Introduction to Data Communications (COMP 3721)

Instructor: Maryam Tanha

Fall 2021

Learning Outcomes of This Lecture

- **By the end of this lecture you will be able to**
  - Explain the Importance of bandwidth utilization.
  - Explain what is multiplexing.
  - Explain TDM as a multiplexing technique in physical layer.

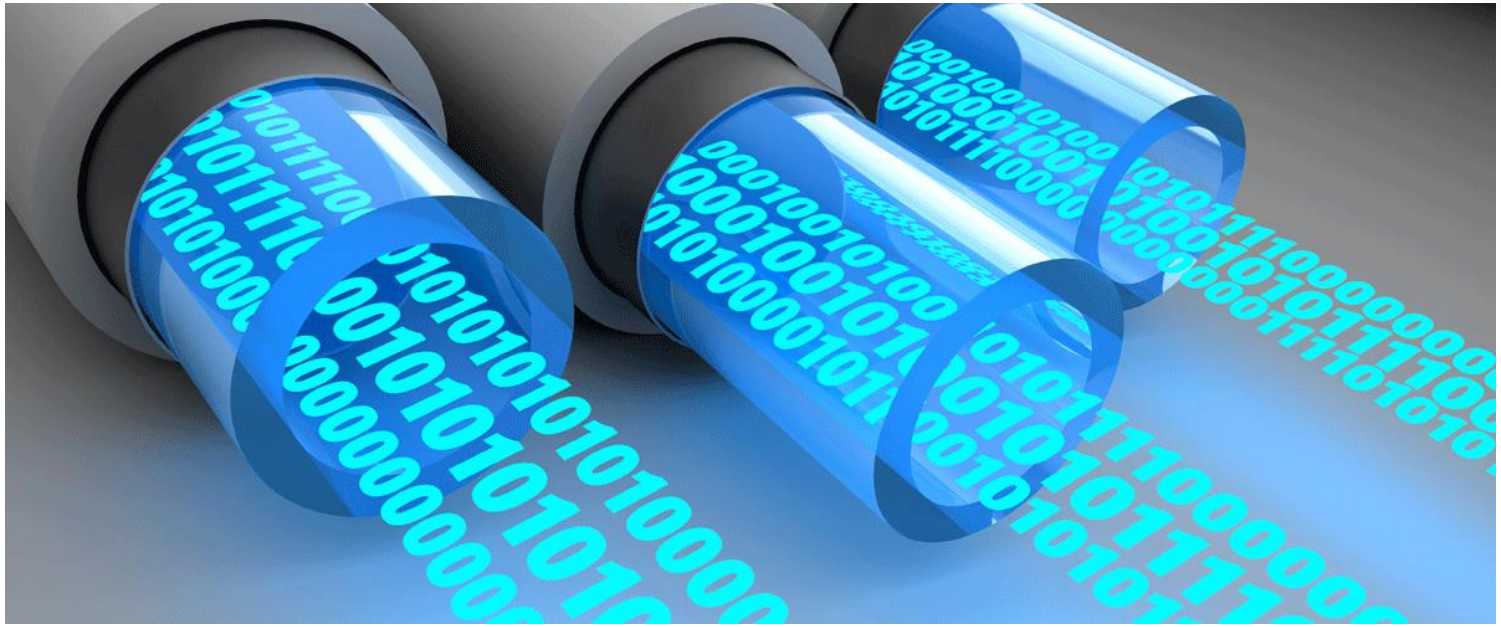
Agenda

- Introduction
- Multiplexing
- Summary

Agenda

- **Introduction**
- Multiplexing
- Summary

Introduction



Bandwidth Utilization

Bandwidth utilization **is the wise use of available bandwidth to achieve specific goals, e.g., efficiency, privacy, etc.**

Agenda

- Introduction
- **Multiplexing**
- Summary

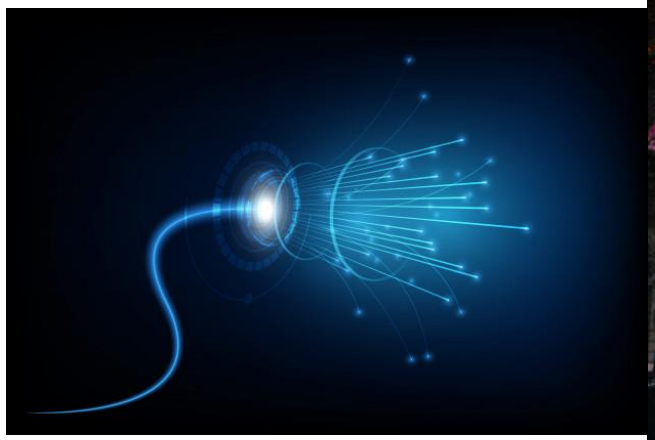
Introduction to Multiplexing

- In data and telecommunications, the increase in traffic can be accommodated by
  - adding individual links each time a new channel is needed
  - installing higher-bandwidth links and use each to carry multiple signals

Introduction to Multiplexing

- In data and telecommunications, the increase in traffic can be accommodated by
  - adding individual links each time a new channel is needed
  - installing higher-bandwidth links and use each to carry multiple signals

Today's technology includes high-bandwidth transmission media such as optical fiber.

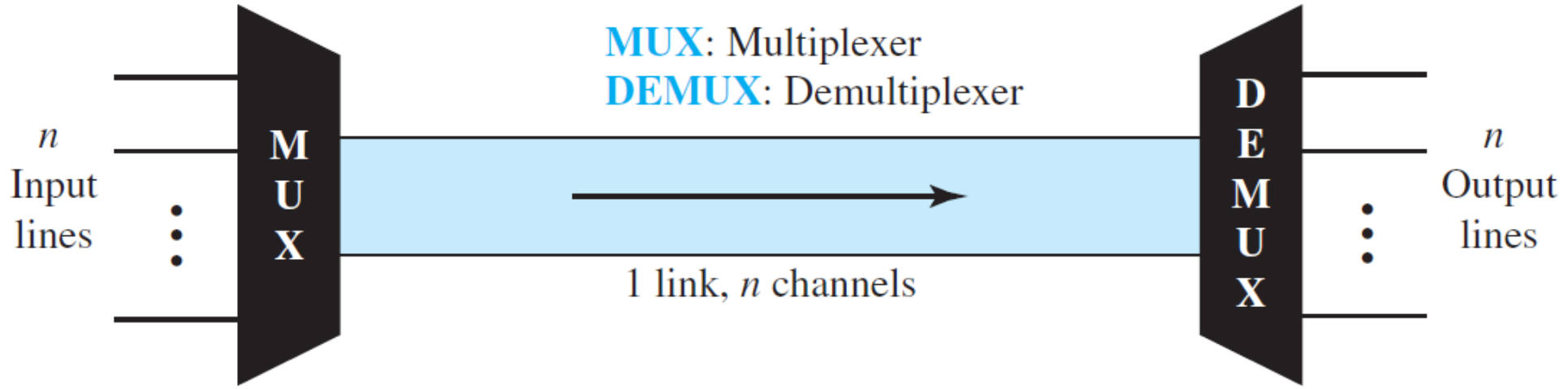


What is Multiplexing?

Multiplexing **is the set of techniques that allow the simultaneous transmission of multiple signals across a single data link.**

What is Multiplexing?

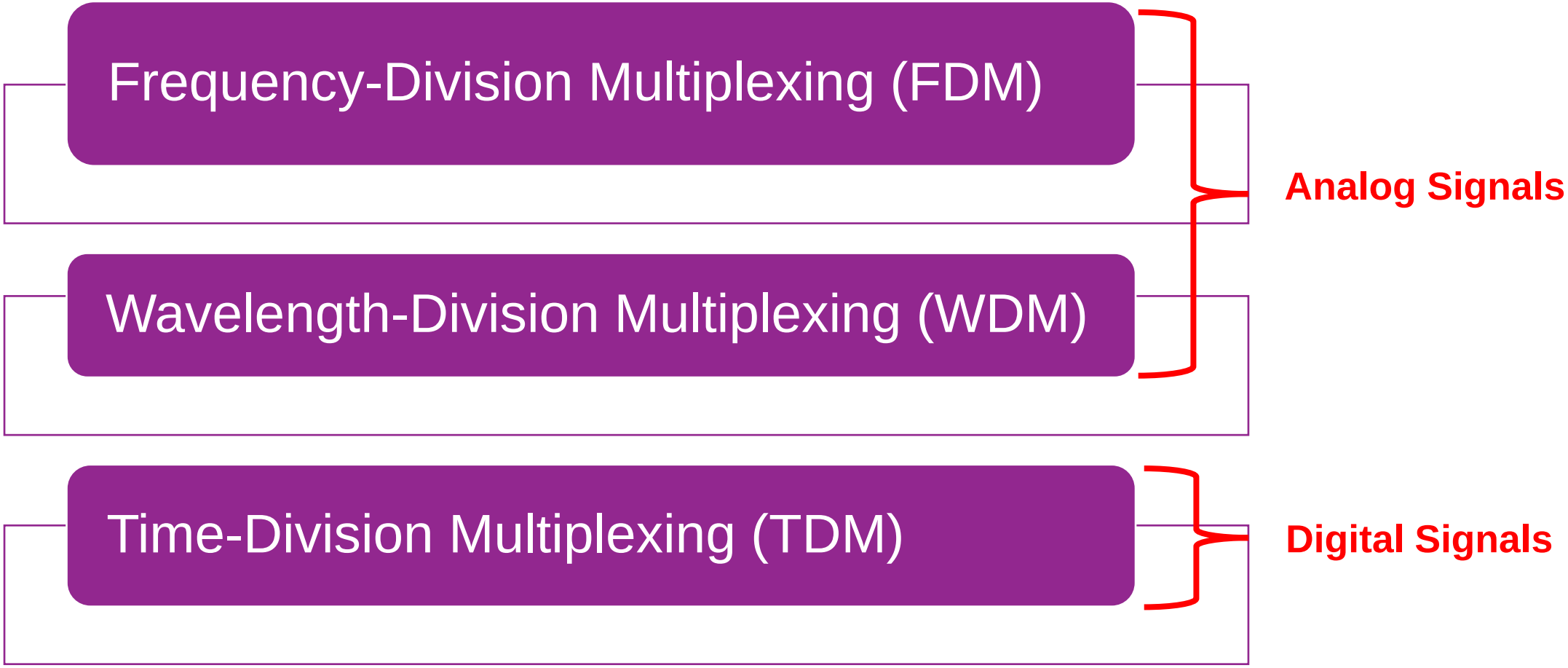
Multiplexing is the set of techniques that allow the simultaneous transmission of multiple signals across a single data link.



Multiplexing Techniques

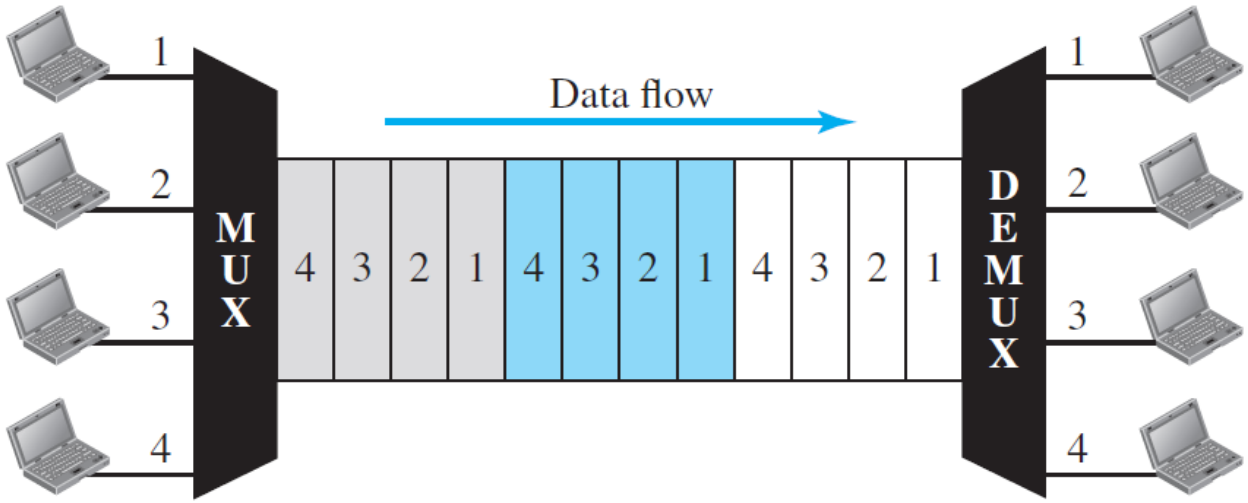
- Frequency-Division Multiplexing (FDM)
- Wavelength-Division Multiplexing (WDM)
- Time-Division Multiplexing (TDM)

Multiplexing Techniques



Time-Division Multiplexing (TDM)

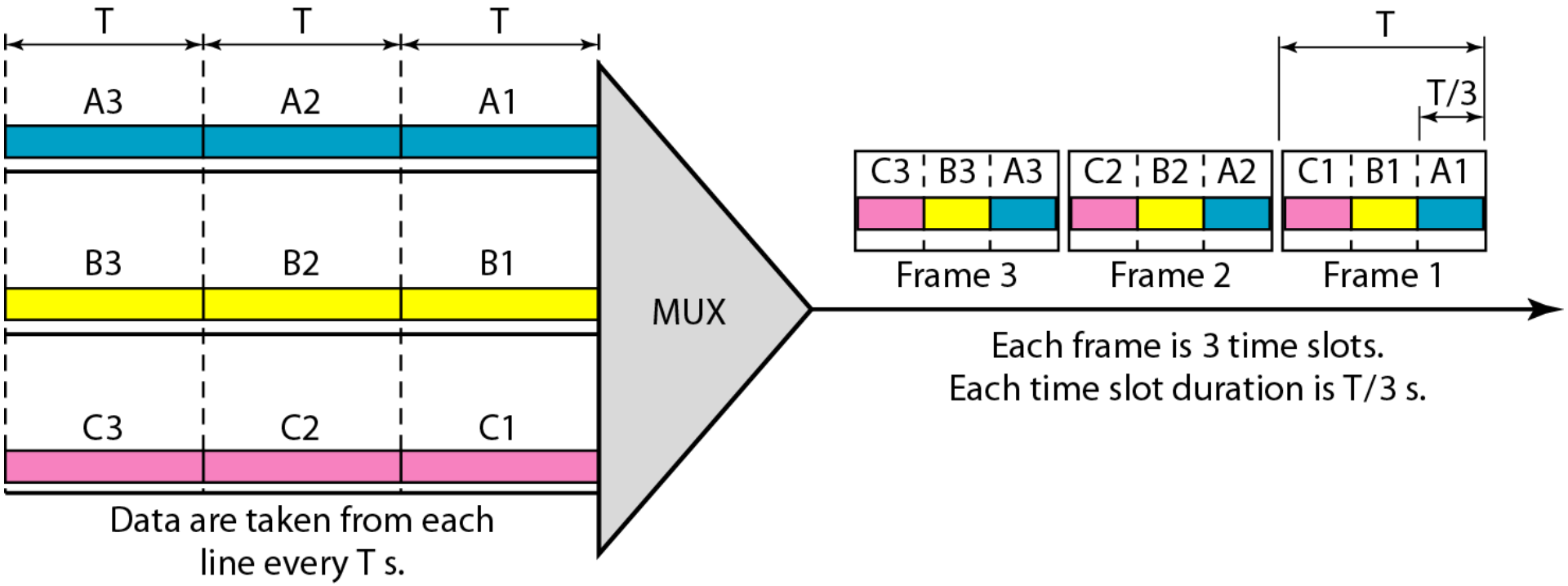
- A digital multiplexing technique that allows several digital signals to share the high bandwidth of a link in time.
  - each connection occupies a portion of time in the link
- An analog signal can be sampled, changed to digital data, and then multiplexed by using TDM.



Time-Division Multiplexing

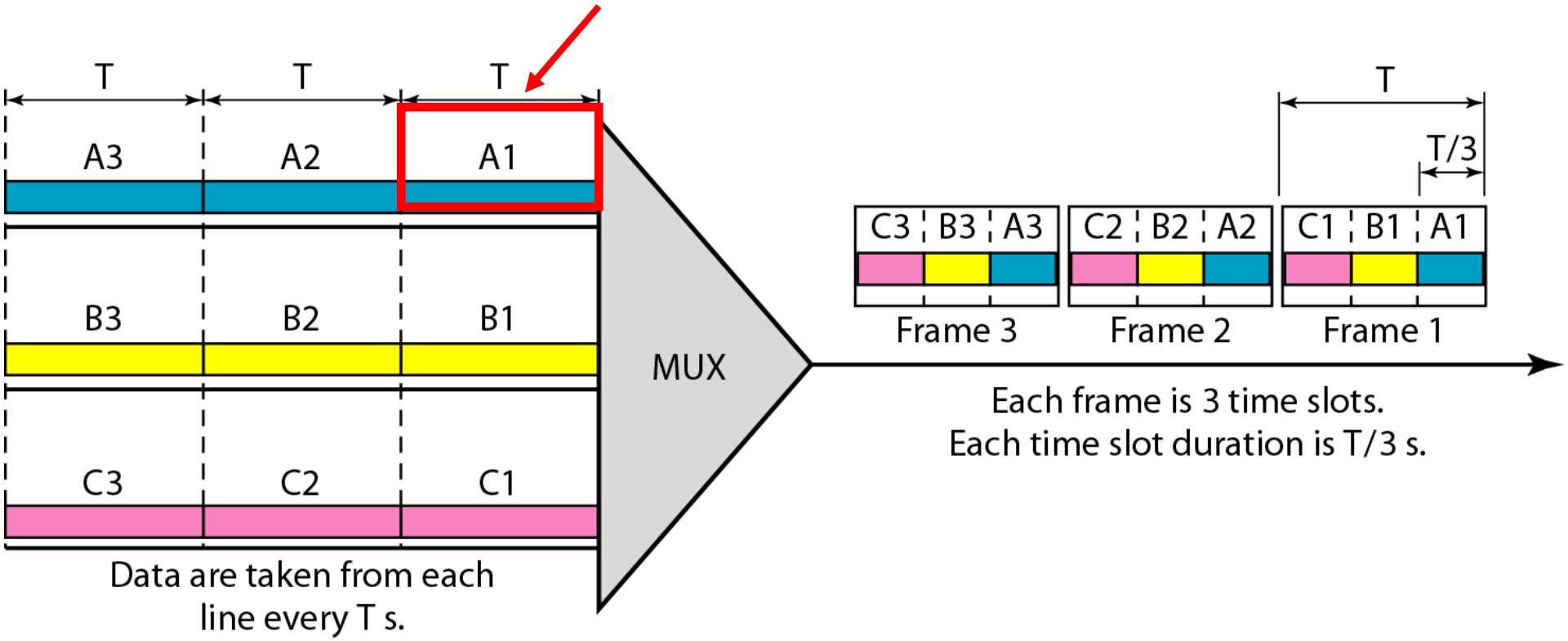
- **Two different TDM schemes**
  1) synchronous TDM
  2) statistical TDM

Synchronous TDM



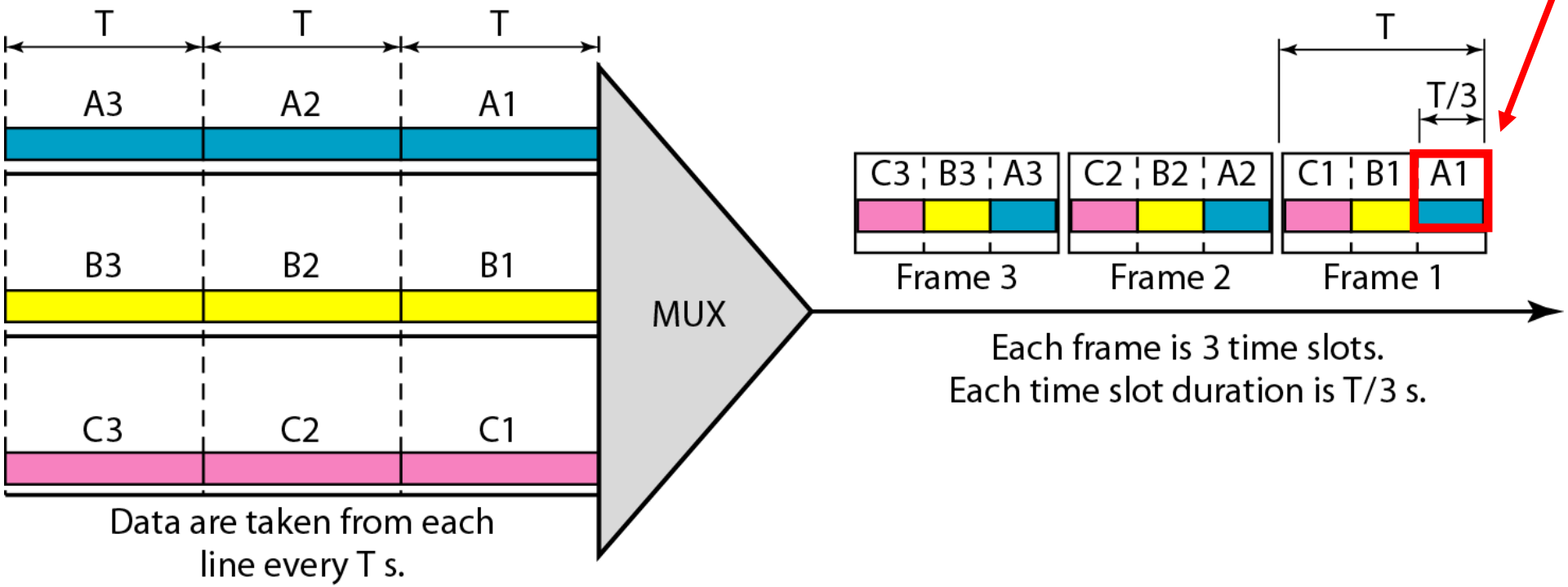
Synchronous TDM

The data flow of each input connection is divided into units (e.g., A1, A2, …), where each unit occupies one input time slot (with duration T)



Synchronous TDM

Each input unit becomes one output unit; however, the duration of an output time slot is *n* times shorter than the duration of an input time slot (n is the number of connections). Here, n=3.



Synchronous TDM – Continued

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

Synchronous TDM – Continued

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

In a system with *n* input lines, each frame has *n* slots, with each slot allocated to carrying data from a specific input line.

Synchronous TDM – Continued

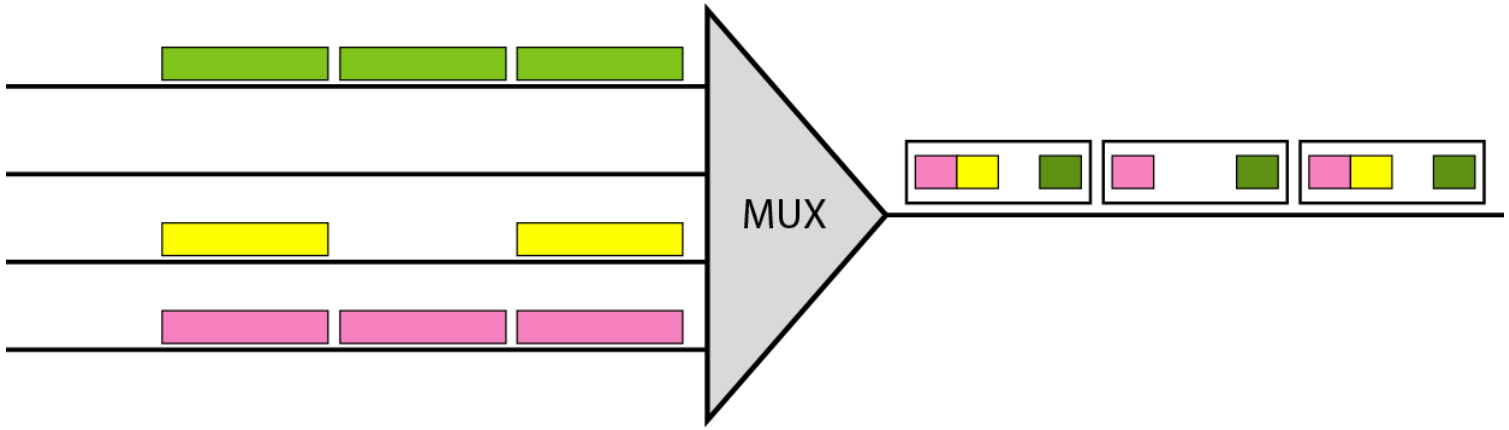
In synchronous TDM, the data rate of the link is *n* times faster, and the unit duration is *n* times shorter.

In a system with *n* input lines, each frame has *n* slots, with each slot allocated to carrying data from a specific input line.

The duration of a frame is the same as the duration of an input unit. The frame rate is always the same as any input rate.

Synchronous TDM – Efficiency and Empty Slots

- Synchronous TDM is not efficient.
- If a source does not have data to send, the corresponding slot in the output frame is empty.

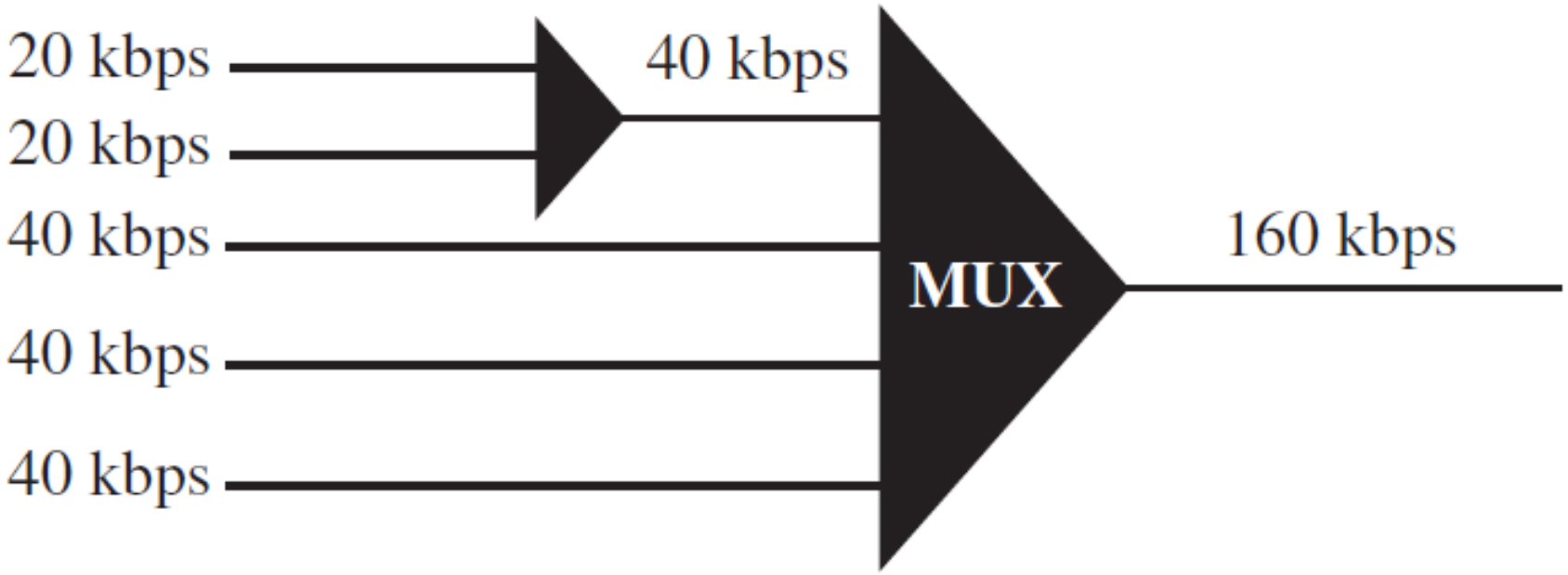


Synchronous TDM – Data Rate Management

- How to handle a disparity in the input data rates?
- Three strategies, or a combination of them, can be used
  1) **Multilevel multiplexing**
  2) **Multiple-slot allocation**
  3) **Pulse stuffing**

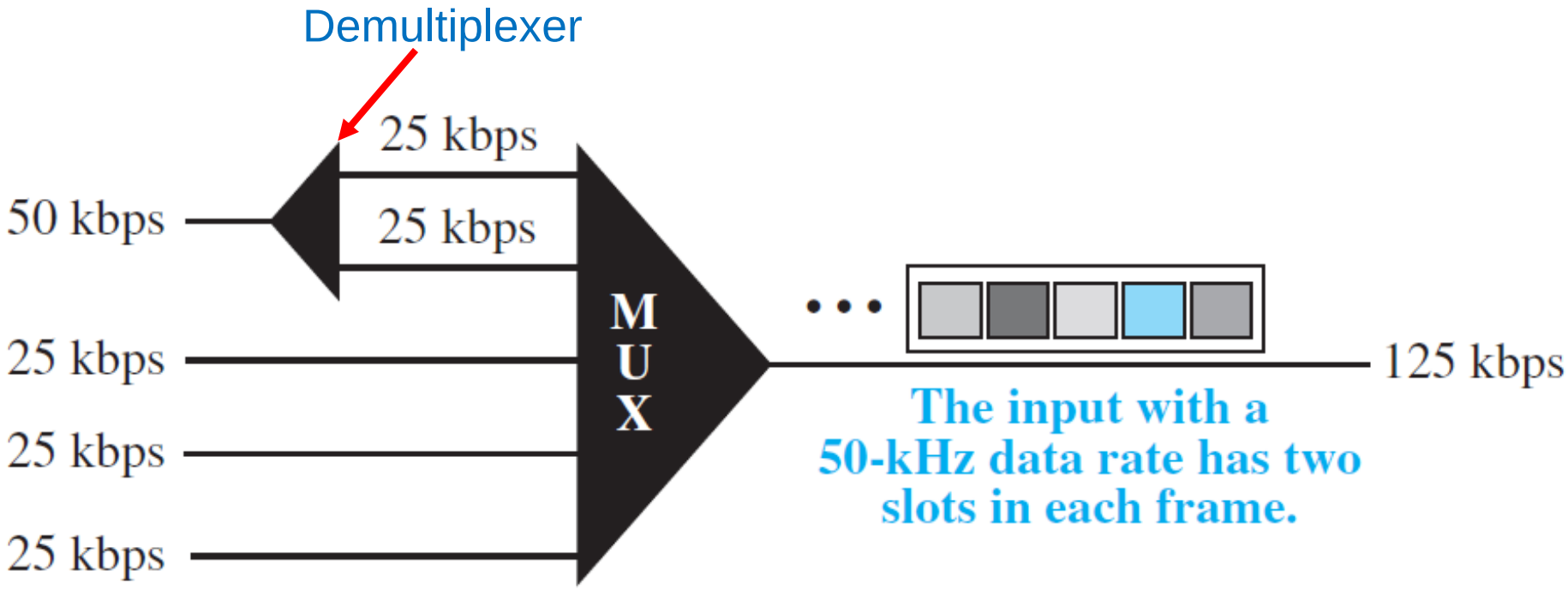
Synchronous TDM – Data Rate Management (Multilevel Multiplexing)

- It is a technique used when the data rate of an input line is a multiple of others.



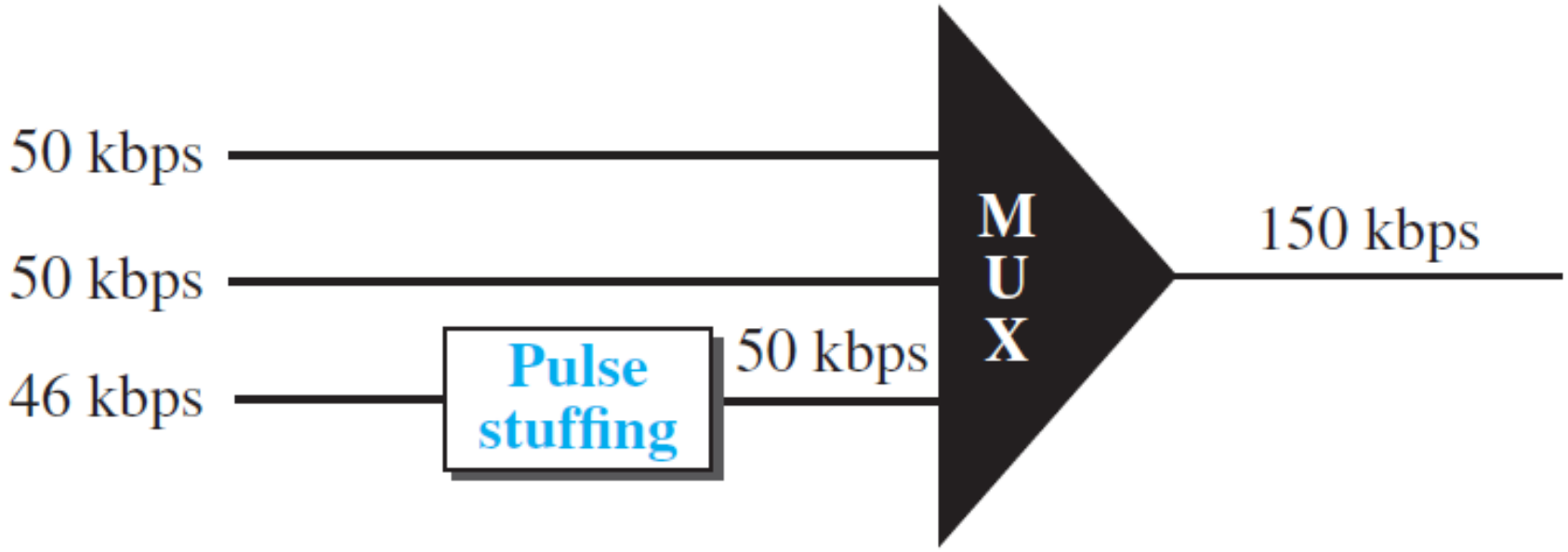
Synchronous TDM – Data Rate Management (Multiple-Slot Allocation)

- Allocating more than one slot in a frame to a single input line.
  - we might have an input line that has a data rate that is a multiple of another input.



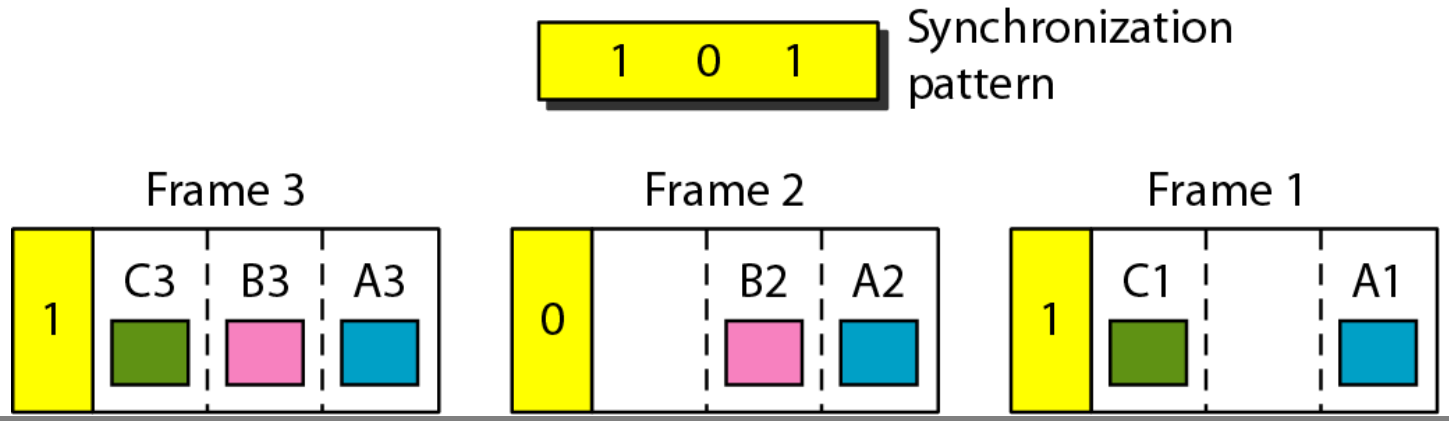
Synchronous TDM – Data Rate Management (Pulse Stuffing)

- **Pulse stuffing** or **bit padding** or **bit stuffing.**
  - used when the bit rates of sources are not multiple integers of each other.
  - makes the highest input data rate the dominant data rate and then adds dummy bits to the input lines with lower rates→ their rates are increased



Synchronous TDM – Frame Synchronizing

- Synchronization between the multiplexer and demultiplexer is a major issue.
- **Framing bits**
  - one or more synchronization bits that are usually added to the beginning of each frame.
  - follow a pattern, frame to frame → allows the demultiplexer to synchronize with the incoming stream so that it can separate the time slots accurately



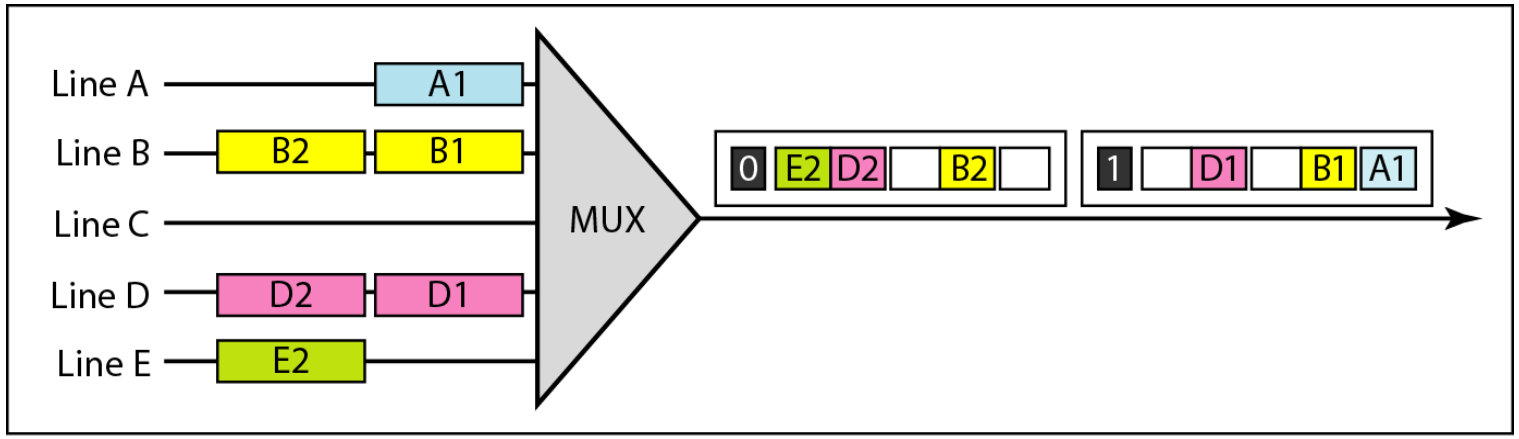
Synchronous TDM Applications

- Telephone companies
- Second-generation cellular phone companies

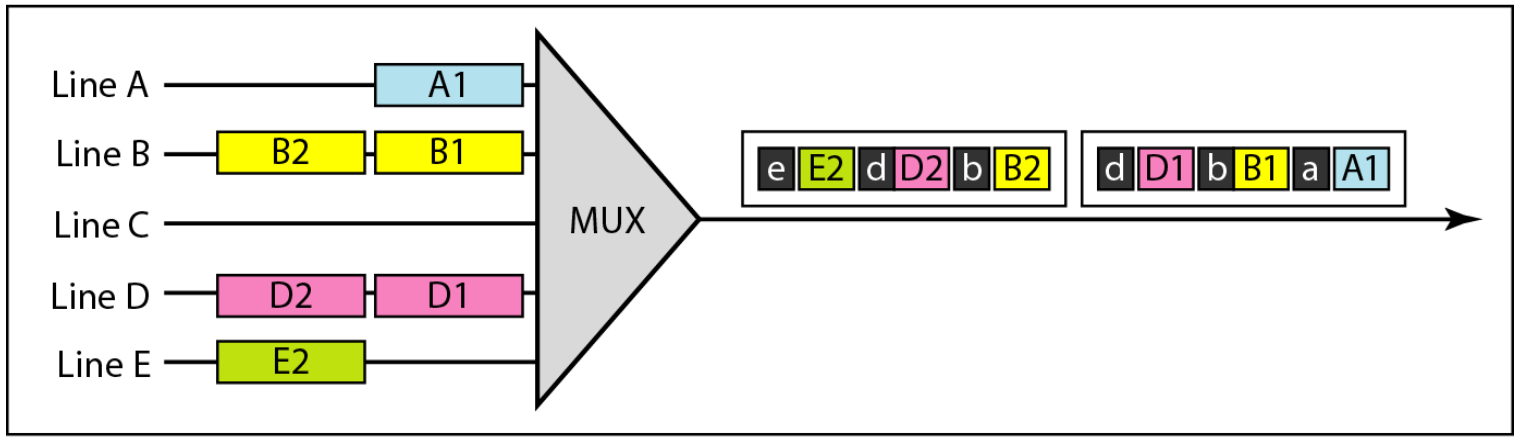
Statistical TDM

- Inefficiency of synchronous TDM since each input has a reserved slot in the output frame regardless of having data to send.
- In statistical TDM, slots are dynamically allocated to improve bandwidth efficiency.
  - only when an input line has a slot's worth of data to send, it given a slot in the output frame.
  - 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.

Statistical TDM – Continued



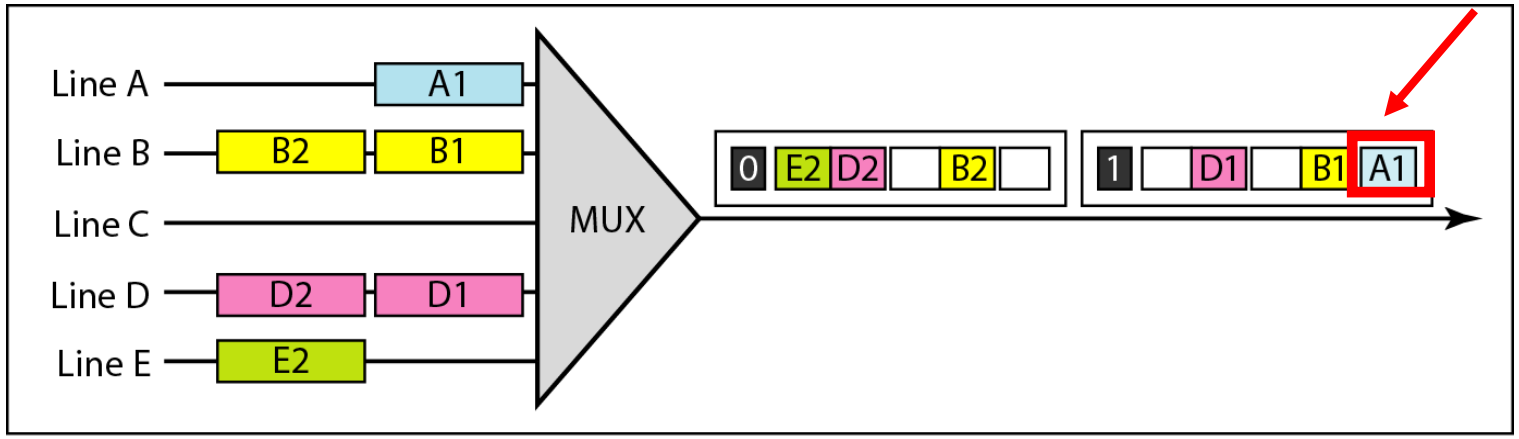
a. Synchronous TDM



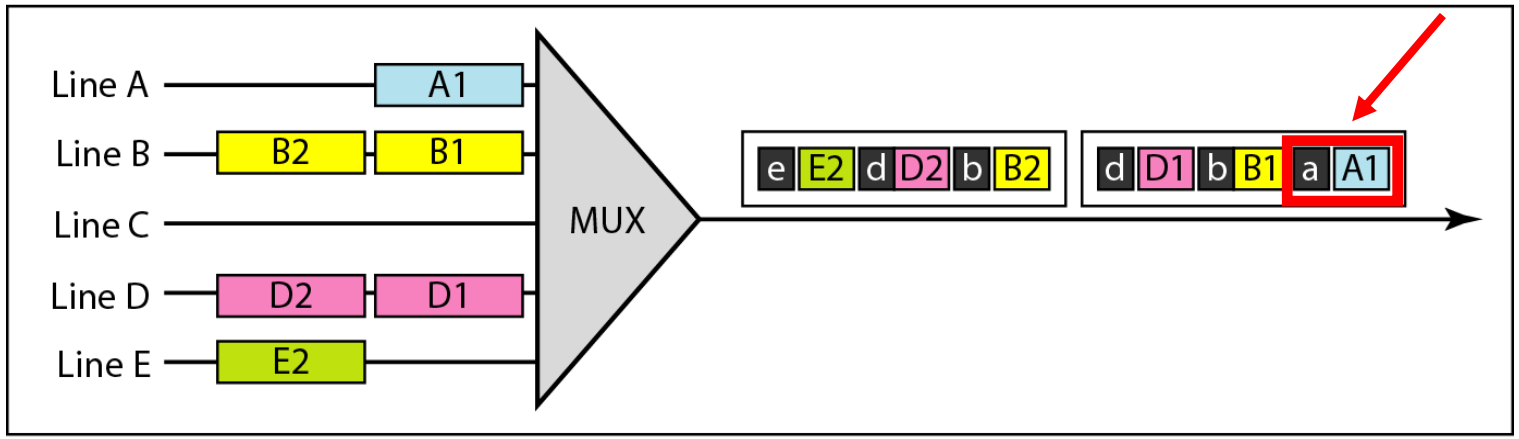
b. Statistical TDM

Statistical TDM – Continued

An output slot is totally occupied by data



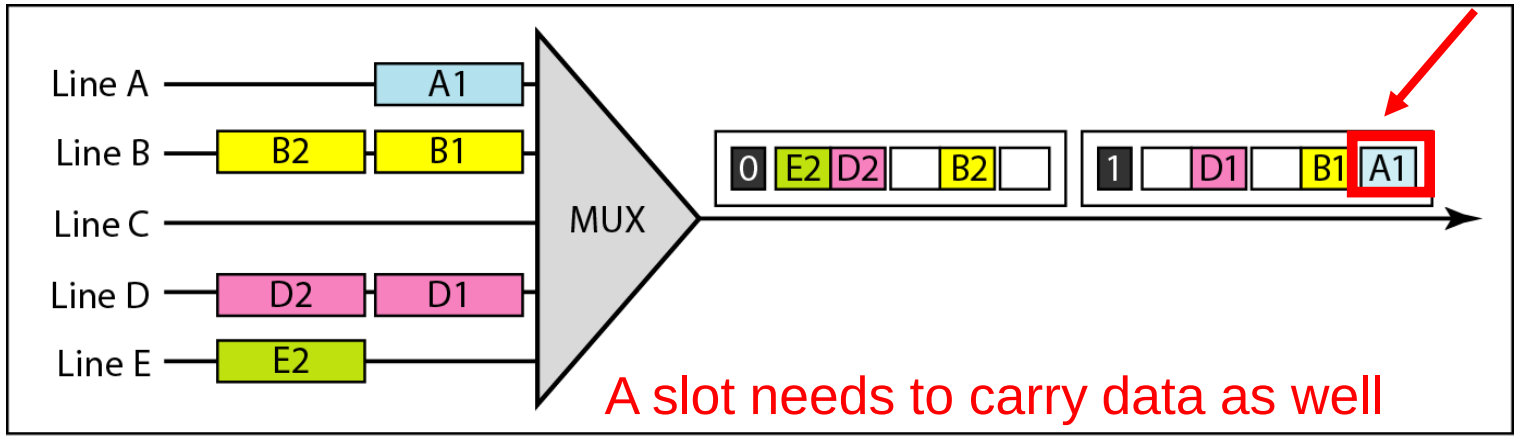
a. Synchronous TDM



b. Statistical TDM

Statistical TDM – Continued

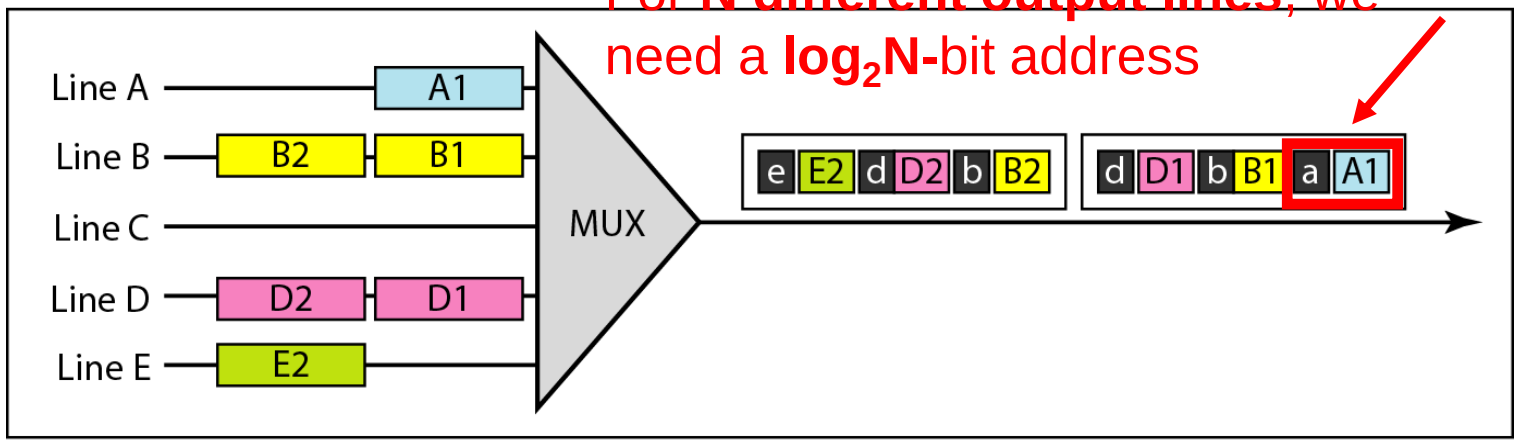
An output slot is totally occupied by data



a. Synchronous TDM

A slot needs to carry data as well as the address of the destination

For **N different output lines**, we need a **$\log_2 N$-bit address**



b. Statistical TDM → No fixed relationship between input and output

Statistical TDM – Continued

- **Slot size**
  - a slot carries both data and an address in statistical TDM
  - the ratio of the data size to address size must be reasonable to make transmission efficient (data portion must be much larger)
- **No Synchronization Bit**
  - the frames in statistical TDM need not be synchronized
- **Bandwidth**
  - the capacity of the link is normally less than the sum of the capacities of each channel.
  - the capacity of the link is usually based on the statistics of the load for each channel.

Agenda

- Introduction
- Multiplexing
- **Summary**

Summary

- Bandwidth utilization
- Multiplexing → Efficiency
- Multiplexing techniques: our focus is on TDM for digital signals
  - Synchronous TDM needs to handle the disparity between data rates and provide synchronization bits.
  - Statistical TDM dynamically allocates slots.

References

[1] Behrouz A.Forouzan, Data Communications and Networking, 5th Ed, 2013, McGraw-Hill companies.