CSE 350
DATA COMMUNICATIONS

Lecture 7: Multiplexing

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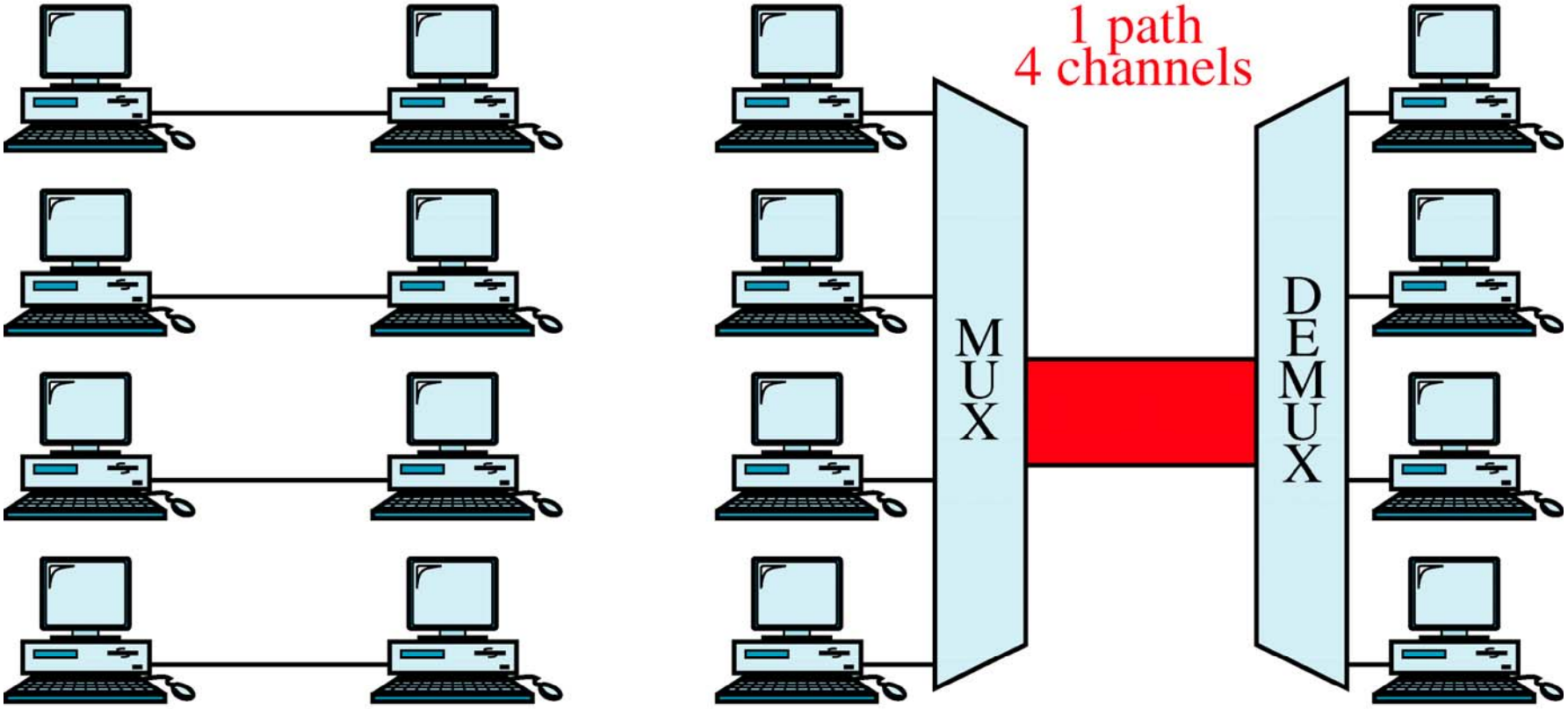
Multiplexing

- To make efficient use of high-speed communications line
- The transmission capacity of a medium linking two devices is greater than the transmission needs of the devices, the link can be shared
- **Multiplexing**:- the set of techniques that allows the simultaneous transmission of multiple signals across a single data link
- N devices share the capacity of one link
- The link is able to carry n separate channels of data

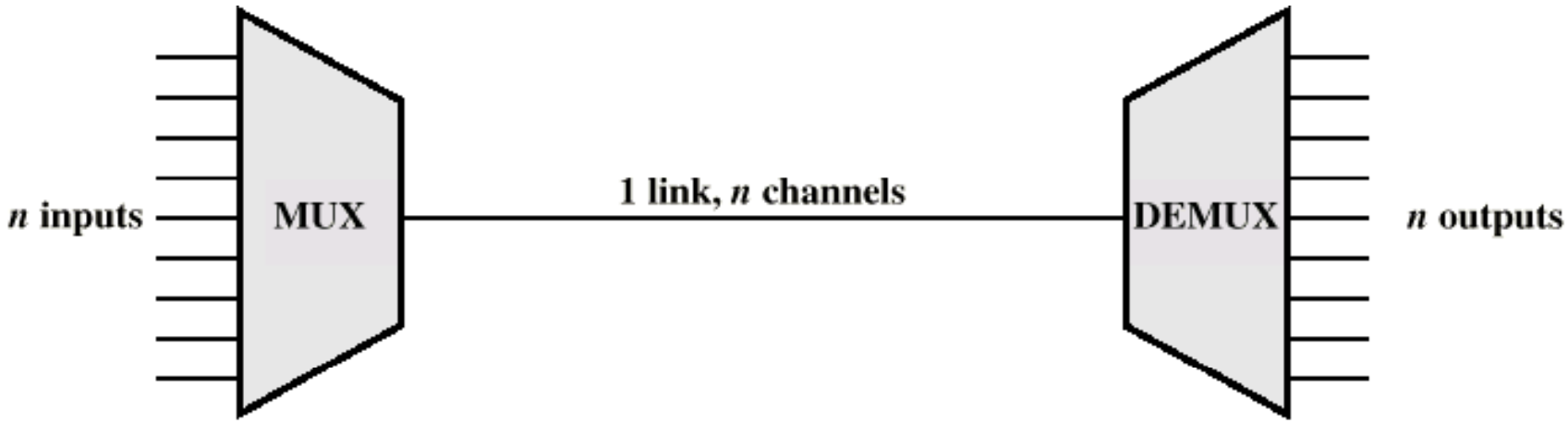
Multiplexing vs. No Multiplexing

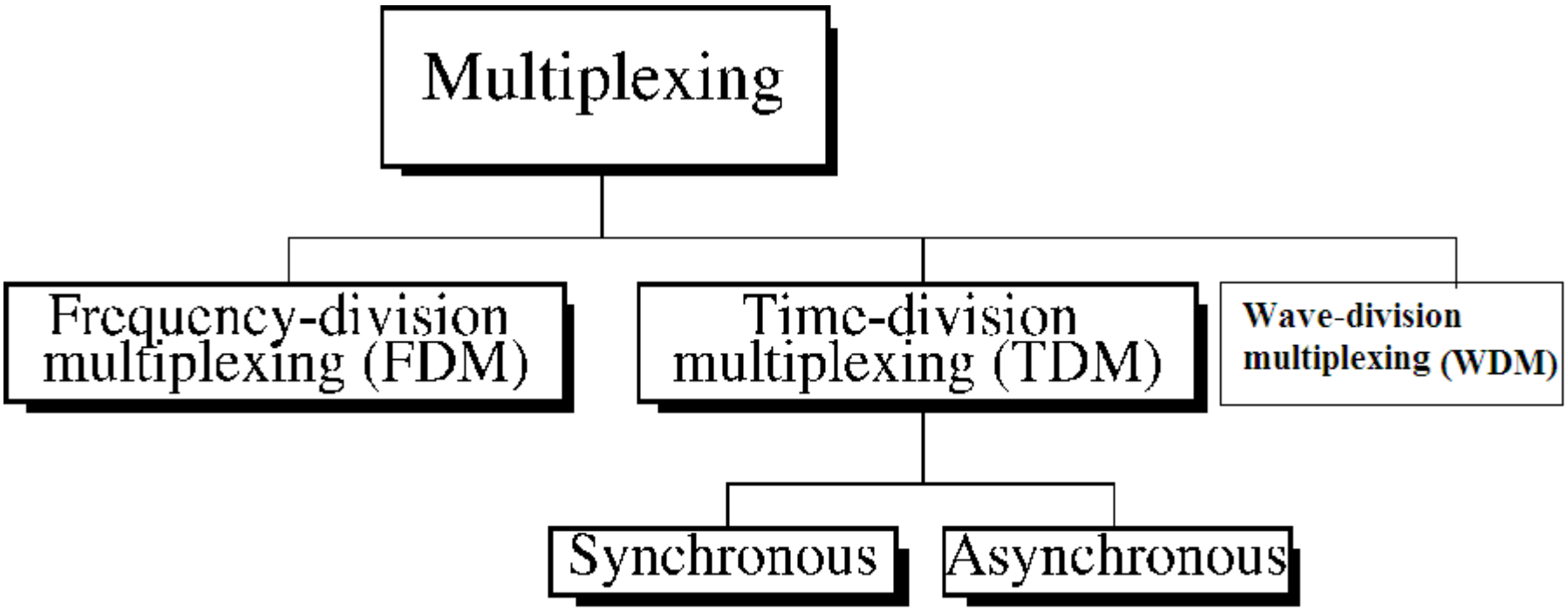


a. No multiplexing

b. Multiplexing

Multiplexing




Multiplexing
Frequency-division multiplexing (FDM)
Time-division multiplexing (TDM)
Wave-division multiplexing (WDM)
Synchronous
Asynchronous

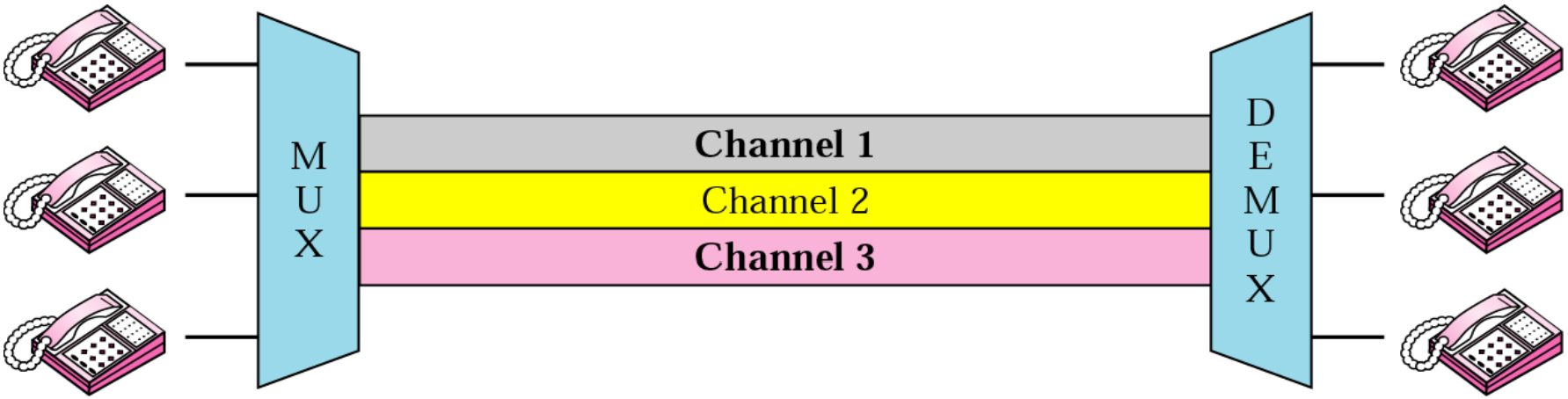
Frequency Division Multiplexing (FDM)

- Analog technique
- The input signals may be either digital or analog
- When the bandwidth of a link is greater than the combined bandwidths of the signals to be transmitted
- Signals generated by each sending device modulate different carrier frequencies
- Combined into a single composite signal that can be transported by the link
- Carrier frequencies are separated by enough bandwidth

Frequency Division Multiplexing

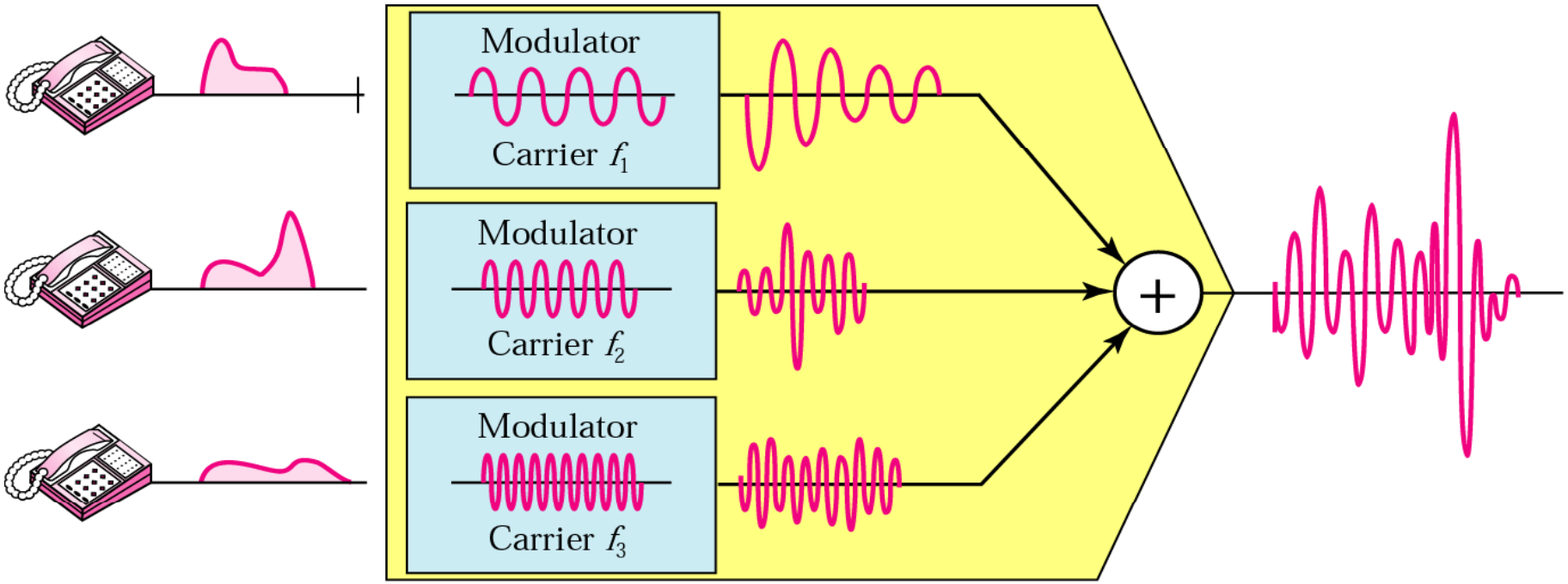
- These bandwidth ranges are the channels through which the various signals travel
- Channels must be separated by strips of unused bandwidth (guard bands) to prevent signals from overlapping
- e.g. broadcast radio, cable television
- Channel allocated even if no data

FDM—Conceptual view

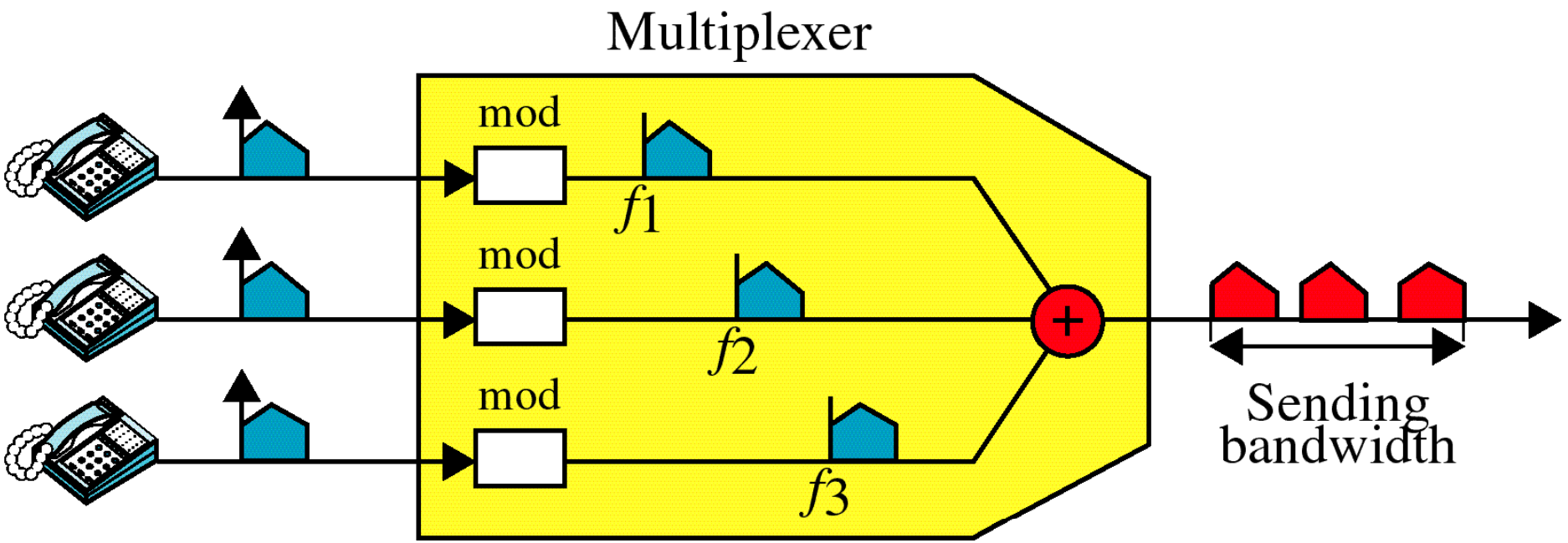


The FDM Process

FDM, Time Domain Multiplexer



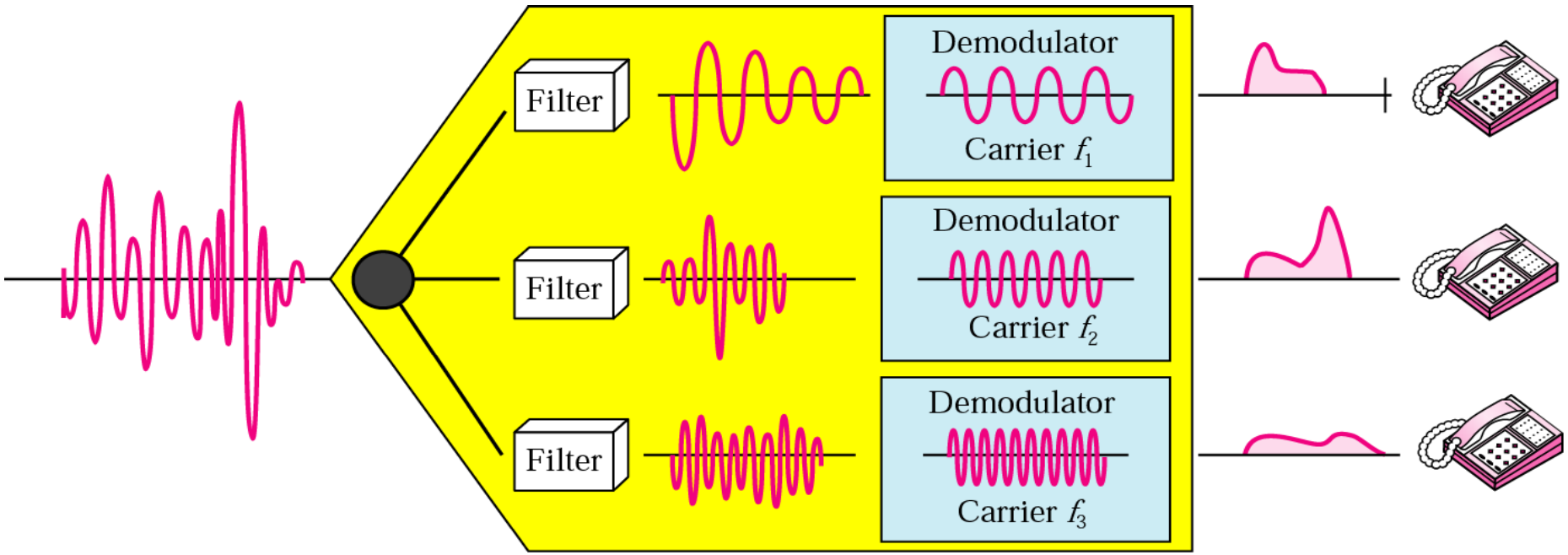
FDM Multiplexing, Frequency Domain



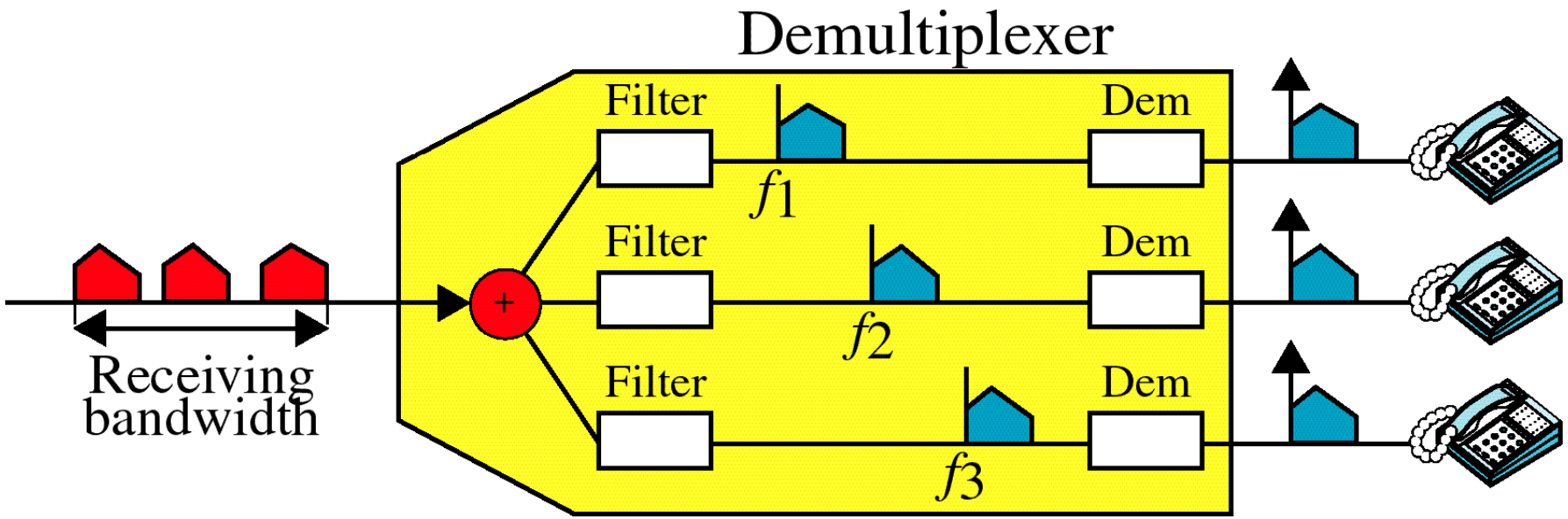
Demultiplexing

- Uses a series of filters to decompose the multiplexed signal into its constituent signals
- The individual signals passed to a demodulator
- Separates them from their carriers
- Passes them to the waiting receivers

Demultiplexing, Time Domain



Demultiplexing, Frequency Domain



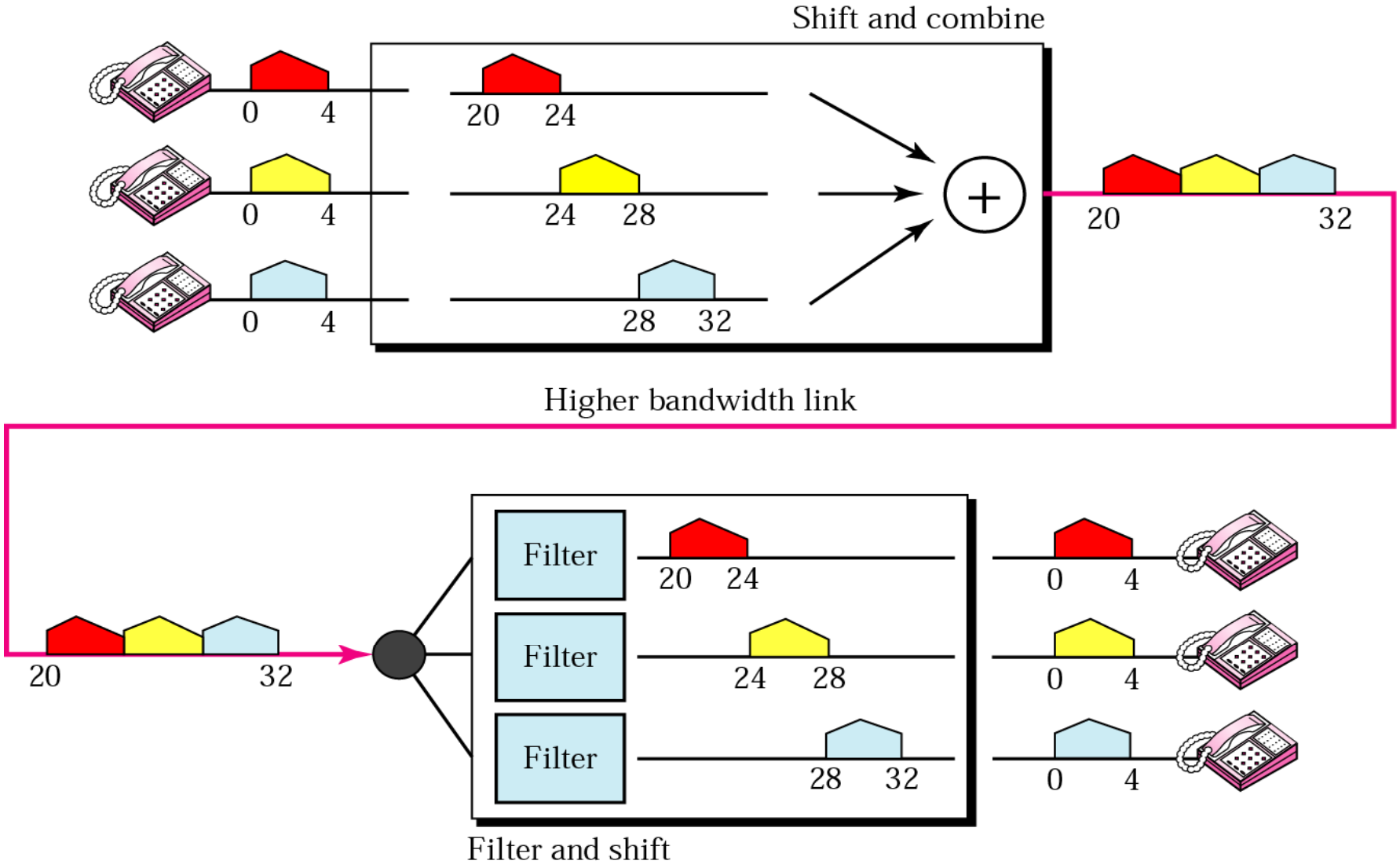
Example 1

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 without the use of guard bands.

Solution

Shift (modulate) each of the three voice channels to a different bandwidth, as shown in Figure .

Example 1


Shift and combine
0
4
20
24
0
4
24
28
0
4
28
32
20
32
Higher bandwidth link
20
32
Filter
Filter
Filter
20
24
24
28
28
32
0
4
0
4
0
4
Filter and shift

Example 2

Five channels, each with a 100-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 10 KHz between the channels to prevent interference?

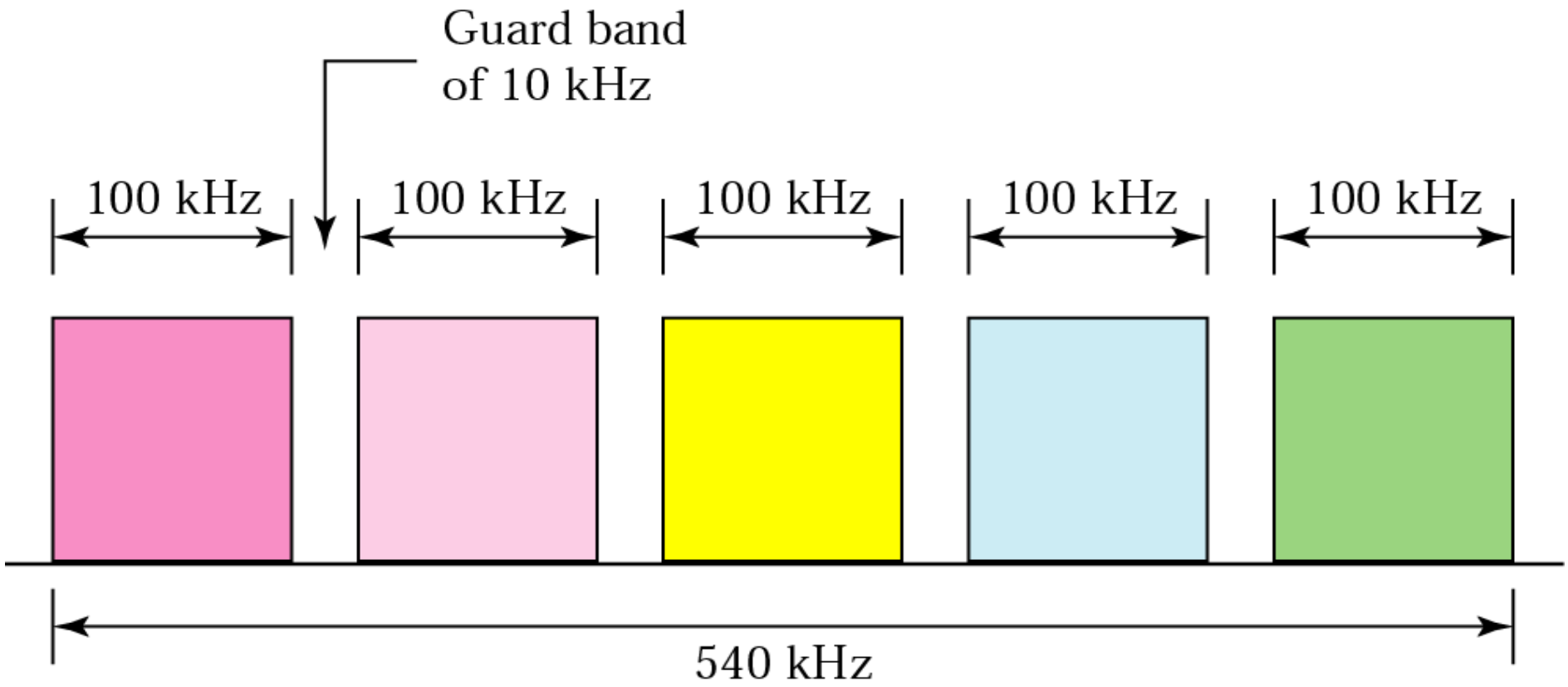
Solution

For five channels, we need at least four guard bands. This means that the required bandwidth is at least

$$5 \times 100 + 4 \times 10 = 540 \text{ KHz},$$

as shown in Figure 6.7.

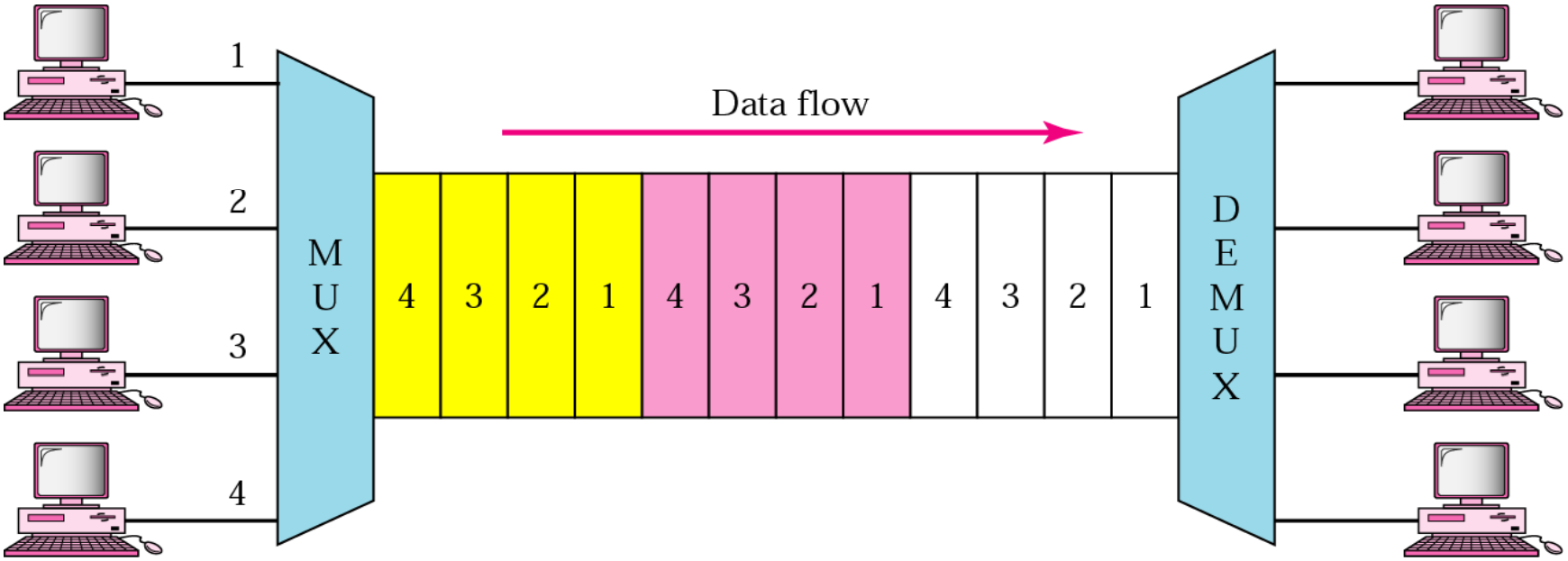
Example 2


Guard band
of 10 kHz
100 kHz
100 kHz
100 kHz
100 kHz
100 kHz
540 kHz

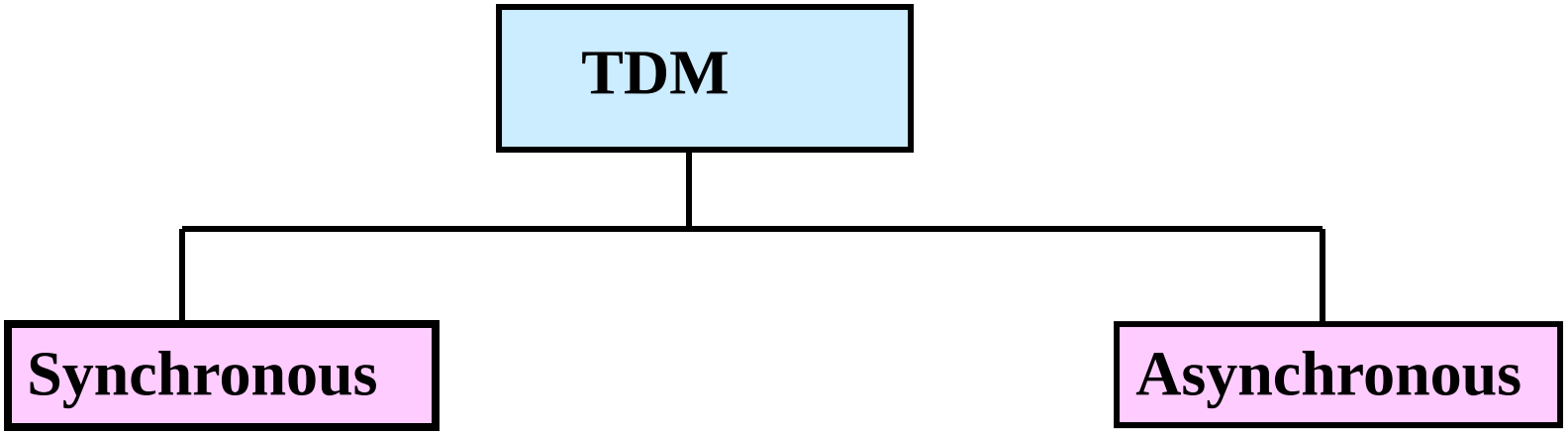
Time-Division Multiplexing(TDM)

- Digital process
- Applied when the data rate capacity of the transmission medium is greater than the data rate required by the sending and receiving devices
- Multiple transmissions can occupy a single link
- By subdividing them
- And interleaving the portions

TDM—Conceptual view



Time-Division Multiplexing(TDM)



Synchronous TDM

- The multiplexer allocates exactly the same time slot to each device at all times
- e.g. time slot A is assigned to device A alone
- Each time its allocated time slot comes up
- A device has the opportunity to send a portion of its data
- If a device is unable to transmit or does not have data to send, time slot remains empty

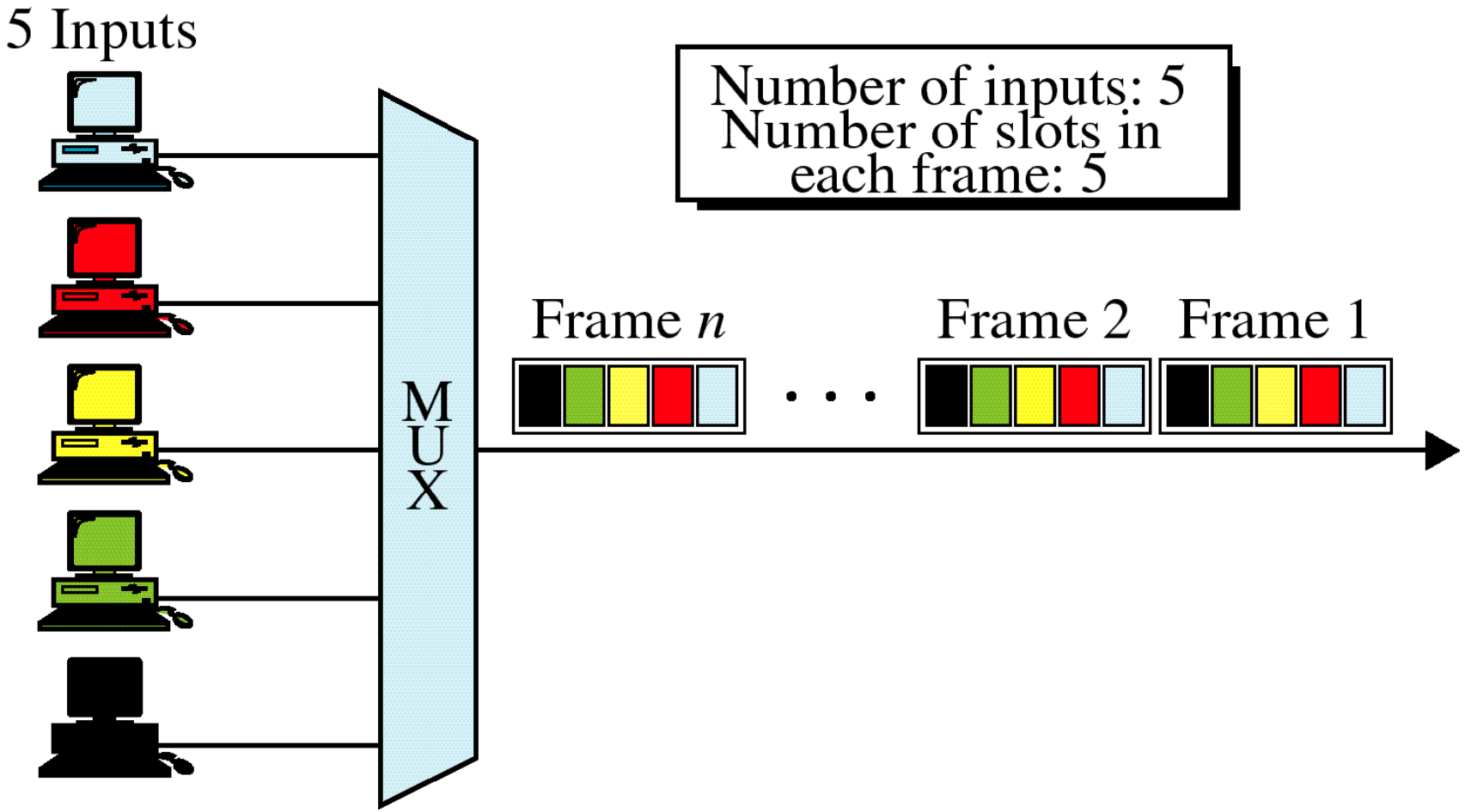
Frames

- Time slots are grouped into frames
- A frame consists of one complete cycle of time slots
- Including one or more slots dedicated to each sending device
- System with n input lines, each frame has at least n slots
- With each slot allocated to carrying data from a specific input line

Frames

- It is possible to accommodate varying data rates
- The time slots dedicated to a given device occupy the same location in each frame

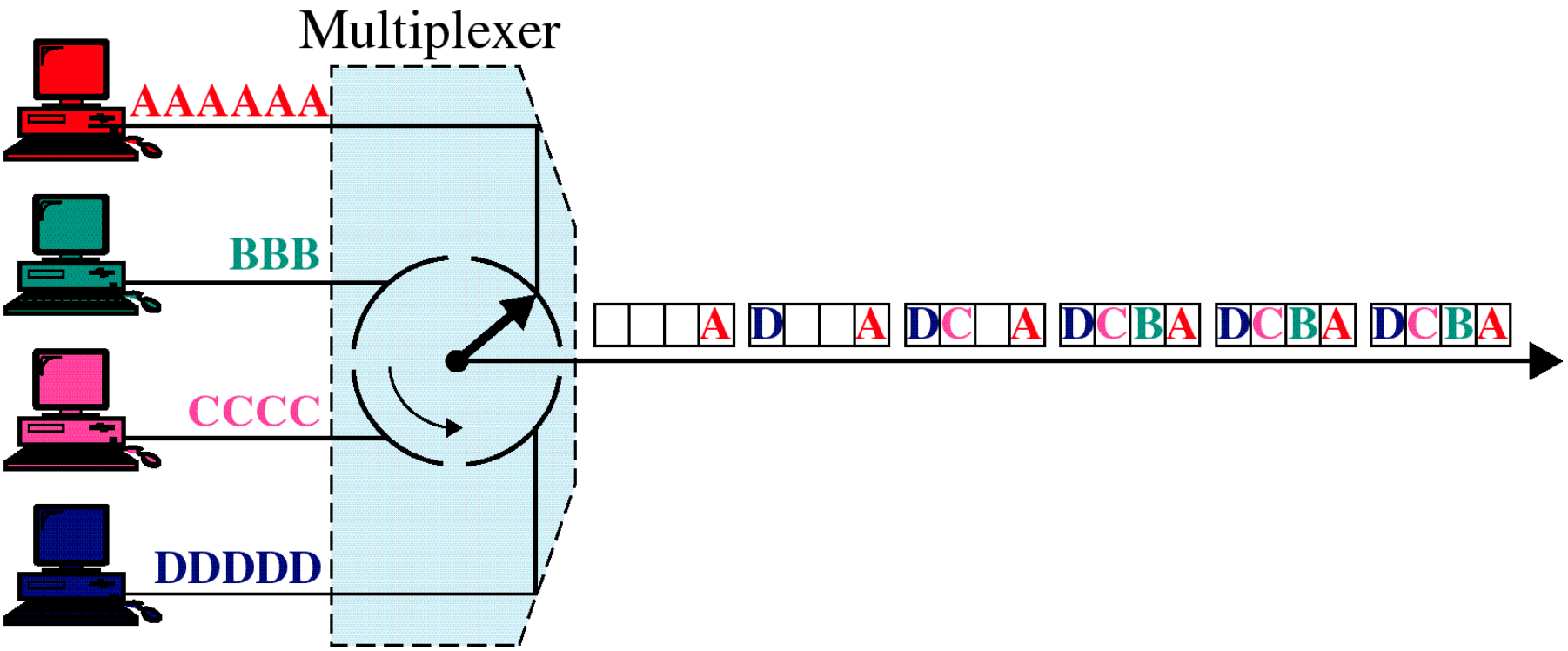
Synchronous TDM



Interleaving

- Very fast rotating switch
- The switch opens in front of a device
- Has the opportunity to send a specific amount of data onto the path
- The switch moves from device to device at a constant rate
- In a fixed order
- **Interleaving**
- Interleaving can be done by bit, byte, or by any other data unit.

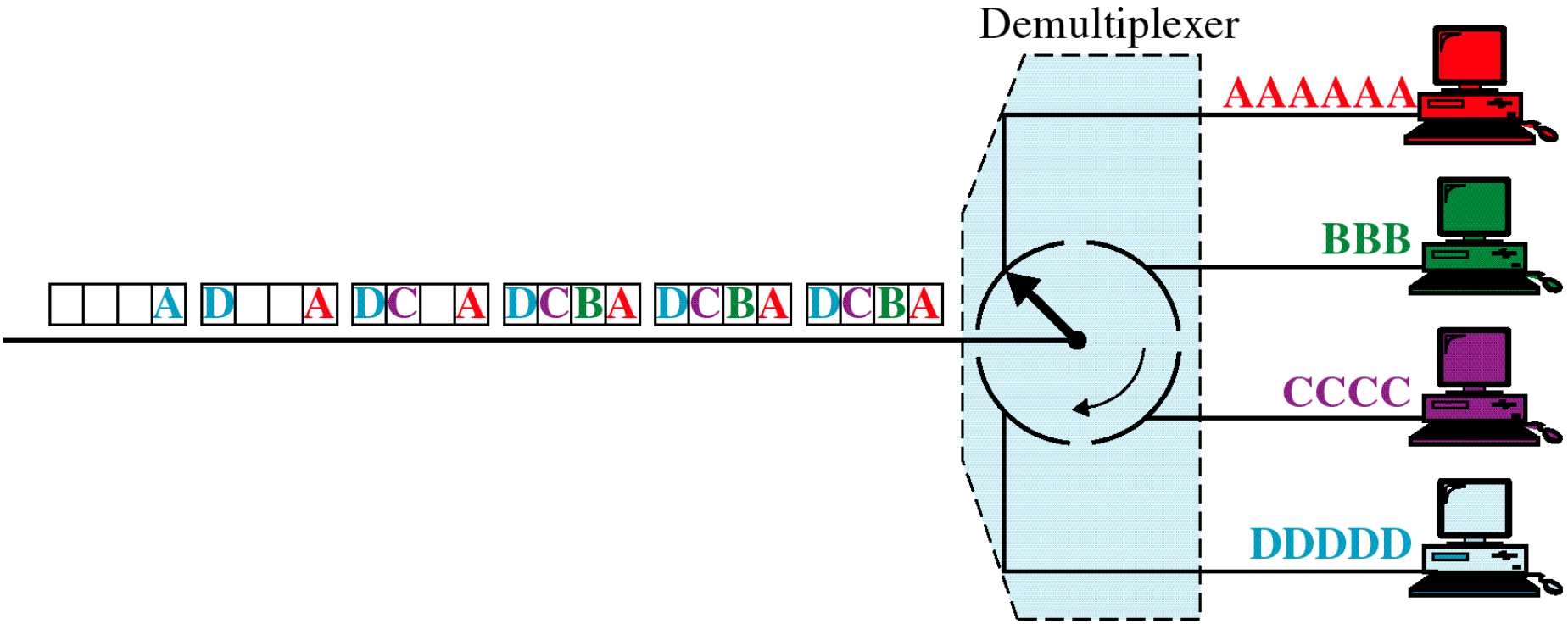
TDM, Multiplexing



Synchronous TDM Demultiplexing

- The demultiplexer decomposes each frame
- By extracting each character in turn
- A character is removed from a frame and
- Passed to the appropriate receiving device

Synchronous TDM, Demultiplexing



Con of Synchronous TDM

- Wastage of the capacity of the link
- 6 empty slots out of 24,quarter of the capacity of the link is being wasted

Class Task

- Draw the synchronous TDM frames showing the character data given the following information:

  Four signal sources:

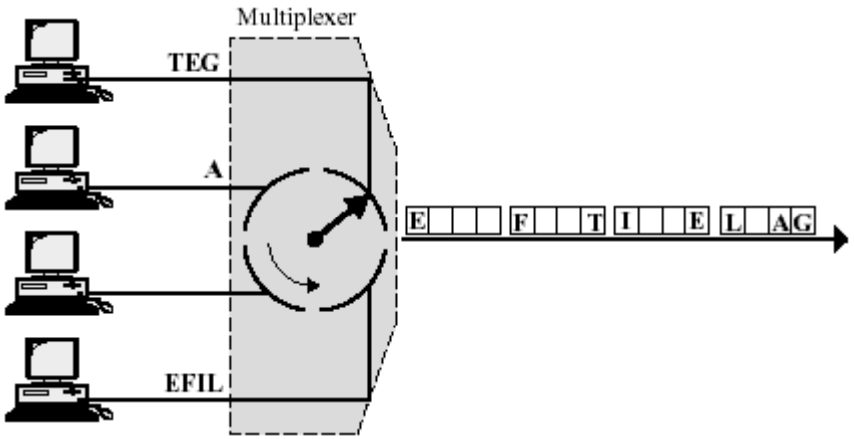
  Source 1 message: T E G

  Source 2 message: A

  Source 3 message:

  Source 4 message: E F I L

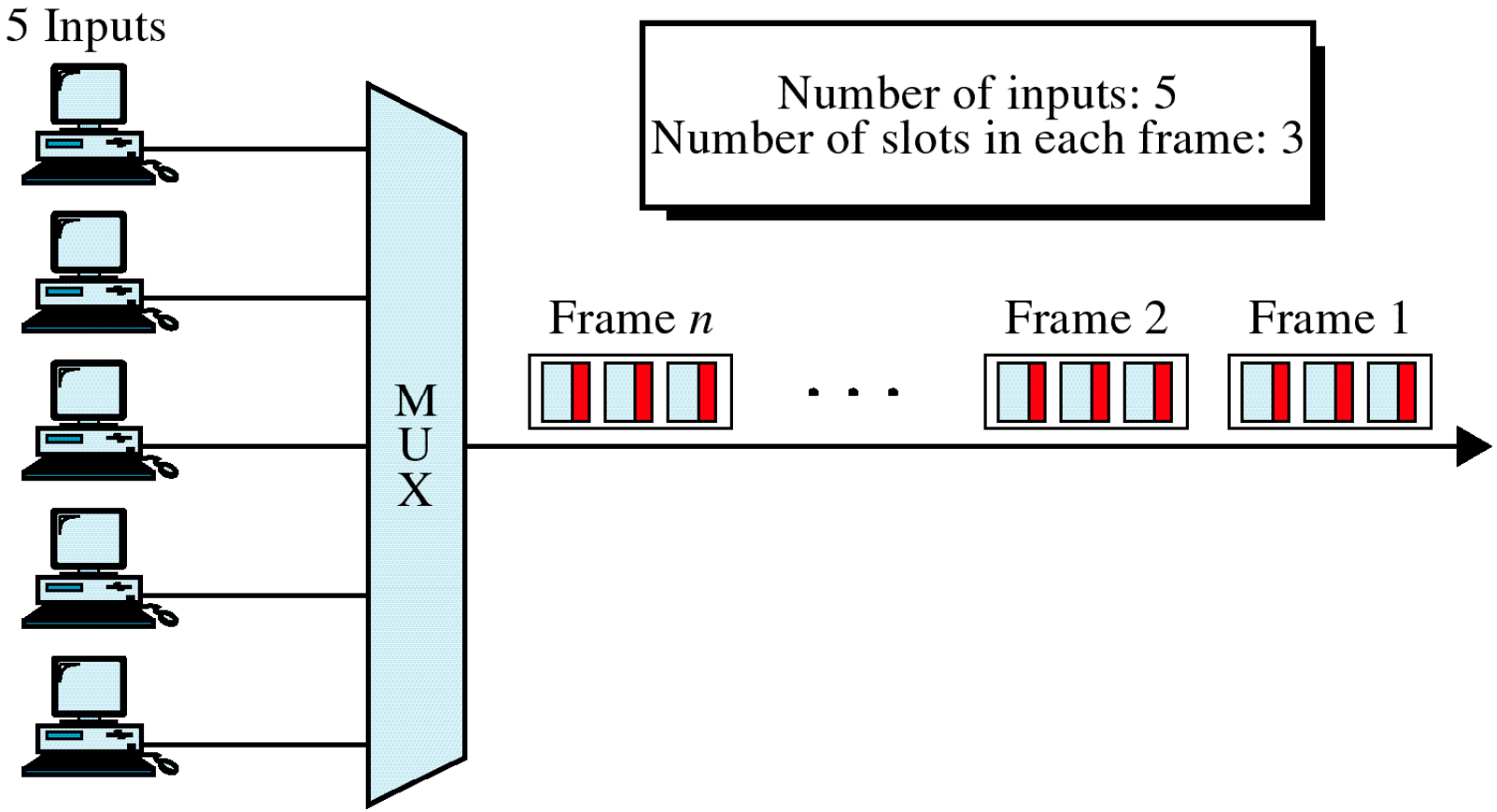
Solution



Asynchronous TDM

- Synchronous TDM: does not guarantee the full capacity of a link is used.
  - Time slots are preassigned and fixed
- Asynchronous TDM: designed to avoid this type of waste
- Asynchronous means : flexible or not fixed
- Allows a number of lower-speed input lines to be multiplexed to a single higher-speed line
- The total speed of the input lines can be greater than the capacity of the path

Asynchronous TDM



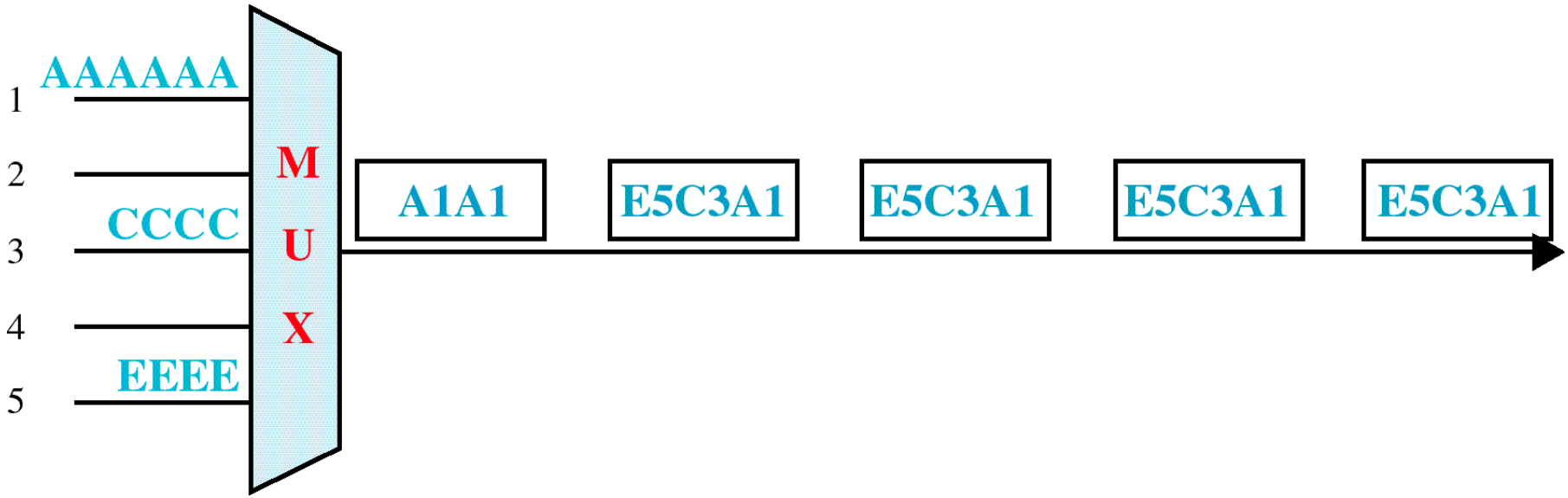
Asynchronous TDM

- N input lines, the frame contains mo more than m slots, m<n
- The number of time slots (m) is based on a statistical analysis of the number of input lines
- Each slot is available to any of the attached input lines that has data to send
- Multiplexer: scans the input lines, accepts portion of data until a frame is filled, then sends the frame

Asynchronous TDM

- Not enough data to fill all the slots in a frame
  - The frame is transmitted only partially filled
  - The full link capacity may not be used 100%
  - Ability to allocate time slots dynamically reduces the degree of waste
- Statistical or Intelligent TDM

Frames and Addresses



a. Case 1:only three lines sending data

Frames and Addresses

b. Case 2:only four lines sending data

Frames and Addresses

c. Case 3: all five lines sending data

Class Task from Asynchronous TDM

- Draw the Asynchronous TDM frames showing the character data given the following information:

  Four signal sources:

  Source 1 message: T E G

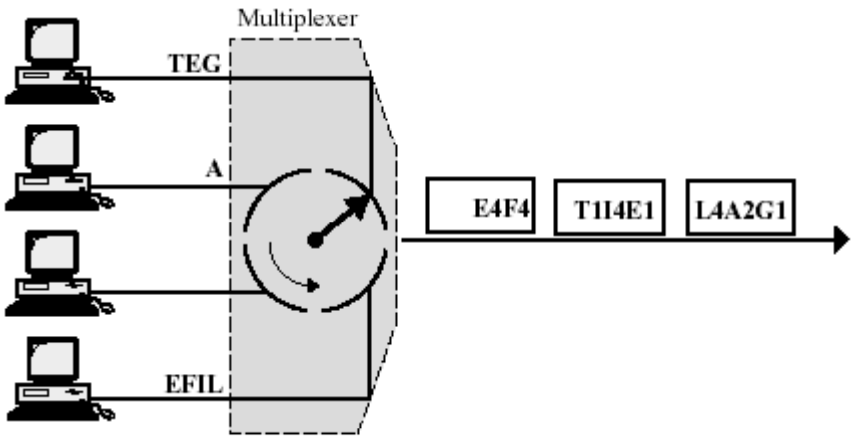
  Source 2 message: A

  Source 3 message:

  Source 4 message: E F I L

Assume a frame size of three characters.

Solution



Addressing and Overhead

- Each time slot must carry an address
- To tell the demultiplexer how to direct the data
- Attached by the multiplexer
- Discarded by the demultiplexer
- Adding address bits to each time slots: increases overhead
- The need for addressing makes asynchronous TDM inefficient for bit or byte interleaving

Variable-length time slots

- Can accommodate traffic of varying data rates by varying the length of the time slots
- Stations transmitting at a faster data rate can be given a longer slot
- Managing variable length fields requires control bits be appended
- To the beginning of each time slot
- Extra bits also increase the overhead of the system

Class task

- Figure shows a statistical TDM multiplexer. How much is the data rate of each line reduced if all 10 lines are sending data? How many stations can send data at the same time with full capacity?

Solution

- Data rate of each line: 40 Kbps
- Number of stations sending at full capacity: 8