Nalanda Open University

Course Name: BCA Part II

Paper-X (Networking)

Topic-Introduction to Computer Network

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E-CONTENT

Topic- Data Transmission

2.1 INTRODUCTION

Transmission of the data is very much important in the services related to the data communication and the information technology as this technique makes use of the data processed in the order to forward the same to the end user.

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. It enables the transfer and communication of devices in a point-to-point, point-to-multipoint and multipoint-to-multipoint environment.

Data transmission is also known as digital transmission or digital communications.

Data transmission can be analog and digital but is mainly reserved for sending and receiving digital data. It works when a device or piece of equipment, such as a computer, intends to send a data object or file to one or multiple recipient devices, like a computer or server. The digital data originates from the source device in the form of discrete signals or digital bit streams. These data streams/signals are placed over a communication medium, such as physical copper wires, wireless carriers and optical fiber, for delivery to the destination/recipient device. Moreover, each outward signal can be baseband or passband.

In addition to external communication, data transmission also may be internally carried to a device. For example, the random access memory (RAM) or hard disk that sends data to a processor is also a form of data transmission.

The most widely used codes that have been adopted for this function are the Extended Binary Coded Decimal (EBCDIC) and the American Standard Code for Information Interchange codes (ASCII). Both coding schemes cater to all the normal alphabetic, numeric, and punctuation characters, collectively referred to as *printable characters* and a range of additional control characters, known as *non-printable characters.*

Data transmission refers to the movement of data in form of bits between two or more digital devices. We conclude the Unit with a brief summary followed by an exercise and some suggested readings for the students.

2.2 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.

2.3 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.

Channel

In a network, a communication channel is the physical path the transmission signals travel. It is the path information travels from computer to computer.

A path through which information is transmitted from one place to another is called communication channel. It is also referred to as communication medium or link. The twisted pair wire, coaxial cable, fiber optic cable, microwave, satellite etc. are examples of communication channels.

In a communication channel, data is transmitted in the form of signals (analog signal). The data transmission is measured in bandwidth. The bandwidth will be higher if more signals can be transmitted. Actually, the bandwidth measures the amount of information that can be transmitted through the media within the given period of time. For analog signals, bandwidth is represented in hertz (Hz). It means number of signals transmitted per second. For digital signals, it is represented in bits per second (bps). Different transmission media have different bandwidths. The higher the bandwidth of the transmission media, the more information can be transmitted.

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.

Baud

A baud is the number of signalling elements per second sent by a communications device such as a modem. In theory, a modem with a high baud rate means fast transmission. The baud rate is therefore equal to the bit rate only if each signal element represents one bit of information.

Unfortunately, in much of today's literature, the terms "baud" and "bits per second" are used synonymously. This is correct in cases where pure two-state signalling is used but is incorrect in general. For this reason, the term "baud" is gradually being replaced by "bits per second," since the latter is independent of the coding method and truly represents the information rate.

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.

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 signalling 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.

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 Megahertz or one MHz to mean 1000 kHz or 1000000Hz.

2.4 MODES OF DATA TRANSMISSION

Transmission mode means transferring of data between two devices. It is also known as communication mode. Buses and networks are designed to allow communication to occur between individual devices that are interconnected.

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.

Types of Data Transmission

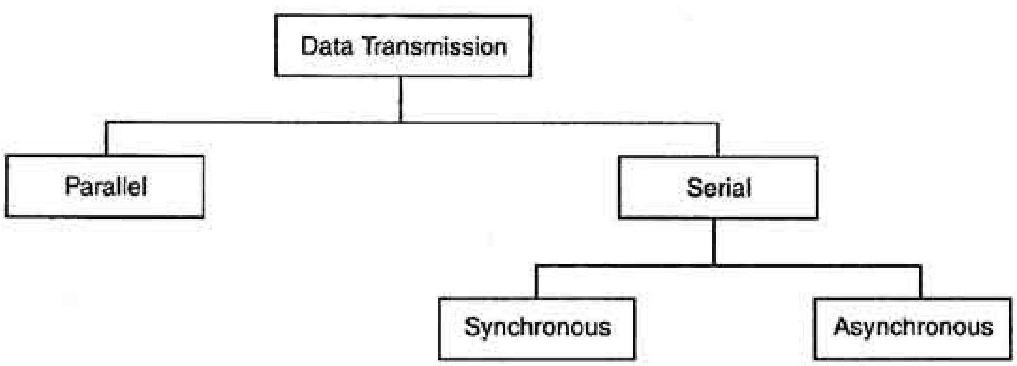


Fig: 1 Data Transmission Mode

Serial and Parallel Communication

1. Parallel transmission

Within a computing or communication device, the distances between different subunits are too short. Thus, it is normal practice to transfer data between subunits using a separate wire to carry each bit of data. There are multiple wires connecting each sub-unit and data is exchanged using a *parallel transfer* mode. This mode of operation results in minimal delays in transferring each word.

• In parallel transmission, all the bits of data are transmitted simultaneously on separate communication lines.

• In order to transmit *n* bits, *n* wires or lines are used. Thus each bit has its own line.

• All n bits of one group are transmitted with each clock pulse from one device to another *i.e.* multiple bits are sent with each clock pulse.

• Parallel transmission is used for short distance communication.

• As shown in the fig, eight separate wires are used to transmit 8 bit data from sender to receiver.

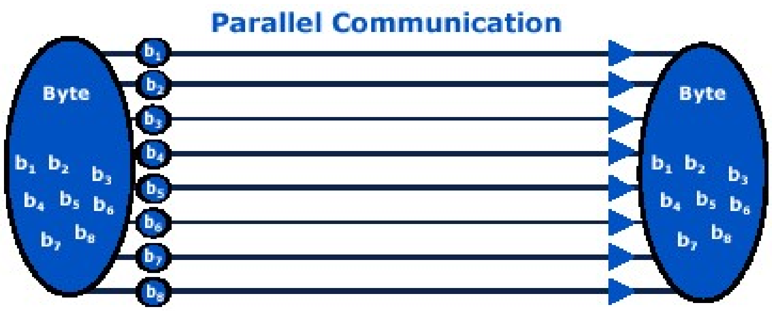


Fig2: Advantage of parallel transmission

It is speedy way of transmitting data as multiple bits are transmitted simultaneously with a single clock pulse.

Disadvantage of parallel transmission

It is costly method of data transmission as it requires *n* lines to transmit *n* bits at the same time.

When transferring data between two physically separate devices, especially if the separation is more than a few kilo meters, for reasons of cost, it is more economical to use a single pair of lines. Data is transmitted as a single bit at a time using a fixed time interval for each bit. This mode of transmission is known as *bit-serial* transmission.

• In serial transmission, the various bits of data are transmitted serially one after the other.

• It requires only one communication line rather than *n* lines to transmit data from sender to receiver.

• Thus all the bits of data are transmitted on single line in serial fashion.

• In serial transmission, only single bit is sent with each clock pulse.

• As shown in fig 3, suppose an 8-bit data 11001010 is to be sent from source to destination. Then least significant bit (LSB) *i,e.* 0 will be transmitted first followed by other bits. The most significant bit (MSB) *i.e.* 1 will be transmitted in the end via single communication line.

• The internal circuitry of computer transmits data in parallel fashion. So in order to change this parallel data into serial data, conversion devices are used.

• These conversion devices convert the parallel data into serial data at the sender side so that it can be transmitted over single line.

• On receiver side, serial data received is again converted to parallel form so that the interval circuitry of computer can accept it

Fig3: Serial transmission used for long distance communication.

Advantage of Serial transmission

Use of single communication line reduces the transmission line cost by the factor of *n* as compared to parallel transmission.

Disadvantages of Serial transmission

1. Use of conversion devices at source and destination end may lead to increase in overall transmission cost.

2. This method is slower as compared to parallel transmission as bits are transmitted serially one after the other.

Types of Serial Transmission

There are two types of serial transmission-synchronous and asynchronous both these transmissions use '**Bit synchronization**'

Bit Synchronization is a function that is required to determine when the beginning and end of the data transmission occurs.

Bit synchronization helps the receiving computer to know when data begin and end during a transmission. Therefore, bit synchronization provides timing control.

Asynchronous, Synchronous and Isochronous Communication Synchronous Transmission

Asynchronous Transmission

- Asynchronous transmission sends only one character at a time where a character is either a letter of the alphabet or number or control character *i.e.* it sends one byte of data at a time.
- Bit synchronization between two devices is made possible using start bit and stop bit which is shown in fig 4.
- Start bit indicates the beginning of data *i.e.* alerts the receiver to the arrival of new group of bits. A start bit usually 0 is added to the beginning of each byte.
- Stop bit indicates the end of data *i.e.* to let the receiver know that byte is finished, one or more additional bits are appended to the end of the byte. These bits, usually 1s are called stop bits.

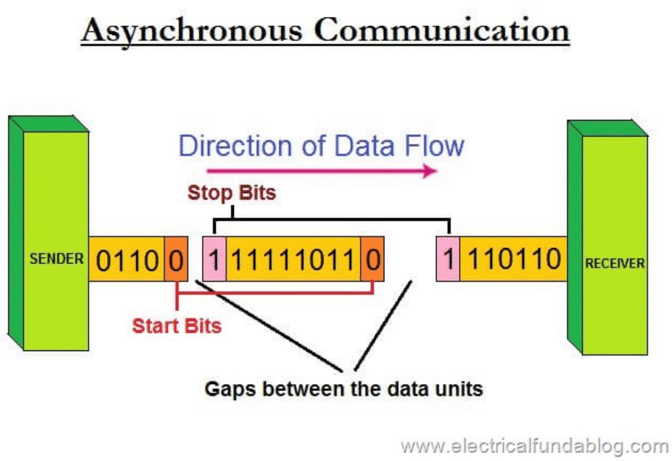


Fig 4 Asynchronous transmission

- Addition of start and stop increase the number of data bits. Hence more bandwidth is consumed in asynchronous transmission.
- There is idle time between the transmissions of different data bytes. This idle time is also known as Gap
- The gap or idle time can be of varying intervals. This mechanism is called Asynchronous, because at byte level sender and receiver need not to be synchronized. But within each byte, receiver must be synchronized with the incoming bit stream.

Application of Asynchronous Transmission

1. Asynchronous transmission is well suited for keyboard type-terminals and paper tape devices. The advantage of this method is that it does not require any local storage at the terminal or the computer as transmission takes place character by character.

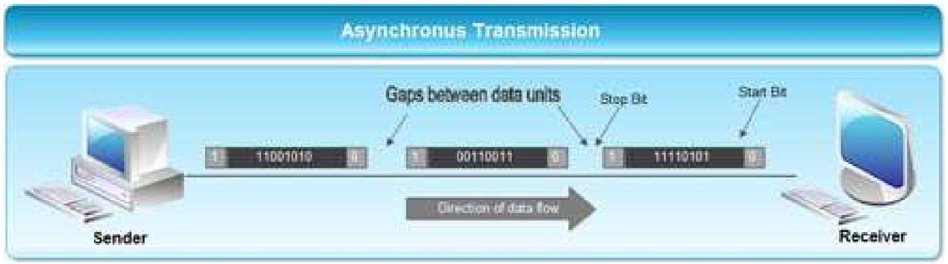


Fig 5 : Asynchronous Transmission

2. Asynchronous transmission is best suited to Internet traffic in which information is transmitted in short bursts. This type of transmission is used by modems.

Advantages of Asynchronous transmission

1. This method of data transmission is cheaper in cost as compared to synchronous *e.g.* If lines are short, asynchronous transmission is better, because line cost would be low and idle time will not be expensive.
2. In this approach each individual character is complete in itself, therefore if character is corrupted during transmission, its successor and predecessor character will not be affected.
3. It is possible to transmit signals from sources having different bit rates.
4. The transmission can start as soon as data byte to be transmitted becomes available.
5. Moreover, this mode of data transmission in easy to implement.

Disadvantages of asynchronous transmission

1. This method is less efficient and slower than synchronous transmission due to the overhead of extra bits and insertion of gaps into bit stream.
2. Successful transmission inevitably depends on the recognition of the start bits. These bits can be missed or corrupted.

Synchronous Transmission

- Synchronous transmission does not use start and stop bits.
- In this method bit stream is combined into longer frames(fig 6) that may contain multiple bytes.
- There is no gap between the various bytes in the data stream.

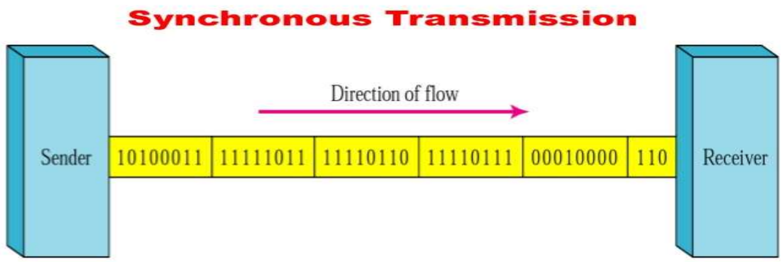


Fig 6: Synchronous Transmission

- In the absence of start & stop bits, bit synchronization is established between sender & receiver by *'timing'* the transmission of each bit.
- Since the various bytes are placed on the link without any gap, it is the responsibility of receiver to separate the bit stream into bytes so as to reconstruct the original information.
- In order to receive the data error free, the receiver and sender operates at the same clock frequency.

Application of Synchronous transmission

• Synchronous transmission is used for high speed communication between computers.

Advantage of Synchronous transmission

1. This method is faster as compared to asynchronous as there are no extra bits (start bit & stop bit) and also there is no gap between the individual data bytes.

Disadvantages of Synchronous transmission

1. It is costly as compared to asynchronous method. It requires local buffer storage at the two ends of line to assemble blocks and it also requires accurately synchronized clocks at both ends. This lead to increase in the cost.

2. The sender and receiver have to operate at the same clock frequency. This requires proper synchronization which makes the system complicated.

Comparison between Serial and Parallel transmission

Sr. No.	Factor	Serial	Parallel
1.	Number of bits transmitted at one clock pulse	One bit	*n* bits
2.	No. of lines required to transmit *n* bits	One line	*n* lines
3.	Speed of data transfer	Slow	Fast
4.	Cost of transmission	Low as one line is required	Higher as *n* lines are required.
5.	Application	Long distance communication between two computers	Short distance communication. like computer to printer.

Comparison between Asynchronous and Synchronous.

Sr. No.	Factor	Asynchronous	Synchronus
1.	Data send at one time	Usually 1 byte	Multiple bytes
2.	Start and Stop bit	Used	Not used
3.	Gap between Data units	Present	Not present
4.	Data transmission speed	Slow	Fast
5.	Cost	Low	High

Simplex, Half Duplex and Full Duplex Communication

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

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

• Simplex.

• Half Duplex

• Full Duplex, sometimes called Duplex.

Simplex mode

Simplex:
In Simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit, the other can only receive. The simplex mode can use the entire capacity of the channel to send data in one direction. Example: Keyboard and traditional monitors. The keyboard can only introduce input, the monitor can only give the output.. Simplex transmission generally involves dedicated circuits. Simplex circuits are analogous to escalators, doorbells, fire alarms and security systems:

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 7. 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.

Examples of Simplex mode:

1. A Communication between a computer and a keyboard involves simplex duplex transmission. A television broadcast is an example of simplex duplex transmission.
2. Another example of simplex transmission is loudspeaker system. An announcer speaks into a microphone and his/her voice is sent through an amplifier and then to all the speakers.
3. Many fire alarm systems work the same way.

Fig 7: Simplex Mode

Half duplex mode

In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa. The half-duplex mode is used in cases where there is no need for communication in both direction at the same time. The entire capacity of the channel can be utilized for each direction. Example: Walkie- talkie in which message is sent one at a time and messages are sent in both the directions.

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 8. 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

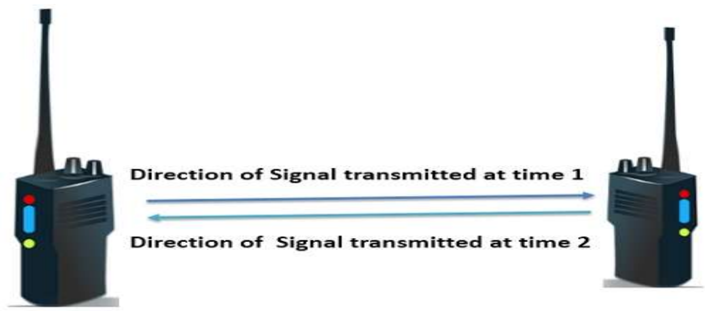


Fig 8: Example of half duplex mode:

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

In full-duplex mode, both stations can transmit and receive simultaneously. In full_duplex mode, signals going in one direction share the capacity of the link with signals going in other direction, this sharing can occur in two ways:

- Either the link must contain two physically separate transmission paths, one for sending and other for receiving.
- Or the capacity is divided between signals travelling in both directions.

Full-duplex mode is used when communication in both direction is required all the time. The capacity of the channel, however must be divided between the two directions. Example: Telephone Network in which there is communication between two persons by a telephone line, through which both can talk and listen at the same time.

A walkie-talkie operates in half duplex mode. It can only send or receive a transmission at any given time. It cannot do both at the same time.

As shown in fig. computer A sends information to computer B. At the end of transmission, computer B sends information to computer A. Computer A cannot send any information to computer B, while computer B is transmitting data.

A full duplex system can transmit data simultaneously in both directions on transmission path. **Full-duplex method is used to transmit the data over a serial communication link. Two wires needed to send data over a serial communication link layer. Full-duplex transmission, the channel capacity is shared by both communicating devices at all times.**

Both the connected devices can transmit and receive at the same time. Therefore, it represents truly bi-directional system. The link may contain two separate transmission paths one for sending and another for receiving.

Example of Full duplex mode:

Telephone networks operate in full duplex mode when two persons talk on telephone line, both can listen and speak simultaneously.

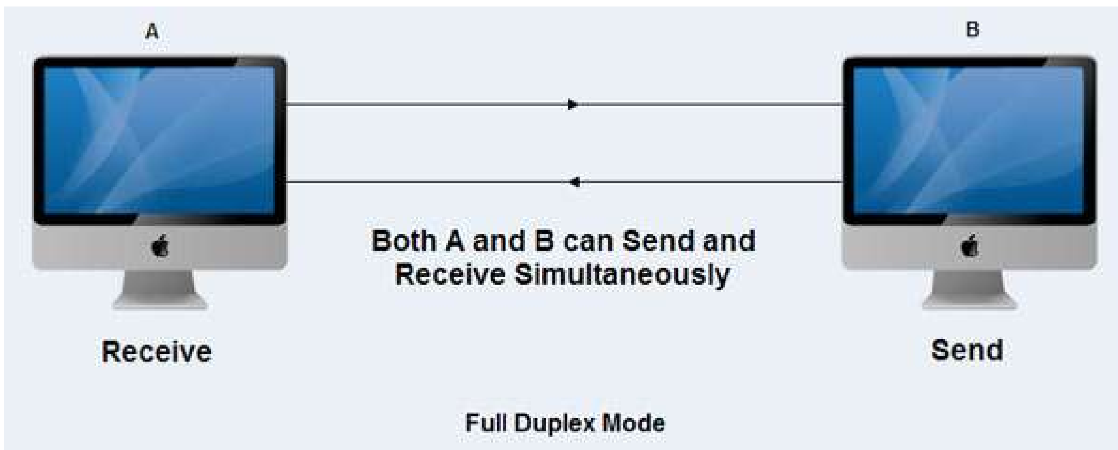


Fig 9: Full Duplex Mode

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 9. As you can see from Figure 9, 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.

ANALOG AND DIGITAL DATA TRANSMISSION

ANALOG TRANSMISSION

Analog is best explained by the transmission of signal such as sound or human speech, over an electrified copper wire. In its native form, human speech is an oscillatory disturbance in the air which varies in terms of its volume or power (amplitude) and its pitch or tone (frequency).

Analogous variations in electrical or radio waves are created in order to transmit the analog information signal for video or audio or both over a network from a transmitter (TV station or CATV source) to a receiver (TV set, computer connected with antenna). At the receiving end an approximation (analog) of the original information is presented

Information which is analog in its native form (audio and image) can vary continuously in terms of intensity (volume or brightness) and frequency (tone or color). Those variations in the native information stream are translated in an analog electrical network into variations in -the amplitude and frequency of the carrier signal. In other words, the carrier signal is modulated (varied) in order to create an analog of the original information stream.

The electromagnetic sinusoidal (waveform) or sine wave can be varied in amplitude at a fixed frequency, using Amplitude Modulation (AM). Alternatively, the frequency of the sine wave can be varied at constant amplitude using Frequency Modulation (FM). Additionally, both frequency and amplitude can be modulated simultaneously.

1. Analog signal can have infinite number of values and varies continuously with time.
2. Analog signal is usually represented by sine wave.
3. As shown in figure 10 each cycle consists of a single arc above the time axis followed by a single arc below the time axis.
4. Example of analog signal is human voice. When we speak, we use air to transmit an analog signal. Electrical signal from an audio tape, can also be in analog form

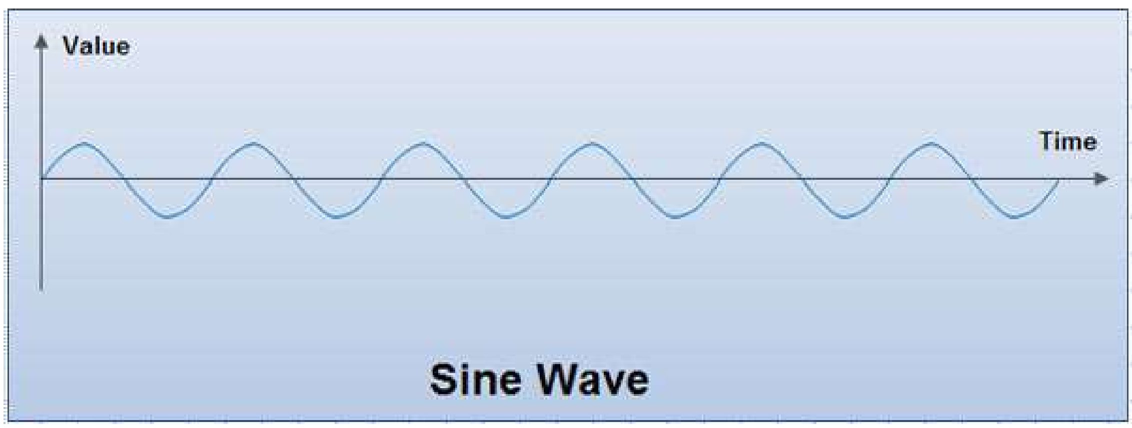


Fig 10: Analog Signal

Characteristics of Analog Signal

1. Amplitude

(i) Amplitude of a signal refers to the height of the signal.

(ii) It is equal to the vertical distance from a given point on the waveform to the horizontal axis.

(iii) The maximum amplitude of a sine wave is equal to the highest value it reaches on the vertical axis as shown in figure11.

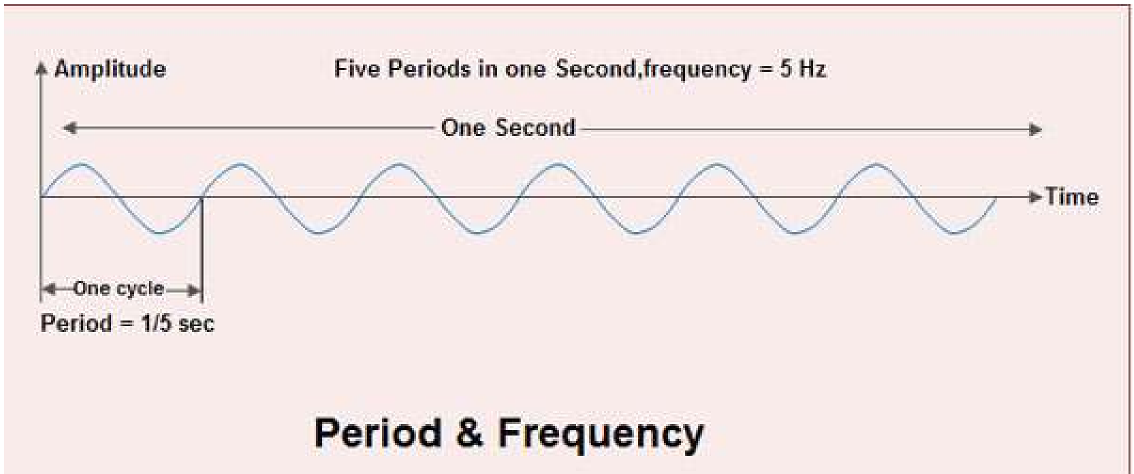


Fig 11: Amplitude, Period and frequency

(iv) Amplitude is measured in volts, amperes or watts depending on the type of signal. A volt is used for voltage, ampere for current and watts for power.

2. Period

(i) Period refers to the amount of time in which a signal completes one cycle.

(ii) It is measured in seconds.

(iii) Other units used to measure period are millisecond (10^{-3} sec.) microsecond (1 0^{-6} sec), nanosecond (10^{-9} sec) and picoseconds (10^{-12} sec).

3. Frequency

(i) It refers to the number of wave patterns completed in a given period of time.

(ii) To be more precise, frequency refers to number of periods in one second or number of cycles per second.

(iii) Frequency is measured in Hertz (Hz)

(iv)Other units used to express frequency are kilohertz (10^3 Hz) Megahertz (10^6 Hz), gigahertz (10^9 Hz) and terahertz (10^{12} Hz).

(v) Frequency and period are the inverse of each other. Period is the inverse of frequency and frequency is the inverse of period.

4. Phase

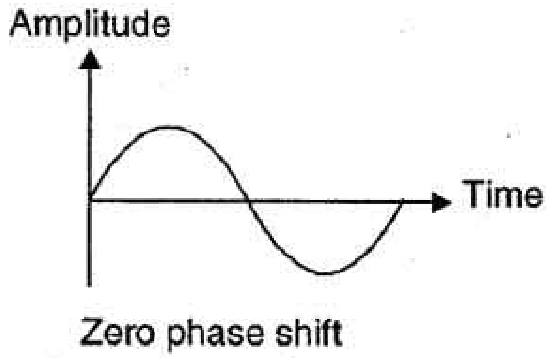
(i) Phase describes the position of the waveform relative to time zero.

(ii) Phase describes the amount by which the waveform shifts forward or backward along the time axis.

(iii) It indicates the status of first cycle.

(iv)Phase is measured in degrees or radians.

(v) A phase shift of 3600 indicates a shift of a complete period, a phase shift of 180° indicates a shift of half period and a phase shift of 90° indicates a shift of a quarter of a period as shown in fig 12. below.



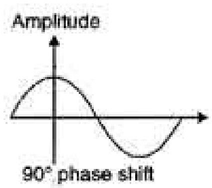


Fig. A shift of a quarter of a period or ¼ cycle.

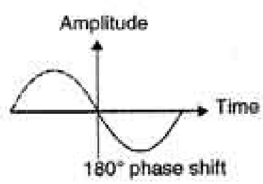


Fig. A shift of half period or ½ cycle

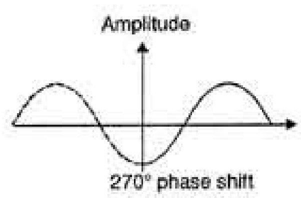


Fig. A shift of ¾ cycle

Fig 12: Phase shifting

Advantages of Analog Signals

(1) Best suited for the transmission of audio and video.

(2) Consumes less bandwidth than digital signals to carry the same information.

(3) Analog systems are readily in place around the world.

(4) Analog signal is less susceptible to noise.

DIGITAL TRANSMISSION

Computers are digital in nature. Computers process, store, and communicate information in binary form, i.e. in the combination of 1s and 0s which has specific meaning in computer language. A binary digit (bit) is an individual 1 or O. Multiple bit streams are used in a computer network.

Contemporary computer systems communicate in binary mode through variations in electrical voltage. Digital signalling, in an electrical network, 'involves a signal which varies in voltage to represent one of two discrete and well-defined states as depicted in Figure 13 such as either a positive (+) voltage and a null or zero (0) voltage (unipolar) or a positive (+) or a negative (-) voltage (bipolar).

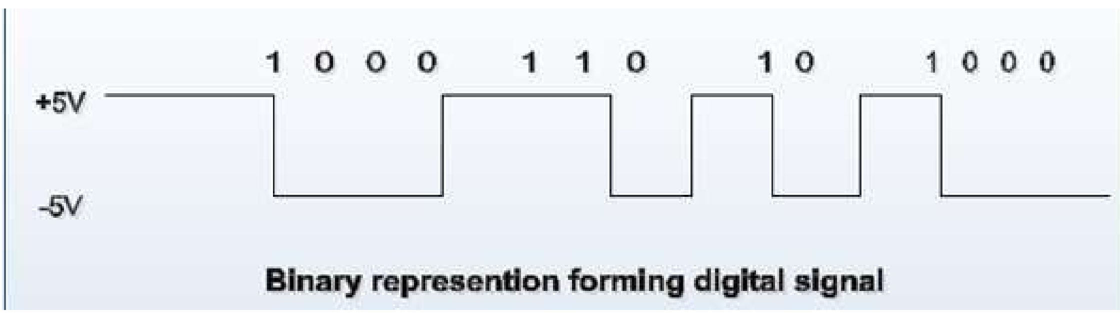


Fig 13: Digital Signal

Although analog voice and video can be converted into digital, and digital data can be converted to analog, each format has its own advantages.

1. It can have only a limited number of defined values such as 1 and O.
2. The transition of a digital signal from one value to other value is instantaneous.
3. Digital signals are represented by square wave.
4. In digital signals 1 is represented by having a positive voltage and 0 is represented by having no voltage or zero voltage as shown in figure.
5. All the signals generated by computers and other digital devices are digital in nature.

Characteristics of Digital Signals

1. Bit interval

It is the time required to send one single bit

2. Bit rate

(i) It refers to the number of bit intervals in one second.

(ii)Therefore bit rate is the number of bits sent in one second as shown in fig.

(iii) Bit rate is expressed in bits per second (bps).

(iv)Other units used to express bit rate are Kbps, Mbps and Gbps.

1 kilobit per second (Kbps) = 1,000 bits per second

1 Megabit per second (Mbps) = 1,000,000 bits per second

1 Gigabit per second (Gbps) = 1,000,000,000 bits per second

Advantages of Digital Signals

Digital Data - Digital transmission certainly has the advantage where binary computer data is being transmitted. The equipment required to convert digital data to analog format and transmitting the digital bit streams over an analog network can be expensive, susceptible to failure, and can create errors in the information.

Compression - Digital data can be compressed relatively easily, thereby increasing the efficiency of transmission. As a result, substantial volumes of voice, data, video and image information can be transmitted using relatively little raw bandwidth.

Security - Digital systems offer better security. While analog systems offer some measure of security through the scrambling of several frequencies. Scrambling is fairly simple to defeat. Digital information, on the other hand, can be encrypted to create the appearance of a single, pseudorandom bit stream. Thereby, the true meaning of individual bits, sets of bits, or the total bit stream cannot be determined without having the key to unlock the encryption algorithm employed.

Quality - Digital transmission offers improved error performance (quality) as compared to analog. This is due to the devices that boost the signal at periodic intervals in the transmission system in order to overcome the effects of attenuation. Additionally, digital networks deal more effectively with noise, which always is present in transmission networks.

Cost - The cost of the computer components required in digital conversion and transmission has dropped considerably, while the ruggedness and reliability of those components has increased over the years.

Upgradeability - Since digital networks are comprised of computer (digital) components, they are relatively easy to upgrade. Such upgrading can increase bandwidth, reduces the incidence of error and enhance functional value. Some upgrading can be effected remotely over a network, eliminating the need to dispatch expensive technicians for that purpose.

Management - Generally speaking, digital networks can be managed much more easily and effectively due to the fact that such networks consist of computerized components. Such components can sense their own level of performance, isolate and diagnose failures, initiate alarms, respond to queries, and respond to commands to correct any failure. Further, the cost of these components continues to drop.

With any communications system, the signal that is received may differ from the signal that is transmitted 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. In this section, we examine the various impairments and how they may affect the information-carrying capacity of a communication link; The most significant impairments are

• Attenuation and attenuation distortion

• Delay distortion

• Noise

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 which is depicted in figure 14. 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.

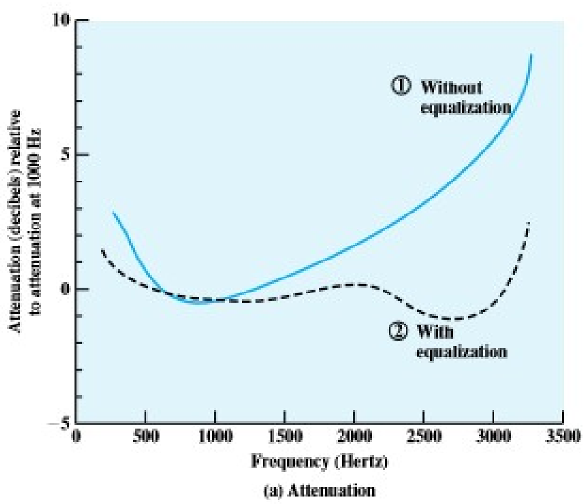


Fig 14: Attenuation

Delay Distortion

Delay distortion is caused by the fact that the signals of varying frequencies travel at different speeds along the medium which is shown in figure 15. 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.

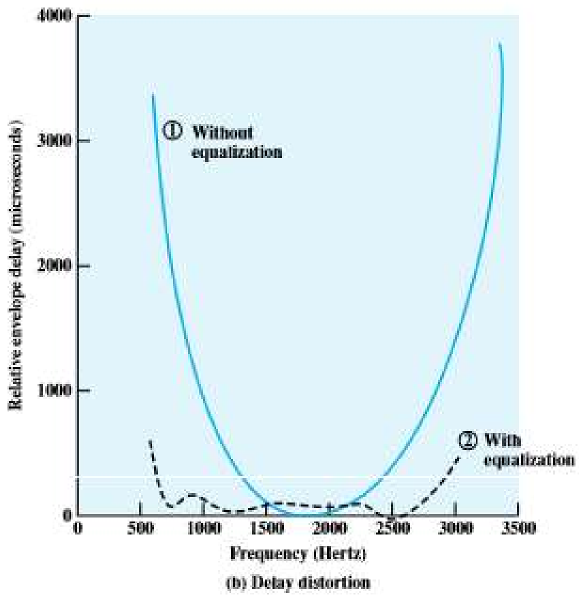


Fig 15: Delay Distortion

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.

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.

Noise may be divided into four categories:

- Thermal noise
- Intermodulation noise
- Crosstalk
- Impulse noise

Thermal noise

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. Thermal noise is uniformly distributed across the bandwidths typically used in communications systems and hence is often referred to as white noise. Thermal noise cannot be eliminated and therefore places an upper bound on communications system performance. Because of the weakness of the signal received by satellite earth stations, thermal noise is particularly significant for satellite communication.

The amount of thermal noise to be found in a bandwidth of 1 Hz in any device or conductor is

N_0 = kT1W/Hz2

Where

N_0 = noise power density in watts per 1 Hz of bandwidth

k = Boltzmann's constant = 1.38 * 10-23 J/K

kelvin T = temperature, in kelvins (absolute temperature), where the symbol K is used to represent 1 kelvin

EXAMPLE

Room temperature is usually specified as or 290 K. At this temperature, the thermal noise power density is

N0 = 11.38 * 10-232 * 290 = 4 * 10-21 W/Hz =-204 dBW/Hz

where dBW is the decibel-watt, defined in Appendix 3A.

The noise is assumed to be independent of frequency. Thus the thermal noise in watts present in a bandwidth of B Hertz can be expressed as

N = kTB

or,in decibel-watts,

N = 10 log k + 10 log T + 10 log B

=-228.6 dBW + 10 log T + 10 log B

EXAMPLE :

Given a receiver with an effective noise temperature of 294 K and a 10-MHz bandwidth, the thermal noise level at the receiver's output is

N =-228.6 dBW + 10 log12942 + 10 log 107

=-228.6 + 24.7 + 70

=-133.9 dBW

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. For example, the mixing of signals at frequencies and might produce energy at the frequency This derived signal could interfere with an intended signal at the frequency f1 +f2

Intermodulation noise is produced by nonlinearities in the transmitter, receiver, and/or intervening transmission medium. Ideally these components behave as linear systems; that is, the output is equal to the input times a constant. However, in any real system, the output is a more complex function of the input. Excessive nonlinearity can be caused by component malfunction or overload from excessive signal strength. It is under these circumstances that the sum and difference frequency terms occur.

Crosstalk

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. 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. Typically, crosstalk is of the same order of magnitude as, or less than, thermal noise. All of the types of noise discussed so far have reasonably predictable and relatively constant magnitudes. Thus it is possible to engineer a transmission system to cope with them.

Impulse noise

Impulse noise, however, is non-continuous, 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. For example, voice transmission may be corrupted by short clicks and crackles with no loss of intelligibility. However, impulse noise is the primary source of error in digital data

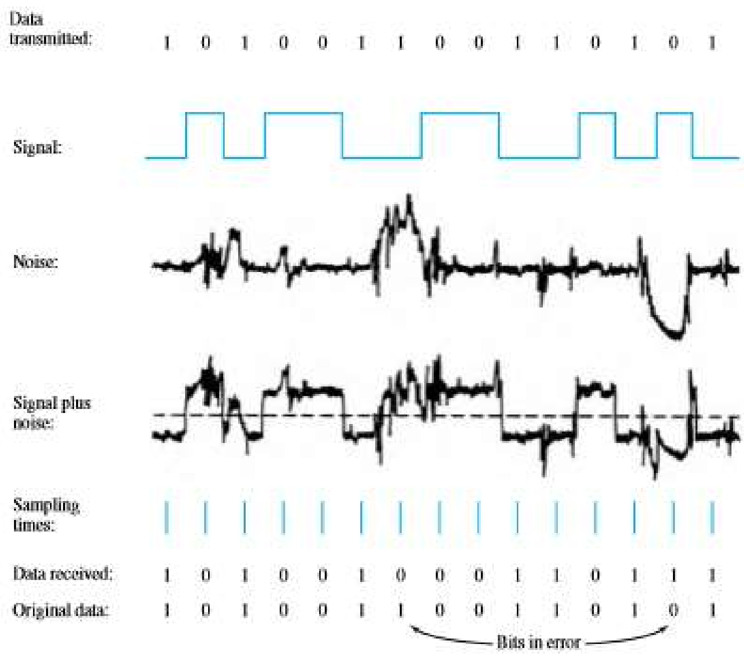


Fig 16: Effect of Noise on a Digital Signal

communication. For example, a sharp spike of energy of 0.01 s duration would not destroy any voice data but would wash out about 560 bits of digital data being transmitted at 56 kbps. Figure 16 is an example of the effect of noise on a digital signal. Here the noise consists of a relatively modest level of thermal noise plus occasional spikes of impulse noise. The digital data can be recovered from the signal by sampling the received waveform once per bit time. As can be seen, the noise is occasionally sufficient to change a 1 to a 0 or a 0 to a 1.

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.