Unit-2

Data Transmission

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 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 (subchannel) 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. 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.

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.

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.

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.

Modes of data transmission

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

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

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

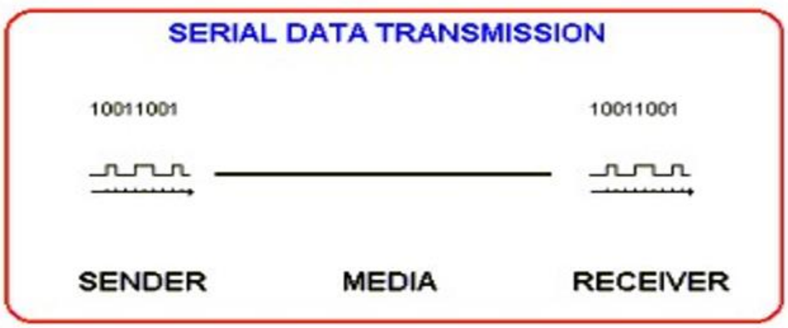

Figure: Serial communication

In Serial data transmission, bits are transmitted serially, one after the other, as shown in *Figure*. 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

In Parallel transmission, all the bits of a byte are transmitted simultaneously on separate wires as shown in the *Figure*. 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.

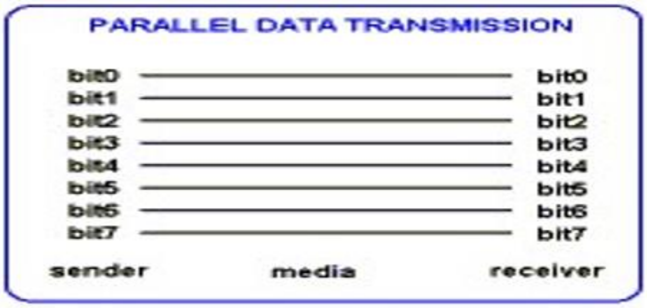

Figure: Parallel communication

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 draft out of synchronization, 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 synchronize 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 synchronize the receiving station.

Sync signals, generally utilize a bit pattern that cannot appear elsewhere in the messages, ensuring that they will always be distinct and easy for the receiver to recognize. As the transmitter and receiver remain in synchronization 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 summarizes 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 recognize 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 kbits.

- 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………nt where n is any positive integer. Here, the signal is expected to be received within certain delay bounds say Tmin to Tmax.

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 it’s necessary to ensure that the clocking device is fault tolerant.

Simplex, Half Duplex and Full Duplex Communication

Simplex

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*. 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.

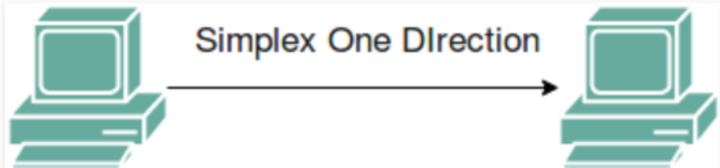

Figure: Simplex

Half Duplex

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

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

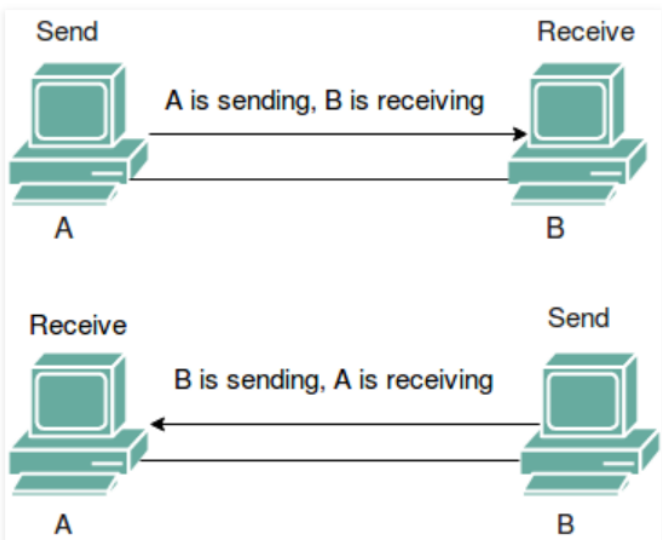

Figure: Half duplex

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.

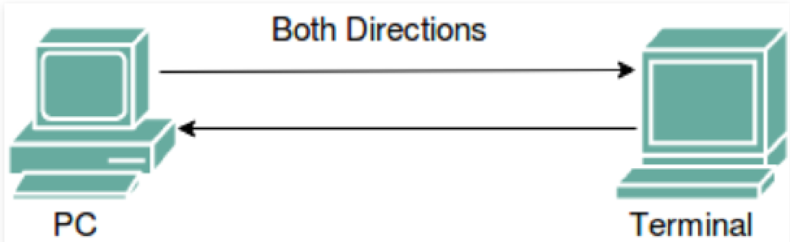

Figure: Full duplex

Comparison between simplex, half duplex and full duplex

Basis for Comparison	**Simplex**	**Half Duplex**	**Full Duplex**
Direction of Communication	Unidirectional	Two-directional, one at a time	Two-directional, simultaneously
Send / Receive	Sender can only send data.	Sender can send and receive data, but one at a time.	Sender can send and receive data simultaneously.
Performance	Least performing mode of transmission.	Better than Simplex	Most performing mode of transmission.
Example	Keyboard and monitor	Walkie-talkie	Telephone

Analog and Digital data transmission

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

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.

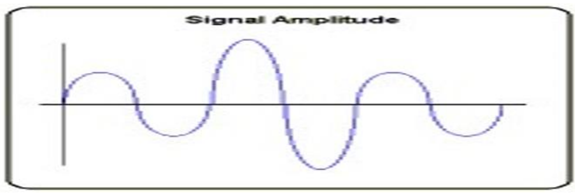

Figure: Analog signal

Digital signal

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.

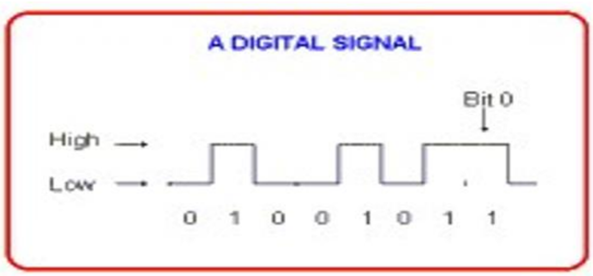

Figure: Digital data transmission

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 unrecognizable 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 recognize 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.

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.

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 recognized 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.

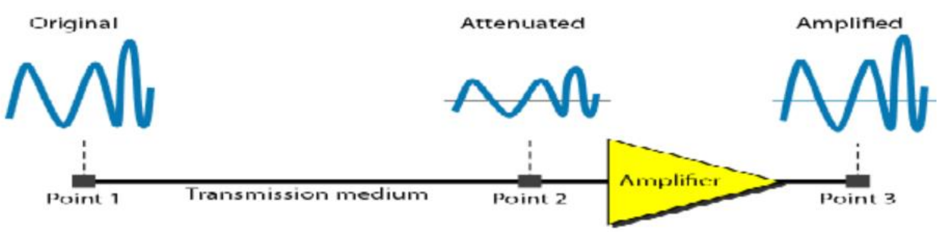

Figure: Measurement of attenuation

dB = 10log10P2/P1

P1 - input signal

P2 - output signal

Example:

Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P2 is (1/2)P1. In this case, the attenuation (loss of power) can be calculated as

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5P_1}{P_1} = 10 \log_{10} 0.5 = 10(-0.3) = -3 \text{ dB}$$

A loss of 3 dB (–3 dB) is equivalent to losing one-half the power.

Distortion

Means that the signal changes its form or shape. Distortion occurs in composite signals. Each frequency component has its own propagation speed traveling through a medium. The different components therefore arrive with different delays at the receiver. That means that the signals have different phases at the receiver than they did at the source.

The velocity of propagation of different frequency components of a signal are different in guided media. This leads to delay distortion in the signal. For a band limited signal, the velocity of propagation has been found to be maximum near the center frequency and lower on both sides of the edges of the frequency band. In case of analog signals, the received signal is distorted because of variable delay of different components. In case of digital signals, the problem is much more severe. Some frequency components of one bit position spill over to other bit positions, because of delay distortion. This leads to intersymbol interference, which restricts the maximum bit rate of transmission through a particular transmission medium. The delay distortion can also be neutralized, like attenuation distortion, by using suitable equalizers.

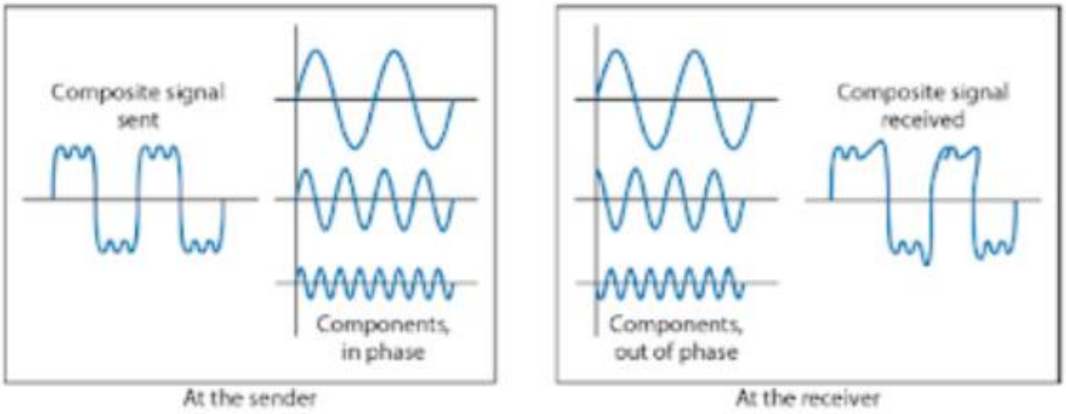

Figure: Distortion

Noise

Noise is unwanted energy from sources other than the transmitter. Noise can be categorized into the following four types:

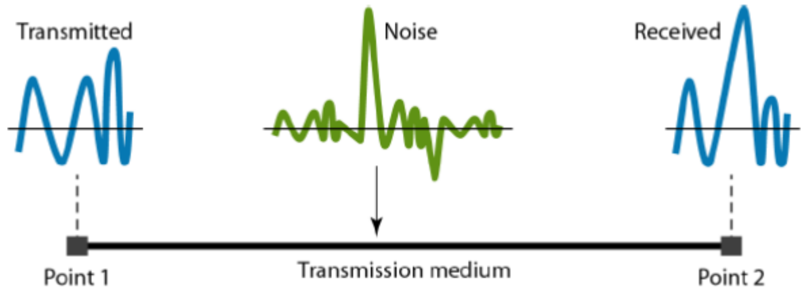

Figure: Noise as impairments

a. Thermal noise: The thermal noise is due to thermal agitation of electrons in a conductor. It is distributed across the entire spectrum and that is why it is also known as white noise (as the frequency encompass over a broad range of frequencies).
b. Intermodulation noise**:** When more than one signal share a single transmission medium, **intermodulation noise** is generated. For example, two signals f1 and f2 will generate signals of frequencies (f1 + f2) and (f1 - f2), which may interfere with the signals of the same frequencies sent by the transmitter. Intermodulation noise is introduced due to nonlinearity present in any part of the communication system.
c. Cross talk : Cross talk is a result of bunching several conductors together in a single cable. Signal carrying wires generate electromagnetic radiation, which is induced on other conductors because of close proximity of the conductors. While using telephone, it is a common experience to hear conversation of other people in the background. This is known as cross talk.
d. Impulse noise: Impulse noise is irregular pulses or noise spikes of short duration generated by phenomena like lightning, spark due to loose contact in electric circuits, etc. Impulse noise is a primary source of bit-errors in digital data communication. This kind of noise introduces burst errors.

Concept of delay

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.