Multiplexing ✓ 1-M

Multiplexing:

If we have no. of xmitting sources ~~then multiplexing~~ and a large xmission capacity (channel of wide b.W.) then multiplexing ~~is used~~ allows several xmission sources to share a larger xmission capacity.

In multiplexing low b.W. or data rate signals are combined to form a single high b.w. or large data rate signal.

Three methods of multiplexing:

1. Frequency division multiplexing (FDM)
2. Time division multiplexing (TDM)
3. Statistical time division multiplexing (STDM)
4. Code division multiplexing.

FDM: Can be used with analog signals (If digital signal pass it through MODEM)

No. of signals are carried simultaneously on the same medium by allocating each signal a diff. frequency band.

Modulation/equipment is required to take each signal to a particular freq. band.

Multiplexing/Multiplexing equipment is reqd. to combine the modulated signals.

Common application of multiplexing:

In long haul Comm. Trunks on long haul comm. are fiber, coaxial, μ-wave links → The links can carry large voice & data simultaneously without interference to each other

2'-M

* If the signals overlap, orginal signal will be difficult to recover.
* The composite signal may be shifted as a whole to another carrier frequency by an additional modulation step. The second modulation method may or may not be different; depending on transmission medium

Scanned with CamScanner

TDM

3-M

Each signal is allowed to use all the b.w. only for a part of time.

Hartley's law:

$$I = ktB$$

I = Quantity of information to be xmitted
k = Depends on ~~ges~~ type of modulation & S/N of channel
t = Time available
B = Channel BW.

Eqn. shows that time & BW. are equal

At least theortically, A comm. medium can be shared by dividing either quantity BW. or Time among users.

Freq. spectrum can be divided and part of it allocated to diff. users on full time basis; in FDM/FDMA.

Whole spectrum can be allocated to a user for part of time as in TDM/TDMA.

∴ Each signal is allowed to use all BW. only for a part of time.

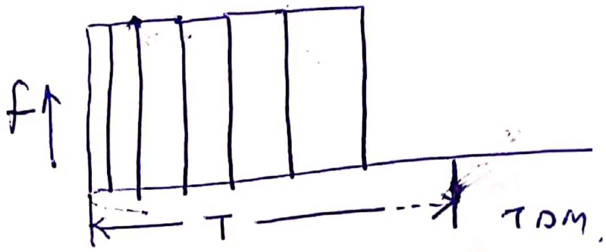
[FDM simpler when applied to cables. ~~These~~ Here the signals are generally under the control of one organization and these can be adjusted easily in freq & power level to minimize interference. (Tele cables, cable T.V. etc.)]

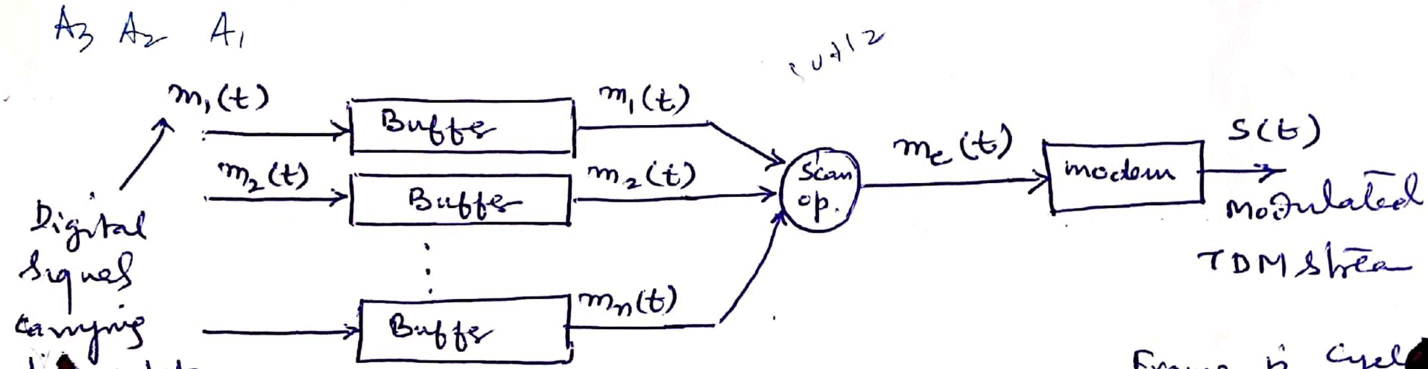
Continously varying signals (analog, audio) are suitable for TDM; Since the signal is present all the time; Sampled audio is suitable & it is possible to xmit one sample from each of the several sources sequentially, then send next sample from each source & so on. Continously varying signals need ~~*~~ mod. for making digital

TDM2 Synchronous Time-Division Multiplexing 4-M

* STDM is possible when the acheivable D.R. of medium exceeds the data rate of signals to be xmitted.
* Multiple digital Signals (or analog Signals carrying digital data) can be carried on a Single xmission path by interleaving portions of each Signal in time.
* Interleaving can be at bit level or blocks of bytes or lager quantities.

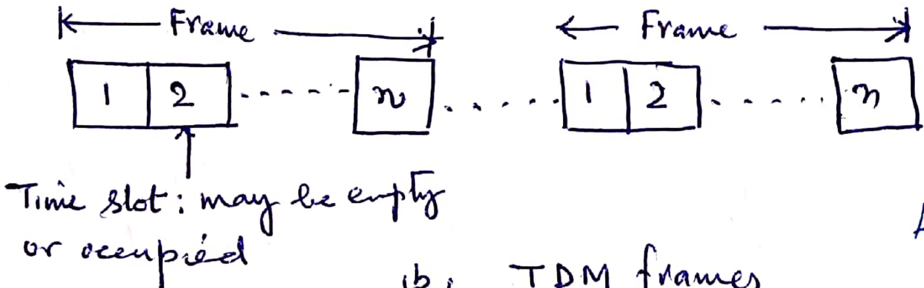
If there are 6 inputs of 9.6 kbps; A Single line (with a capacity of 9.6×6 + over head capacity) could accomodate all six sources.



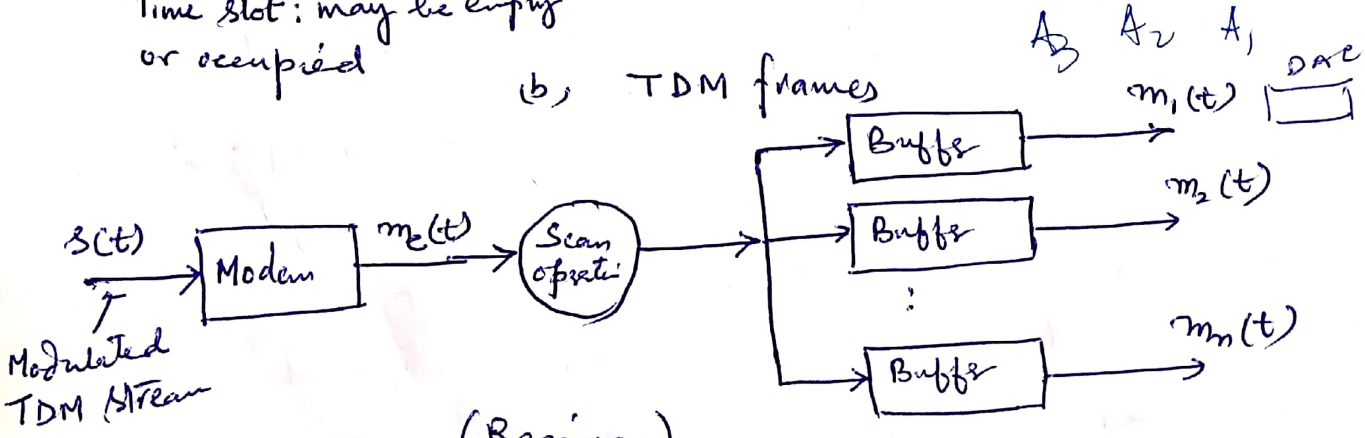


(a) Transmitter

Frame is cycle of time slots



(b) TDM frames



(Receiver)

Scanned with CamScanner

~~TDM~~ 5-M

* At receiver, the interleved data are demultiplexed and routed to appropriate destination buffer.
* For each input source $m_i(t)$ there is an identical output source that will receive the input data at same rate at which it was generated.
* Synchronous TDM is called synchronous because of the ~~preassigned~~ time slots are preassigned to source and fixed.
* Time slots are xmitted, weather or not source has data to send.

  This is so with FDM as well. In both cases the capacity is wasted to acheive simplicity of implementation.
* Even when fixed assignment is used, however, it is possible for a synchronous TDM device to handle soures ~~at~~ of different data rates.
* eg. Slowest input device could be assigned one slot per cycle.

  Faster devices are assigned multiple slots per cycle.

~~TDM~~ 6-M

number of signal [$m_i(t)$, $i = 1, n$] are to be multiplexed

* on to the same transmission medium.

* The digital data are briefly buffed. (Buffer of 1 bit or 1 char in length).

* Buffers are scanned sequentially to form composite digital data stream $m_c(t)$. Scan operation is rapid, so that buffer is emptied before more data can arrive.

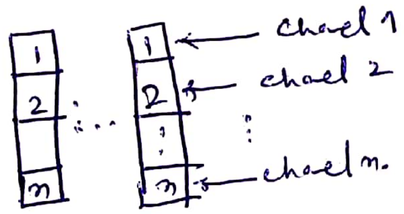
Thus $m_c(t) \geq \sum_{i=1}^{n} m_i(t)$

* $m_c(t)$ can be xmitted directly or through MODEM so that analog signal is xmitted.

(In either case transmission is synchronous)

* In each frame one or ~~two~~ more slot is dedicated to each data source

The sequence of slots from frame to frame constitute a channel.



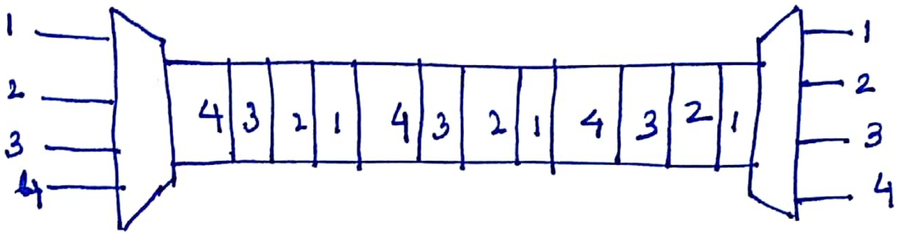
Slot length ≡ Transmitter buffer length ≡ bit or character

* Character interleaving is used with asynchronous sources. Each time slot contains one character of data. Typically, start stop bits are eliminated before xmission and reinserted by the receiver, thus improving efficiency.

At receiver, interleaved data are demultiplexed and routed to the appropriate destination buffer.

STDM (continued)

~~Thus~~ STDM is a digital process that allows several conections to share the high band width link. Each time occupies a portion of tie in the link.



Conceptual view of TDM.

Note that same link can be used in FDM. In FDM howevr, freq. has to be shared. Here, howeve, the link is sectioned by time rather than frequency. Here we are conected with multiplexing and not switching. This means that data from source 1 gos to 1. Simlarly 2-2; 3-3; 4-4. The delivery is fixed unlike switching.

Time slots & frames.

In STDM, The data flow of each input unit is divided in units, whee each input occupies one input tie slot. A unit can be 1 bit, 1 characte or 1 block of data. Each input unit becoms one output unit and occupis one o.p tie slot. Howeve, the duration of an o.p. tie slot is n tis shorte than duration of an input tie slot.
e.g. Input tie slot is T sec; o.p. tie slot is T/n.

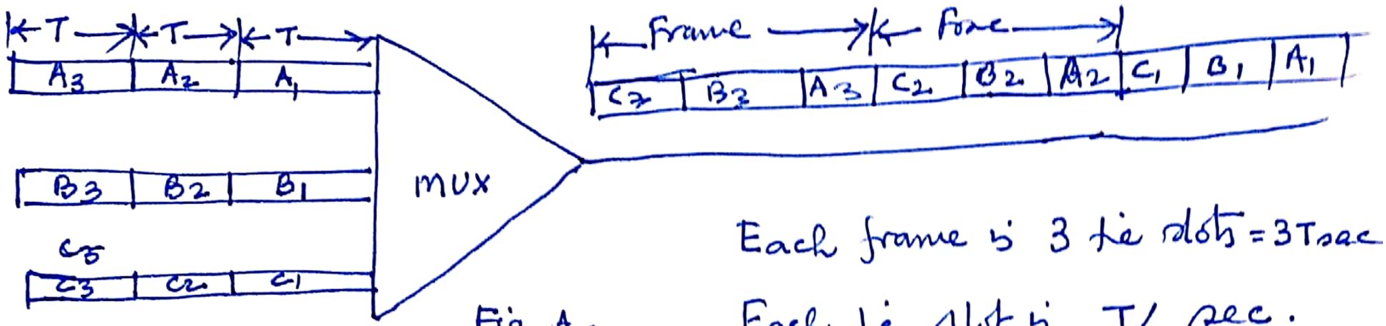


Fig. A.

Each frame is 3 time slots = 3T sec

Each time slot is T/3 sec.

Data is taken from each line every T sec.

So if you want a particular data rate per connection; you will have to provide link having data rate equal to ~~Sum~~ Sum of data rates of individual connections.

Thus in STDM, data rate of link is n times faster and unit duration is n-times shorter.

Example In Fig-A., the data rate for each input connection is 1 kbps. If 1 bit at a time is multiplexed What is duration of: (a) Each input slot (b) Each o.p. slot & (c) Each frame.

a: The data rate of each input connection is 1 kbps

∴ Bit duration is 1/1000 sec or 1 ms;

Duration of input time slot is 1 ms (same as bit duration)

(b) Duration of each o.p. time slot is 1/3 of input time slot

∴ Duration of o.p. slot is 1/3 ms

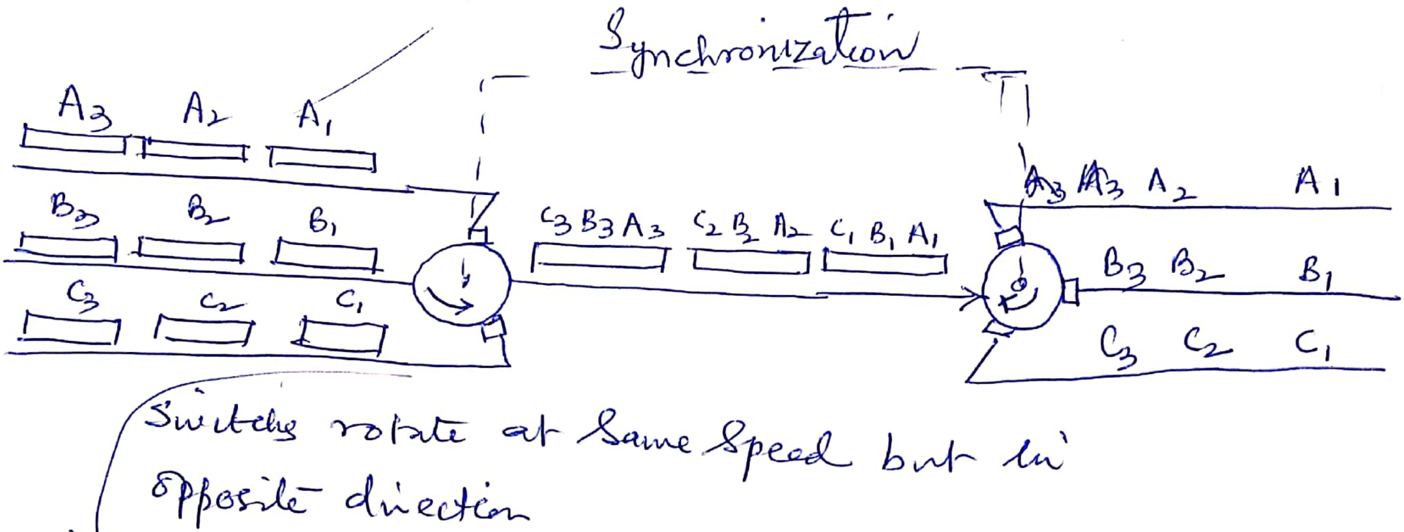
(c) Each frame is 3 o.p. time slots. Therefore duration of frame is 3 × 1/3 ms. = 1 ms

Thus duration of frame is same as duration of an input unit

Interleving

9-M

TDM can be visualized as two fast rotating Switches One on MUX Side and other on Demux Side Switches Synchronized to rotate at Same Speed



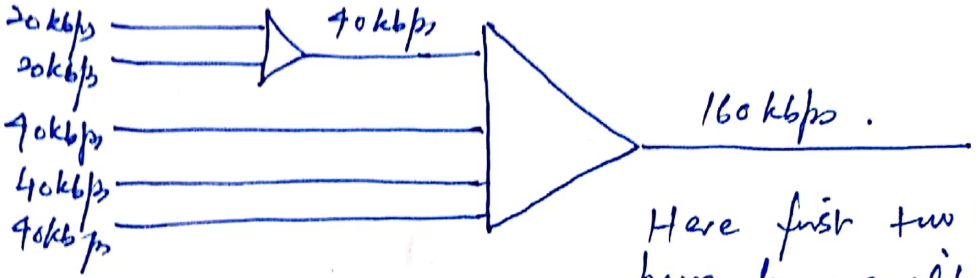
On MUX Side one Switch opens the unit Say A, B, C goes on to path. The process is called Interleving (one element of each data is interleved)

One Demux Side Switch opens in front of connection and connection has an opportunity to receive a unit from the path

Data rate management.

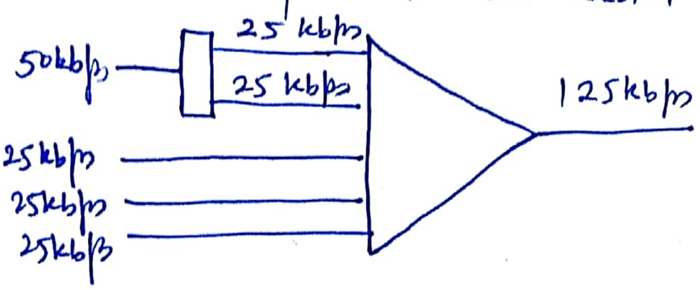
So far we assumed that data rates of all input lines are same. However, the data rates of all input lines may not be same. To handle this disparity, three strategies or combinations can be used.

1. Multilevel Multiplexing:
   This technique is used when data rate of input line is multiple of others.



Here first two inputs of 20 kbps have been multiplexed to provide d.r. equal to other three.

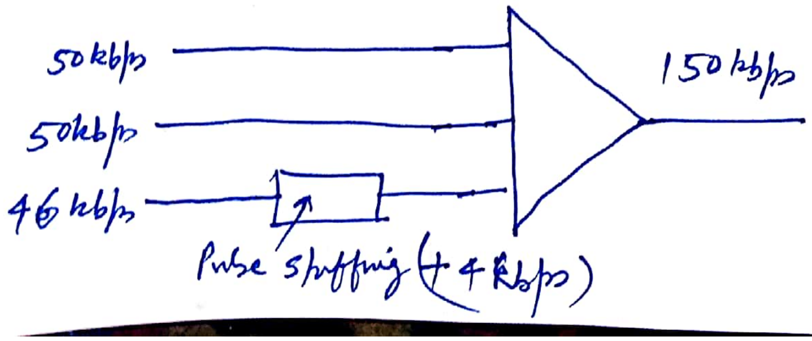
2. Multiple Slot allocation.



Here input with 50 kbps can be given two t.s slots. All others ons 1 t.s slot.

3. Pulse Stuffing

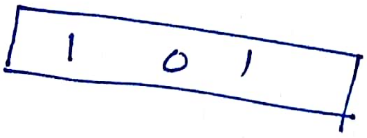
Some t.s bit rates of Sources are not multiple integers of each other. One soln. is to make highest input data rate dominant then add dummy bits to input lines with lower data rates; to increase their rates.



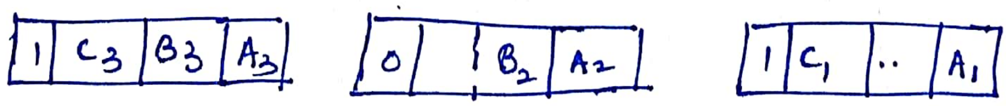
Frame Synchronization:

In implementing STDM, synchronization is important between multiplexer & demultiplexer & an issue. If synchronization is not proper, a bit belonging to one chanel may be recevied by wrong chanel. Therefore, one or more Synchronization bits are usually added to begining of each frame. The bits ~~are~~ called framing bits, follow a pattern ~~frame~~ from frame to frame, that allows demultiplexer to Synchronize with incoming stream so that it is able to separate the slots accurately.

In most case, this synchronization information consists of 1-bit frame, alternating between 0 and 1 as shown in fig



Synchronization pattern.

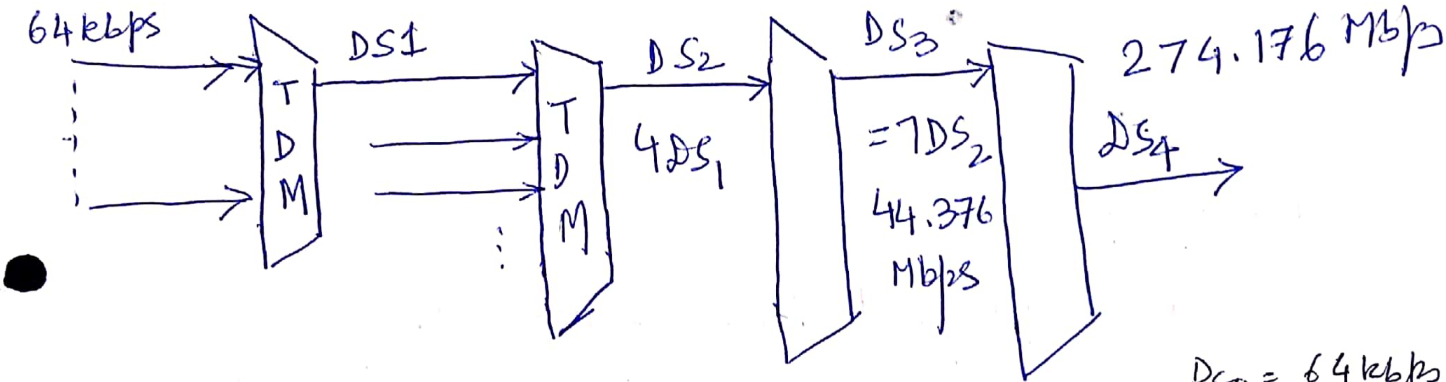


Frame: 3 Frame 2 Frame 1

Digital Signal Service :

No. of standards of TDM hierarchy

Telephone companies implement TDM through a hierarchy of digital signals called Digital Signal (DS) service or digital hierarchy



DS0 = 64 kbps.

DS1 = 24 × DS0 = 24 × 64 kbps = 1.544 Mbps

(This includes 8 bits of over head)

DS2 = 6.312 Mbps = 4 DS1

or 96 DS0

~~1.536~~

(This includes over head of 168 kbps)

DS3 = 672 DS0 channels

DS4 = 4032 DS0 channels.

A channel is sampled at 8 KHZ with 8 bits/sample Find B.R.

8 K × 8 = 64 Kbps.

DS0, DS1, DS2 ... DS4 are names of Services

T- lines :

To implement these services telephone companies use T- lines (T-1 to T-4)

Services	Line	Rate (Mbps)	Voice chanels
DS-1	T-1	1.544	24
DS-2	T-2	6.312	96
DS-3	T-3	44.736	672
DS-4	T-4	274.176	4032

Voice signals can be xmitted over high capacity x-mission links, eg., optical fiber, co-axial cables or μ-wave etc.

As clear from table, DS0 is not offered as a service, but it has been defined as a basis for ref. purpose.

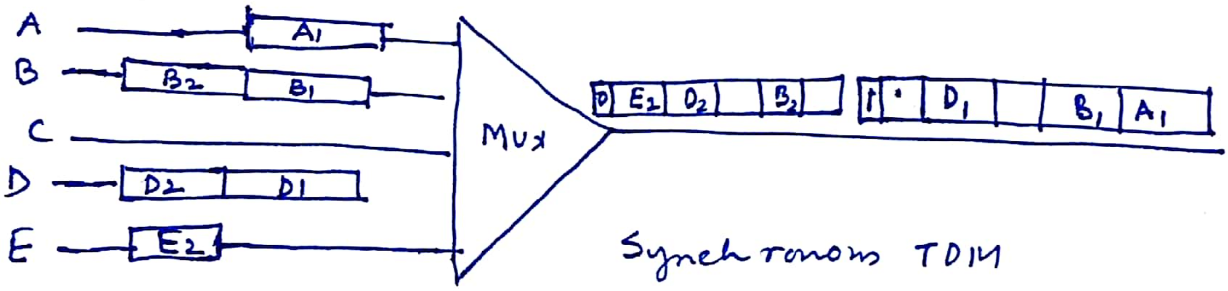
T-1 to T-3 lines are commercially available.

Statistical TDM.

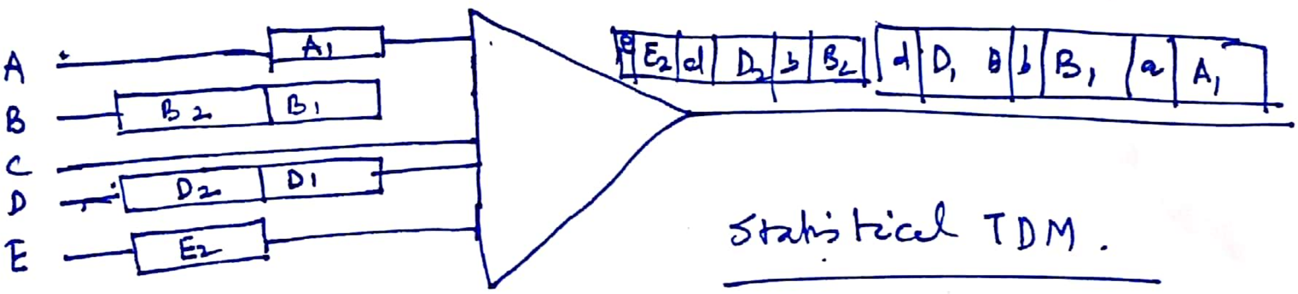
In STDM we ~~says~~ saw, that each input has a reserved slot in the output frame. This can be inefficient if some input lines have no data to send. In statistical TDM, slots are dynamically alloted to improve band width efficiency.

Only when an input line has a slots worth of data to send it is given a slot in output frame. Therefore in Statistical TDM, no. of slots in each frame is less than the no. of input lines.

The multiplexer checks each input line in round robin fashion; it allocates a slot for an input line if the line has data to send; otherwise it skips the line and checks next line.



Synchronous TDM



Statistical TDM.

In STDM, obviously, the time slots corresponding to no. data are wasted. In Statistical TDM, however, slots are allocated to different sources on demand

In STDM corresponding n I/O lines; we require n time slots. In Statistical TDM corresponding to n I/O lines, we only require k time slots where k ≤ n.

~~In other words~~ Thus statistical ~~MUX~~ multiplexer can use lower data rate to support as many devices as synchronous multiplexer or in other words

If ~~same~~ a link is used with a particular data rate, statistical multiplexer can support more devices than synchronous multiplexer

Addressing:

In synchronous multiplexer there is no need of addressing; synchronization and preassigned relationships between inputs and outputs serve as address; e.g. input 1 goes to output 1. This is guaranteed, if multiplexer and demultiplexer are synchronized.

In statistical multiplexer, there is no fixed relationship between I/P & O/P because there are no preassigned time slots. Therefore, we need to include address of the receiver inside each slot to show where it is to be delivered. ~~For~~ addressing 'n' bits can be used to define N diff. O/P lines with $n = \log_2 N$.

Slot Size & Synchronization

Since slot carries both data and address in Statistical TDM, the ratio of data size to address size must be reasonable to make transmission efficient.
e.g; it would be inefficient to send 1 bit per slot when address is 3 bits. This is 300% overhead.
In Statistical TDM, a block of data is usually many bytes ~~to accomodate~~ for address to be less no of bytes.

Moreover, frames in Statistical TDM need not be synchronized. Therefore, no need of synchronization bits.

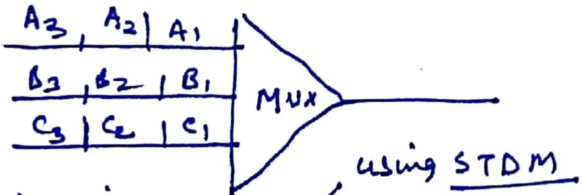
Bandwidth

In statistical TDM, the capacity of link is usually less than capacities of each channel. Therefore, designers of Statistical TDM define the capacity of the link based on the statistics of load on each channel. Of course, during peak time some slots will have to wait.

AH Mir

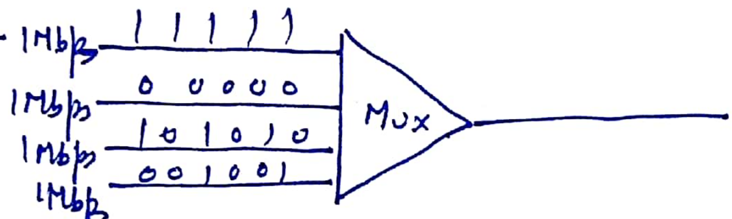
T- Sheet (M) 17-M

Q 1



In Fig given above, data rate of each input conection is 3 kbps. If 1 bit at a time is multiplexed, what is duration of: (a) each input slot (b) each o.p. slot and (c) Each frame. (1 ms. ; 1/3 ms ; 1 ms.)

Q 2



The given fig shows STDM with data stream for each input and one data stream for o.p. The unit of data is 1 bit. Find (a) I/p bit duration, (b) o.p. bit duration (c) o.p. bit rate and (d) o.p. frame rate.

(1 μs, 1/4 μs, Mbps, 1 μs)

Q3 Four 1 kbps conection are multiplexed together. A unit is 1 bit. Find (a) duration of 1 bit before multiplexing (b) Transmission rate of the link (c) Duration of time slot and (d) Duration of frame.

(1 ms, 4 kbps, 250 μs, 1 ms)

Q. 4 Two chanels with a bit rate of 100 kbps and another with a bit rate of 200 kbps are to be multiplexed. How this can be acheived? What is frame rate? What is frame duration and What is bit rate of the link.