

Computer Networks(CS30006)

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Bandwidth Utilization & Multiplexing

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Bandwidth Utilization



Bandwidth: The maximum amount of data transmitted over an internet connection in a given amount of time.

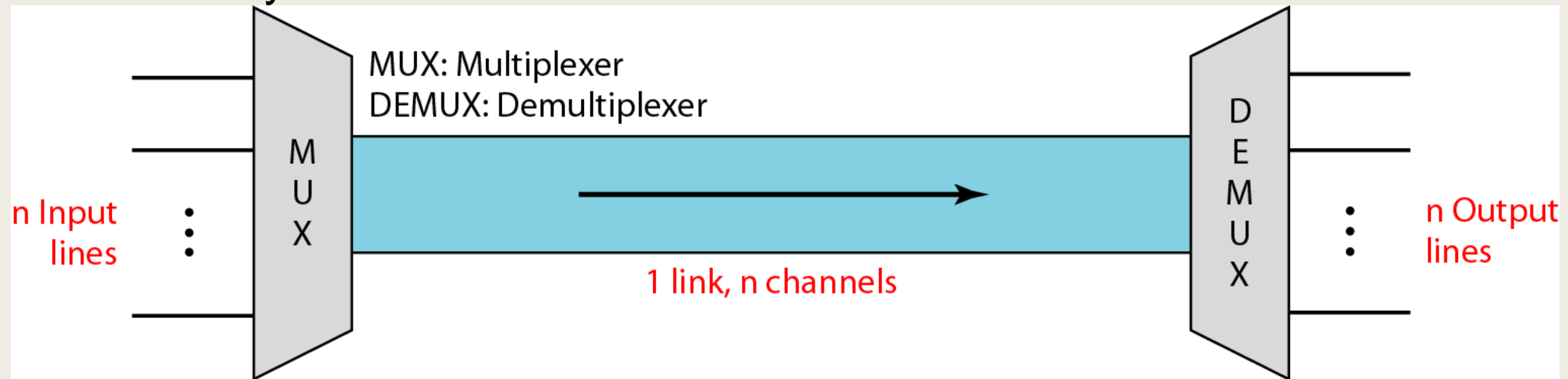
Bandwidth utilization : Bandwidth utilization is the wise use of available bandwidth to achieve specific goals.

Efficiency can be achieved by multiplexing; i.e., sharing of the bandwidth between multiple users.

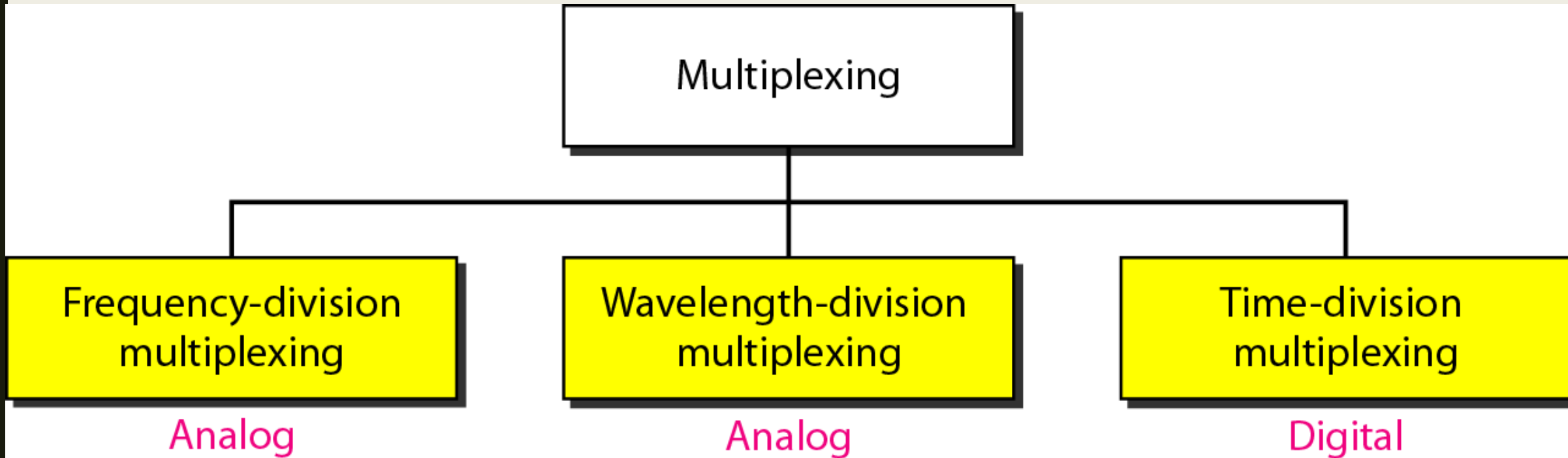
Multiplexing



- Multiplexing is the process of combining multiple signals into one signal, over a shared medium.
- It describes how several users can share a medium with minimum or no interference.
- It divides the high capacity medium into low capacity logical medium which is then shared by different streams.

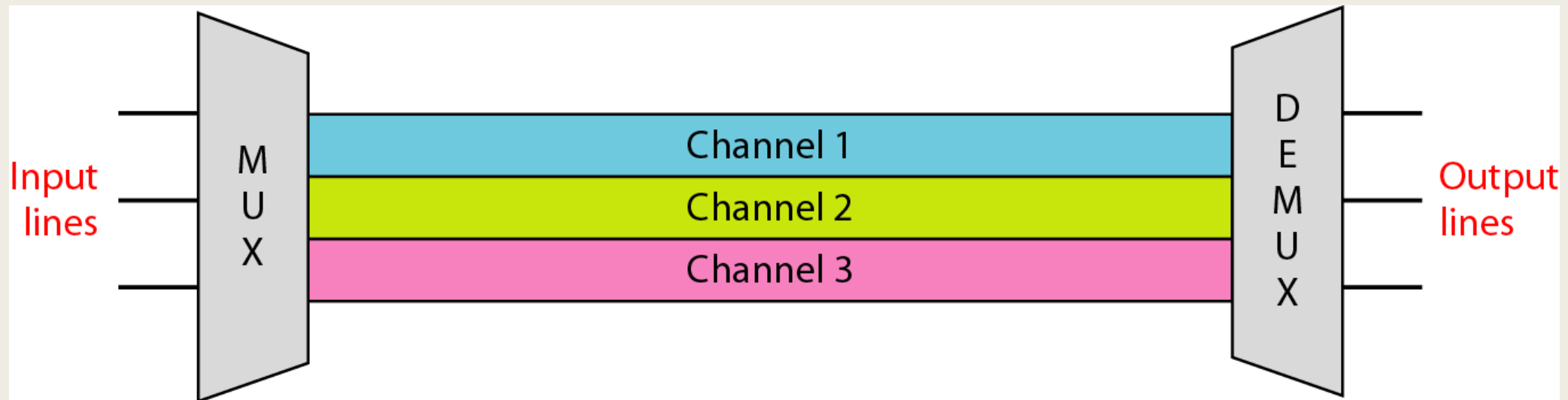


Categories



Frequency Division Multiplexing

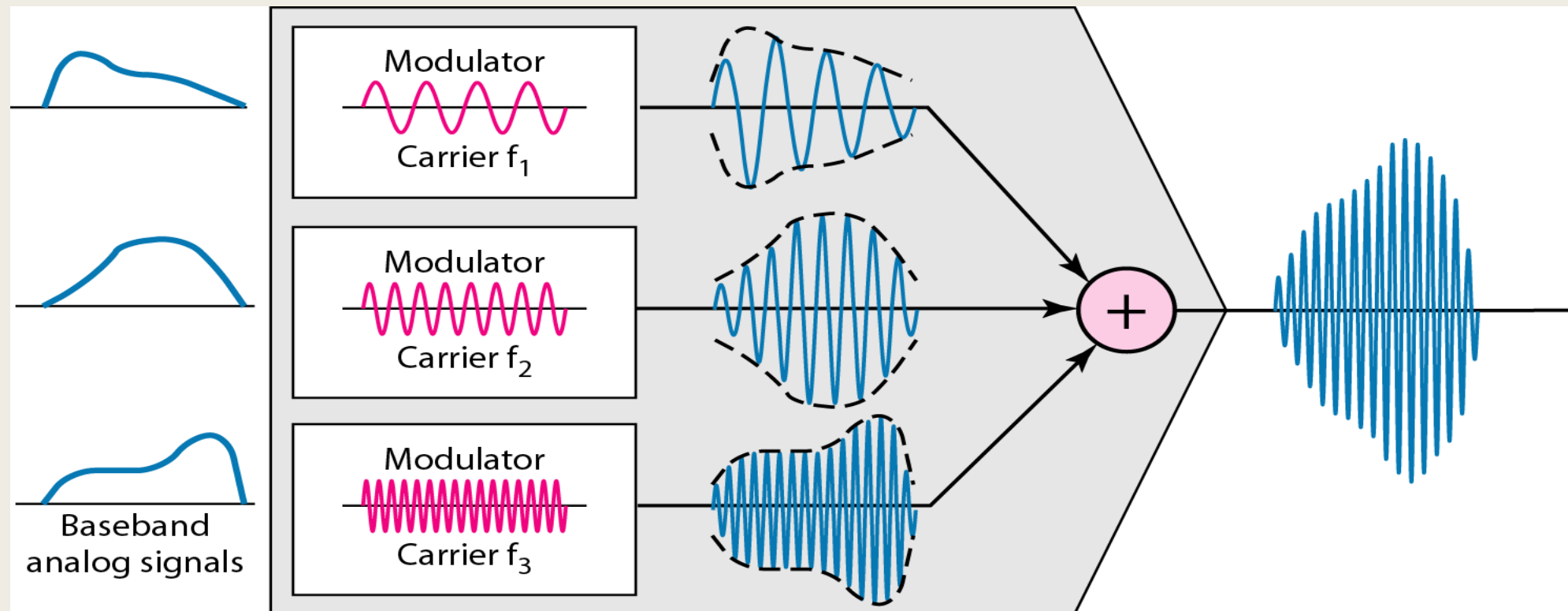
- ❑ FDM divides the link into logical channels and allocates one user to each channel.
- ❑ Each user can use the channel frequency independently.
- ❑ The channels do not overlap with each other.
- ❑ Channels are separated by guard bands.



FDM Process



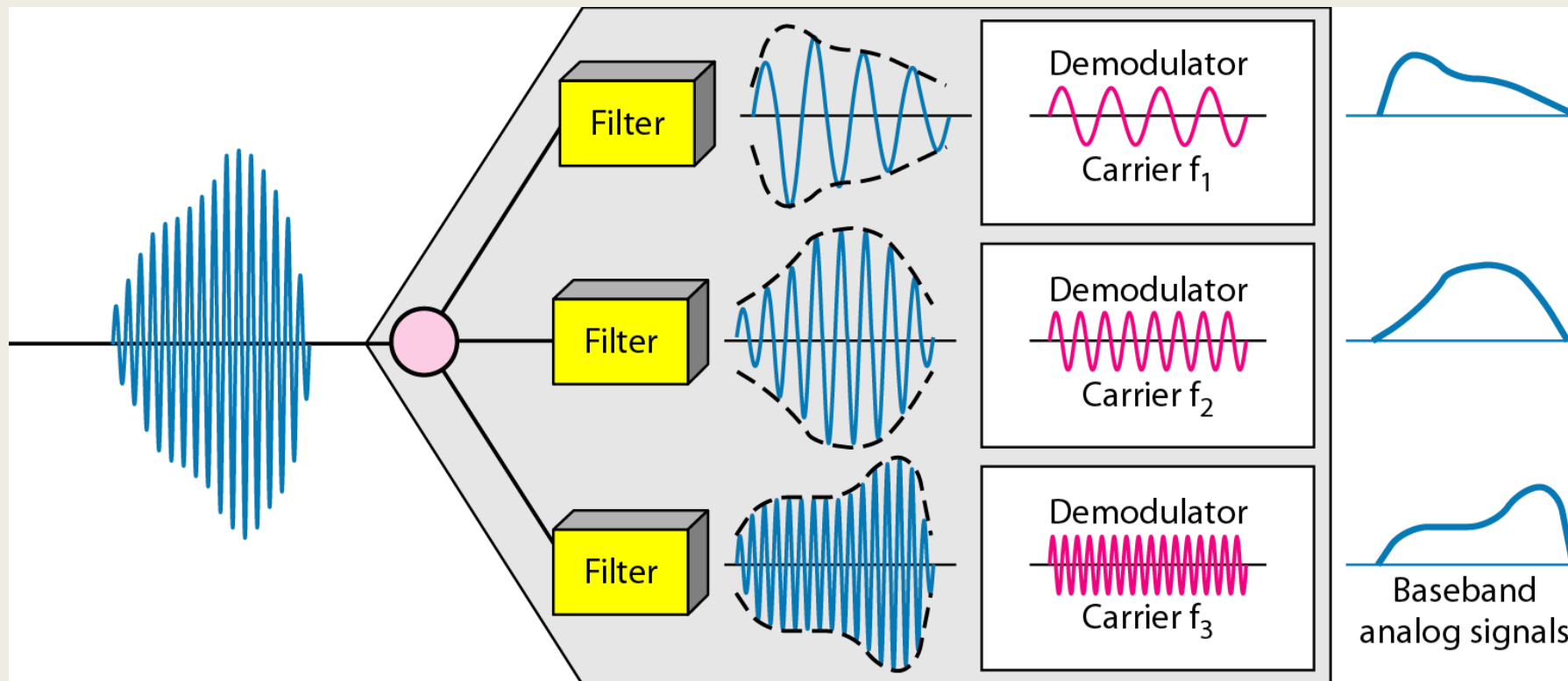
- Each source generates a signal of a similar frequency range.
- Inside the multiplexer, these similar signals modulate different carrier frequencies.
- The resulting modulated signals are then combined into a single composite signal that is sent out over a media link that has enough bandwidth to accommodate it.



FDM Demodulation 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 and passes them to the output lines.



Example

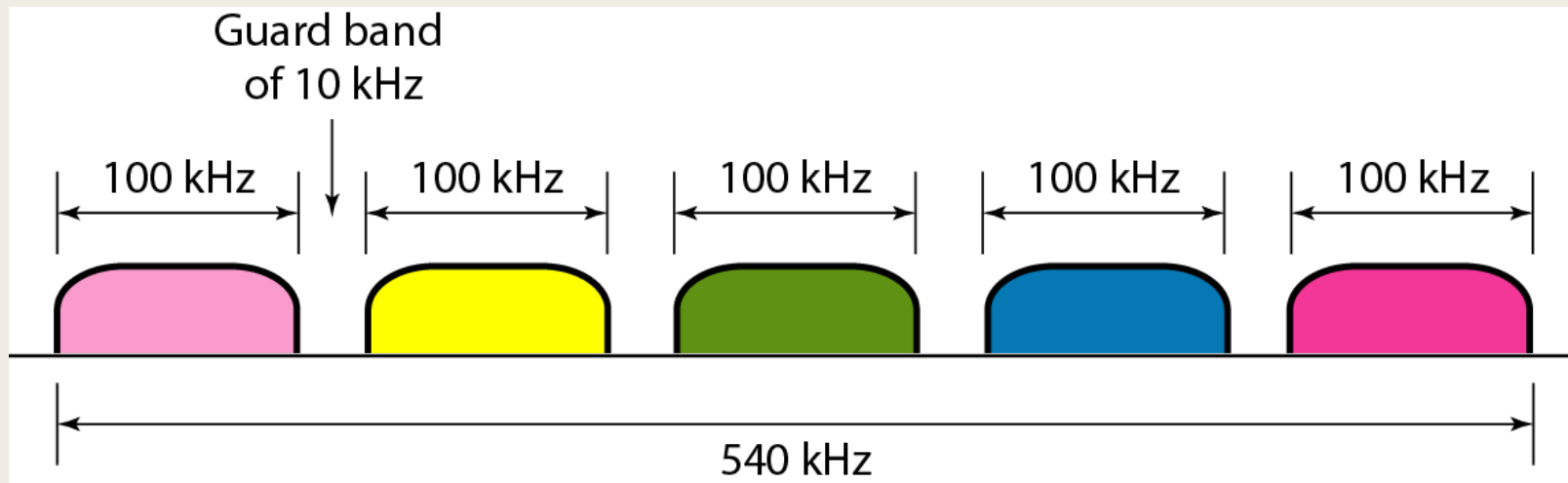


Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

Solution



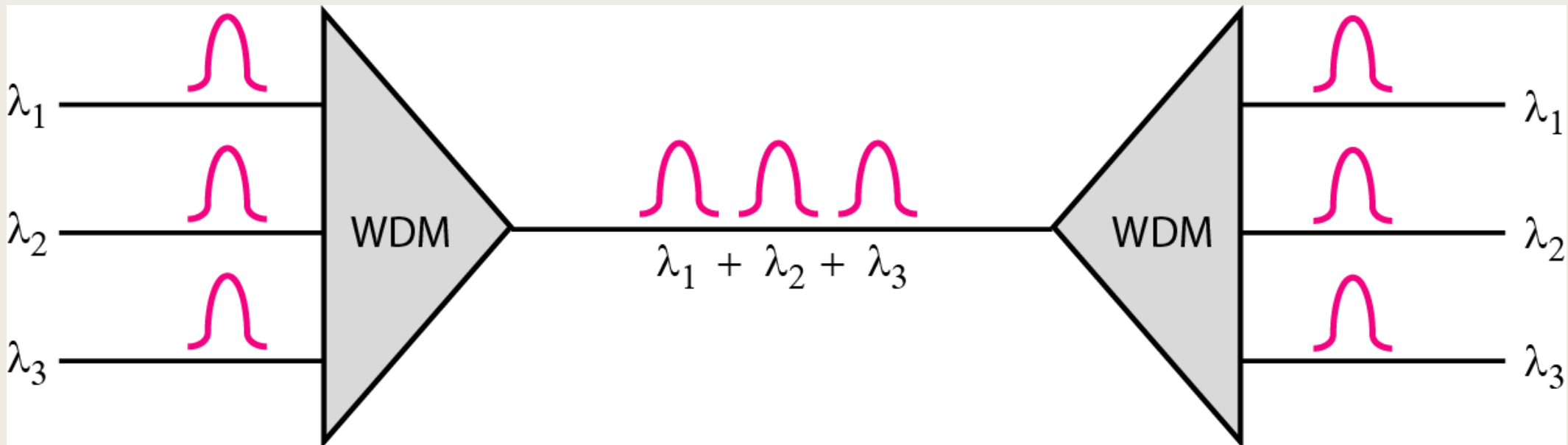
For five channels, we need at least four guard bands. This means that the required bandwidth is at least $5 \times 100 + 4 \times 10 = 540$ kHz



Wavelength Division Multiplexing

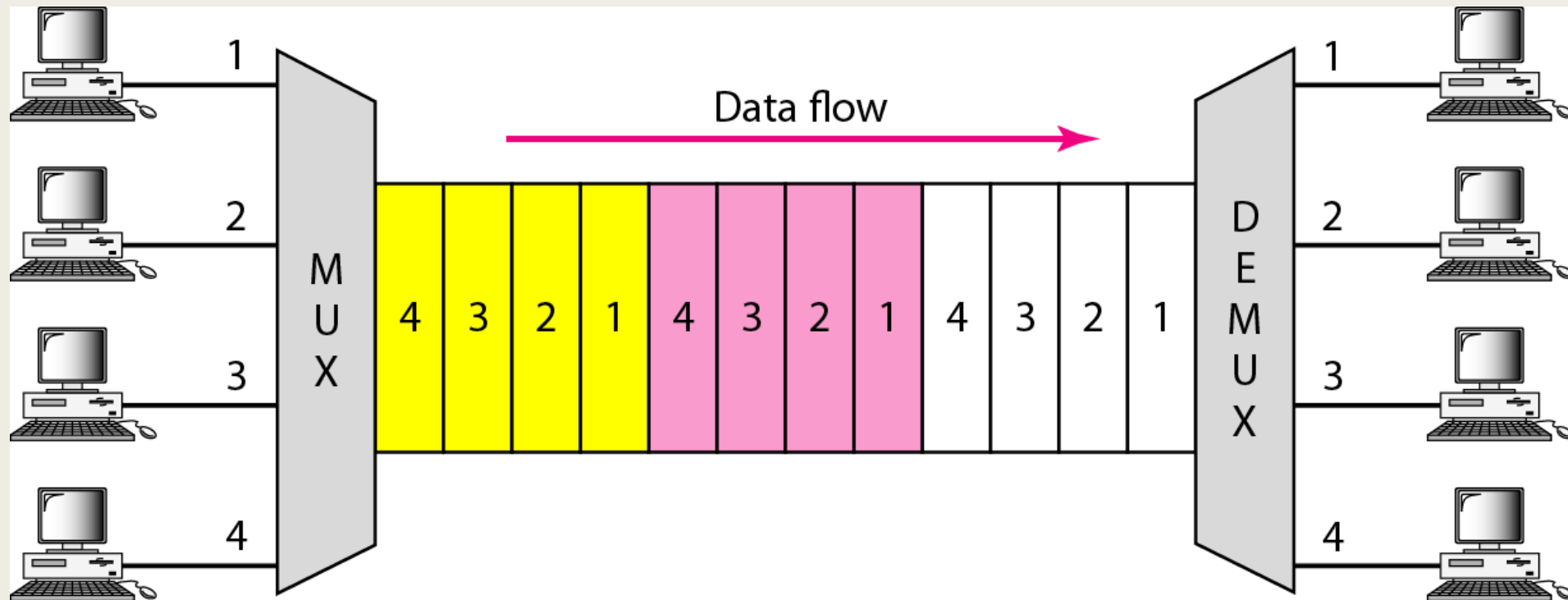


- WDM is an analog multiplexing technique to combine optical signals.
- The multiplexing and demultiplexing involve optical signals transmitted through fiber-optic channels.
- Combining different signals of different frequencies.
- The frequencies are very high.



Time Division Multiplexing

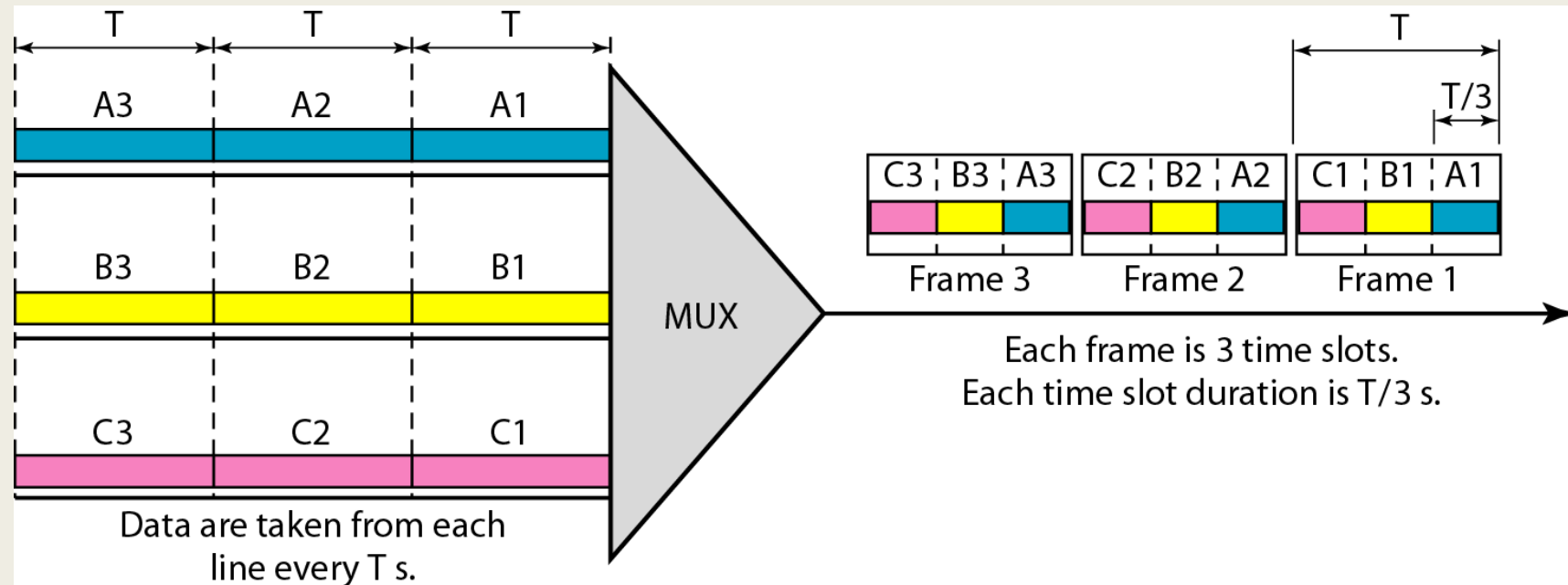
- ❑ In TDM the shared channel is divided among its user by means of time slot.
- ❑ Each user can transmit data within the provided time slot only.



Synchronous Time Division Multiplexing



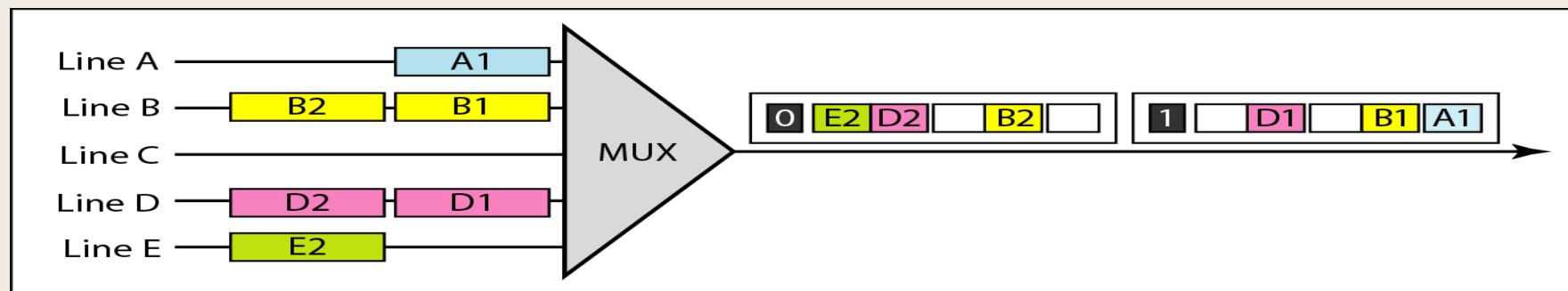
In synchronous TDM, the data rate of the link is n times faster, and the unit duration is n times shorter.



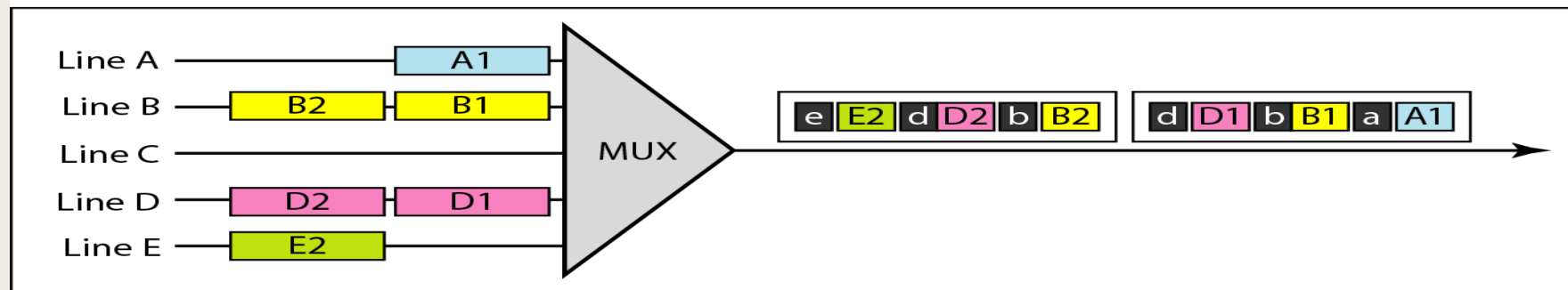
Statistical Time Division Multiplexing



- In statistical multiplexing, the number of slots in each frame is less than the number of input lines.
- The multiplexer checks each input line in round robin fashion; it allocates a slot for an input line if the line has data to send; otherwise, it skips the line and checks the next line.



a. Synchronous TDM

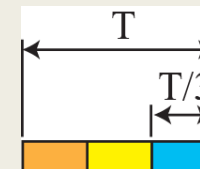
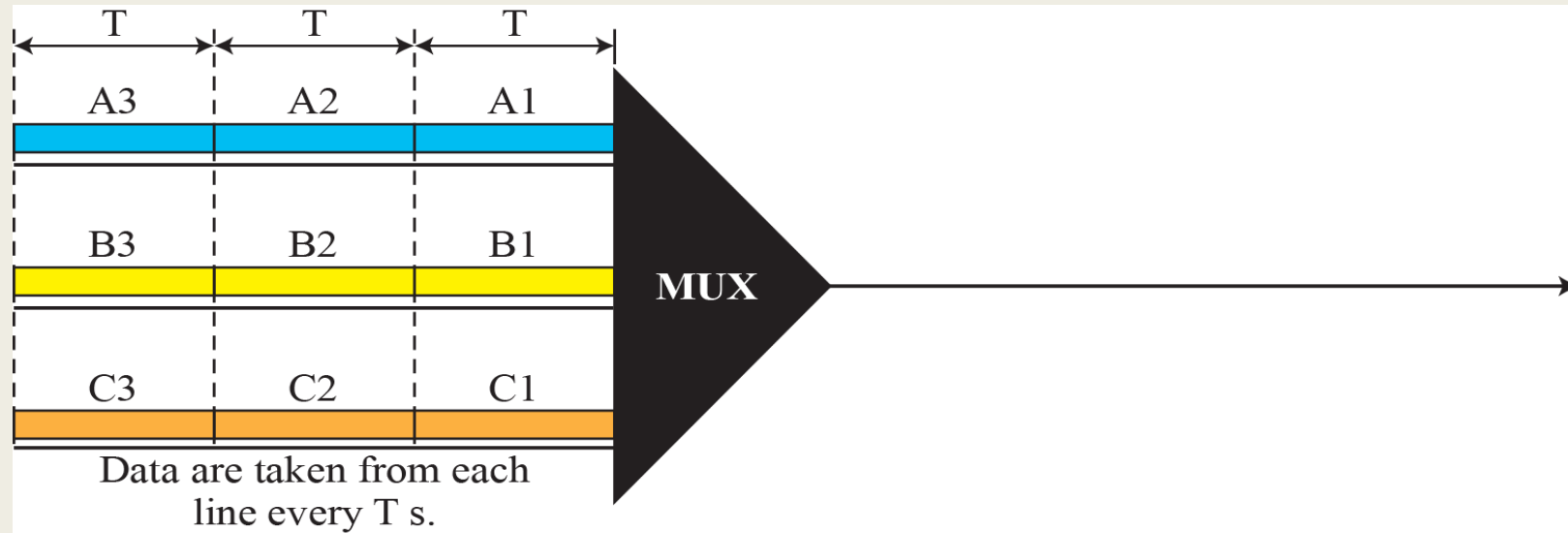


b. Statistical TDM

Example

In Figure, the data rate for each input connection is 1 kbps. If 1 bit at a time is multiplexed (a unit is 1 bit), what is the

- duration of each input slot
- each output slot
- each frame?



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

Source: B. A. Forouzan, "Data Communications and Networking," McGraw-Hill Forouzan Networking Series, 5E.

Solution



1. The data rate of each input connection is 1 kbps. This means that the bit duration is $1/1000$ s or 1 ms. The duration of the input time slot is 1 ms (same as bit duration).
2. The duration of each output time slot is one-third of the input time slot. This means that the duration of the output time slot is $1/3$ ms.
3. Each frame carries three output time slots. So the duration of a frame is $3 \times (1/3)$ ms, or 1 ms. The duration of a frame is the same as the duration of an input unit.



Space Division Multiplexing

- ❑ SDM is a multiplexing technique in MIMO wireless communication, fiber-optic communication and other communications technologies used to transmit independent channels separated in space.

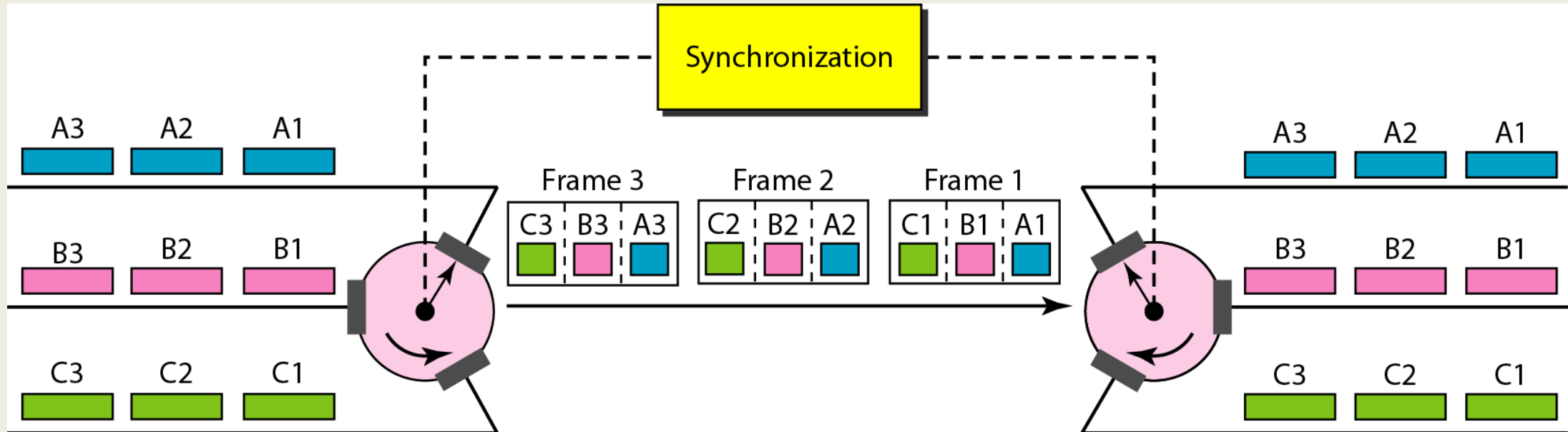
Code Division Multiplexing

- ❑ It allows its users to fill bandwidth and transmit signals all the time using a unique code.
- ❑ Each station is assigned with a unique code, called chip. Signals travel with these codes independently, inside the whole bandwidth.

Interleaving

The process of taking a group of bits from each input line for multiplexing is called interleaving.

We interleave bits 1 - n from each input onto one output.



Example

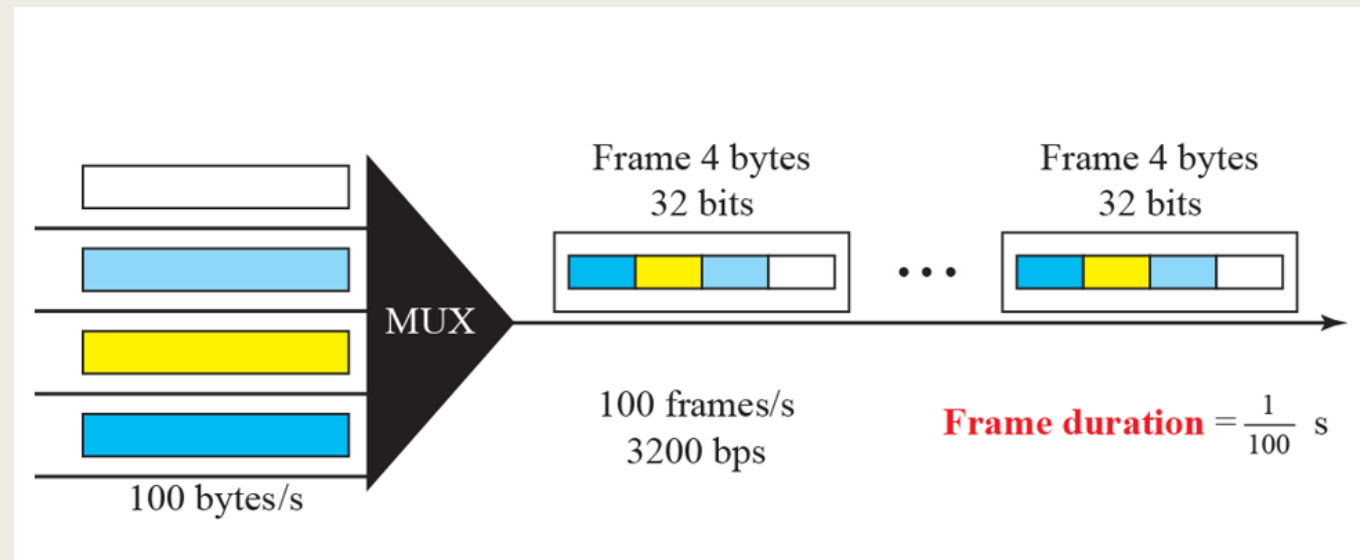


Four channels are multiplexed using TDM. If each channel sends 100 bytes/s and we multiplex 1 byte per channel, show the frame traveling on the link, the size of the frame, the duration of a frame, the frame rate, and the bit rate for the link.

Solution



Each frame carries 1 byte from each channel; the size of each frame, therefore, is 4 bytes, or 32 bits. The frame rate is 100 frames per second. The duration of a frame is therefore $1/100$ s. The link is carrying 100 frames per second, and since each frame contains 32 bits, the bit rate is 100×32 , or 3200 bps.





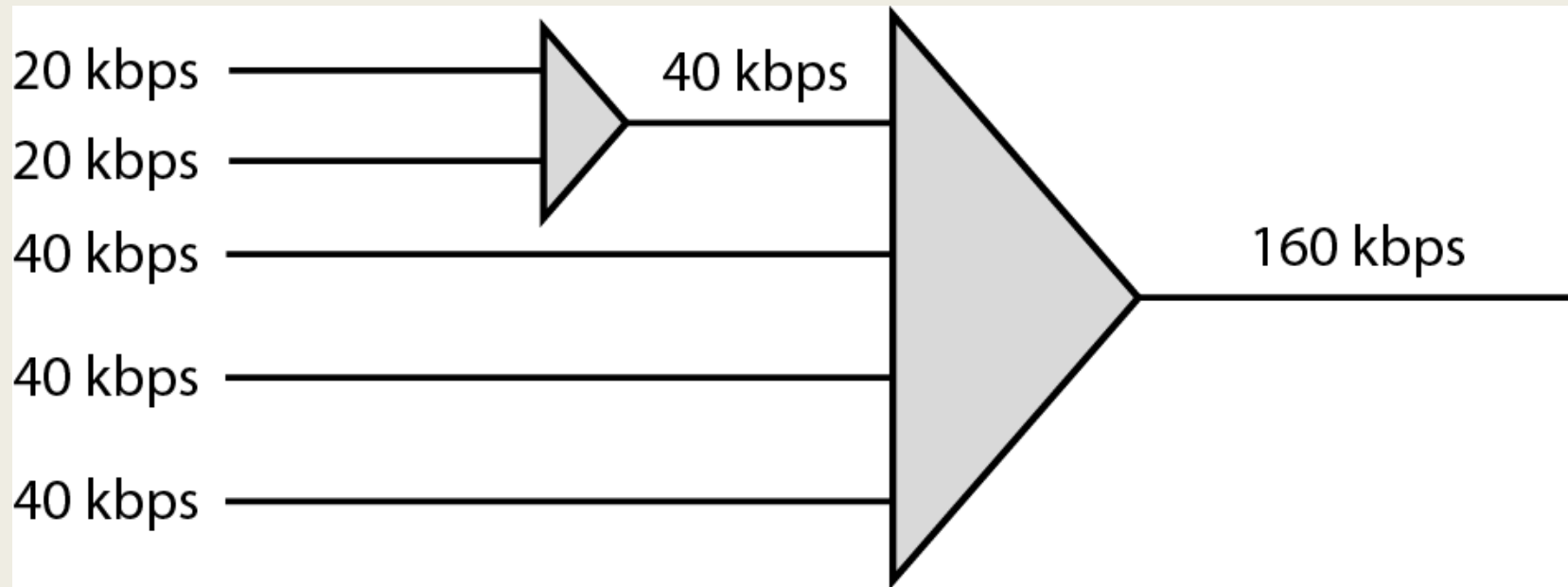
Data Rate Management

- Not all input links maybe have the same data rate.
- Some links maybe slower. There maybe several different input link speeds.
- There are three strategies that can be used to overcome the data rate mismatch: multilevel, multi-slot and pulse stuffing

Multilevel Multiplexing

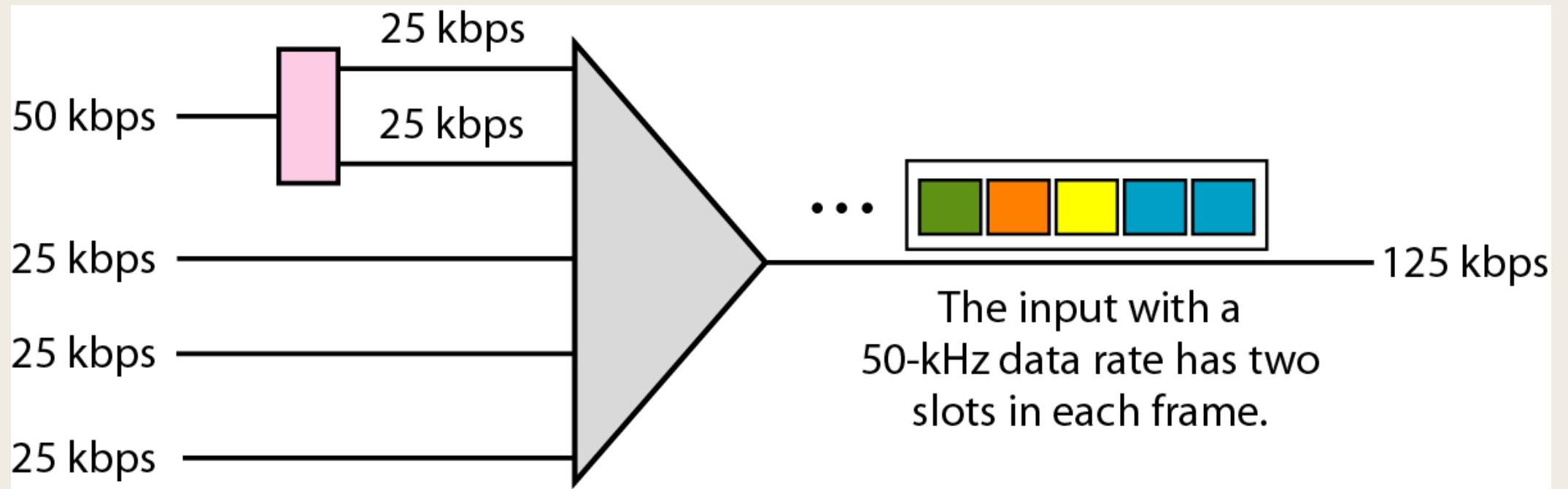
Multilevel multiplexing is a technique used when the data rate of an input line is a multiple of others.

For example, we have two inputs of 20 kbps and three inputs of 40 kbps. The first two input lines can be multiplexed together to provide a data rate equal to the last three. A second level of multiplexing can create an output of 160 kbps.



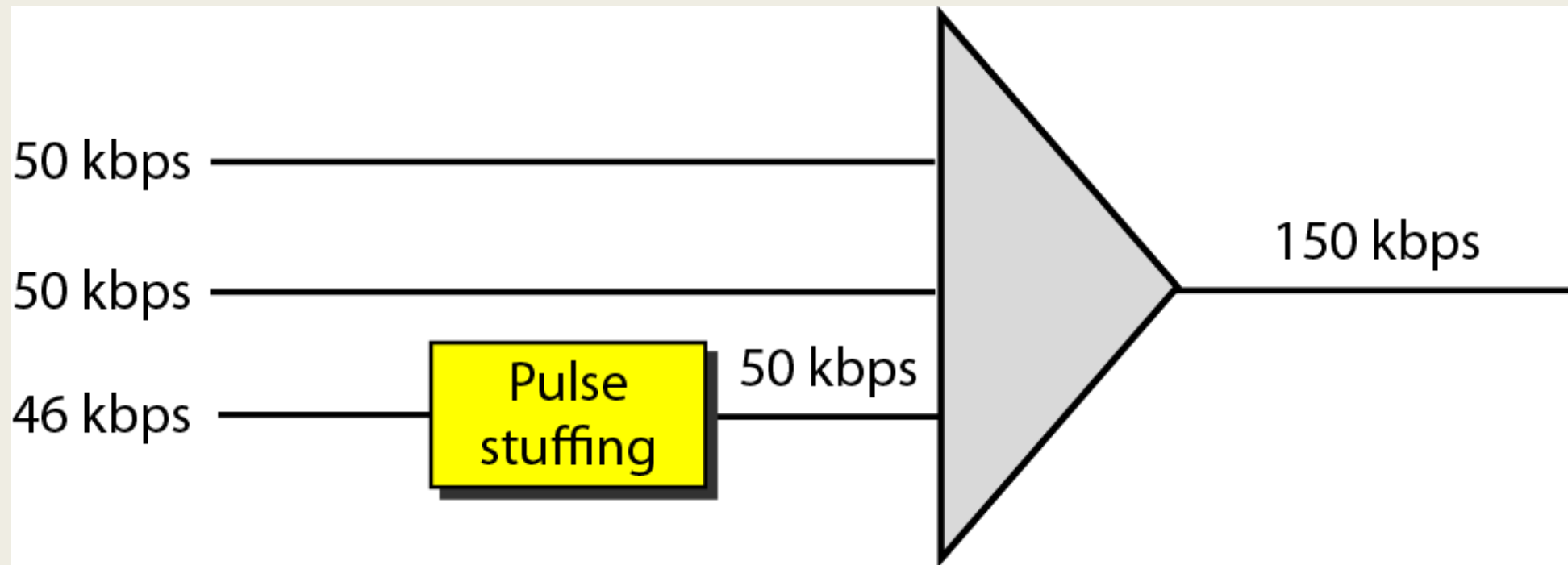
Multiple Slot Multiplexing

Used when there is a GCD between the data rates. The higher bit rate channels are allocated more slots per frame, and the output frame rate is a multiple of each input link.



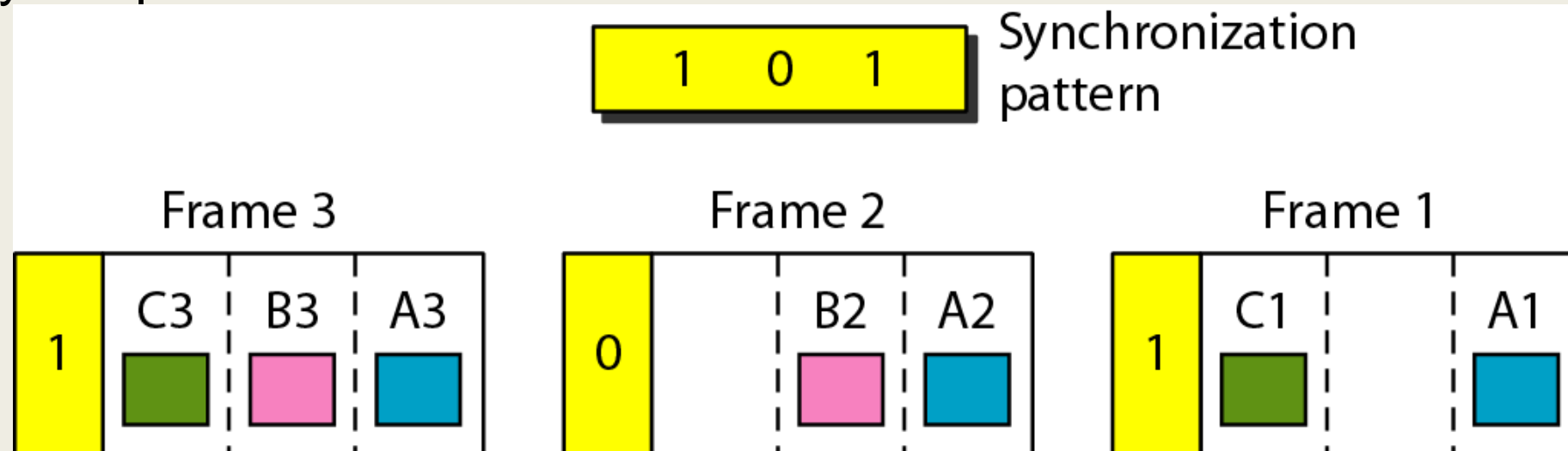
Pulse Stuffing

Used when there is no GCD between the links. The slowest speed link will be brought up to the speed of the other links by bit insertion, this is called pulse stuffing.



Synchronization

- To ensure that the receiver correctly reads the incoming bits, i.e., knows the incoming bit boundaries to interpret a “1” and a “0”, a known bit pattern is used between the frames.
- The receiver looks for the anticipated bit and starts counting bits till the end of the frame.
- Then it starts over again with the reception of another known bit.
- These bits (or bit patterns) are called synchronization bit(s).
- They are part of the overhead of transmission.



Example



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.

Solution



1. The data rate of each source is $250 \times 8 = 2000$ bps = 2 kbps. (Assume that the character is 8 bits long).
2. Each source sends 250 characters per second; therefore, the duration of a character is $1/250$ s, or 4 ms.
3. Each frame has one character from each source, which means 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 carries 4 characters and 1 extra synchronizing bit. This means that each frame is $4 \times 8 + 1 = 33$ bits.
6. The link sends 250 frames per second, and each frame contains 33 bits. This means that the data rate of the link is 250×33 , or 8250 bps.

Example



Two channels, one with a bit rate of 100 kbps and another with a bit rate of 200 kbps, are to be multiplexed. How this can be achieved? What is the frame rate? What is the frame duration? What is the bit rate of the link?.

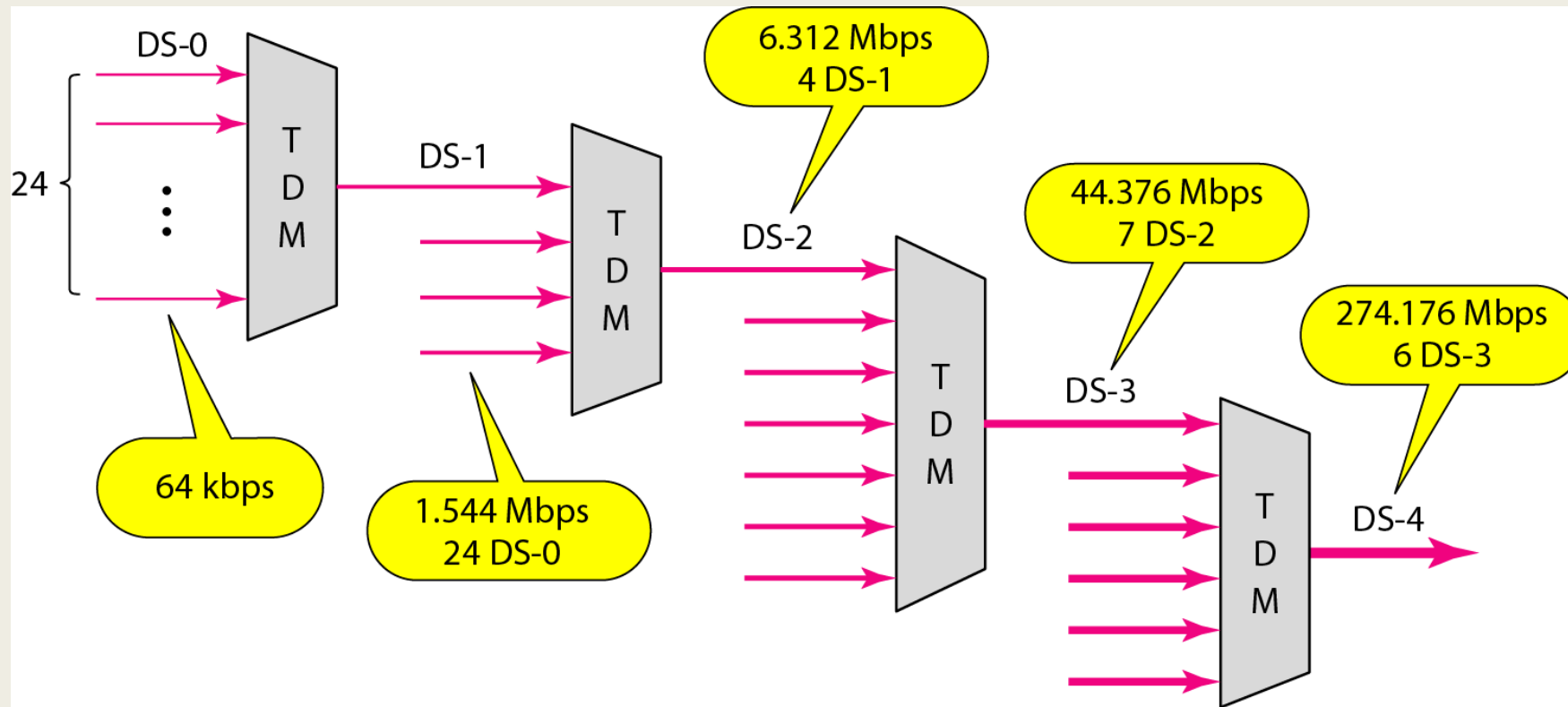
Solution



We can allocate one slot to the first channel and two slots to the second channel. Each frame carries 3 bits. The frame rate is 100,000 frames per second because it carries 1 bit from the first channel. The frame duration is $1/100,000$ s, or 10 ms. The bit rate is $100,000 \text{ frames/s} \times 3 \text{ bits per frame}$, or 300 kbps.

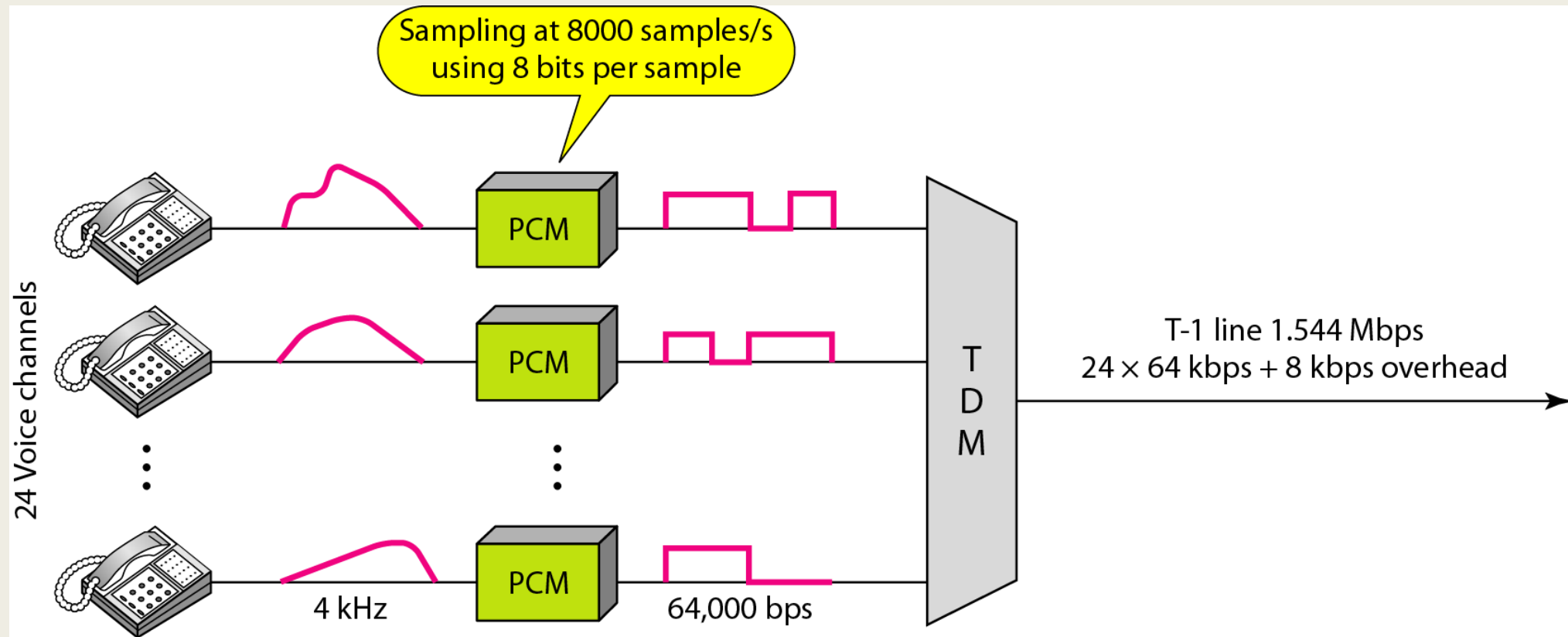
Digital Signal Service

- Telephone companies implement TDM through a hierarchy of digital signals, called digital signal (DS) service or digital hierarchy.

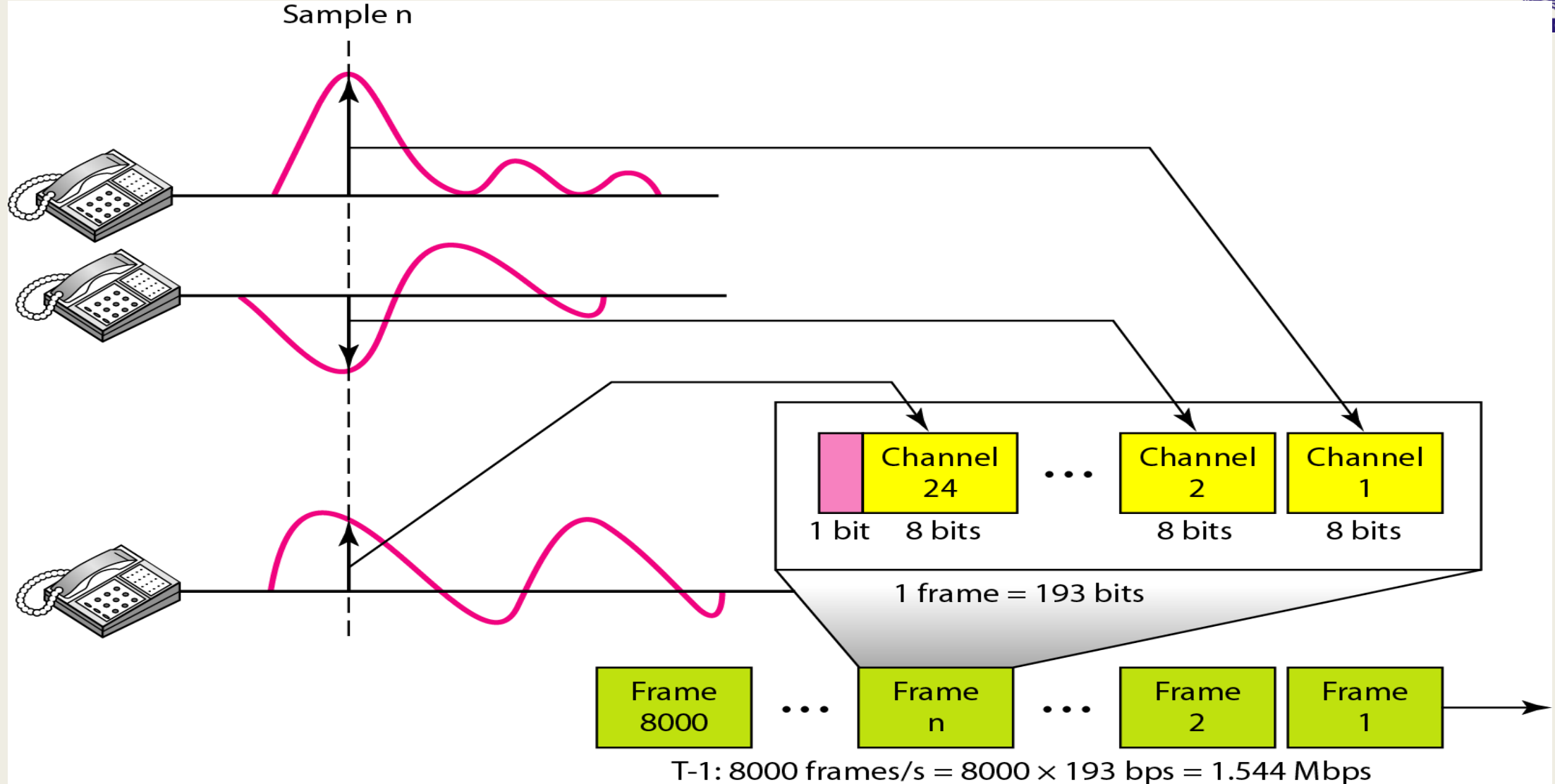


T lines

- T lines are digital lines designed for the transmission of digital data, audio, or video.

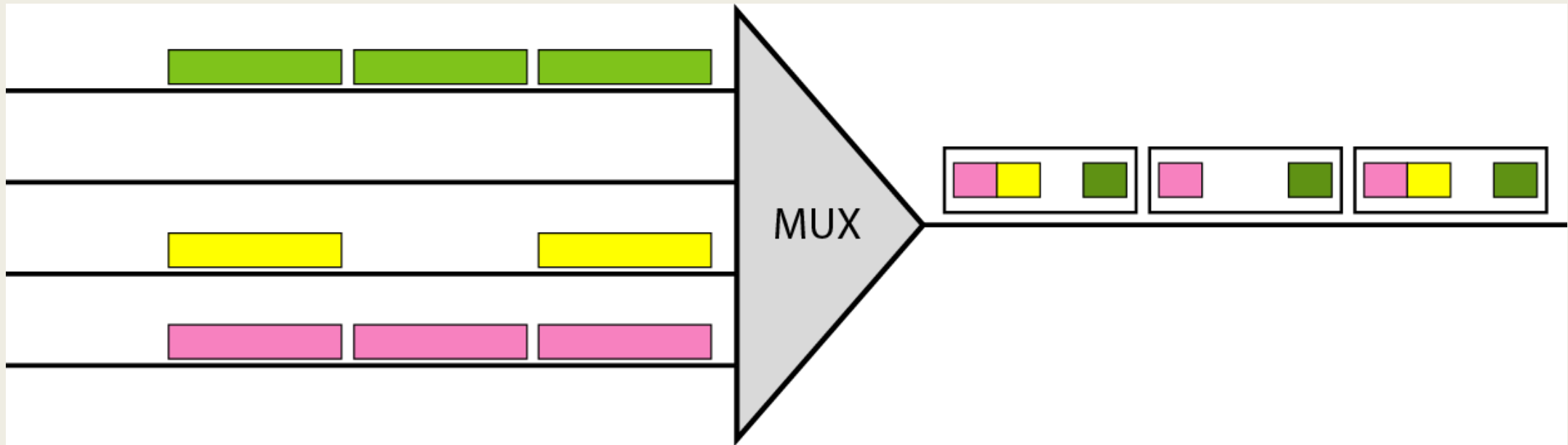


T-1 Frame Structure



Inefficient Use of Bandwidth

- Sometimes an input link may have no data to transmit.
- When that happens, one or more slots on the output link will go unused.
- That is wasteful of bandwidth.



Thank You!!!