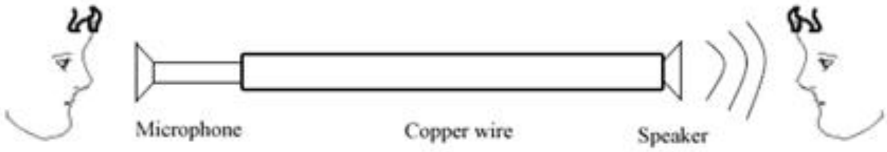
1. Overview of Communication & Networks

1.1 People Communication

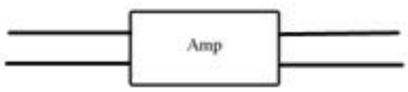
People use voice as the main communication method to exchange information. Similarly computers use data to exchange information. To exchange information, we need a media. If two people are close each other, the voice transmission is done through air.

The voice travels as a sound signal through the air. In this case, we called that the air is the transmission media.

If the two people are far away they cannot talk each other in natural voice through air. The sound signal should be converted to an electric signal and send through a transmission media. Normally the transmission media is two copper wires.



If the distance between two persons further increases, an amplifier should be used in between.



If the two people are very far away (e.g. : Colombo and Kandy), the telephone network should be used. The telephone network is called public switched telephone network (PSTN).

The telephone network consists of many components. Telephone, Copper Wires, Telephone Exchanges, Multiplexers, Transmission Equipments etc.

1.2 Computer Communication

Computer can communicate each other by using an electrical signals only. Normally this is called data. In order to send the data, a transmission media is needed. If the two computers are close by, copper wires can be used as transmission media. In addition an interface device is required to connect the computer to the transmission media. (Similar to telephone which is used as the interface equipment between the person and transmission media.)

If many computers need to exchange information among each other, the computers should be connected in a systematic manner. This is called a Computer Network. If close by computers are connected each other, such a network is called a Local Area Network (LAN). If far away computers are connected each other, such a network is called Wide Area Network (WAN).

Similar to telephone networks, computer networks also have many devices such as hubs, switches, routers etc.

1.3 Transmission Media

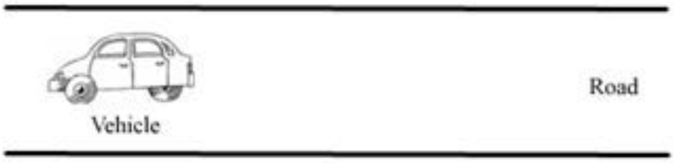
Just like vehicles travel on roads, the signals (data) travels through transmission medias. There are three types of transmission medias mainly used,

Copper
Fibre
Air (free space)

Media	Signal Type
Copper	Electrical
Fiber	Optical[Light]
Air	Radio

1.4 Signals and Transmission Medias

Can any vehicle travel on any road? We know that before we travel through any road, we make sure that the vehicle can go through that road without any problem. Similarly, before we send any signal through a transmission media, we should make sure that the signal can send through the transmission media without any problem. In this case signal analogous to vehicle and the road analogous to transmission media.



In order to travel a vehicle through a road, the width of the vehicle should be less than the width of the road. The width measures in meters. The similar unit of signal is frequency. The frequency measures in Hertz (Hz). The width of vehicle analogous to width of frequency of signal and it is called frequency bandwidth. In order to send a signal through a transmission media, the bandwidth of the signal should be less than the bandwidth of transmission media.

1.5 Transmission Media Characteristics

When a signal travels through a transmission media it will encounter many problems.

The main two problems are,

Noise

Attenuation

Different transmission medias have different noise characteristics and attenuation characteristics. Different copper wires have different noise and attenuation characteristics. Different fibre optics have different noise and attenuation characteristics.

Apart from this the radio signal may encounter interference problem.

1.6 Types of Signals

The signals can be mainly categorized as,

Analog Signals
Digital Signals

When a natural signal converts to an electrical signal it does not have a definite pattern. Such signals are called analog signals. (e.g. voice to electrical).

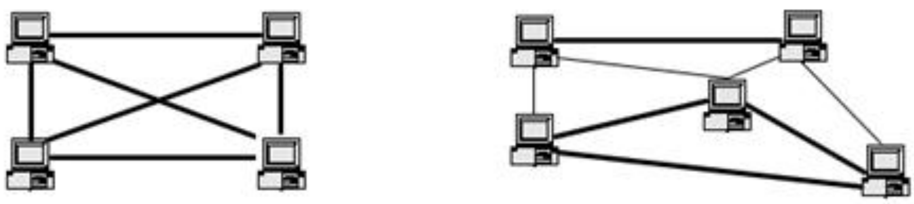
The computers are communicating by using digital signals where it has a definite number of voltage or current levels.

Analog signals are measured with frequency and frequency bandwidth and digital signals are measured with bits and bit rates.

In some occasions it is necessary to convert analog signals to digital signals and vice versa.

1.7 Networks

Network is used to exchange information between two or more end devices. (Telephones or computers).

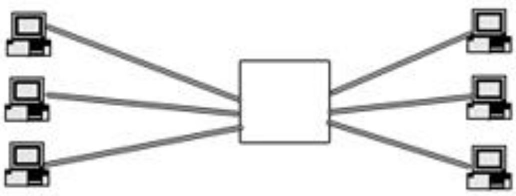


No. of Devices	No. of Connections
1	1
2	3
3	6
10	450

In order to connect 10 telephones each other, 450 copper pairs are needed.

Therefore it is impossible to connect individual pairs for a large number of telephones or computers. Therefore, one of the economical methods is switched connection or broadcast connection.

Switched Connection

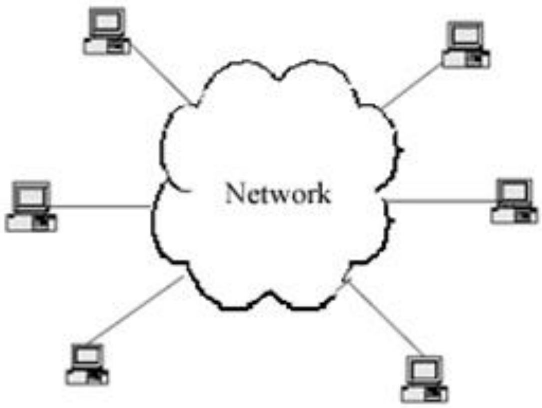


Whenever necessary two telephones/computers are connected. There are two methods of switching.

- ③ Circuit Switching
  Telephone networks used circuit switching.

- ③ Packet Switching
  Computer networks used packet switching.

Broadcast Networks



In broadcast network, one device transmits and all other devices receive the signal. Although all devices receive the same signal only correct recipient will accept the message. Others ignore it.

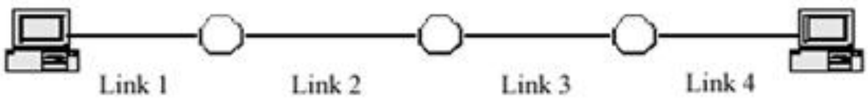
1.8 Computer Communication

Computer to computer communication is done to exchange information of a particular application. Widely used applications are, e-mail, World Wide Web (Internet) etc.

The following aspects to be considered for computer communication.

(a) The user of the application should have the access to the network/computers.

(b) The information should be converts to bit streams.
The data encryption to be done for secure transmission.
The data compression to be done to reduce the number of transmitted bits.



(c) Check point for group of bits to be included to avoid retransmission of whole data in case of a problem occurred.

(d) The data may go through several junctions called routers.
Normally the data send as packets. A packet is a group of small number of bits. A message consists of several packets.

Delivery of messages from the transmit end (source) application to receive end (destination) application.

(e) Delivery of packets from the source to destination. (Computer to Computer).

(f) Link wise reliable data transfer.

(g) Interface to transmission medium. All bits should be converted to electrical or optical (light) signals.

In addition, there are many more things to be considered for computer communication. These will be discussed in detail in other chapters.

The above a,b,c,d,e,f and g functions are the seven stages to be followed in computer communication. This was introduced by International Standard Organization (ISO) and it is called ISO-OSI (Open System Architecture) seven layers. They have given a name for each layer as follows.

ISO - OSI Seven Layers

Application	-	Layer 7
Presentation	-	Layer 6
Session	-	Layer 5
Transport	-	Layer 4
Network	-	Layer 3
Data Link	-	Layer 2
Physical	-	Layer 1

Salient points on ISO - OSI 7 layers.

③ The physical layer converts the raw bits to electrical signals. It has both hardware and software components.

③ All other layers are operated by software only.

③ Layer 1 to layer 4 is network related activities.

③ Layer 5 to Layer 7 is Application related activities.

Data link and physical layers are required for Network Access. Therefore both layers together can be considered as Network Access Layer.

1.9 Layered Architecture

The above demarcation of different functions (as shown in ISO-OSI seven layers) is called layered architecture. The advantage of such architecture is to make path to have more manufacturers to the market for the same network devices.

Please consider the following network.

The network consists of switches and routers. We can purchase two switches from two vendors two routers from another two vendors and implement the above network.

In order to satisfy this requirement the function of switches to be defined. The function of the routers to be defined. In addition the interfaces of each device to be defined. This means that the standards for the functions and interfaces to be defined. If the functions and interfaces of each layer is defined, such as system is called an open system. (Otherwise if it is vendor dependent and it is called proprietary)

The ISO-OSI layers define the functions of each layer as follows.

Layer	Functions
Physical Layer	• Interface with the communications hardware and transmission medium. • Transmission of an unstructured stream of data bits.
Data-link Layer	• Transmission of frames containing data and/or control information. • Provides error control and flow control over the data link.
Network Layer	• Source Computer to destination computer delivery of packets. • Logical addressing and routing.
Transport Layer	• Provides a reliable end-to-end transfer of data between the two Applications.
Session Layer	• Manages the session [establishment, dialogue exchange, recovery, termination].
Presentation Layer	• Resolves differences in data representation in end systems. • Provides common transfer syntax.
Application Layer	• Enables the user to access the network. User can be a human or software.

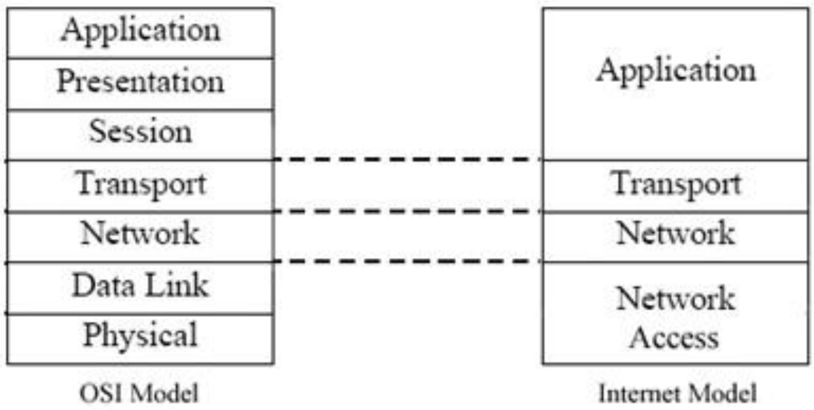
Standard Bodies

The standards for each layer is defined by ISO. Some of the useful standard bodies are

- International Telecommunication Union - Telecommunication Sector (ITU-T) former International Telegraph and Telephone Consultative Committee (CCITT)
- American Institute of Electrical and Electronic Engineers (IEEE)
- Europen Telecommunication Standards Institute (EISD) are some of the standard bodies.

The ISO and IEEE produce standards for use by computer manufacturers. ITU-T defines standards for connecting equipment to public networks.

In addition **Internet Society** defines standards for computer communication. It defines the following Layers and its relationship to ISO -OSI layers is given below.



Protocols

In order to communicate between two persons same language to be used. Similarly, communicate between two computers, same protocol to be used. In fact a protocol is a set of rules governing the exchange of data between two computers. The protocols are used in each layer. One layer can have more than one protocol. For example, the transport layer protocols used by Internet Society are TCP and UDP. There network layer protocol is IP.

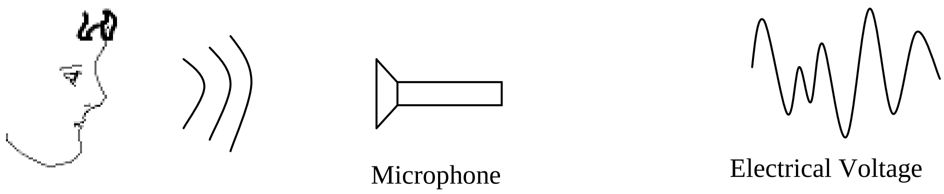
Some of the protocols used in different layers are given below.

Layer	Protocols
Application Layer	HTTP, FTP, SMTP, SNMP
Presentation Layer	X.216
Session Layer	X.215
Transport Layer	NetBEUI, TCP, UDP, X.214
Network Layer	IP, IPX, X.213
Data Link Layer	PPP, HDLC, X.212
Physical Layer	X.21, X.21 bis, V.24

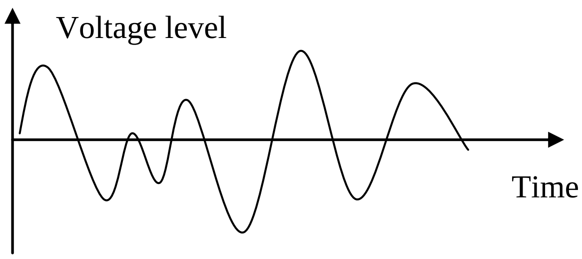
2. Communication Fundamentals

Analog Signal

A Signal is an electrical voltage or current, which varies with time. It is used to carry some information from one end to another. A typical example is a voice signal.



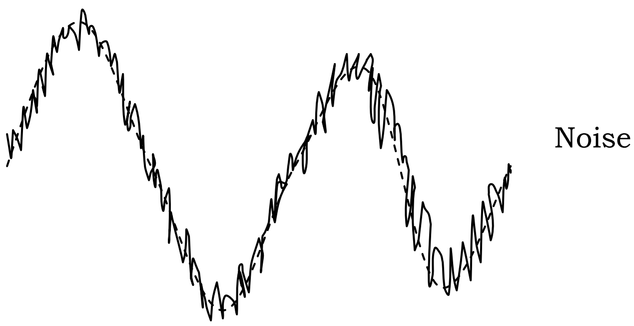
The microphone converts the sound signal to an electrical voltage.



This signal is continuously varying with time. This type of signal is called an analog signal.

Noise

Noise is an unwanted signal. There are some freely moving electrons in the conductors. An electron movement is a current. Unwanted movements of electrons create unwanted currents. That is an unwanted signal or noise. Please note that there are some other ways of creating noise such as transistor noise, shot noise, galactic noise etc.

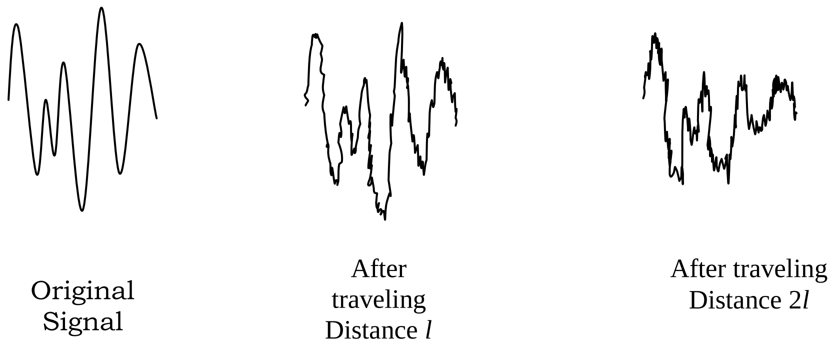


If any signal goes through a conductor it mixes with noise. The ratio of signal level and noise level is called the S/N or Signal to Noise ratio. The quality of a signal is measured as S/N

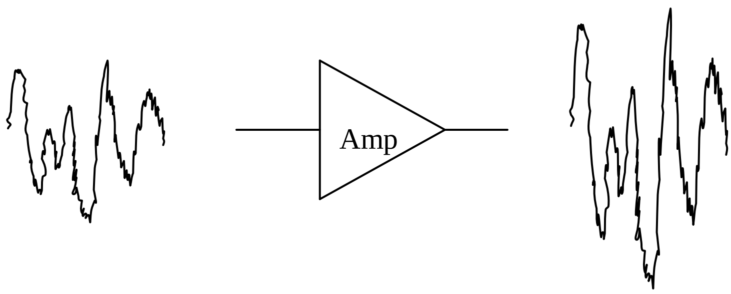
Quality of a signal = S/N

Higher the S/N better the signal quality.

If an analog signal travels a long distance, more and more noise is added to it. Therefore, the S/N reduces and the signal quality is degraded. The biggest disadvantage of an analog signal is, the noise cannot be removed and it accumulates.



The other problem is, if the signal is amplified the noise is also amplified.



Power Ratios

Normally the power ratio measured by a unit call decibel (dB). Consider a signal of power – P1 and another signal of power – P2.

The power ratio is = P1 / P2
= log (P1/P2) Bell
= 10 log (P1/P2) dB

Power ratio = 10 log (P1/P2) dB

Eg. (I) if P1 = 1000mw and P2 = 10 mw.

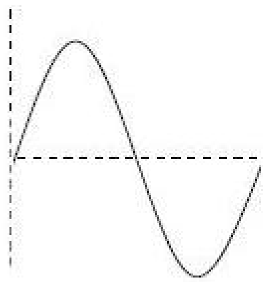
(P1 / P2) = 1000 / 10 = 100.
10 log 100 =20dB

Eg. (II) Consider two signals which have power level s of 1000mw and 1mw.

The power ratio is = 10 log (1000/1) dB
= 30 dB.

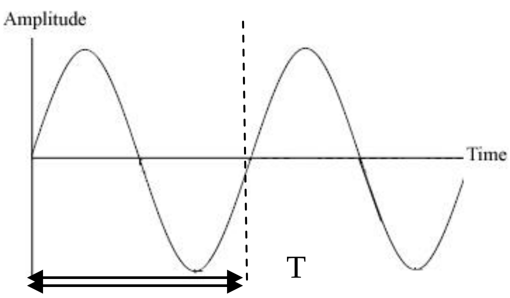
Sinusoidal signal

Mathematics has sine, cosine and tan functions. A signal which has a sine curve characteristic is called a Sinusoidal signal.



Basic Characteristics
The basic Characteristics of a Sinusoidal signal are,

- Amplitude
- Frequency
- Phase



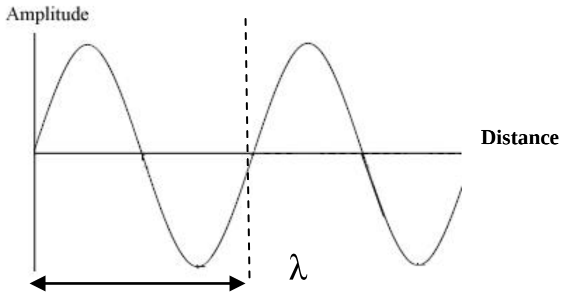
Amplitude characteristic

1 Cycle (1 Period)

1 Cycle = T s
T s = 1 Cycle
1 s = 1/ T Cycles

Number of Cycles per Second is called as Frequency and it is measured in Hz
So Frequency = 1/ T

$$\boxed{F = 1/T}$$



1 wave length

For $\quad T\ s = \lambda$

$\qquad 1\ s = \lambda / T$

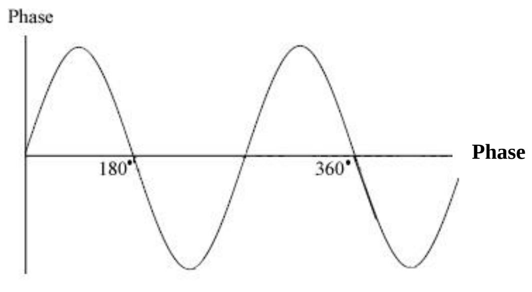
So Velocity (Speed) = λ / T

$V = \lambda / T$

$V = 1/T * \lambda$

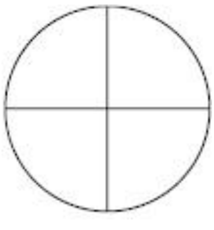
$V = F * \lambda$

$$\boxed{V = F\lambda}$$



Phase characteristic

Phase Diagram



Angular velocity ω

$\omega = \frac{\theta}{t}$

$\theta = \omega t$

$$\boxed{\omega = 2\pi f}$$

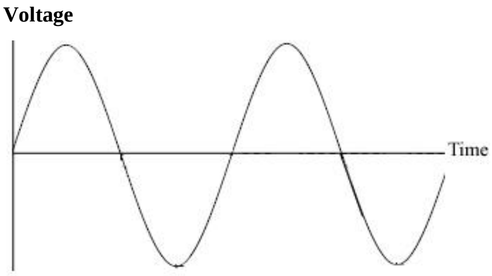
Relationship with power and voltage

RMS (Root Mean Square)

For an alternating current (AC), the rms value is equal to the peak value divided by the square root of 2.

[For a cyclic quantity, it is equal to the square root of the average of the squares of the quantity at each instant over a complete cycle; where the variation is a sine wave, the rms value is equal to the peak value divided by √2. In electrical engineering, for example, the rms value of the current or voltage in an AC circuit is used in power calculations. The rms value is also used as a measure of the amplitude of randomly varying quantities, such as the noise in a telecommunications channel.]

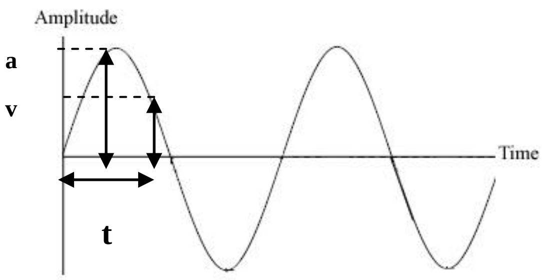
V = Peak Voltage



RMS Voltage = $\frac{V}{\sqrt{2}}$

RMS Power = $\frac{V^2}{2}$

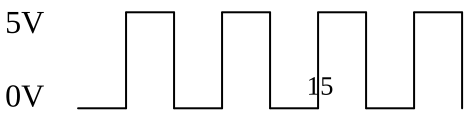
Mathematics representation



V = a sin (ωt)
V = a sin (2πf t)

$\boxed{V = a \sin (2\pi f\, t)}$

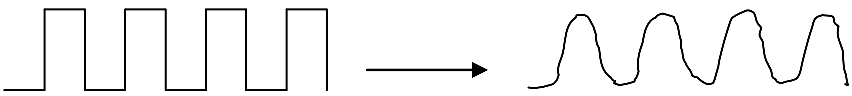
Digital Signal



5V=1
0V=0

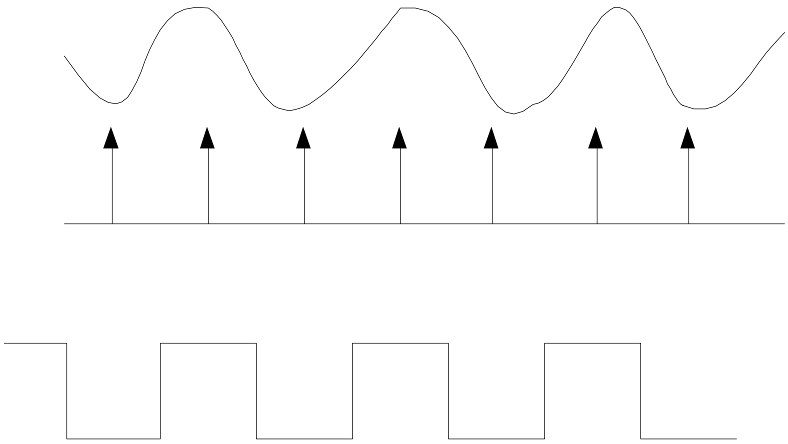
A discrete electrical signal, which has only two levels, is called a digital signal. These two levels are named as “1” and “0”. Normally a digital signal has a fixed number of bits and travels within a particular duration. This is called the pulse rate or bit rate.

The digital signal also gets mixed with noise.



Original Signal After Transmission

The centre location of the digital signal can be identified by using a special bit pattern called a clock signal.



By checking the level at the centre location of each bit it can be decided whether it is a “0” or a “1”. This process is called the regeneration of the signal. By this method, the original signal can be generated and noise can be completely eliminated. This is the main advantage of a digital signal over an analog signal.

But there is a possibility to change the bit from 1 to 0 or 0 to 1 due to high noise. This is called an error. However there are many methods to correct these errors. Hence at the receive end the original bit pattern can be obtained. Hence digital signal quality will not depend on the distance traveled by the signal.

How to convert an analog signal to a digital signal?

The most commonly used method is the Pulse Code Modulation (PCM). Normally all voice telephone channels use this method.

Voice telephone channel frequency band is = 0.3 kHz to 3.4 kHz.

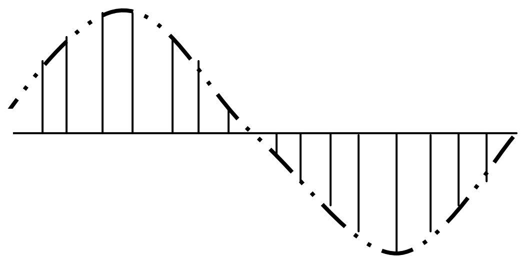
The process can be described as follows.

(i) Sampling
(ii) Quantizing
(iii) Encoding

What is sampling?

The samples of an analog signal are taken.

The sampled signal is called a pulse amplitude modulated signal.



It can be shown that the original signal can be constructed at the receive end using these samples.

Sampling Theorem (Nyquist's Theorem)

In order to completely reconstruct the original signal from the samples, the sample rate should be at least twice its highest frequency.

i.e. sampling rate $\geq$ 2 X highest frequency

The highest frequency of telephone voice channel is 3.4 kHz.

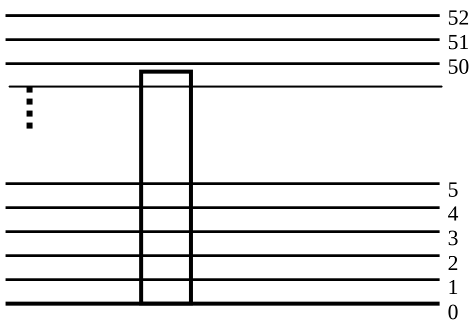
Hence sampling rate $\geq$ 2 X 3.4
$\geq$ 6.8 kHz

Hence a sample rate of 8 kHz is selected.

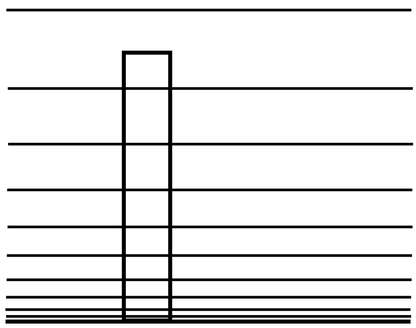
i.e. An analog signal is sampled at a rate of 8000 samples per second.

Quantizing

The samples are divided into many discrete levels. Then each sample is numbered according to their corresponding level.



There is no exact level for the above sample. The approximate level of the above sample is 50. Therefore the level of the sample is considered as 50. Hence an error will be introduced. This is called the quantizing error. This will reflect as noise at the receive end and it affects to the signal to noise ratio at the receive signal. It can be shown that, higher amplitude pulses will have high S/N and small amplitude pulses have low S/N. But we expect equal S/N for all pulses. In order to achieve this, non-linear quantizing is introduced.



It can be shown that using this method equal S/N can be obtained for all pulses.

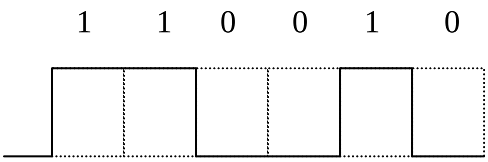
Encoding

After quantizing the corresponding level it is to be represented in some manner.

E.g. If the level is 50, it can be represented as,

Decimal	-	50
Hexa	-	32
Octal	-	62
Binary	-	110010

The 110010-bit pattern should be represented as an electrical signal, i.e. current or voltage. To represent a decimal number 10 voltage levels are required. Likewise 16, 8 and 2 voltage levels are required for hexa, octal and binary respectively. But practically representing more than two voltage levels is difficult. The most convenient and reliable method is using two levels. i.e. binary



This is called a bit stream.

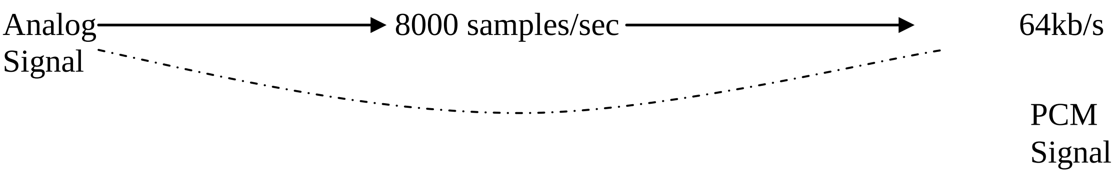
Then we have to decide, how many quantizing levels are required. The more quantizing levels are used more bits are required. It may cause to increase the bit stream and hence the bandwidth. Therefore, an optimum number of levels are to be selected. The standard number of levels is 256. (By CCITT)

$$2^8 = 256$$

In order to represent 256 levels 8 bits are required. Hence each pulse is encoded to 8 bits.

1 sample	=	8 bits
Signal	=	8000 samples/sec
	=	8000 x 8 bits /sec
	=	64000 bits/sec
	=	64 kb/s

Therefore, bit rate of a digital telephone channel is 64 kb/s.



Modulation

Modulation is a technique used to send information by modifying the characteristics of a basic electromagnetic signal. The basic signal is called the carrier signal.

The characteristics of a signal are amplitude, frequency and phase.

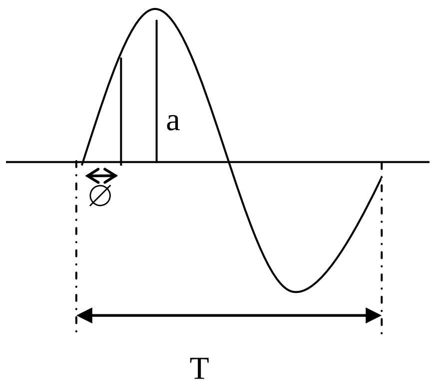
A signal can be represented by

$$a \text{ Sin } (\omega t + \varnothing)$$

a - amplitude

ω - $2\pi f$ f – frequency, ω - angular velocity

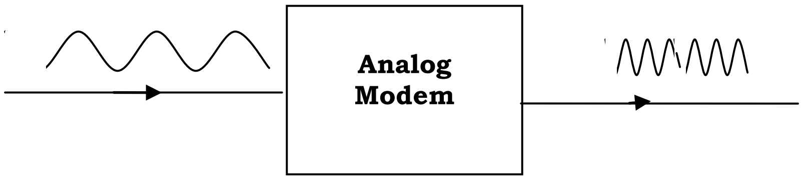
$\varnothing$ - Phase



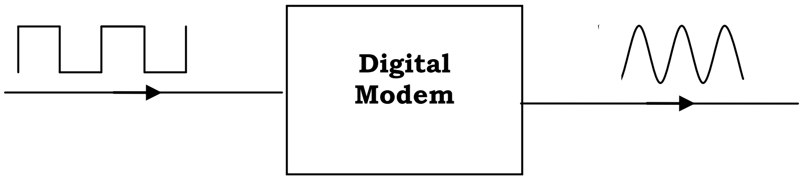
T = Period

$$f = \frac{1}{T}$$

Modulation can be used to convert a low frequency analog signal to a high frequency analog signal,

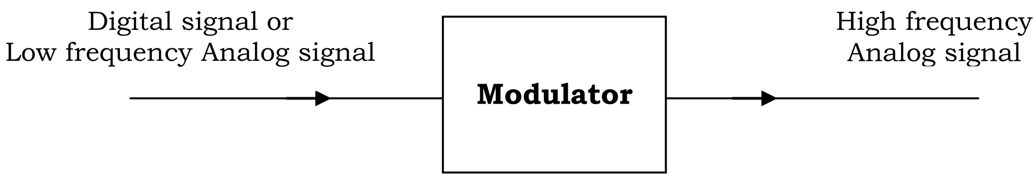


or a digital signal to an analog signal. For example a modem falls into the second category



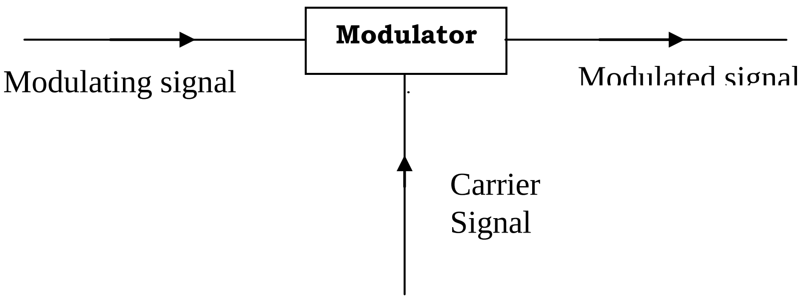
The input bit rate can be 9.6, 14.4, 19.2, 28.8, 56 kb/s. The output is an analog signal of frequency band 0.3 – 3.4 kHz.

Another application of modulation is to convert an analog or a digital signal to a very high frequency radio signal to transmit it through free space. (Broadband Radio Transmission)



(Radio Transmission is discussed in another section)

Modulation Process



Modulating Signal

This is the useful signal. This can be an analog signal or a digital signal. If the modulating signal is analog it is called analog modulation. If the modulating signal is digital, it is called digital modulation.

Carrier Signal

This is a high frequency analog signal.

Modulated Signal

The three characteristics of any signal are amplitude, frequency and phase. One of these characteristics is changed according to the shape of the input analog signal or the bit pattern of the input digital signal.

Modulation Methods

If the modulating signal is an analog signal, the three modulation methods are called,

- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation (PM)

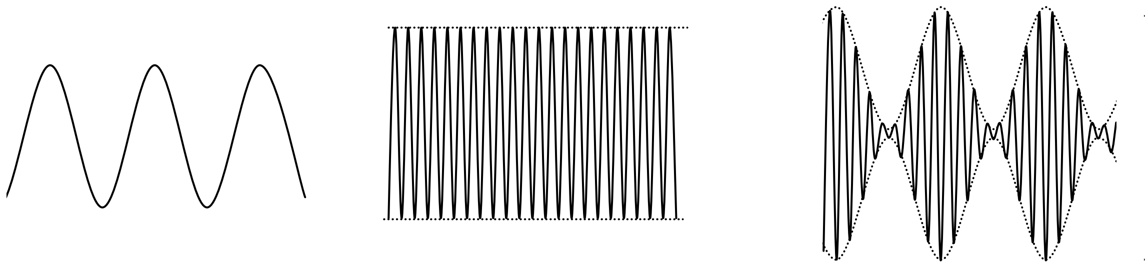
▪

If the modulating signal is a digital signal, the three modulation methods are called,

- Amplitude Shift Keying (ASK)
- Frequency Shift Keying (FSK)
- Phase Shift Keying (PSK)

Analog Modulation

Amplitude Modulation (AM)



Modulating Signal   Carrier Signal   Modulated Signal

Amplitude of carrier signal varies according to the amplitude of modulating signal. The envelop of modulated signal is same as the shape of modulating signal.

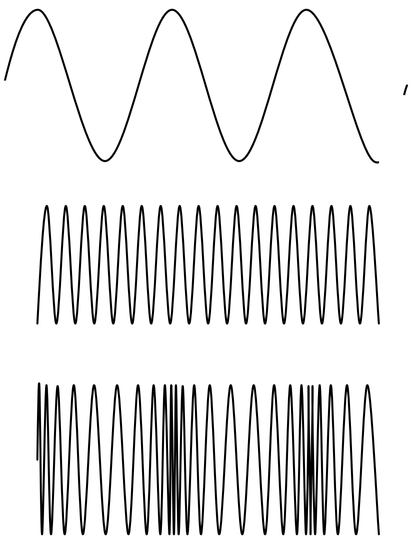
Please note that the frequency or phase of the carrier signal is not changed.

<u>Frequency Modulation</u>

Modulating Signal

Carrier Signal

Modulated Signal



The carrier signal frequency changes according to the amplitude of the modulating signal. When amplitude increases, the modulated carrier signal's frequency increases. If the modulating signal amplitude is negative, the frequency of the modulated carrier signal is decreased.

Please note that the amplitude and phase of the carrier signal is not changed.

Phase Modulation

Same as AM or FM. Instead of Carrier Amplitude or Frequency the carrier phase is changed.

It is not possible to show it pictorially.

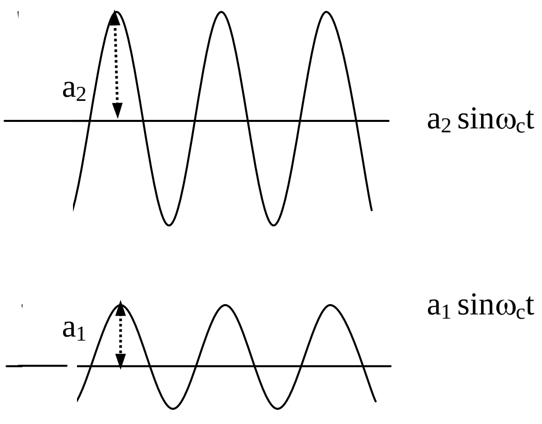
Digital Modulation

The digital signals are transmitted as 1s and 0s. The characteristic of the carrier signal is changed according to 1 or 0. That means there can be two states of amplitude, frequency or phase. The modulator switches (keying) the carrier to relevant state.

Amplitude Shift Keying (ASK)

The two states are,

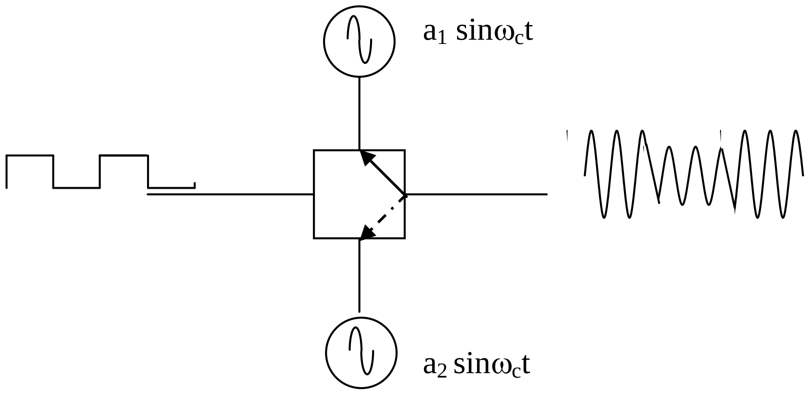
0 – amplitude 1 (a_1)
1 – amplitude 2 (a_2)



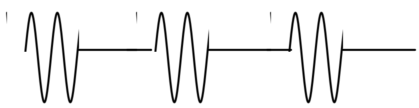
ω_c - $2\Pi f_C$ f_c – Carrier frequency

Please note that the frequencies of both carrier signals are same.

$a_2 > a_1$



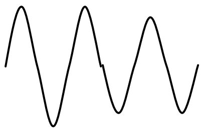
If a_1 = 0V an a_2 = 1V input bit stream is 1 0 1 0 1 0, then the modulated signal pattern will be,

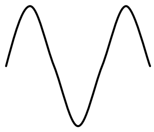


Frequency Shift Keying (FSK)

The two states are,

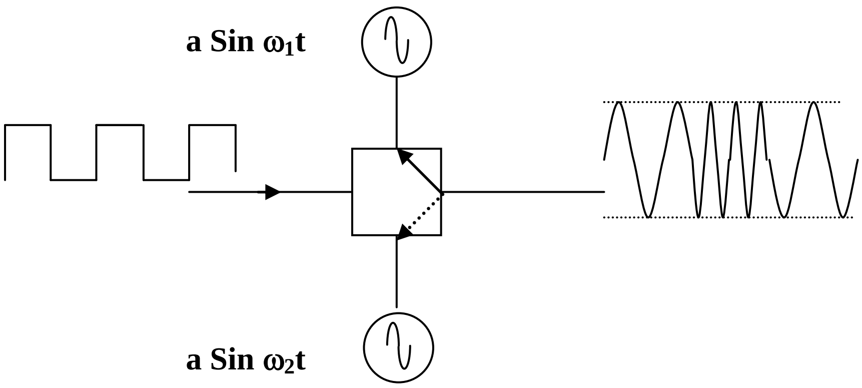
0 - frequency 1 (f1)
1 - frequency 2 (f2)

f_1  $a \text{ Sin } \omega_1 t$ $\omega_1 = 2\pi f_1$

f_2  $a \text{ Sin } \omega_2 t$ $\omega_2 = 2\,\pi f_2$

Note that the amplitude of both signals is same.

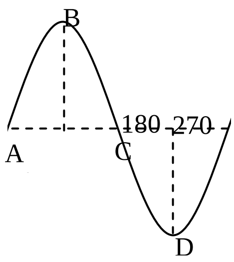
$\omega_1 > \omega_2$



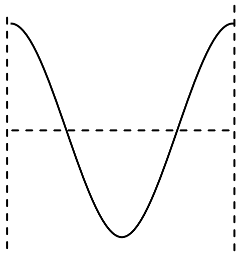
Phase Shift Keying (PSK)

In this method, the carrier signal phase is shifted according to the input digital signal.

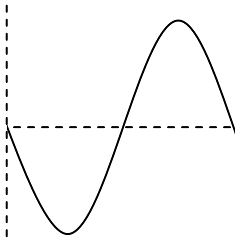
Let us first understand the phase of a signal.



The phase difference between A and B is 90^0.
In other words the point B is 90^0 phase shifted.

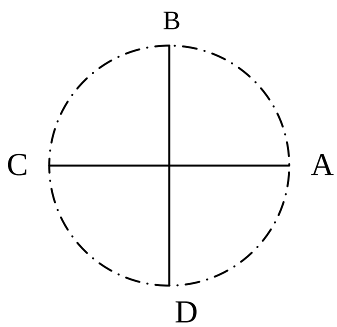


90^0 phase shifted signal.

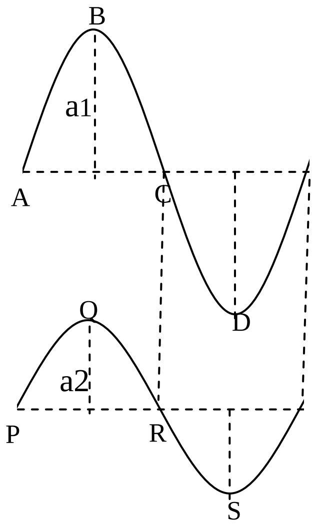


180^0 phase shifted signal.

This also can be represented by using a phaser diagram.



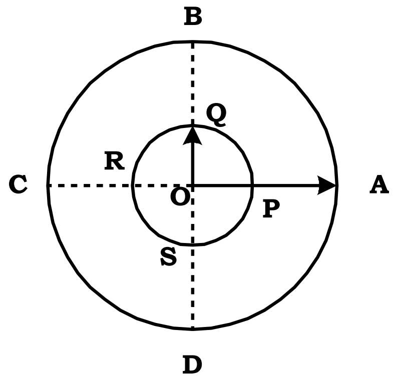
Consider two sinusoidal signals that have the same frequency but different amplitudes.



Signal 1 $a_1 \sin \omega t$

Signal 2 $a_2 \sin \omega t$

The phaser diagram can be drawn as follows.

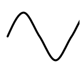


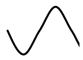
$OA=a_1$
$OQ=a_2$

The PSK has different versions.
BPSK, QPSK, 8PSK, 16PSK etc.

<u>Bipolar Phase Shift Keying (BPSK)</u>

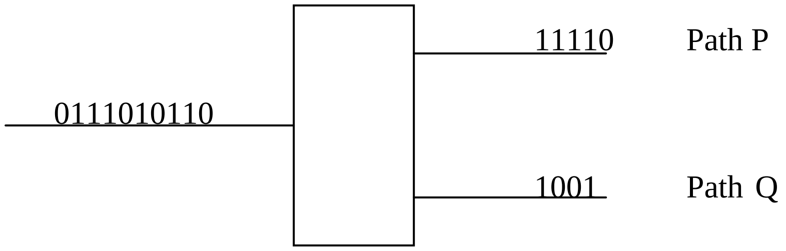
There are only two phases.

0 - no phase shift. 

1 - 180^0 phase shift 

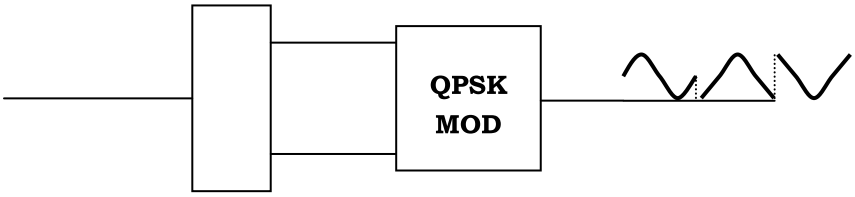
Quadrature Phase Shift Keying (QPSK or 4PSK)

In this method, first the input data stream is divided into two parallel streams.



Divider

First bit goes to P, second bit goes to Q, third bit goes to P, forth bit goes to Q and so on.

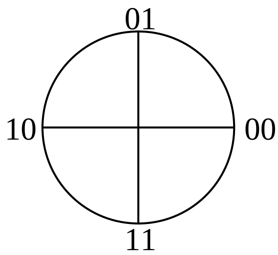


Divider

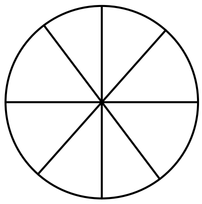
At the input of the QPSK Modulator, four types of bit combinations can be expected.
That is 00
01
10
11

These bit combinations will have four different phases.
00 - 0^0, 01 - 90^0 , 10 - 180^0, 11 - 270^0

Phaser diagram



Similarly the 8PSK phaser diagram can be represented as follows.



Bit Combination	Phase Shift (Degrees)
000	0
001	45
010	90
011	135
100	180
101	225
110	275
111	305

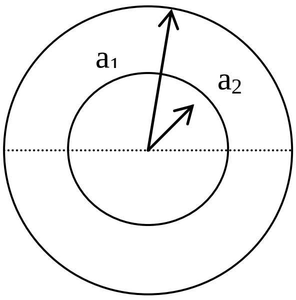
Hybrid Modulation

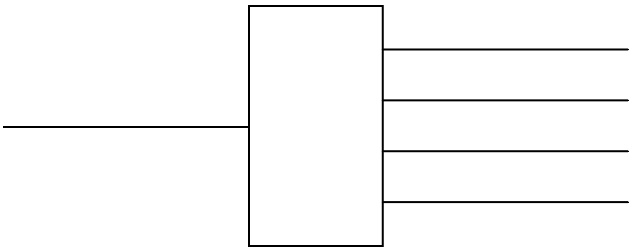
This is a combination of ASK and PSK.
This method of modulation is called Amplitude Phase Shift Keying (APSK) or Quadrature Amplitude Modulation (QAM).

It can be 16 QAM, 64 QAM etc.
In this method two carrier signals with different amplitudes are involved.

a_1 Sin ωt $\qquad$ a_2 Sin ωt

The phaser diagram can be drawn as follows.



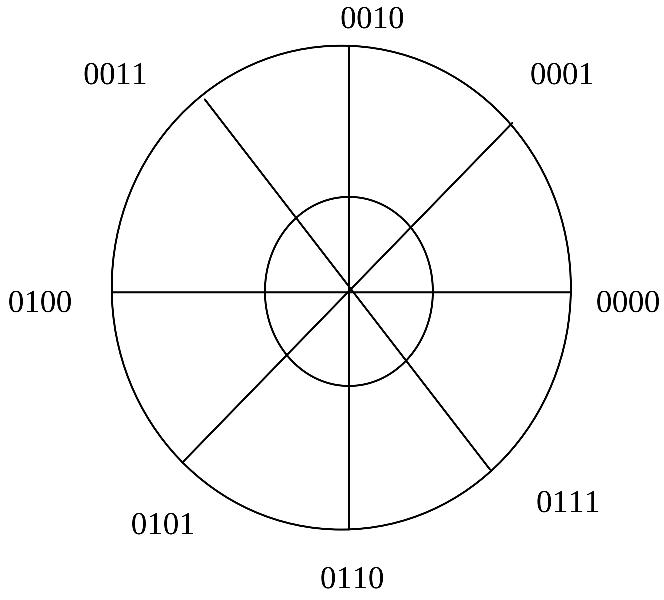


Divider

In this example, there are 16 combinations.

0000, 0001, 0010 …………….. 1111

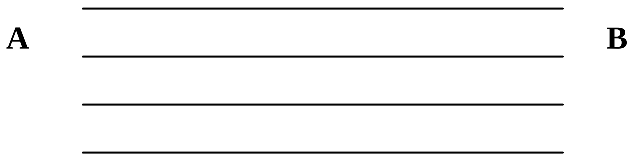
The 16 locations of the phaser diagram is as follows.



The inner circle corresponding locations represent 1000, 1001, 1010……..1111.

If the circle is divided into 16, 32 QAM can be represented.
If the circle is divided into 32, 64 QAM can be represented.

Multiplexing



Suppose we need to transmit four 64 kb/s signals from A to B. For this purpose, it is required to have four channels. Each channel needs at least 2 wires. If the length from A to B is 100m, we need 4 X 2 X 100 = 800m Copper Cable. If the length is 1000m the required length increases to 8000m.

If we can combine all four channels together without any mixing, a single pair of cable is sufficient. This type of combination (packing) of signal is called Multiplexing.

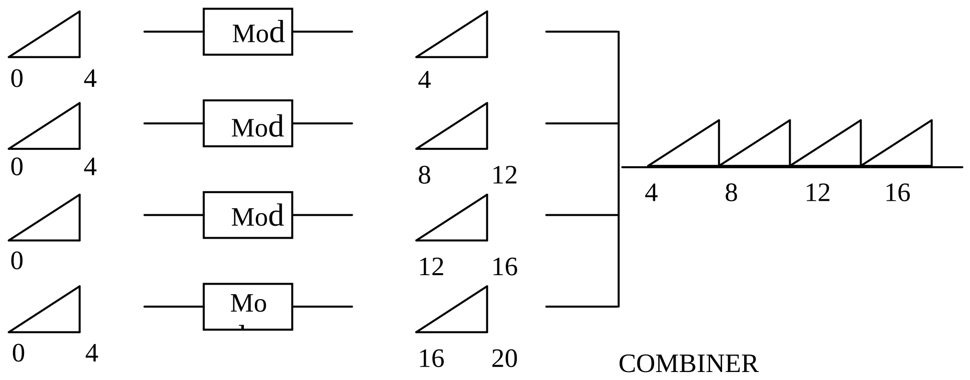
There are mainly two types of Multiplexing.

- Frequency Division Multiplexing (for Analog Signals)
- Time Division Multiplexing (for Digital Signals)

Frequency Division Multiplexing (FDM)

Let us consider multiplexing of telephone channels.
One Channel - 0 – 4 kHz. (Actually it is 0.3 – 3.4 kHz).

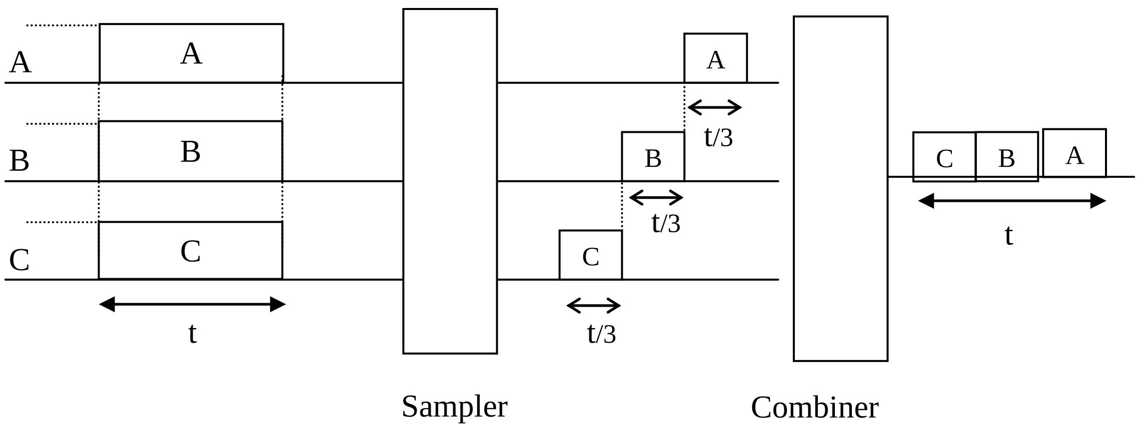
The frequency band can be shifted by modulation.



Here it can be seen that there is no interference of channels. This process is called Frequency Division Multiplexing.

Time Division Multiplexing (TDM)

Suppose we want to multiplex three Digital Signals, which have the same bit rate.



This process is called Time Division Multiplexing.
Suppose the input bit rate is n bits/sec
Time duration is t

t second $\longrightarrow$ 1 bit

1 second $\longrightarrow \frac{1}{t}$ bits $= n$ bits/sec

At the output

t second $\longrightarrow$ 3 bits

1 second $\longrightarrow \frac{3}{t}$ bits

$= 3 \text{ X } \frac{1}{t}$ bits

$= 3$ n bits/sec.

It can be seen that in the TDM process, the output bit rate is increased.

Note : If A, B, C are single bits, the TDM method is called “bit interleaving”.
If A, B, C are each 8 bits, the TDM method is called “word interleaving”.
8 bits are also called a Byte or a Time Slot (TS).

TDM Systems

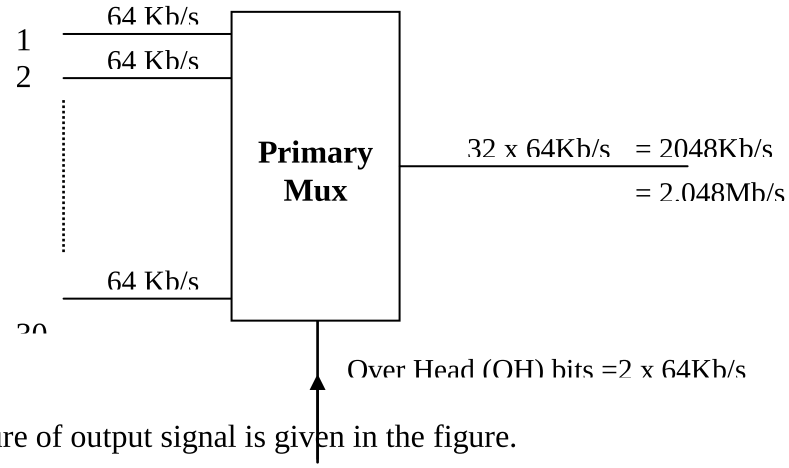
In actual systems, in addition to channel data, additional data is added. They are called the Over Head Bits. (OH bits)

E.g. Synchronization bits

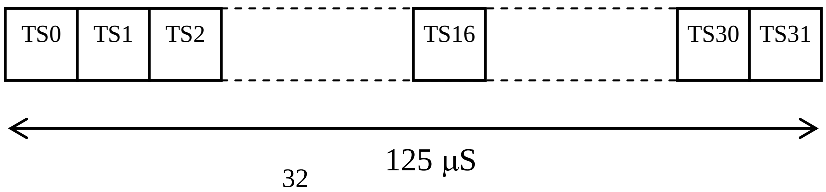
C	B	A	Syn	C	B	A	Syn

Primary Mux (E1 Channel)

By multiplexing 30 channels (each channel is 64 kb/s) the primary mux output is formed.



The frame structure of output signal is given in the figure.



Time Slot 0 (TS0) and Time Slot 16 (TS16) are overhead bits.

One Time Slot	=	8 bits
Therefore, 1 frame	=	8 X 32 bits
	=	256 bits.

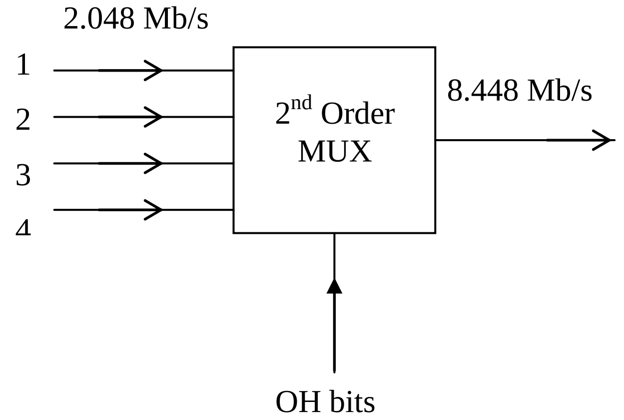
There is another Primary Mux that will multiplex 24 channels, and its output bit rate is 1.544 Mb/s. This is called a T1 channel.

Note : In Sri Lanka E1 multiplexing is used.
One TS carries data of one channel.
One channel is 64 kb/s.
Therefore, one TS is = 64 kb/s.
If you need a 64 kb/s data channel, the data circuit provider allocates you one Time Slot. If you need 128 kb/s data circuit, two Time Slots are allocated. Similarly for 512 kb/s data channel, 8 Time Slots are allocated. If you need a 2.048 Mb/s data channel the whole E1 is allocated.

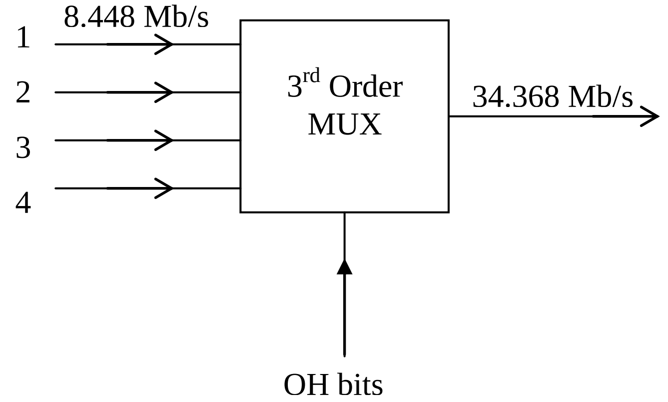
Higher Order Muxes

The primary mux is also called a 1st order mux. Four primary mux output can be again multiplexed and a 2nd order mux output is made.

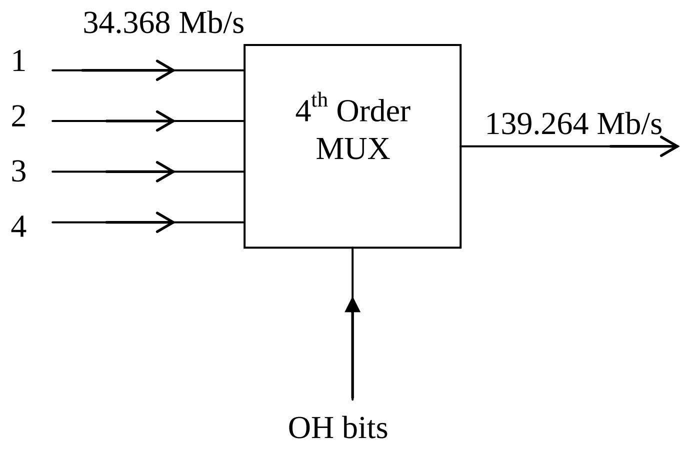
2nd Order Mux (E2 Channel)



3rd Order Mux (E3 Channel)

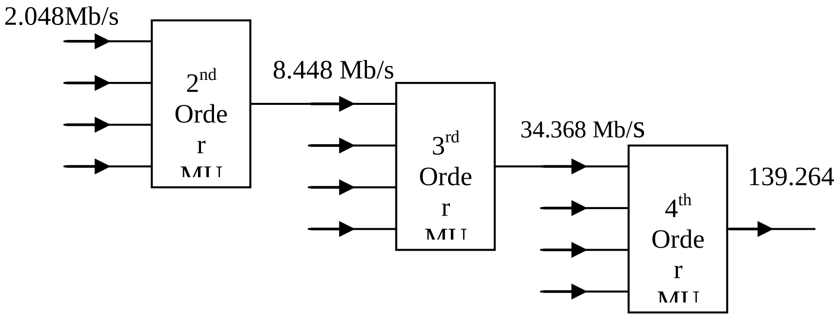


4th Order Mux (E4 Channel)



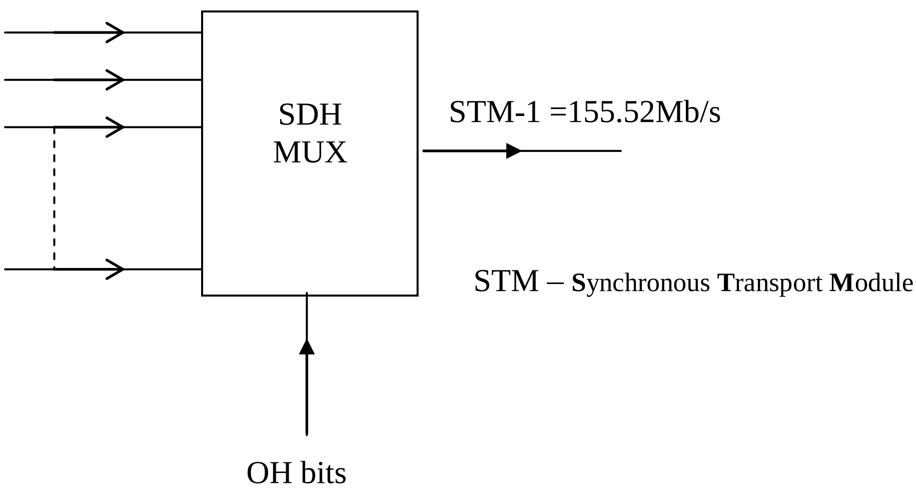
Plesiochronous Digital Hierarchy (PDH)

This is one of the digital multiplexing hierarchies.



Synchronous Digital Hierarchy (SDH)

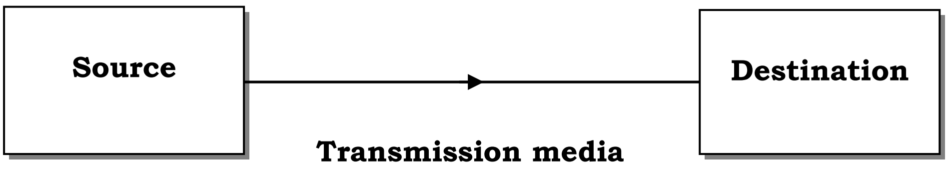
This is the modern digital multiplexing hierarchy.



The input can be E1 or E2 or E3 or E4.
The inputs can be configured.
The output bit rate is 155.52 Mb/s.

4 X STM - 1	=	STM - 4
4 X STM - 4	=	STM - 16
4 X STM - 16	=	STM - 64

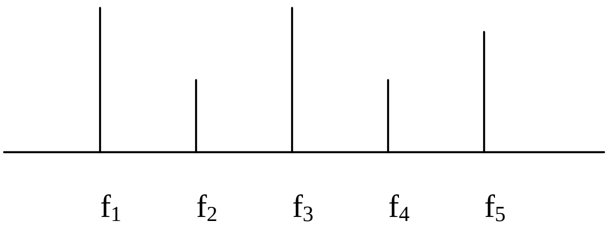
Bandwidth of a Signal



Any signal should travel from one point to another point. The starting point is called the source and the ending point is called the destination. Also it is called Transmitter and Receiver. Transmission media connects the source and destination. It can be a copper cable, fibre optic cable or radio. The media bandwidth is a major cost factor of the system since the media cost depend on the bandwidth of the signal.

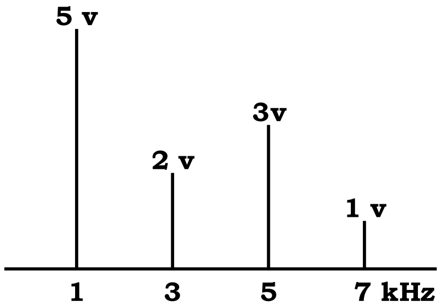
Bandwidth

The correct term should be the frequency bandwidth. Any signal can be considered as a combination of sinusoidal signals. This is proved from a theory called Fourier Analysis which will be discussed later. The spread of frequencies can be shown pictorial in the following manner and it is called the frequency spectrum.

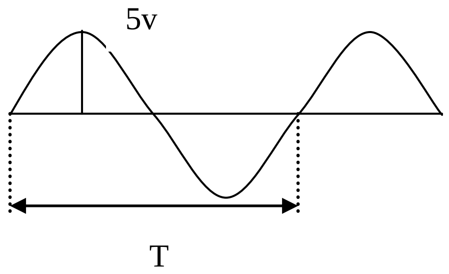


The vertical height shows the amplitude of the signal.
According to the above frequency spectrum the bandwidth of the signal is f_5 minus f_1 ($f_5 - f_1$).

E.g.



The bandwidth is 7-1 = 6kHz or 1kHz to 7 kHz.
The 1kHz signal is



$T = 1/1 \times 10^3$ Seconds
$= 1$ ms

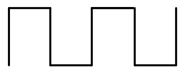
The 3kHz, 5kHz, 7kHz signals also can be represented in a similar manner.

Fourier Analysis

The signal transmitted from source to destination can be,

a digital signal
an analog modulated signal
a digital modulated signal etc.

How can we find the bandwidth of these signals?

Digital Signal $\longrightarrow$ 

It is very strange if somebody says this digital signal is a mixture of sinusoidal signals. But there is a mathematical formula called Fourier Analysis (or Fourier Transformation) that proves that any signal is a combination of sinusoidal signals.

Bandwidth of a Digital Signal

Consider a digital signal (unipolar) that has a bit pattern of
1 0 1 0 1 0 1 0 1 0 1 0 (Alternative 1s and 0s)
Suppose the bit rate is *n* bits/second (*n* b/s).

It can be shown from the Fourier Analysis that the fundamental frequency (lowest frequency of the spectrum) is $n/2$ Hz.

Note: Fourier signals consist of fundamental and harmonics frequencies. Harmonic frequencies are integer multiples of fundamental frequency.
Fundamental frequency - f
Harmonics – 2f, 3f, 4f, 5f etc. or 3f, 5f, 7f etc. or 2f, 4f, 6f etc.

Consider a digital signal sent from source to destination. In the media it travels as individual sinusoidal (analog) signals. In order to regenerate the signal at the destination, at least the fundamental frequency is needed. Therefore, the media should support the travel of, at least up to $n/2$ Hz. Therefore, we can say the media bandwidth should be from 0Hz to $n/2$ Hz. Therefore, the bandwidth is $n/2 – 0 = n/2$ Hz.
Therefore, in general, we say that if the bit rate is *n* b/s, the required media bandwidth should be at least $n/2$ Hz.

In other words we say, if the media has N Hz bandwidth, it supports up to 2N b/s.

E.g. : If the media bandwidth is 3 kHz, we can send a digital signal which has maximum bit rate of 2 X 3 kb/s = 6 kb/s.

In general we can write the following expression. The maximum bit rate a media supports is also called its capacity (C).

$$\text{Capacity} = 2 \times \text{Bandwidth}$$
$$C = 2\,B$$

The above expression is also correct for ASK, FSK and BPSK modulated signals. But there will be a difference in QPSK, 8PSK, 16QAM, and 64QAM signals. They are called multilevel signals. The level (L) is defined by how many bit combinations is considered at the modulator input.

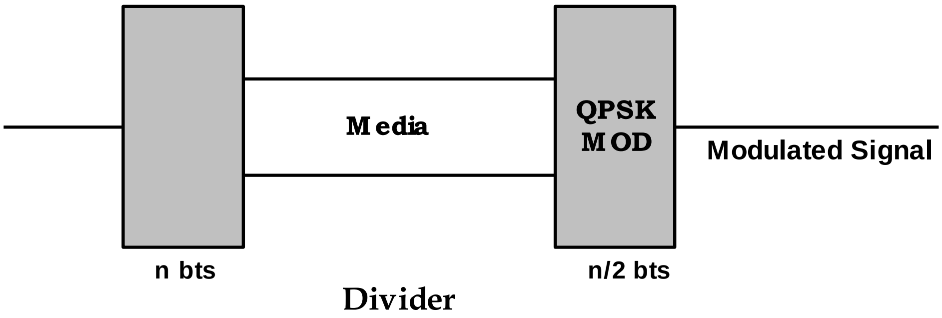
For examples:	QPSK	L = 4	8PSK	L = 8
	16QAM	L = 16	64QAM	L = 64

For multilevel signals, the above equation can be modified as follows.

$$C = 2\,B\,\log_2 L$$
$$\log_2 4 = 2 \qquad \log_2 8=3 \qquad \log_2 16=4 \qquad \log_2 64=6$$

For modulated signals the bandwidth depends on the change of rate of carrier frequency. This is called the “baud rate”.

Consider a QPSK signal.



The change of rate of Carrier Frequency is $n/2$ Hz. Therefore, the bandwidth of the modulated signal is $n/2$ Hz. The bandwidth of unmodulated signal is n Hz. Therefore, QPSK modulation reduces the required bandwidth to ½ (half).

Similarly for 8PSK signal the required bandwidth is reduced to 1/3rd.

In other words, if the media bandwidth is not changed, QPSK can increase the input bit rate by 2 times. 8PSK can increase the input bit rate by 3 times.

Actual Bandwidth of a Media

In the above explanation we considered only the bandwidth requirements. The actual bandwidth available in a media depends on the signal level and the noise level. This relationship was given by Shannon and it is called Shannon's Law.

Shannon's Law

$$C = B \log_2 (1+S/N)$$

C	-	Capacity (b/s)
B	-	Bandwidth of the media (Hz)
S	-	Signal Level
N	-	Noise Level

Therefore, in practical problems, we should follow the following steps.

Calculate the input bit rate (capacity), which can be increased by multilevel digital modulation. Use the following equation.

$$C_1 = 2 B \, log_2 L$$

Note : We used the modulation technique to increase the input bit rate.

Next we have to check whether the transmission media supports the above bit rate. Therefore, check the highest bit rate supported by the media under the presence of noise by using the following equation.

$$C_2 = B \, log_2 (1+S/N)$$

If $C_1 < C_2$ the modulated signal can be sent through the media.

3. Transmission Media Characteristics

A source sends data through a transmission media. We cannot send an unlimited bandwidth through the media due to many limitations. The major problems in any transmission media is,

- Noise
- Attenuation
- Group Delay
- Interference

Noise

Noise is an unwanted electrical signal (voltage or current). This mainly occurs due to random movement of electrons. This is called "thermal noise" or "white noise". Copper (metal) conductors are highly affected by thermal noise.

Noise which mainly affects copper conductors are,

- cross talk - adjacent channel's signal is induced.
- impulse noise - occurs from another electromagnetic source.

Radio signals are affected by atmospheric noise due to atmospheric water vapour, dust particles etc. Another type of noise affected by radio signals are the "Galactic Noise" due to unwanted electromagnetic waves radiated form some stars.

Fibre optics has no much effect from noise.

Attenuation

Assume that there is no noise in the media. Then can we transmit a signal to any distance? No, since the signal strength reduces when it ravel through the media. This effect is called attenuation.

In copper conductors this is due to heat dissipation. The signal goes as an electrical current. A current i dissipate i^2 R (R-Resistance) thermal power. This is a waste of energy of useful signal. Therefore, the signal level is degraded.

In radio transmission, the signal is attenuated due to atmospheric absorption by water vapour, dust etc.

In fibre optic transmission attenuation occurs due to scattering, absorption, bending losses and this will be discussed later.

- Group Delay

The velocity of an electromagnetic signal travelling through a transmission media depends on the frequency of the signal. We noticed that any signal is a combination of many sinusoidal waves, which have different frequencies. Therefore, the signal wave components travel with different velocities and reach the destination at different times. This effect is called the group delay. Due to this effect the destination end should wait until all sinusoidal frequency components are received to reconstruct the original signal. The disadvantage of this effect is some frequency components of previous signal reach the destination after some frequency components of following signal are reached. The signal is reconstructed at the receive end and it is not similar to the original signal due to group delay and it is called the delay distortion or intersymbol distortion. In order to avoid this effect the bit rate should be limited.

The effect for copper cables due to group delay is negligible. For radio transmission it has considerable effect. For fibre optic transmission, this has a very bad effect and it is called “dispersion”.

Interference

Radio signals are transmitted through free space. Since there are many frequencies (carriers) transmitted through free space, one carrier can interfere with another carrier.

For copper cables interference can occur electromagnetic frequencies. This could happen when copper data cables are laid near to power cables, some other data cables etc…

For fibre optic transmission electromagnetic interference does not occur since it operates at very high frequencies.

Transmission Media

Let us see the characteristics of different transmission media. It is important to study and decide the most cost effective transmission media when designing computer networks.

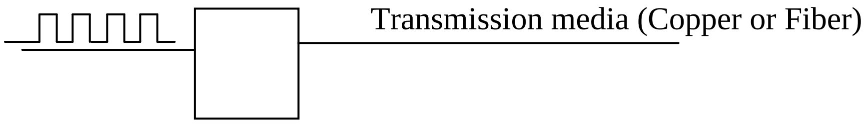
Transmission media can be mainly divided into two categories.

- Guided transmission media
- Unguided transmission media

- Guided Media
  - Copper Cables
  - Fiber Optic Cables
- Unguided Media
  - Domestic Radio
  - Satellite Communication
  - Mobile Radio

Guided Media

It is a point-to-point communication. The signal can be transmitted without changing the frequencies. These signals normally cannot be interfered with other signals. Only the line coding should be done which we will study later.



Line Terminal Equipment

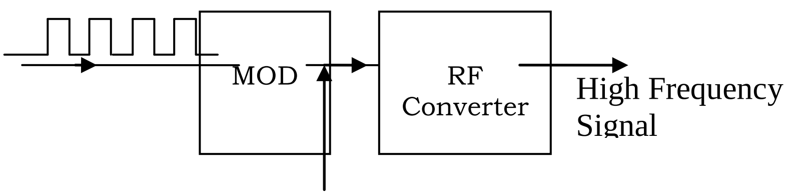
Functions of LTE are,

- Line coding
- Add overhead bits for supervisory purposes
- Power feeding for repeaters (for copper cable)
- Electrical to optical conversion (for fibre optic)

At the receive end LTE will do the reverse functions of the transmit end LTE.

Unguided Media

The signal is transmitted into free space. Therefore, each signal should operate with a unique frequency. If two signals have the same frequency, then those two signals can interfere. (Just like the flying of airplanes. They should fly at different heights, if not they can collide). Therefore, the original signal should be converted to a unique high frequency. This is done by modulation.



Inter mediate Frequency (IF)

Modulation converts the original signal to an Intermediate Frequency (IF). This is normally a fixed frequency (e.g. 70 MHz). Then the RF converter (RF – Radio Frequency, normally this is the term used for high frequencies) converts the IF signal to the required frequency.

Important: Please note that modulation is needed only for radio transmission. For line (copper or fibre), transmission, modulation is not necessary.

Copper Cables

Copper cables are used for different purposes.

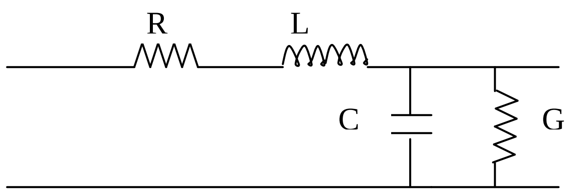
- For voice communication in telecommunication systems.
  (Exchange to Distribution Point (DP) and DP to home). The DP to home copper cables is called Aerial Cable.

- For multichannel (high bandwidth) signal transmission. These are called, Coaxial Cables.

- For data transmission, Unshielded Twisted Pair (UTP) or Shielded Twisted Pair (STP) is used.

Common Characteristics of a Copper Cable

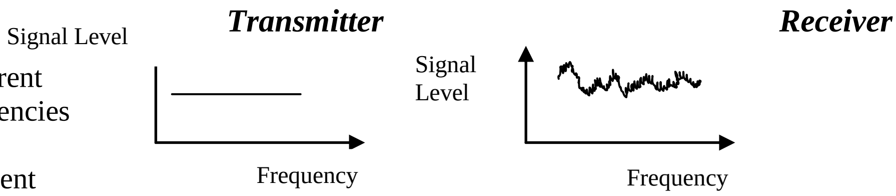
A copper cable pair has the resistive, capacitive, inductive and conductive effect and it can be represented as follows.



R - Resistance
L - Inductance
C - Capacitance
G - Conductance

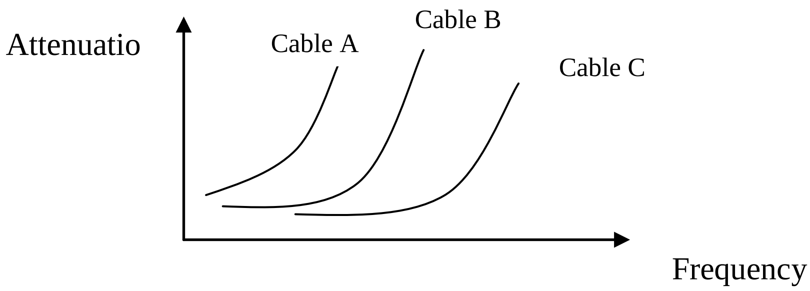
The capacitor has high impedance at low frequencies and the inductor has high impedance at high frequencies. Therefore, capacitances and inductors can be used as frequency filters. Since the cable acts as a capacitor and inductor it filters some frequencies. Therefore, the transmit end and the receive end Amplitude- frequency characteristics can have a difference, as shown in the following figure.

Different frequencies have different attenuations



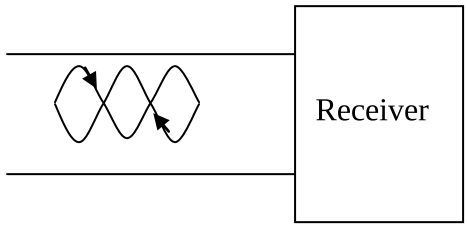
This effect is called amplitude distortion. This can be corrected by using amplitude equalizers. This does not have an effect for short distances.

Attenuation VS Frequency Characteristic



Attenuation increases with the frequency. The above figure shows the characteristic of three different copper cables. Therefore, we should select a copper cable, which has low attenuation for the whole required signal bandwidth.

Reflection



We need two cables (a pair) for TX and two cables (a pair) for RX.

Part of the signal goes to the receiver and the remaining part is reflected at the receiver. These two signals are called the incident signal and the reflected signal respectively.

Reflection is an unnecessary occurrence. We need to send the whole signal to the receiver. Since part of the signal energy is reflected, it can be considered as loss of signal energy.

The characteristic Impedance (Z_0) of a cable is defined as,

$$Z_0 = \sqrt{\frac{(R + j\omega L)}{(G + j\omega C)}}$$

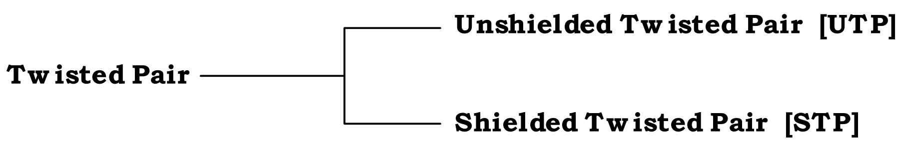
It can be shown that if the receiver input impedance is equal to the characteristic impedance of the cable then there will be no reflection. This condition is called "matched condition" The standard characteristic impedance of cables are ohms 50, 75, 120, 300 etc.

Note: The above characteristics are true for any metallic cable, not only for copper cables.

Types of Copper Cables used in data networks

Twisted Pair Cable

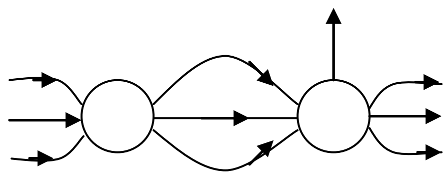
A twisted pair consists of two insulated copper wires. These wires are twisted together in a helical form. This twisted form is used to reduce cross talk. (Electrical interference of adjacent channels/cable pairs).



If an individual pair has a metallic shield it is called a STP Cable.

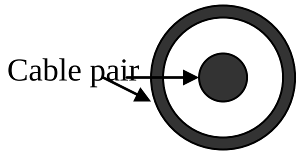
But now high quality UTP Cables are produced which can carry 10 Mb/s, 100 Mb/s and even 1000 Mb/s (1Gb/s). Therefore, present Computer Networks (LAN) use UTP cables and there are many categories called Cat5, Cat5e and Cat6 where the standards are defined by EIA/TIA standards body.

Coaxial Cable



The above figure shows the magnetic flux pattern of a current (signal) carrying cable pair. You can see that some flux is going to free space and some magnetic energy is lost by the cables.

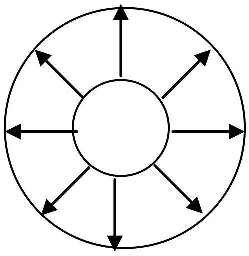
If the two cables are arranged in the following manner, there will be no such loss of energy.



In between the cables, there is an insulator.

Since both cables have the same axis, this is called a Coaxial Cable.

The electrical flux pattern is as follows.



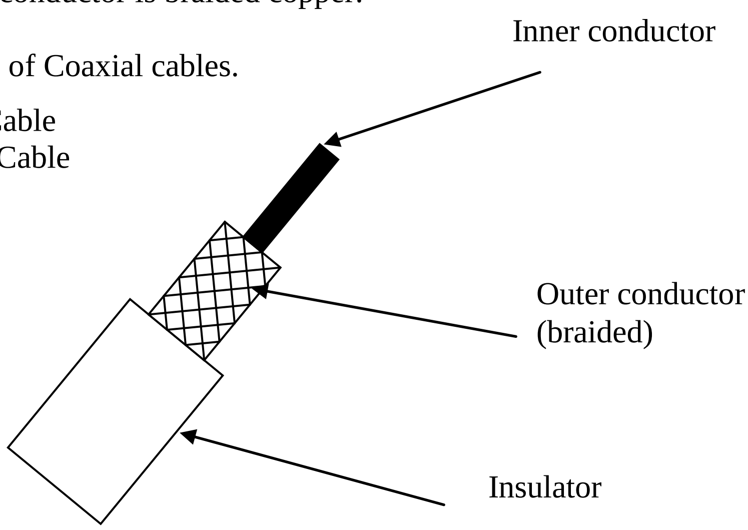
There is no loss of energy.

Therefore, Coaxial Cables can be used for long distance transmission.

A typical Coaxial Cable is given in the figure.
Normally the outer conductor is braided copper.

There are two types of Coaxial cables.

- Thin Coaxial Cable
- Thick Coaxial Cable



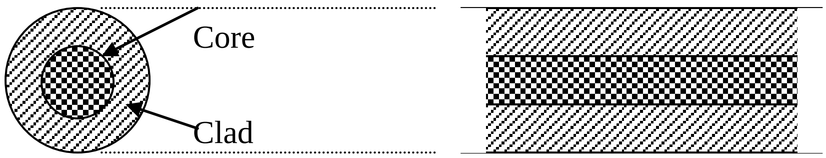
Fibre Optics

Signals can be transmitted as optical signals. For this purpose a fibre optic cable can be used.

Some of the advantages of optical fibre are,

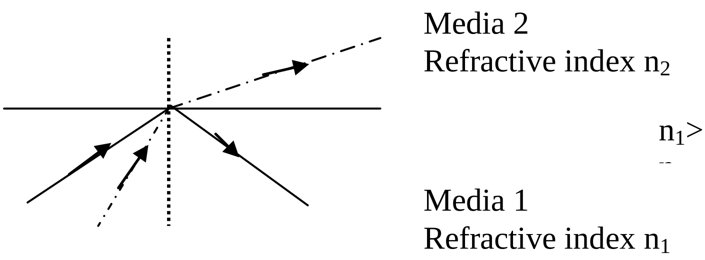
- The information carrying capacity is high. (That means it has a greater bandwidth)
- Not electrically conductive, therefore no interference from electrical signals.
- Less attenuation, therefore signal can travel a long distance without repeaters.

The fibre optic cable consists of two parts. The inner fibre (core) and the outer fibre (clad).



The Core and Clad can be glass or plastic.

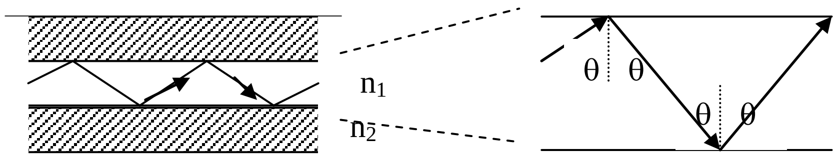
<u>Principles of light transmission in a fibre</u>



If the incident angle is less than the critical angle, the light ray is refracted to media 2.

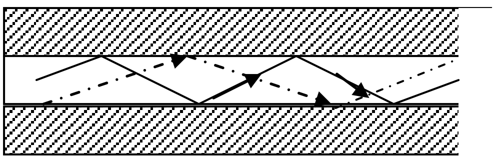
If the incident angle is greater than the critical angle, the incident light ray reflects back to the same media (media 1). This is called the total internal reflection.

$n_1 > n_2$



The incident angle to the core is θ where θ > critical angle. Therefore, it is reflected back to the same media. Again it is reflected from the opposite surface in a similar manner. Hence the light ray goes through the core in a zigzag path.

Depending on different incident angles of light rays, they can travel in different paths.



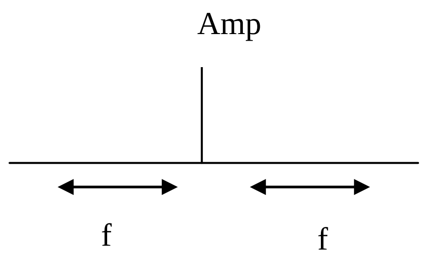
These are called the different modes of optical ray. If the radius increases, many modes of signals (light rays) can travel through the core.

If only one ray, which goes through the axis, is allowed by the fibre, it is called Single Mode Fiber. (SMF)

If many rays are allowed, it is called Multi Mode Fibre. (MMF)

	Single mode	Multimode
Core diameter (μm)	8	50/62.5
Clad diameter (μm)	125	125

Why high bandwidth?



If the carrier frequency is f, the theoretical possible bandwidth is, left side f Hz and for symmetry right side is also f. (i.e. 2f Hz)

The light rays operate at 10^{14} Hz.
Therefore, the possible bandwidth is 2 x 10^{14} Hz = 200 THz.
This is a very high bandwidth.

Attenuation Characteristics

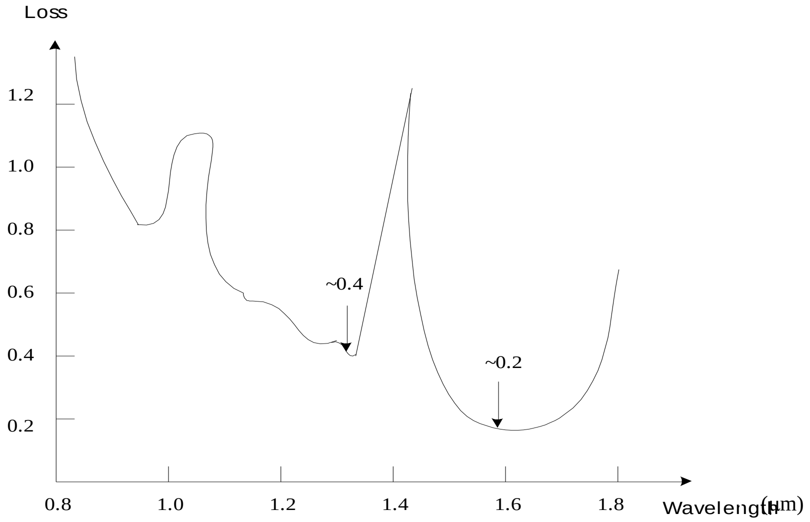
Material absorption Loss

The energy of the signal is absorbed by the water contamination and by the ion impurities.

Scattering Loss

During the glass forming process there can be a density variation of core and clad. This will result in scattering of portion of the light passing through the core.

Attenuation Characteristic



By considering the attenuation characteristics, three operating wavelengths are selected.

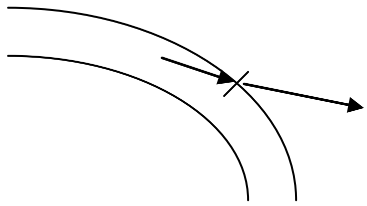
800nm, 1300nm, 1550nm

Normally used wavelength is 1300nm or 1550nm.

Other losses

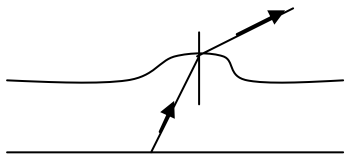
Bending losses - There are two types of bending losses. They are constant radius bending and micro bending.

Constant radius bending



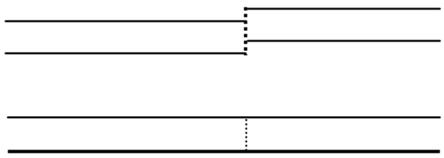
At the time of installation the fibre may have bends. The incident angle at a bend can be less than the critical angle and part of the signal can be refracted and it will cause a signal loss.

Microscopic bending



It is a microscopic bending of the core of the fibre that results at the time of manufacturing. This may change the incident angle; part of the signal is refracted and will cause a signal loss.

Coupling losses - Imperfectly formed splices or imperfectly aligned connectors.



This will cause to reflect back part of the signal at a joint or at a connector.

Another type of loss can occur at the core, clad interface due to imperfections such as small variation in the core diameter or air bubbles in the glass.

The incident angle may be changed and part of the signal can be refracted.

Dispersion

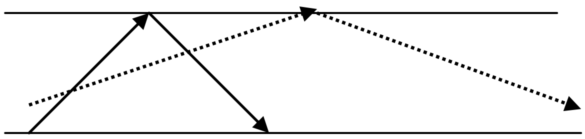
The pulse is broadened due to dispersion.
Δt - Dispersion time.

The possible maximum bit rate R = $\dfrac{1}{t + \Delta t}$

When Δt increases, R decreases.
Higher the dispersion, lower the pulse (bit) rate.
Therefore, the bit rate is limited due to dispersion.

There are different types of dispersions.

Intermodal Dispersion



The different modes of signals have different incident angles and they travel different distances and the pulse gets broadened at the receive end. This is called Intermodal Dispersion.

Since the single mode fibre has only one mode, it has only one incident angle. Therefore, there is no intermodal dispersion for single mode fibres.

Material Dispersion

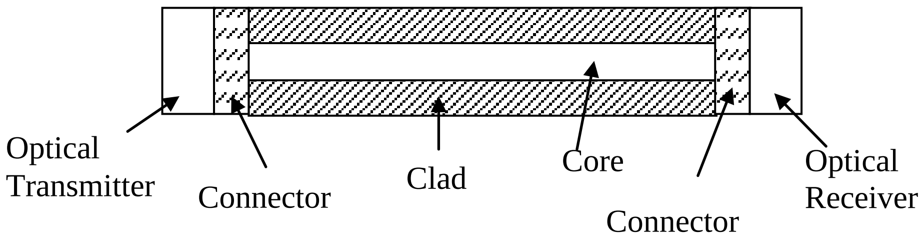
The refractive index of glass depends on the wavelength of the optical signal. Again the speed of the signal depends on the refractive index.

Normally the optical ray is not a single wavelength. It has several different wavelength and they travel at different speeds. Therefore, the signal is subjected to dispersion and it is called material dispersion.

Wave guide Dispersion

The plane of polarization of the signal can vary with the time and it affects the speed. Therefore, the signal is subjected to dispersion. This is called wave-guide dispersion.

Optical System



Optical Transmitter

The optical transmitter converts the signal from electrical energy to optical energy. The typical optical transmitters are,

- Light Emitting Diode (LED)
- Semiconductor Laser Diode (SLD)

Optical Receiver

The optical receiver converts the signal from optical energy to electrical energy. The typical optical receivers are,

- p-*i*-n photo diode
- Avalanche photo diode

Connectors

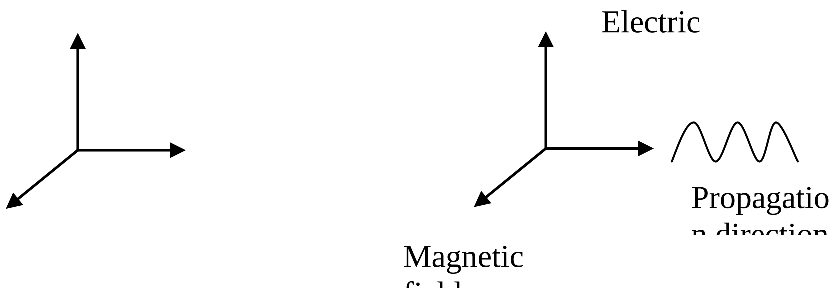
There are two types of connectors.

- ST (bayonet)
- SMA (threaded)

Radio Transmission

A radio signal is an electromagnetic wave, which travels through free space (unguided media).

Electromagnetic Wave



If a signal has an electric field and a magnetic field together and if their strengths are varying with time, it can be shown mathematically that the energy propagates (travels) as shown in the above figure.

Note: If the electric field and magnetic filed are orthogonal (90^0 apart) then the energy (signal) travels through the other orthogonal axis as shown in the figure. Such an electro magnetic wave is called a Transverse Electromagnetic wave. But this is not a mandatory requirement. That means it is not necessary for electric field and magnetic field to be orthogonal.

The signals travelling through a copper cable or a fiber optic cable are also electro magnetic waves.

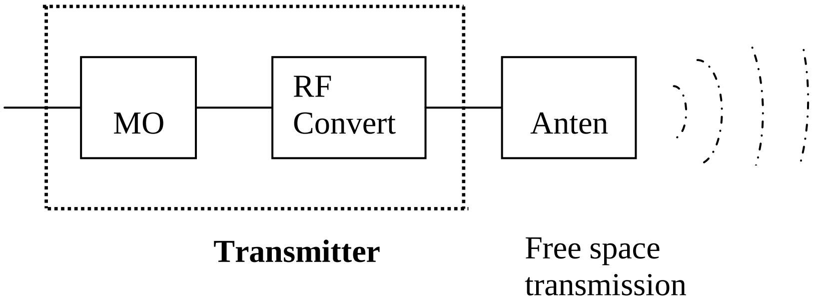
When a radio signal travels through free space its electric and magnetic fluxes can be subjected to changes due to other influences. Also they can be subjected to reflection refraction etc. In some waves these changes cause considerable influence but in some it does not. This mainly depends on the frequency of the wave. Therefore, the radio frequency spectrum (range) is divided in to different ranges and categorized with different names.

Category	***Abbreviation***	***Frequency Band***
Very Low Frequency	VLF	3-30 kHz
Low Frequency	LF	30-300 kHz
Medium Frequency	MF	300-3000 kHz
High Frequency	HF	3-30 MHz
Very High Frequency	VHF	30-300 MHz
Ultra High Frequency	UHF	300-3000 MHz
Super High Frequency	SHF	3-30 GHz
Extra High Frequency	EHF	30-300 GHz
Optical	Optical	100 THz range

Velocity of Electromagnetic Wave

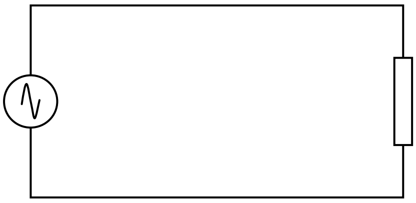
The velocity in the free space and fibre are about $3x10^8$ m/s. The velocity in the copper is about $2x10^8$ m/s.

Radio System

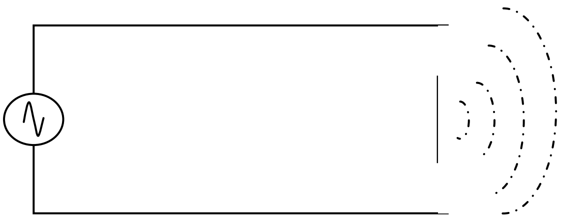


The main components of any radio system are given in the figure.

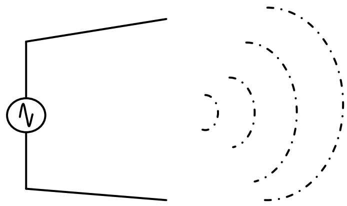
Antenna



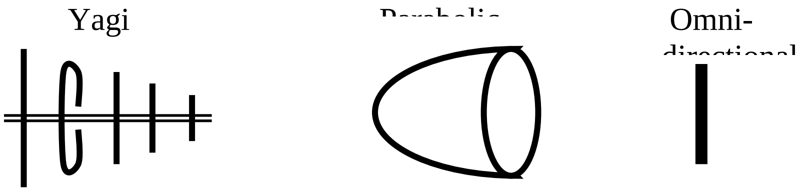
Suppose a signal source is connected to a load by using two wires. Suppose the load resistor is removed. Now how can the signal travel?



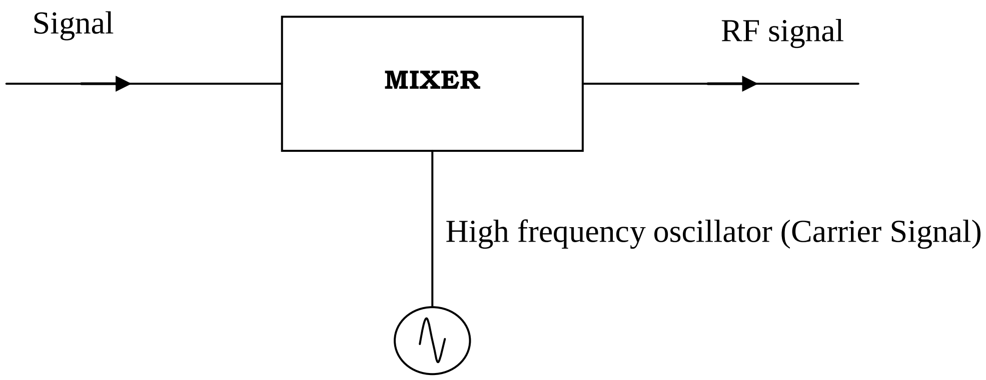
Now the signal travels to free space.



By changing the shape of the two-wires the amount of wave (energy) and the directions etc. can be changed. This is the simplest antenna. There are different antennas used for different applications/different frequencies.

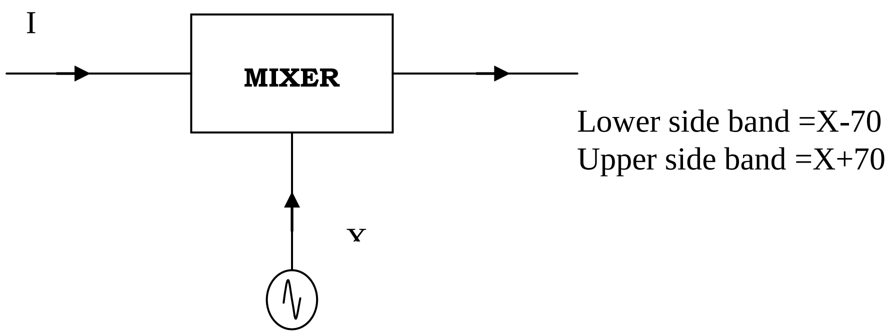


RF Converter (Up Converter)



The mixer is an analog modulator (e.g. AM modulator). The modulator output is a fixed frequency (IF) e.g. 70 MHz.

Suppose we want to convert the IF signal to 2.4 GHz (2400 MHz).



Both side bands exist at the output. By using a filter we can select either. Suppose we selected the LSB.

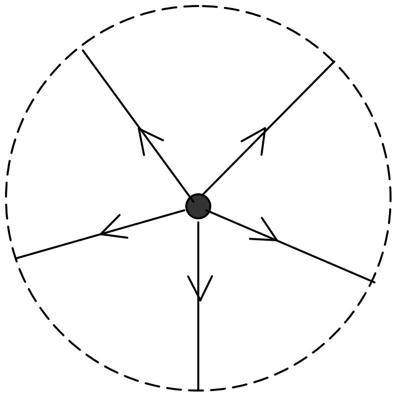
Then $X - 70 = 2400$

$X = 2470$ MHz.

Then we have to adjust the carrier signal to 2470 MHz. In a Similar way by adjusting the carrier signal the required output frequency can be obtained.

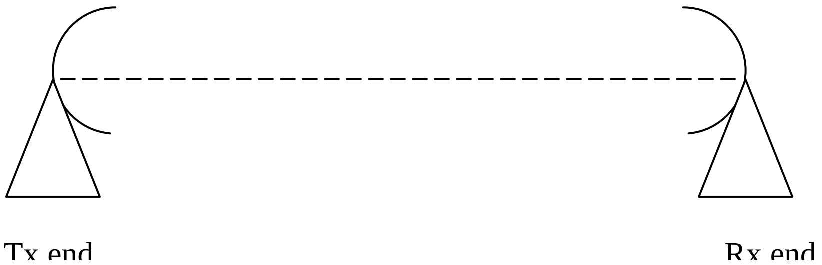
Signal Radiation

Pattern

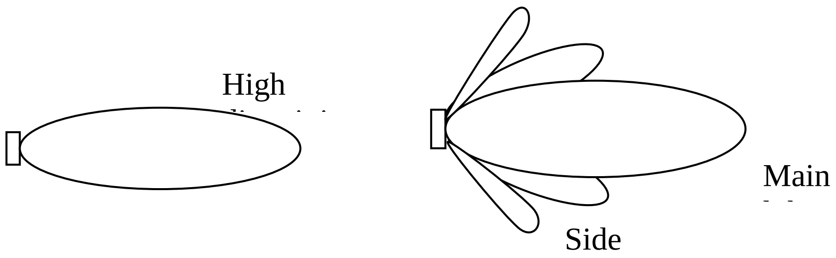


If the signal is transmitted to the free space without an antenna the signal will travel in all directions.

But our requirement is to transmit the signal to a particular destination or area. For this purpose an antenna is required.

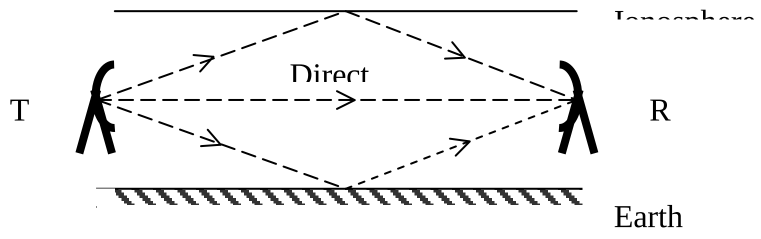


The pattern of the signal propagation is called the radiation pattern.



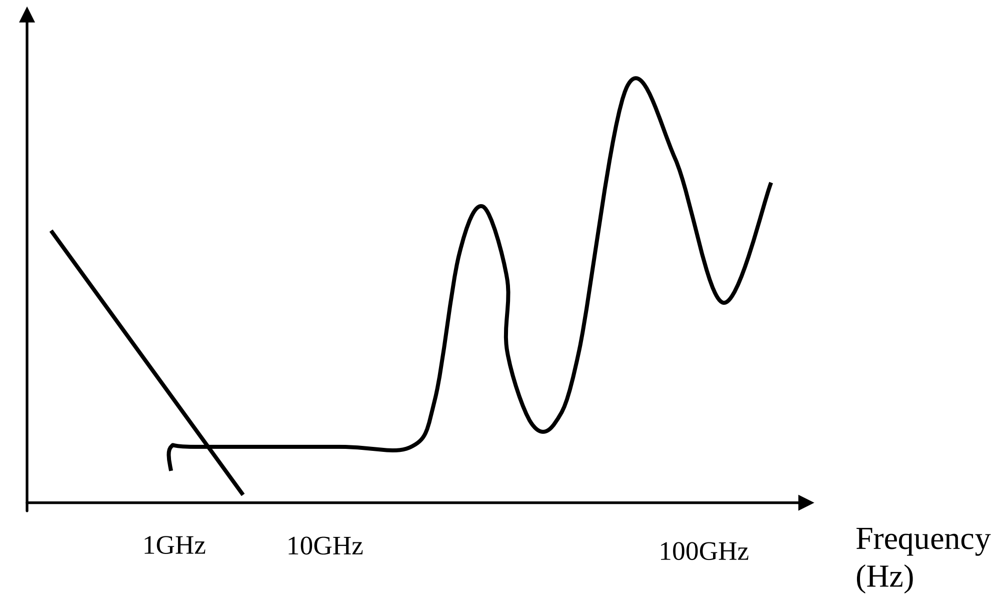
The radiation pattern depends on the type of antenna and the frequency of the signal. Higher the frequency higher the directivity.

Reflection



The upper surface of the atmosphere is called the ionosphere. The signal can be reflected from both the earth surface and the ionosphere. The receiver output will be a mixture of all these signals. The resultant signal may have less strength than the direct signal or vise versa. This badly affects microwaves.

Effect of Noise



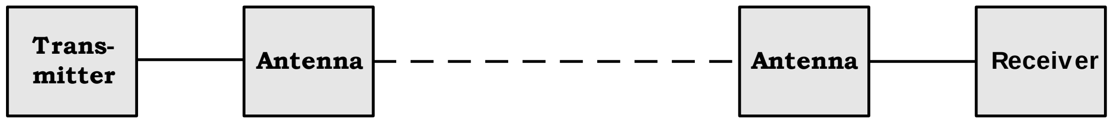
This has the biggest effect for radio signals. It can be seen that the best operating frequency range is 1 GHz – 10 GHz. This is also called the Radio Window. Therefore, most of the applications use this frequency range.

E.g.	Mobile	1-2 GHz
	Satellite	4-6 GHz
	Wireless LAN	2.4 GHz and 5 GHz.

Note: For different bands different letters are used.

S band
C band

Typical Radio System



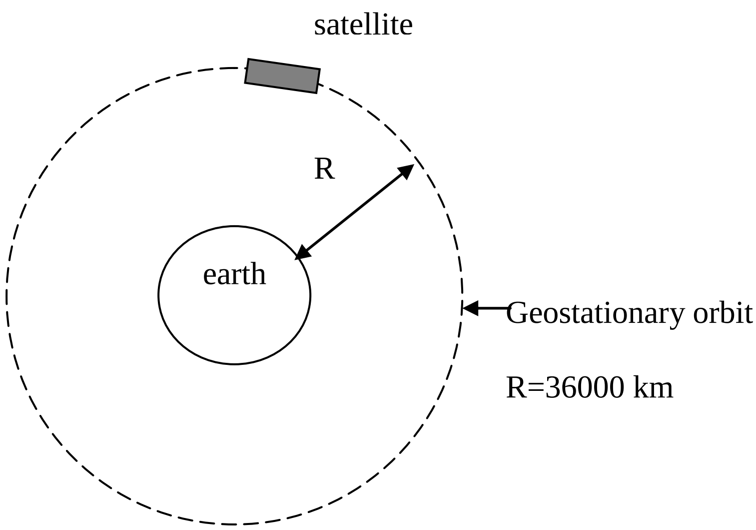
Receiver performs the reverse function of the Transmitter. If the transmitter and receiver are in one unit it is called a Transceiver.

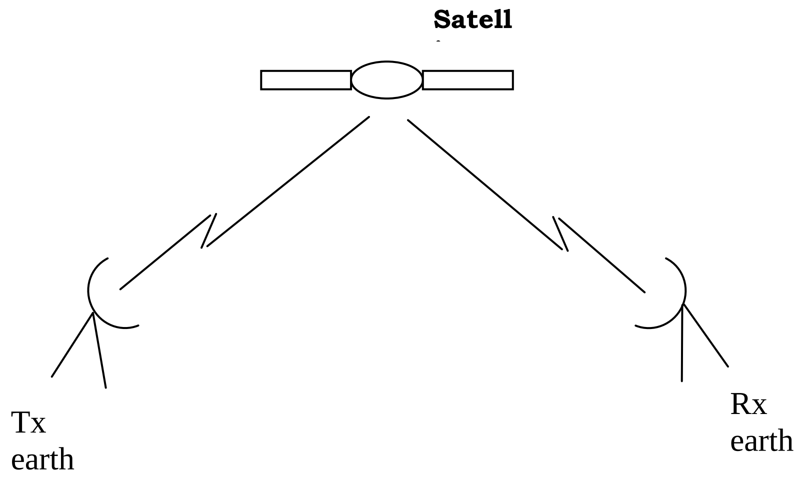
Applications of frequency bands

The following are some of the applications of different frequency bands.

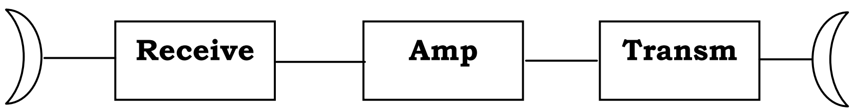
VLF	-	Telegraph transmission for navigation.
LF	-	Sound broadcast through earth surface. It can travel about 1500 km.
MF, HF	-	Commercial radio broadcasting.
VHF, UHF	-	TV broadcasting
Microwaves	-	Domestic Carrier (wide band) transmission by Telcos. Satellite Communication

Satellite Communication





For long distance communication satellite communication can be used. The main function of the satellite is to receive the signal, amplify and transmit back to earth.



There are two frequency bands used for satellite communication.

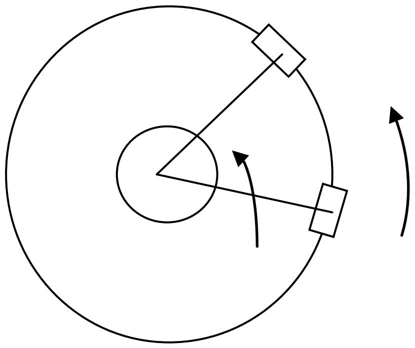
C-band	Tx	-	5.925	-	6.425	GHz
	Rx	-	3.7	-	4.2	GHz

Ku-band	Tx	-	14 GHz range
	Rx	-	11/12 GHz range

C-band has less effect on attenuation and noise compared to ku-band.

Satellite Orbit

A satellite can travel in any orbit around the earth. But the most useful orbit is the Geostationary Orbit where it takes 24 hrs. to travel one orbit in the same direction as the earth's travel. Therefore, both travel the same angle for a given time.



Hence the satellite is stationary with respect to the earth. This orbit is called the Geostationary orbit and it is located at about 36000 km away from the earth surface.

Signal travels from earth to the satellite and comes back from the satellite to earth. This is called one hop.

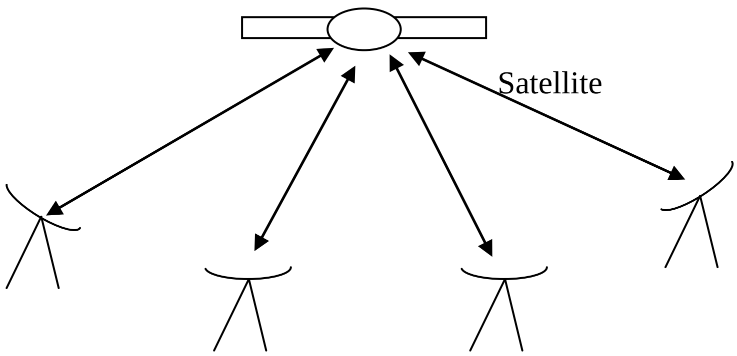
One hop travels 2 x 36000 = 72000 km.

The velocity of the signal is = 3×10^8 m/s

Therefore, the time taken to travel one hop is $= \dfrac{72000 * 10^3}{3 * 10^8}$ *Seconds*

The propagation delay of one satellite hop is approximately 250 ms. This causes a considerable effect on data communication.

Satellite Access Methods



Earth stations

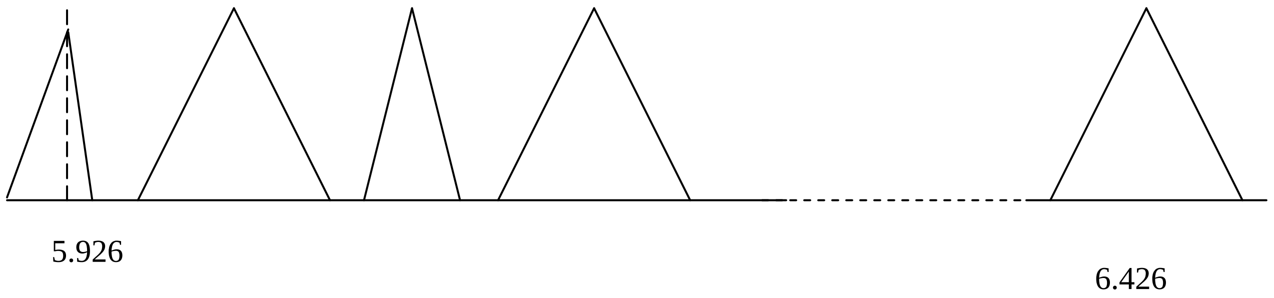
There are three satellite access methods.

- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

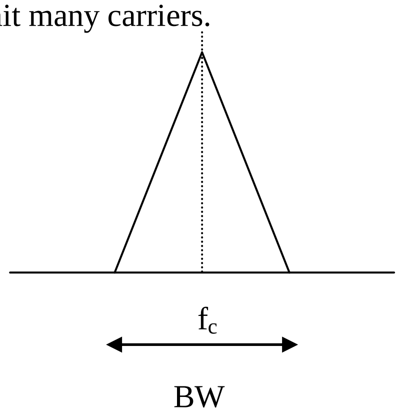
FDMA

Consider the c-band where the Tx frequency range is 5.925 – 6.425 GHz.

There is a 500 MHz band.



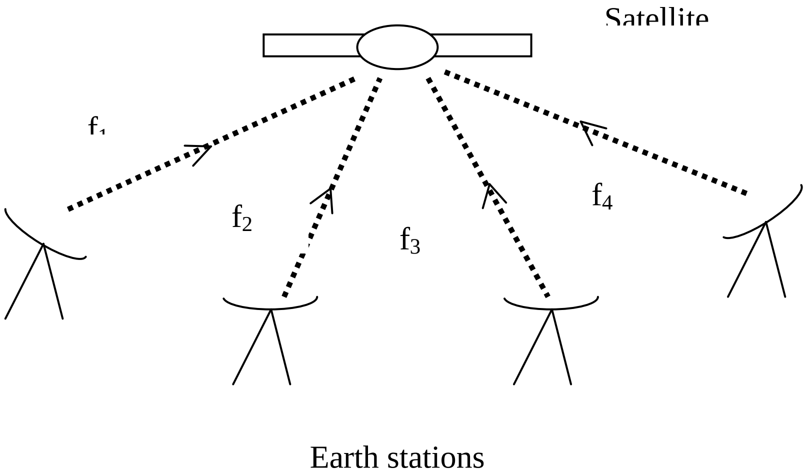
Different frequencies are allocated for different carriers (earth station). One earth station can transmit many carriers.



Fc - Centre Frequency
BW - bandwidth

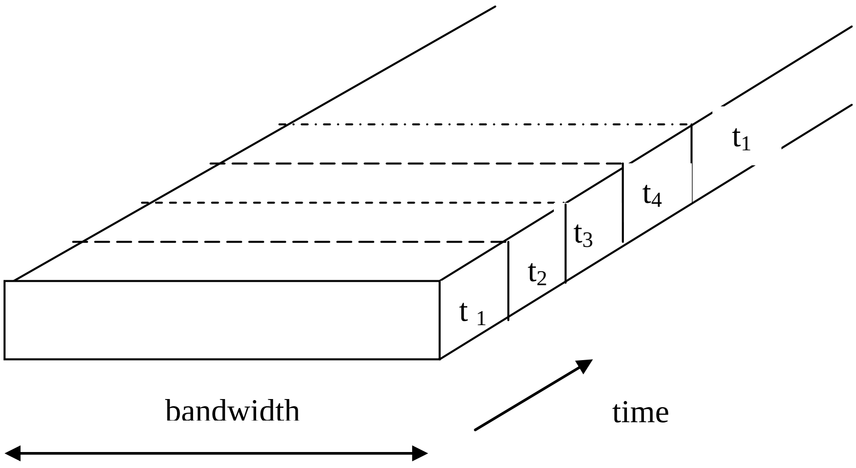
e.g. fc = 6000 MHz.
BW = 5 MHz.

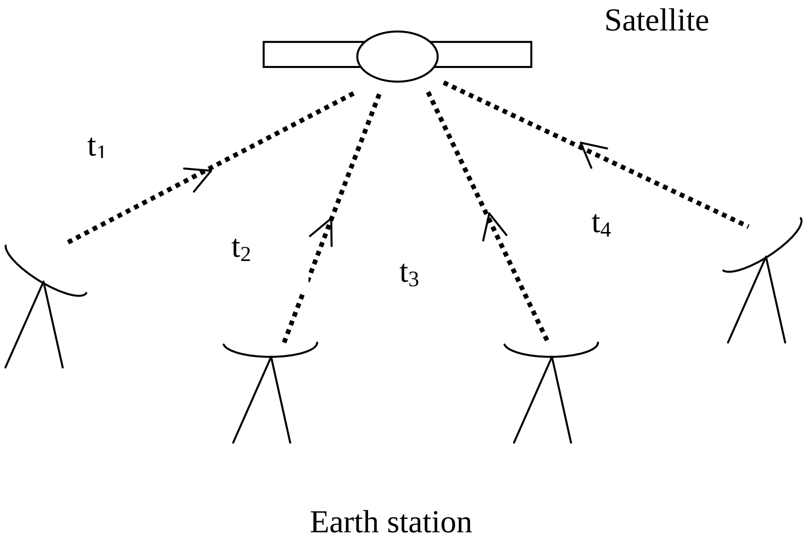
The bandwidth depends on the amount of information to be transmitted.



There is no information of signals at the satellite or free space. Since they operate at different frequencies.

TDMA





In this method all carriers use the whole bandwidth. But they do not transmit continuously as FDMA.

Carrier 1	transmits	-	t_1 ms
Carrier 2	transmits	-	t_2 ms
Carrier 3	transmits	-	t_3 ms
Carrier 4	transmits	-	t_4 ms

Again

Carrier 1	transmits	-	t_1 ms
Carrier 2	transmits	-	t_2 ms

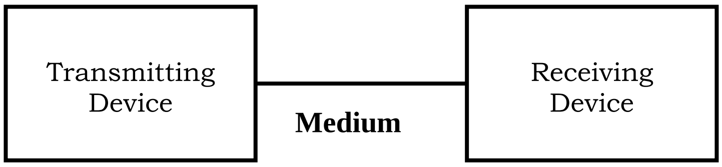
And this pattern is repeated.

Very Small Aperture Terminal (VSAT)

Normally very large antennas such as 18 m diameter antennas are used for satellite communication. These antennas have a very large aperture. But if we transmit a carrier of about 512 kb/s, such a big antenna is not economical. Therefore, especially for data communication or low information transmission, specially designed earth stations are used. They use very small aperture antennas such as 5 m diameter. Such earth stations are called VSATS. The operation of a VSAT is similar to a normal earth station.

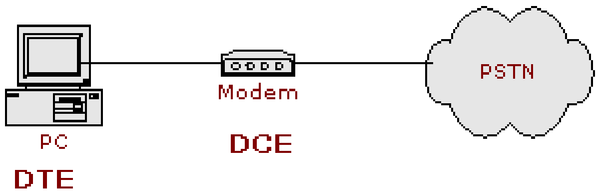
4. Data Communication - Fundamentals

Communication Model



To transmit information between two locations, it is necessary to have a transmitter, receiver and a transmission medium, which provides the connection.

DTE/DCE



Data Terminal Equipment (DTE)

The terminal equipment (PC or Dumb terminal) connected to a network is called Data Terminal Equipment (DTE).

Data Communication Equipment (DCE)

The interface connected to the DTE and network is called DCE. This is also called Data Circuit Terminating Equipment.

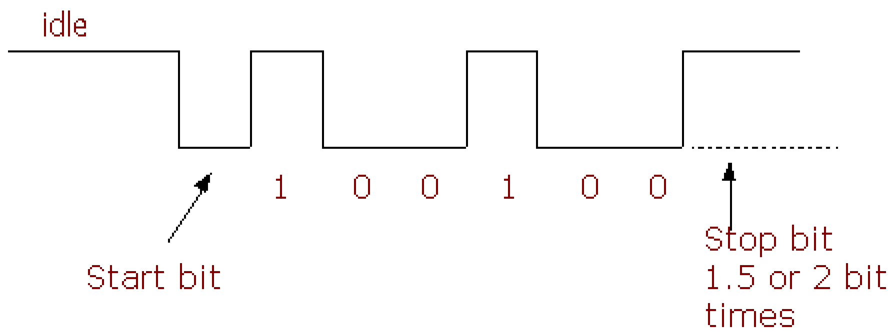
Transmission Modes

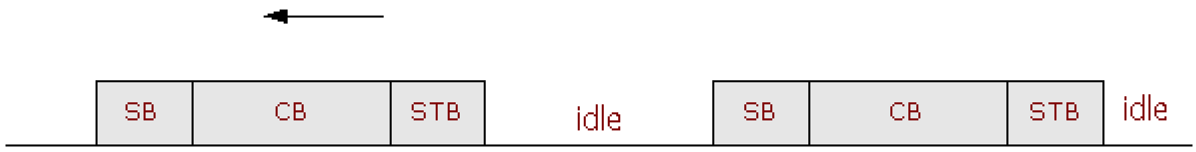
There are two transmission modes.

- Asynchronous Transmission
- Synchronous Transmission

Asynchronous Transmission

Data is not transmitted continuously. A character can be represented by a group of bits. (E.g. 8 bits) Each set is sent with a start bit and a stop bit.





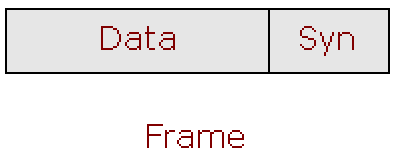
SB - Start Bit
STB - Stop Bit
CB - Character Bit

Characters are transmitted intermittently.

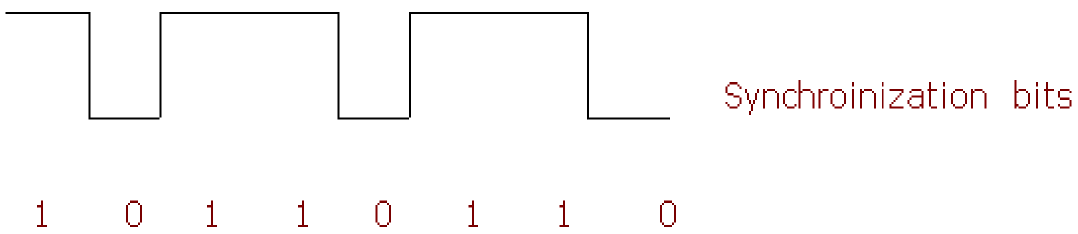
At the idle condition the line voltage can be positive. When the start bit is received by the Receiver it detects the start bit by changing the voltage to zero level. The end of bits is detected by a stop bit, which has longer bit duration.

Synchronous Transmission

Data is transmitted continuously as frames.

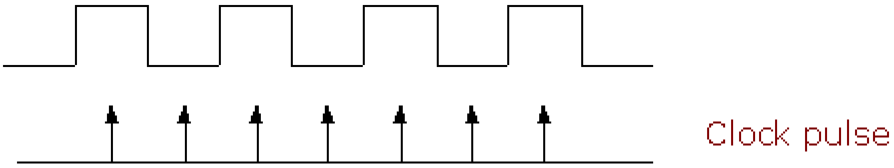


A frame consists of synchronization bits and data bits.



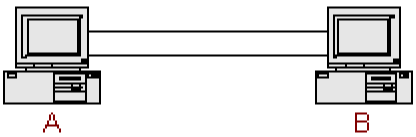
Synchronization bits are a predefined bit pattern. The receiver scans all received bits until it receives the synchronization bits. After it detects the SYN bits, the receiver knows that the next fixed numbers of bits are data bits.

In order to detect a bit a clock pulse is used.



Note : *Clock pulses are a continuous pulse stream which has a bit rate equivalent to data bit rate and a very small pulse width. This can be generated separately or from the incoming data bits. If it is generated from the incoming bit stream it is called clock recovery.*

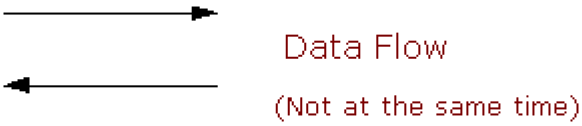
Transmission Techniques



Simplex - Transmit in only one direction.

2 wire circuit

Half Duplex - Transmits in both directions. But not simultaneously. (2 wire circuit)



A to B transmits and stop, then B to A transmits.

2 wire circuit

Full Duplex -

A to B and B to A transmit simultaneously.
This is normally a 4 wire circuit.

(A → B 2 wire, A ← B 2wire)

Note : *By using Frequency Division Multiplexing, this can be done using two wires.*

Base band

The whole bandwidth of the cable is occupied by the signal.

Broad Band

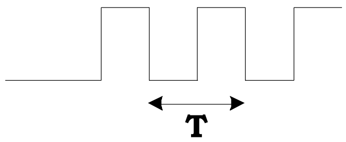
The bandwidth of the cable is used by more than one multiplexed signal.

Data Encoding

Data encoding means the bit pattern is modified for better clock recovery and less attenuation. There are different types of line codes such as AMI, Manchester 2 BIQ etc.

In order to understand line codes, we should be familiar with the following terms.

Cell or Unit Interval (UI)



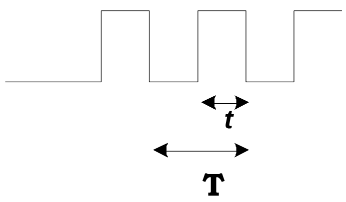
The time allocated for one bit is called the Unit Interval. That is the period of the pulse train.

Unit Interval = T

Bit Rate

Number of bits per second, Bit Rate = $\frac{1}{\mathrm{T}}$

Duty Cycle



Duty Cycle = $\frac{t}{\mathrm{T}} \times 100\%$

Unipolar Signals

Only one potential relative to ground level is available.

There are two types of unipolar signals.
(i) Non Return to Zero (NRZ)
(ii) Return to Zero (RZ)

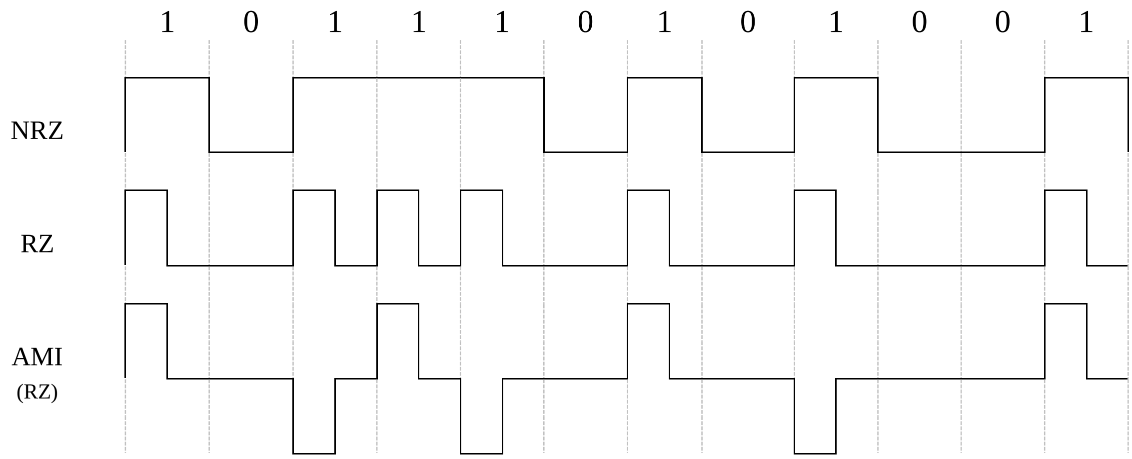
NRZ signals have a 100% duty cycle.
RZ signals have less than 100% duty cycle.

Types of Line Codes

Alternate Mark Inversion (AMI)

Properties of the AMI Code

(i) Zeros are transmitted as zeros without any change.
(ii) Alternative marks are inverted to opposite polarity.



Manchester Coding

1 - Low to High signal (Transition occurs at the center)

0 - High to Low signal (Transition occurs at the center)

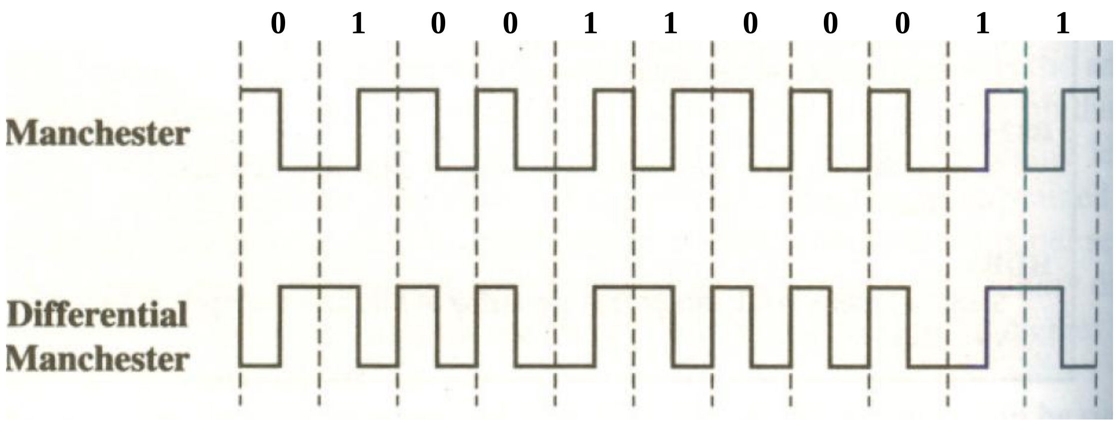
Differential Manchester Coding

Always a transition in middle of interval

0 - Transition occurs at the beginning of interval

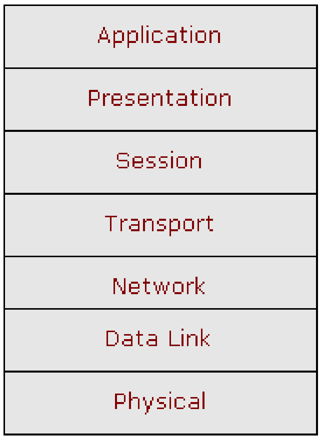
1 - No transition at beginning of interval

(Transition means, it changes the current state irrespective of 1 or 0.)



Optical line codes:

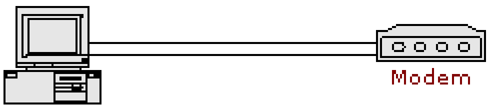
5. ISO-OSI Seven Layers



The International Standards Organization (ISO) defined Open System Interconnection (OSI) Seven Layers.

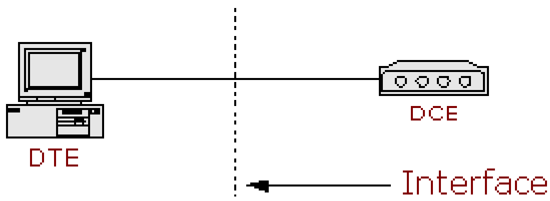
What is the use of this?

Suppose we purchased a PC from one vender and a Modem from another vender.



When we try to connect them, the computer connector may not be compatible with the modem connector. If they were manufactured according to the ISO-OSI standards this problem will not arise.

Physical Layer



The physical layer defines the DTE/DCE interface standards. It defines the following characteristics.

Mechanical Characteristics

- The shape of the connector.
- Number of pins.
- The diameter of a pin.
- The distance between two pins etc.

Electrical Characteristics

The voltage levels used.
e.g. '1' - 5V
0 - 0 V

Both the DTE and the DCE should use the same electrical signal levels.

Functional Characteristics

Function of each pin should be defined.

Example :

- Pin 1 - Ground
- Pin 2 - DTE TX
- Pin 3 - DTE RX

Procedural Characteristics

The procedure of communication between DTE and DCE.
E.g. DTE requests from DCE to send data.
Then DCE says OK etc.

The ISO-OSI defines the basic features of the standards. The other industrial or service oriented associations/institutions introduce the interfaces according to the ISO-OSI recommendations. The two main associations/institutions that introduce such interfaces are,

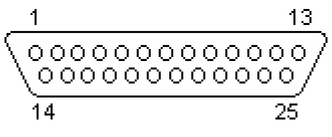
- Electrical Industrial Association (EIA)
- International Telecommunication Union (ITU-T)

E.g. EIA introduced RS-232D interface standard
ITU-T introduced the V.35, X.21, I.440 etc.

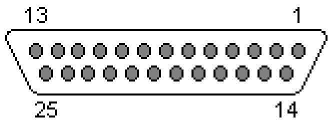
RS232D

What are the mechanical characteristics ?

Connector is named as DB25.



25 pin d-sub Male (At the DTE)



25 pin d-sub Female (At the DCE)

25 PIN D-SUB MALE at the DTE (Computer).
25 PIN D-SUB FEMALE at the DCE (Modem).

Functional Characteristics

Pin	Name	I/O	Description
1	GND	-	Shield Ground
2	TXD	O →	Transmit Data
3	RXD	I ←	Receive Data
4	RTS	O →	Request to Send
5	CTS	I ←	Clear to Send
6	DSR	I ←	Data Set Ready
7	GND	-	System Ground
8	CD	I ←	Carrier Detect
9	-	-	RESERVED
10	-1	-	RESERVED
11	STF	O →	Select Transmit Channel
12	S.CD	I ←	Secondary Carrier Detect
13	S.CTS	I ←	Secondary Clear to Send
14	S.TXD	O →	Secondary Transmit Data
15	TCK	I ←	Transmission Signal Element Timing
16	S.RXD	I ←	Secondary Receive Data
17	RCK	I ←	Receiver Signal Element Timing
18	LL	O →	Local Loop Control
19	S.RTS	O →	Secondary Request to Send
20	DTR	O →	Data Terminal Ready
21	RL	O →	Remote Loop Control
22	RI	I ←	Ring Indicator
23	DSR	O →	Data Signal Rate Selector
24	XCK	O →	Transmit Signal Element Timing
25	TI	I ←	Test Indicator

***Note:** Do not connect SHIELD(1) to GND(7).*

Electrical Characteristics

+3V to +15V - ON or '1'

-3V to -15V - OFF or '0'

The voltage range from -3V to +3V is considered as the transition region, that has no effect upon the condition of the circuit.

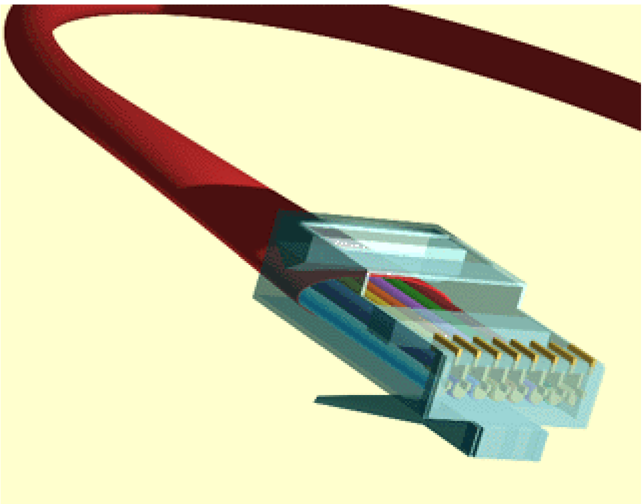
Procedural Characteristics

The DTE needs to send data to the DCE.

The DTE activates the DTE Ready (DTR), Pin 20
The DCE responds by activating DCE ready Pin 6.
After some other steps the DTE Transmits Data (TXD), Pin 2 etc.
Similarly for any DTE-DCE interface above all are to be defined.
E.g. V.34 28.8 kbps modem interface.

RJ-45 Jack

Most DCEs are designed to connect to the PSTN by using RJ45 Jacks.



The RJ-45 Connector has 8 pins.
Pins 1,2 Tx from DTE to DCE
Pins 3,6 Rx to DTE from DCE

Wiring Diagrams for Straight Through, Cross Over Cables

Note: *The hook is underneath in all cases and Pin one is always on the Left.*

Straight Through Cable	Color Code
Pin 1	White orange
Pin 2	Orange
Pin 3	White green
Pin 4	Blue
Pin 5	White blue
Pin 6	Green
Pin 7	White brown
Pin 8	Brown

Side A		Side B	
Cross Over Cable	**Color Code**	**Cross Over Cable**	**Color Code**
Pin 1	White green	Pin 1	White orange
Pin 2	Green	Pin 2	Orange
Pin 3	White orange	Pin 3	White green
Pin 4	Blue	Pin 4	Blue
Pin 5	White blue	Pin 5	White blue
Pin 6	Orange	Pin 6	Green
Pin 7	White brown	Pin 7	White brown
Pin 8	Brown	Pin 8	Brown

Data Link Layer

Suppose there is a physical connection between two computers. Computer **A** needs to transfer data to computer **B**.

Before sending data, computer **A** should establish a live connection with computer **B**. Then transfer the data. After completion of the sending data, the live link should be terminated. This is the responsibility of the Data Link Layer.

That is

- Establishment of the link
- Data transfer
- Termination of the link

When transferring data, it is to be made sure that all data will be transferred without any error.

How can we transfer the data without any error?

Detect the error, then correct the error.
i.e.

- Error detection
- Error correction

Error Detection

The simplest method of error detection is parity check. Suppose the frame size is 8 bits. 7 data bits and 1 parity bit.

0	1	1	0	0	1	1	P

Odd Parity - the parity bit (P) is set to 1 or 0 to make the **total number of '1's to an odd number.**
For above example P = 1

Even Parity - the parity bit (P) is set to 1 or 0 to make the **total number of '1's to an even number.**
For above example P = 0

At the receive end the total number of '1's in the frame is checked. If we use odd parity, the number of '1's should be an odd number. If not, there is an error. Then the same frame is requested from the transmit end.

Note: *This method is true only for single bit errors.*

Cyclic Redundancy Check (CRC)

The data (n bits) is divided by another number (m bits where m<n)
e.g. data - 1010001101
division - 110101
Modulo 2 arithmetic is used.

After dividing, the remainder can be obtained. This is called the ***"Frame Check Sequence (FCS)"***

For above example it can be shown that FCS = 01110
The data and FCS is transmitted together.
101000110101110

At the receive end it is divided by the same division (110101). If the remainder is zero, there was no error. If not there are errors and the same frame is requested from the transmit end.

Error Correction

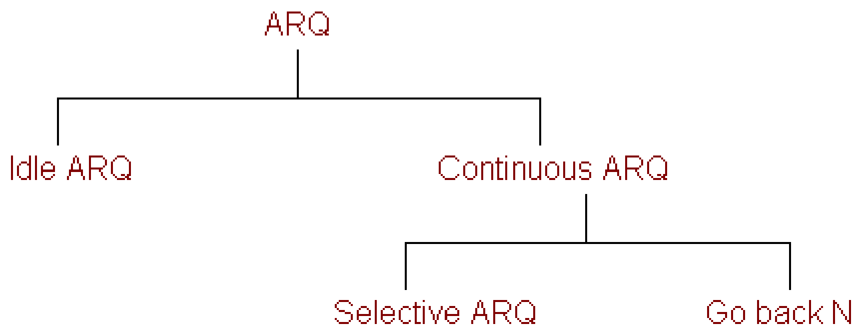
Forward Error Correction (FEC)

Detect the errors and correct the errors at the receive end.

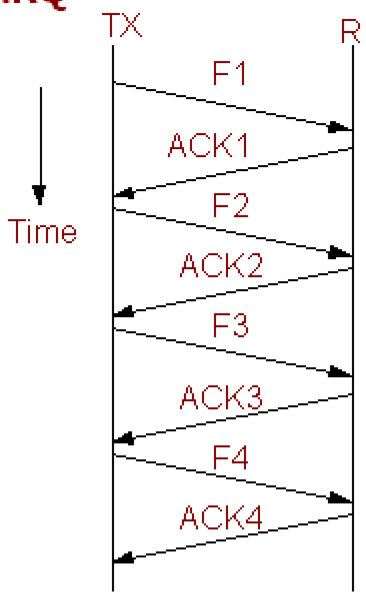
Backward Error Correction

Data is transferred by frames. If any error is detected, it is requested from the transmit end to retransmit the frame. Normally this process is done automatically. Therefore it is called the **A**utomatic **R**epeat re**Q**uest (ARQ).

ARQ methods



Idle ARQ



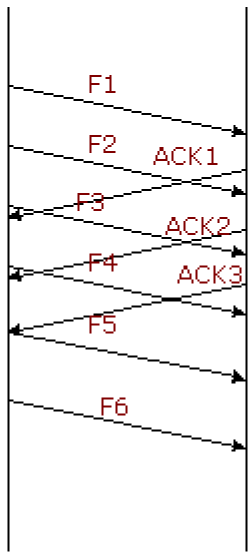
ACK - Acknowledge

NAK - Negative Acknowledge (where an error is detected)

If NAK is received the same frame is retransmitted.

This is also called the stop and **waitmethod.**

Continuous ARQ



The frame 3 has errors and NAK3 was received.

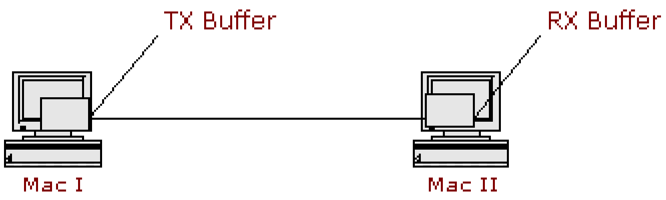
Selective Retransmission

- retransmit F3
- Next transmit F7, F8 etc.

Go back N

- retransmit F3
- Next transmit F4, F5 etc.

Flow Control



Because of error control, another problem arises. That is the frames are temporarily stored at the receive end, checked and if errors are detected request the frame from the transmit end. The Transmit end also keeps the frames in a temporary store, until the confirmation from the receive end is received. The temporary store is called the ***buffer*** and it has a limited memory space.

Suppose the receive buffer has only 5 frames space. If there are 5 frames already in the buffer and another frame is also received, it has no memory space in the buffer. Therefore the frame will be overflowed and the data is lost. In such a situation the receive end should inform the transmit end to suspend sending of frames. When the memory has free space, it is informed to the transmit end to resume sending of the frames.

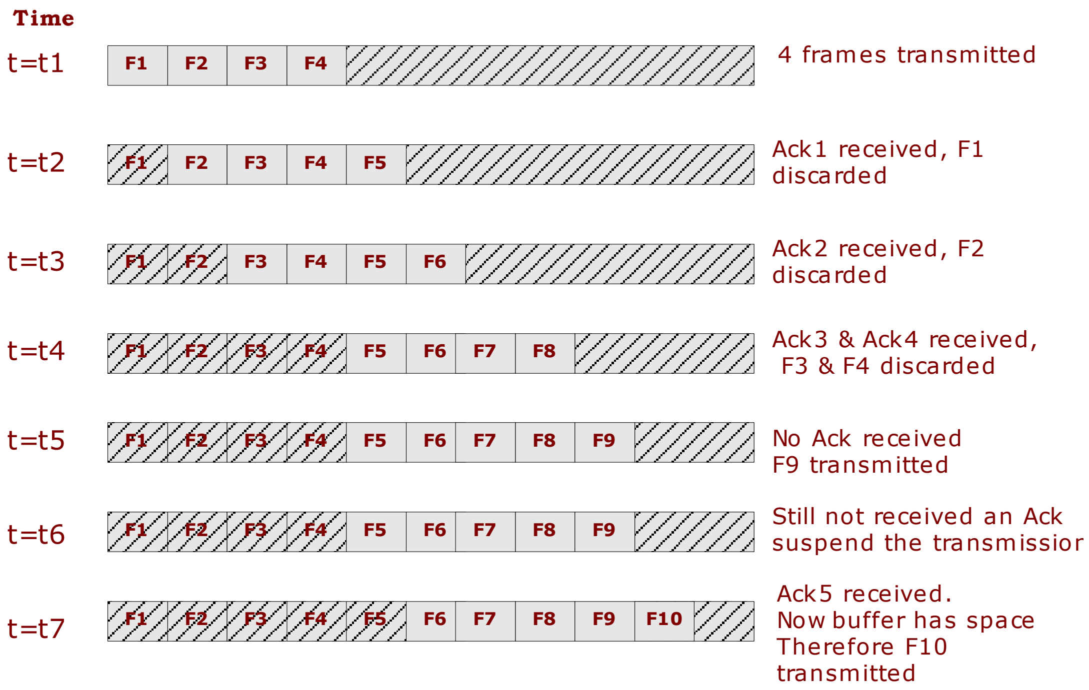
Similarly if the transmit buffer is full the transmission of frames is to be suspended until sufficient space is available in the transmit buffer.

This process is called ***flow control***. The most popular method for flow control is the sliding window mechanism.

Sliding Window Mechanism

Suppose the TX buffer size is 5 frames.

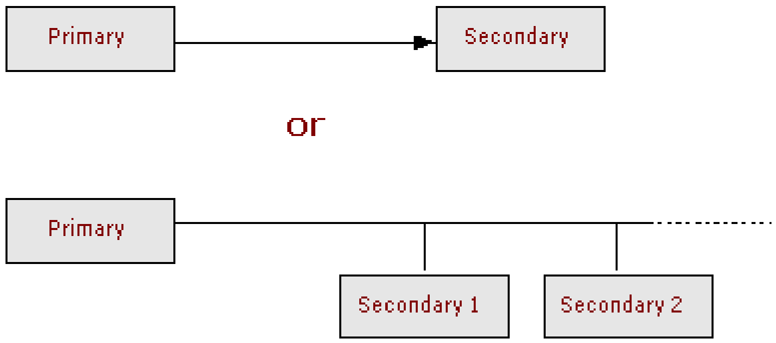
Consider the buffer content at different times.

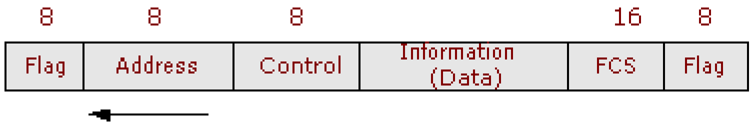


This mechanism is just like sliding a window. Therefore, it is called <u>Sliding Window Mechanism</u>.

High Level Data Link Control (HDLC)

This is a general frame format used in the Data Link Layer. This is a point to point link protocol.



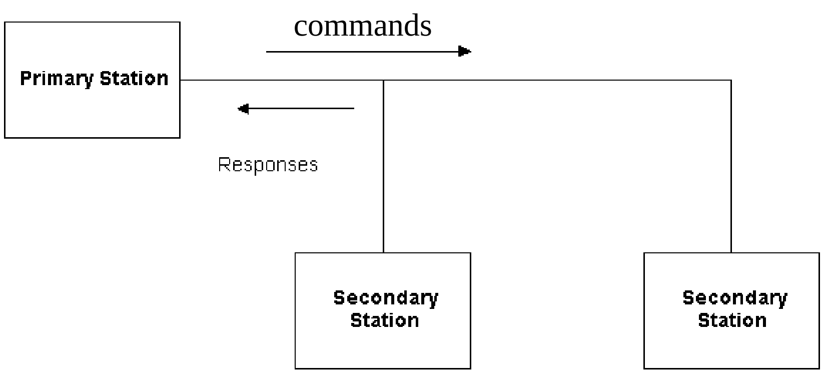


Flag - For synchronization
Address - Address of secondary. (if more than one secondary is available)
Control - For link establishment, termination, ACK, NAK and other control information.

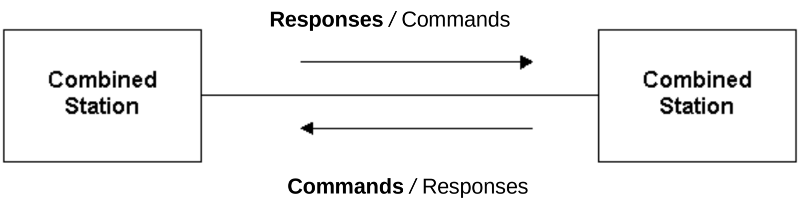
In HDLC, the frames sent by the primary station to the secondary station are known as *commands* and those from secondary to the primary as *responses*.

In the way primary and secondary are arranged there are two configurations.

- Unbalanced configuration.
- Balanced configuration.



Unbalanced configuration



Balanced configuration

HDLC offers three different modes of operation.

- Normal Response Mode (NRM)
- Asynchronous Response Mode (ARM)
- Asynchronous Balanced Mode (ABM)

Normal Response Mode (NRM)

This is the mode in which the primary station initiates transfers to the secondary station. The secondary station can only transmit a response when, and only when, it is instructed to do so by the primary station. Once the secondary station transmits the last frame, it must wait once again from explicit permission to transfer anything, from the primary station. Normal Response Mode is only used within an unbalanced configuration.

Asynchronous Response Mode (ARM)

In this mode, the primary station doesn't initiate transfers to the secondary station. In fact, the secondary station does not have to wait to receive explicit permission from the primary station to transfer any frames. This is used in unbalanced configuration.

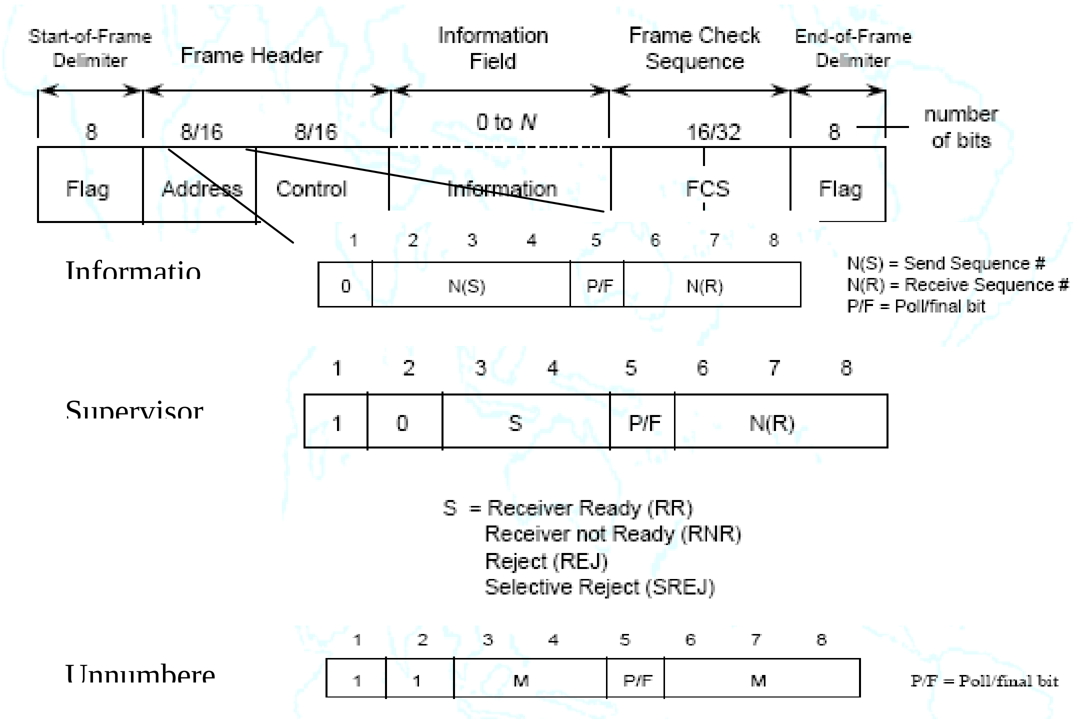
Asynchronous Balanced Mode (ABM)

This mode uses combined stations. That is in balanced configuration. There is no need for permission on the part of any station in this mode. This is because combined stations do not require any sort of instructions to perform any task on the link.

There are three types of frames used in HDLC

- Information frames (I- Frames)
- Supervisory frames (S-Frames)
- Unnumbered frames (U-frames)

There are identified by the control field bit pattern

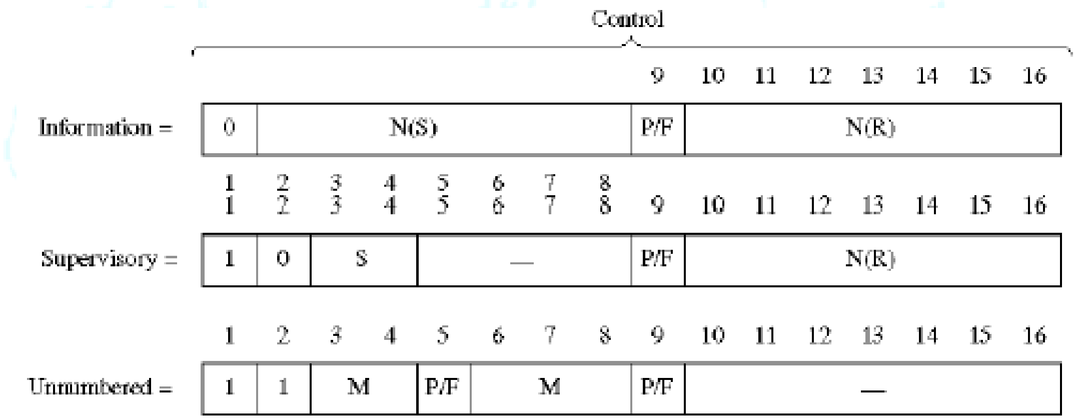


Information frames –(I-frames) – Carry information (Data) can be used to give acknowledgements

Supervisory frames – (S-frames) – Used for error and flow control, hence contain send and receive sequence numbers.

Unnumbered frames – (U-frames) – used to link setup and link disconnection.

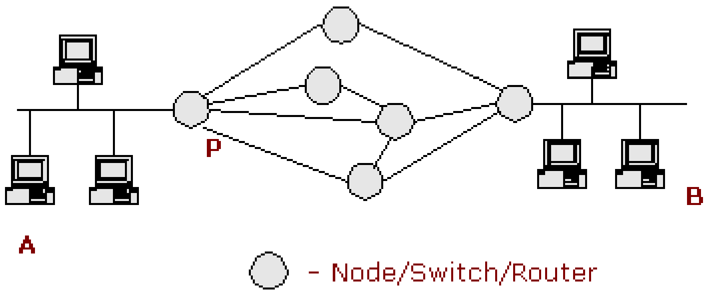
This is the standard frame format. It also can have the extended frame format. That is as follows.



Other Data Link Layer Protocols

LAP - B - X.25 DLL Protocols.
LAP - D - ISDN DLL Protocols.
Point-to-Point Protocols. (PPP).
Logical Link Control (LLC) and Media Access Control (MAC) Protocols for LANs.

Network Layer



The above figure shows a switched network. Computer A needs to connect to computer B. When data goes to P, it has many routers and it should switch the data to the correct path. Therefore at each node, the data has to be switched to the correct route. This process is called routing.

The group of bits sent by the network layer is called a packet. The packet has data and a Network Header (NH).

The NH has the Source and Destination logical addresses and other information related to the Network Layer. At each node the destination logical address is analyzed and switching is done accordingly.

It is the responsibility of the Network layer to carry a data packet from the source computer to the destination computer.

Packet Switching / Routing

The data is divided into small groups of bits and these are called Packets. Each packet is given a number and transmitted one by one. Each host in the network is given a unique identification called address. The packet also includes the source host address and the destination host address. The Packet Switching Exchange (PSE) / router analyzes the packet. It checks the destination host address and directs to the correct route at each PSE / router. This process is called Packet Switching. There are two types of packet switching.

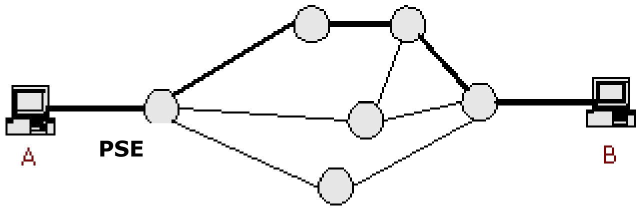
- Datagram
- Virtual Circuit

Datagram

Each packet is analyzed at each node, the route is found and the packet is directed to that route. If 1000 packets are sent from one end to the other end, each node should analyze all 1000 packets. Therefore nodes need considerable processing power. This method is suitable to transmit small number of packets. Also packets can go through different routes and the packets may not reach the receiver end in the correct order. This means that packet 12 can reach the destination before packet 10. The receiver end removes the headers of each packet and assembles the data in the correct order. In this process there is no initial connection setup between transmit end and receive end. Therefore, this is called a connectionless process.

Virtual Circuit

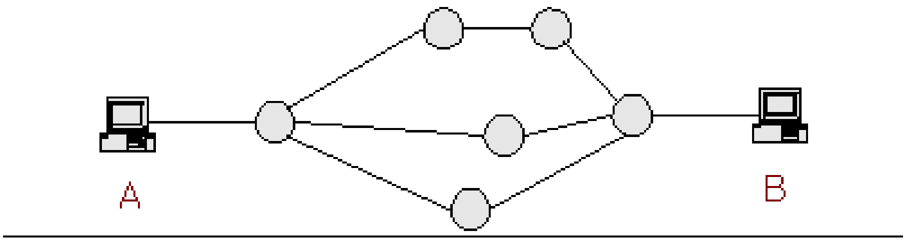
Initially a special packet is sent to find the route. This packet is analyzed at each node and one route is selected at each node to transmit the packets. Then the path is setup between transmit end and receive end. This is called a virtual circuit.



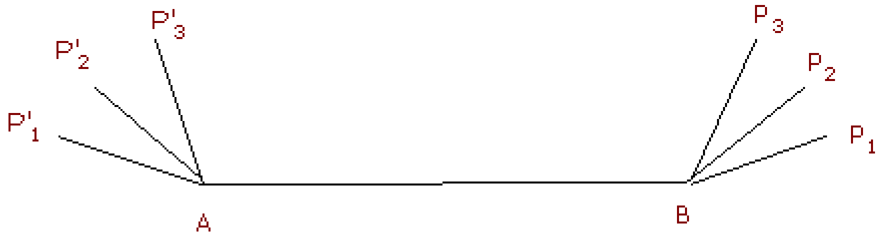
The dark line shows the virtual circuit path between **A** and **B**.

Now A can transmit all data packets to B through this path. The packets will reach A in the correct order. The advantage of this method is that each packet is not analyzed at each node to find out which virtual circuit each belongs to. Therefore a node needs less processing power compared to the datagram method. This is also called a connection-oriented process.

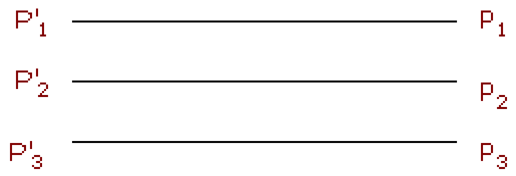
Transport Layer



Suppose computer **B** is the server and computer **A** is the client. **B** can run several processes (programs) at the same time. Normally these are called server processes. **A** can work with all these processes, but **A** should run the corresponding client processes.



P_1,P_2,P_3 - Server processes
P'_1,P'_2,P'_3 - Client processes

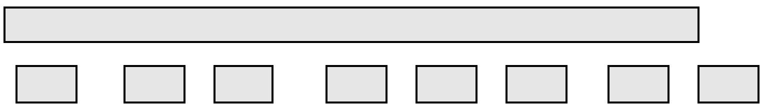


Carrying the data from A to B is the responsibility of the Network Layer.

Establishment of connection between processes is the responsibility of the Transport Layer.

Each process is gives an identification number. This is called a "Port number".

Another responsibility of the Transport Layer is segmentation. The Session Layer (The layer above Transport Layer) sends data to the Transport Layer. The Transport Layer divides the data into small units.



This process is called segmentation.

Then, each data unit is combined with the Transport Header (TH) which consists of some information related to the Transport Layer, including the Source and Destination Port numbers.

Therefore the responsibilities of the Transport Layer are,

- Segmentation of data (Tx end) and reassembly of data (receive end).
- Establish connection between processes.
- Flow control of data (process to process)
- Error control of data (process to process)
- After completion of transferring data terminate the connection.

Session Layer

The services provided by the first three layers (physical, data link, and network) are not sufficient for some processes. The session layer is the network dialog controller. It establishes, maintains, and synchronizes the interaction between communicating system.
Specific responsibilities of the session layer include the following :

Dialog control

The session layer allows two systems to enter into a dialog. It allows the communication between two processes to take place either in half-duplex (one way at a time) or full-duplex (two ways at a time). For example, the dialog between a terminal connected to a mainframe can be half-duplex.

Synchronization

The session layer allows a process to add checkpoints (synchronization points) into a stream of data. For example, if a system is sending a file of 2,000 pages, it is advisable to insert checkpoints after every 100 pages to ensure that each 100-page unit is received and acknowledged independently. In this case, if a crash happens during the transmission of page 523, the only pages that need to be resent after system recovery are pages 501 to 523. Pages 524 to 2000 still come as well.

Presentation Layer

The presentation layer is concerned with the syntax and semantics of the information exchanged between two systems.

Translation

The processes (running programs) in two systems are usually exchanging information in the form of character strings, numbers, and so on. The information should be changed to bit streams before being transmitted. Because different computers use different encoding systems, the presentation layer is responsible for interoperability between theses different encoding methods. The presentation layer at the sender changes the information from its sender-dependent format into a common format. The presentation layer at the receiving machine changes the common format into its receiver-dependent format.

Encryption

To carry sensitive information a system must be able to assure privacy. Encryption means that the sender transforms the original information to another form and sends the resulting message out over the network. Decryption reverses the original process to transform the message back to its original form.

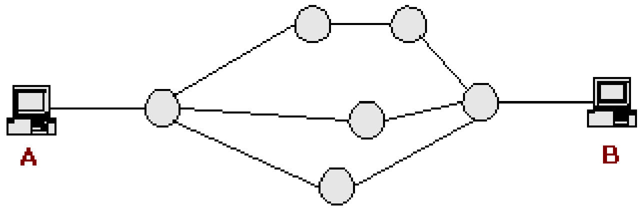
Compression

Data compression reduces the number of bits contained in the information. Data compression becomes particularly important in the transmission of multimedia such as text, audio, and video.

Application Layer

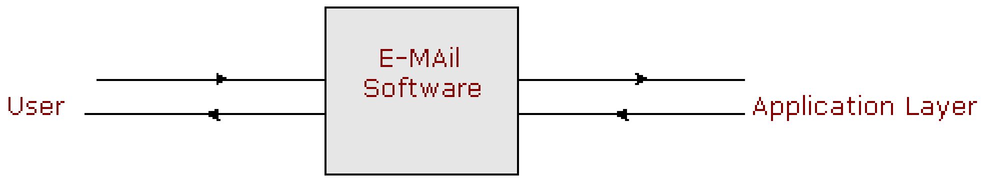
The application layer enables the user, whether human or software, to access the network. It provides user interfaces and support for services such as electronic mail, remote file access and transfer, shared database management, and other types of distributed information services.

Application Layer interacts with the user and the Presentation Layer. The other six layers support to carry the application data from transmit end to receive end. Example of an application is E-Mail.

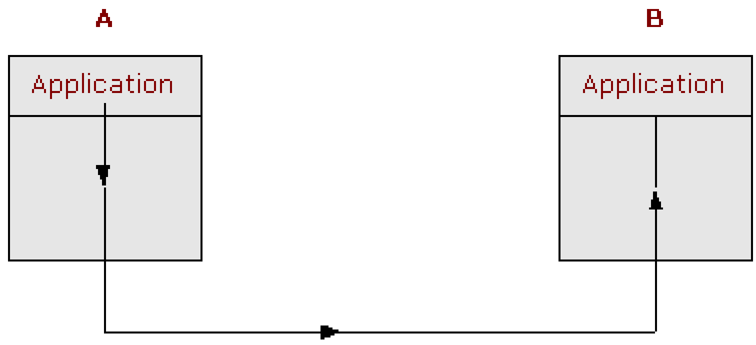


How can we send E-Mail from A to B?

Suppose **A** is the client and **B** is the Mail Server.
After **A** makes a connection with **B, A** types a letter (data)
This data is sent to Presentation, Session and Transport Layers.



The Transport Layer segments the data, adds the transport Header and sends to the Network Layer. Then it is sent to the Data Link Layer, the Physical Layer and finally put to the transmission media.



B will do the reverse process of **A**.

Important points of ISO-OSI Seven Layers

Segment - group of bits at Transport Layer level.
Packet - group of bits at Network Layer level.
Frame - group of bits at Data Link Layer level

Process to process (users' program to program) connection is made by Transport Layer (TL).

Computer (Host) to computer (Host) connection is made by Network Layer (NL).

A network has many links. Data packets are switched to the correct link (route) at a node.

Carrying Data from one end of the link to the other end is done by Data Link Layer (DLL)).

Port Address	-	Identifies the process. Related to the Transport Layer.
Logical Address	-	Identifies the computer. Related to the Network Layer.
Physical Address	-	Identifies the computers at two ends of a link. Related to the Data Link Layer.

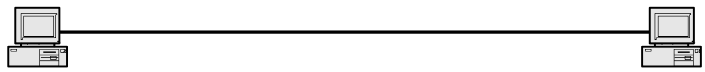
An example of a logical address is IP Address.

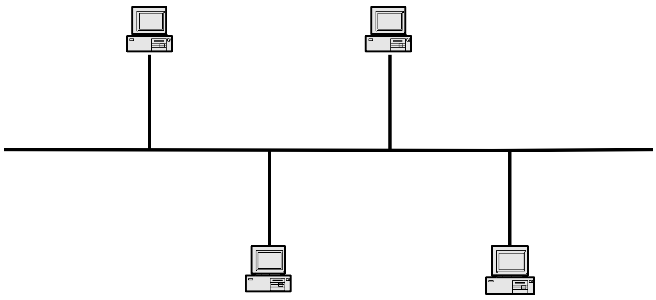
An example of a physical address is MAC Address.

6. Computer Networks

How can we connect two or more computers?

If the computers are located in close proximity, cables can be used.

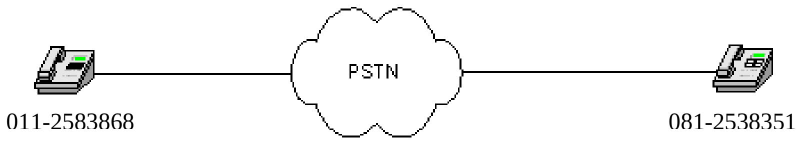




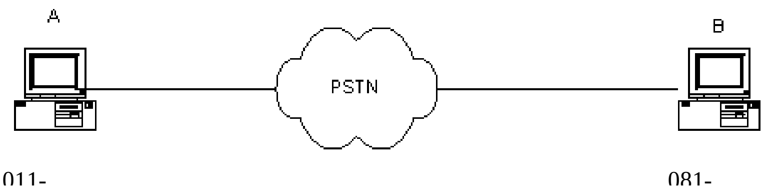
This type of network is called a Local Area Network. (LAN)

If the computers are located very far away a Public Network can be used.

A well-known Public Network is the Telephone Network. Normally this is called a Public Switched Telephone Network. (PSTN)



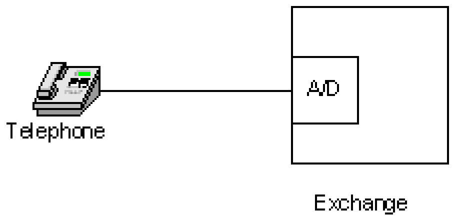
We can remove two telephones and connect two computers instead.



If computer **A** dials the number 081-2538351, it can connect to the computer **B.**

This type of connection is called a dial up connection. Also this type of a network is called a Wide Area Network. (WAN)

However, there is a problem in connecting a computer directly to PSTN.

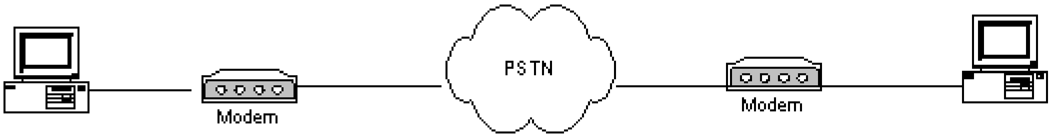


The telephone output signal is an analog signal with a bandwidth of 0.3 – 3.4 KHz.

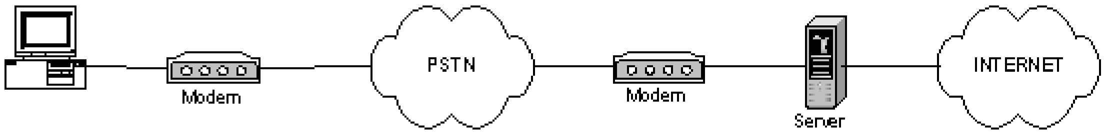
At the telephone exchange this analog signal is converted to a digital signal. (Analog to Digital conversion or A/D Conversion). For this purpose Pulse Code Modulation (PCM) is used.

Since the exchange expects an analog signal, the computer output digital signal should be converted to an analog signal. For this purpose a Modulator is required. Similarly for the received side of computer, the analog signal sent by the exchange has to be converted to a digital signal. For this purpose a Demodulator is required.

Normally the Modulator and Demodulator come as one unit and it is called a MODEM.



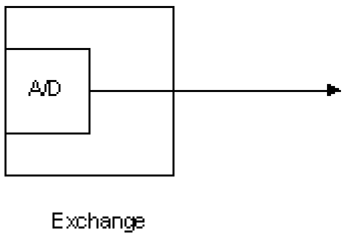
How to connect Internet through PSTN



To connect to the SLT Internet Server, you have to dial the number 150.

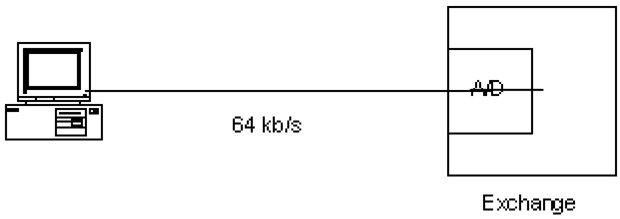
After connecting a Modem to a computer, it should be configured using the appropriate software which comes in a diskette along with the Modem.

The bit rates supported by a normal modem is 4.8 kb/s, 9.6 kb/s, 14.4 kb/s, 19.2 kb/s, 28.8 kb/s, 56 kb/s.



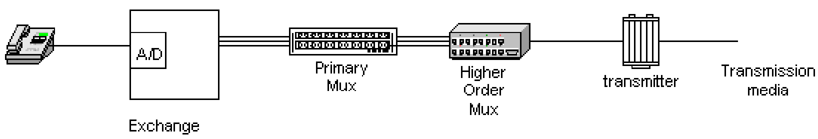
The A/D conversion process at the exchange is PCM.

The PCM output is 64 kb/s.

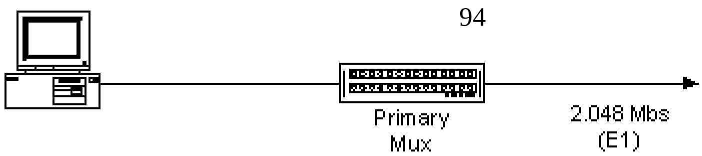


If we bypass the A/D conversion part of exchange, we can send a 64 kb/s digital signal from the computer to the exchange.

Normal telecommunication system is as follows.



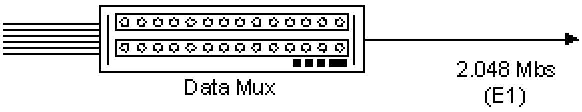
If we by-pass the exchange the computer can be directly connect to the Primary MUX.



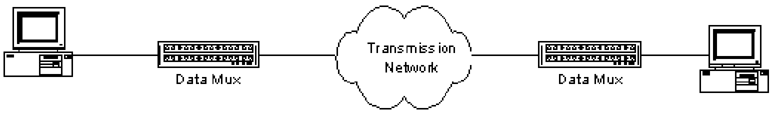
Each input channel of the Primary MUX is 64 kb/s. Therefore the computer can send 64 kb/s digital signal.

However, the Primary MUX does not have the ability to provide service for bit rates of multiples of 64 kb/s. That is 128 kb/s, 192 kb/s, 256 kb/s, 512 kb/s etc.

Therefore for data transmission purposes the Data MUX is used.



The input ports can be configured for different bit rates. That is 128 kb/s, 192 kb/s, 256 kb/s, 512 kb/s etc.

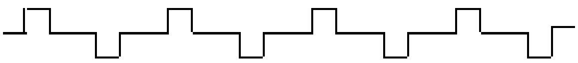


This type of circuit is called a leased circuit.

The computer output signal is a unipolar binary signal.

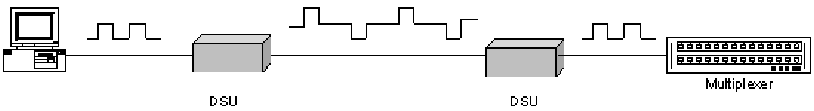
When such a signal travels more than about 100 m it can get attenuated.

In order to send a Computer signal to a long distance, it should be converted to some pattern of a bipolar signal.



This is called a line code.

By using a Digital Service Unit (DSU), line coding can be achieved.



For leased digital circuits we have to use a DSU at the computer and DSU at the Data Mux.

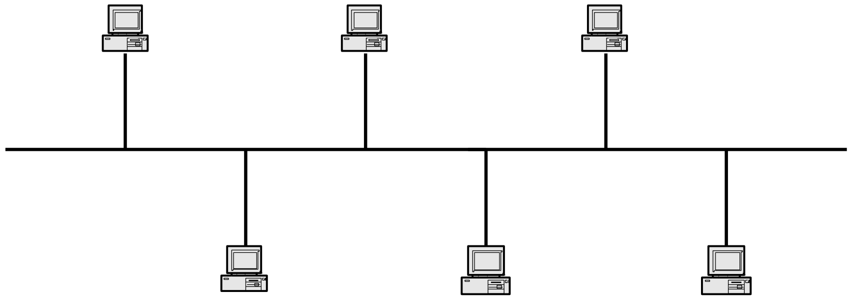
For dial up connections we have to use a Modem at the computer.

Local Area Networks (LAN)

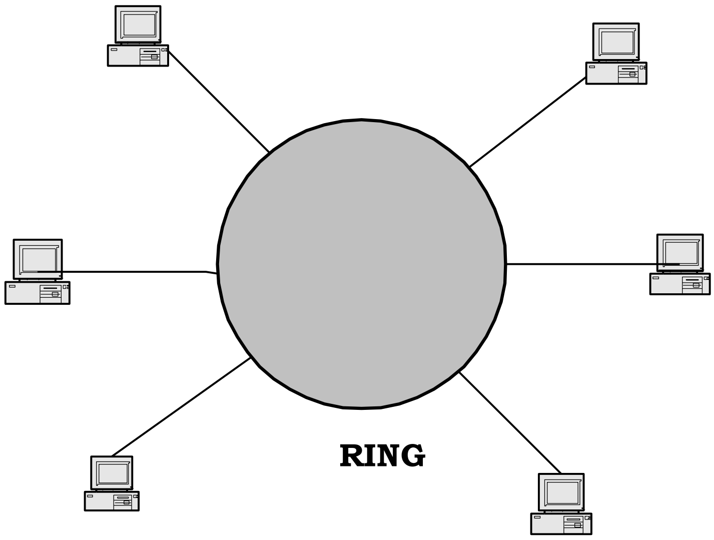
If the computers are connected by cables, (which are in close proximity), it is called a Local Area Network (LAN).

Network topologies

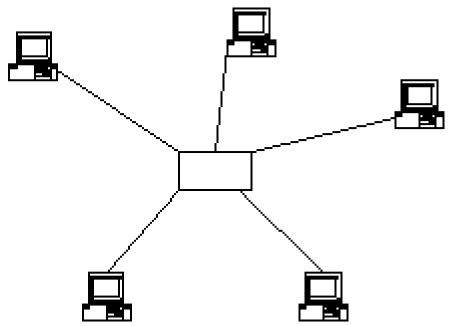
The way of connection of computers is called "Topology".



BUS



RING



STAR

The computers can be connected as in the configurations above. These are called network topologies.

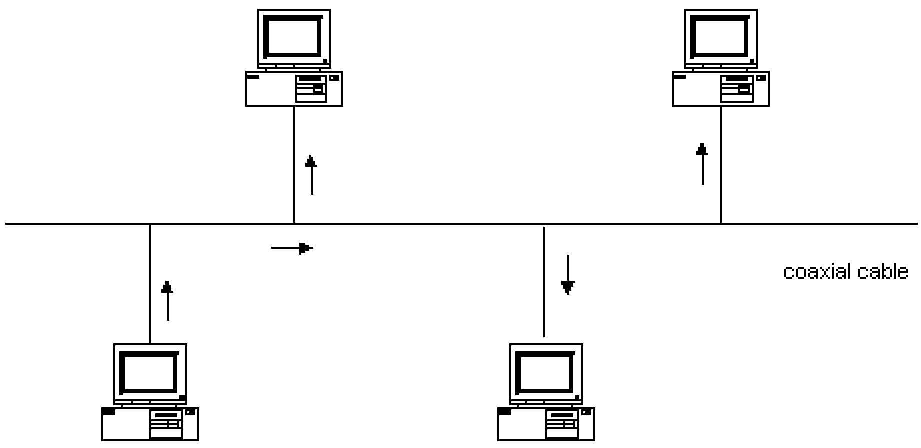
If a signal is put to a bus or a ring, all hosts connected to that network can receive the signal. Therefore, bus and ring networks are called "Broadcast Network".

The widely used topology is Bus.

The computers can be connected using a coaxial cable.

There are two types of coaxial cables.

- Thin Coaxial
- Thick Coaxial



A

If computer **A** transmits a signal, all other computers will receive it. This feature is called broadcasting. Therefore, the bus network is a broadcasting network.

Media Access Control (MAC)

In a bus network or ring network, if two computers release signals to the cable (media), there will be a collision of signals. In order to avoid collisions, the access to the media has to be controlled. The method of media access control is called MAC Protocol.

The widely used two MAC protocols are CSMA/CD and Token.

CSMA/CD

Before transmitting a signal to the media it should be checked whether a signal is already in the media. This is called Carrier Sense (CS).

By this method multiple computers can access the media at different times. This is called Multiple Access (MA). However, there is a possibility to transmit signals by two computers at exactly the same time. Then there can be a collision. Therefore, after releasing the signal to the media it should be monitored whether there is any collision.

This is called collision Detection (CD). If a collision is detected the signal has to be retransmitted. This is one of the MAC protocols. It is called CSMA/CD.

Control Token

A small frame called token is continuously going through the ring or bus. If any host in the network wants to transmit, first it checks the token in the media. If the token is available, it gets the token and releases the data frame. The data frame goes round the network (ring or bus) and come back to the transmitted host. Then it releases the token to the media.

Ethernet

If the topology is Bus and the MAC protocol is CSMA/CD, it is called Ethernet.

Thin Coaxial → Thin Ethernet

Thick Coaxial → Thick Ethernet

The bit rate of a coax cable is 10 Mb/s.

If there is a LAN, of 100 Mb/s, it is called Fast Ethernet. If the bit rate is 1000 Mb/s, it is called Gigabit Ethernet.

Token Ring

If the topology is Ring and the MAC protocol is token it is called a "Token Ring"

Token Bus

If the topology is Bus and the MAC protocol is token it is called a "Token Bus"

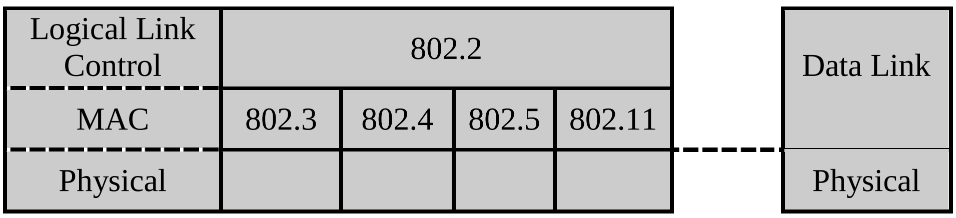
MAC Address

In order to identify computers, each computer is given a 48-bit identification number. This is called MAC Address or Physical Address.

IEEE 802 LAN Standards

The LAN standards are defined by the IEEE 802 recommendations. (IEEE- Institute of Electrical and Electronic Engineers)

IEEE 802 Reference Model



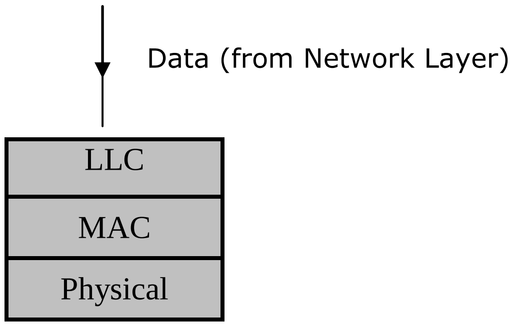
IEEE 802 Model

OSI Reference Model

802.2	-	Logical Link Control (LLC) Protocol.
802.3	-	CSMA/CD Bus
802.4	-	Token Bus
802.5	-	Token Ring
802.11	-	Wireless

The LLC Layer is common for all MAC Protocols.

LLC Frame Structure



The LLC Layer receives data from the Network Layer.

1	1	1	
DSAP	**SSAP**	**Control**	**Information**

DSAP - Destination Service Access Point - 1 byte
SSAP - Source Service Access Point - 1 byte

These two fields are used to keep the protocol information on destination and source Network Layer.

The control field also has one byte length. This is used for supervisory functions and for sending and receiving frame sequence numbers etc.

IEEE 802.3 Ethernet Frame Structure

Ethernet

If the topology is Bus and the MAC protocol is CSMA/CD it is called an Ethernet.

When a packet of data is handed over to the MAC layer to be transmitted over the physical channel, MAC layer appends some other information to it and creates a frame known as the ***Ethernet frame.***

Ethernet Frame

Data	**Overhead Bits**

The data is transmitted as a frame. The frame will have some additional bits in addition to data. They are called Overhead (OH) bits. It carries Source Address, Destination Address, and Synchronization etc.

When a frame is released to the media all computers receive it. But the computer, which has the MAC Address equal to the Destination Address of the frame, will accept the signal. Otherwise ignore it.

The IEEE 802.3 Ethernet frame structure is as follows,

7	1	6	6	2	0 - 1500	0 - 46	4
Preamble		DA	SA		Data	Pad	FCS
	Start of Frame Delimiter			Length Of Data			

Each frame starts with a preamble of 7 bytes, each containing the bit pattern 10101010. The Manchester encoding technique is used to encode this pattern to a set of electrical pulses.

- The next byte containing ‘10101011’ denotes the start of the frame.

- Each Ethernet Card Address has 48 bits or 6 bytes. This address is used in LANs to identify the parties involved in a communication session. The next two slots, i.e. Destination address & the Source address represent the Ethernet address of the destination computer and the source computer respectively.

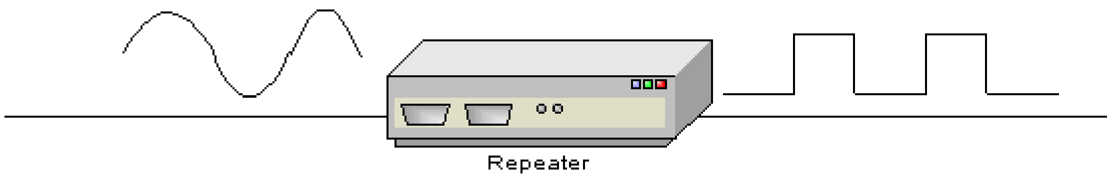
- Next two bytes represent the total number of bytes in the data field.

- The next field consists of the actual data bytes to be sent from the source computer to the destination computer.

- In order to distinguish valid frames from garbage frames IEEE defined a minimum frame length for the valid frames. That is 64 bytes from Destination address field to checksum field. Therefore if the data field is less than 46 bytes, the Pad field is used to fill out the frame to the minimum length. Also the maximum size of data is 1500 bytes.

- The final field of the Ethernet frame is the checksum field. These 32 bits are used to prepare a code for the data to detect erroneous situations. The cyclic redundancy algorithm is used to generate these check bits.

Repeater



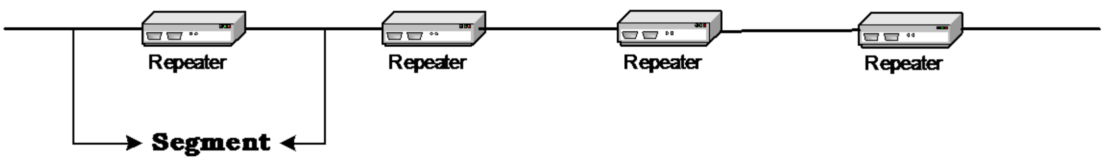
The repeater can reconstruct the original signal.

If thin Coaxial cable is used, a repeater is used after 200 m.

One side of a repeater is called a segment. The maximum number of repeaters recommended for one bus is four. In other words, the maximum number of segments is five.

<u>Segment of Ethernet</u>

The maximum number of repeaters allowed is four.

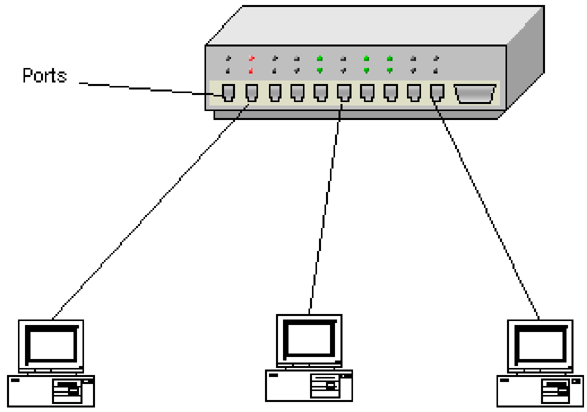


If thin coax is used, the maximum segment length is 200 m.
If thick coax is used, the maximum segment length is 500 m.

Therefore, the maximum length of a coax LAN can be 1000 m or 2500 m. (end to end). This has 5 segments but act as a single bus. If any two computers transmit frames to the cable at the same time, those two frames will collide. Therefore, we say that the whole LAN is in one-collision domain.

Hub

A hub has many connecting points. They are called ports.



Each port is connected to a computer by using an unshielded Twisted Pair (UTP) Cable with a RJ45 connector. The hub is a "Multi Port Repeater".

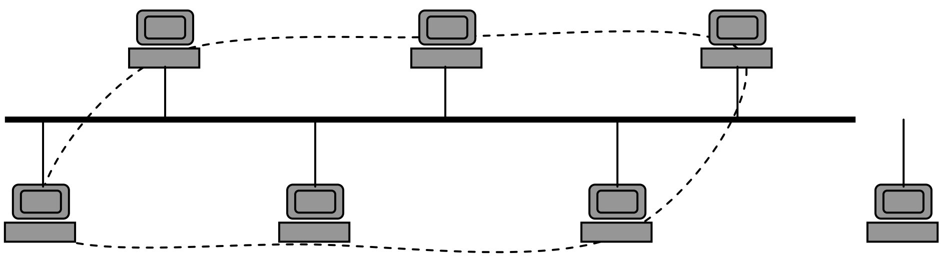
If computer **A** transmits a signal it is repeated and retransmitted to all other computers. That is, the hub broadcasts the message. This is same as the bus network.

Therefore, the hub, logically works as a bus network (physically it is a star network). The MAC protocol used is CSMA/CD. Therefore, this is an Ethernet.

Nowadays all Ethernet LANs are connected using hubs. Unlike coaxial cable, the hub can easily increase the number of computers connected to the network.

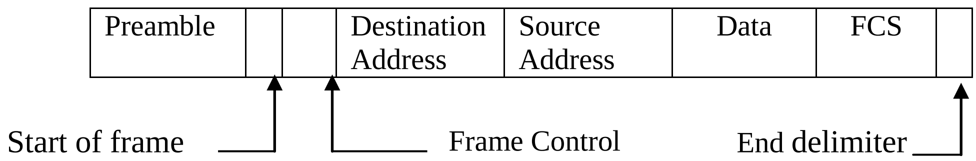
Token Bus (IEEE 802.4)

Physically the token bus is a linear cable in to which the stations are attached. Logically these stations are organized into a ring as illustrated in the diagram below, with each station knowing the address of the station to its 'left' and right.



When the ring is initialized, stations are inserted into the logical ring in order of station address, from highest to lowest. A special control packet known as a token propagates around this logical ring, with only the token holder being permitted to transmit frames. The token holder can transmit frames for a certain amount of time and then it passes the token to its neighbour. If the station has no data to be sent, it passes the token to the next station immediately. Since only one station at a time holds the token, collisions do not occur in this algorithm.

Frame format of IEEE 802.4 is as follows.



Frame control field is used to specify the frame type. I.e. is data frames and control frames.

Token Ring (IEEE 802.5)

This standard was defined for the networks with ring topology. In this standard a special bit pattern called the token circulates around the ring whenever all stations are idle. When a station wants to transmit a frame, it is required to seize the token. Only the token holder is permitted to transmit a frame over the channel. This standard also solves the collision problem as the token bus.

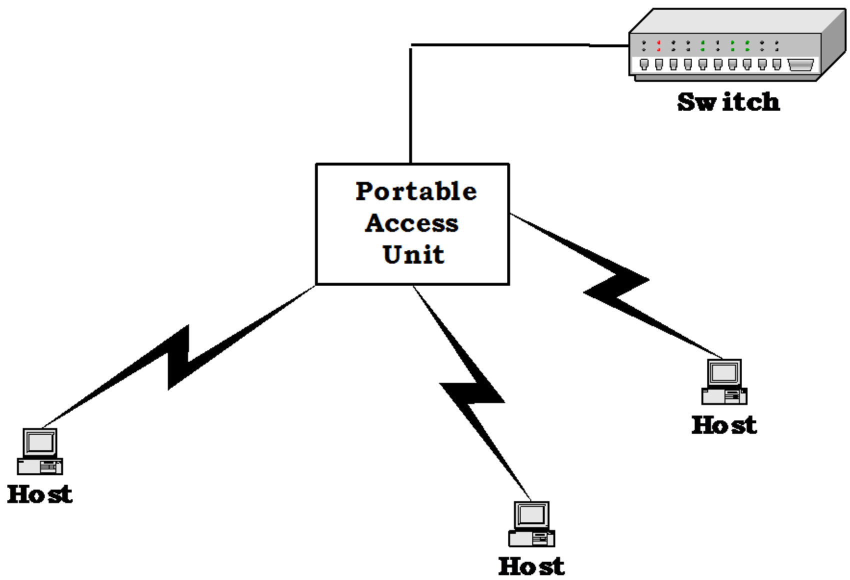
This also has the facility to prioritize the token. That is, different stations can have their own priority level, which is defined, by a control station called a Monitor.

A station wishing to transmit must wait for a free token with the existing priority is less than the required priority. If this is not satisfied it reserves the token to its required priority.

If the token priority is the same as the set priority it seizes the token and transmits the normal Data Frame. After completion of sending data it releases the token with priority same as reserved priority.

Wireless LANs

The cabling of LANs is a problem in some occasions such as open office spaces. Sometimes the cables or connectors can be damaged and also it is not nice looking since the cables are hanging here and there. The solution for such occasion is the wireless LANs.



The computers are linked to the Portable Access Unit (PAU). The PAU is wired to a switch or other network devices. The link between Host and PAU is wireless. This link can be radio or infrared.

The MAC methods that can be used are,

- CDMA
- CSMA/CD (with comb)
- CSMA/CA
- TDMA

There are four transmission schemes used with radio wireless LANs.

- Direct Sequence Spread Spectrum
- Frequency Hopping Spread Spectrum
- Single Carrier Modulation
- Multi Subcarrier Modulation.

The IEEE standard for wireless LANs is 802.11.

In wireless LANs, the media between a computer and PAU is radio. Two bands of radio can be used for this purpose. That is microwave and infrared.

Media Access Control Methods

In wireless LAN, MAC method should consider that how the radio media can be used without interference. Therefore, additional precautions should be taken when comparing to Wired LANs.

CSMA/CD

Wired LANs host can transmits and receives the signal at same time. In radio and infrared cannot transmit and receive the same frequency at same time it uses a variation of CSMA/CD known as Collision Detection (comb).

CSMA/CA

CSMA with Collision Avoidance.

TDMA

Time Division Multiple Access

FDMA

Frequency Division Multiple Access

Standards

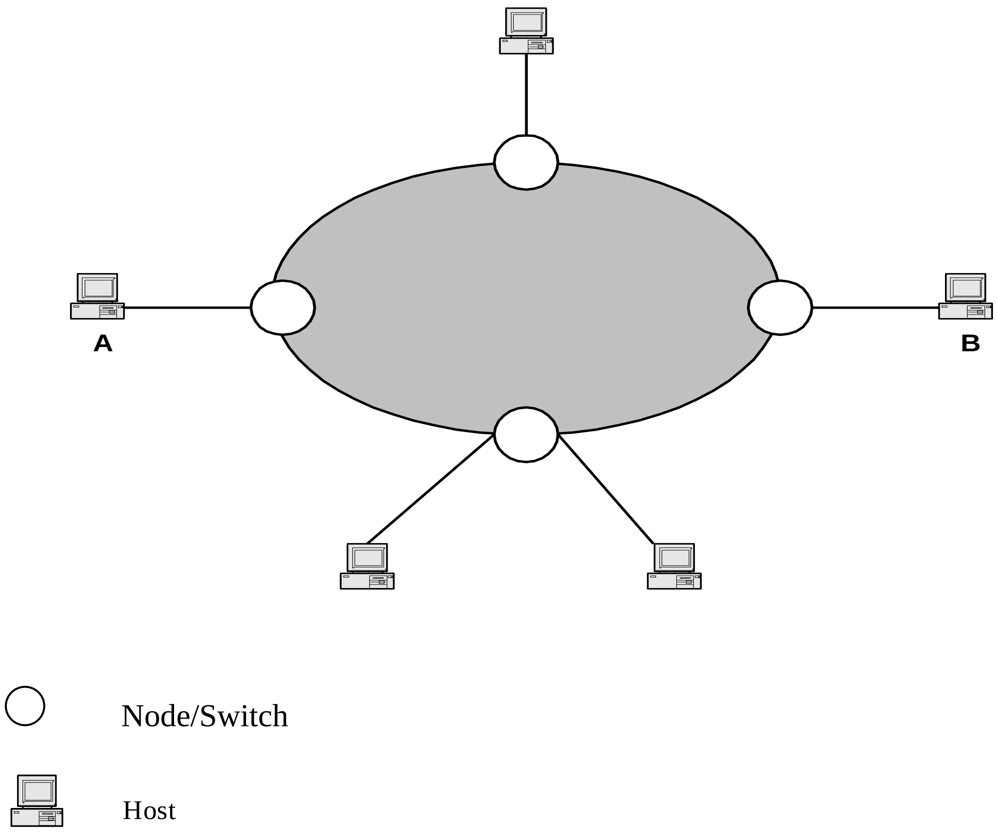
IEEE 802.11 and its variation are used.

Standard	Bit Rate	Transmit Frequency	Remarks
802.11 b	11 Mbps	2.4 GHz	Normal use
802.11 a	54 Mbps	5 GHz	Normal use
802.11 g	54 Mbps	2.4 GHz	Normal use
Hyper LAN	23.5 Mbps	5.1 – 5.3 GHz	For adhoc networks
Hyper LAN II	25 Mbps	5.4 – 5.7 GHz	For QoS Wireless networks

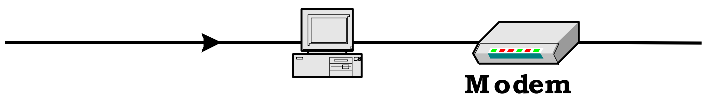
7. Wide Area Network (WAN)

If the computers are far away it is not practicable to connect them by using a physical wire like in LANs. In this case an existing network can be used to establish a connection.

E.g. Public Switched Telephone Network (PSTN)



If PSTN is used, the telephone is removed at one point and a computer and modem is connected instead.

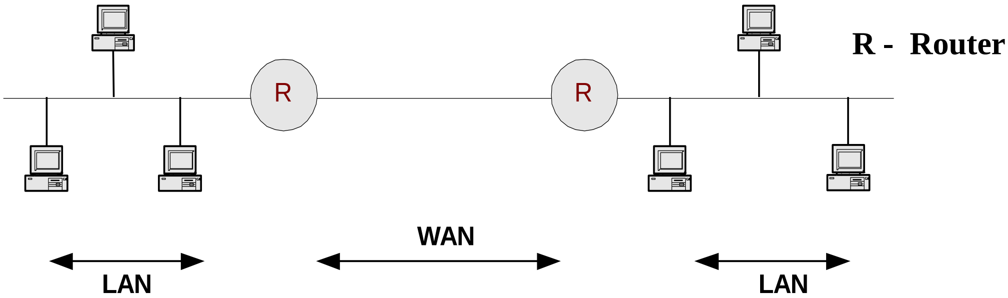


The computer dials the destination telephone number and establishes the link.

Apart from PSTN, the other methods that can be used are,

- Leased Line
- Packet Switched Connection
- Frame Relay
- ISDN
- ADSL
- IP-VPN

The above connection links are used to connect two remotely located LANs.



The Router has two types of ports.

- LAN Ports
- WAN Ports

The WAN Port is connected to the Leased Line or Frame Relay or any of the above types of connection links.

PSTN

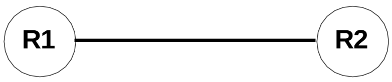
The PSTN connection is not a dedicated connection. Therefore, it is suitable for occasional connection such as access to Internet from home.

Leased Line

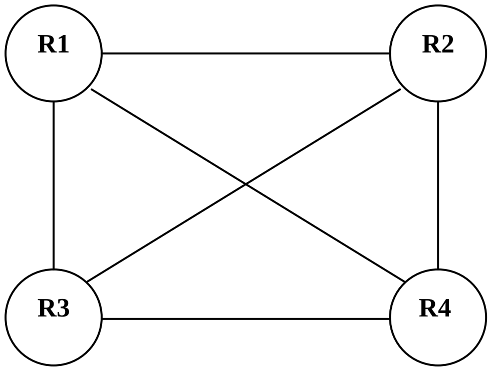
This link is secure, dedicated, but the cost is high. We can get bit rates of 64 kb/s, 128 kb/s, 256kb/s, 512kb/s, 1024 kb/s and E1 (2048 kb/s) etc.

Frame Relay

Why we need frame relay?



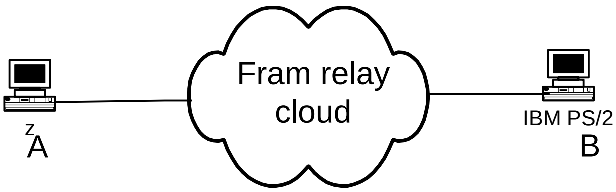
Consider the Router R1 and Router R2 connected by using a Leased Line. If the Leased Line has any problem we cannot communicate between the two routers. In order to have redundancy we should have another Leased Line (standby). This will increase the operational cost of the network.



If we have four Routers (R1, R2, R3 and R4), to have connectivity among all Routers, 6 Leased Lines are required. Again this is a costly network.

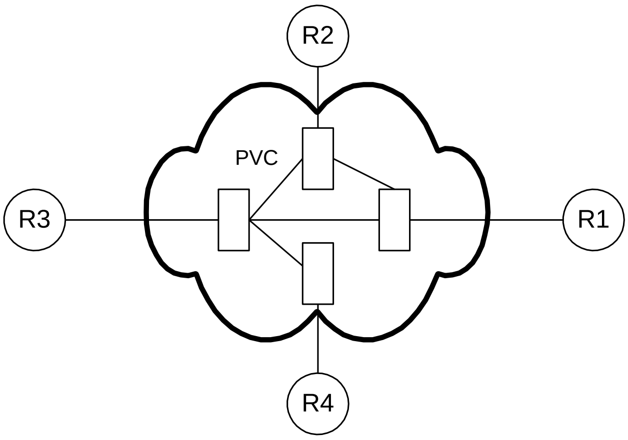
The solution for this kind of problem is "Frame Relay"

The Frame Relay cloud is same as PSTN. It has many Frame Relay Switches.



If a Frame Relay link is needed between A and B, a special number is given to A to reach B and another special number is given to B to reach A. These numbers are called Data Link Connection Identifier (DLCI)

Normally we give a unique DLCI for each Router. Frame Relays switches are configured to make the connection. The connection path is same as X.25 and it is called a virtual circuit. Normally Frame Relay uses PVCs only.



Consider four routers connected to a Frame Relay cloud as shown in the figure.
DLCIs of the four Routers are 50,51,52 & 53.

The frame format is as follows.

F R Header	Data	FR Trailer

The main fields of Header are,
- DLCI
- FECN (Forward Explicit Congestion Notification)
- BECN (Backward Explicit Congestion Notification)

The Trailer is the Frame Check Sequence (FCS) for error detection.

When R1 sends a frame to R2, the DLCI is put as 52. When this frame comes to FR switch it knows to which route it is to be switched.

Frame Relay Switches are configured in a way that if the normal link fail it is automatically switched to an alternative route. Therefore, we do not need to maintain separate redundant links.

Also we can get PVCs with alternate Routers.

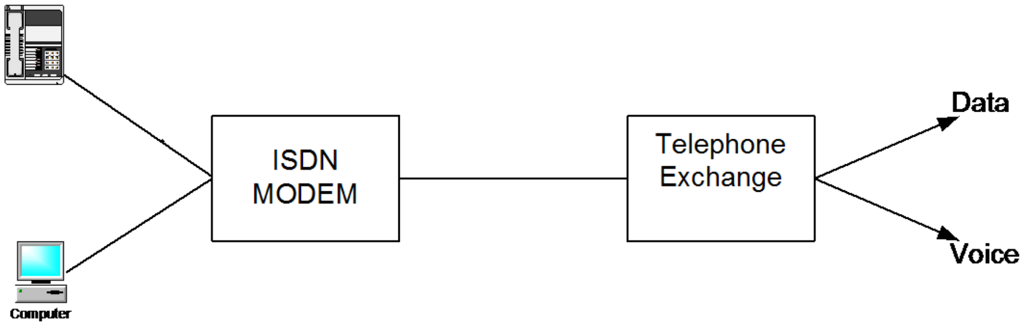
E.g. R1 to R2
One PVC – direct R1 – R2
Second PVC – R1 – R3 – R2

The PVC is cheaper than the Leased Line.

Broadband Technologies

Integrated Services Digital Network (ISDN)

The PSTN is designed to establish connection among telephones. If we want to use PSTN for data communication the telephone should be disconnected from the line and instead of that a modem and a computer is connected to the line. The main disadvantage of this method is the telephone and computer cannot be used simultaneously. ISDN is the solution for this problem.



If we use and ISDN modem at home both the telephone and the computer can be used simultaneously. Please note that the “ISDN Modem” is not the correct term but normally subscribers use this term.

This has the following facilities.

For normal subscribers,

2 x 64 kb/s channels + 1 x 16 kb/s channel.
One 64 kb/s channel is called a Bearer Channel (B Channel).
The 16 kb/s channel is called a D Channel.
One B channel can be used for voice. (Telephone).
The other B channel can be used for data (Computer) or 2 B (128 kb/s) can be used for data.
D channel is normally used for signaling between the ISDN modem and the exchange. If it is not used for signaling, that also can be used for data.

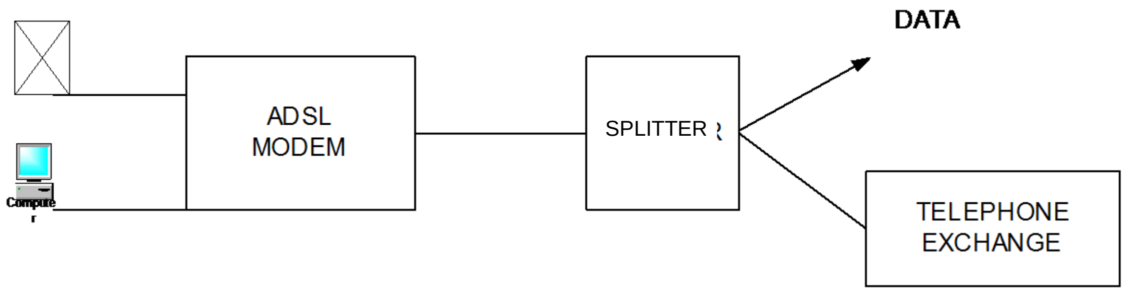
All the channels are represented as,

2B + D

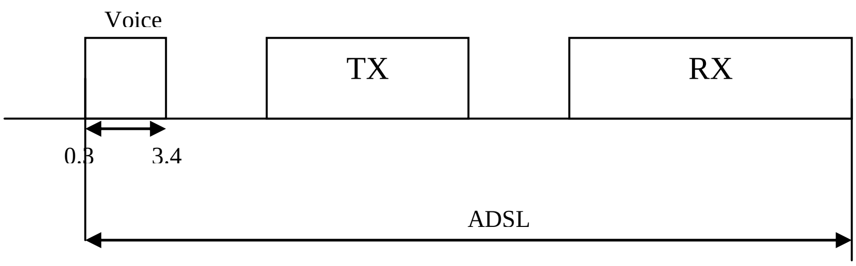
If all channels are used for data, a 144 kb/s bandwidth can be used for data.
In addition to 2B +D, the overhead bits of 48 kb/s are also added. Therefore, the total bit rate will become 192 kb/s.

Asymmetric Digital Subscriber Line (ADSL)

This is a further development of better utilization of the normal telephone line. This was mainly developed for Internet users.



The ADSL modem use a special line code and converts the multiplexed (voice and data) to an analog signal. The bandwidth utilization is as follows.



The Tx and Rx bandwidths are not the same. Therefore, it is called Asymmetric. The reason is, for Internet download information (data) is more than the upload information. Therefore, higher bandwidth is allocated for downloading.

Theoretically the upload bandwidth and download bandwidth can go up to 1 Mb/s and 8 Mb/s. But these bandwidths depend on the distance between the exchange and subscriber premises. However, at least 512 Kb/s download can be obtained easily.

Note : ADSL can be used for both normal telephone and data simultaneously.
ADSL can be used for both ISDN and ADSL data simultaneously.

IP-VPN

The Internet is used for the connectivity. Since the Internet is a public network and not secure, special encryption methods are used to send data. The data is decrypted at the receive end. Although Internet is a public network, after encryption it will become virtually a private network. Therefore, it is called a Virtual Private Network (VPN).

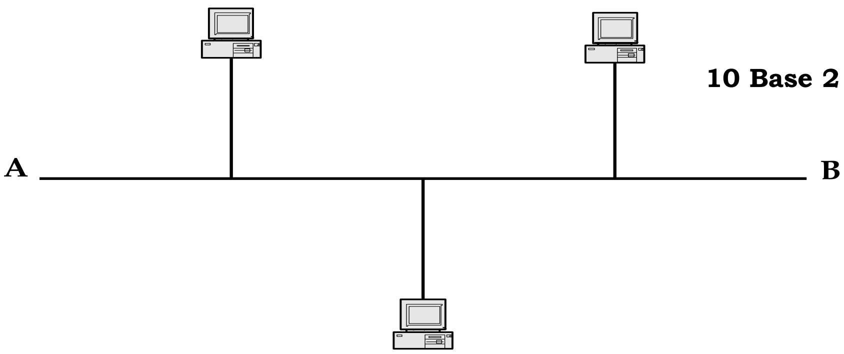
8. Network Devices and Internetworking

There are many networking devices used in LANs and WANs. Some of the networking devices are,

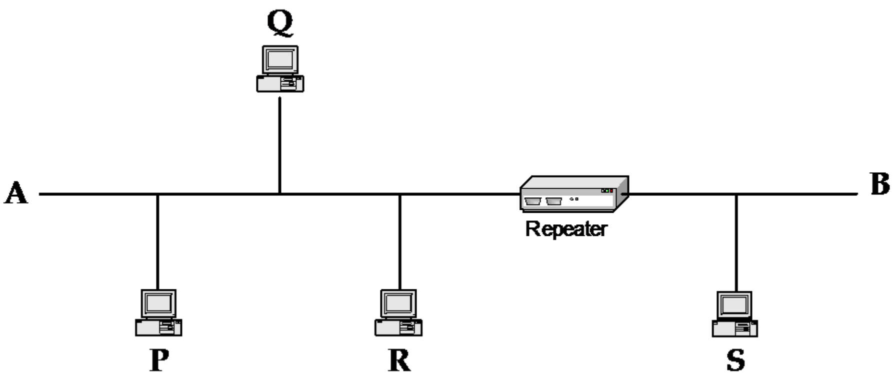
- Repeater
- Hub
- Bridge
- L2 Switch
- L3 Switch
- Routers

Repeater

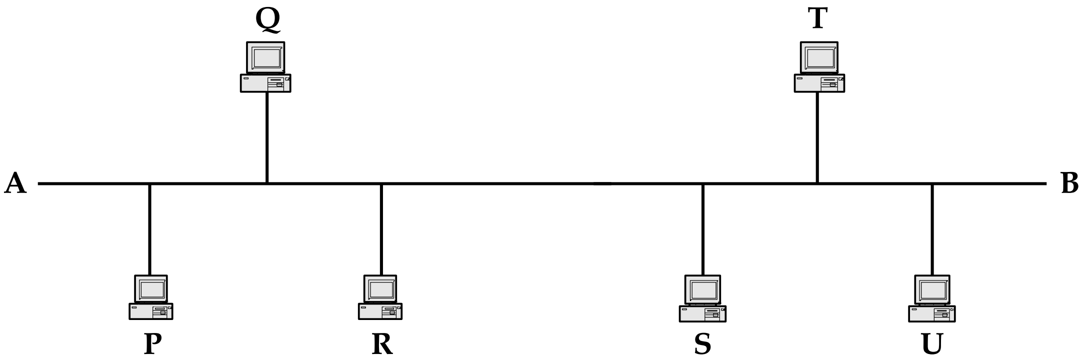
Consider a 10 Base 2 LAN. Thin coaxial cables are used and the signal can travel a maximum of 200 m length without repeaters.



A to ***B*** maximum length can be 200 m.
This is called a segment.
If it is more than 200 m length, a repeater can be used.

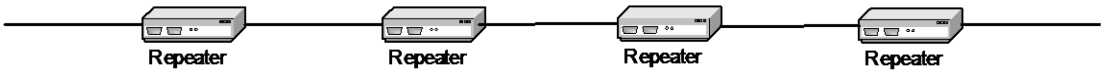


The above network has two segments. But it acts as one Ethernet network.



If *P* and *Q* transmit a frame at the same time there will be a collision. Any two computers in any segment transmitting simultaneously will make a collision. Therefore, the above network has one “Collision Domain”.

The maximum number of repeaters allowed is four. That is five segments.

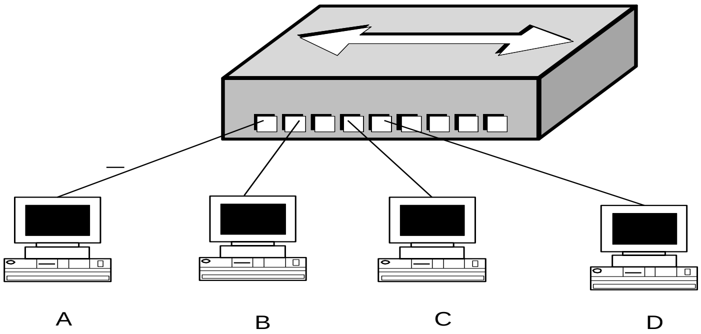


5 Segments
1 Collision Domain

Also if one computer broadcasts a message it will be received by all computers in the above network. Therefore, the network has only one “Broadcast Domain”.

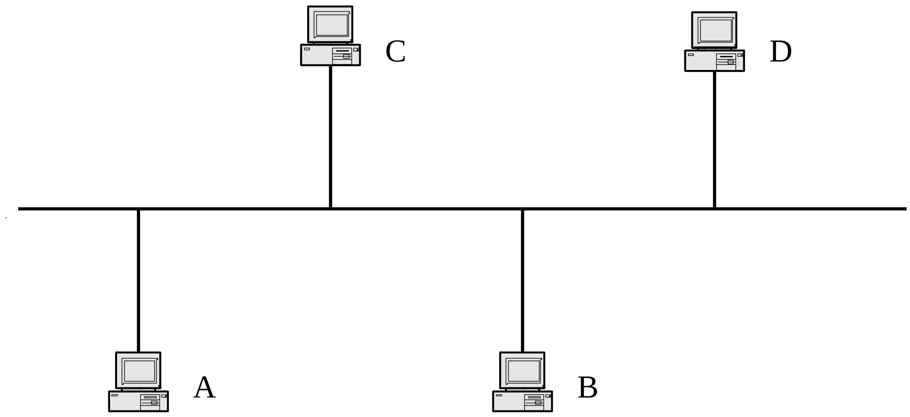
Hub

Installation and expansion (increase the number of hosts) of a network is rather difficult and coaxial cable is costly compared to UTP cables. Now there are UTP cables available which can operate even with 1000 Mb/s (1 Gb/s). Therefore, now the trend is to use UTP cables instead of coaxial cables. For this purpose a hub is used.



The hub is a repeater, which has many ports. It is a passive device. That means it cannot analyze the packets or frames. It can see only raw bits 1s and 0s. Therefore, hub operates at the physical layer.

Consider the following bus network.



If ***A*** sends a signal B, C and D will receive it. The same thing happens in the hub. Therefore, hub is physically a star but logically a bus.

Therefore, now everybody uses hubs to make bus networks. The maximum length the signal can travel in one port is 100 m.

How to install a LAN using a Hub?

The required items are,

- Hub
- UTP Cables
- RJ45 Connectors
- Network Interface Card (NIC)

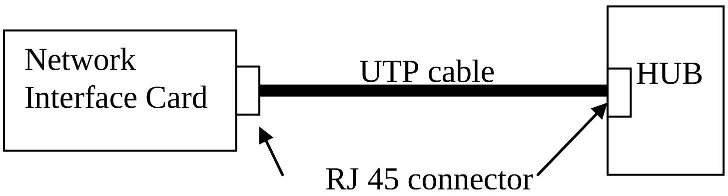
In each computer a NIC should be installed and configured.

Network Interface Card

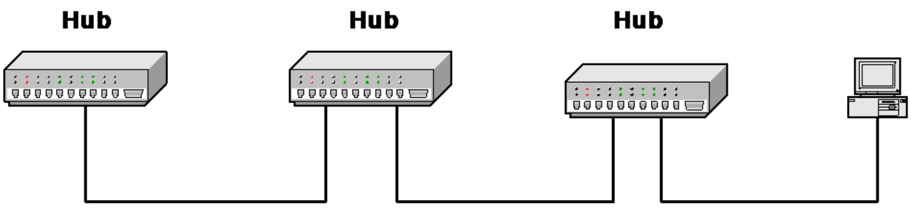
This is the interface between the computer and the LAN media. The NIC performs the following functions.

- Carrier sense
- Conversion of binary signal to Differential Manchester Coded Signal and vice versa.
- Media Access Control

The NIC can operate either in half duplex or full duplex mode. Some NICs can operate at 10 Mb/s whereas some can operate at both 10 Mb/s and 100 Mb/s.

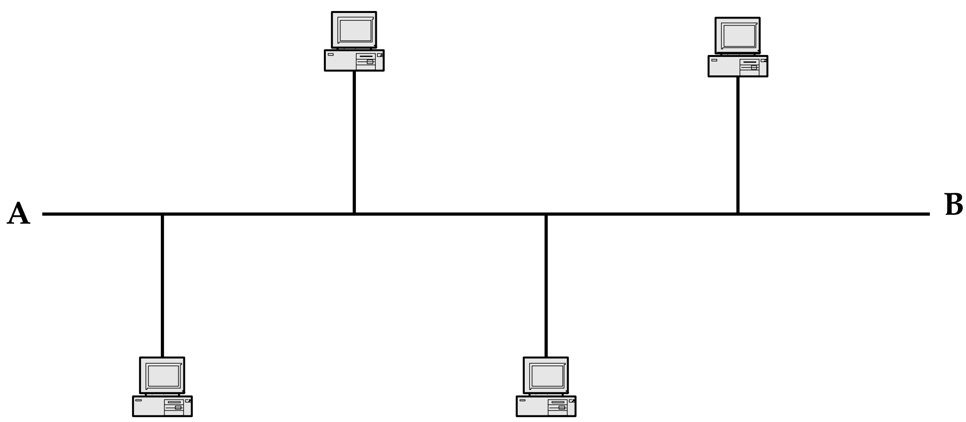


The maximum allowable length is 100 m. If you want to operate at more than 100m cascaded hubs can be used.



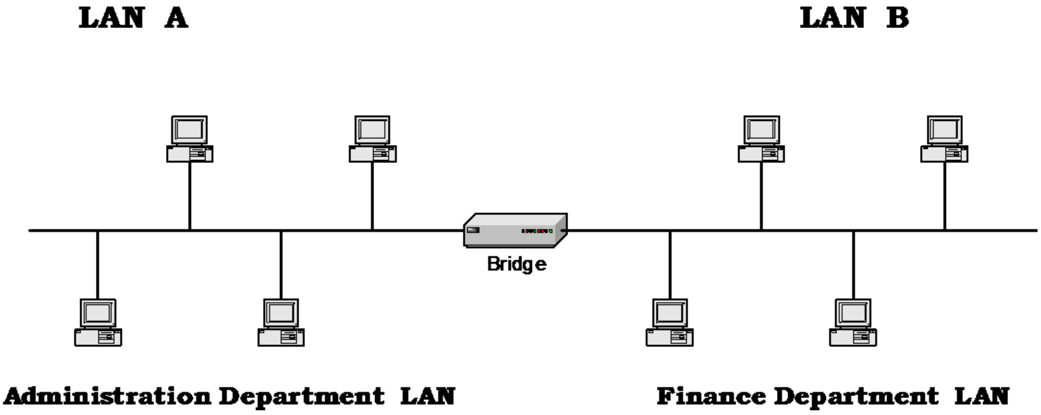
It is not recommended to cascade more than two hubs.

Bridge



Suppose a bus network has 6 Computers which are used by Finance Department and the Administration Department. At this stage collisions may not be affected for the performance of the network.

If the number of computers increase to 20, it can affect the performance due to collisions. Therefore, it is advisable to separate the two departments into two LANs. But there should be provisions to access from one department to other department, whenever necessary. In order to satisfy this requirement a Bridge can be used.



Bridge is an intelligent device, which can connect two or more similar types of LANs.

The operation of the Bridge is as follows.

When it receives a frame, the destination MAC address is checked. If it is in the same network it is ignored. If it is in the other network it is transmitted to the other network. This has two advantages. It improves the performance and security.

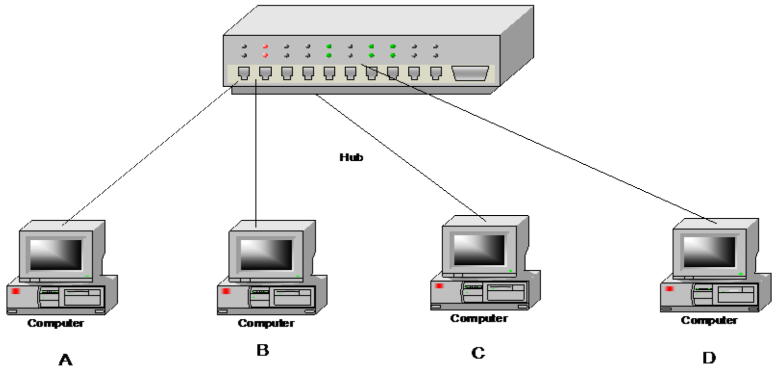
The Bridge operates at the second layer of OSI model.
If any computer broadcasts a message all computers in all the networks will receive it connected to the bridge. (Bridge can have more than two ports).

Consider the above example. It has,

- Two segments.
- Two collision domains.
- One broadcast domain.

Switches

Switch is an intelligent device. When it receives a frame, it analyzes the frame and obtains the destination address. Then it refers the MAC address table and finds out the port to which the destination address host is connected. Then the two ports are switched to make a connection between the two hosts



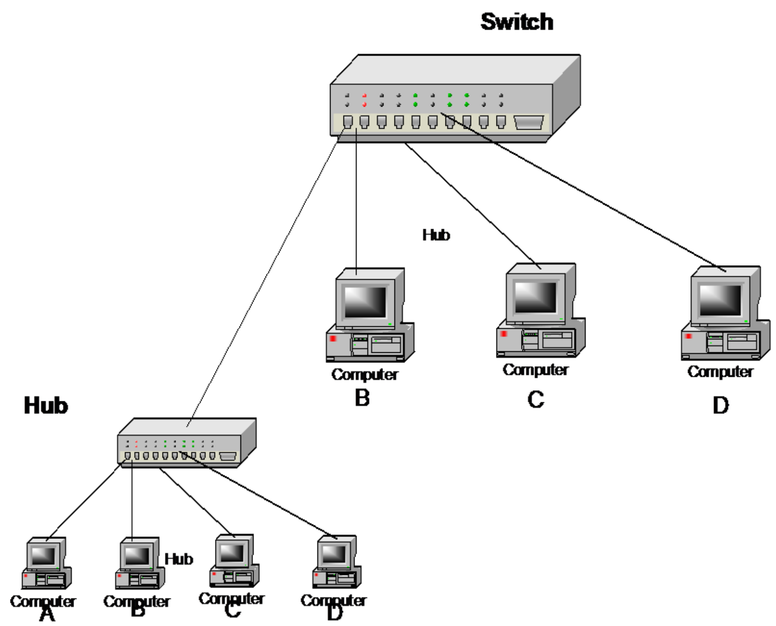
In the above figure, suppose ***A*** wants to send a frame to ***B*** and, ***C*** wants to send a frame to ***D***. The switch makes the connections ***A*** to ***B*** and ***C*** to ***D*** simultaneously. Therefore, switch has higher performance compared to a hub when there are many computers connected to the network.

Switch can operate with half duplex or full duplex modes. Some switches support both 10 Mb/s and 100 Mb/s bit rates.

If one computer broadcasts a signal it is broadcasted to all computers by the switch.

Therefore, in a switch one port is one segment and one collision domain. All ports are in one broadcast domain.

Switch can operate with hubs also.



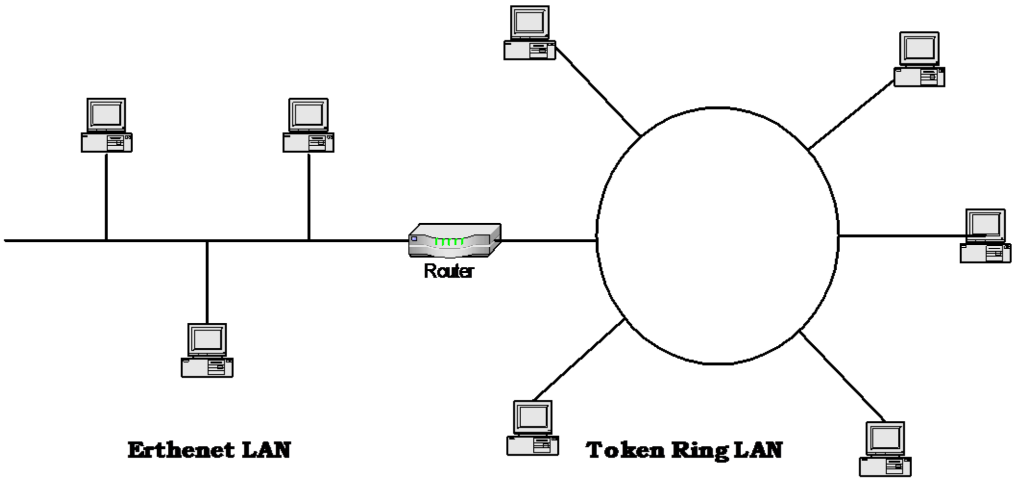
If the distance from the switch to the host is more than 100m, a hub or a repeater can be used in between of the switch and the host.

Normally switches operate at layer 2 and they are called L2 switches or Ethernet switches.

Some switches can operate at layer 3 where they can analyze the network layer packet (e.g. IP Packet) and take decisions. They are called L3 switches.

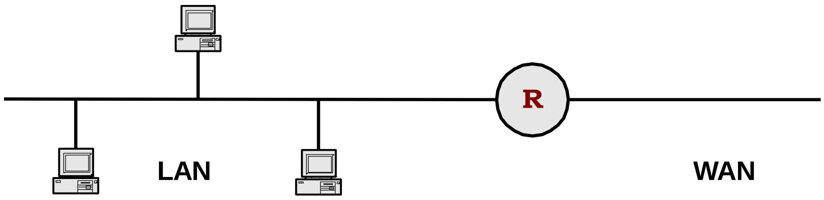
Routers

Routers can be used to connect dissimilar types of LANs or LANs and WANs.



Router has two types of ports.

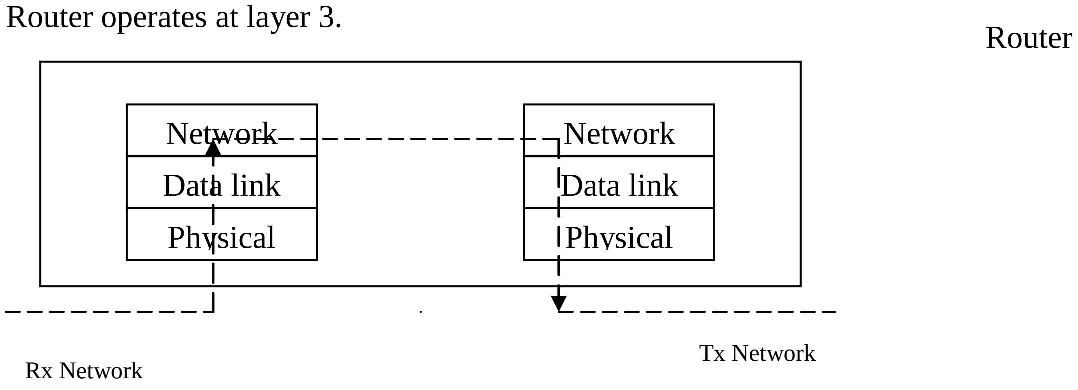
- LAN Ports
- WAN Ports



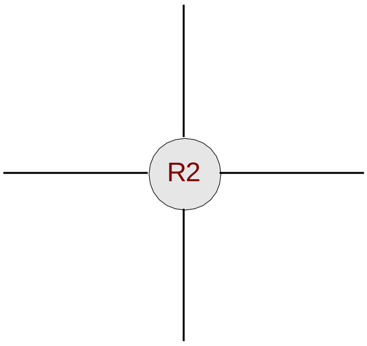
The WAN port can be connected to a,

- Leased Line
- Frame Relay connection
- ISDN connection
- ADSL connection
- Dial Up connection
- IP-VPN connection

Router operates at layer 3.



The raw bits are received from media to Physical Layer. It sends to the data to the Data Link Layer. It removes the DLL header and trailer and sends it to the Network Layer. It analyses the packet and finds out the destination address. The Router maintains a routing table. By referring to the routing table it can decide to which port the packet is to be sent. Then it changes some parameters in the network header (IP header) and sends it to the DLL. It adds the DLL header and trailer and sends to Physical Layer. The Physical Layer sends the raw bits (1s and 0s) to the correct port (interface).



Suppose a Router, has four ports. The router does not perform broadcasting to all ports.

Gateway

The Router operates at the third layer. The gateway can operate at high layers such as Transport or Application Layers.

9. Introduction to Internet

What is Internet?

This is a group of connected networks all over the world. This was originated in 1967 by the US Department of Defense to interconnect their networks, which were in different locations. Later it was expanded to some universities of USA. Finally it was expanded to millions of networks dispersed all over the world.

Internet Administration

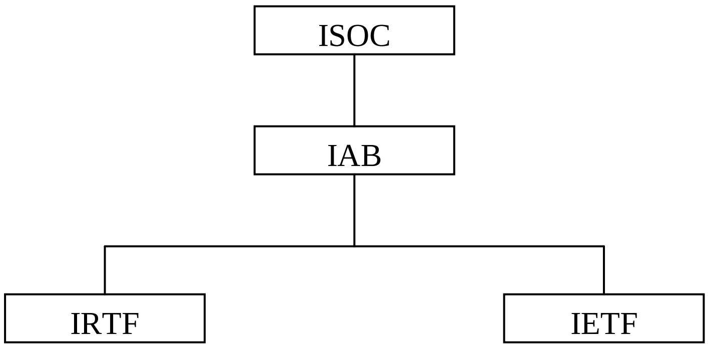


Fig. 1-1 Internet Organization

Internet Society

Internet Society (ISOC) is an international non-profit organization formed in 1992 to provide support for the Internet standards. It has many supporting administrative bodies such as IAB, IETF and IANA. ISOC also promotes research and other development activities related to the Internet.

Internet Architecture Board (IAB)

IAB is technical advisor to ISOC. It accomplishes this through IRTF and IETF. Another responsibility of IAB is the editorial management of RFCs.

The Internet standards are continuously developed. Specification of a standard begins as an Internet draft. Upon recommendation from the Internet authorities, a draft may be published as a **Request for Comment** (RFC). Each RFC is assigned a number and made available to all interested parties. After several processes an RFC will become a permanent standard of Internet.

Internet Engineering Task Force (IETF)

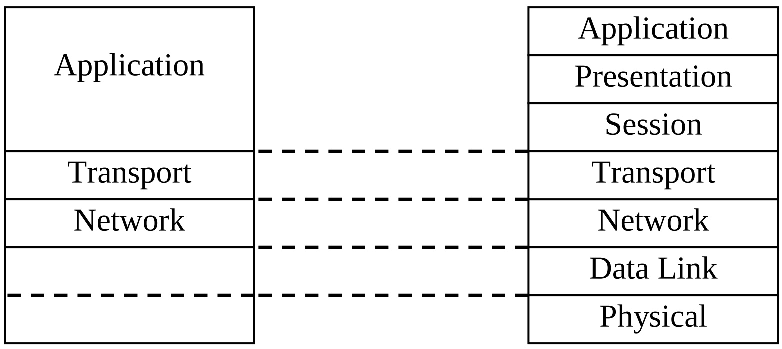
IETF is responsible for identifying operational problems and proposing solutions to these problems. It also develops and reviews specifications of Internet standards.

Internet Research Task Force (IRTF)

IRTF is responsible on long-term research topics related to Internet protocols, applications, architecture and technology.

<u>Internet Protocols</u>

TCP/IP is the protocol family used in Internet. This will be discussed in detail in other chapters. The TCP/IP protocol suite and its relationship to ISO-OSI Model is given in fig 1-2.



TCP/IP Model　　　　OSI Model

Fig. 1-2 TCP Model and OSI Model

TCP/IP does not define the physical layer and Data Link layer. It can work with any existing such layers that were defined by any other standard body such as IEEE and ITU-T.

The top most layer of TCP/IP is Application layer. It is equivalent to Session, Presentation and Application layers of OSI model.

Network Protocol

TCP/IP has one network protocol called Internet Protocol (IP)

Transport layer protocols

The Transport layer has two protocols. They are Transport Control Protocol (TCP) and User Datagram Protocol (UDP).

Application layer protocols

Application layer has many protocols and some of them are given in Table 1-1

Protocol	Use
HTTP	Web applications
TELNET	Remote log to a computer
FTP	Transfer long files
TFTP	Transfer short messages
SMTP	To send E-mail
SNMP	Remotely manage network devices

Table 1-1 TCP/IP Application Layer Protocols.

HTTP - Hypertext Transfer Protocol.
FTP - File Transfer Protocol
TFTP - Trivial File Transfer Protocol
SMTP - Simple Mail Transfer Protocol
SNMP - Simple Network Management Protocol

Relationship with different layer protocols

Each application should select either TCP or UDP as their Transport layer protocol. This is defined in the application and we cannot change it. All applications should select IP as the Network layer protocol.

The relationship among these three layers is given in Table 1-2.

Application Protocol	Transport Protocol	Network Protocol
HTTP	TCP	IP
TELNET	TCP	IP
FTP	TCP	IP
TFTP	UDP	IP
SMTP	TCP	IP
SNMP	TCP	IP

Table 1-2 Relationship of three layer protocols.

It can be noticed that, although we can use the term TCP/IP, there are UDP/IP applications as well.

Internet Services

By using different application protocols we can provide many services via Internet. The most popular services are web service (HTTP) and e-mail service (SMTP).

Private Network and Public Network.

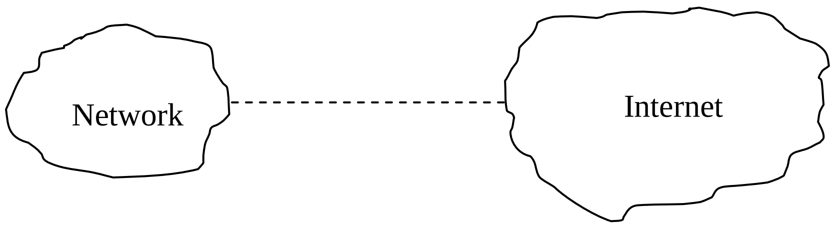


Fig. 1-3 Private and Public Networks

The Internet is a public network. If a network is not directly connected to Internet, it is called a private network. If it is directly connected to Internet, it will become a part of Internet.

In public networks Internet standards have to be followed where as in private networks it is not mandatory. However TCP/IP protocol suit can be used in private networks also.

Intranet and Extranet

A private network maintained by a company or particular organization is called Intranet. For instance Sri Lanka Telecom uses their own Intranet for exchanging internal information, which is restricted to the public.

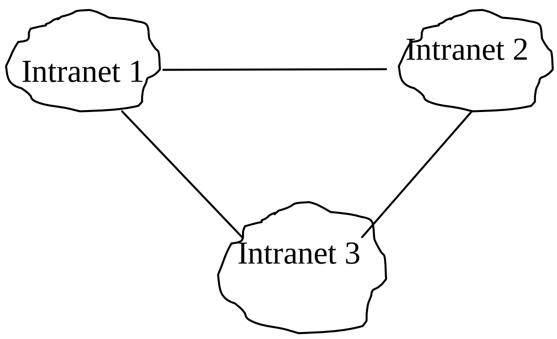


Fig. 1-4 Extranet

An interconnected Intranet is called an Extranet.

10. Overview of TCP/IP

TCP/IP Operation

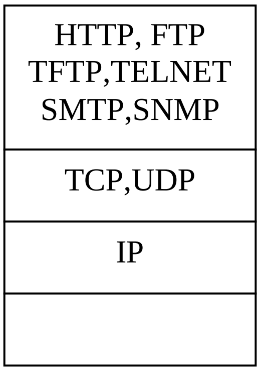
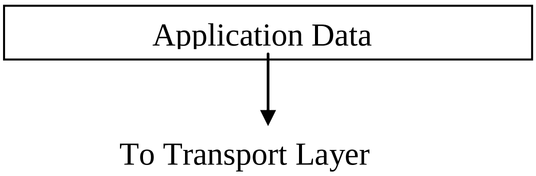


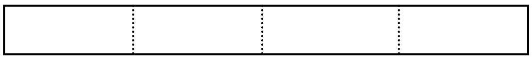
Fig. 2-1 TCP/IP Protocol Suite

The TCP/IP protocol suite is shown in the fig 2-1.
The operation of TCP/IP model is as follows.

Application layer sends the application data to Transport layer.



At the Transport layer the application data is divided into small parts. This process is called “segmentation”.



Each segments is combined with a TCP header or a UDP header. The selection of TCP or UDP depends on the application.

The Transport layer can receive more than one application data at the same time.

Each application is given a port number for its identification. Also each segment is given a sequence number in the case of TCP.

Eg: Application 1 - Port number 80, sequence numbers 1000, 1001, …1258

Application 2 - Port number 21, sequence numbers 1518, 1519, …9887

This information is included in the TCP header or UDP header. The standard size of TCP header is 20 bytes and UDP header is 8 bytes.

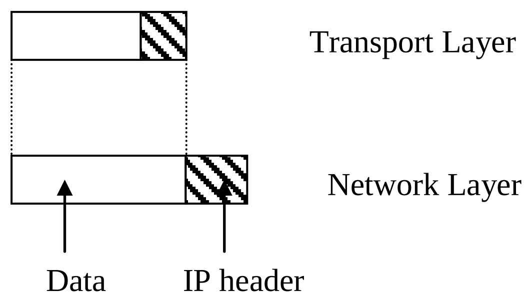


Fig. 2-2 Formation of IP Packet

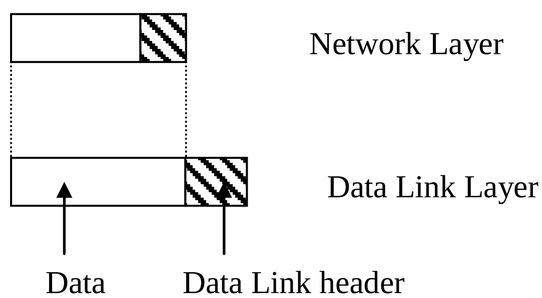
The Transport layer sends the application data and TCP or UDP header to Network layer. The fig 2-2 shows this operation. It can be observed that the application data and TCP or UDP header will consider as data for Network layer. The **standard IP header size is 20 bytes**.

Eg.	Segment data	-1000 bytes
	TCP header	-20 bytes
	IP data	-1000 + 20 = 1020 bytes
	IP header	-20 bytes
	IP packet	-1020 + 20 = 1040 bytes

The IP data and IP header together is called an IP Packet. However the maximum total length of the IP Packet is 65535 bytes. Therefore the maximum segment size should be limited to 65535 – 20 = 65515 bytes.

The IP header consists of many information. One of the most important header fields is destination IP address.

The IP packet is sent to the data link layer. The whole IP packet is considered as data for the data link layer frame.



The above explanation is for the transmit process. The reverse process is done for the received data.

Data link layer removes the data link header and sends to the Network layer.

Network layer removes the network header (IP header) and sends to the transport layer.

In TCP operation, the header is removed; the segments are assembled in order and sent to the Application layer. In UDP operation, the header is removed and data is sent to Application layer.

<u>TCP/IP Operation in LANs</u>

The widely used LAN protocol is Ethernet. That is IEEE 802.3 standard.

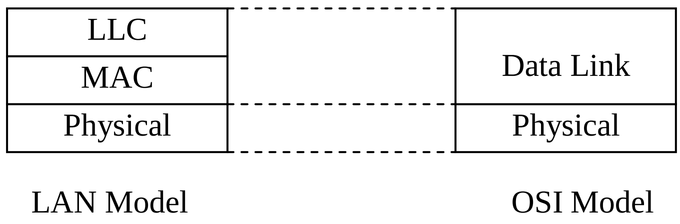


Fig. 2-3 LAN and OSI Comparison

The LAN model has three layers and it is equivalent to Physical and Data link layers of OSI model.

4	46-1500	2	6	6	1	7
CRC	Data	Length	SA	DA	SOD	Preamble

Fig. 2-4 Ethernet Frame Structure

The Ethernet frame structure is shown in fig 2-3. It can carry maximum of 1500 bytes of data.

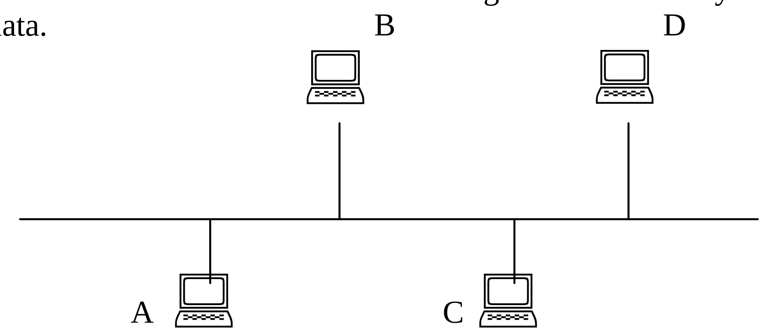


Fig. 2-5 Ethernet LAN

Fig 2-5 shows a typical Ethernet LAN. Suppose Host D is a web server. Host A wants to access the web server. Just the IEEE 802 LAN model is not sufficient for this task. Since the Application (HTTP) is in the Application layer of TCP/IP, the TCP/IP model should be combined with IEEE 802.3 model as shown in fig 2-6.

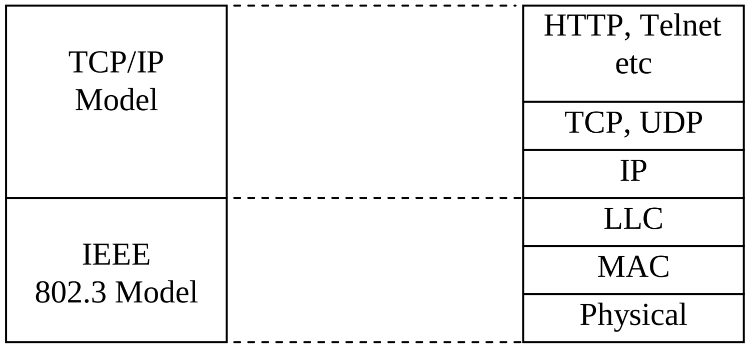


Fig. 2-6 TCP/IP in Ethernet LAN

The data flow is shown in fig 2-7.

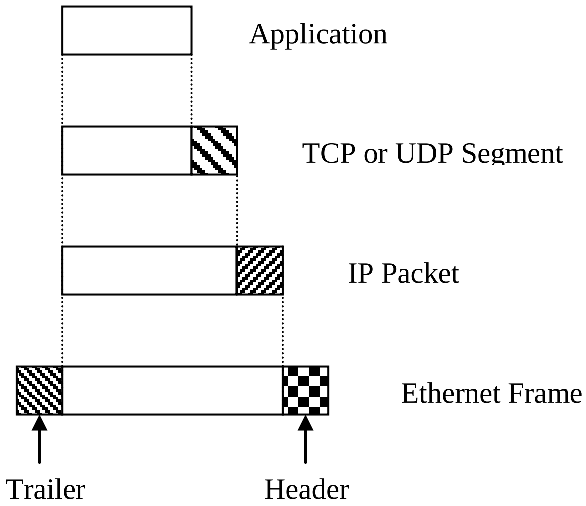


Fig. 2-7 Dataflow from Application to Ethernet

The application layer sends data to the transport layer. It adds a TCP or UDP header and sends to the IP layer. It adds the IP header and sends to the Ethernet frame. (LLC and MAC layers) It adds the header and trailer.

The Ethernet header consists of mainly destination MAC address and source MAC address.

Data Limitation of Ethernet Frame

The maximum size of an IP packet is 65535 bytes. The maximum data size of an Ethernet frame is 1500 bytes.

What happens if the IP packet is more than 1500 bytes?

It cannot be embedded into the Ethernet frame. Therefore a special process called fragmentation is done at the IP layer before it sent to the Ethernet frame.

Eg. Suppose the IP packet size is 2980 bytes.

The IP data part is separated and two new IP packets will be prepared.

Now the size of an IP fragment is 1480 + 20 = 1500 bytes. The new IP packet can be embedded to the Ethernet frame. At the receiving end all fragmented IP packets are defragmented (combined) before sending to the transport layer.

TCP/IP Operation in WAN

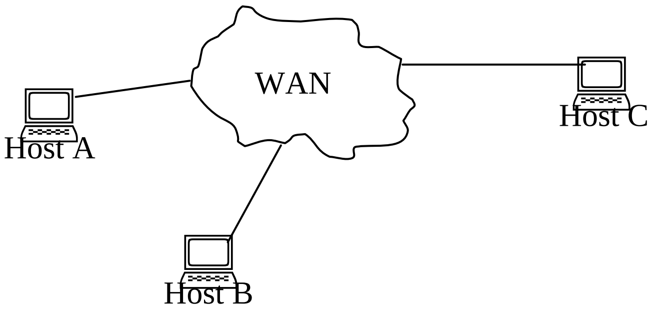
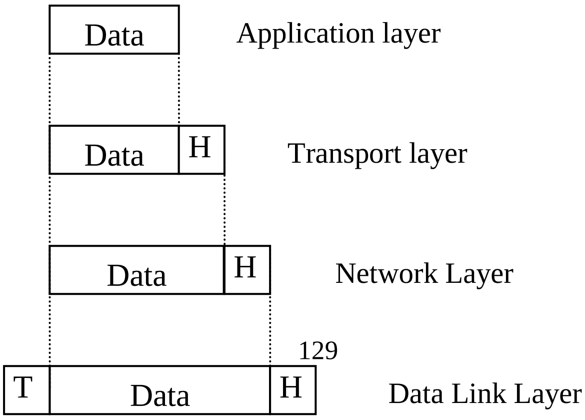


Fig. 2-8 WAN

Host A wants to access to web server (Host C) through the WAN.

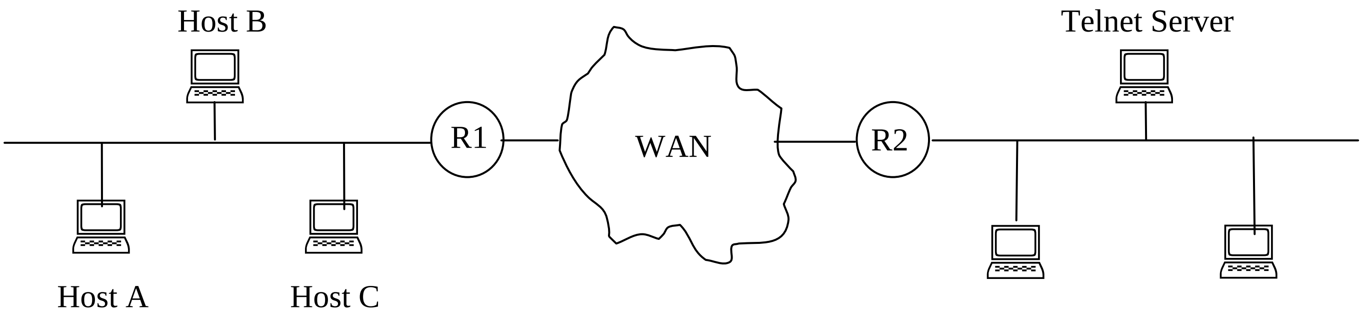
TCP/IP Model	HTTP, Telnet, etc
	TCP, UDP
	IP
WAN Model	HDLC, PPP
	Physical Layer

Fig. 2-9 TCP/IP in WAN



The operation is same as in LAN. The difference is that instead of Ethernet frame, the IP packet is sent to a WAN data link layer protocol frame such as HDLC or PPP.

TCP/IP in LAN and WAN



LAN P Fig. 2-10 LAN and WAN **LAN Q**

Host A in LAN P needs to access the Telnet server in LAN Q

The operation is as follows.

- Host A application data is sent to the transport layer.
- It adds the TCP header and is sent to the IP layer. It adds the IP header and sends to the Ethernet layer.
- The Ethernet frame is sent to the Router (R1).
- Router removes the header and trailer of the Ethernet frame and data is send to the IP layer.
- IP layer modifies the IP header and sends to the data link layer of WAN protocol.

Eg. HDLC

The HDLC frame is sent to the other Router (R2) through WAN.

R2 removes the header and trailer of HDLC frame and sends data to the IP layer. It removes the IP header and sends the IP packet to the Ethernet layer. It adds the header, trailer and broadcasts to LAN Q.

Telnet server receives the Ethernet frame, removes header, trailer and sends data to the IP layer. It removes the IP header and sends data to the transport layer. The transport layer removes the TCP header and sends data to the application layer.

11. Client Server Application

Overview of Client Server Model

All programs connecting through Internet work as client and server combinations. This means that each program runs in a separate host. The program running in the server is called Server Process and the program running in client host is called Client Process. There can be confusion between server and server process. Normally server means a high-end computer. But server process is a program running in a computer (server) and one computer (server) can run several server processes at the same time. Eg. HTTP server, Telnet server. The client process can access the server process via the network (Internet).

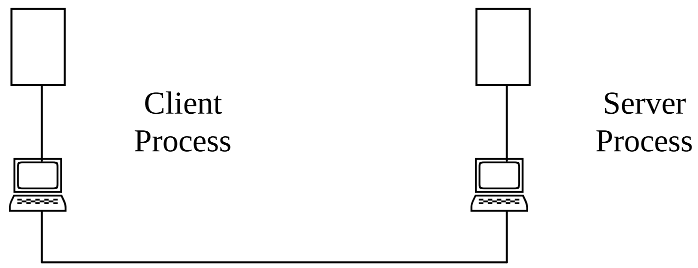


Fig. 3-1 Client – Server connection

There can be client-server, one to one connection. This is called iterative server. Such servers can give only one client connection at a time.

There can be client-server, many to one connection. This is called concurrent server. Such servers can give many client connections at the same time.

Identification of Processes

Identification of processes is done at the Transport layer. It assigns a special number called "port number" to each process. Each server process is assigned a unique port number. For example HTTP server port number is 80. Telnet server port number is 23.

Therefore, when a client needs to connect to server, it knows the destination port number. The source port number can be assigned arbitrarily by the client.

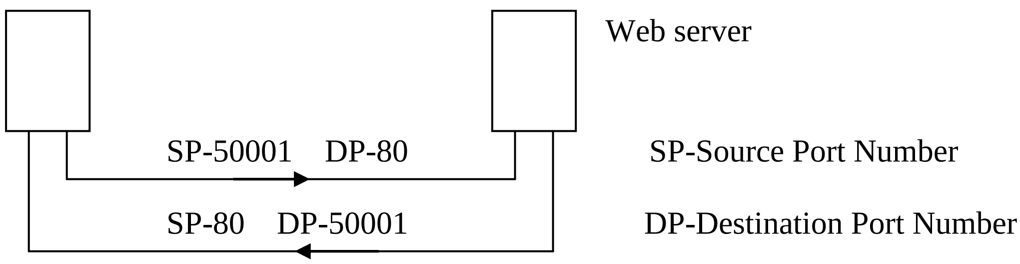


Fig. 3-2 Client and Server ports

Fig. 3-2 shows a web client-server connection. The client should originate the connection. Client knows the port number of the server process (port 80). Client arbitrarily selects a port number for its client process (port 50001). The client sends a segment of data to the server. Now the server knows that from where the request comes. Therefore it can send back segments with destination port 50001.

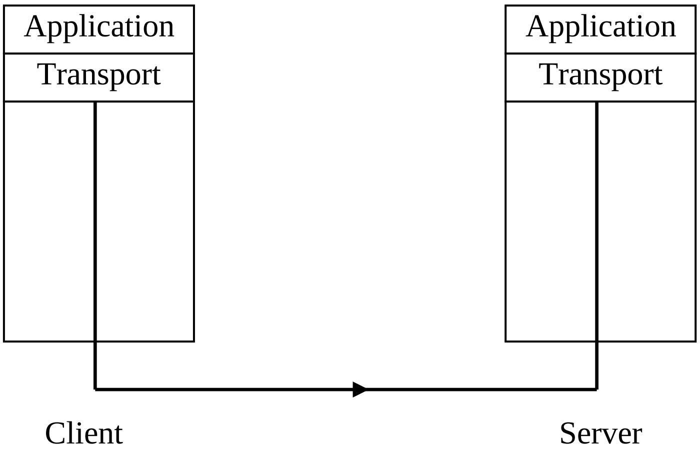


Fig. 3-3 Client Transport – Server Transport connection

The data from client transport layer to server transport layer can be sent in two different ways.

- Connection oriented
- Connectionless

Connection Oriented

In this method, before sending data, a connection is established between the client transport layer and the server transport layer. The connection request is sent by the client to the server. If the server positively acknowledges, a connection can be established. Then data is transferred. After completing sending data, the connection is terminated (same as in data link layer)

In this case, an acknowledgement is received for each data segment. Error control and flow control is also part of this process. Therefore data transfer is reliable. TCP uses this method.

Connectionless

In this method no connection is established prior to sending data. A data segment is released from the client with the destination port number. It will go through the network and reach the transport layer of the server. The server does not send any acknowledgement. Therefore the client does not know whether the data is received by the server or not. Hence this method is unreliable. UDP uses this method. Normally UDP is used to send small amount of data in a periodic manner. Eg. Routing information. Suppose the period of sending some kind of data is 30 seconds. If server does not receive the first data segment, there is a chance to receive the second segment send after 30 seconds.

Data sent through a WAN

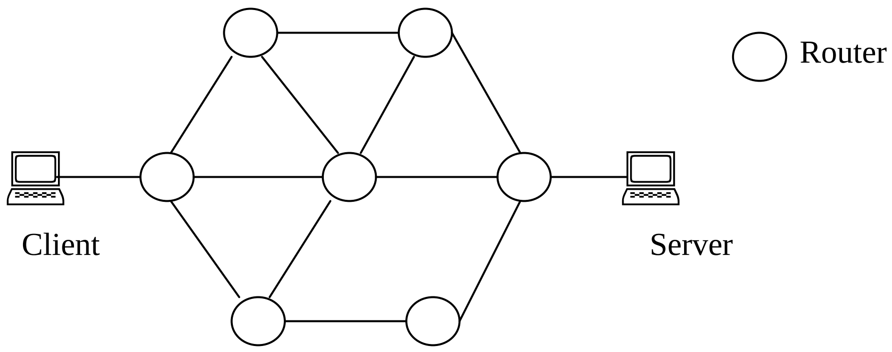


Fig. 3-4 Data through WAN

Normally a WAN is a switched network.

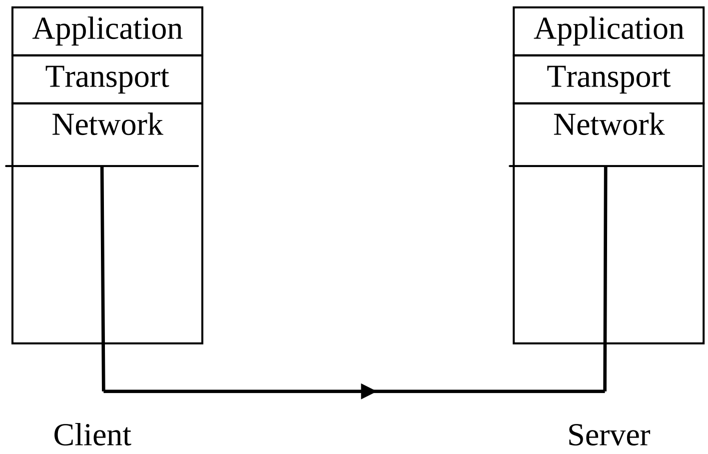


Fig. 3-5 Client Network layer & Server Network layer connection

The application layer sends data to the transport layer. It adds the source and destination port numbers and sends to the network layer. TCP/IP uses Internet Protocol (IP) as the network layer protocol. The network layer adds the corresponding destination IP address and source IP address and sends the data packet to the network as shown in Fig. 3-4. When it comes to the first router it checks the destination IP address, refer the routing table and find out the relevant output port and put the data to that port. Then the packet goes to second router and performs the same. This happens until the data packet reaches the router connected to the server and it delivers the data packet to the server.

It is the responsibility of the network layer to deliver the data packet to the correct destination network layer. It can be noticed that IP protocol is connectionless. No connection is established before sending data. Therefore error control and flow control does not occur at the network layer. Hence IP is an unreliable protocol. Since TCP is reliable, TCP and IP together will become a reliable combination of protocols. However UDP and IP together is not a reliable combination.

Although IP does not give feedback to the source, it uses a separate protocol called Internet Control Message Protocol (ICMP) to send back some error messages to the source.

At the server, network layer removes the IP header and sends the data segment to the transport layer. The transport layer checks the destination port number, removes the TCP or UDP header and directs data to the relevant application.

Data Link Layer Operation of a WAN

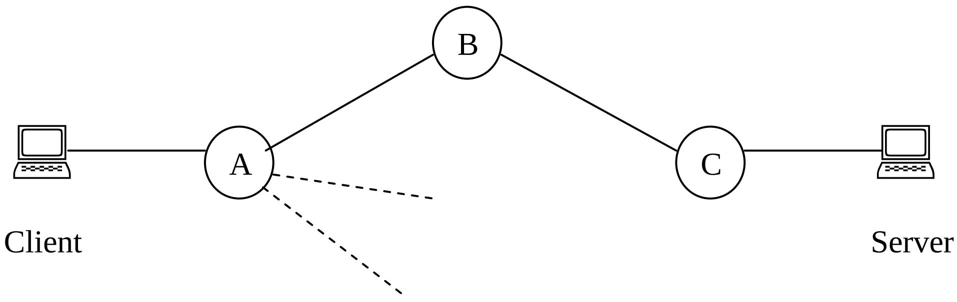


Fig. 3-6 Data encapsulation in WAN

The network layer selects the path ABC to send data. How many data links are involved in this path?

Client → A, A→ B, B→ C, C → Server

There are four data links involved.

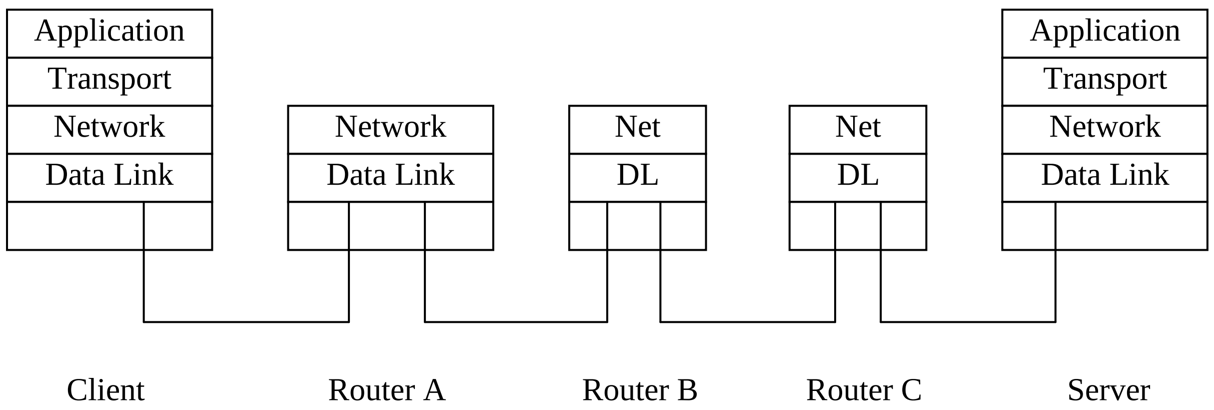


Fig. 3-7 Layers involved in WAN connectivity

At the client, IP packets are sent from network layer to the data link layer. It makes the data frame as per the data link layer protocol. It includes the source physical address and the destination physical address. The source is the client and the destination is the router A. If the client connects to router A through a LAN the physical address is the MAC address and the data frame is Ethernet frame. In this case source physical address is client's MAC address and destination address is router A's LAN port (Ethernet port) MAC address.

The Router A receives the data frame and removes the header and the trailer and adds a new header and a trailer as per the data link layer protocol between router A and router B. For example it can use HDLC protocol. The new source address is router A's WAN port physical address, which connects to router B. The destination physical address is router B's WAN port physical address, which connects to router A. But practically this may not happen.

The Router B receives the data frame and removes the header and the trailer and adds a new header and a trailer as per the data link layer protocol between router B and router C. For example it can be PPP protocol. The new source address is router B's WAN port physical address, which connects to router C. The destination physical address is router C's WAN port physical address, which connects to router B. (May not happen practically)

The router C receives the data frame and removes header and trailer and adds a new header and trailer as per the data link layer protocol between router C and the server. If the router C connects to the server through a LAN the source address is router C's Ethernet port MAC address and destination address is server MAC address.

The server removes the Ethernet frame and header and sends the data packet to network layer. It removes the IP header and sends the data segment to transport layer. It checks the destination port number and directs the data to the application.

Data sent through a LAN

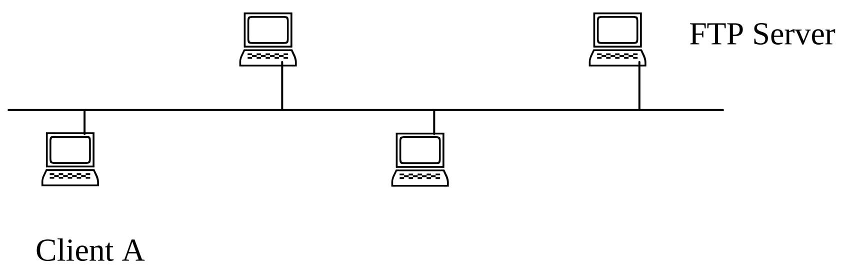


Fig. 3-8 Ethernet LAN

Fig. 3-8 shows an Ethernet LAN. Its network topology is a bus topology. All computers share the same media. If one computer sends data to the media it goes as an electric current. Since all computers are connected to same media this current is received by all the other computers. This means that if one computer transmits a signal to the media, it is received by all the other computers. Therefore this is a broadcasting network.

If client A wants to access the FTP server it sends a data frame to the media. All other computers receive this data frame and they check the destination MAC address in the Ethernet frame. The destination MAC address is FTP server's MAC address. Therefore only the FTP server accepts the data frame and the other computers ignore the data frame.

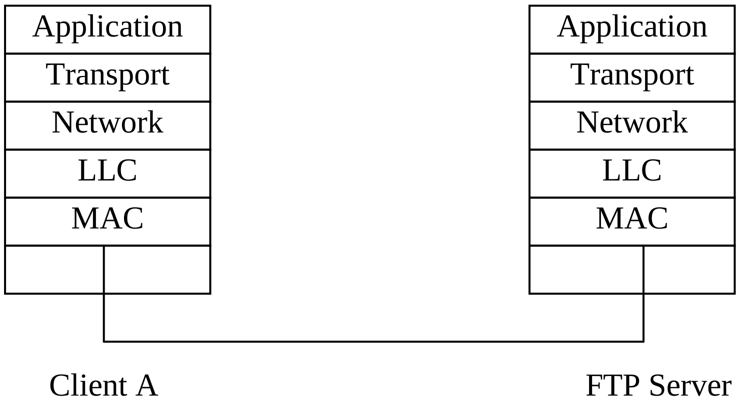


Fig. 3-9 MAC Layer in the data transmission

The operation of data flow is, the client application layer sends data to the transport layer. It adds the source and destination port numbers and sends to the network layer. The network layer adds the corresponding destination IP address and source IP address and sends the data packet to LLC and MAC layer. Those layers add corresponding destination MAC address and source MAC address and sends the Ethernet frame to the media (bus). The server accepts the Ethernet frame at the MAC layer. At the server the other layers will do the reverse process of client layers and finally the transport layer sends data to the application layer.

How to find out destination MAC address?

In the above example the client MAC layer adds the destination MAC address to the Ethernet frame. The client should know the destination IP address. But the client may not have the information of the destination MAC address. For this purpose a separate protocol called "Address Resolution Protocol" (ARP) is used.

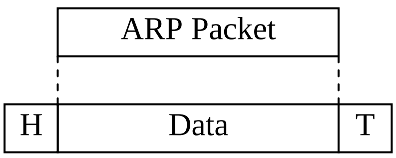


Fig. 3-10 Ethernet Frame with ARP packet.

The ARP packet is encapsulated in an Ethernet frame and broadcasted to find out the MAC address of a particular IP address.

In some applications (eg. DHCP server) we have to do the reverse process of ARP. That is, we know the MAC address and the corresponding IP address has to be found. For this purpose Reverse Address Resolution Protocol (RARP) is used.

How to send a message to a Group of Computers

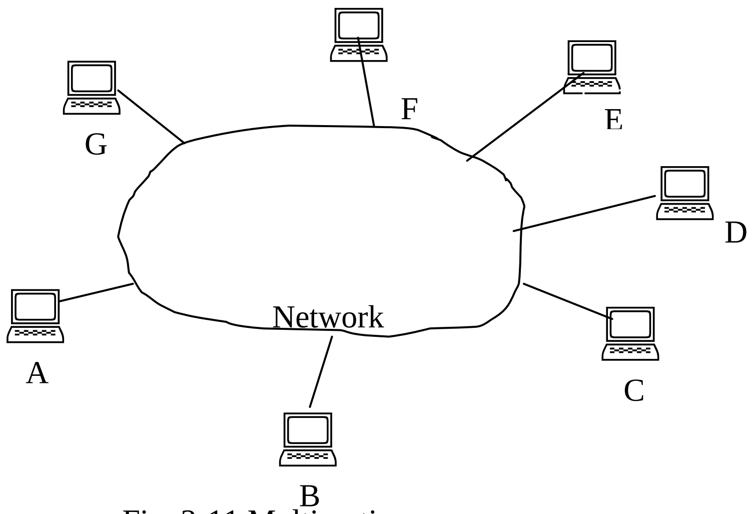


Fig. 3-11 Multicasting

Figure 3-11 shows a computer network. It can be a WAN. Computer A wants to send a message to computers B, E and F only. This is called multicasting. For this purpose a special protocol called "**Internet Group Management Protocol**" (IGMP) is used.

Routing Protocols

The routers in a WAN individually maintains routing tables. The router reads the destination IP address in the IP packet and the routing decision is taken (to which port the IP packet should be put) as per the information in the routing table. The routing table should have all routing information in the whole network. If a new network is connected to the existing network, all routers should update such routing information. If there are many routers in the network it is very difficult to perform this task manually. Therefore automatic routing information or dynamic routing is used. For this purpose routing protocols are used. The well-known routing protocols are RIP, OSPF and BGP.

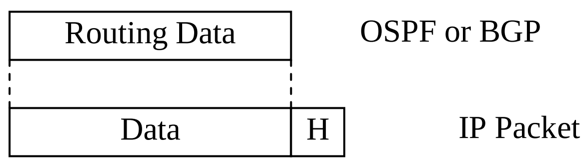


Fig. 3-12 Encapsulation of routing protocols.

The routing protocol data is encapsulated in the data part of the IP packet. This will become a special IP packet.

Application Layer Protocols

There are many application layer protocols. Some of them are briefly explained below.

Dynamic Host Configuration Protocol (DHCP)

IP address of a Host can be manually assigned. In large networks there is a possibility of allocating the same IP address to two computers. Then an IP conflict can occur which will prevent both computers or one of the computers from accessing the network. In order to avoid such a situation the IP address can be dynamically (automatically) allocated by using a special server process, which uses the DHCP protocol.

Domain Name System (DNS)

It is easy to remember a domain name such as www.slt.lk rather than remember the corresponding IP address. However TCP/IP needs the destination IP address to fill the destination IP address field of the IP packet. Therefore the domain name and corresponding IP address should be maintained in a separate server and this program is called the DNS server process and the corresponding protocol is called DNS protocol.

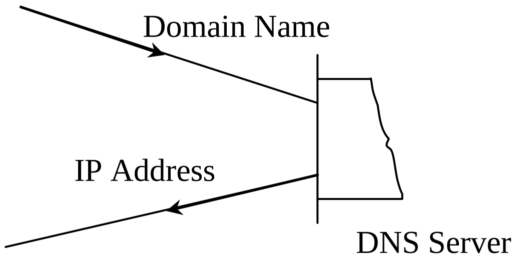


Fig. 3-13 DNS Operation

TELNET

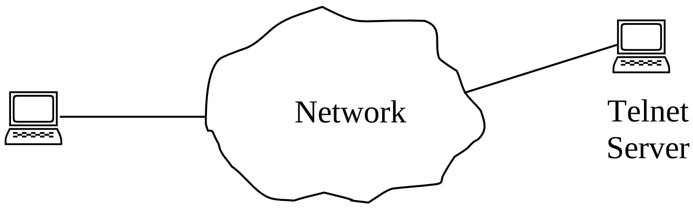


Fig. 3-14 TELNET Operation

In some occasions we may need to access a server located in a remote location in the network and to perform some changes in the database, application etc. In this case the Telnet protocol can be used. The remote host should run the Telnet server process. The computer which needs to access the remote database should run Telnet client process.

File Transfer Protocol (FTP)

We can transfer a file as an attachment of an e-mail. But this is difficult for a big file such as 10 MB. Since many mail servers restrict the attachment size. For this type of application FTP is an appropriate protocol.

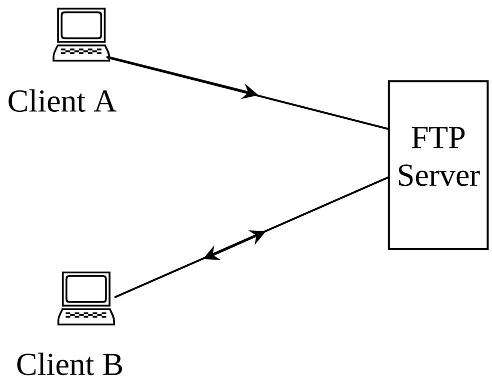


Fig. 3-15 FTP Operation

Client A needs to send a file to client B. Client A sends the file to an FTP server. Client B access the FTP server and obtains the file. FTP uses the TCP as the transport layer protocol.

Trivial File Transfer Protocol (TFTP)

TFTP is same as FTP. Normally it is used to send small files. Since TFTP uses UDP as the transport layer protocol it is an unreliable protocol.

Simple Network Management Protocol (SNMP)

This protocol is used to remotely manage network devices. The network device should run the SNMP server process. Then we can run SNMP client process in the network management server or any other computer and communicate with remote network device. This is mainly used to remotely configure the network devices and remotely diagnose the faults.

Simple Mail Transfer Protocol (SMTP)

SMTP is used to send e-mails.

Hyper Text Transfer Protocol (HTTP)

HTTP is used for web applications.

Data Communications & Computer Networks I
1st Year, 2nd Semester
2009

Tutorial 1

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1. What are the three types of transmission media?
2. Explain main problems encounter in transmission media.
3. What are the advantages of using standards in network industry
4. Name main standards for networking and explain them
5. What are the steps to be considered for computer communication?
6. What are the layers in OSI model
7. Briefly explain IEEE LAN model and TCP/IP.
8. Explain how the errors can be occurred in digital signal

Data Communications & Computer Networks I
1^{st} Year, 2^{nd} Semester
2009
Tutorial 2

1. Briefly explain an analog signal and digital signal with aid of sketch?
2. Explain amplifying process for analog signals and regeneration process for digital signals?
3. What is thermal noise and how it is generated?
4. What do you mean by Signal to Noise ratio $\left(\dfrac{S}{N}\right)$?
5. Describe how SNR affect to the signal quality.
6. What are the main steps in PCM and explain them briefly?
7. Write the Nyquist's theorem.
8. Explain the advantage of non-linear quantization.
9. If the level of a sample is 72, draw the corresponding bit pattern if we use CCITT PCM standard.
10. Bandwidth of a signal 5-25 kHz. Number of quantization levels 1000. What is the output bit rate?
11. The highest frequency of a signal is 20 kHz. What should be the minimum sampling rate of this signal according to sampling theorem? If each sample is quantized to 1024 levels what should be the minimum bit rate?
12. We need to store 5 minutes song on a CD .Signal bandwidth is 0-20 kHz and number of quantization levels are 1024. What is the capacity required in a CD to record a song? How many songs can be recorded in a 700MB CD?
13. Briefly explain
    a. Modulation
    b. Analog Modulation
    c. Digital Modulation

Data Communications & Computer Networks I
1^{st} Year, 2^{nd} Semester
2009
Tutorial 3

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14. A signal has a 100mW power and its noise power is 1mW. Find the signal to noise ratio.
15. a signal has a fundamental frequency of 1000Hz. What is its period?
16. What is the wave length of a signal with 100MHz frequency, travel through free space? Velocity of free space is $3*10^8$.
17. Speed of radio signal is $3*10^8$. If the wave length of signal is 3m, what is the frequency of this signal?
18. Mathematical representation of a wave signal can be shown by V=a sin 2 π f t.
    a. Signal 1 - 10 sin 100 π t
    b. Signal 2 - 5 sin 100 π t
    c. Signal 3 - 10 sin 200 π t
        i. Draw the signal 1 and 2.
        ii. Draw the signal 1 and 3.
19. Consider the following bit pattern for the digital modulation.

    1 0 0 0 1 0 0 1 1 1 1 0

    a. Draw the wave pattern for the following.
        i. FSK
        ii. ASK
        iii. BPSK
        iv. QPSK

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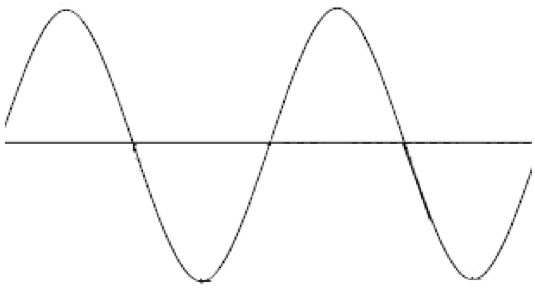
20. Consider the following wave pattern for the Analog Modulation. High frequency signal used as carrier signal for the modulator.



Draw the wave pattern for the following.

i. Frequency Modulation
ii. Amplitude Modulation

21. Explain the Quadrature Amplitude Modulation (QAM) and draw the phase diagram for 16 combinations.
22. Explain TDM and FDM briefly.
23. There are three input channels in a hypothetical TDM MUX. The bit rate of each channel is 56 kbps. What should be the minimum bit rate at output of MUX?
24. What is the usage of OH bits in TDM
25. Explain PDH
26. How do you get 150 kbps channel from PDH
27. Explain SDH and what are the advantages over PDH

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1. Four channels are to be multiplexed together using FDM. Each channel contains 100 KHz bandwidth. It required guard band of 10 KHz between the channels to prevent interference.
   a. What is the minimum bandwidth of the output link?
   b. Draw the output bandwidth in a frequency domain?

2. Four channels are multiplexed using TDM. If each channel sends 800 bits/s and it multiplex 8 bits per channel.
   a. Show the frame travelling on the output link?
   b. What is the size of the frame?
   c. What is the duration of a frame?
   d. What is the frame rate?
   e. What is the bit rate of the output link?

3. A TDM multiplexer is combine 25 digital sources, each of 100 Kbps. Each output slot carries 1 bit (bit interleaving) from each digital source, and one extra bit is added to each frame for synchronization. Answer the following questions.
   a. What is the size of an output frame in bits?
   b. What is the output frame rate?
   c. What is the duration of an output frame?
   d. What is the output data/bit rate?
   e. What is the efficiency of the system? (ratio of useful bits to the total bits)

4. Repeat the question 6 if each output slot carries 8 bits (word / byte interleaving) from each source? Assume no extra bits added for synchronization.

5. Data is to be transmitted over the PSTN using transmission scheme with eight levels per signaling element. If the bandwidth of the PSTN is 3000Hz, find out the capacity. (data transfer rate)

6. Assume S/N is 127 and PSTN has a bandwidth of 3000Hz. Find out highest bit rate (C - capacity) supported by media. The capacity you found in question 5, can be transfer through the media. Justify your answer.

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Tutorial 6

1. What are the major impairments in any transmission media?
2. Explain effect of those impairments in copper, radio and optical fiber Medias.
3. Explain how the optical fibers are preventing from Thermal Noise, Crosstalk and External Electromagnetic interferences.
4. What is group delay? What are the factors contributing to group delay?
5. What is the advantage of using twisted pair wires instead of using two open wires?
6. Explain how the coaxial cables providing grater segment length than UTP.

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Tutorial 7

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1. Briefly describe "reflection" and "refraction" in terms of light propagation
2. A beam of light moves from one medium to another medium with less density. The critical angle is 600. Do we have refraction or reflection for each of the following incident angles?
    a. 500
    b. 600
    c. 750
3. Calculate the bandwidth of the light for the following wavelengths
    a. 1000 nm
    b. 1200 nm
4. What are the two modes of fiber and briefly explain them using diagrams
5. Explain how the optical fibers are effected from attenuation and dispersion
6. Name the advantages of optical fiber over twisted-pair and coaxial cable

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Tutorial 8

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7. What are the types of antennas and draw the directivities of them.

8. What are the satellite access methods and explain them with aid of diagrams.

9. Compare TDMA and FDMA.

10. What do you mean by clock recovery? Explain briefly.

11. Briefly explain Asynchronous Transmission mode and Synchronous Transmission mode.

12. Draw the Line Coding for the following encoding methods.

    a. NRZ encoding

    b. RZ (50% duty cycle) encoding

    c. AMI (RZ – 50%) encoding

    d. Manchester encoding (start from high voltage level)

    e. Differential Manchester encoding (start from high voltage level)

    Bit pattern: 1 0 1 1 0 1 0 0 1 0 1

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Tutorial 9

1. Explain main characteristics of the physical layer?
2. Explain the functions of pins in RJ 45 connector.
3. What are the responsibilities of Data Link Layer?
4. Distinguish between Forward error correction and backward error correction.
5. Automatic Repeat reQuest (ARQ) is a example for Backward Error Correction
    a. What do mean by Backward Error Correction
    b. Draw the timing diagrams for the followings,
        i. Send 5 frames and 3^{rd} frame has errors. - use Idle ARQ
        ii. Send 6 frames and 4^{th} frame has errors - use Selective ARQ
        iii. Send 6 frames and 4^{th} frame has errors – use Go-Back-N ARQ
6. Which types of circumstances you select above ARQ methods? Justify your answer.

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Tutorial 10

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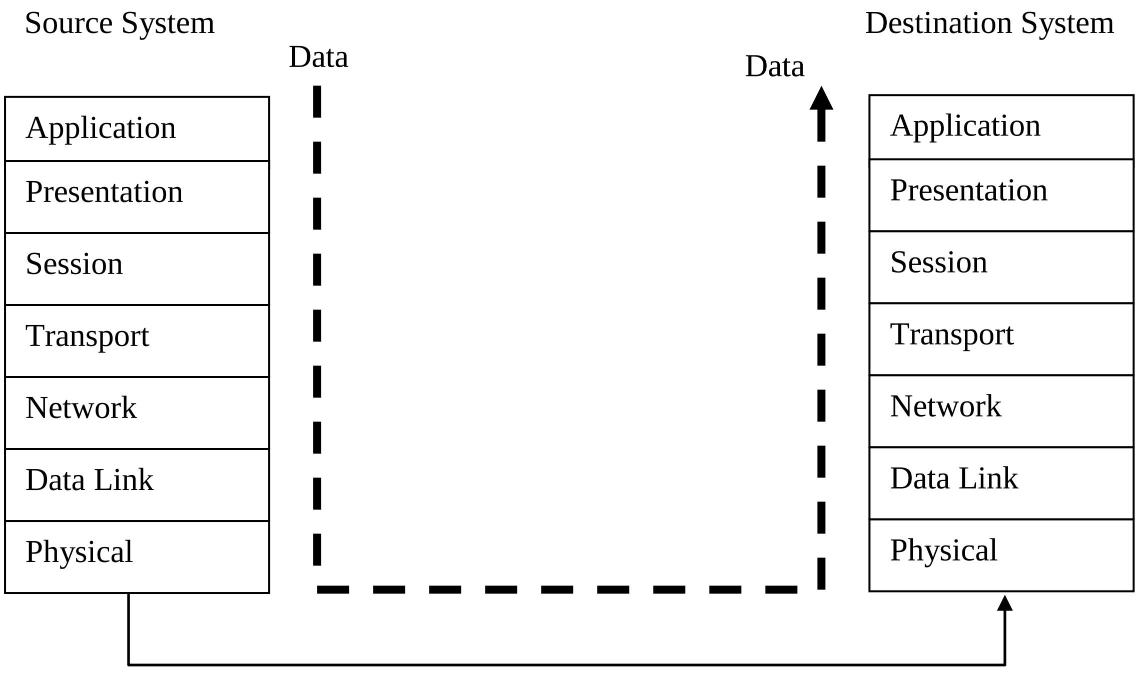
1. Draw HDLC frame structure and briefly explain the fields of them.
2. Write-down the types of frames in HDLC and the purpose of those frames.
3. HDLC is one of protocols used in Data Link Layer. What are the other protocols used in Data Link Layer.
4. Briefly explain the responsibilities of Network Layer.
5. Briefly explain following packet forwarding methods.
    a. Virtual Circuit
    b. datagram
6. Briefly explain the responsibilities of Transport Layer.
7. Define the followings.
    a. Segment
    b. Packet
    c. Frame
    d. Port address
    e. Logical address
    f. Physical address
8. Briefly explain the processes at each when we send data from source computer to destination computer.



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Tutorial 11

9. Briefly explain the responsibilities of following layers.
    a. Session Layer
    b. Presentation Layer
    c. Application Layer.
10. Write three different types of topologies used in LAN.
11. Name two widely used Media Access Control protocols and explains them.
12. Draw the LLC (802.2) and Ethernet (802.3) frame structures and explain the fields of them.
13. Draw the suitable LLC and Ethernet frames for the followings
    a. When 200 Bytes coming from Network layer to LLC.
    b. When 20 Bytes coming from Network layer to LLC.
14. How to connect to internet through PSTN?
15. Compare the Dial-up and Leased connection with following terms
    a. Availability
    b. Data rate
    c. Device involved

Self Reference Questions

1. Ethernet frame required minimum of 64 bytes. (from 'Destination Address' field to 'FCS' field including both) Explain why?

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Tutorial 12

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1. What are the media access control methods used in Wireless LANs?

2. Briefly explain the following,

   a. Leased lines

   b. Frame Relay

   c. ISDN

   d. ADSL

   e. IP – VPN

3. What are the devices used in networking. Explain them including followings,

   i. Main task of the device?

   ii. Device operates in which layer?

   iii. No. of collision domains?

   iv. No of broadcast domains?

4. Explain the TCP/IP operation in LAN and WAN with aid of diagrams.

Self Reference Questions

1. What is RFC? Give some examples associated to Data Communication and Computer Networks.

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Tutorial 13

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1. Consider the following scenario in TCP / IP model and Ethernet frame in LAN Model.

   2950 bytes of application layer data are going through transport layer, network layer and data link layer. Maximum Transfer Unit (MTU) of Ethernet frame is 1500 bytes.

   a. Draw the TCP segment, IP packet /s and Ethernet frame /s with the number of bytes in each header and data sections.

   (Note: Assume LLC Frame is not used when TCP / IP combine with Data Link Layer - Ethernet frame.)

2. Explain the client server model and identification of the processes in client and server?
3. Explain the Iterative server and Concurrent server?
4. Explain the connection oriented method and connection less method used in transport layer?
5. Explain how to find destination MAC address?
6. Briefly explain the following protocols

   i. DHCP
   ii. DNS
   iii. FTP
   iv. TFTP
   v. SNMP
   vi. HTTP
   vii. SMTP

LAB 01
Identifying Major Components of a Computer and familiarize with common terms.

Components:
Computer with necessary hardware components.
Objectives:

- Identify the major components of a computer.
- Major functions of those components.
- Familiarize with terms used and places they are used.

** You are required to fill out the following lab sheet. Instructor will provide you with necessary information and you may discuss with your group before filling this sheet.*

1. List the major components of a computer. Write the major functions of each component.

Component	Major Function

2. Name four types of input and output ports. Draw a picture of each port.

Port Name	Port Name
Port Name	Port Name

3. Draw a basic layout of a Motherboard. Name all the major components.

4. What are the meanings of following acronyms?

Acronym	Stands for
PCI	
ISA	
EISA	
USB	
PCMCIA	

5. What are the uses of these Slots/Ports?

Slots/Ports	Uses
PCI	
ISA	
EISA	
USB	
PCMCIA	

<u>Lab 2</u>

<u>Identifying the Types of Cables & Connectors used in Computer Networks.</u>

Components:

Cable (UTP), Jack (RJ 45), Wire stripper and RJ 45 Crimping Tool.

Objectives:

- Identify the major types of cables used in computer networks.
- Identify the major types of connectors used in computer networks.
- Understand Cross cable and straight through cable connections.

** You are required to fill out the following lab sheet. Instructor will provide you with necessary information and you may discuss with your group before filling this sheet.*

1. What is a computer network?

____

____

2. Standard (type) of the cable?

____

____

2.1. Number of wires (leads) in the cable?
2.2. Colors of the wires (leads)

3. Color code of the wiring standard (Refer figure 1)

1	2	3	4	5	6	7	8

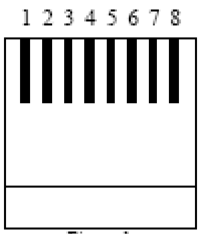


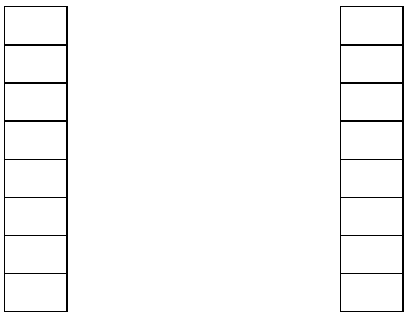
Figure 1

4. What are the types of cables used in computer networks and different type of connectors used with those cables?

Cable Type	Connector Type

5. Sketch each of the connectors stated in question 4.

6. What is the difference in Cross and Straight through cable connection?



Cross Cable

Straight Through

7. Where you can use the cross cable and straight through cable?

Cross Cable	Straight Through Cable

Lab 03

Usage & Configuration of Basic Network Services.

Components:

Computer, Network Interface Card (NIC), Cables.

Objectives:

- Identify necessity of a network.
- File sharing in a network.
- File transfer between in two computers using a cross cable.

** You are required to fill out the following lab sheet. Instructor will provide you with necessary information and you may discuss with your group before filling this sheet.*

1. What are the advantages of networking the computers?

2. Write the procedure to install a NIC (write the basic steps)

3. Write the procedure to connect two computers using cross cable and how to find out whether the connection is made. (Write important steps, settings, configurations required).

4. How do you share a file or folder in a computer?

5. What are the options available in file & folder sharing?

6. How to transfer a file using File Transfer Protocol (FTP)

Lab 04

Implement a Simple computer Network using a Hub.

Components:

Computer with necessary hardware components, Hub, UTP cables (straight through)

Objectives:

- Understand the common computer topologies.
- Identify the advantages and disadvantages of different computer network topologies.
- Understand the client server configuration of a network.

** You are required to fill out the following lab sheet. Instructor will provide you with necessary information and you may discuss with your group before filling this sheet*

1. What are the commonly used computer network topologies?

i

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ii

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iii

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iv

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v

2. Show above network topologies diagrammatically.

3. What are the devices used in internetworking?

4. List the basic advantages and disadvantages of different types of topologies.

5. Instructor will configure the network. Write down the steps involved in sequence. Discuss about the things that you find difficult to understand.

Lab 05

Implementing a Wireless Local Area Network (WLAN)

Components:

Computer, Hub, Access Point, Wireless network card (PCI), Wireless USB adapter.

Objectives:

Understand the requirement of a wireless network.
Identify the equipments used in a wireless network.
Understand the general layout of a wireless network.

** You are required to fill out the following lab sheet. Instructor will provide you with necessary information and you may discuss with your group before filling this sheet.*

1.Why wireless networking is required in a LAN?

2. Name the items (equipment) used to build up a wireless network

3. What type of NIC cards (adapters) is available for wireless networks? Sketch them.

4. Identify the advantages and disadvantage of those adapters?

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5. What are the frequencies used for WLANs and standards used?

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6. Sketch the basic network diagram when it is used in 'Infrastructure mode' and 'Ad-hoc mode'. Identify the difference in two modes.

Infrastructure mode	Ad-hoc mode

7. Write down the settings you need to set if a computer is in a wireless network?

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8. Transfer some data between computers using folder sharing and ftp. Write down the steps. Are there any differences from what you have done in wired LAN?

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Lab 06

Structured cabling and tests in a computer network.

Components:

Display boards available, some other networking components and items used in computer network.

Objectives:

- Understand the requirement of a structured cabling.
- Identify the tests to be carried out in a computer network.
- Understand the general layout of a computer (and voice) network.

** You are required to fill out the following lab sheet. Instructor will provide you with necessary information and you may discuss with your group before filling this sheet.*

1. What do you understand by structured cabling?

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2. Why do you need structured cabling?

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3. If you were assign to design a network for two buildings, list down the procedure to how you set about it. (Things to consider, type of transmission media (for voice and data), components to be used, location of devices etc…)

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4. Sketch the basic network diagram for your design. (Indicate all the important things i.e. devices, cable types, components used etc… on the diagram)

5. What do you understand by structured cabling tests?

6. Name few structured cabling tests (for different types of media) and state how it is carried out