CS311: DATA COMMUNICATION

Multiplexing

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Outline of the Lecture

- What is Multiplexing and why is it used ?
- Basic concepts of Multiplexing
- Types of Multiplexing:
  - Frequency Division Multiplexing (FDM)
  - Wavelength Division Multiplexing (WDM)
  - Time Division Multiplexing (TDM)
    - Synchronous
    - Asynchronous
  - Inverse TDM

Introduction

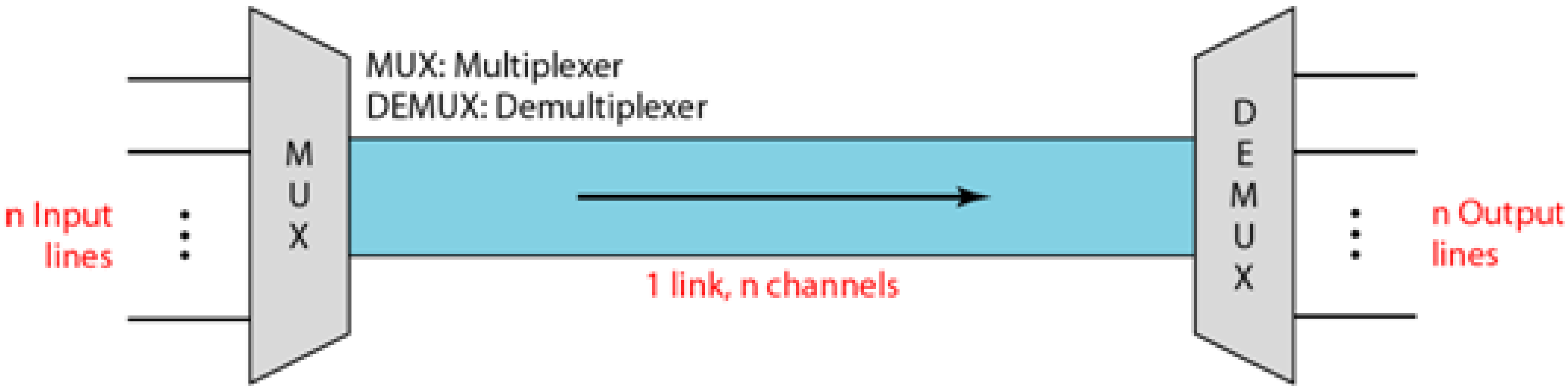
- To make efficient use of high-speed tele-communications lines, some form of multiplexing is used. **Multiplexing allows several transmission sources to share a larger transmission capacity.**
- Most individual data communicating devices typically require modest data rate and the media usually has much higher bandwidth.
- Two communicating stations do not utilize the full capacity of a data link.
- The higher the data rate, the most cost effective is the transmission facility.

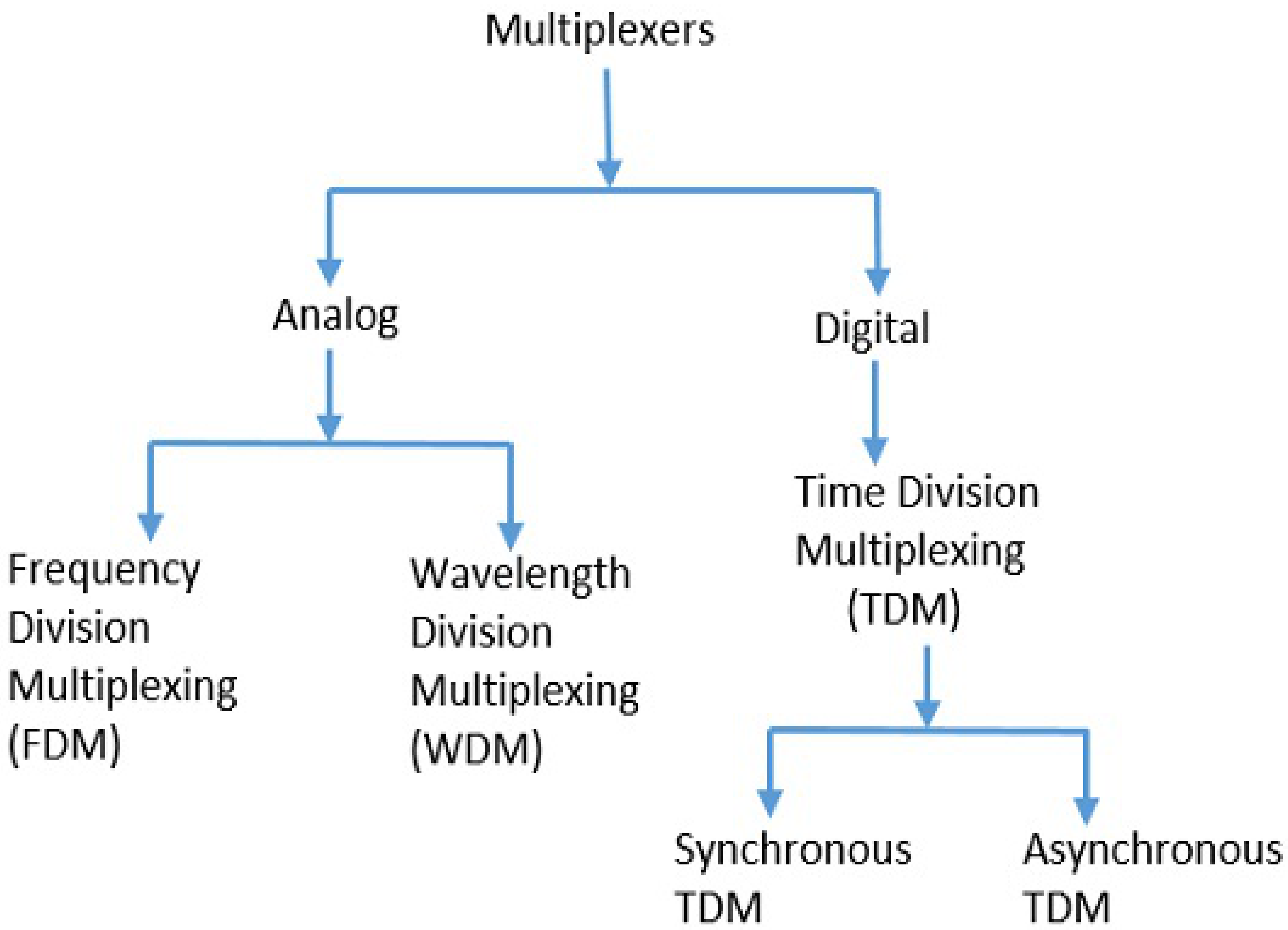
Introduction

- When the bandwidth of a medium is greater than individual signals to be transmitted through the channel, a medium can be shared by more than one channel of signals by using Multiplexing.
- For efficiency, the channel capacity can be shared among a number of communicating stations.
- Most common use of multiplexing is in long-haul communication using coaxial cable, microwave and optical fibre.

Basic Concept

- A device known as Multiplexer (MUX) combines ‘n’ channels for transmission through a single medium or link.
- At the other end a De-multiplexer (DEMUX) is used to separate out the ‘n’ channels.




Multiplexers
Analog
Digital
Frequency Division Multiplexing (FDM)
Wavelength Division Multiplexing (WDM)
Time Division Multiplexing (TDM)
Synchronous TDM
Asynchronous TDM

Two Basic Approaches

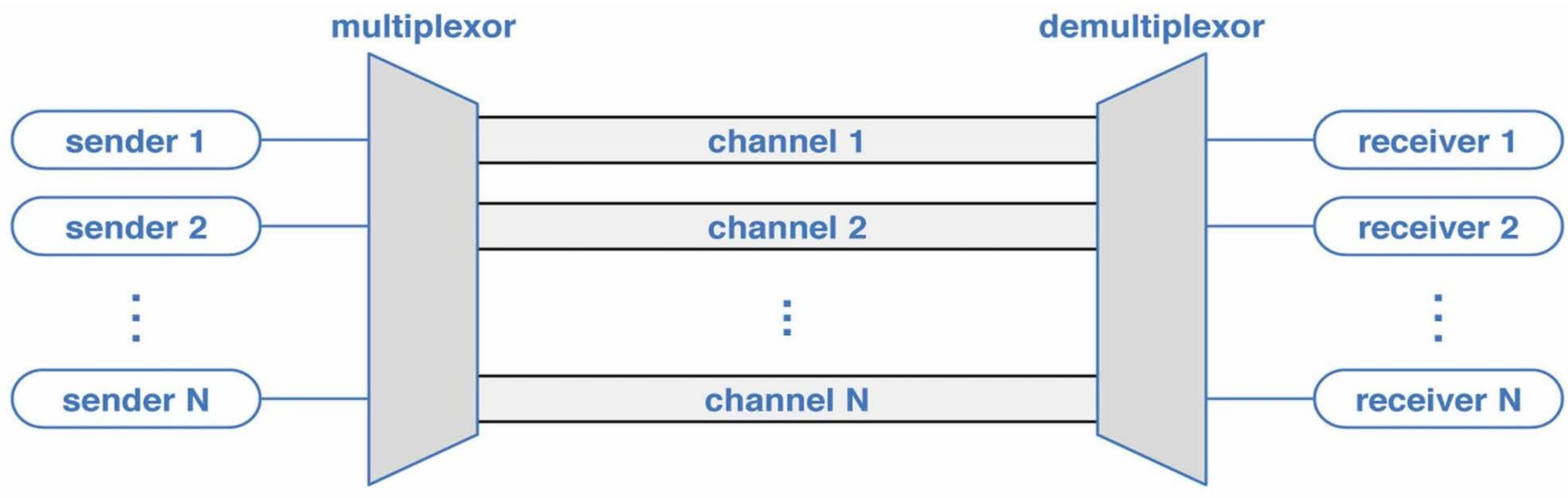
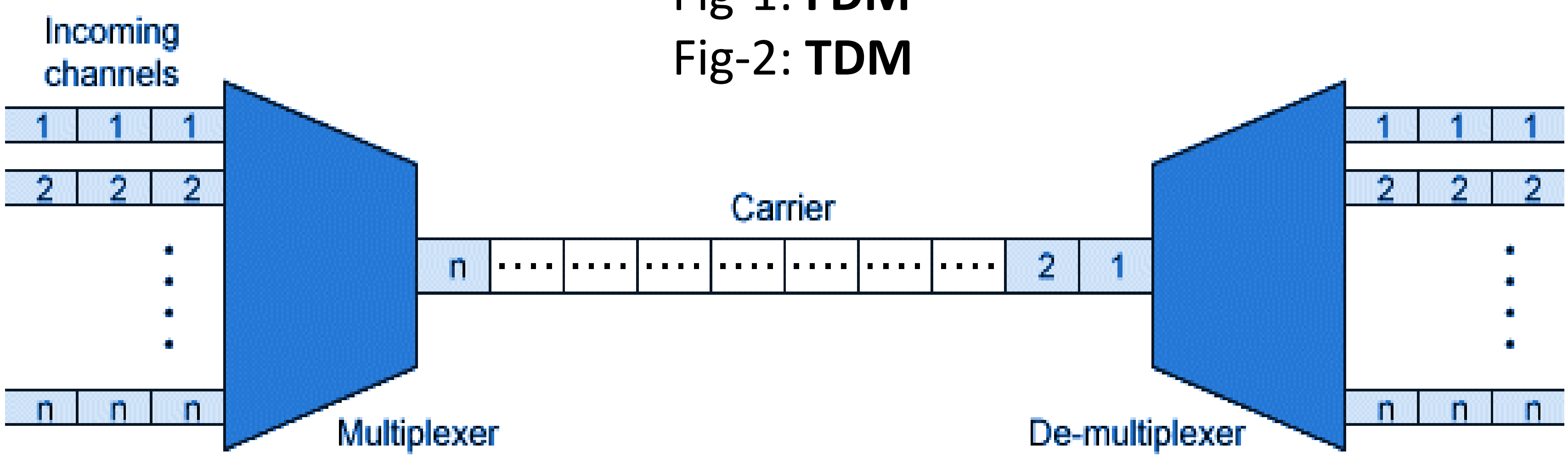


Fig-1: **FDM**

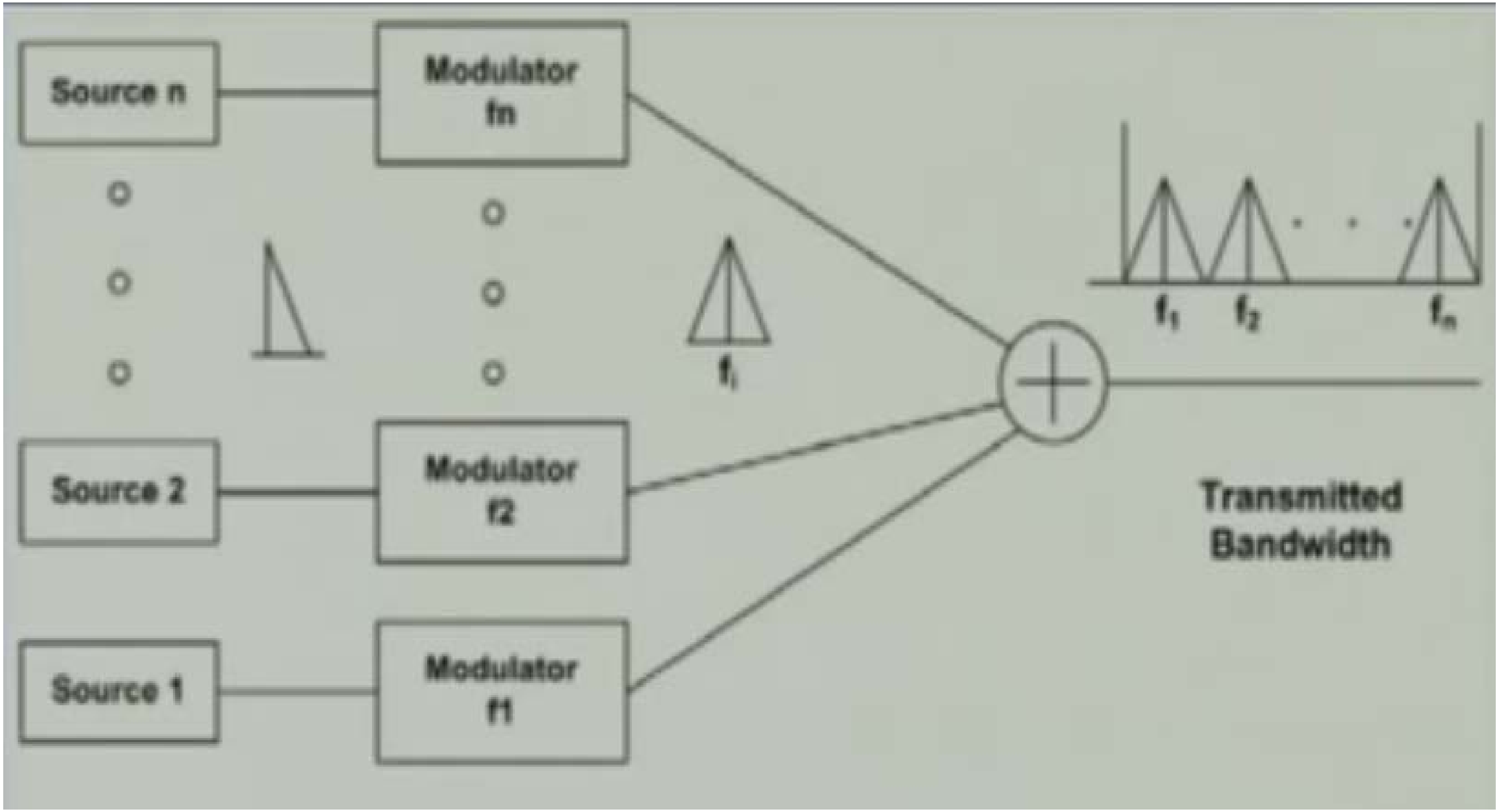
Fig-2: **TDM**



Frequency Division Multiplexing

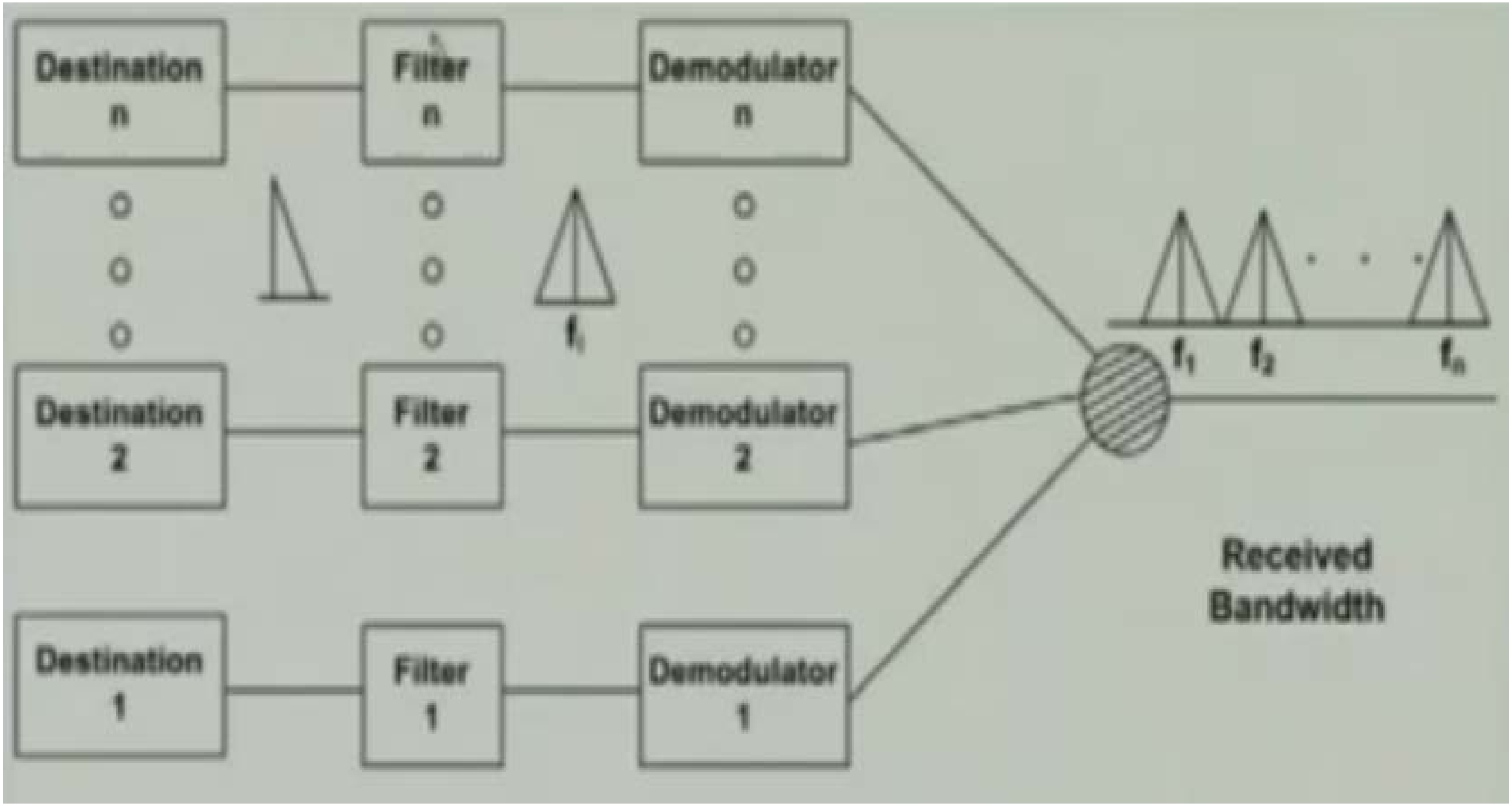
- **FDM** can be used with analog signals. A number of signals are carried simultaneously on the same medium by allocating to each signal a different frequency band.
- **FDM is possible when the useful bandwidth of the transmission medium exceeds the required bandwidth of signals to be transmitted**.
- A number of signals can be carried simultaneously if each signal is modulated onto a different carrier frequency and the carrier frequencies are sufficiently separated that the bandwidths of the signals do not significantly overlap.

Frequency Division Multiplexing



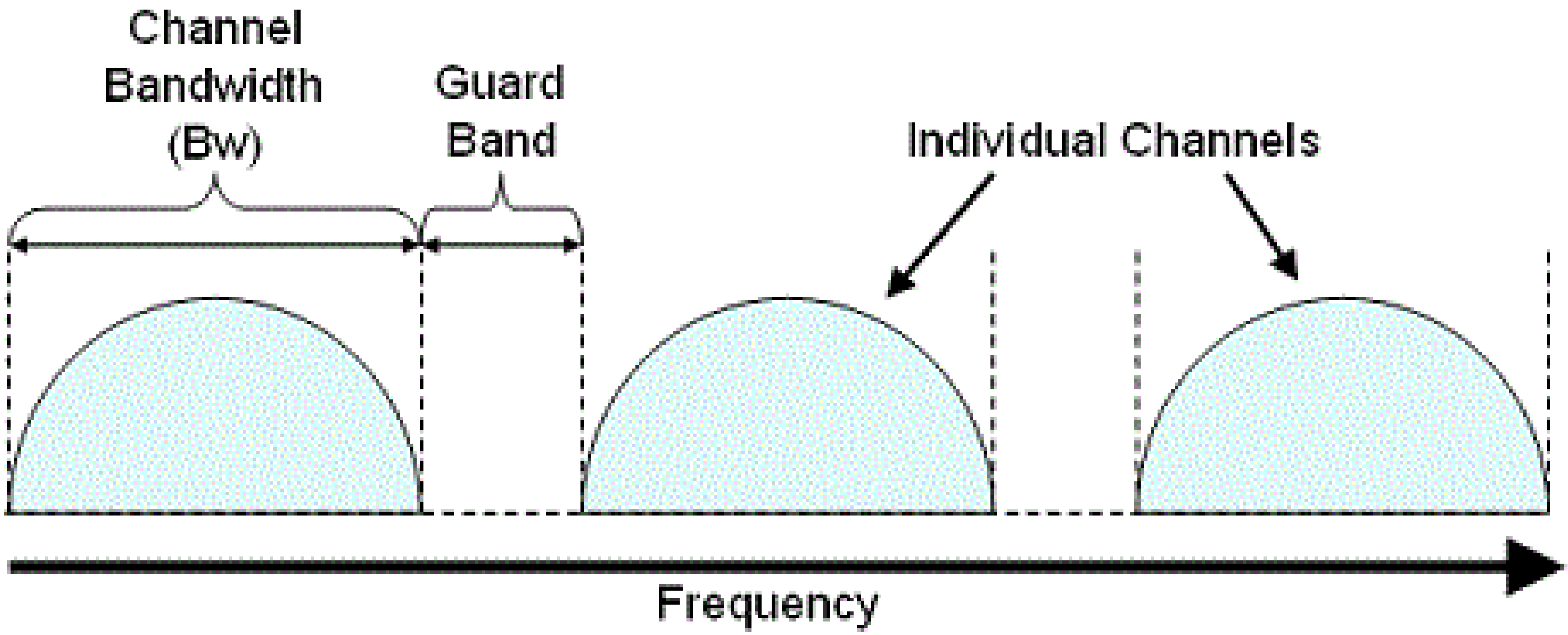
FDM Multiplexing Process

Frequency Division Multiplexing



FDM De-Multiplexing Process

Frequency Division Multiplexing



- A **Guard-Band** is a narrow **frequency** range that separates two ranges of wider frequency.
- This ensures that simultaneously used communication channels do not experience interference or cross-talk, which would result in decreased quality for both transmissions.

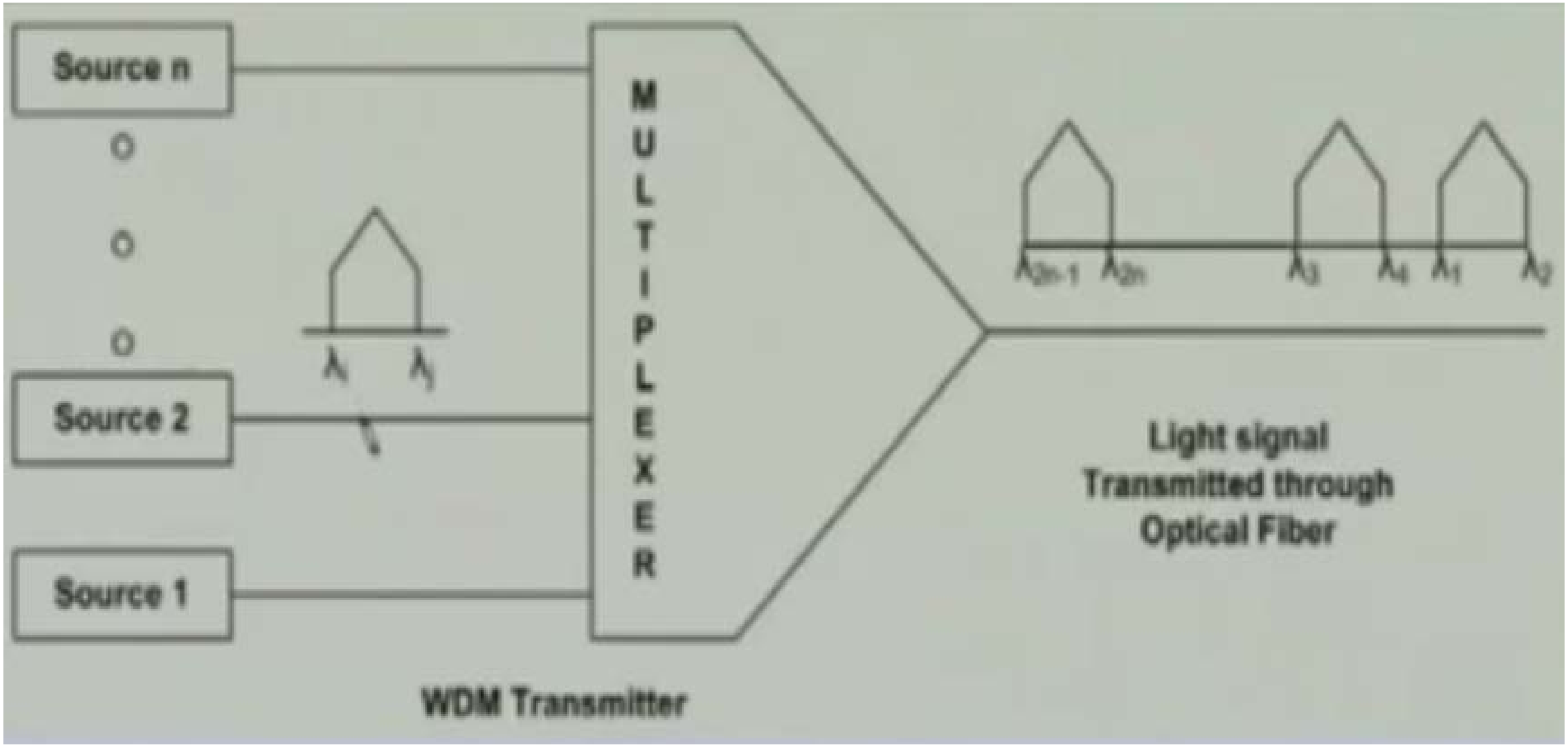
Applications of FDM

- Transmission of AM/FM Radio broadcasting
- TV broadcasting
- Cable television

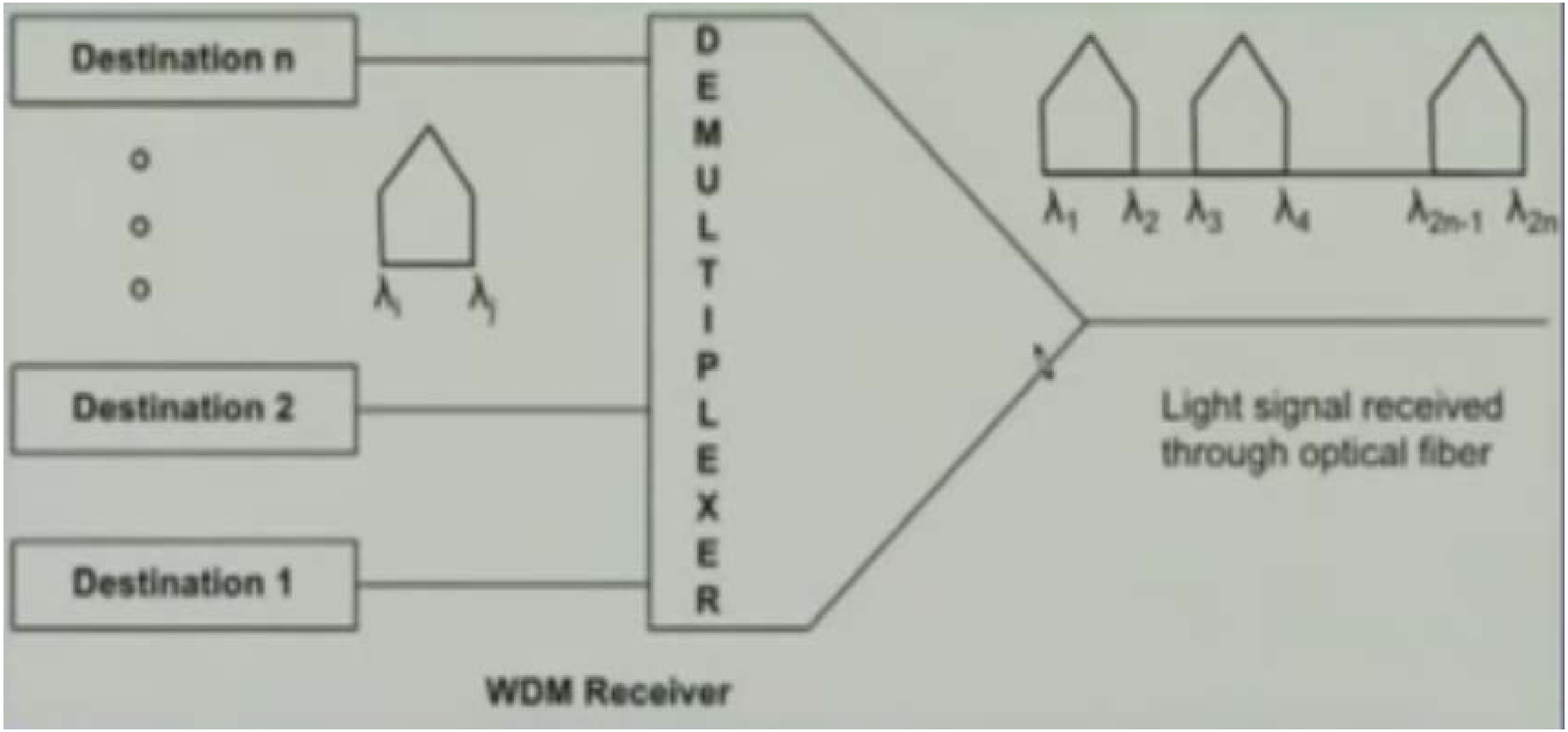
Wavelength Division Multiplexing

- Optical fiber medium provides enormous bandwidth.
- WDM is the most viable technology that overcomes the huge opto-electronic bandwidth mismatch.
- WDM optical fiber network comprises optical wavelength switches/routers interconnected by point-to-point fiber links.
- End users may communicate with each other through all-optical (WDM) channels known as ***Light-paths***, which may span over more than one fiber links.

Wavelength Division Multiplexing



Wavelength Division Multiplexing



Time Division Multiplexing

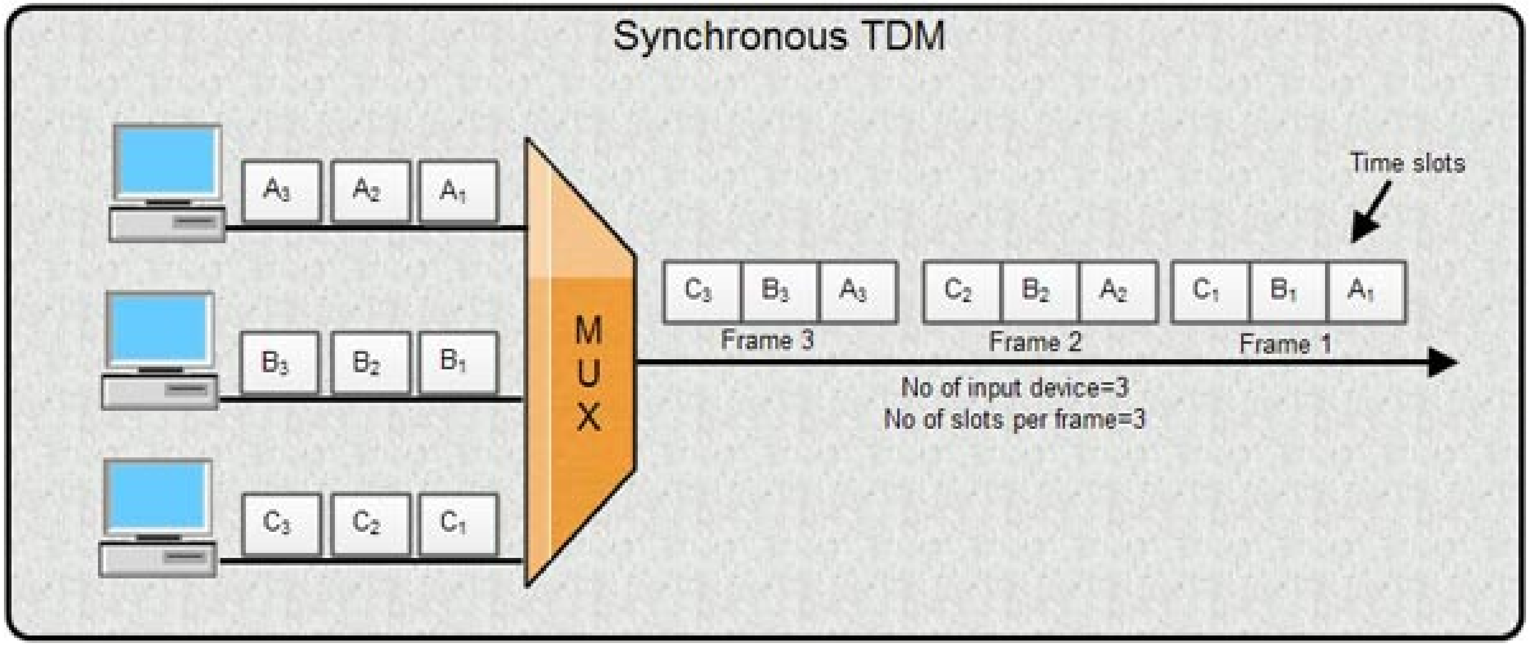
- Possible when the bandwidth of the medium exceeds the data rate of digital signals to be transmitted.
- Multiple digital signals can be carried on a single transmission path by interleaving portions of each signal in time.
- Interleaving can be at the bit level or in blocks of bytes.

Time Division Multiplexing

- The incoming data from each source are briefly buffered.
  - Each buffer is typically one bit or one character in length.
  - The buffers are scanned sequentially to form a composite data stream.
  - The scan operation is sufficiently rapid so that each buffer is emptied before more data can arrive.

Synchronous TDM

- Composite data rate must be at least equal to the sum of the individual data rate.
- The composite signal can be transmitted directly or through a modem.



Synchronous TDM

Frame Synchronization

- In this scheme, typically, one control bit is added to each TDM frame. An identifiable pattern of bits, from frame to frame, is used as a "control channel."
- Thus, to synchronize, a receiver compares the incoming bits of one frame position to the expected pattern. If the pattern does not match, successive bit positions are searched until the pattern persists over multiple frames.
- Once frame synchronization is established, the receiver continues to monitor the framing bit channel. If the pattern breaks down, the receiver must again enter a framing search mode.

Synchronous TDM

Pulse Stuffing

- If each source has a separate clock, any variation among clocks could cause loss of synchronization.
- With pulse stuffing, the outgoing data rate of the multiplexer, excluding framing bits, is higher than the sum of the maximum instantaneous incoming rates.
- The extra capacity is used by stuffing extra dummy bits or pulses into each incoming signal until its rate is raised to that of a locally generated clock signal. The stuffed pulses are inserted at fixed locations in the multiplexer frame format so that they may be identified and removed at the de-multiplexer.

Limitations of Synchronous TDM

- In synchronous TDM, many of the time slots in a frame may be wasted.
- The problem is overcame in Statistical/Asynchronous/Intelligent TDM.
- In Statistical TDM, time slots are allocated dynamically on demand.
- It takes the advantage of the fact that not all the attached devices may be transmitting all of the time.

Asynchronous TDM

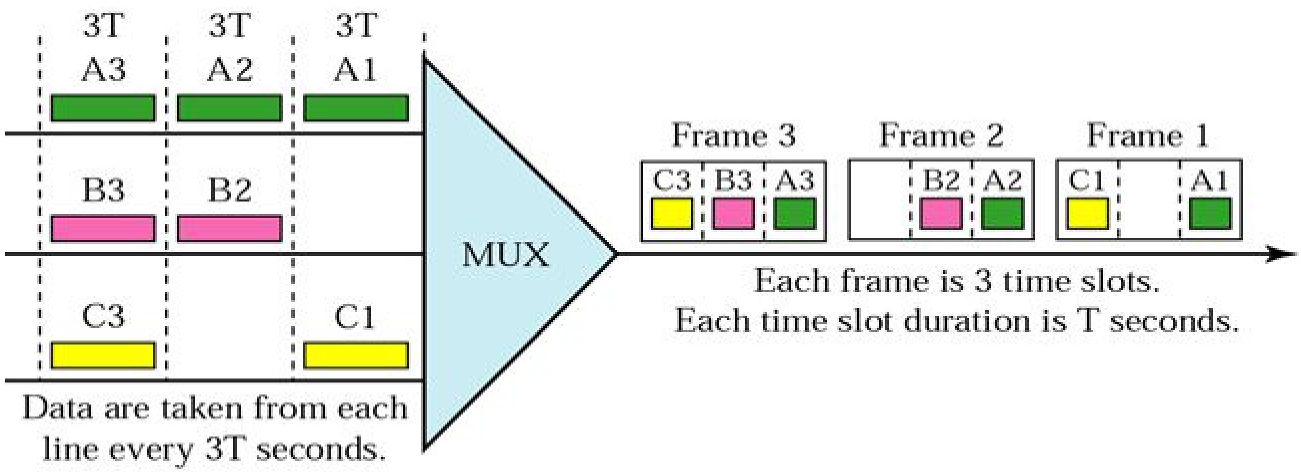
- As with a synchronous TDM, the statistical multiplexer has a number of I/O lines on one side and a higher-speed multiplexed line on the other. Each I/O line has a buffer associated with it.

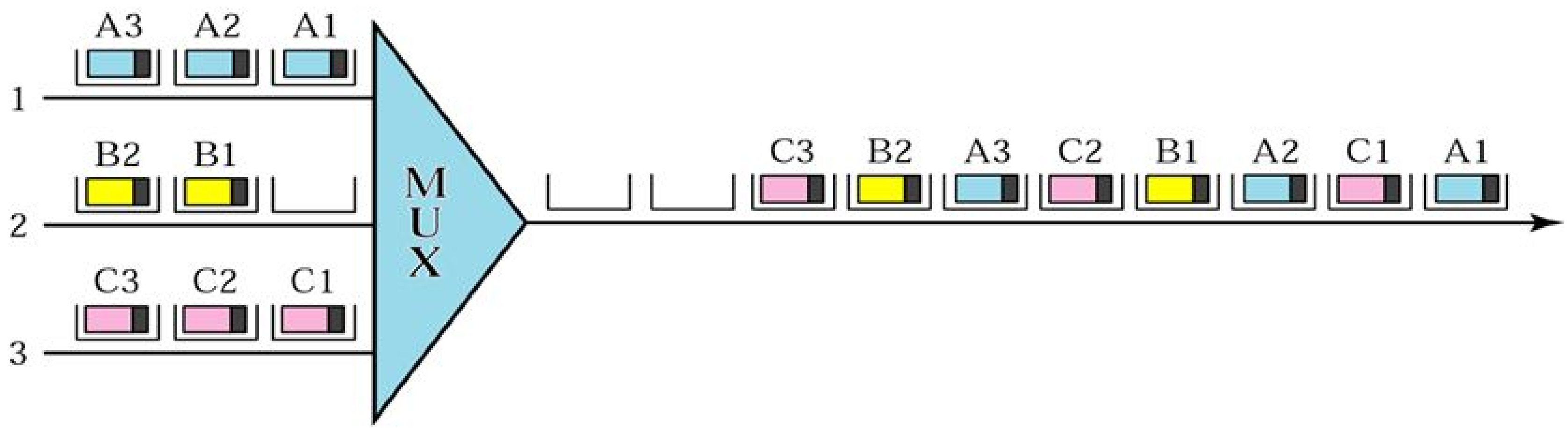
- In the case of the statistical multiplexer, there are 'n' I/O lines, but only k, where $k < n$, time slots available on the TDM frame.

- For input, the function of the multiplexer is to scan the input buffers, collecting data until a frame is filled, and then send the frame.

- On output, the multiplexer receives a frame and distributes the slots of data to the appropriate output buffers.

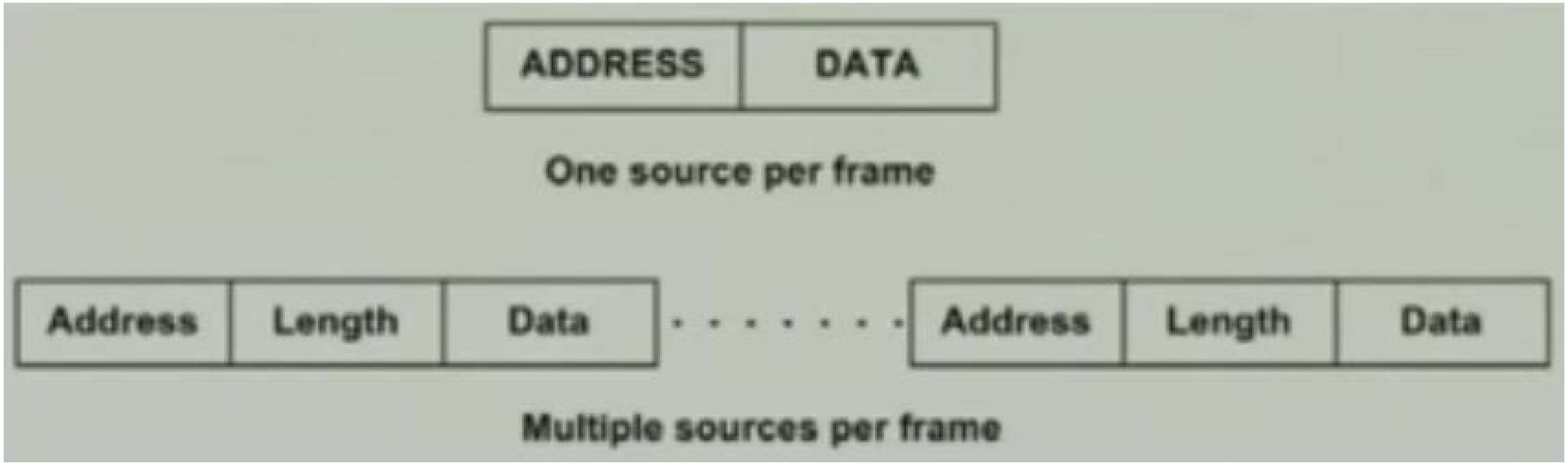
Synchronous vs. *Asynchronous* TDM





Asynchronous TDM

- Since data arrive from and are distributed to I/O lines unpredictably, *address information* is required to assure proper delivery.
- This leads to more overhead per slot.
- Relative addressing can be used to reduce overhead.



Performance of Asynchronous TDM

- In ATM, the data rate at the output is less than the data rate at the input. However, in peak periods the input may exceed capacity.

- Buffers of suitable size may be included to overcome this problem.

- Let ‘n’ = number of inputs, ‘r’ = data rate of each source, ‘M’ = effective capacity of the output, ‘α’=mean fraction of time each input is transmitting, $0 < \alpha < 1$. Then a measure of compression is $C = M/(nr)$, bounded by $\alpha < C < 1$.

Inverse Multiplexing

- An inverse multiplexer (IMUX) is a device performing the opposite function of a multiplexer (MUX).
- Instead of allowing one or more low-speed analog or digital input signals (or data streams) to be selected, combined and transmitted at a higher speed on a single shared medium i.e. multiplexing, an inverse multiplexer breaks the combined and related higher speed analog or digital signals into several concurrent lower-speed related signals or data streams.
- Thus, using multiple slower lines, the data stream can be more evenly distributed across all lines.

Inverse Multiplexing

- The difference between de-multiplexing (DEMUX) and inverse multiplexing is that the output streams of de-multiplexing are unrelated but the output streams of inverse multiplexing are related.

- Just as multiplexers are combined with de-multiplexers to create bi-directional data flow, inverse multiplexers may be combined with an inverse DEMUX (i.e. the reverse of an inverse multiplexer).

Thanks!