Open system Interconnection (OSI)

Bandwidth Utilization: Multiplexing and Spreading

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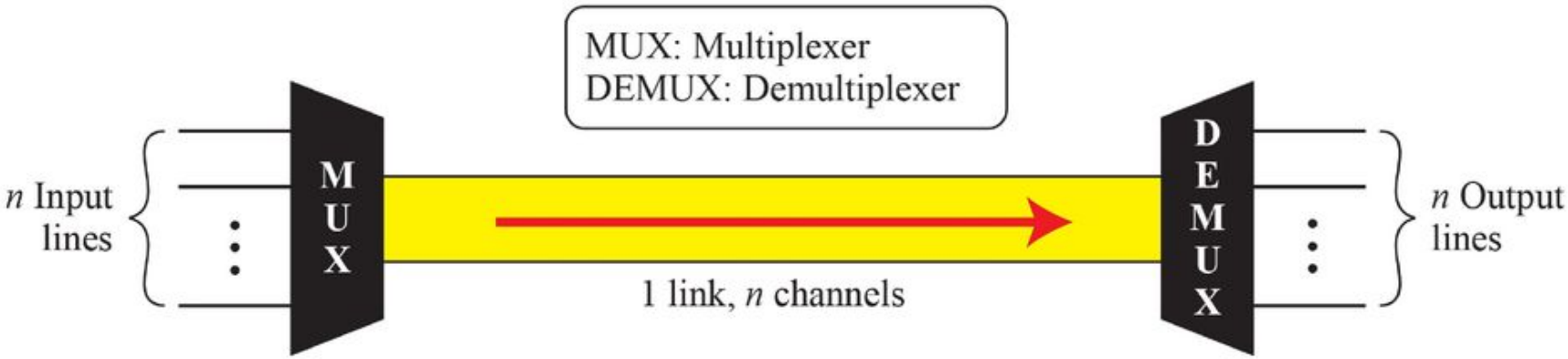
Multiplexing

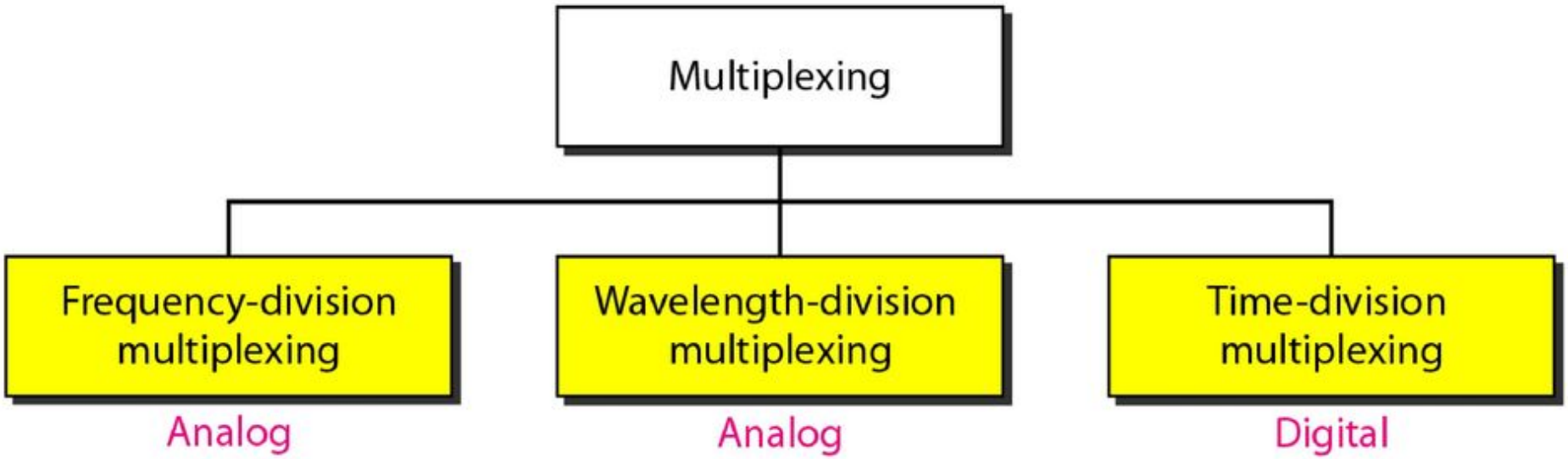
- Bandwidth utilization is the wise use of available bandwidth to achieve specific goals specific goals.
- Efficiency can be achieved by multiplexing; privacy and anti jamming can be achieved by spreading
- Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

Figure 1: Dividing a link into channels



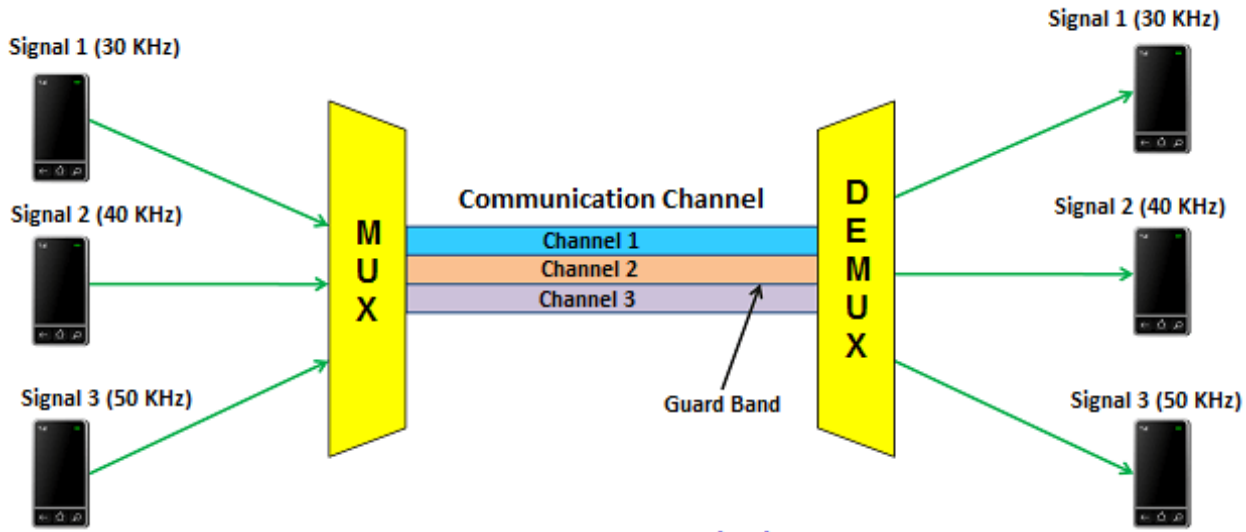
Multiplexing Cont...

- There are three basic multiplexing techniques:
  - **frequency-division multiplexing**
  - **wavelength-division multiplexing**
  - **time-division multiplexing**
- The first two are techniques designed for **analog signals**, the third, for **digital signals**



Frequency-Division Multiplexing

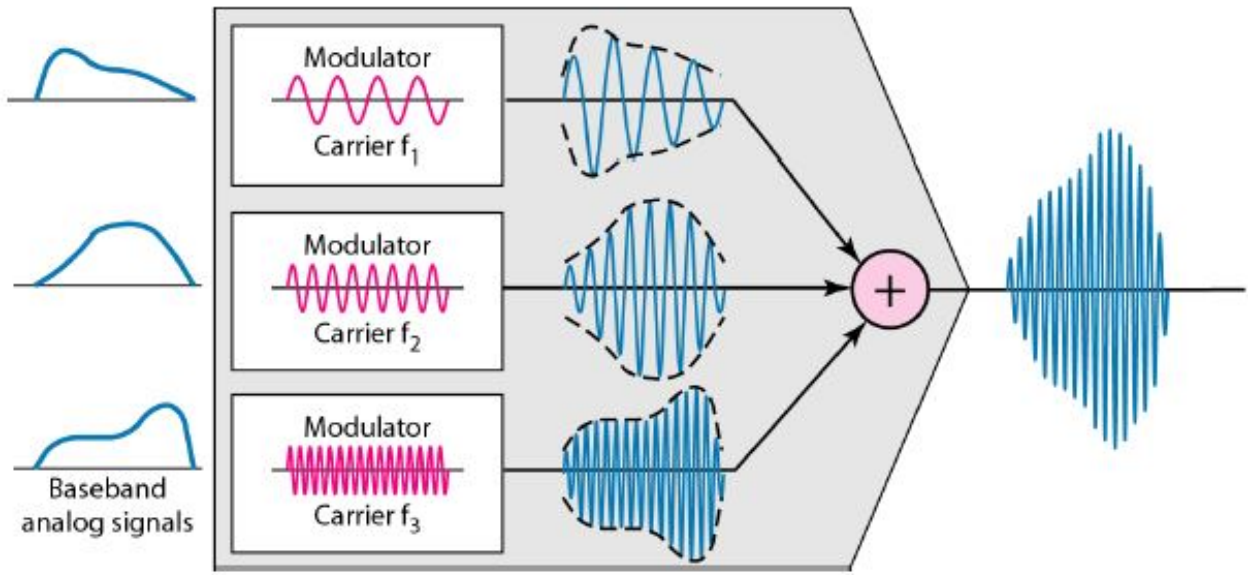
- Frequency-division multiplexing (FDM) is an analog technique that can be applied when the bandwidth of a link (in hertz)
- In FDM, signals generated by each sending device modulate different carrier frequencies.
  - These modulated signals are then combined into a single composite signal that can be transported by the link
  - Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal
  - These bandwidth ranges are the channels through which the various signals travel.



Frequency Division Multiplexing

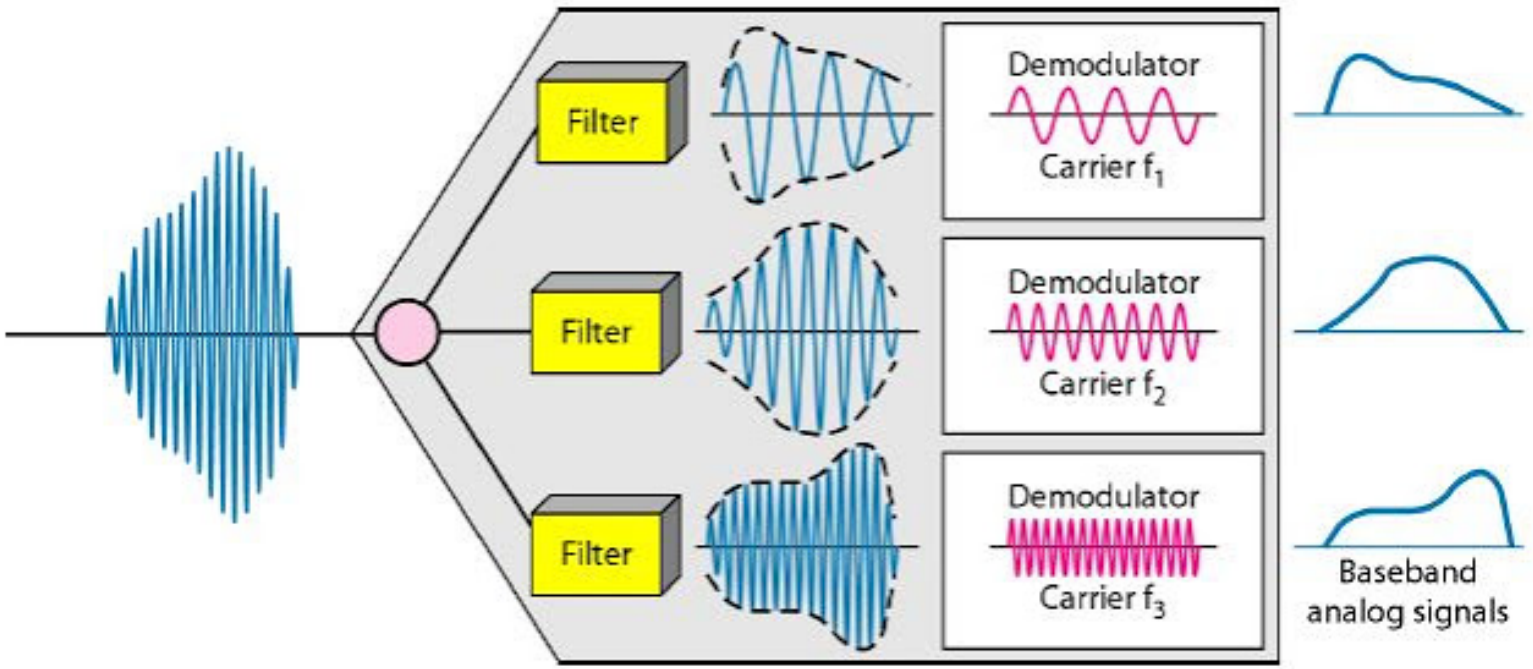
Frequency-Division Multiplexing

- FDM is an analog multiplexing technique that combines analog signals.
- Each source generates a signal of a similar frequency range.
- These similar signals modulates different carrier frequencies ($f_1, f_2, and\ f_h$).
- The resulting modulated signals are then combined into a single composite signal



Demultiplexing Process

- The demultiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals.
- The individual signals are then passed to a demodulator that separates them from their carriers



Examples:

- Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.

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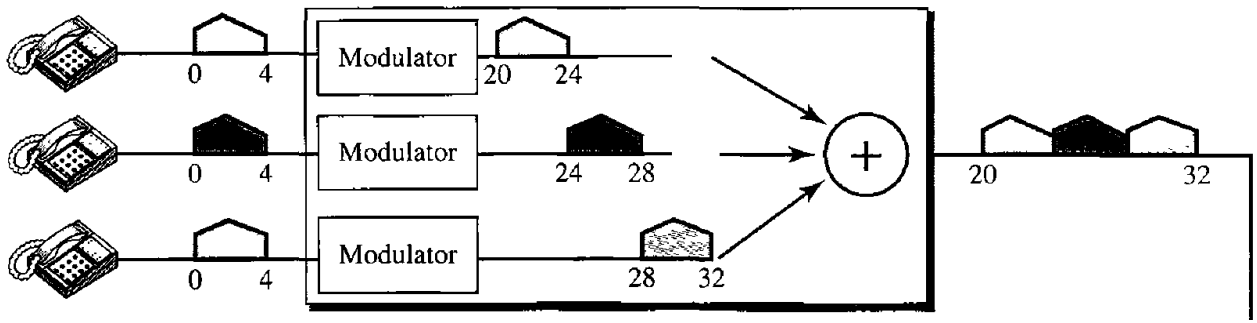

- Five channels, each with a IO0-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10kHz between the channels to prevent interference?

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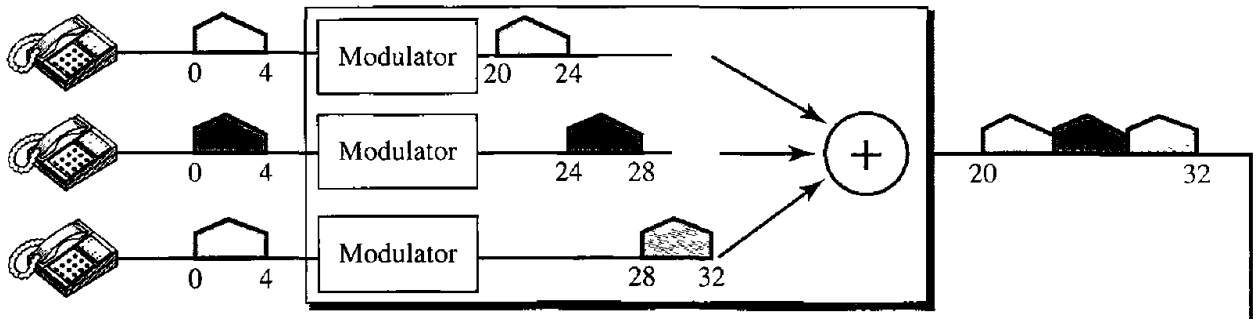

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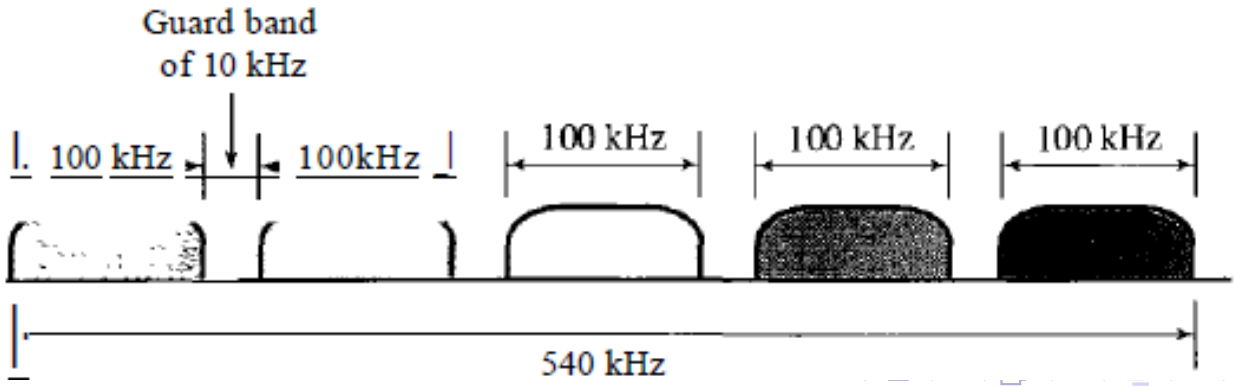
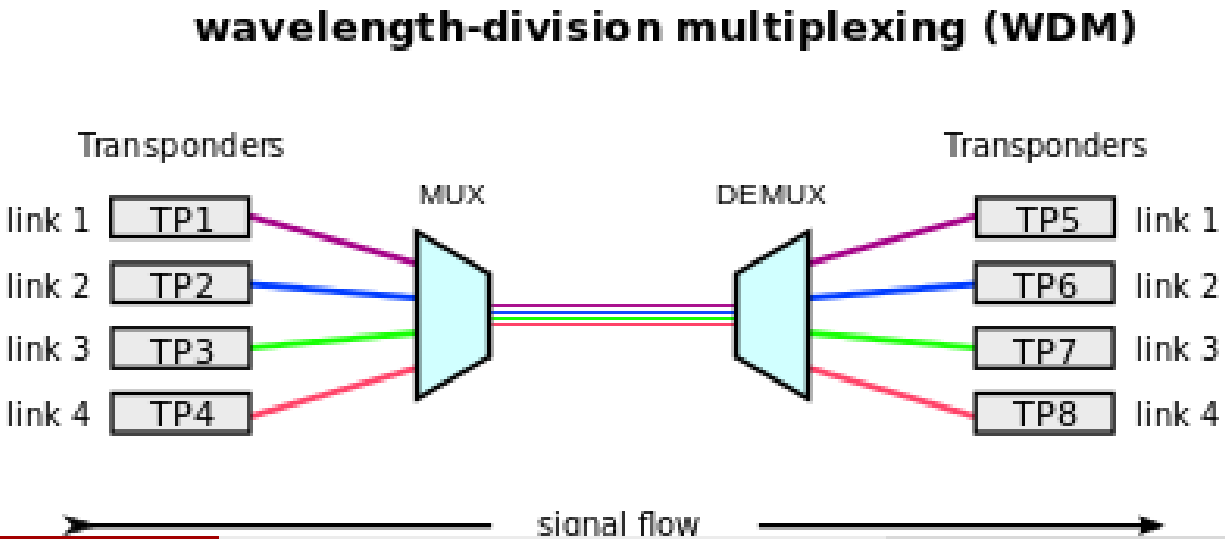


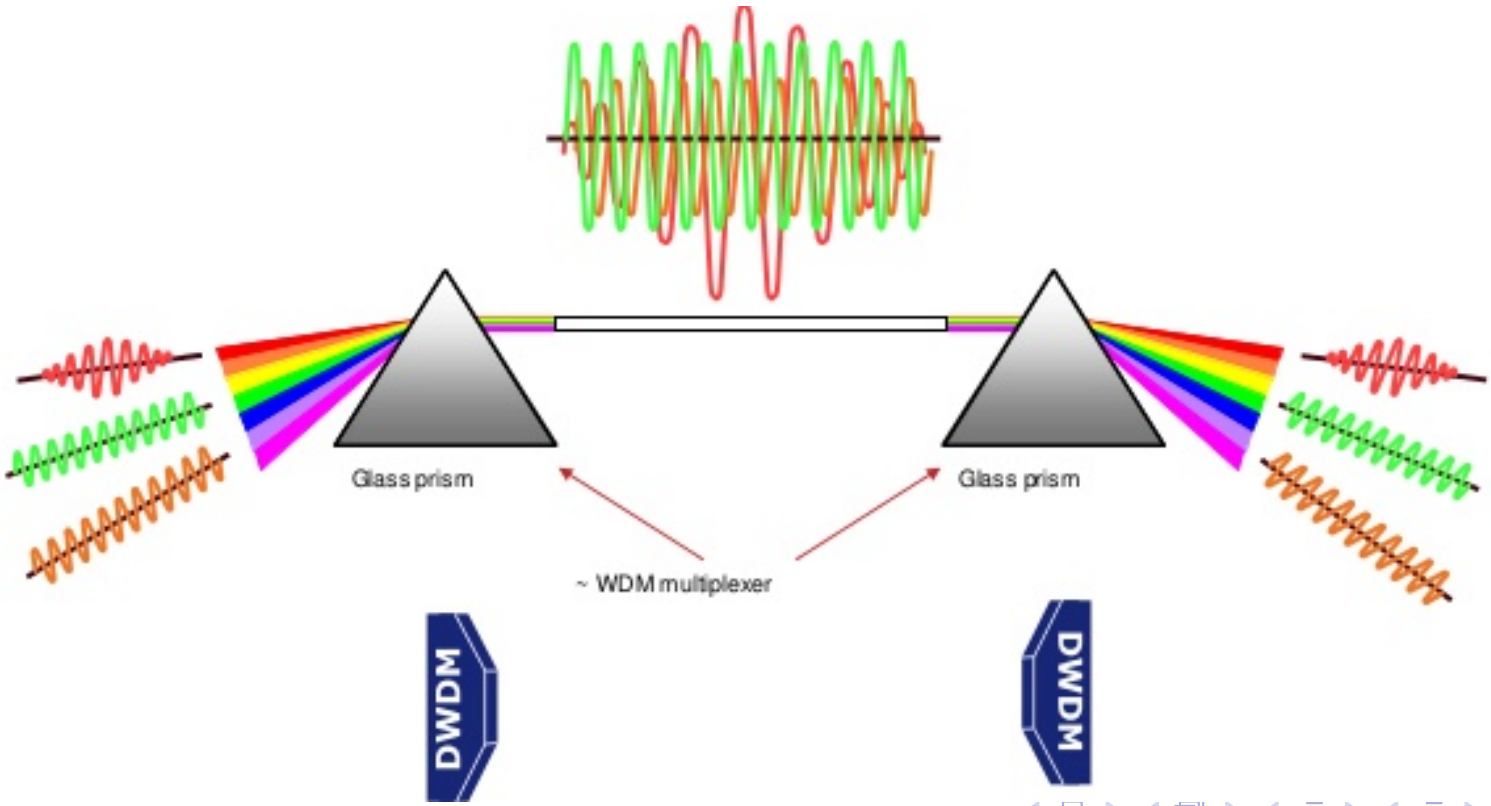
Wavelength-Division Multiplexing

- Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable.
- Using a fiber-optic cable for one single line wastes the available bandwidth
- Multiplexing allows us to combine several lines into one.
  - Multiplexing and demultiplexing involve optical signals transmitted through fiber-optic channels.
  - Very narrow bands of light from different sources are combined to make a wider band of light.
  - At the receiver, the signals are separated by the demultiplexer



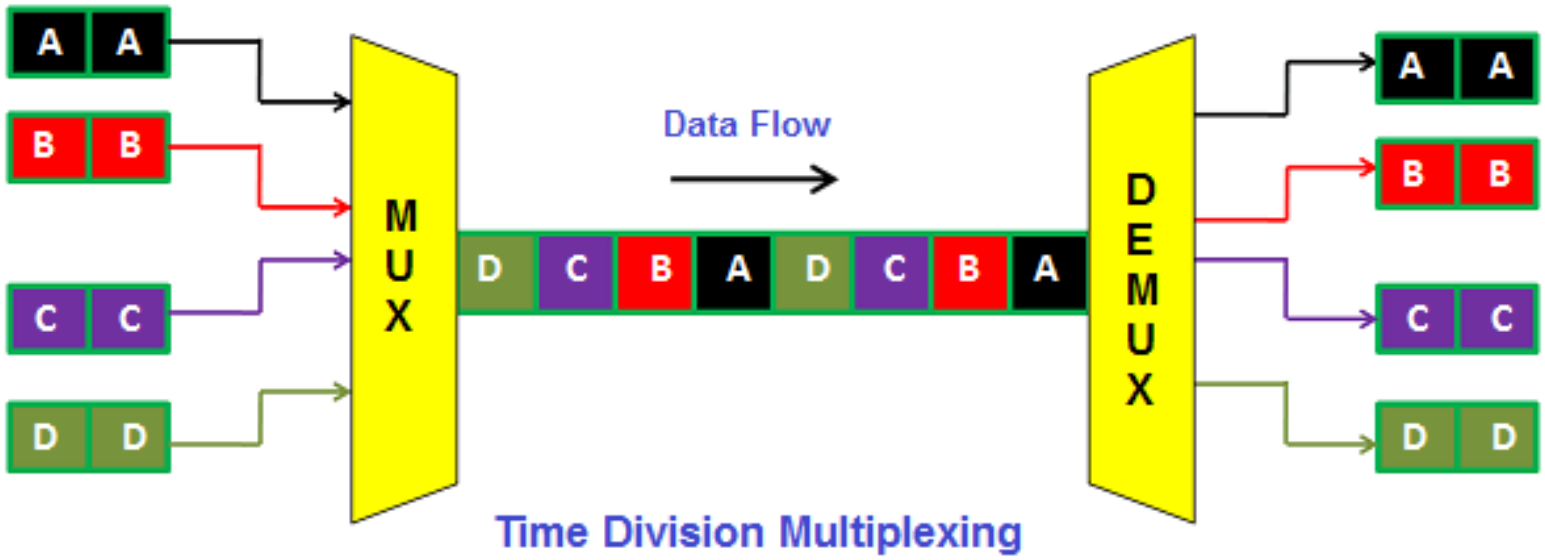
Wavelength-Division Multiplexing

- WDM is an analog multiplexing technique to combine optical signals.
- The combining and splitting of light sources are easily handled by a prism.
- One application of WDM is the Synchronous Optical Network (SONET) network



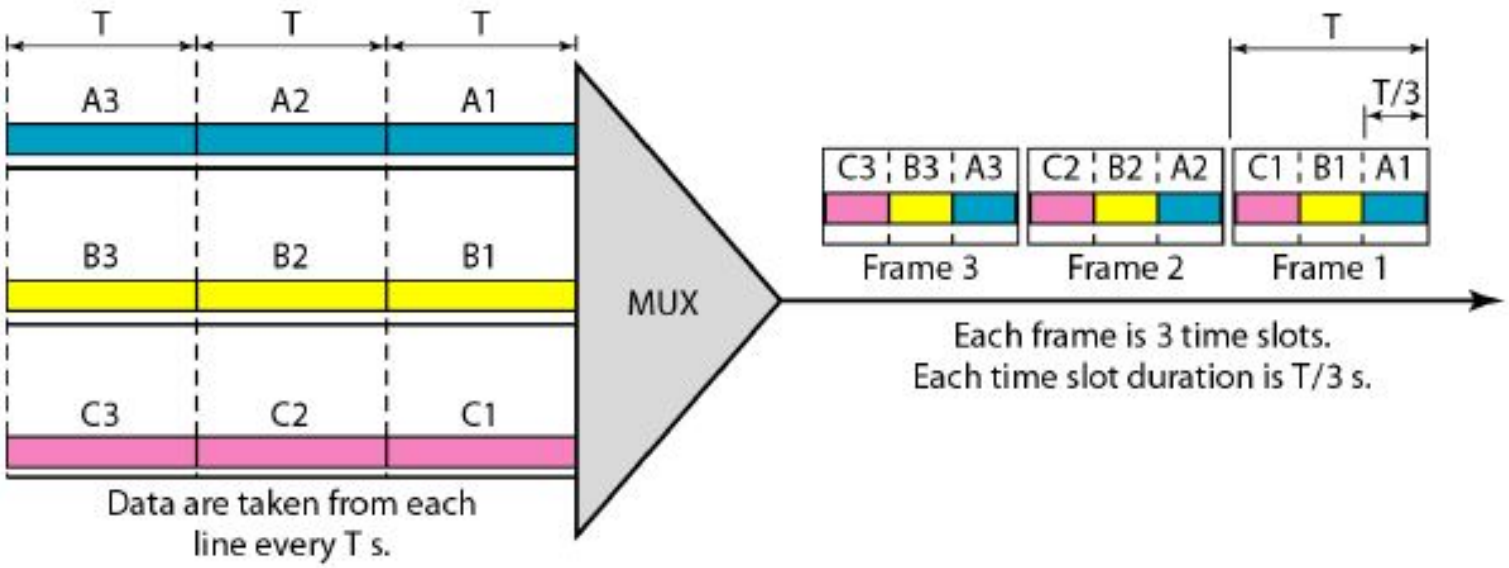
Synchronous Time-Division Multiplexing

- Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link.
- Instead of sharing a portion of the bandwidth as in FDM, time is shared.
- Each connection occupies a portion of time in the link.
- TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one.



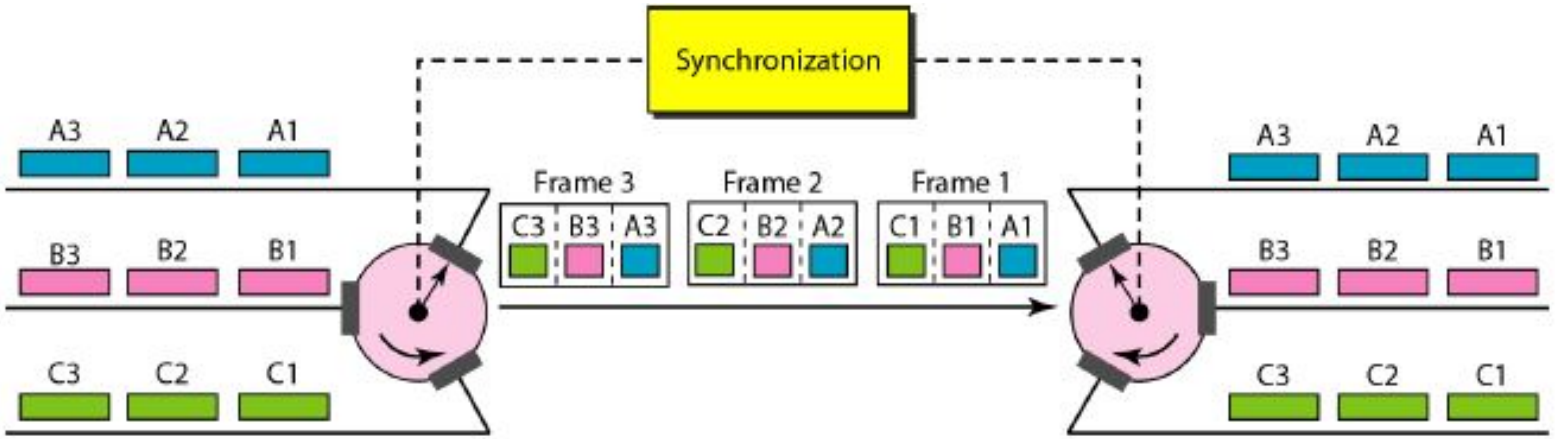
Synchronous Time-Division Multiplexing

- We can divide TDM into two different schemes:
  1. **Synchronous**
  2. **Statistical**
- Time Slots and Frames
  - In synchronous TDM, the data flow of each input connection is divided into units
  - A unit can be 1 bit, one character, or one block of data.
  - In synchronous TDM, the data rate of the link is n times faster, and the unit duration is n times shorter.



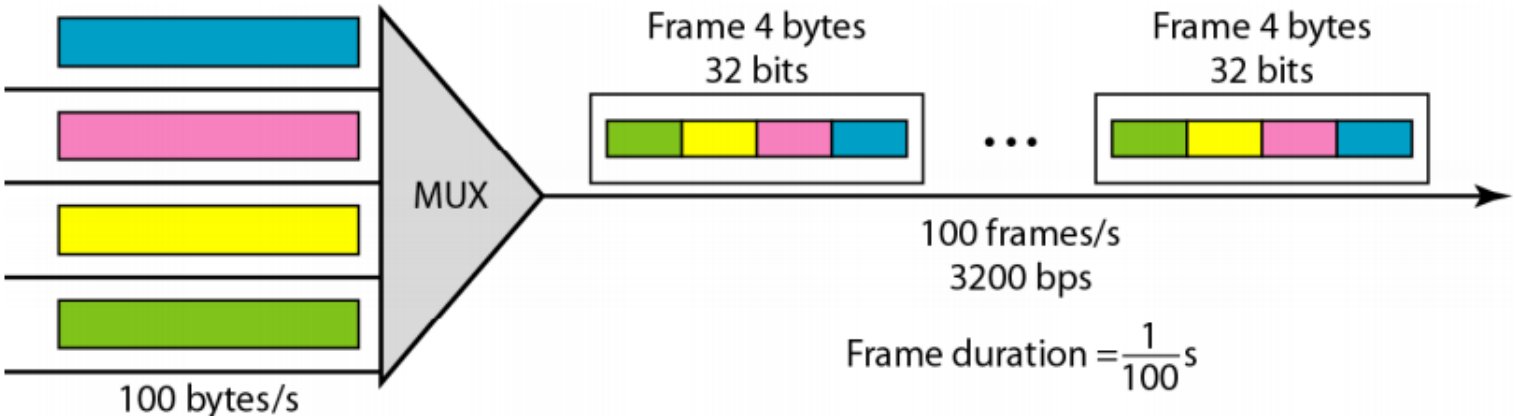
Interleaving

- TDM can be visualized as two fast-rotating switches,one on the multiplexing side and the other on the demultiplexing side
- The switches are synchronized and rotate at the same speed, but in opposite directions.

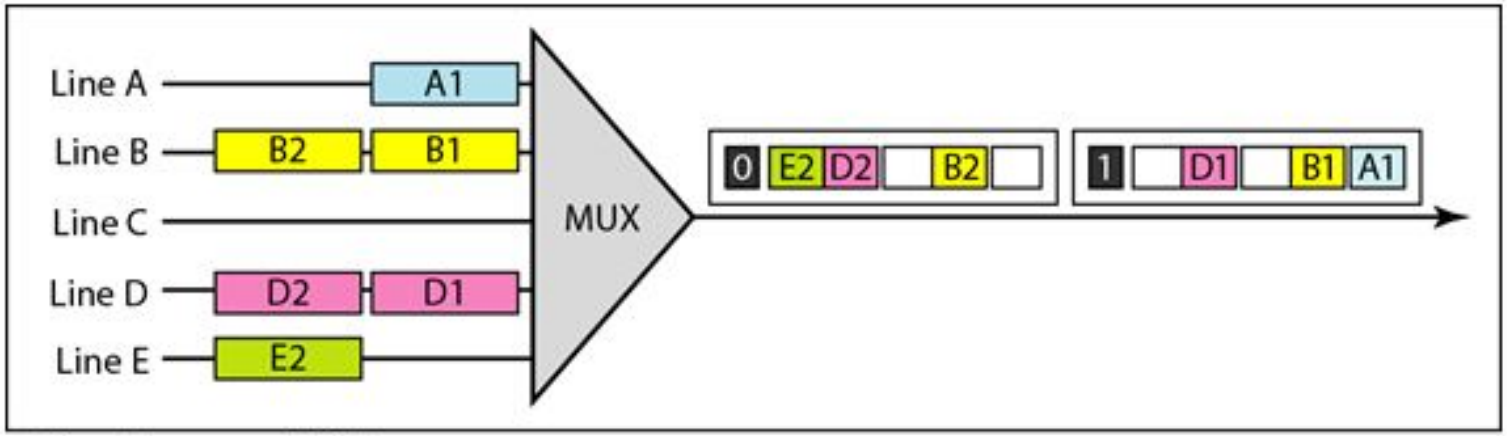


Example

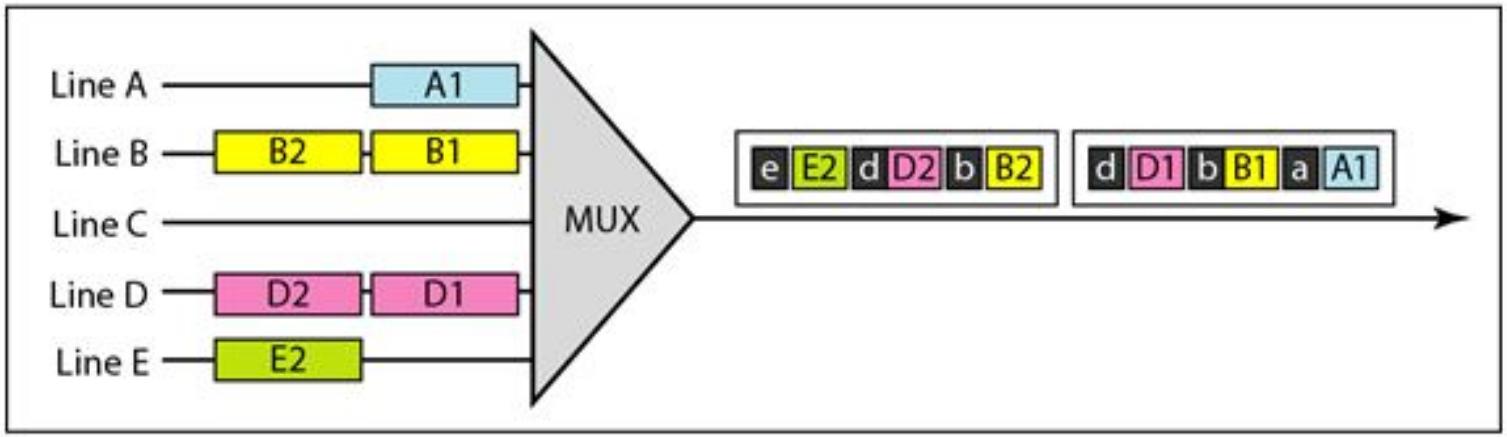
- Four channels are multiplexed using TDM. If each channel channel sends 100 bytes /s and we multiplex multiplex 1 byte per channel, show the frame traveling on the link, the size of the frame, the duration duration of a frame, the frame rate, and the bit rate for the link.



Synchronization vs Statistical TDM



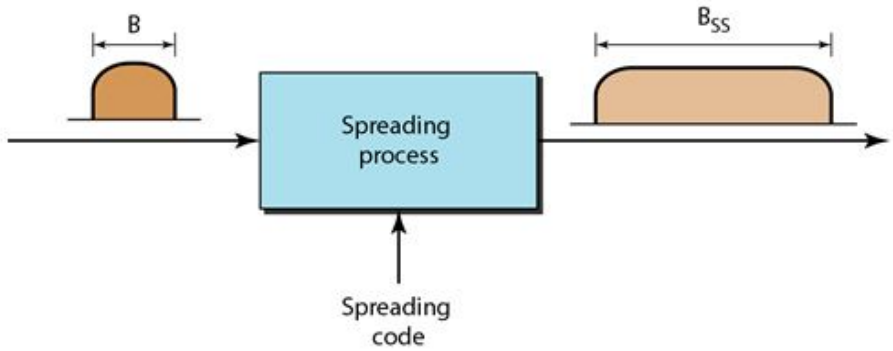
a. Synchronous TDM



b. Statistical TDM

Spread Spectrum

- In spread spectrum spectrum (SS), we combine combine signals signals from different different sources sources to fit into a larger bandwidth bandwidth.
- To achieve achieve these goals, spread spectrum spectrum techniques techniques add redundancy redundancy.
- Stations must be able to share this medium without interception by an eavesdropper and without being subject to jamming from a malicious intruder
- There are two techniques to spread the bandwidth:
  - Frequency hopping spread spectrum (FHSS)
  - Direct sequence spread spectrum (DSSS).



Thank You