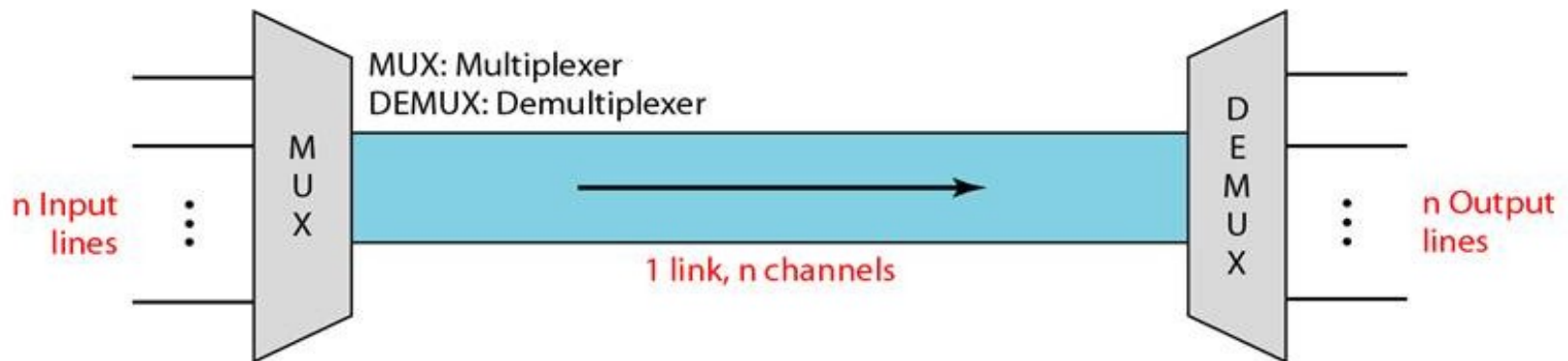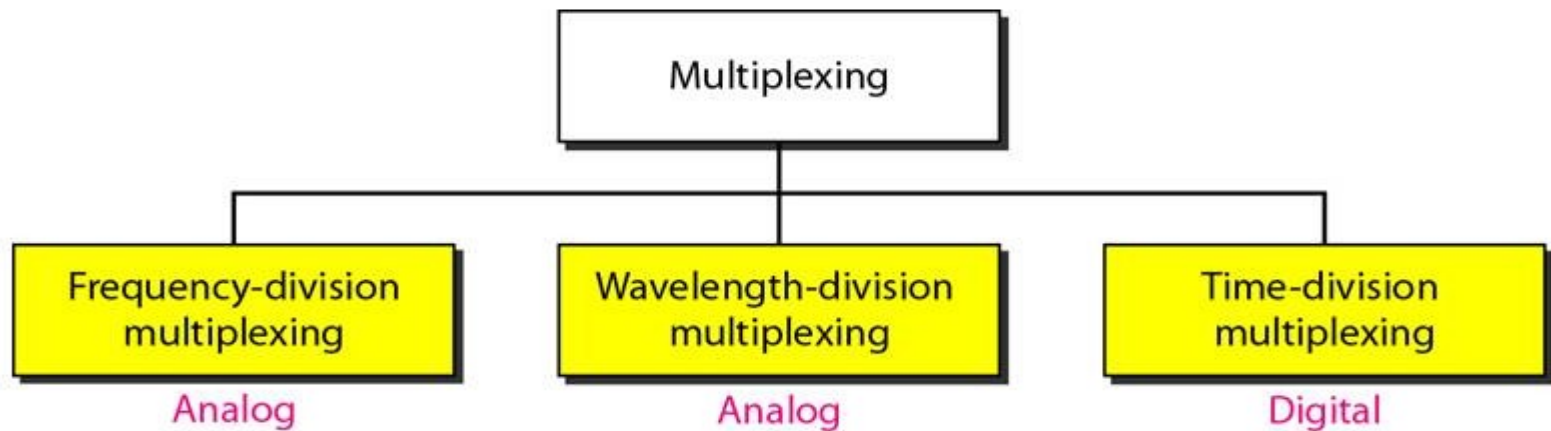# CSE 350
Data Communication

Chapter 6 :Multiplexing

Multiplexing

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

MUX: Multiplexer
DEMUX: Demultiplexer

n Input lines

M U X

1 link, n channels

D E M U X

n Output lines

6-2

Categories of Multiplexing
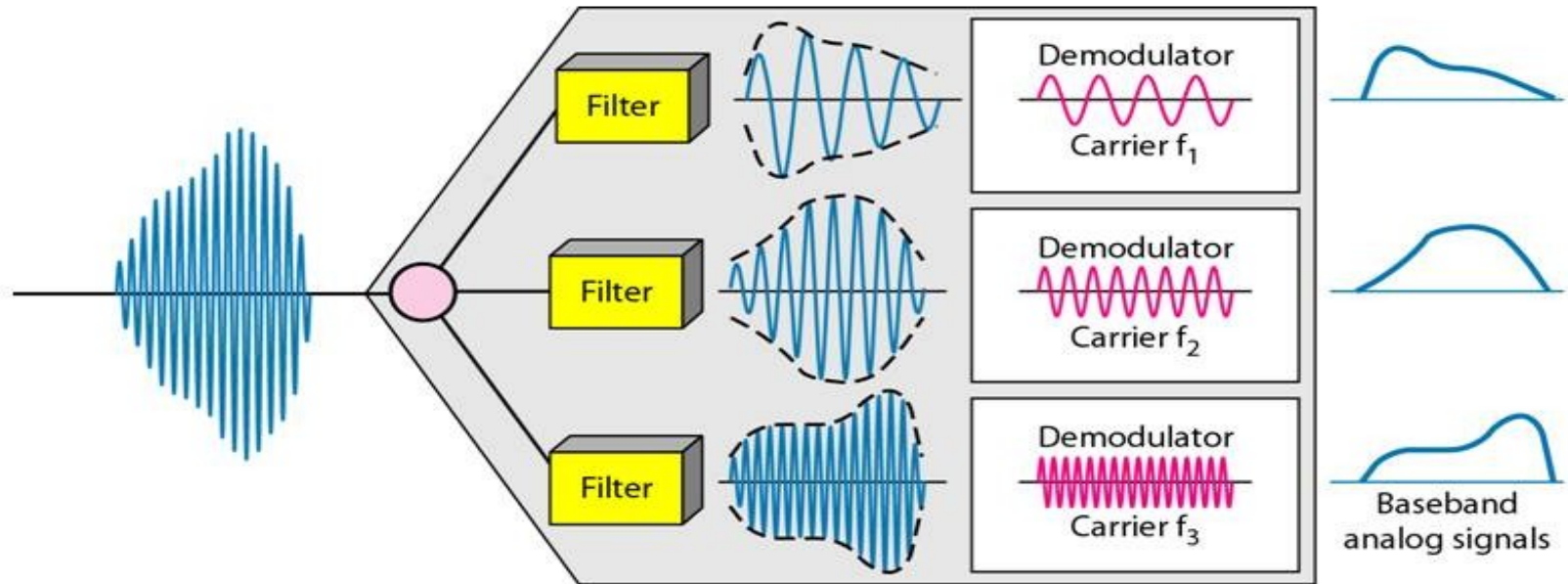
Frequency Division Multiplexing

- FDM is an analog multiplexing technique that combines analog signals
- Signals modulate different carrier frequencies
- Modulated signals are combined into a composite signal
- *Channel* – Bandwidth range to accommodate a modulated signal
- Channels can be separated by strips of unused bandwidth (*guard band*) to prevent overlapping

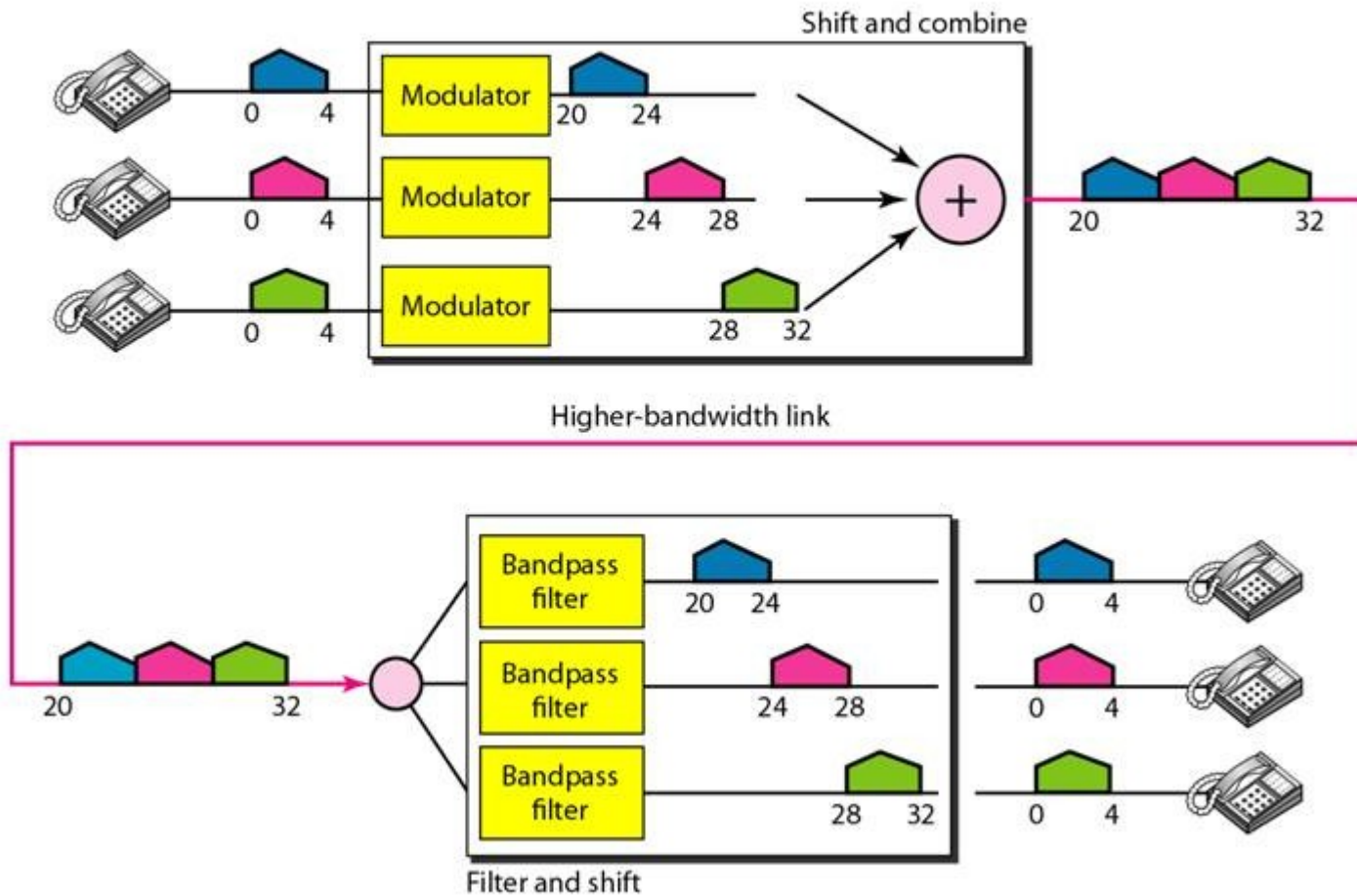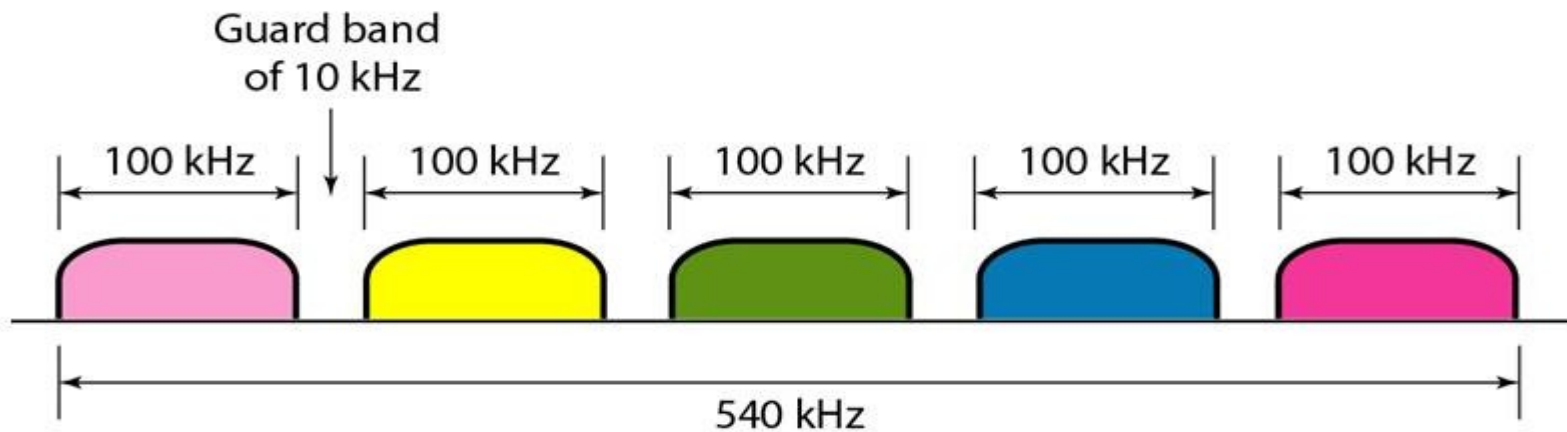Input lines | M U X | Channel 1 / Channel 2 / Channel 3 | D E M U X | Output lines

6-4
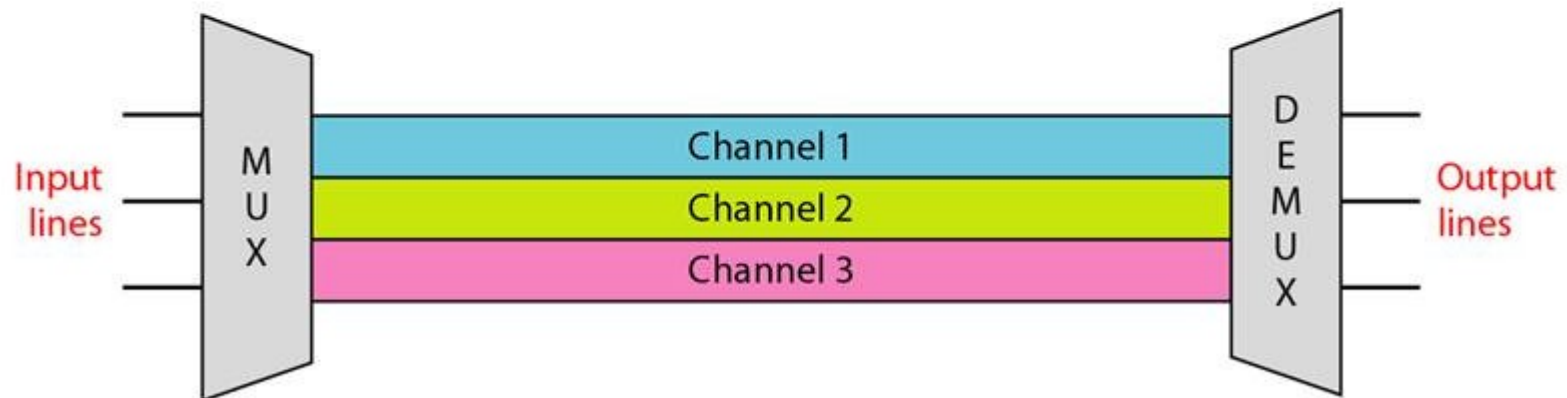
FDM Process
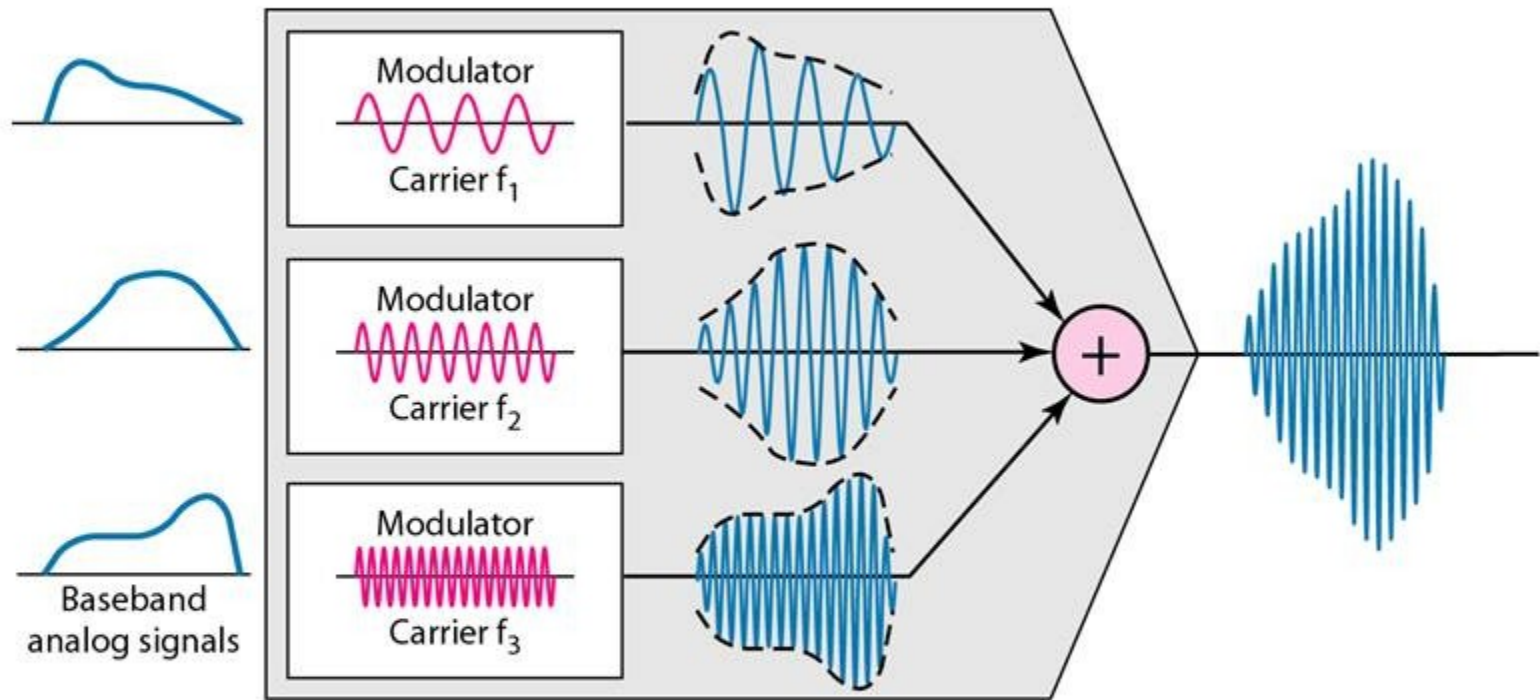
FDM Demultiplexing Example

FDM: Example 1

FDM: Example 2
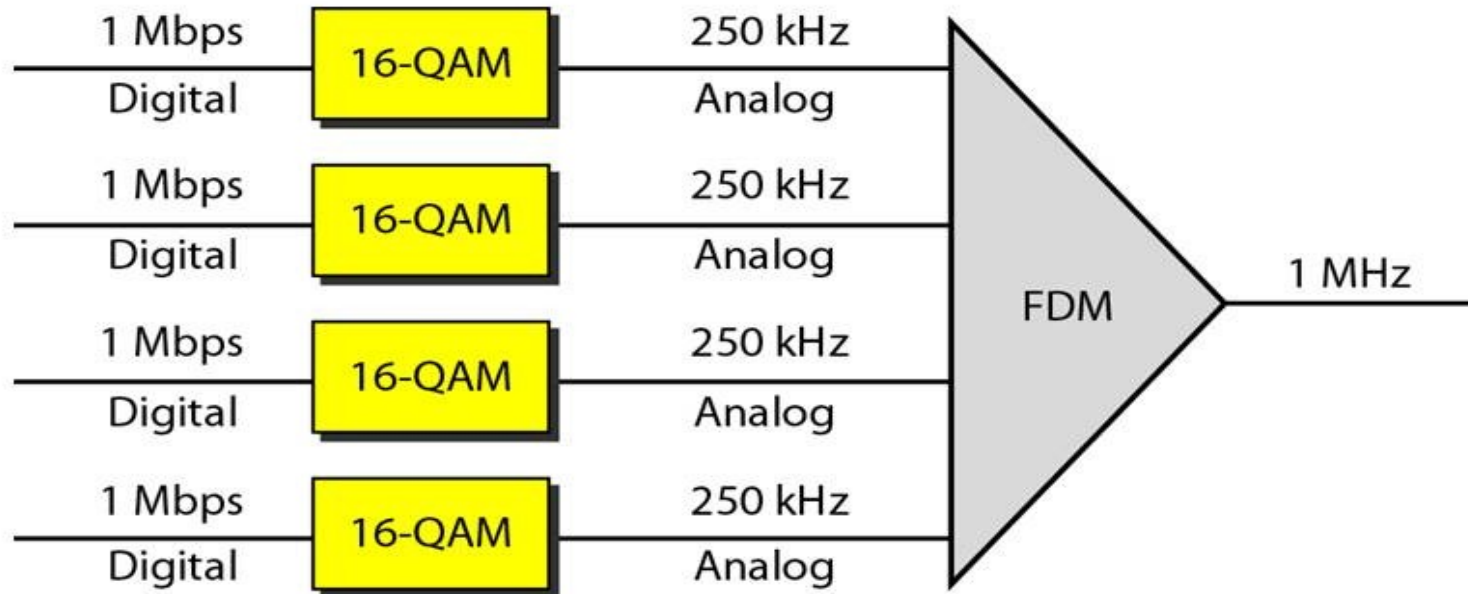

Guard band of 10 kHz

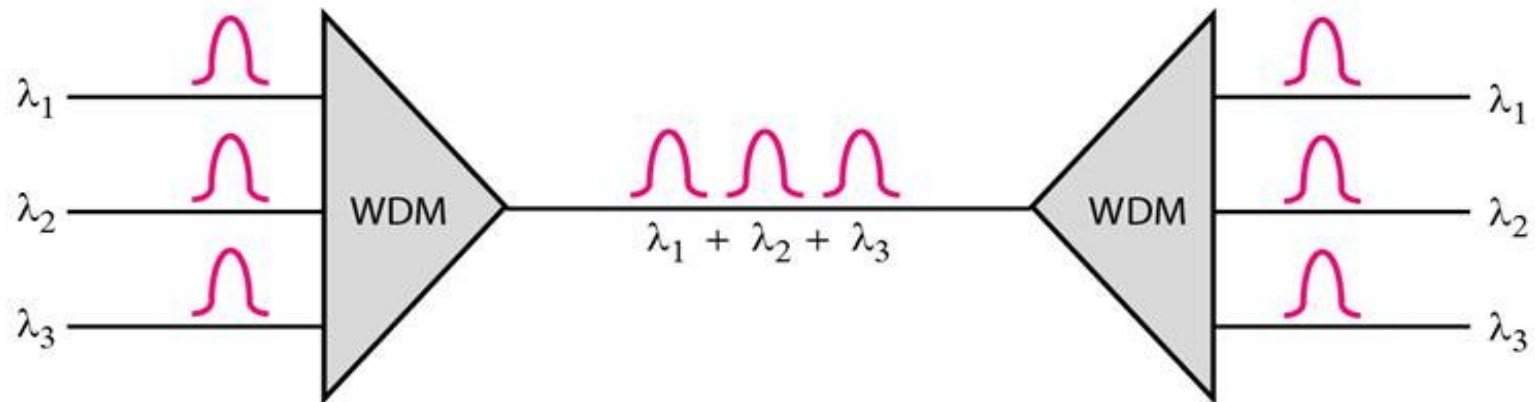100 kHz | 100 kHz | 100 kHz | 100 kHz | 100 kHz

540 kHz

FDM: Example 3

Wave Division Multiplexing

- Analog multiplexing technique to combine optical signals
- Conceptually the same as FDM
- Light signals transmitted through fiber optic channels
- Combining different signals of different frequencies (wavelengths)

6-10

Prisms in WDM

- **Combining and splitting of light sources are easily handled by a *prism***

- **Prism bends a light beam based on the incidence angle and the frequency**

λ_1

λ_2

λ_3

Multiplexer

$\lambda_1 + \lambda_2 + \lambda_3$

Fiber-optic cable

λ_1

λ_2

λ_3
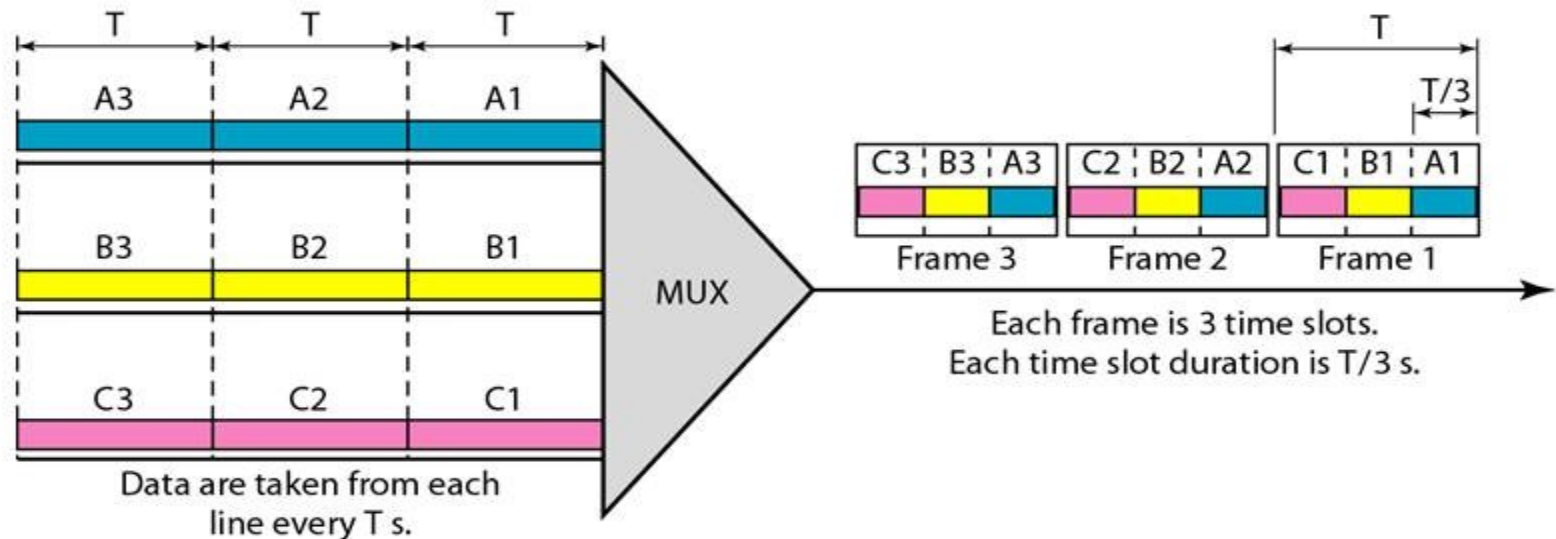
Demultiplexer

6-11
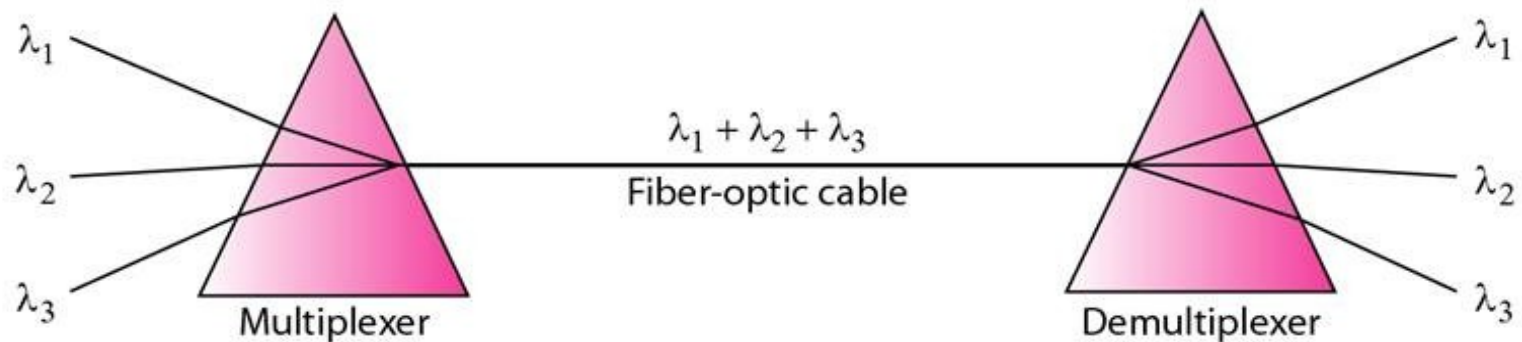
Time Division Multiplexing

Digital multiplexing technique for combining several low-rate • channels into one high-rate one

6-12
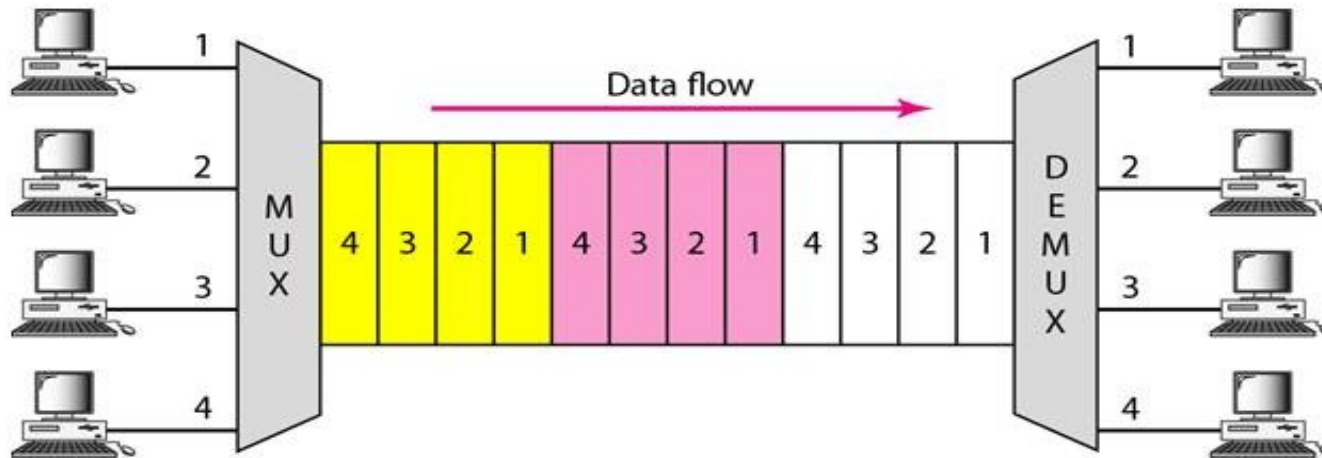
TDM: Time Slots and Frames

- **In synchronous TDM, the data rate of the link is *n* times faster, and the unit duration is *n* times shorter**

Data are taken from each line every T s.

Each frame is 3 time slots.
Each time slot duration is T/3 s.

TDM: Example 1

- Four 1-Kbps connections are multiplexed together. A unit is 1 bit. Find (a) the duration of 1 bit before multiplexing, (b) the transmission rate of the link, (c) the duration of a time slot, and (d) the duration of a frame?
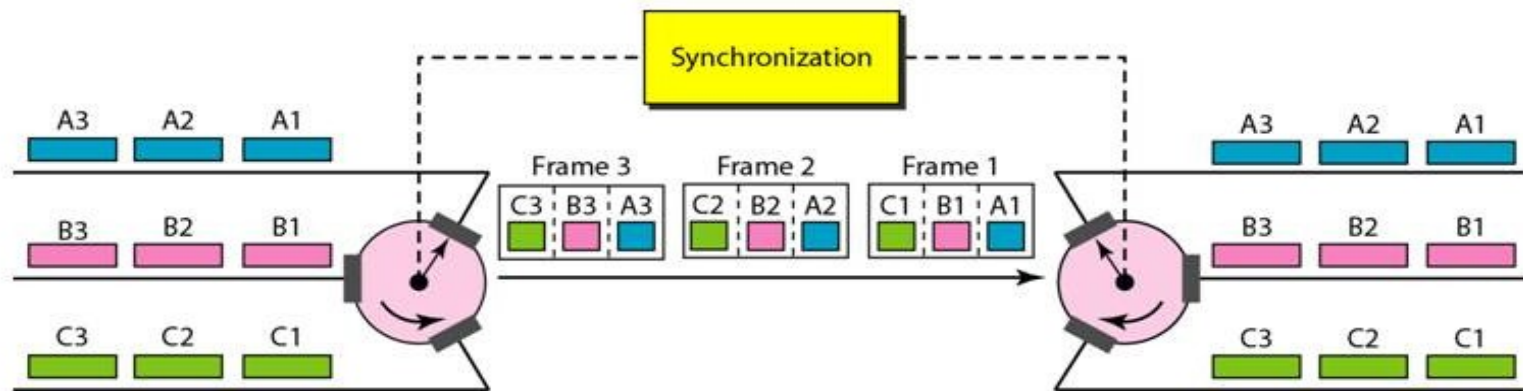
a) *The duration of 1 bit is 1/1 Kbps, or 0.001 s (1 ms).*

b) *The rate of the link is 4 Kbps.*

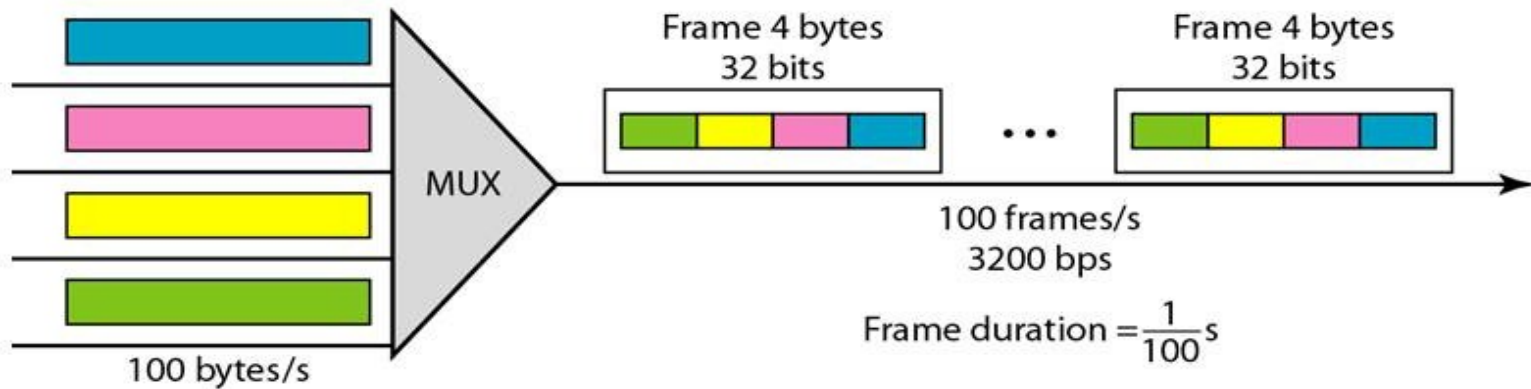c) *The duration of each time slot 1/4 ms or 250 μs.*

d) *The duration of a frame 1 ms.*
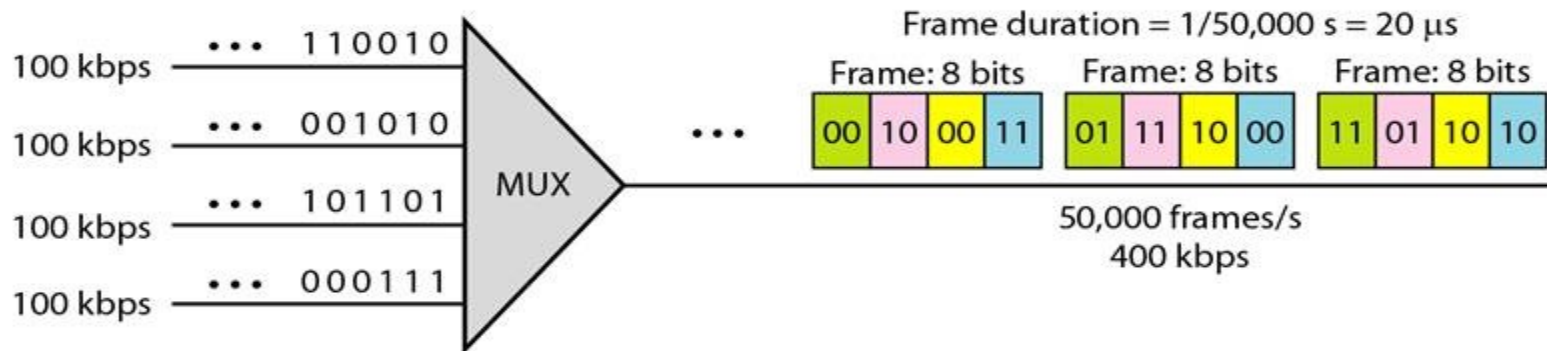
Interleaving

- **Interleaving can be done by bit, by byte, or by any other data unit**
- **The interleaved unit is of the same size in a given system**

TDM: Example 2

TDM: Example 3

100 kbps ⋯ 110010

100 kbps ⋯ 001010

MUX

100 kbps ⋯ 101101

100 kbps ⋯ 000111

⋯

Frame duration = 1/50,000 s = 20 μs

Frame: 8 bits   Frame: 8 bits   Frame: 8 bits

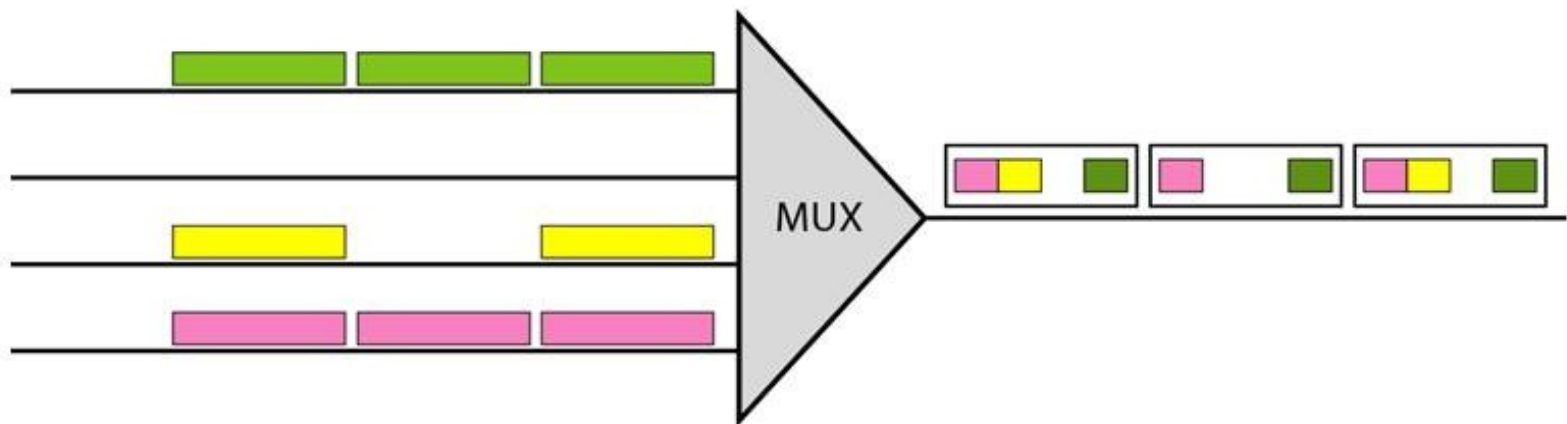| 00 | 10 | 00 | 11 | 01 | 11 | 10 | 00 | 11 | 01 | 10 | 10 |

50,000 frames/s
400 kbps

Empty Slots

- **Synchronous TDM is not efficient in many cases**
- **Statistical TDM can improve the efficiency by removing the empty slot from the frame**

Thank you