Computer Networks

Multiplexing

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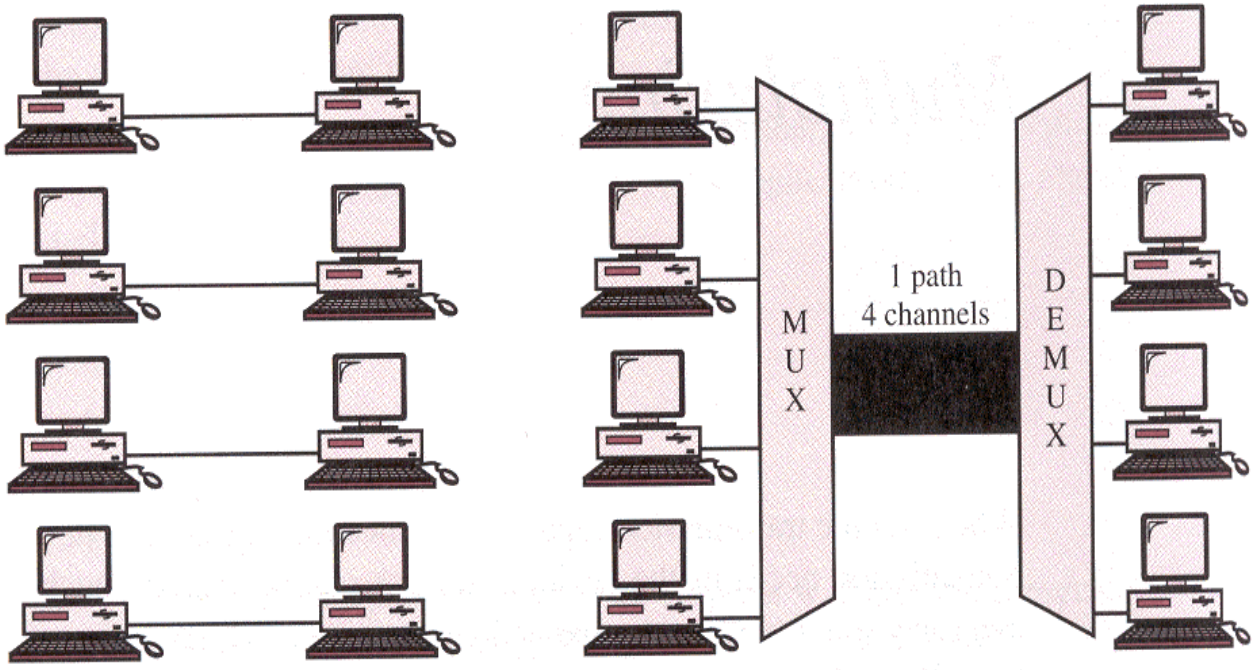
Multiplexing

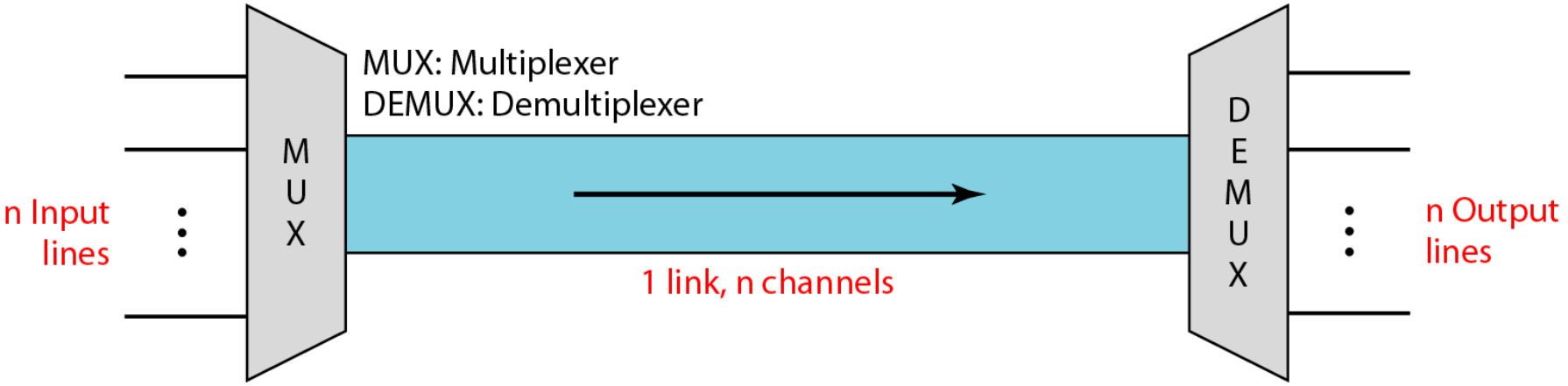
- Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link
- **Multiplexer** (MUX): A device that combines several signals into a single signal
- **Demultiplexer** (DEMUX): A device that performs the inverse operation

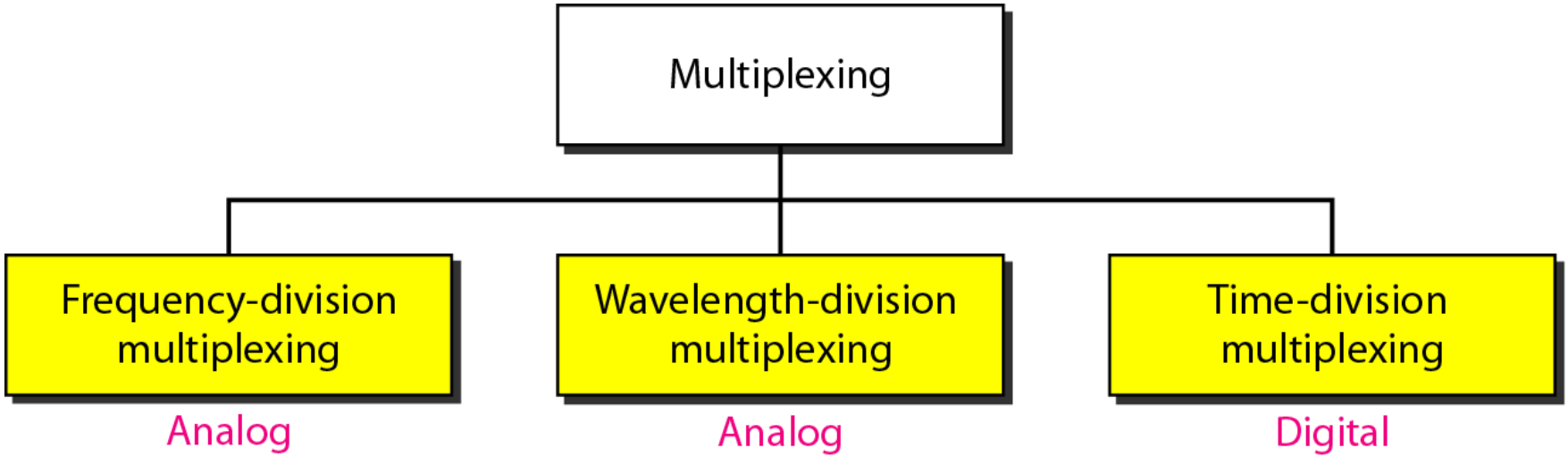


a. No multiplexing

b. Multiplexing

Multiplexing

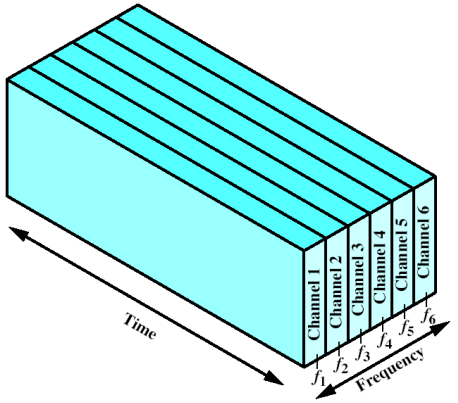




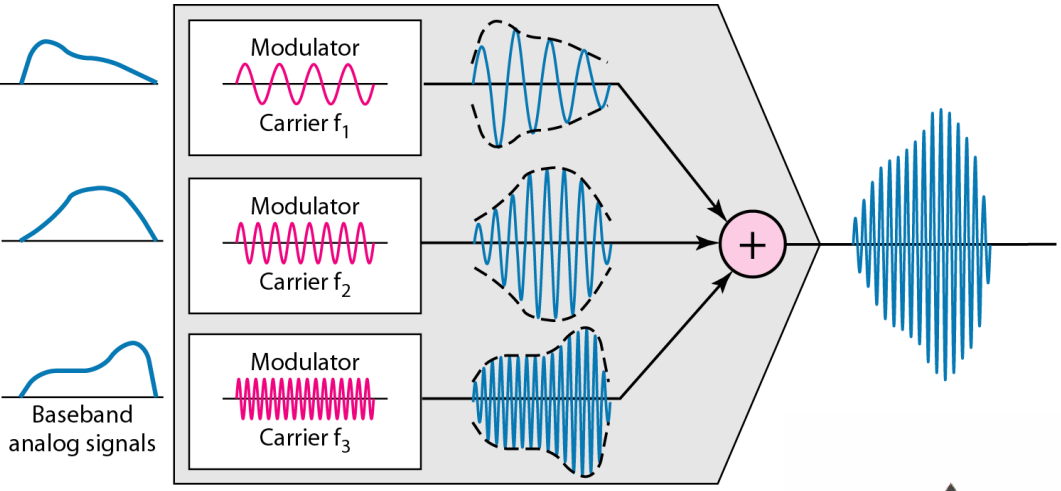
Frequency Division Multiplexing

FDM

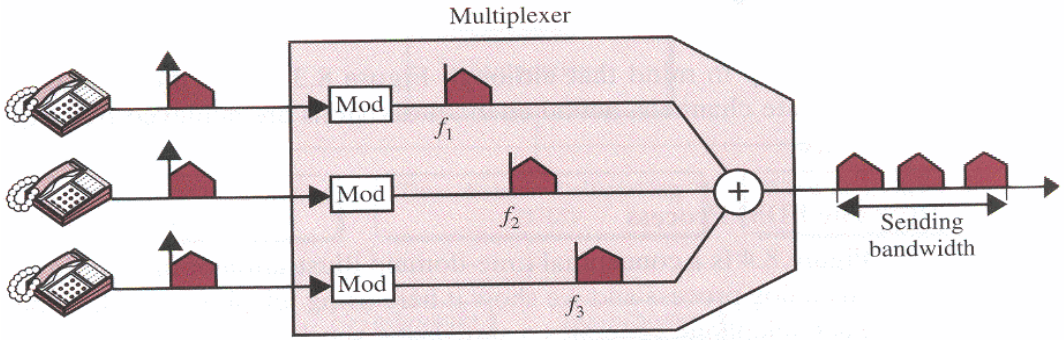
- Each signal is allocated a different frequency band
- Usually used with analog signals
- Modulation equipment is needed to move each signal to the required frequency band (channel)
- Multiple carriers are used, each is called sub-carrier



(a) Frequency division multiplexing



$$B > \sum_{i=1}^{n} B_i$$



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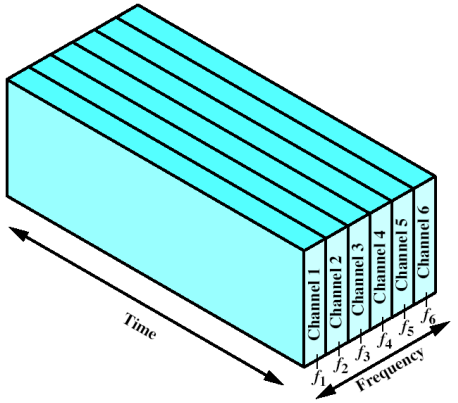

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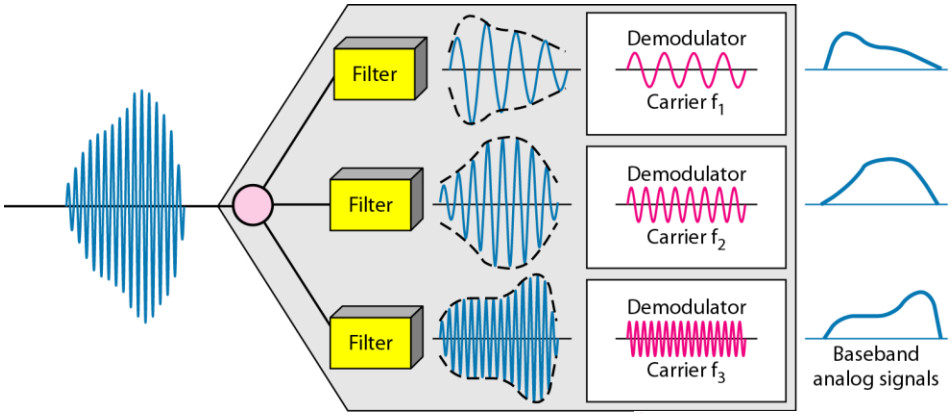

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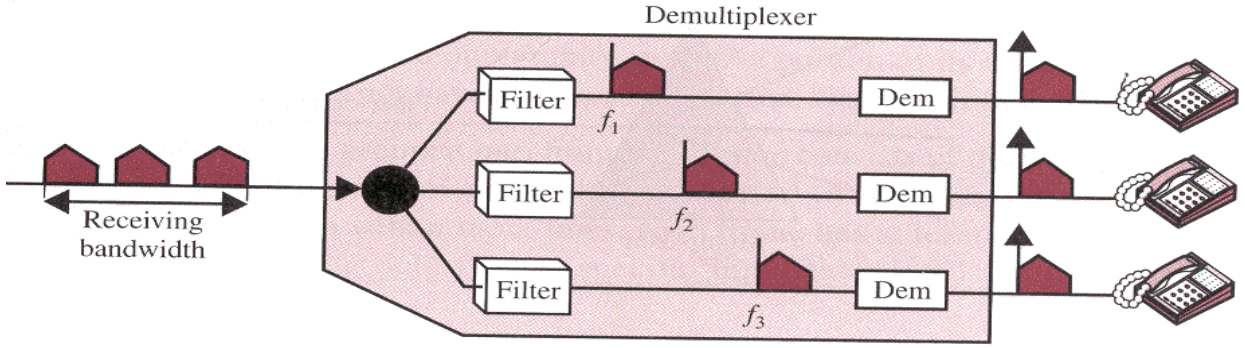
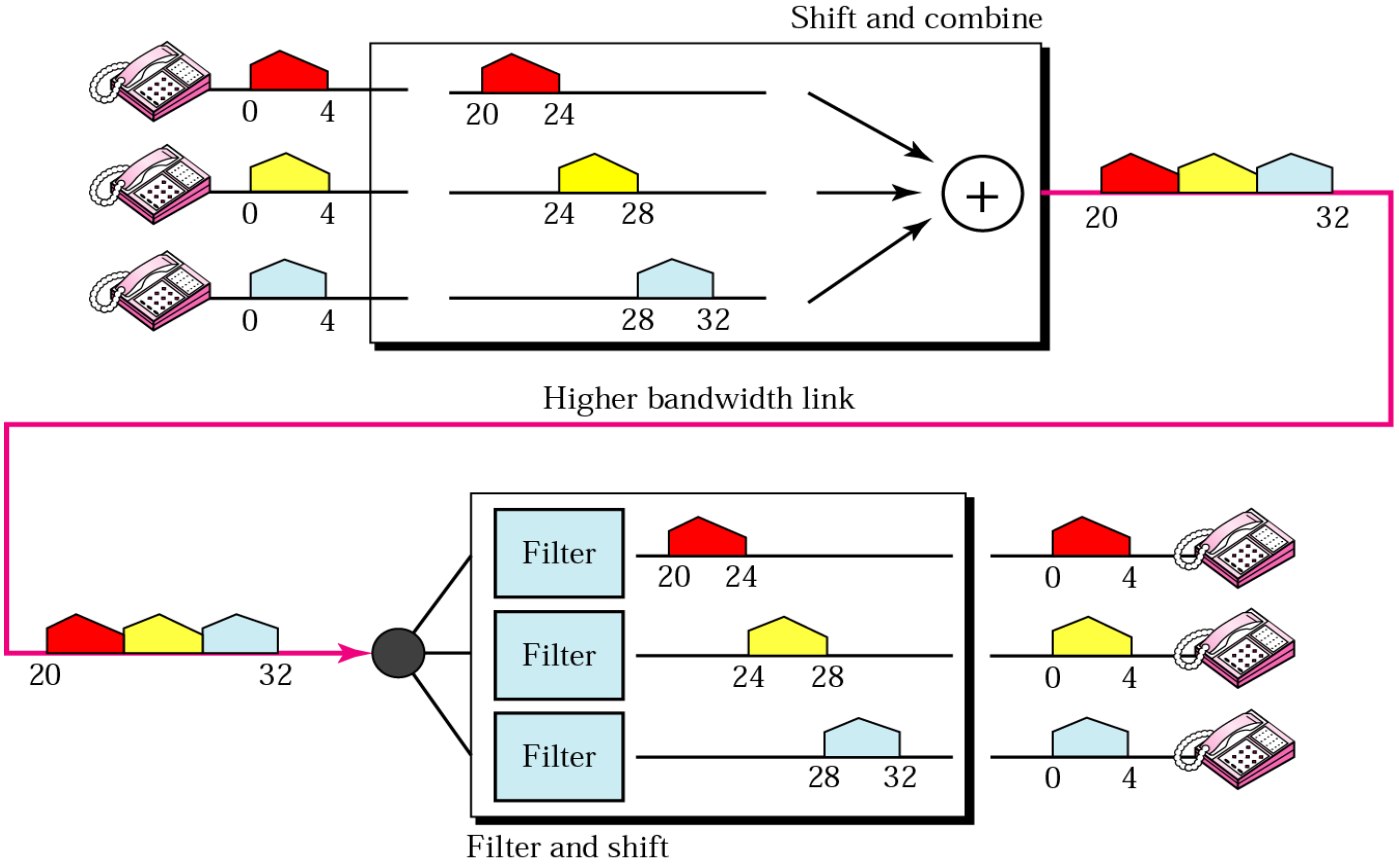


FDM: Example 1

- 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.

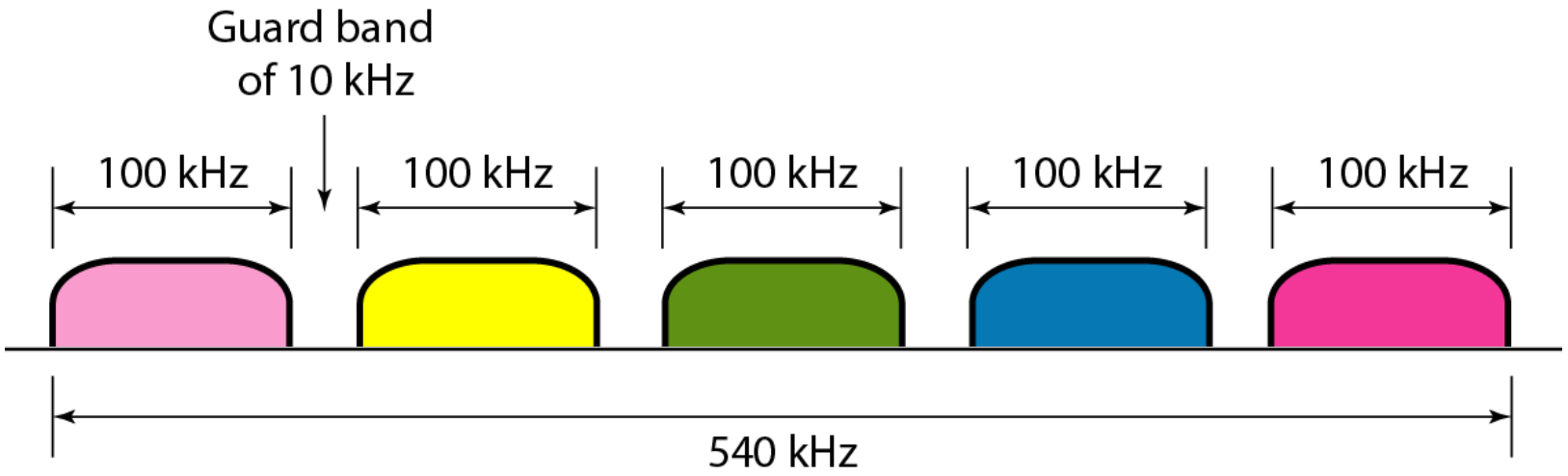


FDM: Example 2

- 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?

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

5 x 100 + 4 x 10 = 540 KHz

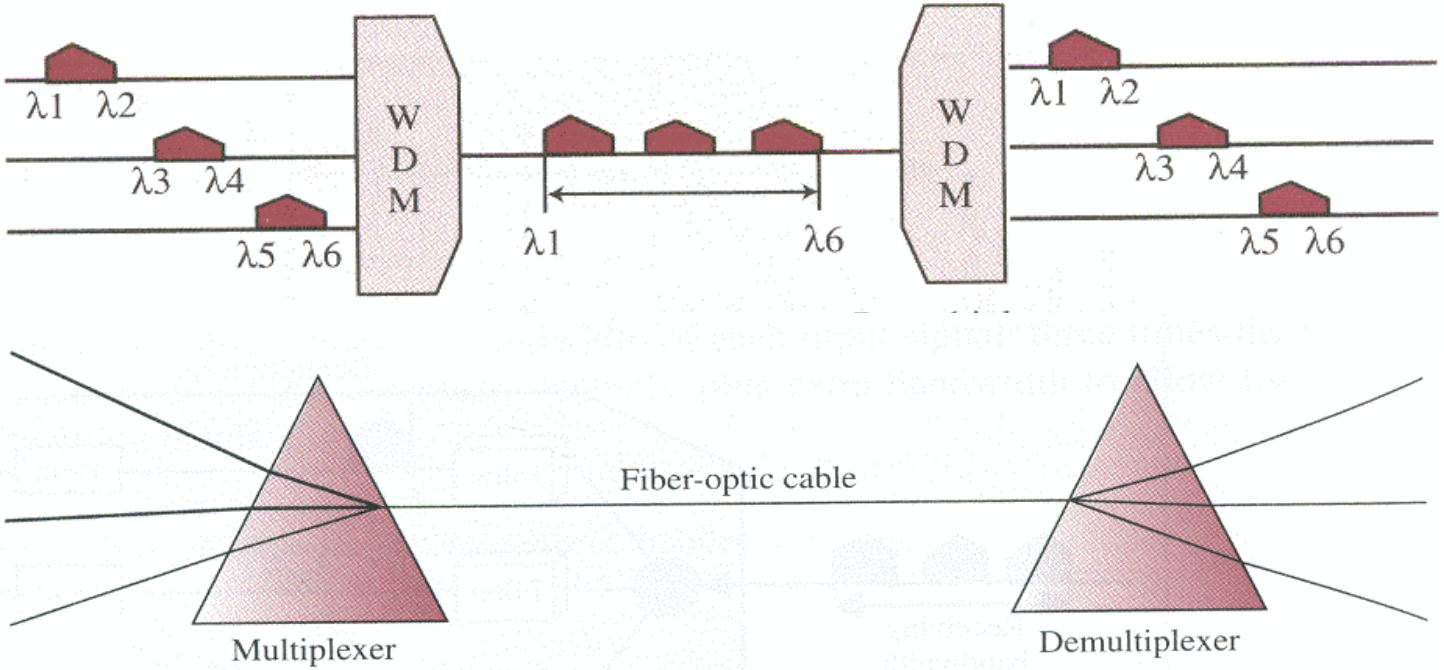


Wavelength Division Multiplexing

WDM

- Wave-division multiplexing is conceptually the same as FDM, except that multiplexing and demultiplexing involve light signals transmitted through fiber-optic channels

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

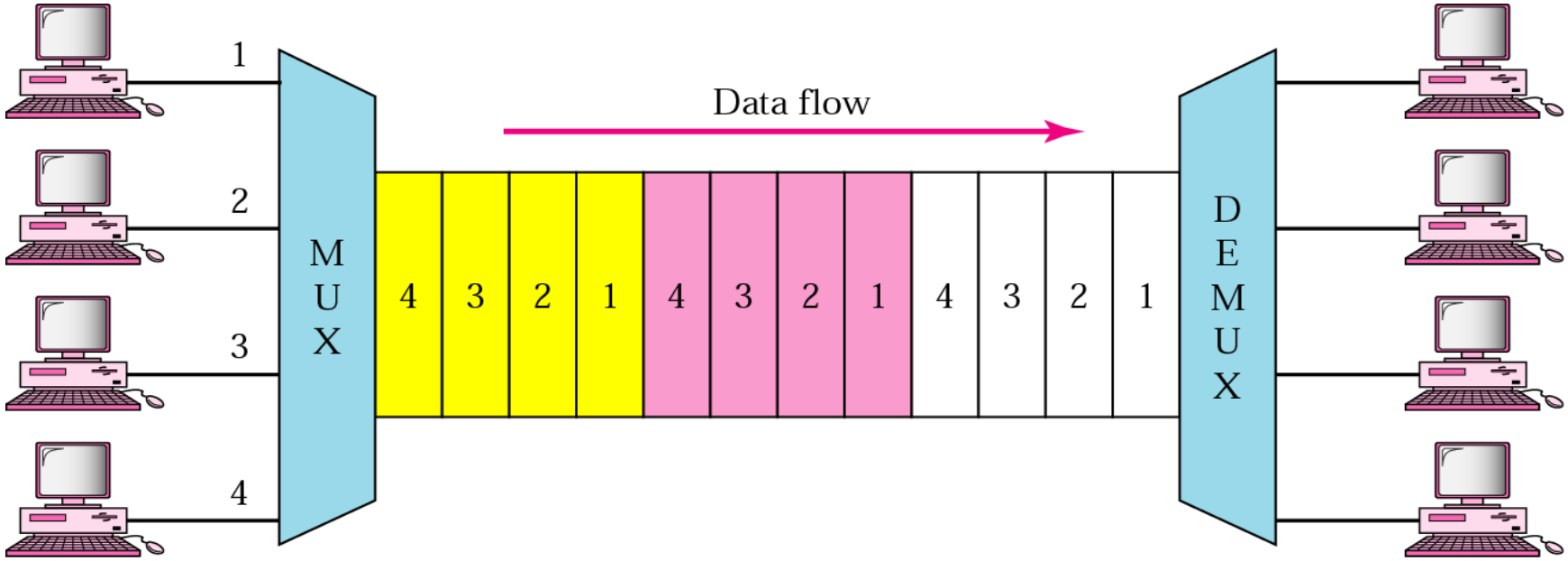


Time Division Multiplexing

TDM

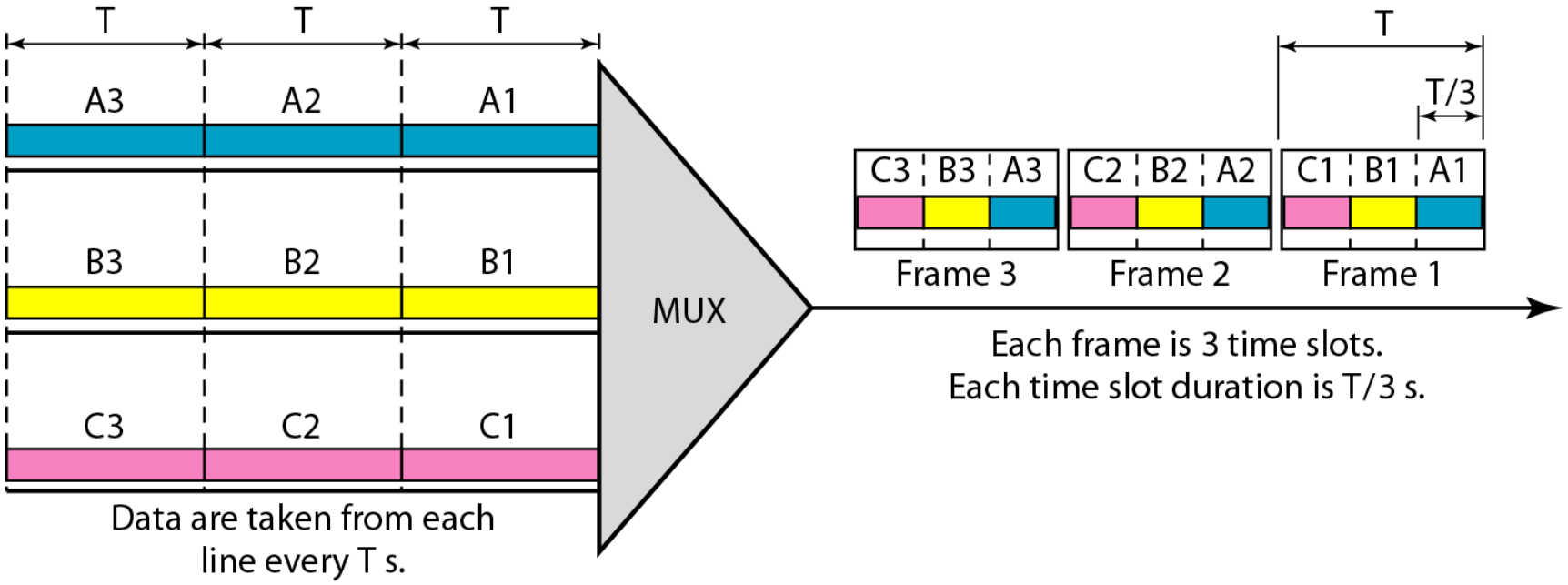
- TDM is a digital process that can be applied when the **data rate capacity of the transmission medium is greater than the data rate required by the sending and receiving devices**

- TDM:
  - Synchronous TDM
  - Asynchronous TDM



Synchronous TDM

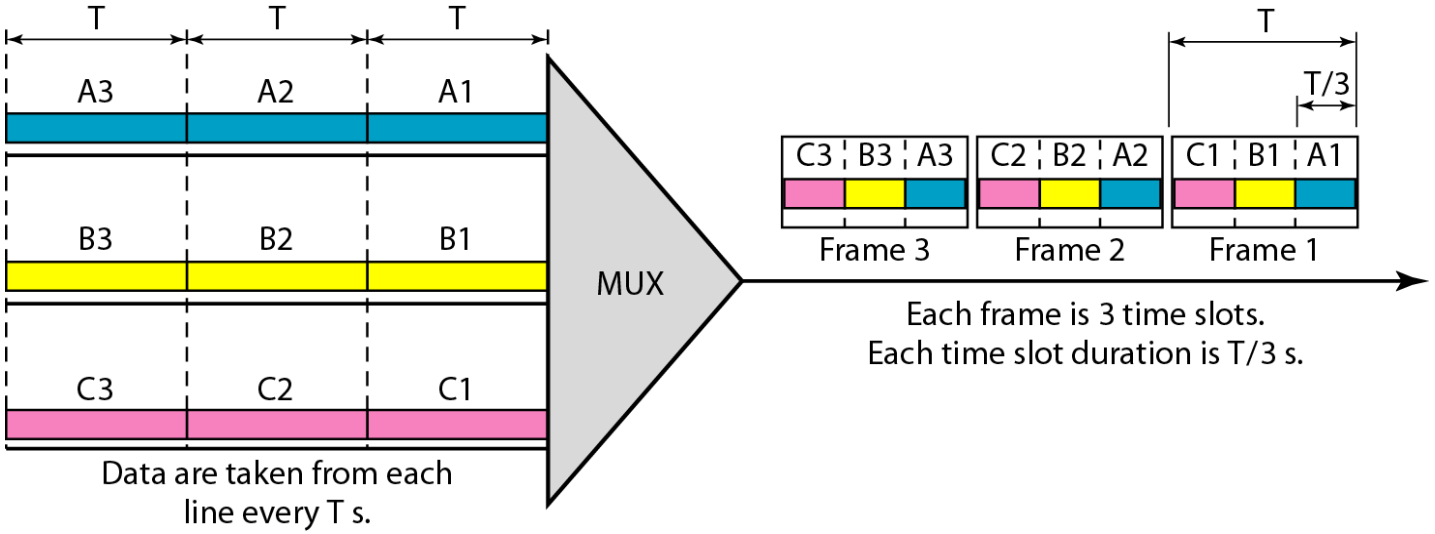
- Multiplexer allocates exactly the same time slot to each device at all times, whether or not a device has anything to transmit



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

Synchronous TDM: Example 1

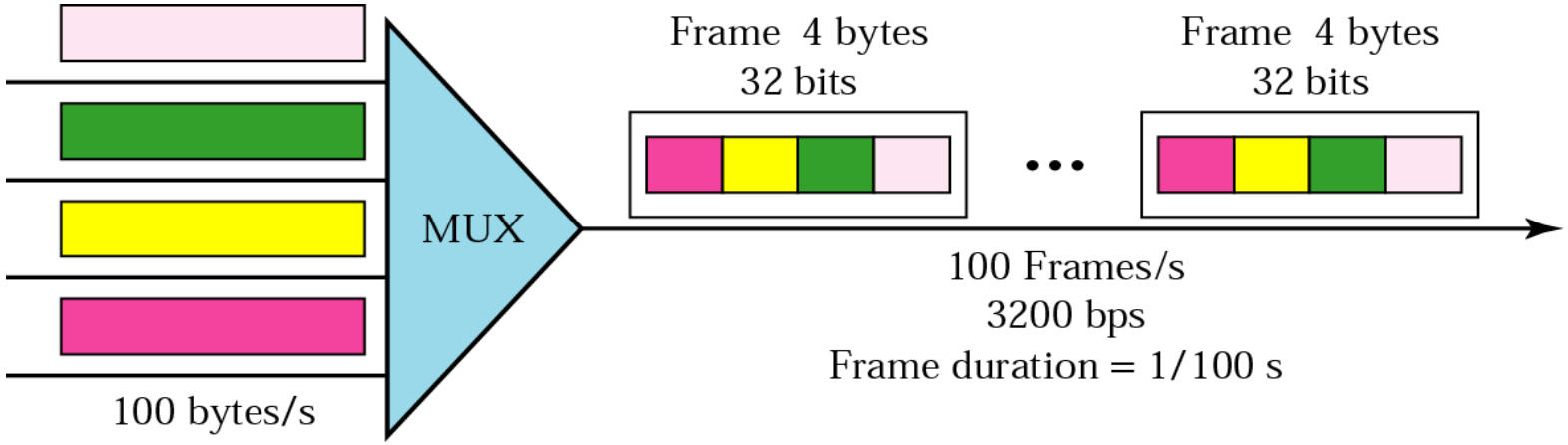
- Four 1-Kbps connections are multiplexed together. A unit is 1 bit. Find (1) the duration of 1 bit before multiplexing, (2) the transmission rate of the link, (3) the duration of a time slot, and (4) the duration of a frame?



1. ***The duration of 1 bit is 1/1 Kbps, or 0.001 s (1 ms).***
2. ***The rate of the link is 4 Kbps.***
3. ***The duration of each time slot 1/4 ms or 250 μs.***
4. ***The duration of a frame 1 ms.***

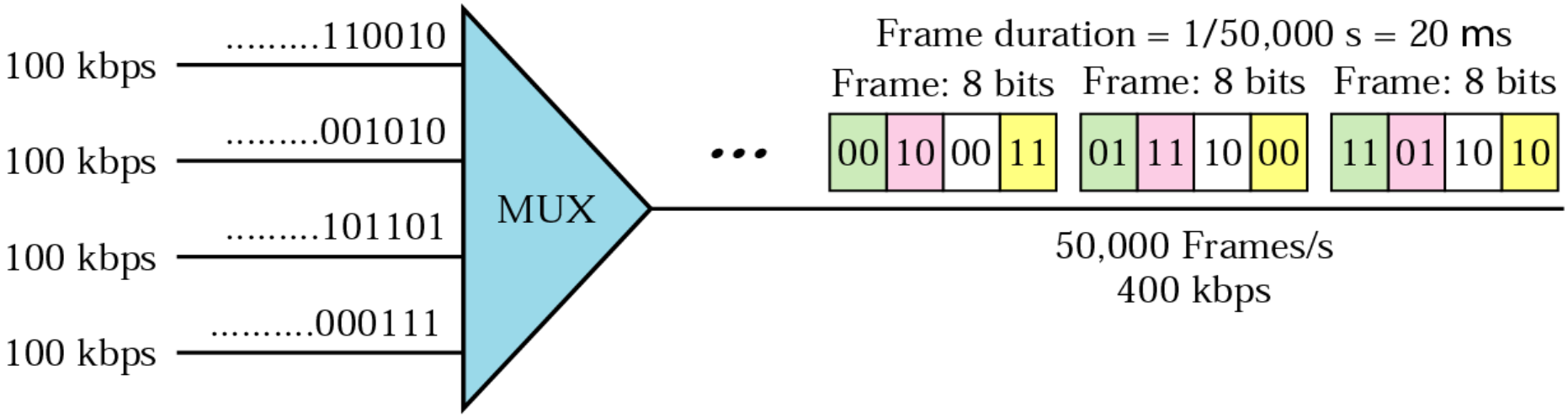
Synchronous TDM: Example 2

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



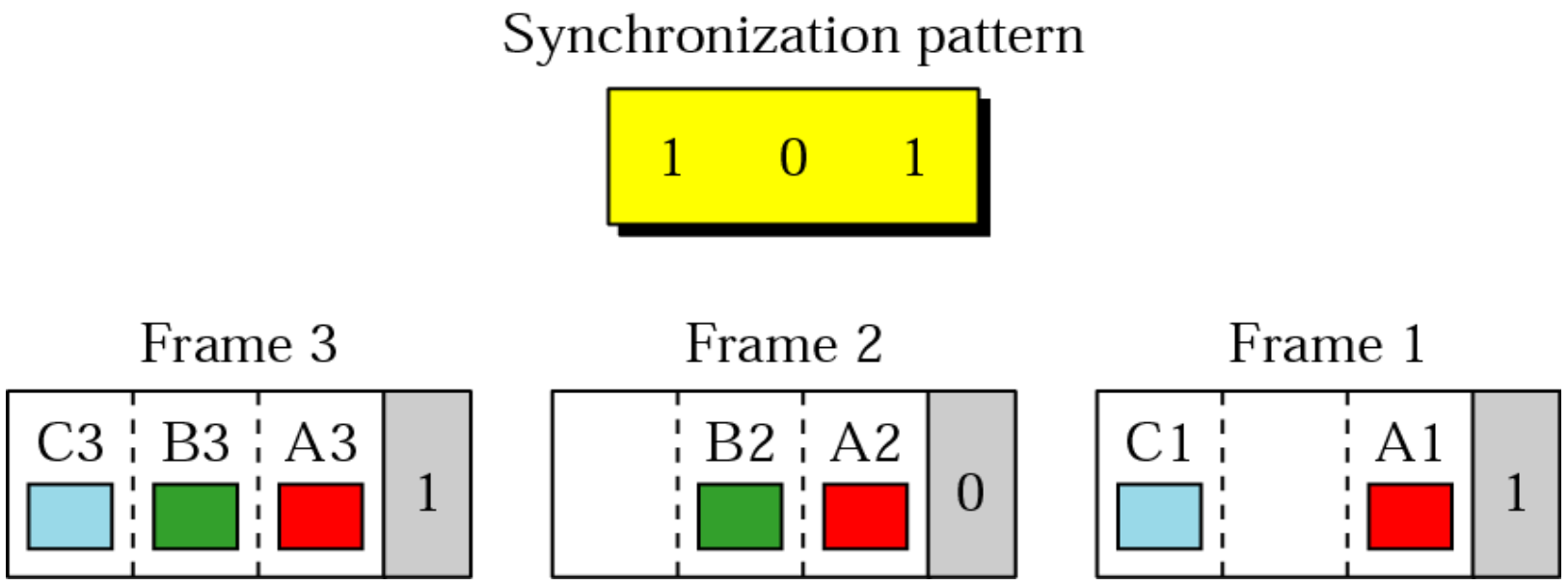
Synchronous TDM: Example 3

- A multiplexer combines four 100-Kbps channels using a time slot of 2 bits. Show the output with four arbitrary inputs. What is the frame rate? What is the frame duration? What is the bit rate? What is the bit duration?



Synchronous TDM: Synchronization

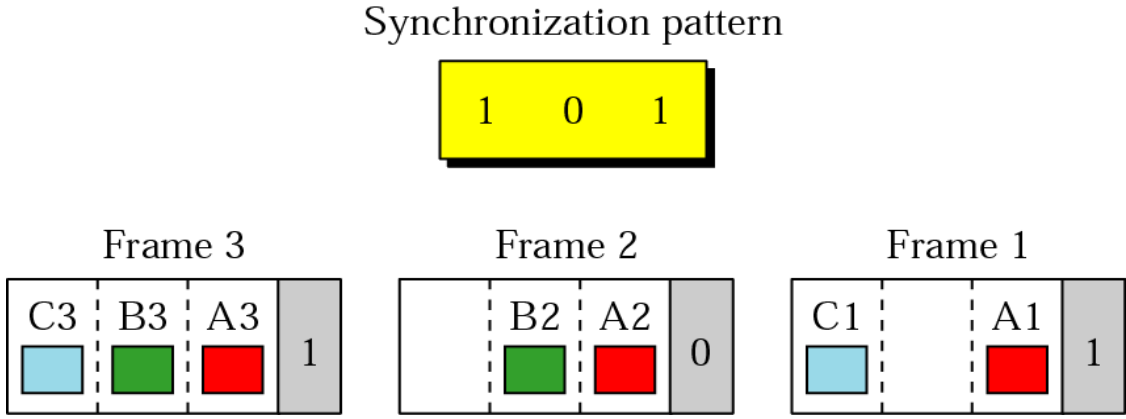
- **Framing bits:** Because the time slot order in a synchronous TDM system does't no vary from frame to frame, very little overhead information needs to be included in each frame. However, one or more synchronization bits are usually added to the beginning of each frame. These bits, called framing bits, allows the demultiplexer to synchronize with the incoming stream so that it can separate the time slot accurately



Synchronous TDM: Example 4

- Suppose that we have four input devices on a synchronous TDM link, where the transmissions are interleaved by character. If each device is generating 250 characters per second, and each frame is carrying 1 character from each device, what is the minimum data rate of this link?

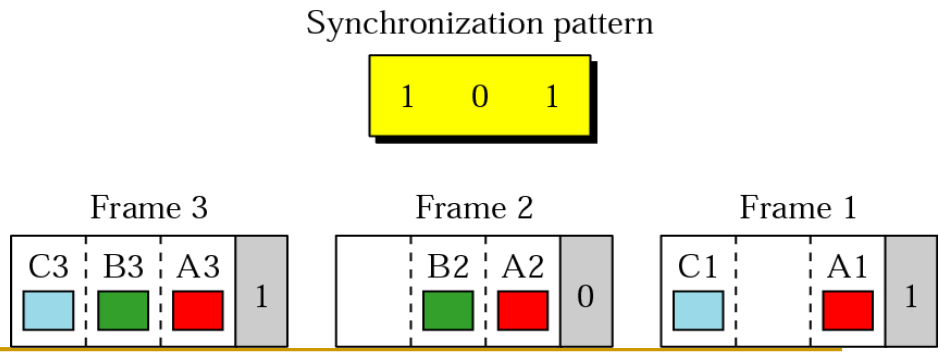
- Answer:
  - The link must be able to carry 250 frames per second.
  - If we assume that each character consists of 8 bits, then each frame has 4x8 + 1= 33 bits (32 bits for the four characters plus 1 framing bit).
  - On the other hand, each device is creating 2000bps, because 250 characters per second x 8 bits =2000 bits per second, and the link is carrying 8250 bps, because 250 frames per second x33 bits is 8250 bps.



Synchronous TDM: Example 5

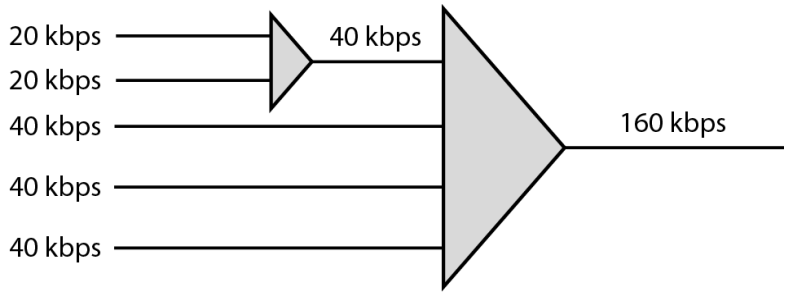
- We have four sources, each creating 250 characters per second. If the interleaved unit is a character and 1 synchronizing bit is added to each frame, find (1) the data rate of each source, (2) the duration of each character in each source, (3) the frame rate, (4) the duration of each frame, (5) the number of bits in each frame, and (6) the data rate of the link.

- Answer:
  - 1. The data rate of each source is 2000 bps = 2 Kbps.
  - 2. The duration of a character is 1/250 s, or 4 ms.
  - 3. The link needs to send 250 frames per second.
  - 4. The duration of each frame is 1/250 s, or 4 ms.
  - 5. Each frame is 4 x 8 + 1 = 33 bits.
  - 6. The data rate of the link is 250 x 33, or 8250 bps.

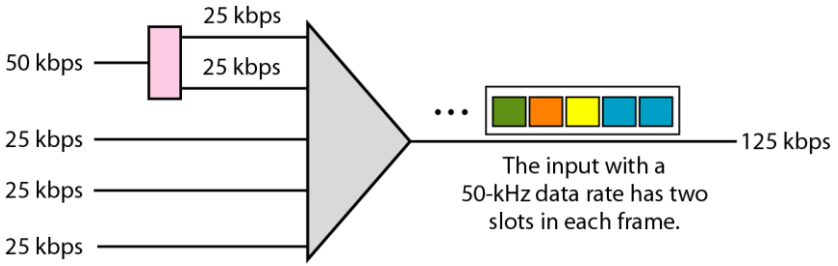


Synchronous TDM: Data Rate Management

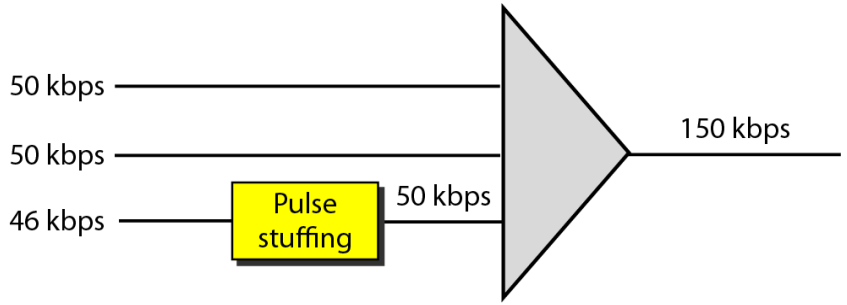
- Multilevel: used when the data rate of the input links are multiples of each other



- Multislot: The higher bit rate channels are allocated more slots per frame, and the output frame rate is a multiple of each input link.

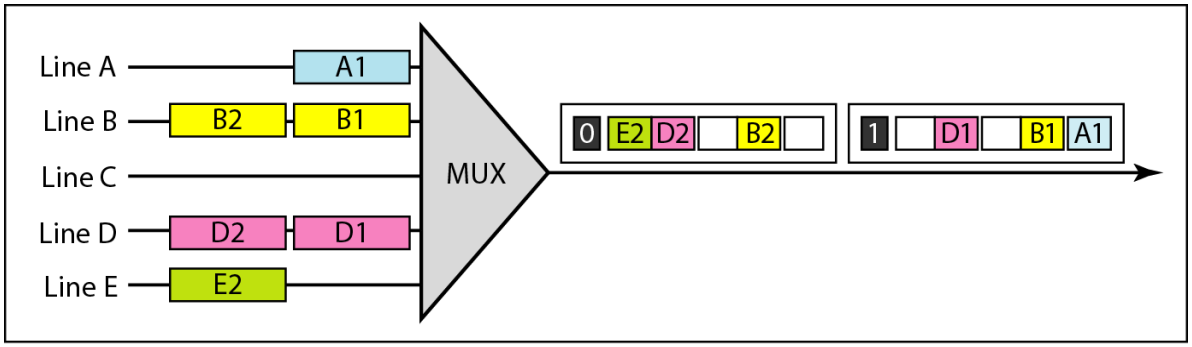


- Pulse Stuffing: The slowest speed link will be brought up to the speed of the other links by bit insertion, this is called pulse stuffing.

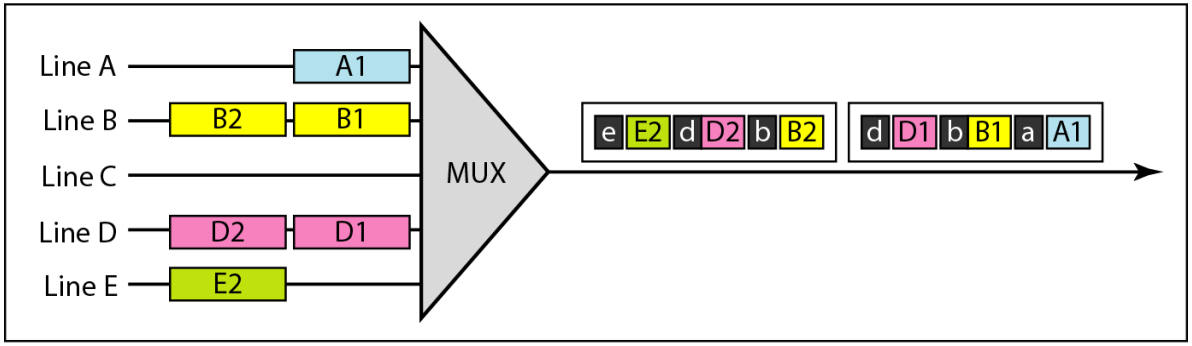


Statistical TDM

- Synchronous TDM does not guarantee that the full capacity of a link is used. Because the time slots are preassigned and fixed, whenever a connected device is not transmitting, the corresponding slot is empty.
- Asynchronous time-division multiplexing, or statistical time-division multiplexing, is designed to avoid this type of waste



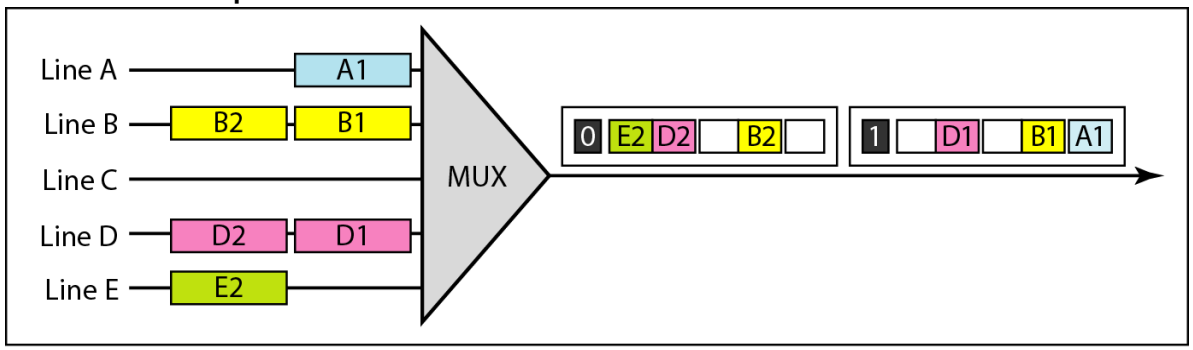
a. Synchronous TDM



b. Statistical TDM

Statistical TDM

- Line data rate lower than input lines rates
- Overhead per slot for statistical TDM because each slot carries an address as well as data
- May have problems during peak periods
  - Must buffer inputs



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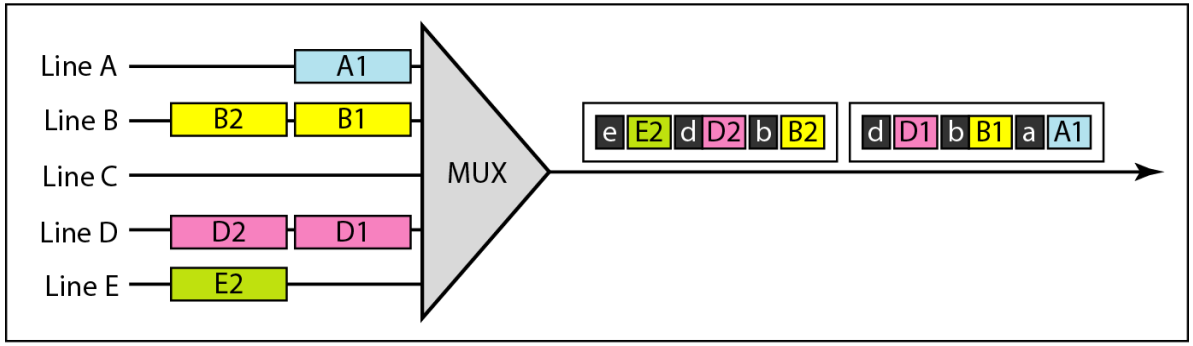

b. Statistical TDM

THANK YOU

QUESTIONS???