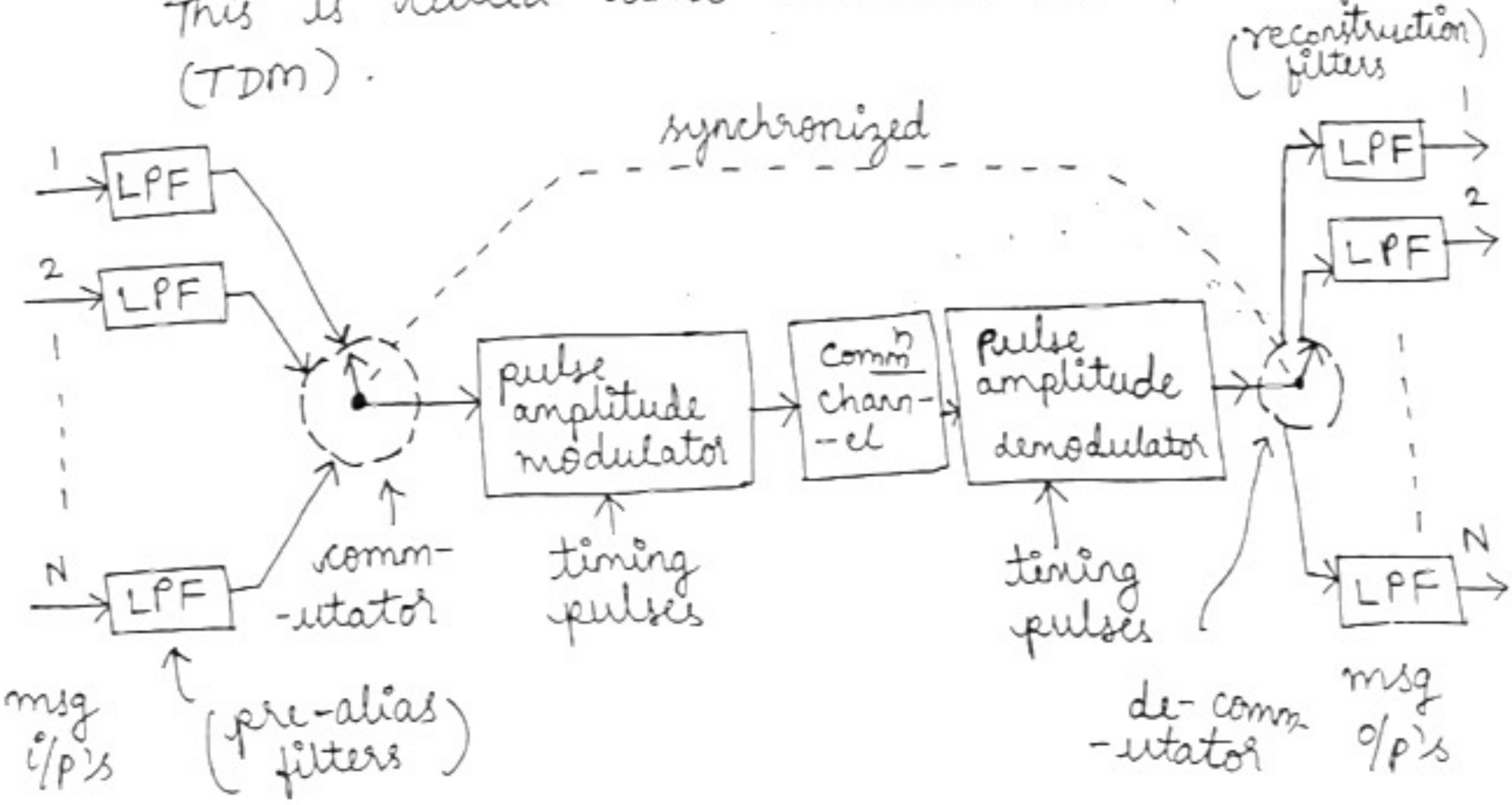
Time division multiplexing (TDM) -

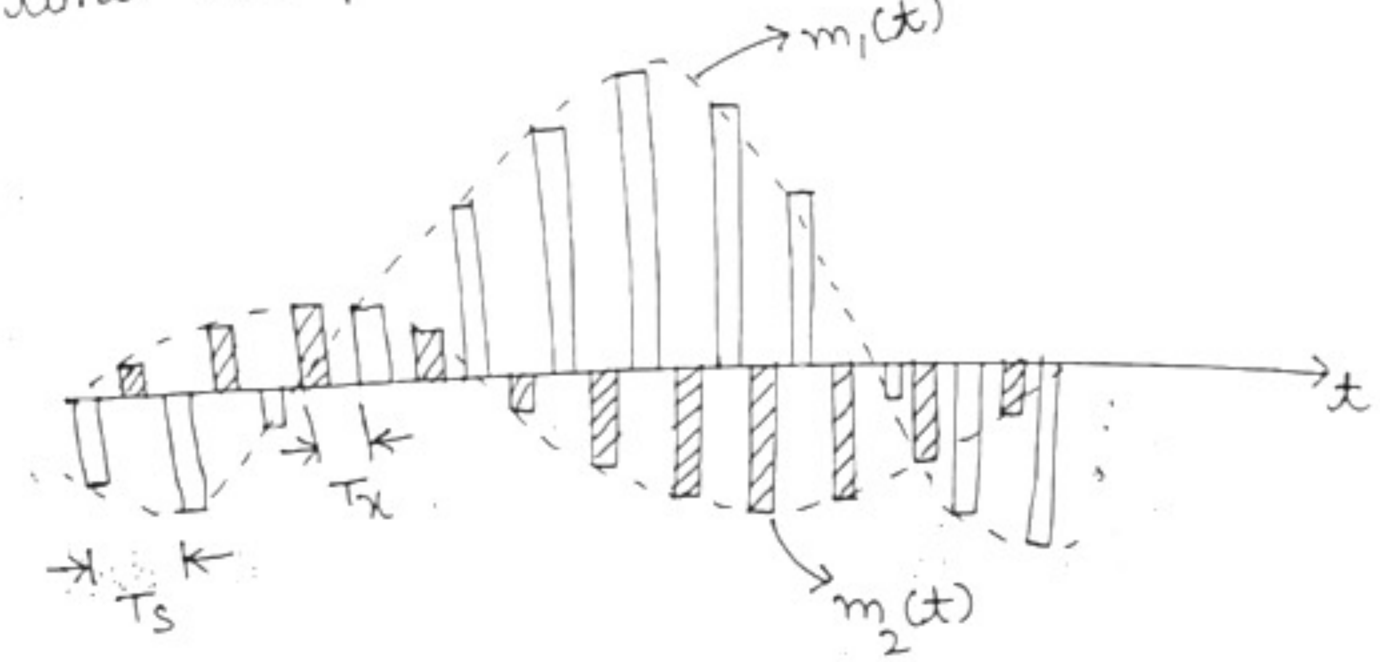
An important feature of PAM is a conservation of time. when PAM waves are transmitted on a communication channel, it engages the channel for only a fraction of the sampling interval on a periodic basis. Hence some of the time interval between adjacent pulses of the PAM wave is cleared for use by other independent msg signals on a time-shared basis. This is called time-division multiplex system (TDM).



Each i/p msg signal is first restricted in bandwidth by a low-pass pre-alias filter to remove the frequencies that are non-essential to an adequate signal representation. The prealias filter o/p's are then applied to a commutator, whose functions are to take a narrow sample of each of N input messages at a rate f_s that is sligthly higher than $2f_m$, where f_m is cutoff frequency of pre-alias filter & to sequentially interleave these N samples inside a sampling interval $T_s = 1/f_s$. This multiplexed signal is applied to a pulse amplitude modulator (PAM) to transform the multiplexed signal into a form suitable for transmission over the communication channel.

multiplexed ... the communication ...
transmission over the communication ...

If N msgs are to be multiplexed, sampling rate for each msg signal is determined according to sampling theorem.
Let 'T_s' be the sampling period & 'T_x' be the time spacing b/w adjacent samples in the time multiplexed signal as shown below -



$\therefore$ we can write

$$T_x = \frac{T_s}{N}$$

ie $T_s = N T_x$

$$\boxed{N = \frac{T_s}{T_x}}$$

$\therefore$ TDM introduces a bandwidth expansion factor N, because the shceme must squeze N samples derived from N msg signals into a time slot equal to one sampling interval (T_s).
At receiver the received signal is applied to pulse amplitude demodulator which performs reverse operation of PAM. The short pulses produced at demodulator o/p is distributed to the appropriate low-pass reconstruction filters by means of a decommutator, which operates in synchronisation with the commutator in the transmitter side.

spacing b/w two samples $= T_x = \left(\frac{T_s}{N}\right)$

nos of pulses per second $= \left(\frac{1}{T_x}\right)$

$$\left(\begin{matrix}\text{nos of pulses} \\ \text{per second}\end{matrix}\right) = \frac{N}{T_s}$$

$$\boxed{\left(\begin{matrix}\text{signalling} \\ \text{rate}\end{matrix}\right) = \left(\begin{matrix}\text{nos of pulses} \\ \text{per second}\end{matrix}\right) = N f_s}$$

WKT $f_s \geq 2 f_m$

$\therefore$ signalling rate $(r) \geq 2 N f_m$

Transmission Bandwidth $B_T = \frac{\text{signalling rate}}{2} = \frac{r}{2}$

$$B_T = \frac{N f_s}{2}$$