2 Physical Layer

2.1 INTRODUCTION

Physical layer:

It deals with electrical, mechanical, and functional characteristics.

Note:

Physical connectivity must be there between one hop to other hop (that connectivity may be wired or wireless).

It is responsible for the transmission of binary data through a medium.

Transmission can be analog (continuous waveform signals) or digital (discrete binary signals).

a) Do you know why a modem is used !!

Convert analog to digital and vice versa.

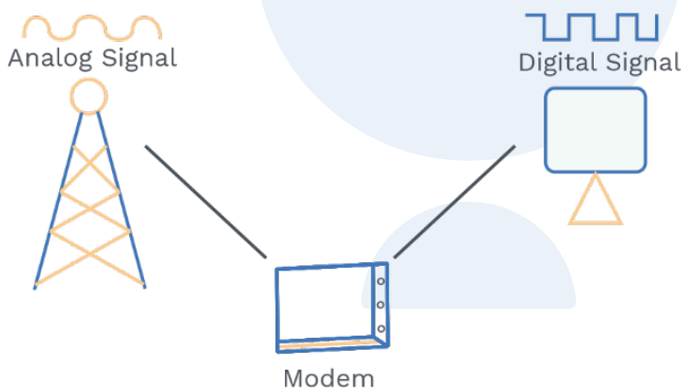


Fig. 2.1 Diagrammatic Representation of Signal Conversion

b) Do you know why multiplexers are used !!

It allows multiple signals to be carried on a single transmission line.

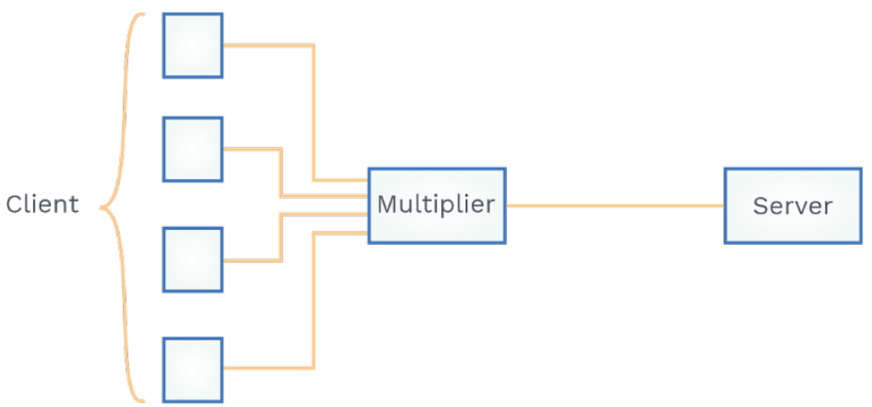


Fig. 2.2 Diagrammatic Representation of Uses of Multiplexer

Baseband transmission:

- Typically it is used in local area network (LAN)
- It uses a digital signal over a single wire.
- In a baseband transmission, the entire bandwidth of the channel is used by digital signals.

Rack Your Brain

a) Is it possible to transmit multiple signals on a single cable !!
b) Baseband signal uses which multiplexing technique !!

Broadband Transmission:

- Typically, it is used in Wide Area Network (WAN).
- It uses analog signals over multiple transmission frequencies.
- In broadband transmission, multiplexing is used using Frequency Division Technique (FDM).

Bandwidth:

- We can say maximum transmission capacity.
- It is a difference between highest and lowest frequencies contained in the composite signal.

$$\text{Bandwidth} = \text{freq}_H - \text{freq}_L$$

You may ask, what are composite signals?
Signals are the composition of many waves it may be periodic or non-periodic.

- Frequency of periodic signals has a discrete value.
- Frequency of non-periodic signals has a continuous value.

Grey Matter Alert!

5kbps vs 5hz, what is the difference !!
Both are bandwidth; these two units are two different measuring values:

5hz : A range of frequencies channel can pass
5kbps : Bandwidth on a link is 5kbps

Basically, any increase in bandwidth in hertz means an increase in bandwidth in bits per sec.

Throughput:
How fast we can send data through a network !!
One may think throughput and bandwidth are the same, but they are different. Let's say preparing 10 subjects per gate cse paper is bandwidth, but babloo is able to finish only 7 subjects in gate cse paper , So the throughput of babloo is 7.

Latency:
It is the delay, how much time it takes to travel a message from source to destination. When the first bit is sent out from the source to the destination.

Latency = Propagation delay + Transmission delay + Queueing delay + Processing delay

Propagation delay: It is the time duration for 1 bit to travel the link
T_p = distance between sender and receiver/velocity of the signal on the link.

Transmission delay: It is the time taken to push the entire packet bits onto the wire.
T_t = Frame size or packet size/Bandwidth

Queuing delay: It is the time taken for a packet to stay in the buffer.

Processing delay: Routers or switches take some time to process the packet header, which is called Processing delay.

Transmission of signal:
How information can be represented in digital signal:
1 $\rightarrow$ Positive voltage
0 $\rightarrow$ Zero voltage
The diagram below has 2 signal levels; it may have 3 or more levels, depending upon the amount of data.

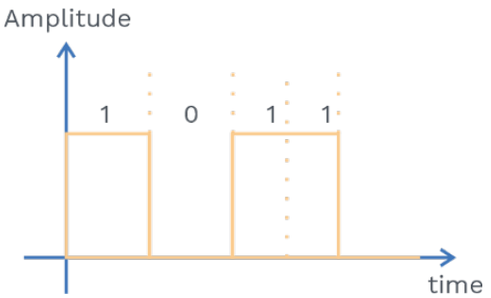


Fig. 2.3 Digital Signal Representation

Please note here for sending information at one bit per level, we need two levels.

Concept Building Exercise

a) For sending information in 2 bits per level, how many levels are needed !!
It is 4, i.e. 2^{bits}

b) What is the bit rate?
Number of bits sends in one sec.

c) What is the baud rate?
It is the number of times signal changes per second.

d) What is channel capacity?
Maximum rate at which data can be communicated.

Encoding/Decoding techniques:

- **Encoding:** Process of converting from one format into another (specified) format.
- **Decoding:** Process of converting from specified format into actual format (It is the reverse of encoding)

Terms used in encoding:

- **Unipolar:** If all the signal elements have the same sign (like all are positive or all are negative), then the signal is unipolar.

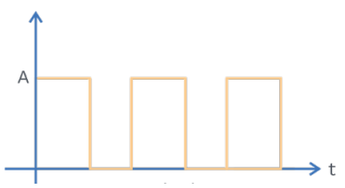


Fig. 2.4 Unipolar Scheme

- **Polar:** If the signal elements have one positive and another negative sign, then the signal is Polar.

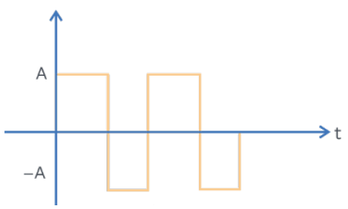


Fig. 2.5 Polar Scheme

- There are different encoding schemes, but we will limit it to Manchester and differential Manchester because it is used in IEEE 802.3.

Manchester encoding scheme:
1 → low to high transition in middle of interval.
0 → high to low transition in middle of interval.

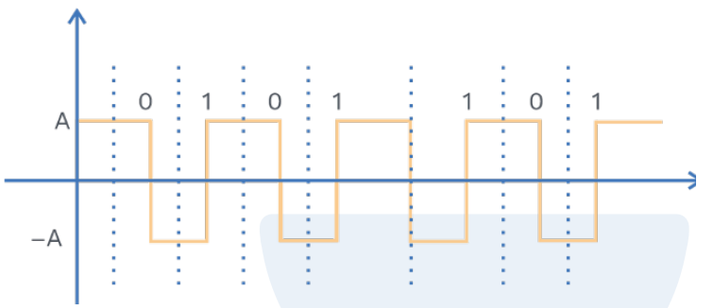


Fig. 2.6 Diagrammatic Representation of Manchester Encoding Scheme

Differential Manchester encoding scheme:
Always inversion at the middle occur,

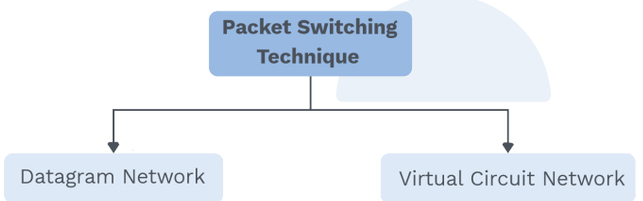
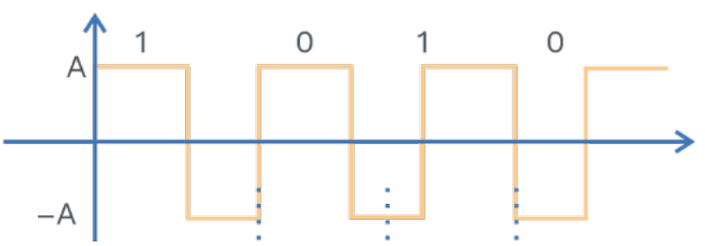


Fig. 2.7 Diagrammatical Representation of Differential Manchester Encoding Scheme



Rack Your Brain

Find the differential Manchester and Manchester encoding of the given code:

10110110

Noise:
When a signal travels, there is a high chance that unwanted signals get attached to the original signal, which creates bad results and is often termed noise. There are several types of noise: Thermal, crosstalk and impulse.

Thermal noise:
It gets created by the random motion of electrons in a wire.

Cross talk:
It is an effect of radiation which is induced on other signals because of close proximity.

Impulse:
It is spike noise which comes for a short duration due to some instant action like lightning.

Signal to noise ratio:
SNR = Average signal power/Average noise power.

Note:

High SNR means the signal is less affected by noise, and low SNR means signal is highly affected by noise:

$$\text{SNR (in db)} = 10\log_{10}\text{SNR}$$

Data rate depends on bandwidth, level of signal and level of noise.

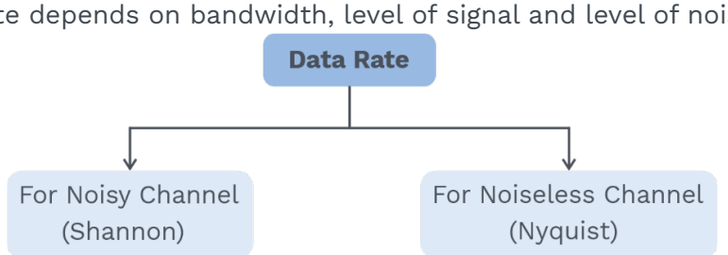


Fig. 2.8 Data Rate Based on Types of Channel

For noiseless channel:
We calculate Nyquist formula
Maximum Bit rate = 2 * Bandwidth * $\log_2 L$ (L is level of signal)

Concept Building Exercise

A channel has a bandwidth of 6000 Hz. Consider the channel is noiseless and the channel is transmitting a signal with 2 signal levels . What should be the maximum bit rate?

Maximum bit rate = 2 * Bandwidth * $\log_2 L$ (L is level of signal)
= 2 * 6000 * $\log_2 2$
= 12000 bps

For noisy channel:
We calculate the Shannon formula:
Maximum bit rate or capacity: Bandwidth * $\log_2(1+SNR)$

Concept Building Exercise

Consider a noisy channel where SNR ratio is too low, consider it as 0, What is the capacity of the channel?
Since SNR is 0, this means the signal is highly affected by noise, and it gets lost
Maximum bit rate or capacity = Bandwidth * $\log_2(1 + 0)$
= 0
Capacity of channel in this case is 0. **Have you observed bandwidth is present still the capacity of channel is zero!**

PRACTICE QUESTIONS

Q1 **If the television channels have a Bandwidth 4MHz. If 8 level digital signals are used. How many bits per second can be sent ? Assume the channel is noiseless.**

Sol: We can use Nyquist in this case:

Maximum bit rate = 2 * 4 * $\log^8_2$ (For 8 levels – 3 bits needed)
= 24 Mbps

Q2 **Can you guess rail road, oil in pipes are which types of communication!!**

Sol: Half duplex, one at a time.

Q3 **What is the effect on rate if the bandwidth gets doubled?**

Sol: The rate is doubled.

Q4 **How will the rate improve if we double the SNR?**

Sol: The rate will slightly increase.

Switching:

Why do we need switching?

When we have many devices, we can connect using point to point (as we have seen in mesh topology) or multipoint connections (as we have seen in star topology). But can we extend these methods when we have a very large network!! BIG NO

Switching helps here; there are 3 types of switching see figure below:

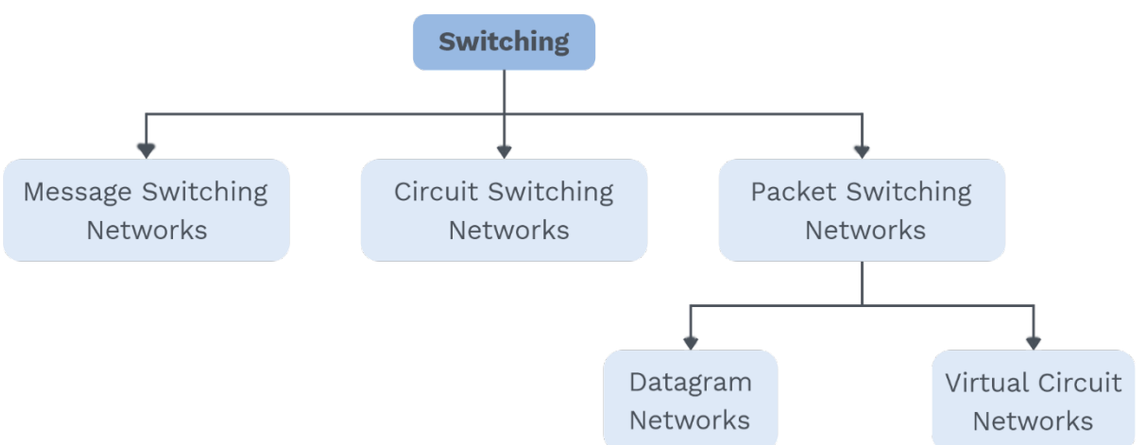


Fig. 2.9 Flow Chart Representing Types of Switching

Circuit switching networks:

Standard Definition

It is made up of a set of switches connected by physical links in which each link is divided into n channels.

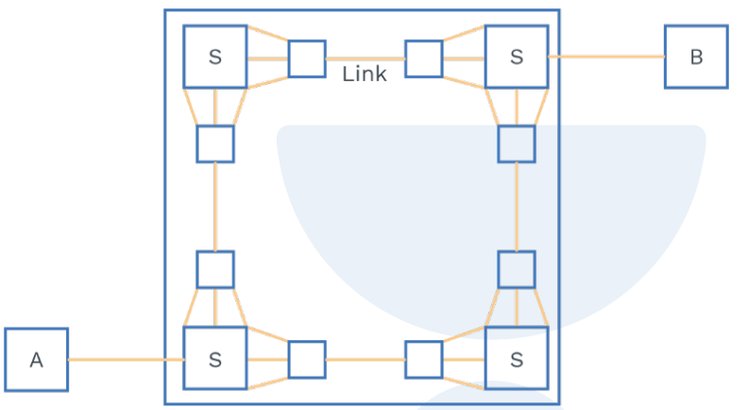


Fig. 2.10 Diagrammatic Representation of Circuit Switching

- Circuit switching needs to be handled at the Physical layer.
- There must be reservation of resources before the communication takes place
- Resources get reserved during the set-up phase, and for the entire, duration it gets fixed until there is a teardown phase.
- Communication happens in three phases:
  Set up phase: A dedicated path needed to be established before the transfer of data.
  Data transfer phase: transfer of data takes place in this phase.
  Tear down phase: A signal is sent to release the resource.
- When the path has established, there is no danger of congestion.
- Switching at the traditional telephone network uses the circuit switching.

Note:

Resource:
It is nothing but channels (bandwidth in case of FDM or time in case of TDM), buffers, ports etc.)

Packet Switching Networks:

Standard Definition

There is no resource reservation; the resource is allocated on demand.

Note:

The message is divided into packets which are fixed or variable sized networks.
There is no need to establish a dedicated path in advance but it can be allocated on demand.
The allocation of resources is done on FCFS basis.
Packet contains the user data and controlled information.

Packet switching technique:

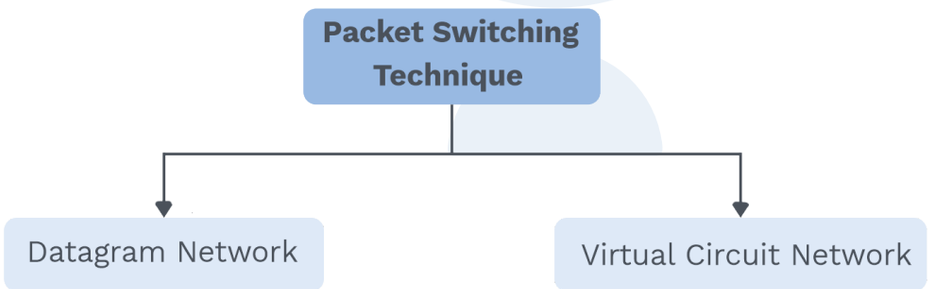


Fig. 2.12 Types of Packet Switching Technique

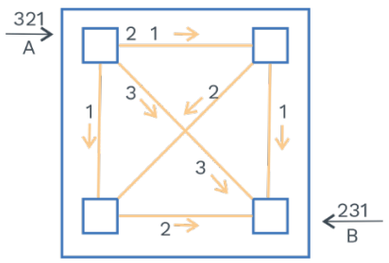
Datagram network:

In this, each packet has no relation to the other packet.

Note:

Packet in this network are called datagram.

- It is normally done at the network layer.
- A switch in the datagram network uses a routing table which is based on the destination address.
- Sometimes, it is said that these networks are connectionless, which means the switch does not keep the information about the connection state.
- The destination address in each packet remains the same.



- Packet may reach out of order as shown in the diagram.
- Switching on the internet is done using the datagram approach.

Concept Building Exercise

Is out of ordering possible in circuit switch networks?

No, since every message follows the same path.

Can you guess whose efficiency is better? And why?

Datagram network, because there is no wastage of bandwidth, resources are allocated on demand.

Virtual circuit network:

Standard Definition

In virtual circuit representation, all the packets follow the same source and destination travel the same path, but the packet may arrive with the different delays if resource allocation is on-demand.

- Packets from the single message travel along the same path.
- Resource reservations can be made during the setup phase or on-demand during the transfer phase.
- Each packet contains a Virtual Circuit Identifier (VCI).
- Again, in a virtual circuit, there are also 3 phases required to transfer the data.

Setup Phase, transfer phase, tear down phase:

- Virtual switch networks are used in switched WAN normally at the data link layer.

PRACTICE QUESTIONS

Q1 **A path in a digital circuit-switched network has a data rate of 1 Mbps. The exchange of 2000 bits is required for the setup and teardown phase. The distance between the two parties is 5000 km. The propagation speed is 2 × 10^8 m/s. What is the total delay if 1000 bits of data are exchanged during data-transfer?**

Sol: Two set up phase + 1 tear down phase, i.e 3 *(t_p + t_r)

Finally data transfer required (t_p + t_r)

So, the total delay = 4(t_p + t_r)

T_p = 5 * 10^6 / 2*10^8 = 25 msec

T_t = 2000/10^6 = 2 msec

= 4(25 + 2)

= 4*(27) msec

= 108 msec

Q2 **Tick mark where you feel end to end addressing is required:**

Sol:

	Setup Phase	Transfer Phase	Tear Down Phase
Circuit Switched Network	✓		✓
Datagram Network		✓	
Virtual Circut	✓	✓	✓

Q3 **Comparison between virtual circuit and datagram circuit:**

Sol:

Virtual circuit	Datagram circuit
The 1st packet needs a global header and for the remaining packet it just needs a local header.	Headers are required for all packets.
It is connection oriented as resources and bandwidth are reserved.	Resources are not reserved; hence datagram circuit is connectionless.
All the packets are in order as the same path is followed.	May follow a different path.
It is highly reliable.	It is not reliable.
Cost is high.	Cost is not high.
ATM uses Virtual circuits.	IP networks use datagram packet.

Previous Years' Question

Q) Which one of the following is false?

a) Packet switching leads to better utilization of bandwidth than circuit switching.

b) Packet switching results in less variation in delay than circuit switching.

c) Packet switching requires more per packet processing than circuit switching.

d) Packet switching leads to reordering, unlike circuit switching.

Sol: b) **(GATE-2004)**

Chapter summary

- Physical layer deals with electrical characteristics by type of link.
  Example: If the link is copper, then we use an electrical signal.
  If the link is optical, then we use a light signal.
- Physical layer deals with mechanical characteristics by type of transmission mode.
  Example: Simplex, Half duplex and Full duplex.
- Physical layer deals with various topologies like Bus, Ring, Star and Mesh.
- Physical layer deals with encoding techniques.
- Bandwidth utilization means using available BW(bandwidth) to realise the goal. and using multiplexing, we can achieve efficiency.
- Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.
- Series of interlinked nodes consist of switching networks; these interconnections can be done using switches.
- Circuit-switched Network: It consists of a set of switches connected via a physical link where each link is dividing into n-channels.
- In circuit switching, there is a setup phase, data transfer phase and termination phase.
- In packet switching, there is no resource allocation for a packet, resource allocation can be done on demand.
- In a datagram network, each packet is treated independently of all others.
- A virtual–circuit network is an intermediate between a circuit–switched network and a datagram network.