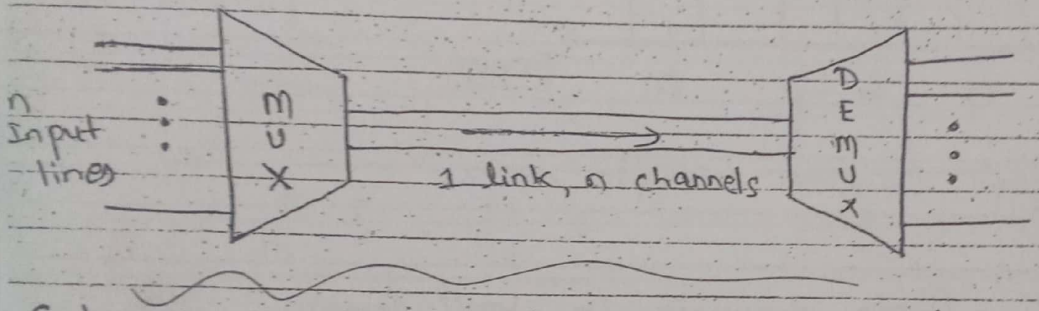
Chapter 9

Multiplexing & switching

Multiplexing

It is the set of techniques that allows the simultaneous transmission of multiple signals accross a single data link whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared.

In a multiplexed system, n lines share the bandwidth of one link. The basic format of a multiplexed system is shown in figure.



Categories of multiplexing

There are three basic multiplexing techniques:

1) Frequency division multiplexing
2) Wavelength " "
3) Time " "

Frequency division multiplexing (FDM)

→ In FDM, signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link. Carrier frequencies are seperated by sufficient bandwidth to accomodate the modulated signal.

channels can be seperated by strips of unused blw called guard bands to prevent signals from overlapping & prevent interference betn carrier frequencies & data frequencies.

e.g. of FDM system is broadcast & cable T

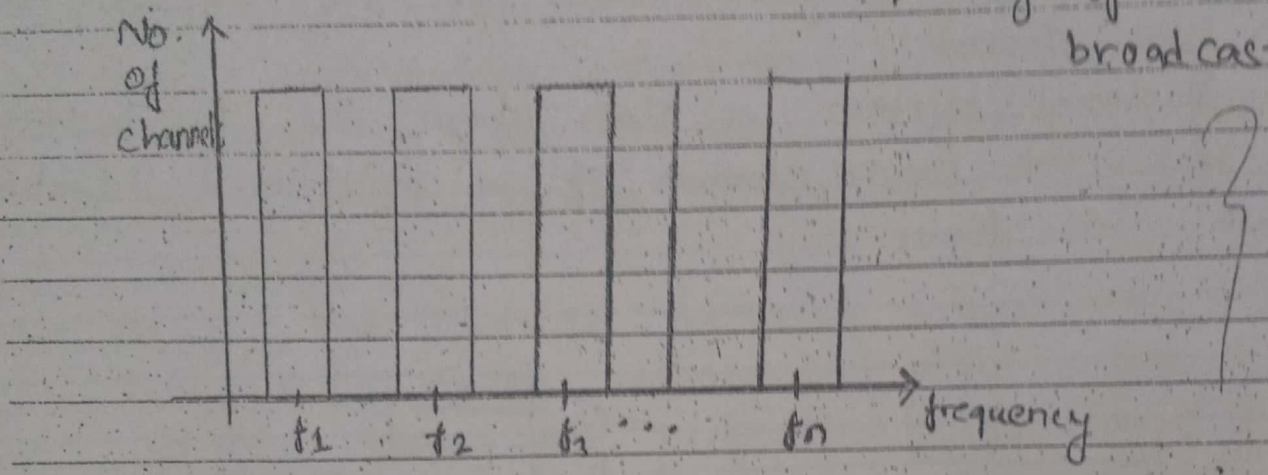
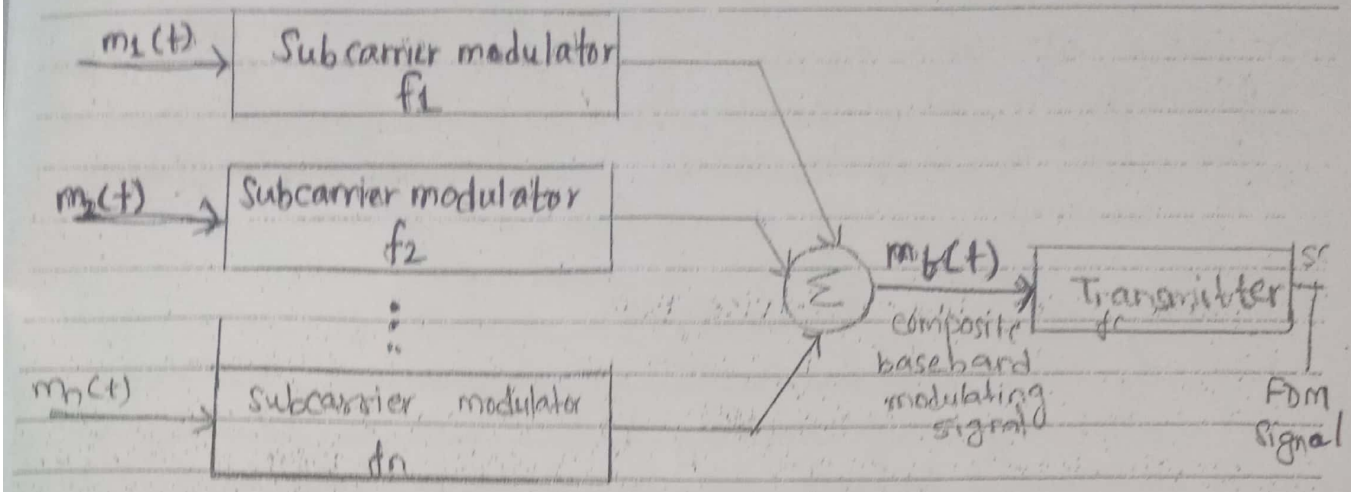


Fig.: Freqⁿ Division multiple access

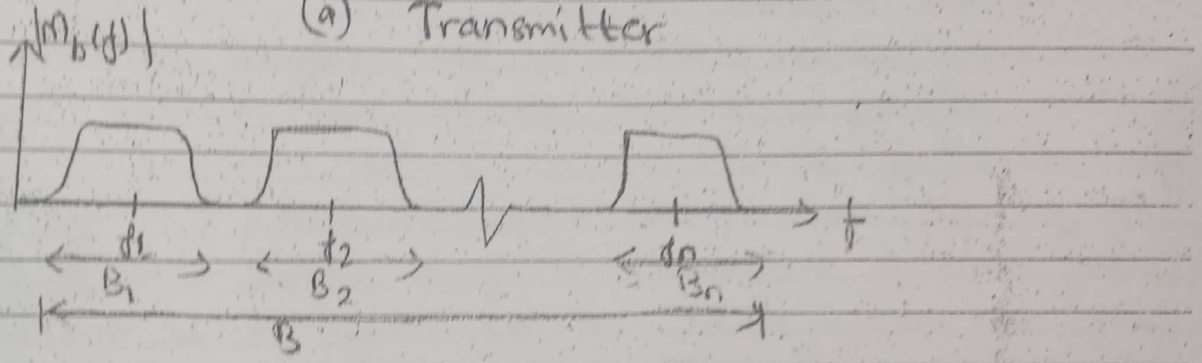
Features
- Combination of multiple channels in freqⁿ domain.
- Old & mature technology.
- Initially used in Analog system.
- Simple circuit
- No need to take care of timing.

Drawbacks
- Freqⁿ resource is limited
- Unsecure
- Spectrum management is difficult.
- Interference occur betⁿ two (frequencies) channels.

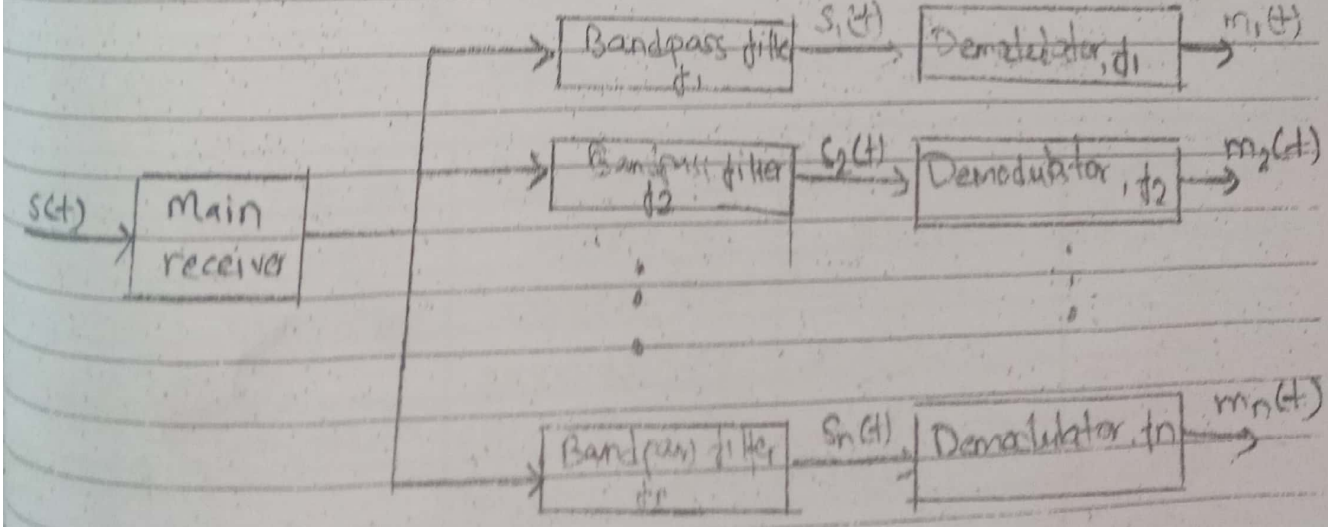
FDM system



(a) Transmitter



(b) spectrum of composite baseband modulating signa



(C) Receiver

Level (1) : Basic Group (12 voice channels multiplexed together)

↓

Level (2) : Super Group (Upto 5 basic groups multiplexed together i.e., upto 60 voice channels)

↓

Level (3) : Master Group (Upto 10 super groups multiplexed together i.e., upto 600 voice channels)

↓

Level (4) : Jumbo Group (Upto 6 master groups multiplexed together i.e., upto 3600 voice channels)

2. FDM Hierarchy

This hierarchy is used by AT & T and has been shown in figure 4.6.

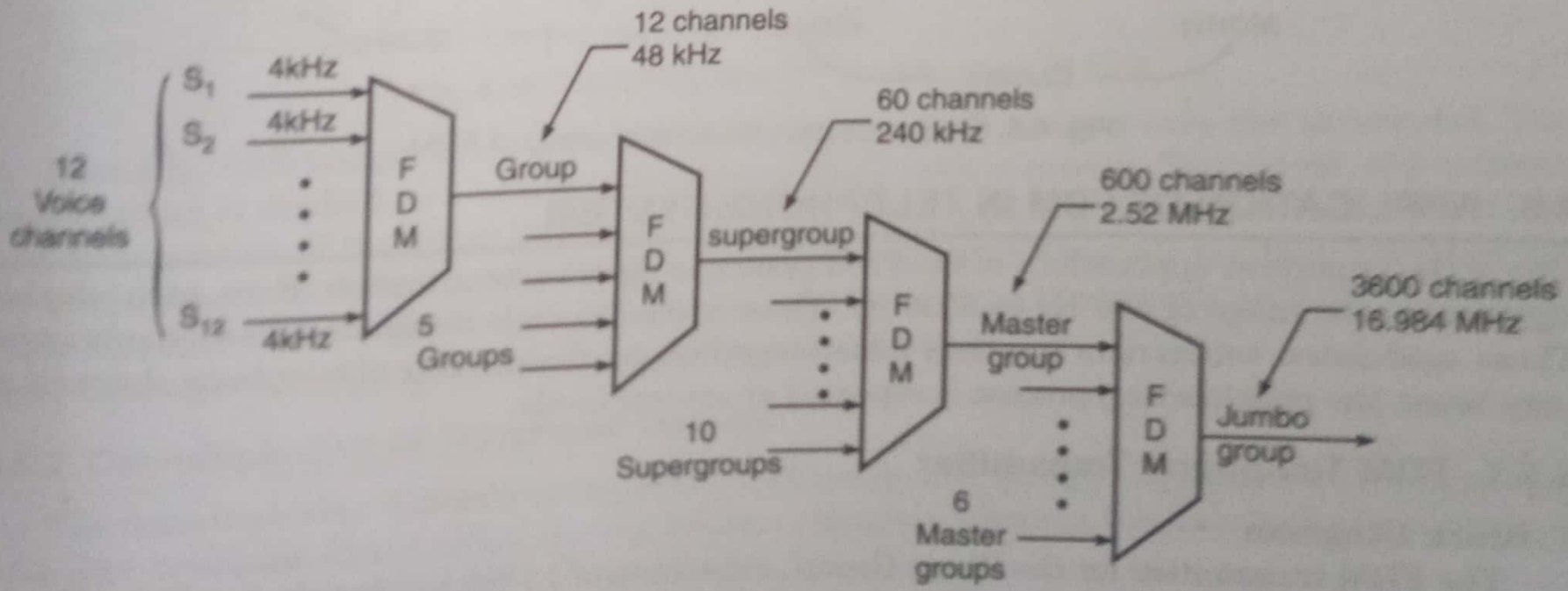


Fig. 4.6. FDM Hierarchy

The levels of multiplexing is also called as **multiplexing hierarchy**.

Various Groups in FDM Hierarchy

In case of voice signals (in telephone system), an effective bandwidth is only 3100Hz (300 to 3400), but a 4KHz bandwidth is adequate (used) to minimize the problem of crosstalk.

Hierarchy of Analog Service (FDM)

- FDM is the earliest, & still a very common, technique for utilizing high-capacity links such as coaxial cable & microwave systems for long-distance transmission of voiceband signals.
- In the United states, AT & T has designed a hierarchy of FDM while in Europe ITU-T has similar type of hierarchy.

At the 1st level of the AT & T hierarchy, 12 voice channels are combined to produce a group signal with a bandwidth of 12 x 4KHz = 48KHz, in the range 60 to 108KHz.

- The next basic building block is the 60 channel supergroup which is formed by freq^n division multiplexing five group signals.
- Similarly other mastergroup, supermastergroup are formed.

No. of voice channel	Bandwidth	Spectrum	AT & T	ITU-T
12	48KHz	60-108KHz	Group	Group
60	240KHz	312-552KHz	Supergroup	Supergroup
300	1.232 MHz	812-2044KHz		Mastergroup
600	2.52	564-3084KHz	Mastergroup	
900	3.872 MHz	8.516-12.388MHz		Supermaster group
N x 600			Mastergroup multiplex	

Wavelength Division Multiplexing

- In case of optical fibre when multiple beams of light of different wavelengths are transmitted on the same fiber we use wave division multiplexing (WDM).
- In WDM system laser beam at different wavelengths generated by number of sources are sent to a multiplexer, which consolidates the sources for transmission over a single fiber line.

→ After transmission of signal over long distance, [low Signal degradati & high data rate in optical fibre], the composite signal arrives at a demultiplexer, where the component channels are seperated & sent to receivers at the destination point.

→ Most WDM systems operate in the 1550nm range. In early systems, 200mHz was allocated to each channel, but today most WDM systems use 50-GHz spacing.

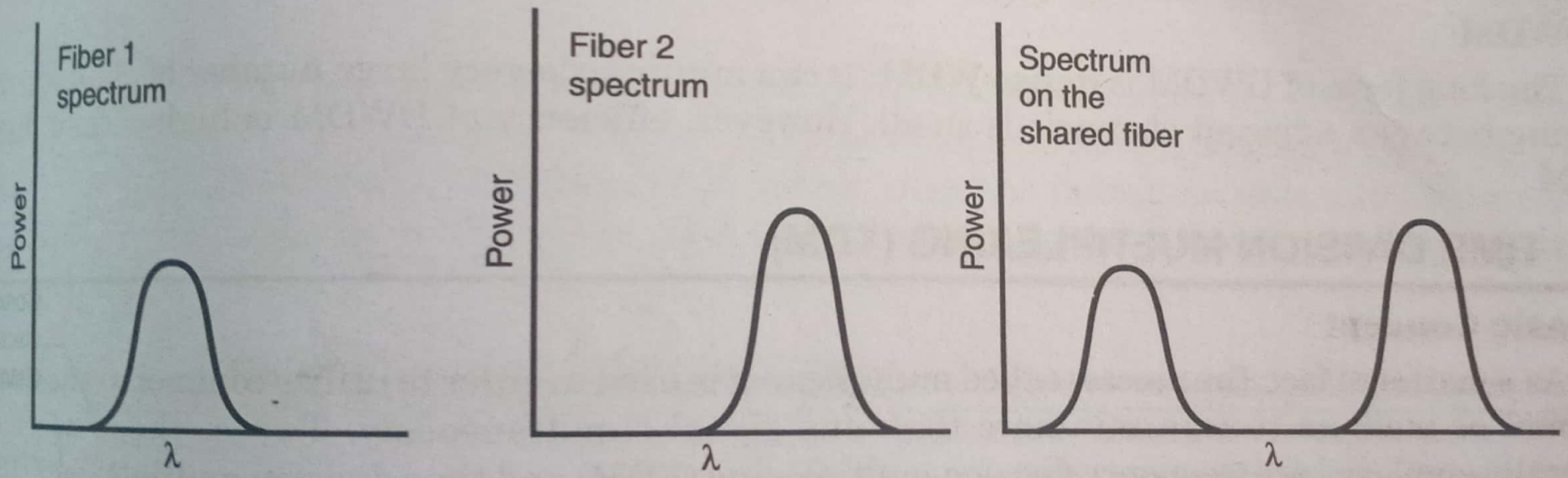
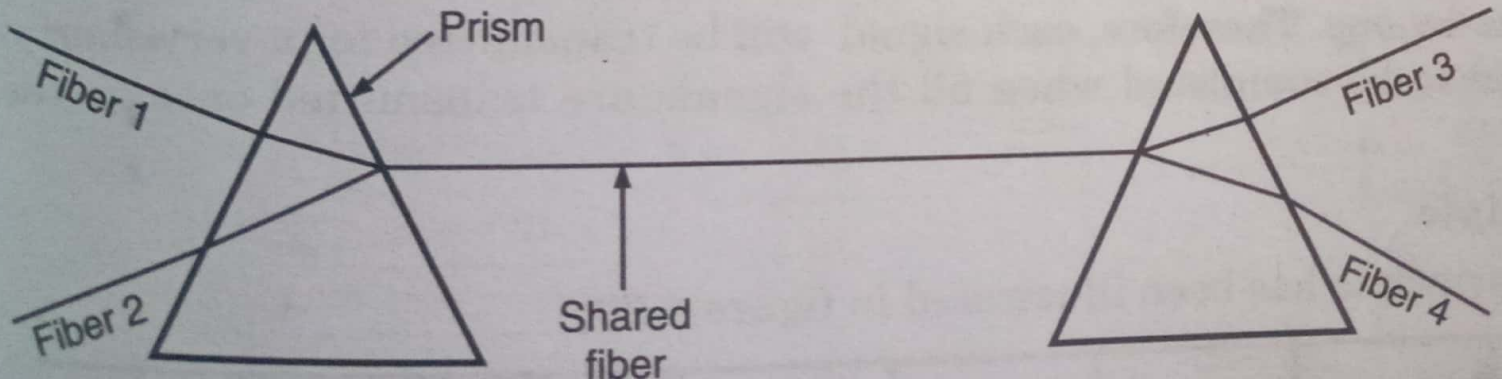


Fig. 4.17.



Time Division Multiplexing

- TDM is possible when the achievable data rate of medium is greater than the data rate of digital signals to be transmitted.
- Multiple digital signals can be carried on a single transmission path by interleaving portions of each signal in time. The interleaving can be at the bit level or in blocks of bytes or larger quantities.

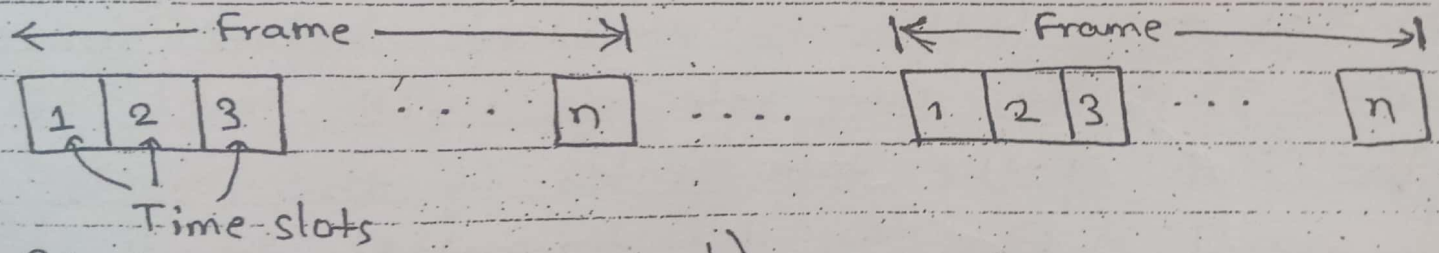
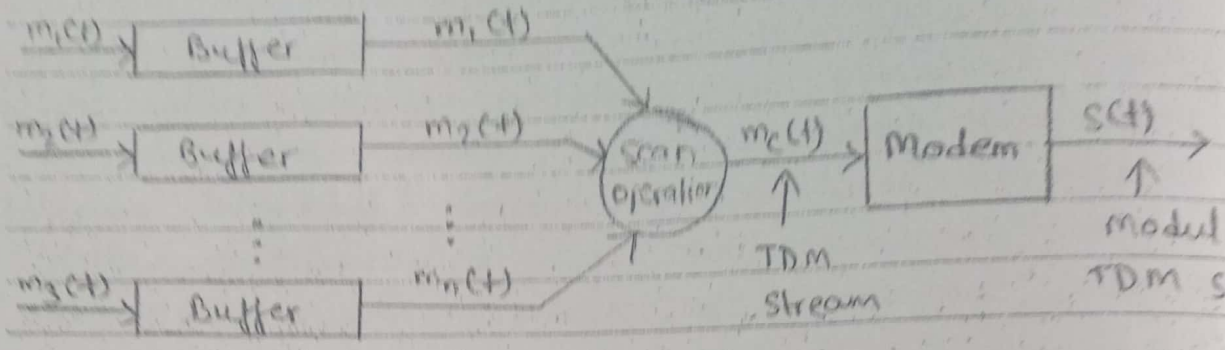
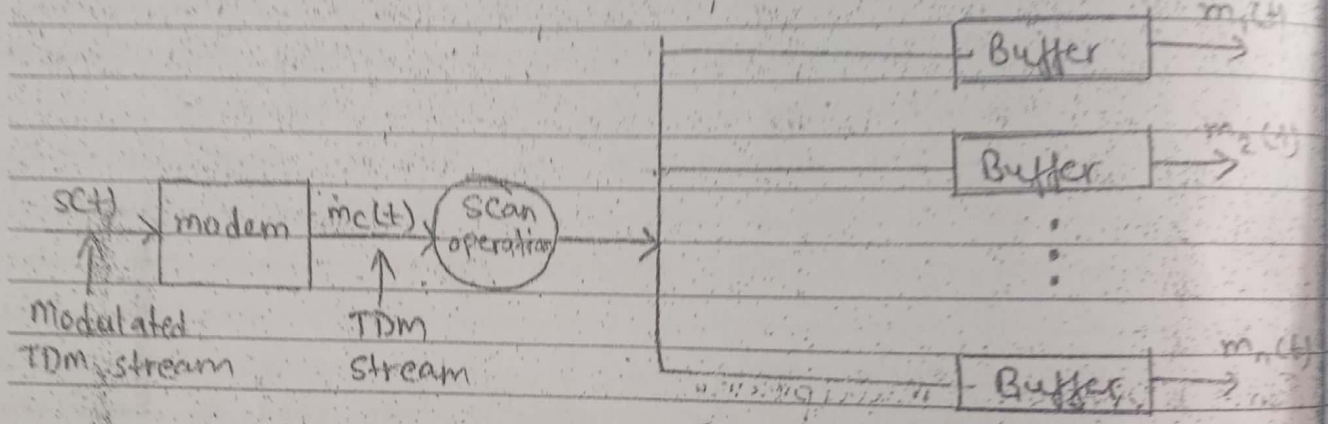


Fig: TDM frames



(a) Transmitter



(b) Receiver

The incoming data from each sources are briefly buffered. Each buffer is typically one bit or one character in length. The buffers are scanned sequentially to form a composite digital data stream $m_c(t)$. The scan operation is sufficiently rapid so that each buffer is emptied before more data can arrive. Thus the data rate of $m_c(t)$ must at least equal the sum of the data rates of the $m_i(t)$. The digital signal $m_c(t)$ may be transmitted directly, or passed through a modem so that an analog signal is transmitted

TDM

Statistical TDM
Time slots are not preassigned.
more efficient

Synchronous TDM
→ Time slots are preassigned & fixed
→ less efficient than statistical becau of limited utilization of resources

Advantages of TDM over FDM
- Digital Technology (easy to implement)
- Secure "
- Encryption possible
- high capacity

Drawbacks
- Complex
- Timing accuracy is important.
- Synchronization required.

Time Division Multiple Access (TDMA)

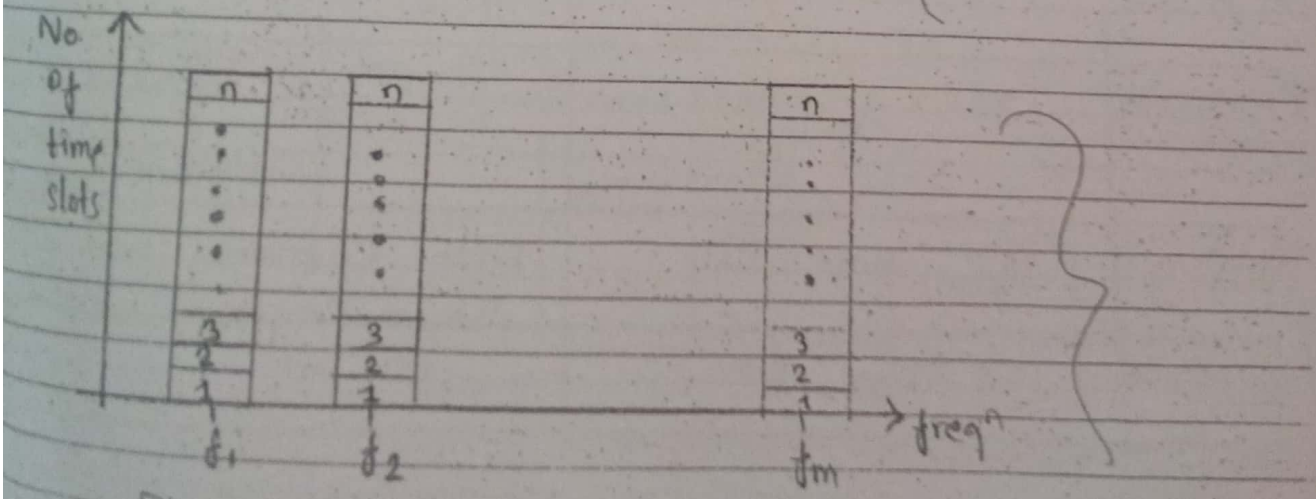
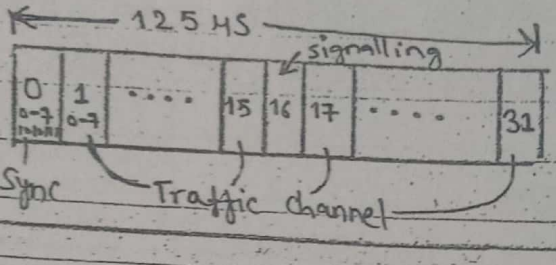
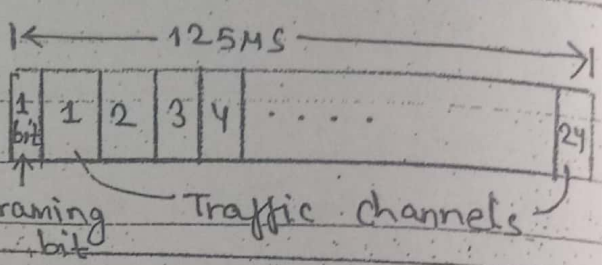


Fig : TDMA

ierarchy of Digital Service (TDM)

specification	E_1 heirarchy	T_1 heirarchy
tandard	European | ITU-T | International	American | Japanese
rame structure		
o. of time slots	32	24
o. of voice channels (traffic)	30	24
Duration of frame	125 MS	125 MS
Duration of Time slots	$\frac{125}{32} = 3.906$ MS	$\frac{125}{24 + 1/8} = 5.181$ MS
Duration of each bit	$\frac{3.906}{8} = 0.49$ MS	$\frac{5.181}{8} = 0.6477$ MS
no. of bits	$32 \times 8 = 256$	$24 \times 8 + 1 = 193$
Transmission rate.	$256 \times \frac{1}{T_s} = 256 \times 8$ KHz $= 2048$ Kbps	$193 \times \frac{1}{125 MS} = 193 \times 8$ KHz $= 1544$ Kbps
Signalling	16th time slot	First 6 frames from 8th bit of each 6th frame.
Synchronization	0th Time slot	1st bit.

SDH

Synchronous Digital Hierarchy.

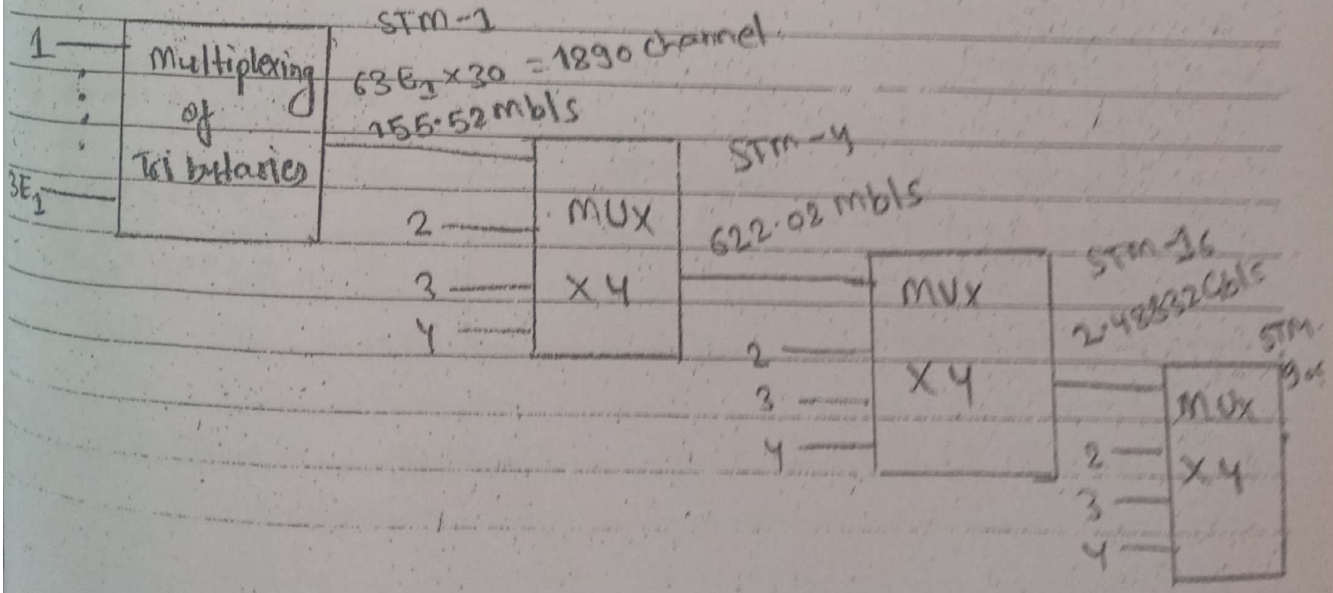
- have same reference clock.
- ITU-T standardized specification of digital data rate.

SONET

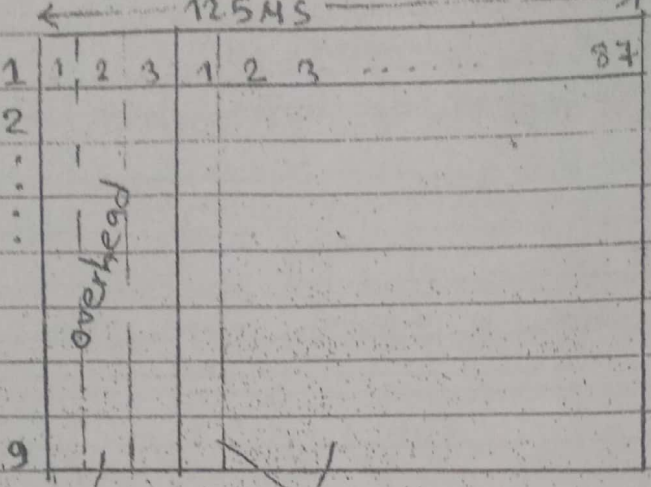
- Synchronous Optical Network.
- ANSI standardized specification of digital data rate.

SONET		SDH
STS-1	51.84 Mb/s	
STS-3	155.52 Mb/s	→ STM-1
STS-12	622.08 Mb/s	→ STM-4
STS-24	1244.16 Mb/s	
STS-48	2488.32 Mb/s	→ STM-16
STS-192	9953.28 Mb/s	→ STM-64

SDH multiplexing



• Frame format of SONET (STS)



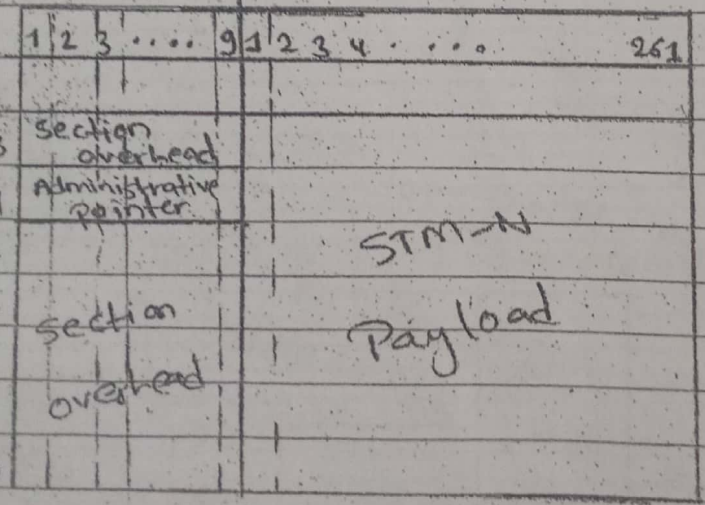
No. of bits = 90 × 9 × 8 = 6480 bits

Transmission rate = $\frac{1}{T_s}$ × No. of bit

= 8000 × 6480

= 51.84 mb/s

Frame format of STM-N



No. of bits = 270 × 9 × 8

= 19440

Tx. rate = $\frac{1}{T_s}$ × 19440

= 8000 × 19440

= 155.52 mb/s

Switching

→ For transmission of data from source to destination throug a network, the switching nodes provide a switching facility that will move the data from node to node until they reach their destination. Here, this switching not cornered with the content of the data.

→ The switching network is classified into following three types

1) Circuit Switching Networks

→ There is a dedicated communication path betⁿ two stations.

→ On each physical link, a logical channel is dedicated to the connection.

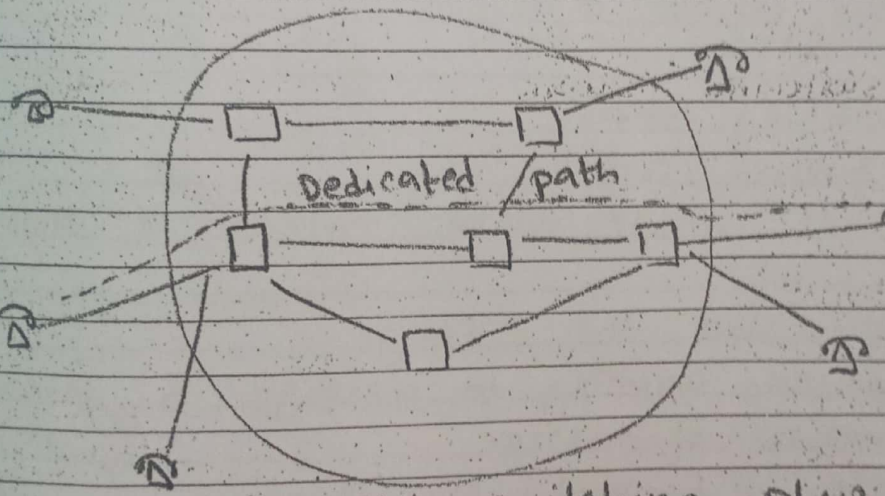


Fig: CKt switching ntw

Circuit switching involves three pases

(i) Circuit establishment : Before any signals can be transmitted, an end-to-end circuit must be established.

(ii) Data Transfer : Information is transmitted from source to Destination (e.g A to C in figure) through to network.

) Circuit disconnect :. After some period of data transfer, the connection is terminated.

Application
→ public telephone network.
→ private branch exchange (PBX)

Drawback
In circuit switching, the connection path is established before data transmission begins. Thus, channel capacity must be reserved betn each pair of nodes in the path & each node must have internal switching capacity to handle the request connection.

) Message switching network
→ Store & forward concept.
→ Each node has storage device, procesor & communication system.
→ storage device store the message.
→ procesor procss according to message & determine the destination of message
→ comm^n system forward the message to correct destination.

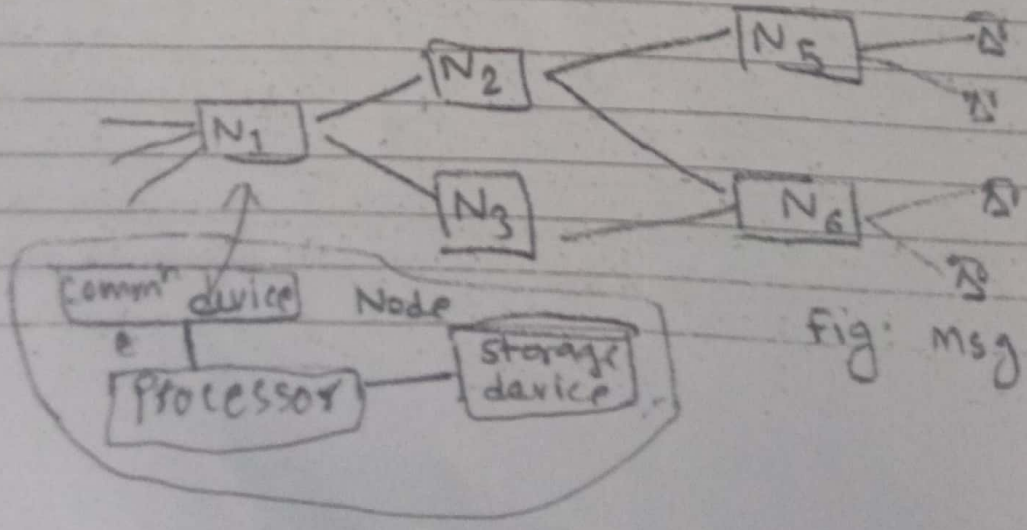


Fig: Msg. switching n

3) Packet switching network

→ Packet switching was designed to provide a more efficient facility than circuit switching for bursty data traffic.

→ In packet switching, a station transmits data in small blocks, called packets. Each packet contains some portion of the user data plus control information needed for proper functioning of the network.

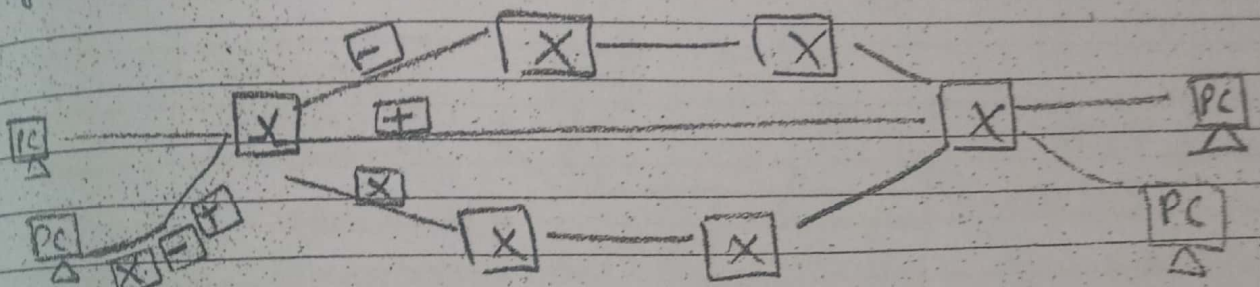


Fig: Packet switching n/w

Packet switching

↓ Datagram approach

- Each packet is treated independently, with no reference to packets that have gone before.
- Each packet contains complete control information & data.

↓ Virtual ckt approach

→ Here, a preplanned route is established before any packets are sent. Once the route established, all packets should follow this same route through the n/w betn stations.

→ Each packet contains a virtual circuit identifier as well as data.

Private Branch Exchange (PBX)

→ It is used to interconnect telephones within a building or office.

→ The main purpose of a PBX is to save the cost of requiring a line for each user to the telephone company's central office.

→ is owned & operated privately. (i.e enterprise rather than telephone company)

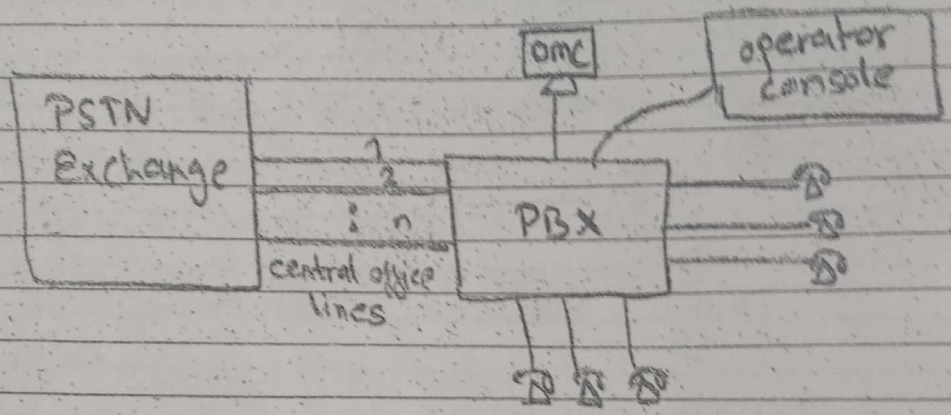


Fig : PBX

PBX includes

→ Multiple phone lines (Telephone trunk) that terminate at the PBX.

→ omc (operation & maintenence Computer): A computer with memory that manages the switching of the calls within the PBX & in & out of it.

→ The network of lines within the PBX.

→ An operator console or switchboard for a human operato