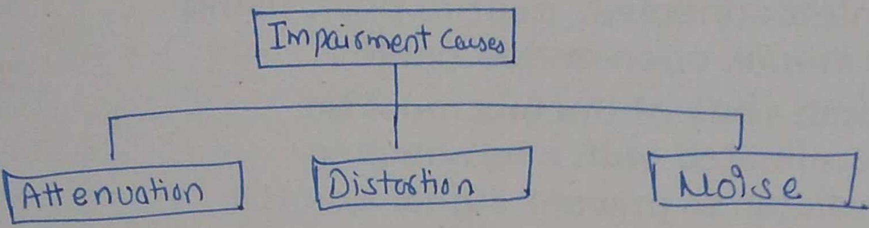
TRANSMISSION IMPAIRMENT ⇒ Signals travel through transmission media which are not perfect. The imperfection causes signal impairment. This means that the signal at the beginning of the medium is not the same as the signal at ~~the beginning~~ the end of the medium. What is sent is not what is received. Three causes of impairment are attenuation, distortion, and noise.



Attenuation → Attenuation means a loss of energy. When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire carrying electric signals gets warm, if not hot, after a while. Some of the electrical energy in the signal is converted to heat. To compensate for this loss, amplifiers are used to amplify the signal.

Decibel:- The decibel (dB) measures the relative strengths of two signals or one signal at two different points. [to show that a signal has lost or gained strength]

** The decibel is negative if a signal is attenuated and positive if a signal is amplified.

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

Variables P_1 and P_2 are the powers of a signal at points 1 and 2 respectiv ex Suppose a signal ~~s~~ travels through a transmission medium and its power is reduced to one-half. This means that $P_2 = \frac{1}{2} P_1$.

Calculate the attenuation (loss of power)

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

$$= 10 \log_{10} \frac{0.5 P_1}{P_1}$$

$$= 10 \log_{10} 0.5$$

$$= 10(-0.3) = \underline{-3\,dB}$$

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

ex A signal travels through an amplifier, and its power is increased 10 times. calculate the Attenuation.

$P_2 = 10 P_1$

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

$$= 10 \log_{10} \frac{10 P_1}{P_1}$$

$$= 10 \log_{10} 10 = 10(1) = \underline{10\,dB}$$

ex The loss in a cable is usually defined in ~~decible~~ decibels per kilometer (dB/km). If the signal at the beginning of a cable with -0.3 dB/km has a power of 2 mW. What is the power of the signal at 5 km?

Solu The loss in the cable in ~~decible~~ decibels is 5×-0.3
$= -1.5\,dB$

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

$$-1.5 = 10 \log_{10} \frac{P_2}{P_1} \Rightarrow \frac{P_2}{P_1} = 10^{-0.15} = 0.71$$

$P_2 = 0.71 P_1$

$\Rightarrow 0.7 \times 2 = 1.4\,mW$

Distortion:- distortion means that the signal changes its form or shape. Distortion can occur in a composite signal made of different frequencies. Each signal component has its own propagation speed through a medium and therefore, its own delay in arriving at the final destination.

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

Propagation speed:- speed at which electrical signal can travel.

In other words, signal components at the receiver have phase different from what they had at the sender. The shape of the composite signal is therefore not the same.

Noise:- Noise is another cause of impairment. Several types of noise

- thermal noise
- induced noise
- cross talk
- impulse noise

may corrupt the signal.

thermal noise:- is random motion of electrons in a wire which creates an extra signal not originally sent by the transmitter.

Induced noise:- comes from sources such as motors and appliances.

Cross talk:- is the effect of one wire on the other.

Impulse noise:- is a spike that comes from power lines lightning and so on.

Signal-to-Noise Ratio (SNR) →

To find the theoretical bit rate limit, we need to know the ratio of the signal power to the noise power.

The signal to-noise ratio is

$$SNR = \frac{\text{average signal power}}{\text{average noise power}}$$

We need to consider the average signal power and the average noise power because these may change with time.

SNR is actually the ratio of what is wanted (signal) to what is not wanted (noise). A high SNR means the signal is less corrupted by noise; a low SNR means the signal is more corrupted by noise.

Because SNR is the ratio of two powers, it is often described in decibel units SNR_{dB}.

$$SNR_{dB} = 10 \log_{10} SNR$$

DATA RATE Limits →

A very important consideration in data communication is how fast, we can send data, in bits per second, over a channel. Data rate depends on three factors

1. The bandwidth available
2. The level of the signals we use
3. The quality of the channel (the level of noise)

Two theoretical formulas were developed to calculate the data rate:

- one by Nyquist for noiseless
- ~~by~~ second by a noisy channel.

Noiseless channel: Nyquist Bit rate : For a noiseless channel,

The Nyquist bit rate formula defines the theoretical maximum bit rate.

$$\text{BitRate} = 2 \times \text{bandwidth} \times \log_2 L$$

where bandwidth is bandwidth of the channel.

L → no of signal levels used to represent data.

* If the number of levels in a signal is just 2, the receiver can easily distinguish between a 0 and a 1. If the level of a signal is 64, the receiver must be very sophisticated to distinguish between 64 different levels.

Increasing the levels of a signal may reduce the reliability of the system.

ex Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

$$\text{Bit Rate} = 2 \times \text{bandwidth} \times \log_2 L$$

$$= 2 \times 3000 \times \log_2 2$$

$$= 6000 \text{ bps.}$$

* when signal level is 4

$$\Rightarrow 2 \times 3000 \times \log_2 4$$

$$= 12{,}000 \text{ bps.}$$

We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need? (6)

⇒

$$\text{Bit Rate} = 2 \times \text{Bandwidth} \times \log_2 L$$

Bit Rate: = 265 kbps = 265000

$$265000 = 2 \times 20000 \times \log_2 L$$

$$\log_2 L = 6.625$$

$$L = 2^{6.625} = \underline{\underline{98.7 \text{ levels}}}$$

Since this result is not a power of 2, we need to either increase the no. of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.

Noisy channel: Shannon Capacity:-

We cannot have a noiseless channel; the channel is always noisy. In 1944 Claude Shannon introduced a formula, called the Shannon capacity, to determine the theoretical highest data rate for a noisy channel:

$$\text{Capacity} = \text{bandwidth} \times \log_2 (1 + SNR)$$

Shannon formula there is no indication of the signal level, which means that no matter how many levels we have, we cannot achieve a data rate higher than the capacity to the channel.

Formula defines a characteristic of the channel, not the method of transmission.

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

$$C = B \log_2 (1 + SNR)$$

$$= B \log_2 (1 + 0)$$

$$= B \log_2 1$$

$$= B \times 0 = \underline{\underline{0}}$$

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

<u>ex</u> A telephone line normally has a bandwidth of 3000 Hz (300 to 3300Hz) asigned for data communications. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$C = B \log_2 (1 + SNR)$$

$$= 3000 \log_2 (1 + 3162)$$

$$= 3000 \log_2 3163$$

$$= 3000 \times 11.62$$

$$= 34860 \text{ bps.}$$

This means that the highest bit ~~ratio~~ rate for a telephone line is 34860 kbps. If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

~~Throughput~~

Performance:- One important issue in networking is the performance of the network - how good is it?

Bandwidth:- One characteristics that measures Network performance is bandwidth. The term can be used in two different contexts with two different measuring values: bandwidth in hertz and bandwidth in bits per second.

Bandwidth in Hertz:- Bandwidth in hertz is the range of frequencies contained in a composite signal or the range of frequencies a channel can pass.

Bandwidth in Bits per Seconds:- The term bandwidth can also refer to the number of bits per second that a channel, a link or even a network can transmit.

In networking, we use the term bandwidth in two contexts.

- The first bandwidth in hertz, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
- The second, bandwidth in bits per second refers to the speed of bit transmission in a channel or link.

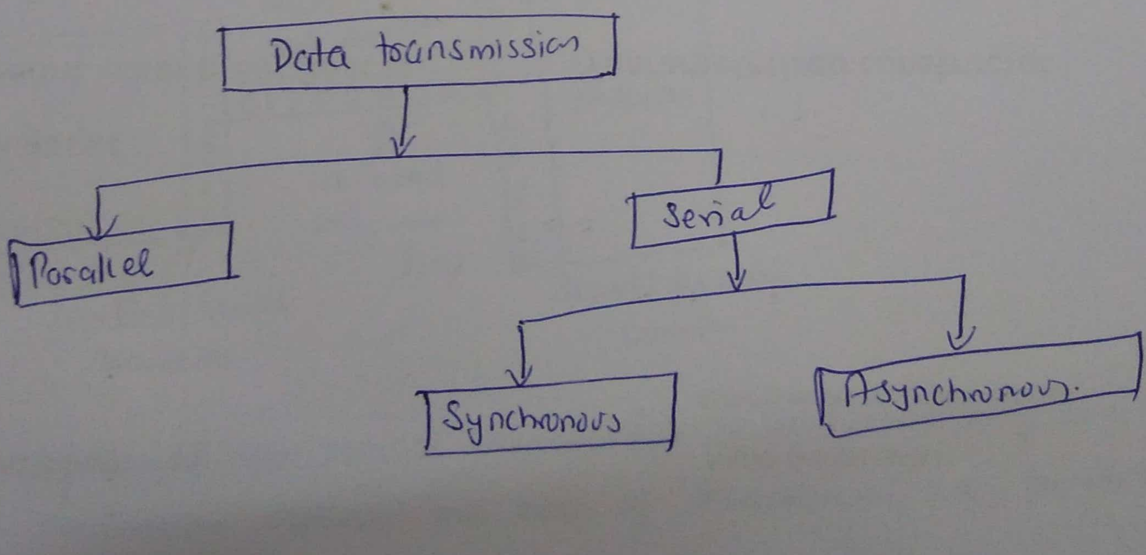
Digital transmission:- Once we have encoded our information into a format that can be transmitted, the next step is to investigate the transmission process itself. PC generates a digital signal but needs an additional device to modulate a carrier frequency before it is sent over a telephone line. How do we relay the encoded data from the generating device to the next device in the process? The answer is a bundle of wires, a sort of minicommunication link, called an interface.

Because an interface links two devices not necessarily made by the same manufacturer, its characteristics must be defined and standards must be established.

The transmission of binary data across a link can be accomplished either in parallel mode or serial mode.

Parallel mode:- multiple ~~bi~~ bits are sent with each clock pulse.

Serial mode:- one bit is sent with each clock pulse. Serial transmission are two subclasses.
- Synchronous
- Asynchronous.



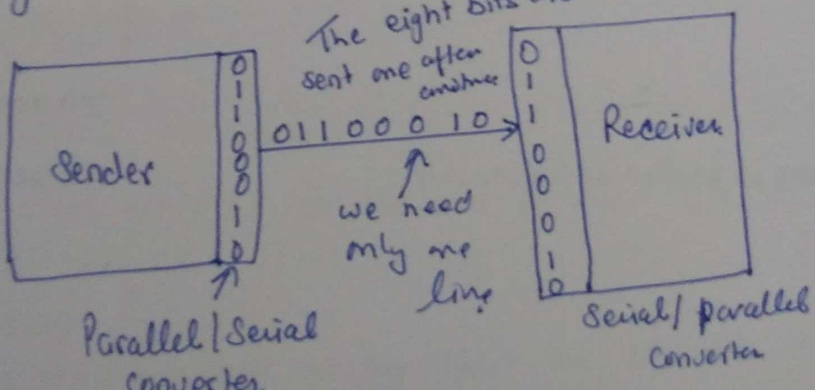
Parallel transmission → Binary data, consisting of 1s and 0s, may be organized into groups of n bits each. By grouping, we can send data n bits at a time instead of one. This is called parallel transmission.

The mechanism for parallel transmission is a conceptually simple one: use n wires to send n bits at one time. That way each bit has its own wire, and all n bits of one group can be transmitted with each clock pulse from one device to another.

The advantage of parallel transmission is speed.

Disadvantage : cost

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



The advantage of serial over parallel transmission is that with only one comm channel, serial transmission reduces the cost of transmission over parallel by roughly a factor of n.

Since communication within devices is parallel, conversion devices are required at the interface between the sender and the line (parallel-to-serial) and between the line and the receiver (serial-to-parallel).

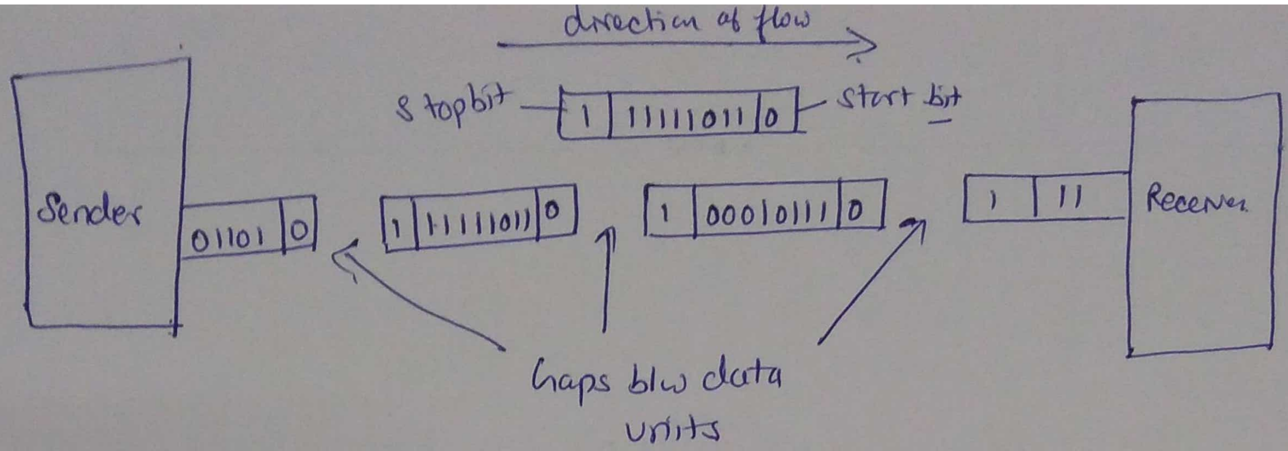
Serial transmission occurs in one of two ways.

- asynchronous
- synchronous.

Asynchronous:- is so named because the timing of a signal is unimportant.
Instead, information is received and translated by agreed-upon patterns.
Without a synchronizing pulse, the receiver cannot use timing to predict when the
next group will arrive. To alert the receiver to the arrival of a new group, therefore
an extra bit is added to the beginning of each byte. This bit, usually a 0,
is called the start bit. To let the receiver know that the byte is
finished, one or more additional bits are appended to the end of the byte.
These bits, usually 1s are called stop bits. By this method, each byte
~~may then be followed by a~~ is increased in size to at least 10 bits, of
which 8 are information and 2 or more are signals to the receiver.

In asynchronous transmission, we send one start bit (0) at the beginning and one or more stop bits (1s) at the end of each byte. There may be a gap b/w each byte.

The start and stop bits and the gap alert the receiver to the beginning and end of each byte and allow it to synchronize with the data stream. This mechanism is called asynchronous because, at the byte level, sender and receiver do not have to be synchronized.

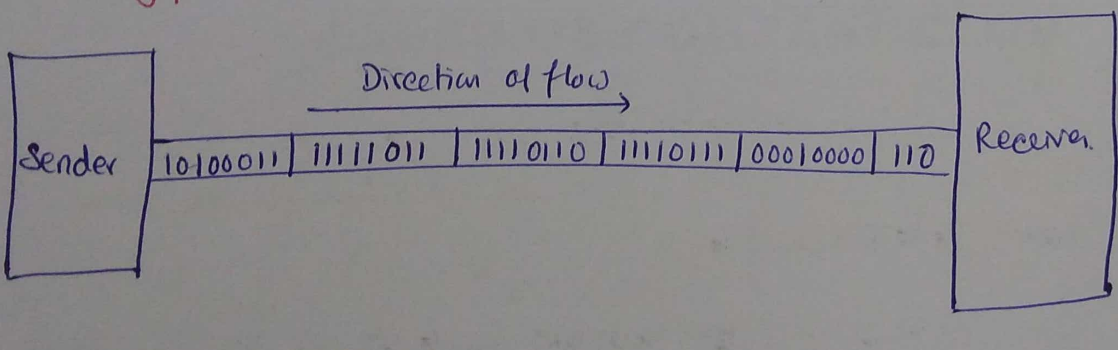


Advantages:- cheap, effective

disadvantage :- slower [low-speed]

Synchronous Transmission:- the bit stream is combined into longer "frames" which may contain multiple bytes. Data are transmitted as an unbroken string of 1s and 0s, and the receiver separates that string into the bytes or characters it needs to reconstruct the information.

In synchronous transmission, we send bits one after another without start/stop bits or gaps. It is the responsibility of the receiver to group the bits.



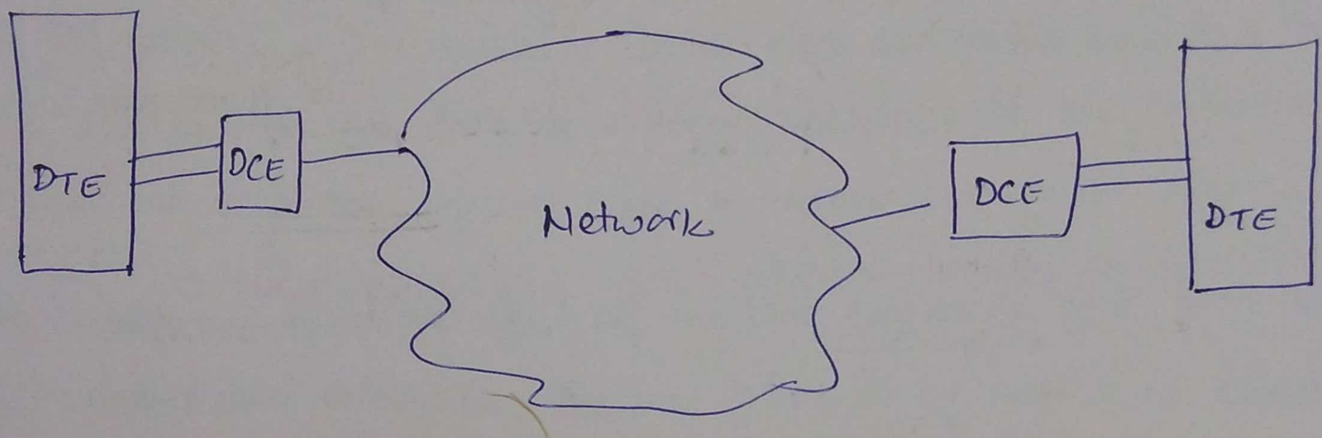
Advantage:- speed.

DTE- DCE INTERFACE :-

DTE → data terminal equipment or
DCE :- data ckt - terminating equipment.

There are usually 4 basic functional units involved in the commⁿ of data

- DTE
- DCE on one end and DCE DTE on other end.



* The DTE generates the data and passes them, along with any necessary control characters, to a DCE. The DCE converts the signal to a format appropriate to the transmission medium and introduces it onto the n/w link.

DTE → data terminal equipment includes any unit that functions either as a source of or as a destination for binary digital data. At the physical layer, it can be a terminal, micro-computer, computer, printer, fax machine or any other device that generates or consumes digital data.

Ex In human communication, brain are DTEs. And vocal chords and mouth are DCE. Air and telephone wire is transmission medium.

A DTE is any device that is a source of or destination for binary digital data.

DCE :- Data-ckt-terminating equipment includes any functional unit that transmits or receives data in the form of an analog or digital signal through a network. At the physical layer, a DCE takes data generated by a DTE, converts them to an appropriate signal, and then introduces the signal onto the telecommunication link. Commonly used DCEs at this layer include modems.

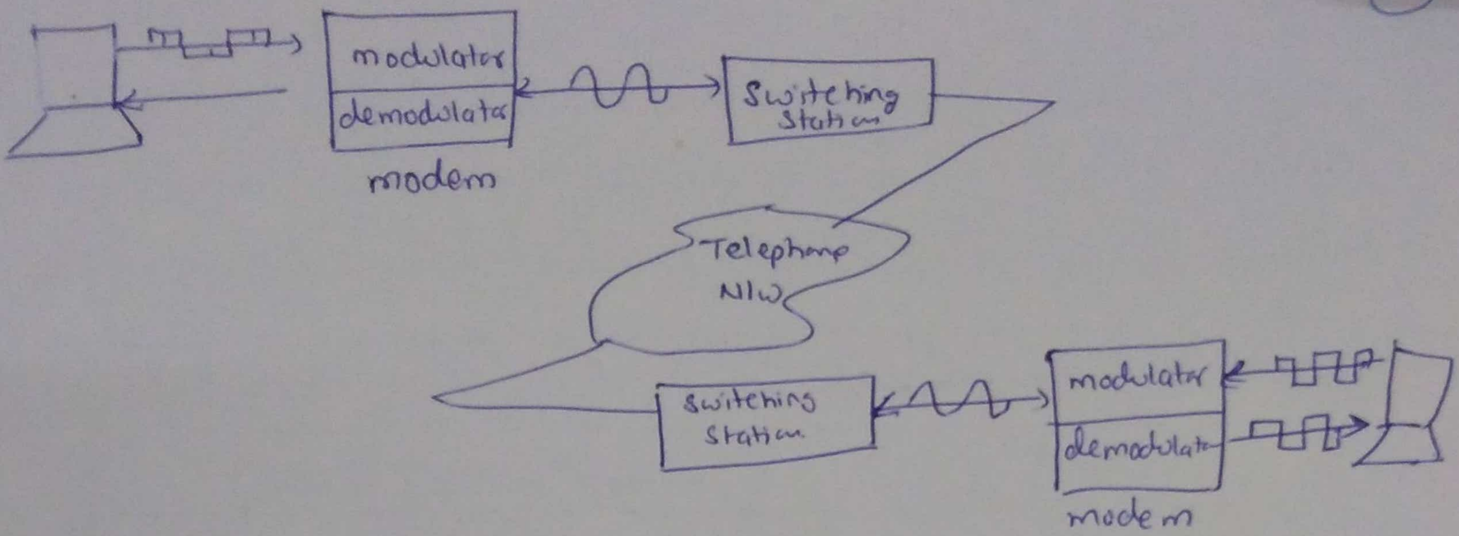
In any network, a DTE generates digital data and passes them to a DCE the DCE converts the data to a form acceptable to the transmission medium and sends the converted signal to another DCE on the N/w.

The second DCE takes the signal off the line, converts it to a form usable by its DTE, and delivers it. The two DTEs do not need to be coordinated with each other, but each must be coordinated with its own DCE, and the DCEs must be coordinated so that data translation occurs without loss of integrm intergrity.

A DCE is any device that transmits or receives data in the form of an analog or digital signal through a network.

MODEMS → The most familar type of DCE is a modem. modem stands for modulator/demodulator. A modulator converts a digital signal into an analog signal using ASK, FSK, PSK or QAM. A demodulator converts an analog-to-digital converter, it is not in fact a converter of any kind.

A modulator converts a digital signal to an analog signal. A demodulator converts an analog signal to a digital signal.



<u>Cable modems</u> → The data rate limitation of traditional modems is mostly due to the narrow bandwidth of the Local Loop telephone line (up to 4KHz). Cable TV provides residential premises with a coaxial cable that has a bandwidth up to 750 MHz and sometimes even more. This bandwidth is normally divided into 6 MHz bands using frequency division multiplexing.