission media are roughly grouped into guided media, such as copper wire and fiber optics, and unguided media, such as radio and lasers.

### 2.6.1 Magnetic Media

One of the most common ways to transport data from one computer to another is to write them onto magnetic tape or floppy disks, physically transport the tape or disks to the destination machine, and read them back in again. While, this method is not as sophisticated as using a geosynchronous communication satellite, it is often much more cost effective, especially for applications in which high bandwidth or cost per bit transported is the key factor.

### 2.6.2 Twisted Pair



**Figure 8: Twisted pair cable**

Although, the bandwidth characteristics of magnetic tape are excellent, the delay characteristics are poor. Transmission time is measured in minutes or hours, not milliseconds. For many applications an on-line connection is needed. The oldest and still most common transmission medium is the twisted pair. A twisted pair consists of two insulated copper wires, typically about 1 mm thick. The purpose of twisting the wires is to reduce electrical interference from similar pairs that may be close by.

The most common application of the twisted pair is in the telephone system. Nearly all telephones are connected to the telephone company office by a twisted pair. Twisted pairs can run several kilometers without amplification, but for longer distances, repeaters are needed. When many twisted pairs run in parallels for a substantial distance, such as, all the wires coming from an apartment building to the telephone company office, they are bundled together and encased in a protective sheath. The pairs in these bundles would interfere with one another if, it were not twisted.

Twisted pairs can be used for either analog or digital transmission. The bandwidth depends on the thickness of the wire and the distance travelled, but several megabits/sec can be achieved for a few kilometers in many cases.

Twisted pair cable has the following advantages:

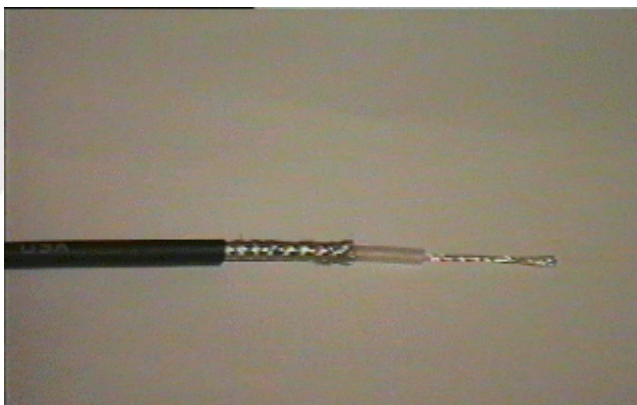
Adequate performance and lowest cost per meter as compared to other cable types as these are inexpensive to install, makes twisted pairs popular and hence, they are widely used and are likely to remain so for years to come.

### **2.6.3 Baseband Coaxial Cable**

Another common transmission medium is the coaxial cable (also known as "coax"). It has better shielding than twisted pairs, so it can span longer distances at higher speeds.

A coaxial cable consists of a stiff copper wire as the core, surrounded by an insulating material. The insulator is encased by a cylindrical conductor, often, as a closely woven braided mesh. The outer conductor is covered with a protective plastic sheath. A cutaway view of a coaxial cable is shown in *Figure 9*.





**Figure 9: Coaxial cable**

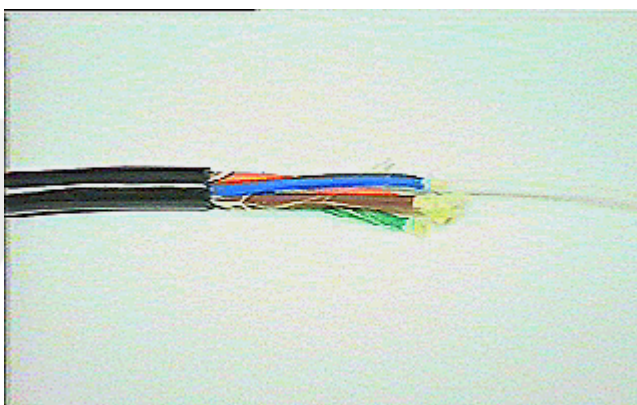
The construction and shielding of the coaxial cable gives it a good combination of high bandwidth and excellent noise immunity. The bandwidth possible depends on the cable length. For 1-km cables, a data rate of 1 to 2 Gbps is feasible. Longer cables can also be used, but only at lower data rates or with periodic amplifiers. Coaxial cables used to be widely used within the telephone system but, have now largely been replaced by fiber optics on long-haul routes. Coax is still widely used for cable television and some local area networks.

#### **2.6.4 Broadband Coaxial Cable**

The other kind of coaxial cable system uses analog transmission on standard cable television cabling. It is called broadband. Although the term “broadband” comes from the telephone world, where it refers to anything wider than 1 MHz, in the computer networking world “broadband cable” means any cable network using analog transmission.

Since, broadband networks use standard cable television technology, the cables can be used up to 300 MHz (and often up to 450 MHz) and can run for nearly 100 km due to the analog signaling, which is much less critical than digital signaling. To transmit digital signals on an analog network, each interface must contain electronics to, convert the outgoing bit stream to an analog signal, and the incoming analog signal to a bit stream. Depending on the type of electronics, 1 bps may occupy roughly, 1 Hz of bandwidth. At higher frequencies, many bits per Hz are possible using advanced modulation techniques.

#### **2.6.5 Optical Fiber**



**Figure 10: Optical fiber**

Fiber optic cable is made of fine strands of silicon glass fiber (thinner than a human hair), and is coated with a refractive surface. The signals are converted to light pulses before being sent. When light (provided by a laser or LED) is shown into the strand, it travels along the fiber strand (the refractive layer prevents it from escaping). Each fiber optic strand can support thousands of speech channels and multiple TV channels



simultaneously. It is used for long haul telecommunications links, for providing high-speed data communications links for computers, and information services to homes (e.g., PAY TV).

Advantages of Fiber optic cable are:

- high capacity (laser bandwidth),
- immune to interference (electromagnetic), and
- can go long distances (low attenuation).

Its disadvantages are,

- costly,
- difficult to join, and
- expensive to install and greater skill is required.

An Optical fiber transmission system has three components: the light source, the transmission medium, and the detector. Conventionally, a pulse of light indicates a 1 bit and the absence of light indicates a zero bit. The transmission medium is an ultra-thin fiber of glass. The detector is a photo-divider that generates an electrical pulse when light falls on it. By attaching a light source to one end of an optical fiber and a detector to the other, we have a unidirectional data transmission system that accepts an electrical signal, converts and transmits it by light pulses, and then reconverts the output to an electrical signal at the receiving end.

Fibers can be connected in three different ways. First, they can terminate in connectors and be plugged into fiber sockets. Connectors lose about 10 to 20 percent of the light, but they make it easy to reconfigure systems.

Second, they can be spliced mechanically. Mechanical splices just place the two carefully cut ends next to each other in a special sleeve and clamp them together. The alignment can be improved by passing light through the junction and then making small adjustments to maximise the signal. Trained personnel can do mechanical splicing in 5 minutes, and show result in a 10 percent light loss.

Third, two pieces of fiber can be fused (melted) to form a solid connection. A fusion splice is almost as good as a single drawn fiber, but even here, a small amount of attenuation occurs. For all three kinds of splices, reflections can occur at the point of the splice, and the reflected energy can interfere with the signal.

### **2.6.6 Comparison between Optical Fiber and Copper Wire**

Optical fiber has many advantages over copper wire. The advantages are:

Optical fiber can handle much higher bandwidths than copper wire. Due to the low attenuation, repeaters are needed only about every 30 km on long lines, whereas, copper wires require repeaters every 5 km, which, is substantial savings in cost.

Optical fiber also has the advantage of not being affected by power surges, electromagnetic interference, or power failures. Neither, is it affected by corrosive chemicals in the air, making it ideal for harsh factory environments.

Optical fiber is lighter than copper. One thousand twisted pairs 1 km long weigh 8000 kg. Two fibers have more capacity and weigh only 100 kg, which greatly reduces the need for expensive mechanical support systems that must be maintained.

For new routes, the installation cost of optical fiber is much lower than that for copper wire.

Finally, optical fibers do not leak light and are quite difficult to tap. This gives them excellent security against potential wire trappers.

The reason that optical fiber is better than copper wire is inherent in underlying physics. When electrons move in a wire, they affect one another and are themselves affected by electrons outside the wire. Photons in a fiber do not affect one another (they have no electric charge) and are not affected by stray photons outside the fiber.

### The disadvantages of optical fiber are:

It is a complex technology requiring skills that most engineers do not possess. Since optical transmission is inherently unidirectional, two-way communication requires either two fibers or two frequency bands on one fiber. Fiber interfaces cost more than electrical interfaces.

### Check Your Progress 2

1) What is Analog data transmission?

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2) Explain the use of repeaters with respect to data transmission.

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3) Describe the three categories of distortion.

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4) List out the significance of delays in data transmission.

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## 2.7 WIRELESS TRANSMISSION



Figure 11: Frequency spectrum for Wireless transmission

Wireless transmission is also called **unbounded media**. Here, there are no physical connectors between the two communicating devices. Usually the transmission is sent through the atmosphere, but sometimes it can be just across a room. Wireless media is used when a physical obstruction or distance blocks the use of normal cable media. The three main types of Wireless Media are:

- Radio wave,
- Microwave, and
- Infrared.

However, wireless also has advantages for fixed devices in some circumstances. For example, if running a fiber to a building is difficult due to the terrain (mountains, jungles, swamps, etc.) wireless may be preferable. It is noteworthy that modern wireless digital communication began in the Hawaiian Islands, where large chunks of Pacific Ocean separated the users and the telephone system was inadequate.

### 2.7.1 Microwave Transmission



Figure 12: Microwave transmission station.

Microwave is a radio system, which uses very high frequencies to send and receive data. Because of the high frequencies involved, microwave stations are located about 30 kilometers apart and in line of sight (visible to each other).

Microwave systems have sufficient bandwidth capacity to support a large number of voice channels and one or two TV channels.

Above 100 MHz, the waves travel in straight lines and can therefore, be narrowly focused upon. Concentrating all the energy into a small beam, using a parabolic antenna (like the familiar satellite TV dish) gives a much higher signal to noise ratio, but the transmitting and receiving antennas must be accurately aligned with each other. In addition, this directionality allows, multiple transmitters lined up in a row to communicate with multiple receivers in a row without interference. Before fiber optics, microwaves formed the heart of long distance telephone transmission system.

Since, microwaves travel in straight lines, if, the towers are too far apart, the earth will get in the way. Consequently, repeaters are needed periodically. The higher the

towers are, the further apart they can be. The distance between repeaters increases roughly, with the square root of the tower height. For 100-m high towers, repeaters can be spaced 80 km apart.

Unlike, radio waves at lower frequencies, microwaves do not pass through buildings well. In addition, even though the beam may be well focused at the transmitter, there is still some divergence in space. Some waves may be refracted off low-lying atmospheric layers and may take slightly longer to arrive than, direct waves. The delayed waves may arrive out of phase with the direct wave and thus cancel the signal. This effect is called multipath fading and is often a serious problem. It is weather and frequency dependent. Some operators keep 10 percent of their channels idle as spares to switch on to when, multipath fading affects some frequency band temporarily.

In summary, microwave communication is so widely used for long-distance telephone communication, cellular telephones, television distribution, and other uses, that a severe shortage of spectrum has developed.

Microwave systems have the advantage of:

- medium capacity,
- medium cost, and
- can go long distances.

Its disadvantages are:

- noise interference,
- geographical problems due to line of sight requirements, and
- becoming outdated.

### **Comparison between Microwave and Optical Fiber**

The microwave has several significant advantages over optical fiber cable. The main one is that no right of way is needed, and by buying a small plot of ground every 50 km and putting a microwave tower on it, one can bypass the telephone system and communicate directly.

Microwave is also relatively inexpensive. Putting up two simple towers (maybe just big poles with four guy wires) and putting antennas on each one may be cheaper than burying 50 km of fiber through a congested urban area or up over a mountain, and it may also be cheaper than leasing optical fiber from a telephone company.

### **Terrestrial Microwave**

Terrestrial Microwave employs Earth-based transmitters and receivers. The frequencies used are in the low-gigahertz range, hence, limiting all communication to line of sight.

Microwave transmissions are carried out using a parabolic antenna that produces a narrow, highly directional signal. At the receiving site a similar antenna, which is sensitive to signals, only within a narrow focus, is placed. As both the transmitter and receiver are highly focused, they must be carefully adjusted so that, the transmitted signal is aligned with the receiver.

Microwave is frequently used as a means of transmitting signals where it would be impractical to run cables.

Terrestrial microwave systems operate in the low-giga hertz range, typically at 2-6GHz and 21-23GHz

Attenuation characteristics are determined by transmitter power, frequency and antenna size. Properly designed systems are not affected by attenuation under normal operational conditions. Rain and fog, however, can cause attenuation at higher frequencies.

Microwave systems might be vulnerable to electronic eavesdropping and signals transmitted through microwave are frequently encrypted.

### **Satellite Microwave**

Satellite Microwave systems relay transmission through communication satellites that operate in geosynchronous orbits (36,000 – 40,000 km) above the Earth.

In order to communicate with satellites, the Earth stations use parabolic antennas. Satellites can retransmit signals in broad or in narrow beams depending on the locations that are to receive the signals. When the destination is on the opposite side of the earth, the first satellite must relay the signal through another satellite, as it cannot directly transmit to the receiver.

Satellite Microwave communication is possible with most remote sites and with mobile devices as no cables are required. Ships at sea and motor vehicles also use Satellite Microwave communication.

As all signals must travel 36,000 miles to the satellite and 36,000 miles when returning to the receiver, the time required to transmit a signal is independent of the distance. The time required for the signal to arrive at its destination is called propagation delay. The delay encountered with satellite transmissions is about 0.5 seconds.

Satellite Microwave communication is extremely expensive, as a result of which, organisations share the cost or they purchase services from a commercial provider.

Satellite links operate in the low-giga hertz range, typically at 4-6 GHz.

Attenuation depends on transmitter power, frequency and atmospheric conditions. Rain and atmospheric conditions may cause attenuation at higher frequencies. Signals transmitted through Satellite Microwave are usually encrypted.

### **2.7.2 Radio Transmission**

The radio portion of the electromagnetic spectrum extends from 10KHz to 1GHz. Within this range there are numerous bands or ranges of frequencies that are designated for specific purposes. Some of the familiar frequency bands are:

- Short wave,
- VHF (Very High Frequency) used for television and FM radio, and
- UHF (Ultra High Frequency) used for television.

Radio waves are easy to generate, can travel long distances, and penetrate buildings easily, so they are widely used for communication, both indoors and outdoors. Radio waves also are omni directional, meaning that they travel in all directions from the source, so that the transmitter and receiver do not have to be carefully aligned physically and that the signal can be received by all the radios within the broadcast area.

The properties of radio waves are frequency dependent. At low frequencies, radio waves pass through obstacles well, but the power falls off sharply with distance from the source, roughly as  $1/r^3$  in air. At high frequencies, radio waves tend to travel in straight lines and bounce off obstacles. They are also absorbed by rain. At all frequencies, radio waves are subject to interference from motors and other electrical equipment.

### 2.7.3 Infrared and Millimeter Waves

Unguided infrared and millimeter waves are widely used for short-range communication. The remote controls used on televisions, VCR's, and stereos all use infrared communication. The remote control transmits pulses of infrared light that carry coded instructions to the receiver on the TV. They are relatively directional, cheap, and easy to build, but they have a major drawback, that is, they do not pass through solid objects (try standing between your remote control and your television and see if it still works). In general, as we go from long-wave radio toward visible light, the waves behave more and more like light and less and less like radio.

Infrared waves do not pass through solid walls well, as a result of which, an infrared system in one room of a building, will not interfere with a similar system in adjacent rooms, which is a great advantage. Due to this nature, security of infrared systems against eavesdropping is better than that of radio systems. Because of these reasons, no government license is needed to operate an infrared system, in contrast to radio systems, which must be licensed.

These properties have made infrared suitable for indoor wireless LANS. For example, the computers and offices in a building can be equipped with relatively unfocused (i.e., somewhat omni directional), infrared transmitters and receivers. In this way, portable computers with infrared capability can be on the local LAN without having to physically connect to it. During a meeting where several people use their portables, they can just sit down in the conference room and be fully connected, without having to plug in. Infrared communication cannot be used outdoors because the sun shines as brightly in the infrared as in the visible spectrum.

Two methods of infrared networking that are in use are:

#### Point-to-point and Broadcast Infrared

**Point-to-point:** The Point-to-point networks operate by relaying infrared signals from one device to the next. Hence, transmissions are focused on a narrow beam, and the transmitter and receiver must be aligned carefully. Point-to point infrared is not suitable for use with devices that move frequently because, here, the devices must be carefully aligned and setup.

High power laser transmitters can be used in order to transmit data for several thousand yards when the line of sight communication is possible.

The cost of Point-to-point infrared equipment is higher than the cost for a comparable cabled network. When systems use transmitters that are based on LED technology and hardware cost is moderate, but, when long distance systems use high powered laser transmitters then the cost is very high.

Infrared devices are insensitive to radio frequency interference, but, the reception can be degraded by bright light. As the transmitters are tightly focused, they are fairly immune to electronic eavesdropping.

**Broadcast Infrared:** Broadcast infrared disperses transmissions so that, they are visible to several receivers. The two possible approaches to broadcast infrared networking are:

- The active transmitter can be located at a high point so that, it can transmit to all devices.
- A reflective material can be placed on the ceiling. Devices transmit toward the ceiling, from where, the light signals are dispersed to other devices in the room.



Installation is simple as device alignment is not critical. Hence, it is essential that each device has clear transmission and reception pathways.

As all devices are sensitive to light interference, during installation, the control of ambient light is very important.

## 2.8 WIRELESS LAN

Wireless LAN's are a system of portable computers that communicate using radio transmission. Wireless LAN's make use of the omnidirectional wireless communication.

The main objective of wireless LAN is to provide high-speed communication among computers that are located in relatively close proximity.

Wireless LAN's are usually configured in an office building with the base stations strategically placed around the building. Optical fiber cable can be used to cable all base stations together. If the transmission power of the base stations and portables is adjusted to a range of 3 or 4 meters, then, each room acts as a single cell, and the entire building acts as a large cellular system. Here unlike the cellular telephone system, each cell has only one channel that covers the entire bandwidth, which is available. Typically its bandwidth is 1 to 2 Mbps.

The disadvantages of using Radio transmitters are:

When the receiver is within the range of two active transmitters, the resulting signal will usually be grabbed and hence, useless.

In indoor wireless LAN's, the presence of walls between the stations have great impact on the effective range of each station.

### Check Your Progress 3

- 1) Discuss the twisted pair cable.

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- 2) Describe co-axial cable and its uses.

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- 3) Describe the structure of optical fiber and mention its advantages and disadvantages.

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- 4) Explain how Radio communication differs from Satellite communication.

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5) Explain the working of Wireless LAN's.

## 2.9 SUMMARY

In this unit, we have studied, the basic concepts of Data Transmission. To start with, we discussed the basic terms that are frequently used in Data transmission like Bandwidth, frequency, channel, baud etc. Bandwidth is the amount of data or signals that a transmission media can carry in a fixed amount of time and its unit of measurement is bits per second (bps) for digital signal and Hertz (Hz) for analog signals. Frequency is the number of cycles or periods that a signal completes within one second and its unit of measurement is Hertz (Hz). Channel refers to the communication path between the source and destination.

As it is essential to know how data can be transmitted from the source to the destination, the different modes of data transmission were outlined as follows:

- Parallel and Serial communication.
- Asynchronous, Synchronous and Isochronous communication.
- Simplex, Half duplex and Full duplex communication.

We also discussed the two major types of signals that is Analog and Digital and, the manner in which these two types of signals can be transmitted from the source to the destination.

When, data is transmitted from the source to the destination, there is, always a scope for transmission errors and the data may not reach in exactly the same form as it was sent. We have seen that these transmission errors are classified into three main categories that is Delay distortion, Attenuation and Noise. Delay distortion is caused because, signals at different frequencies, travel at different speeds along the transmission medium. As the signal travels along the transmission medium, its strength decreases over distance, this is known as Attenuation. Usually, some unwanted electromagnetic energy gets inserted during the course of transmission and this is called Noise. The concept of Delays and how to reduce them were also discussed.

We have seen that transmission media can be classified in to two categories, that are, guided media and unguided media. The guided media uses physical cable for data transmission. Twisted pair, co-axial cable and optical fiber are the three main types of guided media; they differ in their physical characteristics as well as transmission capacities. In case of unguided media, the transmission medium is air. Unguided media can be Radio, Microwave or Infrared. Security is a major concern when using unguided media for transmission.

Towards the end, Wireless LAN's were also discussed. Here, we saw that Wireless LAN's make use of Radio transmission and their main objective is to provide high speed communication among computers that are located in relatively close proximity. In the next unit, we will be studying, the different Data encoding and communication techniques.

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## 2.10 SOLUTIONS/ANSWERS

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### Check Your Progress 1

- 1) Data communication has become an essential and important part of the modern world. The possibilities of exchanging important business documents and information among widely separated users, sharing of information with friends etc., have made data communication very important and hence, it is necessary to understand how it works internally and how to exchange data among different users. Data communication system consists of a combination of hardware and software. A good data communication system must possess the following characteristics.

- **Correct delivery:** When a sender transmits data to a particular recipient, the data must reach only the intended recipient and not someone else.
- **Accurate delivery:** There must not be any sort of attenuation to the data sent during transmission from the sender to the receiver.
- **Timely delivery:** The data must travel from the source to the destination in a finite amount of time.

- 2) Bandwidth is the amount of signals that the transmission media can carry in a fixed amount of time. Bandwidth has a great influence on performance, that is, a higher bandwidth increases the throughput and better performance.

- 3) Solution:

Since Frequency (  $f$  ) is the inverse of period (  $T$  ) we have

$$f = 1/T = 1/3 = 0.33\text{Hz.}$$

therefore, the frequency of sine wave is 0.33 Hz.

- 4)

Parallel Transmission	Serial Transmission
All the Data bits are transmitted simultaneously on separate wires.	Data bits are transmitted one bit at a time serially.
Here multiple circuits interconnecting the two devices are required.	Requires only one circuit interconnecting the two devices.
It is a very fast method of data transmission.	It is slow compared to parallel transmission.
Expensive, as it requires several wires for sending as well as receiving equipment.	Comparatively cheaper.
Suitable for short distance data transmission where, accuracy is of prime importance.	Suitable for long distance data transmission.

- 5) In Full duplex transmission, simultaneously, bi-directional communication is possible, as a result, this configuration requires full and independent transmitting and receiving capabilities at both ends of the communication channel. This increases the throughput without increasing the bandwidth.
- 6) Refer to Section 2.3.2 Synchronous, Asynchronous and Isochronous communication.

## Check Your Progress 2

- 1) Analog data may be transmitted using analog signals. Analog signal is continuous and is represented using sine wave. Amplifiers are used to overcome the attenuation that the signal suffers during transmission. By converting analog signals into digital signals, the original audio or video data can be preserved indefinitely and copied any number of times without distortion.  
Human voice, video and music are all examples of analog signal.
- 2) As the signal flows through the transmission medium, it gets distorted and beyond a certain distance, the signal becomes unrecognisable from the original one. Repeaters are used to regenerate the digital signal. The result of adding a repeater is that the potential length of the overall network is doubled. Some repeaters only amplify signals; this strengthens the signal but, at the same time, also amplifies the noise on the network.

Advanced repeaters both amplify as well as regenerate the signals. Signal regenerating repeaters, identify the data in the signal they receive and use the data to regenerate the original signal. As a result only the strength of the desired signal is amplified while, reducing noise and clearing up any distortion that might be present. Hence, the output of such (regenerating) repeaters is the same as the original data signal.

- 3) When data is transmitted from the source to the destination, there is always a scope for transmission errors and the data may not reach in exactly the same form as it was sent. We have seen that these transmission errors are classified into three main categories that is Delay distortion, Attenuation and Noise. Delay distortion is caused because the signals at different frequencies travel at different speeds along the transmission medium. As the signal travels along the transmission medium, its strength decreases over distance and this is called Attenuation. Usually, some unwanted electromagnetic energy can get inserted during the course of transmission and this is called Noise.

- 4) Refer to section 2.5.4 Concept of delays

### Check Your Progress 3

- 1) The oldest and still most common transmission medium is the twisted pair. A twisted pair consists of two insulated copper wires, typically about 1 mm thick. The importances of twisting the two strands of insulated copper wire are:

- Twisting reduces the sensitivity of the cable to EMI (Electromagnetic Interference).
- Reduces the tendency of the cable to radiate radio frequency noise that interferes with the nearby cables and electronic components.
- Twisting also controls the tendency of the wires in the pair to cause EMI in each other.

The most common application of the twisted pair is in the telephone system. Nearly all telephones are connected to the telephone company office by a twisted pair. Twisted pairs can run several kilometers without amplification, but for longer distances, repeaters are needed. When many twisted pairs run in parallels, for a substantial distance, such as, all the wires coming from an apartment building to the telephone company office, they are bundled together and encased in a protective sheath. The pairs in these bundles would interfere with one another if, they were not twisted.

- 2) The components of a co-axial cable are:

A center conductor, which is usually a stiff copper wire.

Shield, which is an outer conductor that forms a tube surrounding the centre conductor. This conductor consists of braided wires, metallic foil or both.

An insulation layer that also keeps the outer conductor spaced evenly from the inner conductor. A plastic encasement (jacket ) that protects the cable from damage.

- 3) Fiber optic cable is made from fine strands of silicon glass fiber (thinner than a human hair), and is coated with a refractive surface. The signals are converted to light pulses before being sent. When light (provided by a laser) is show into the strand, it travels along the fiber strand (the refractive layer prevents it from escaping). Each fiber optic strand can support thousands of speech channels and multiple TV channels simultaneously. It is used for long haul telecommunications links, high-speed data communications links for computers, and information services to homes (e.g., PAY TV).

Advantages of Fiber optic cable are:

- high capacity
- immune to interference
- can go long distances

Its disadvantages are:

- costly
- difficult to join.

- 4)

RADIO COMMUNICATION	SATELLITE COMMUNICATION
<p><b>Frequency Range:</b> Any part of the radio spectrum can be used. Frequencies in the low Giga-hertz (GHz) range are usually selected in order to achieve high data rates.</p> <p><b>Cost:</b> Depends on the design, but can be low in comparison to other wireless communication.</p> <p><b>Installation:</b> Installation is difficult.</p> <p><b>Attenuation:</b> Attenuation is high.</p> <p><b>EMI Sensitivity:</b> High EMI sensitivity, vulnerable to eavesdropping.</p>	<p><b>Frequency Range:</b> Satellite links operate in the low Giga-hertz (GHz) range typically from 11-14 GHz.</p> <p><b>Cost:</b> Costs are extremely high and are usually distributed among many users by selling communication services.</p> <p><b>Installation:</b> Installation is very difficult.</p> <p><b>Attenuation:</b> Attenuation depends on frequency, signal strength and atmospheric conditions.</p> <p><b>EMI Sensitivity:</b> Low EMI sensitivity, moderately vulnerable to eavesdropping.</p>

- 5) Refer to Section 2.5 Wireless LAN.

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## 2.11 FURTHER READINGS

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- 1) *Computer Networks*, Andrew.S.Tannenbaum, PHI, New Delhi.
- 2) *Data and Computer Communication*, William Stalling, PHI, New Delhi