التعدد "التجميع" Multiplexing
Time-Division Multiplexing (TDM)
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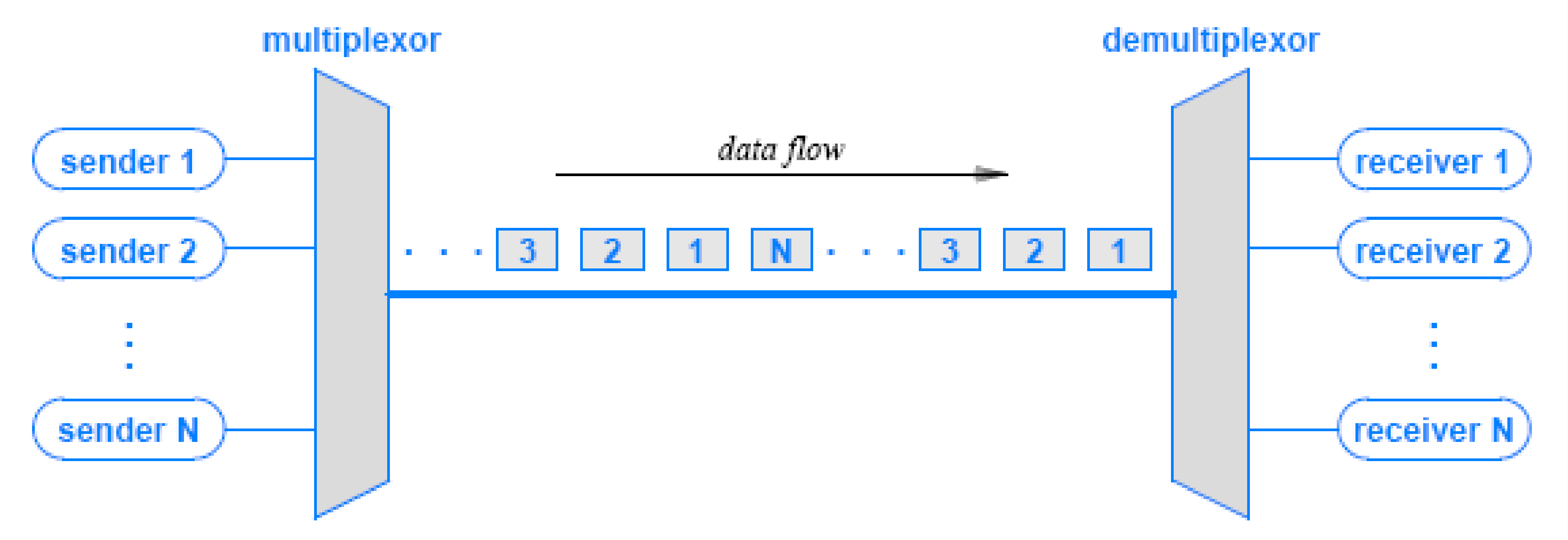
TDM is a digital multiplexing technique for combining several low-rate digital channels into one high-rate one.

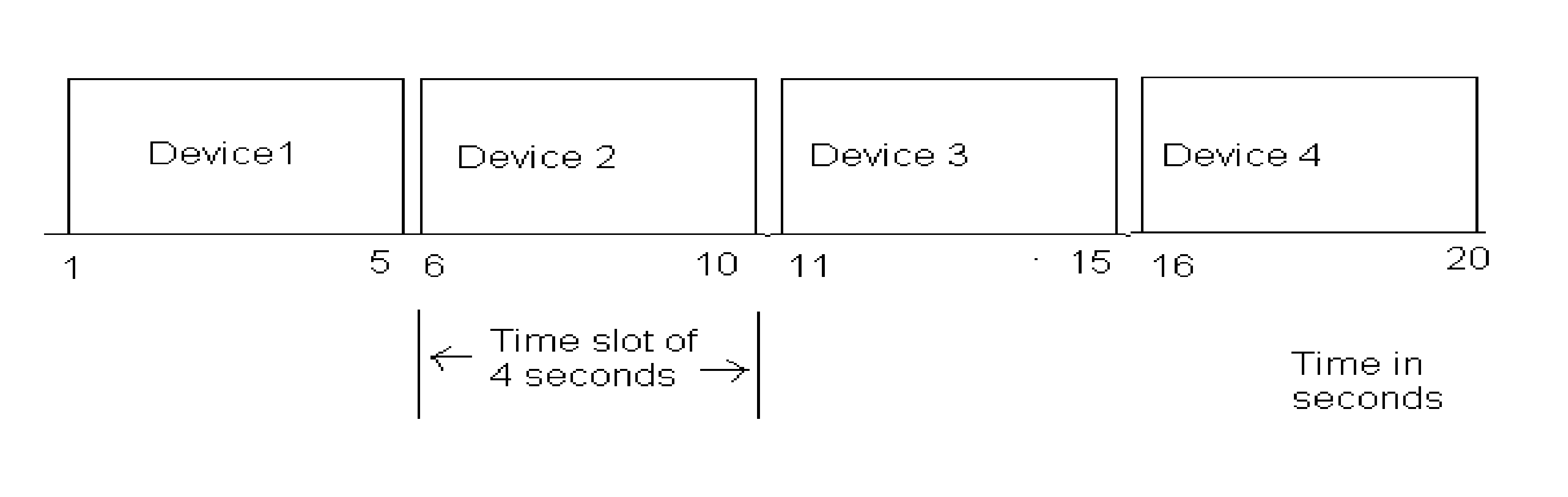
Time Division Multiplexing (TDM)

- TDM is less esoteric than FDM and does not rely on special properties of electromagnetic energy
  - multiplexing in time simply means transmitting an item from one source, then transmitting an item from another source, and so on
- Figure (below) illustrates the concept

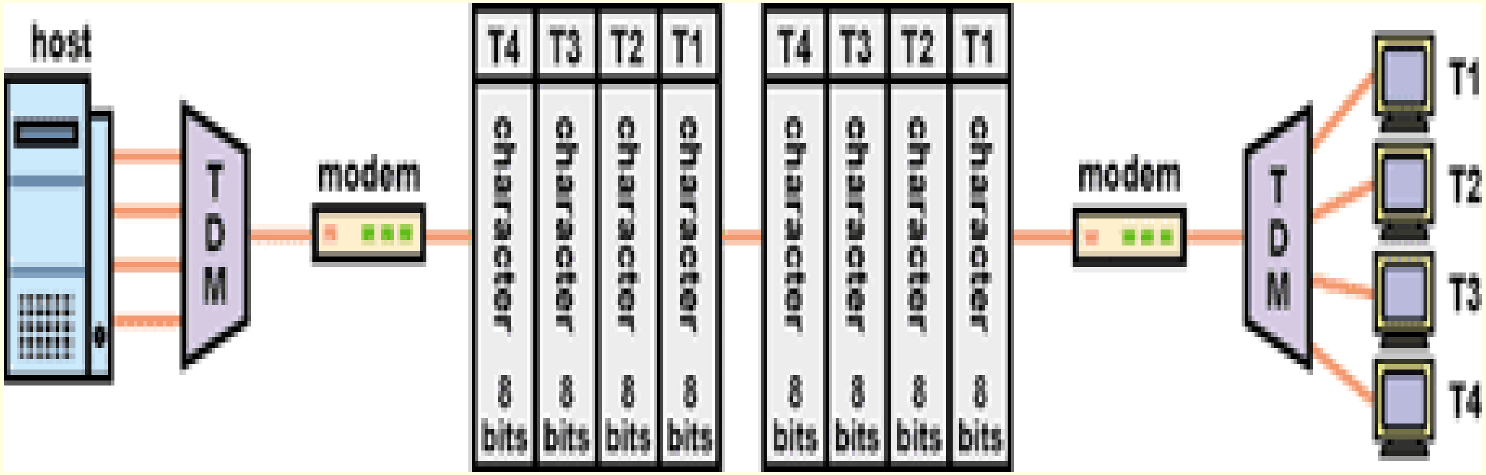


Time-division Multiplexing (TDM)

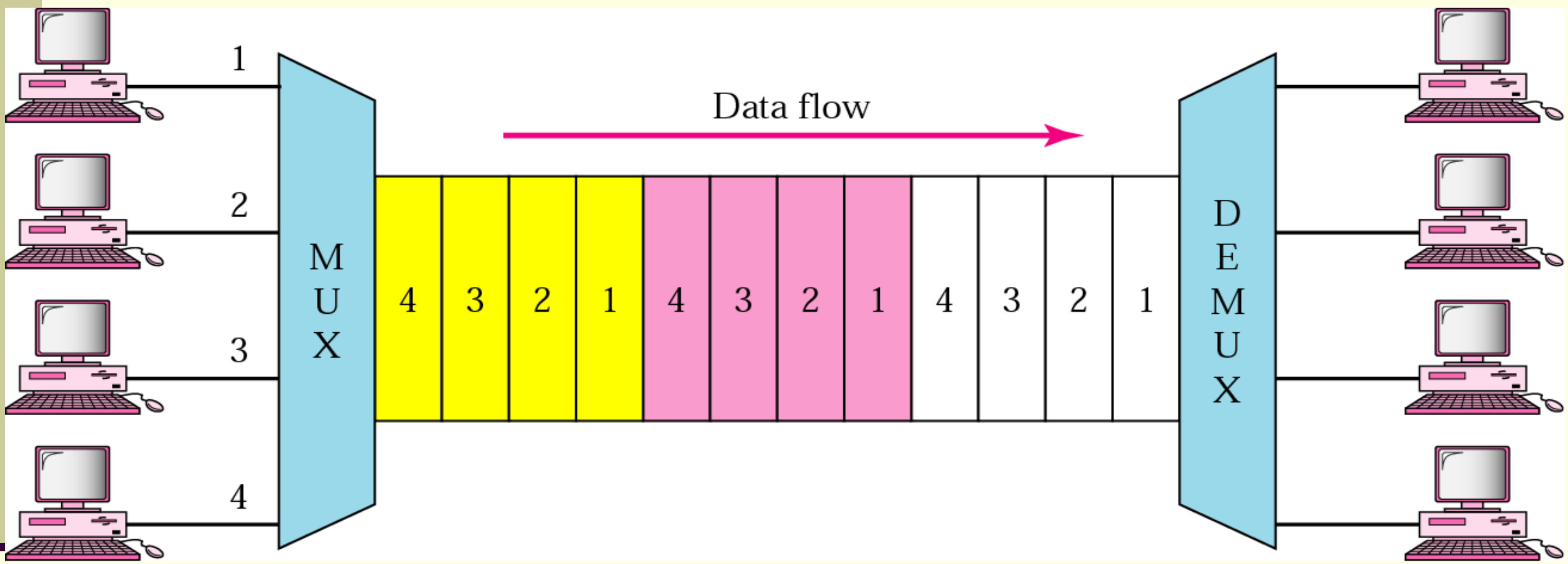
- Time-division multiplexing (TDM) is a digital process that can be applied when the data rate capacity of the transmission medium is greater than the data rate required by the sending and receiving devices.



Time slots are grouped into frames, with each frame covering one complete cycle of all the inputs. Thus, in figure below, there are two frames each covering T1, T2, T3, and T4. Each frame starts with one or more framing bits to help synchronize the mux and demux



TDM

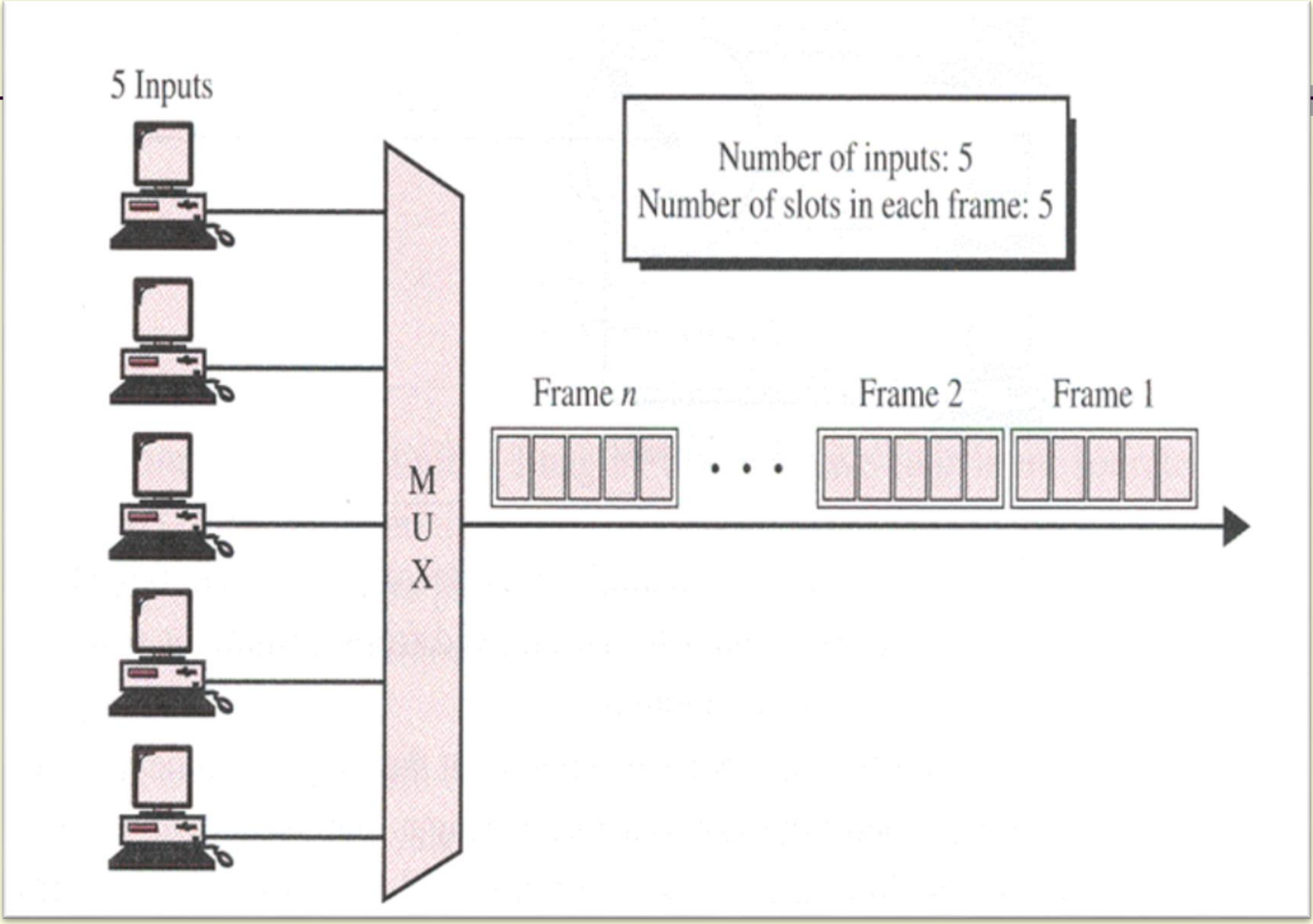


TDM is a digital multiplexing technique to combine data.

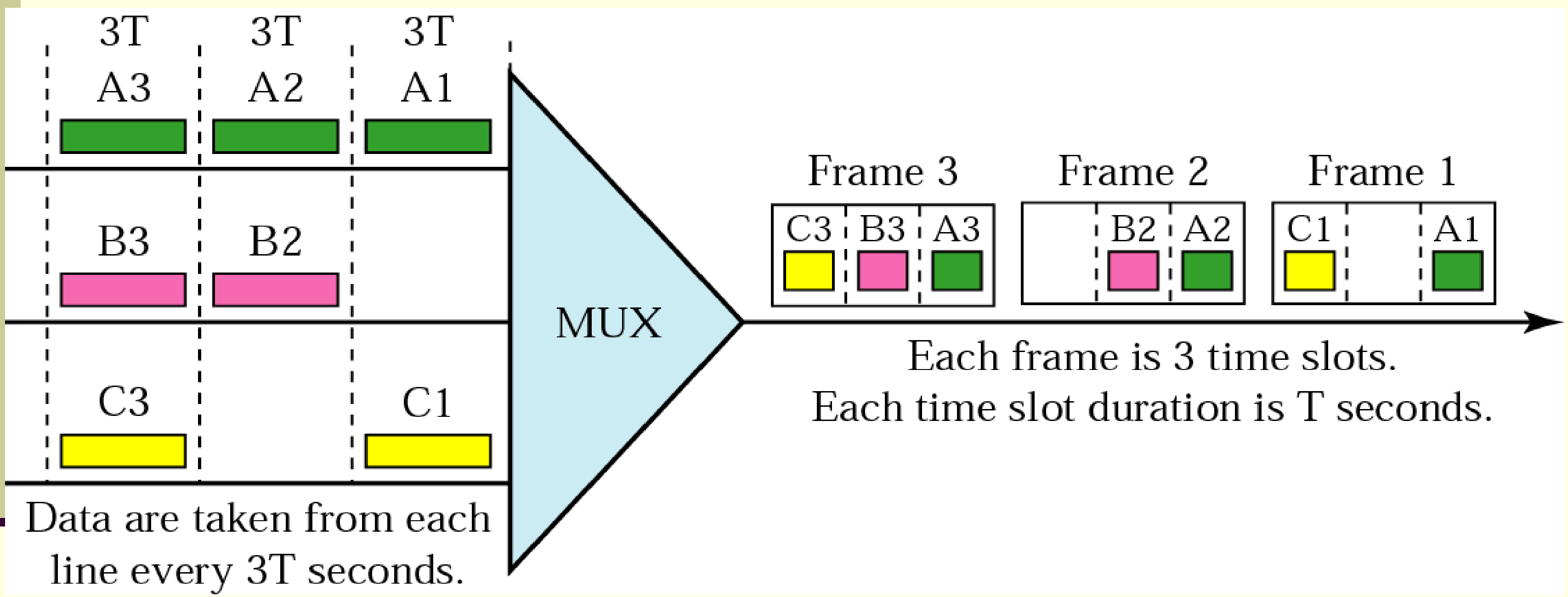
Time-division Multiplexing (TDM)

- TDM can be implemented in two ways: synchronous TDM and asynchronous TDM.
- In synchronous time-division multiplexing, the term synchronous means that the multiplexer allocates exactly the same time slot to each device at all times, whether or not a device has anything to transmit.
- Frames

Time slots are grouped into frames. A frame consists of a one complete cycle of time slots, including one or more slots dedicated to each sending device.


5 Inputs
Number of inputs: 5
Number of slots in each frame: 5
M U X
Frame n
Frame 2
Frame 1
. . .

TDM Frames


3T
3T
3T
A3
A2
A1
B3
B2
C3
C1
MUX
Frame 3
Frame 2
Frame 1
C3
B3
A3
B2
A2
C1
A1
Each frame is 3 time slots.
Each time slot duration is T seconds.
Data are taken from each
line every 3T seconds.

Synchronous TDM

- TDM is a broad concept that appears in many forms
  - It is widely used throughout the Internet
- Figure is a conceptual view, and the details may vary
- Figure shows items being sent in a round-robin fashion
  - Most TDMs work this way, but some others do not
- Figure shows a slight gap between items
  - Recall from Chapter 9 that no gap occurs between bits if a communication system uses synchronous transmission
  - When TDM is applied to synchronous networks, no gap occurs between items; the result is known as Synchronous TDM
- Figure below illustrates how synchronous TDM works for a system of four senders

11.9 Synchronous TDM

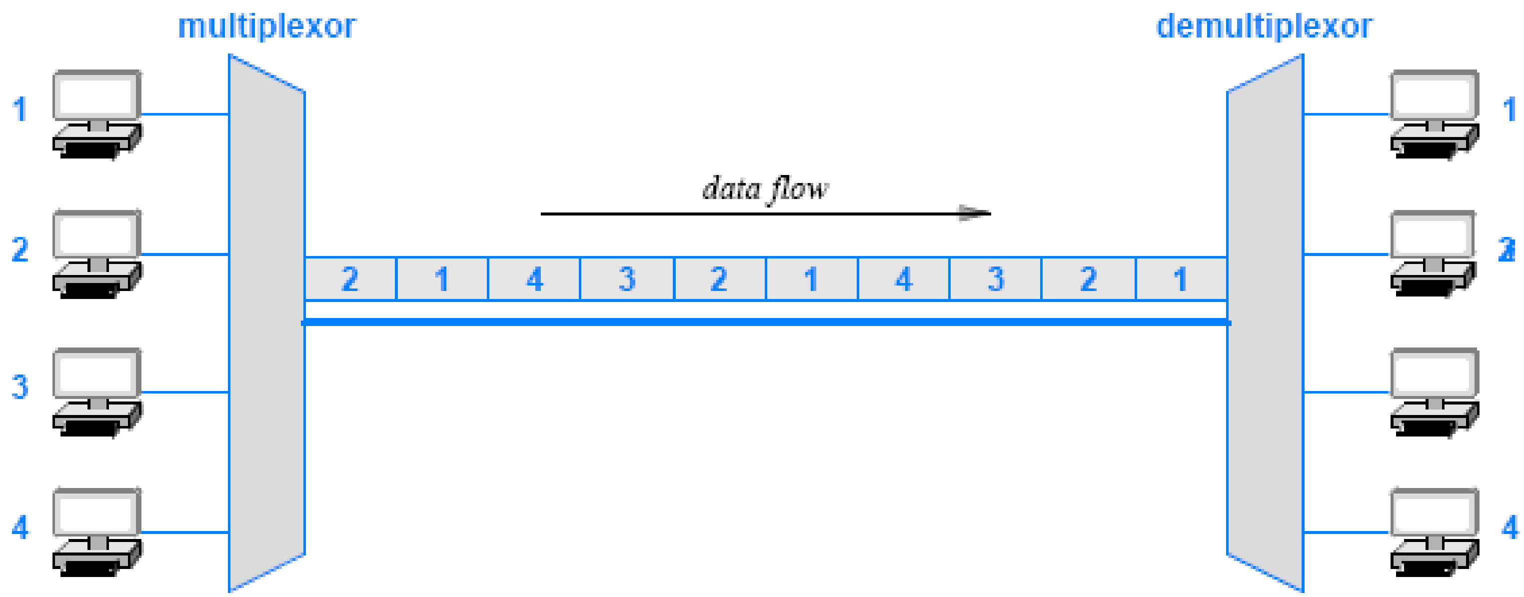
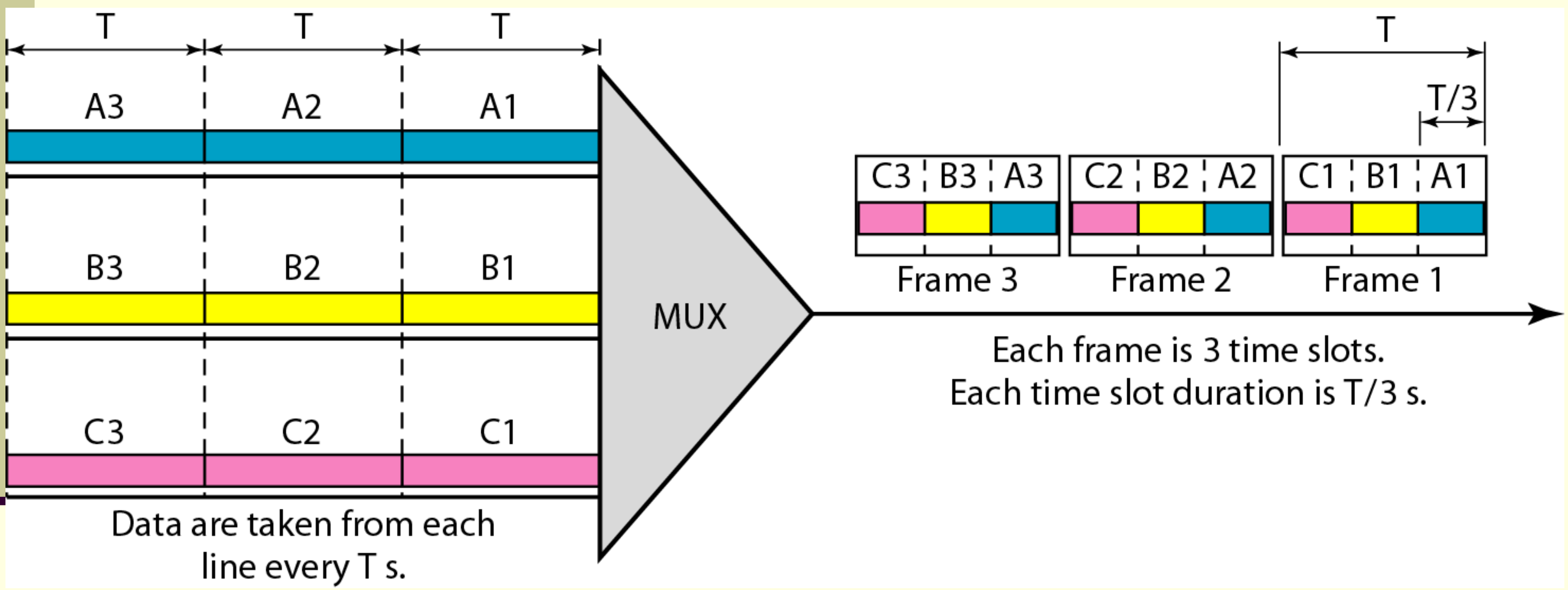
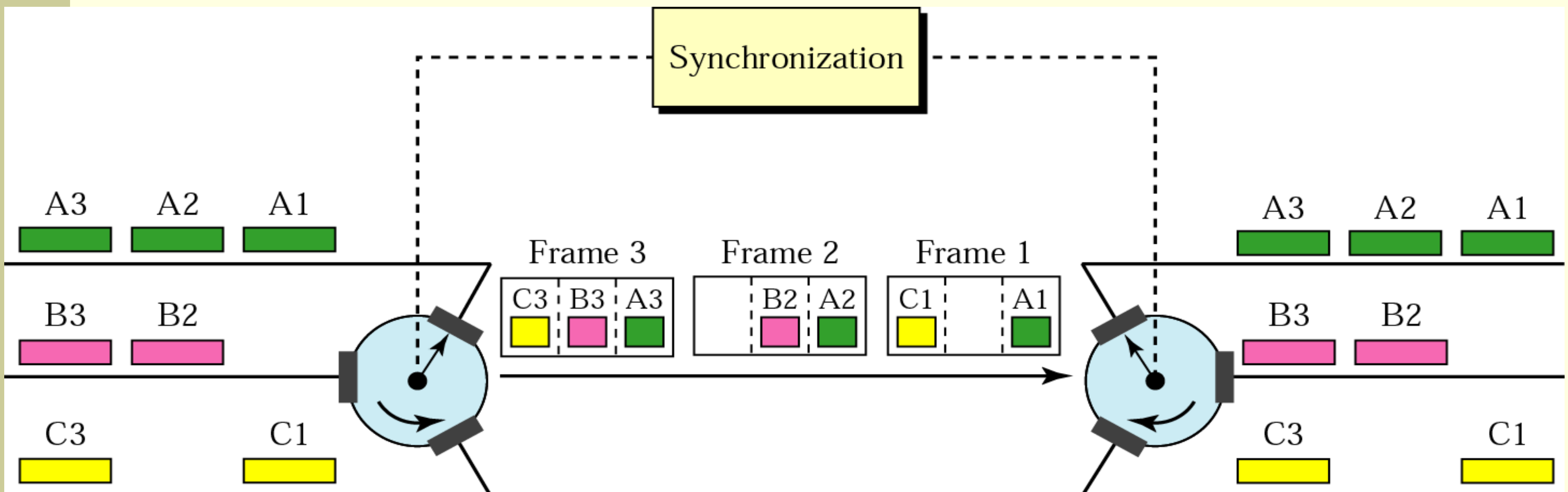


Figure 11.9 Illustration of a Synchronous Time Division Multiplexing system with four senders.

Synchronous time-division multiplexing



Interleaving



Calculation Involving TDM Frames

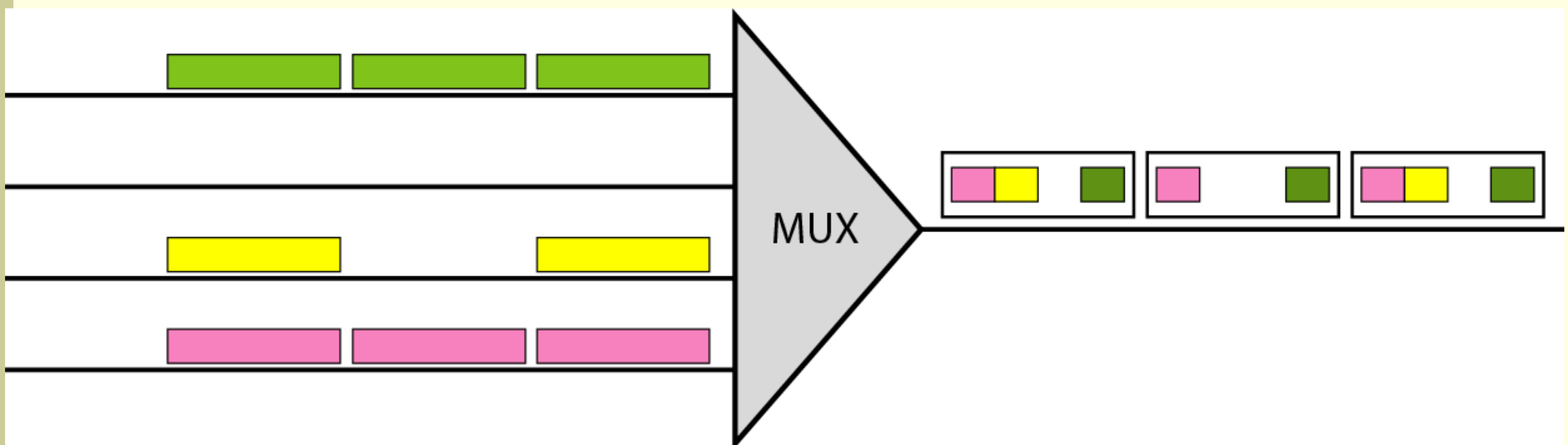
Four signal sources (A, B, C, and D) are multiplexed using TDM. Each source produces 100 characters per second.

- If there is byte interleaving and each frame requires one bit for synchronization, then:
- the frame rate is 100 frames per second
- each frame has 8 X 4 + 1 = 33 bits
- the data rate is 100 X 33 = 3.3 Kbps
- Each frame has the following composition:
- characterD characterC characterB characterA framing bit

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.

Empty slots



The Problem with Synchronous TDM: Unfilled Slots

- Synchronous TDM works well if each source produces data at a uniform, fixed rate equal to 1/N of the capacity of the shared medium
- Many sources generate data in bursts, with idle time between bursts
- To understand why, consider the example in Figure
  - sources on the left produce data items at random
  - the synchronous multiplexor leaves a slot unfilled
    - if the corresponding source has not produced an item by the time the slot must be sent
- In practice, a slot cannot be empty because the underlying system must continue to transmit data
  - the slot is assigned a value (such as zero)
  - and an extra bit is set to indicate that the value is invalid

The Problem with Synchronous TDM: Unfilled Slots

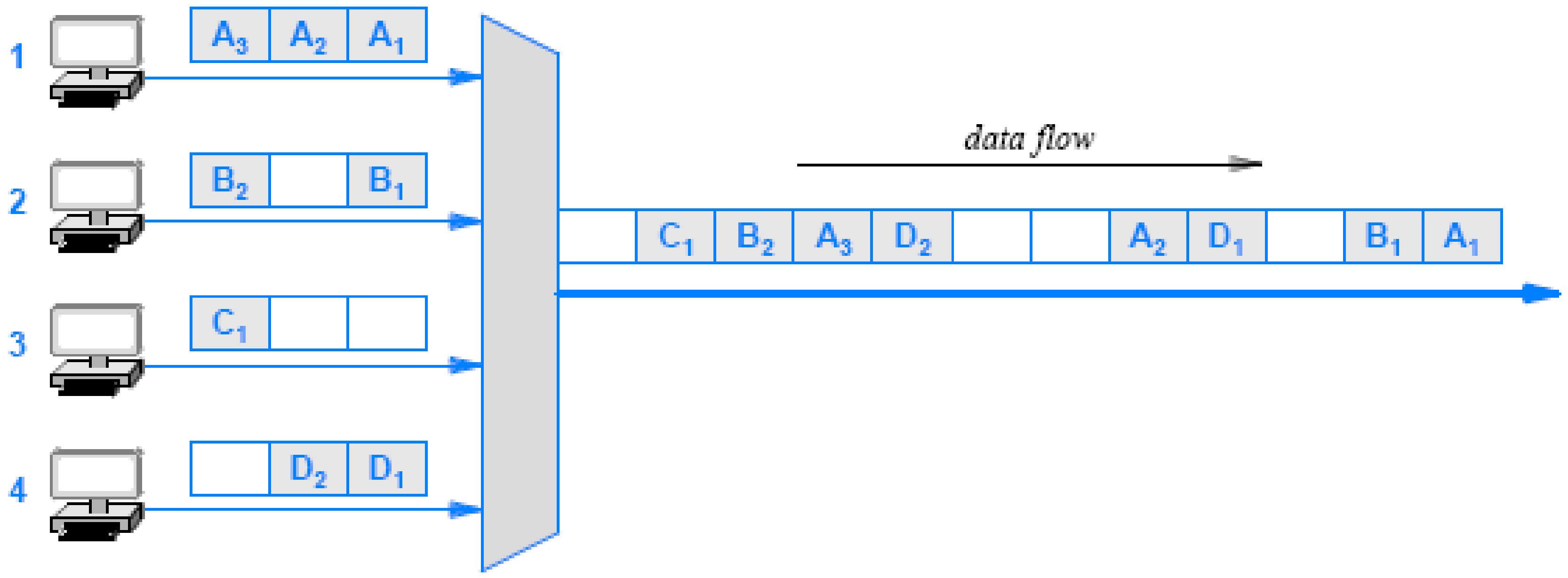


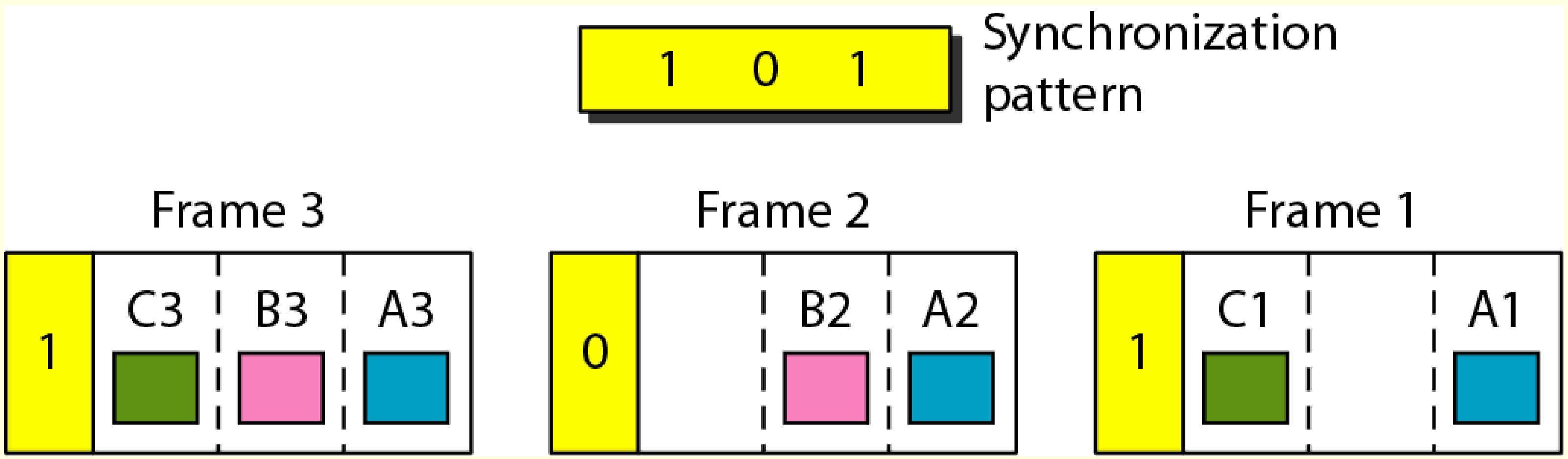
Figure 11.12 Illustration of a synchronous TDM system leaving slots unfilled when a source does not have a data item ready in time.

- Why is synchronization needed?
  - observe that a synchronous TDM sends one slot after another without any indication of the output to which a given slot occurs
- A demultiplexor cannot tell where a slot begins
  - a slight difference in the clocks used to time bits can cause a demultiplexor to misinterpret the bit stream

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.

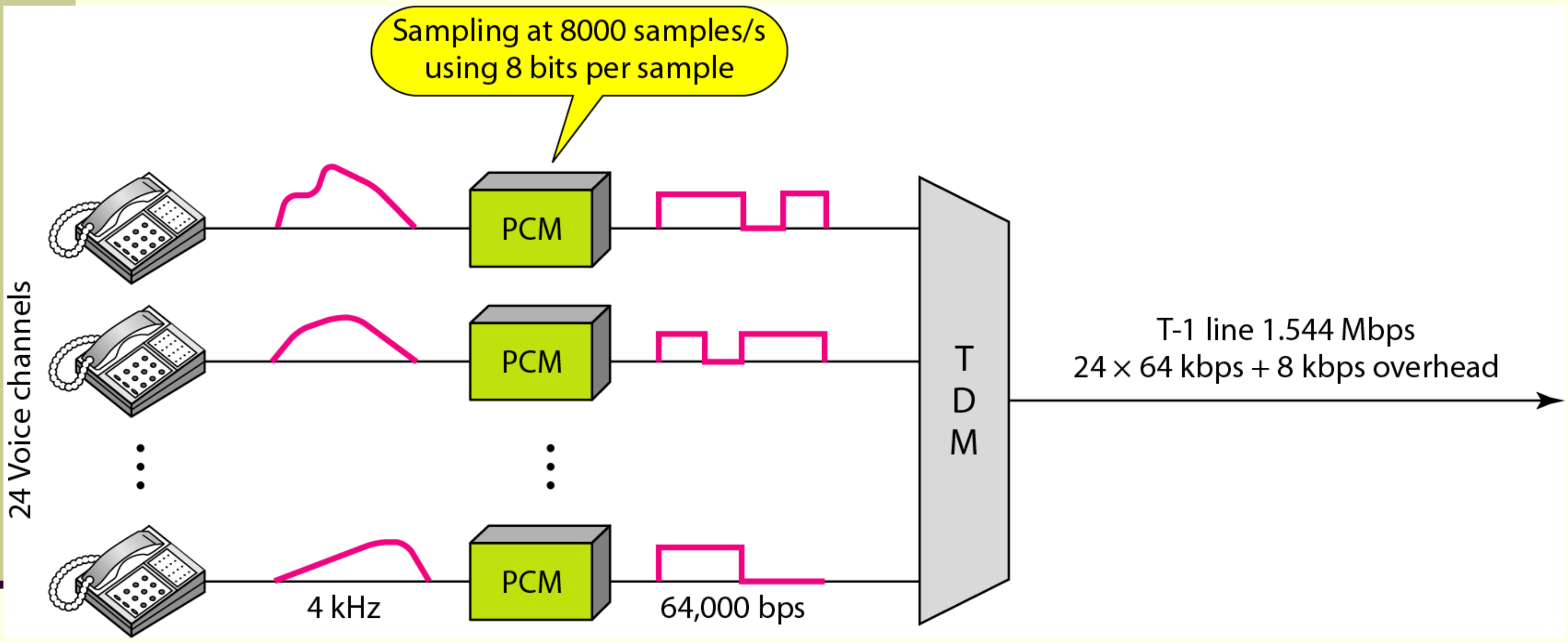
Framing bits



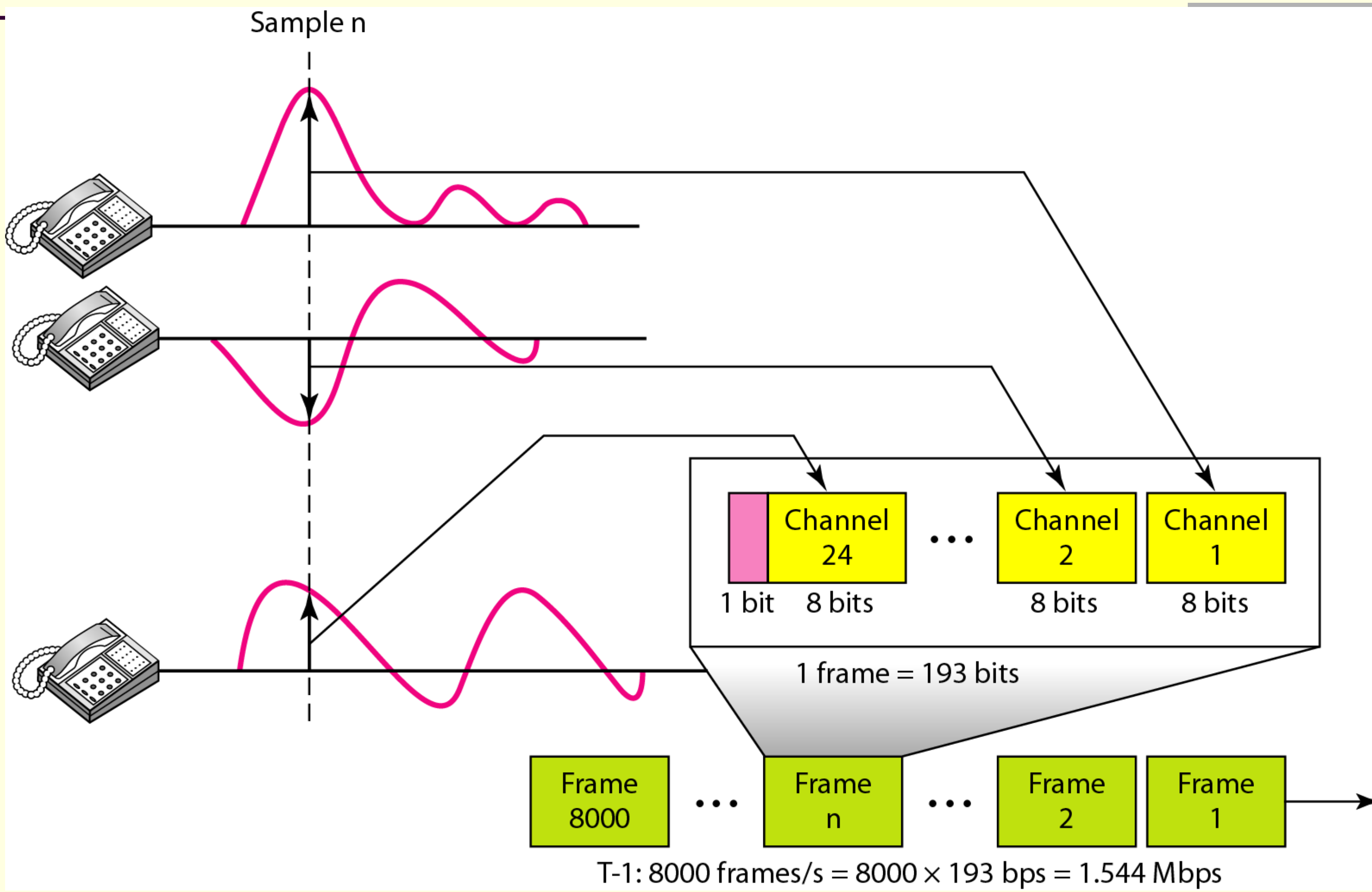
Digital Signal 0

- Digital Signal 0 (DS0) is a basic digital signalling rate of 64 kbit/s.
- The DS0 rate was introduced to carry a single digitized voice call. For a typical phone call, the audio sound is digitized at an 8 kHz sample rate, or 8000 samples per second, using 8-bit pulse-code modulation for each of the samples. This results in a data rate of 64 kbit/s.

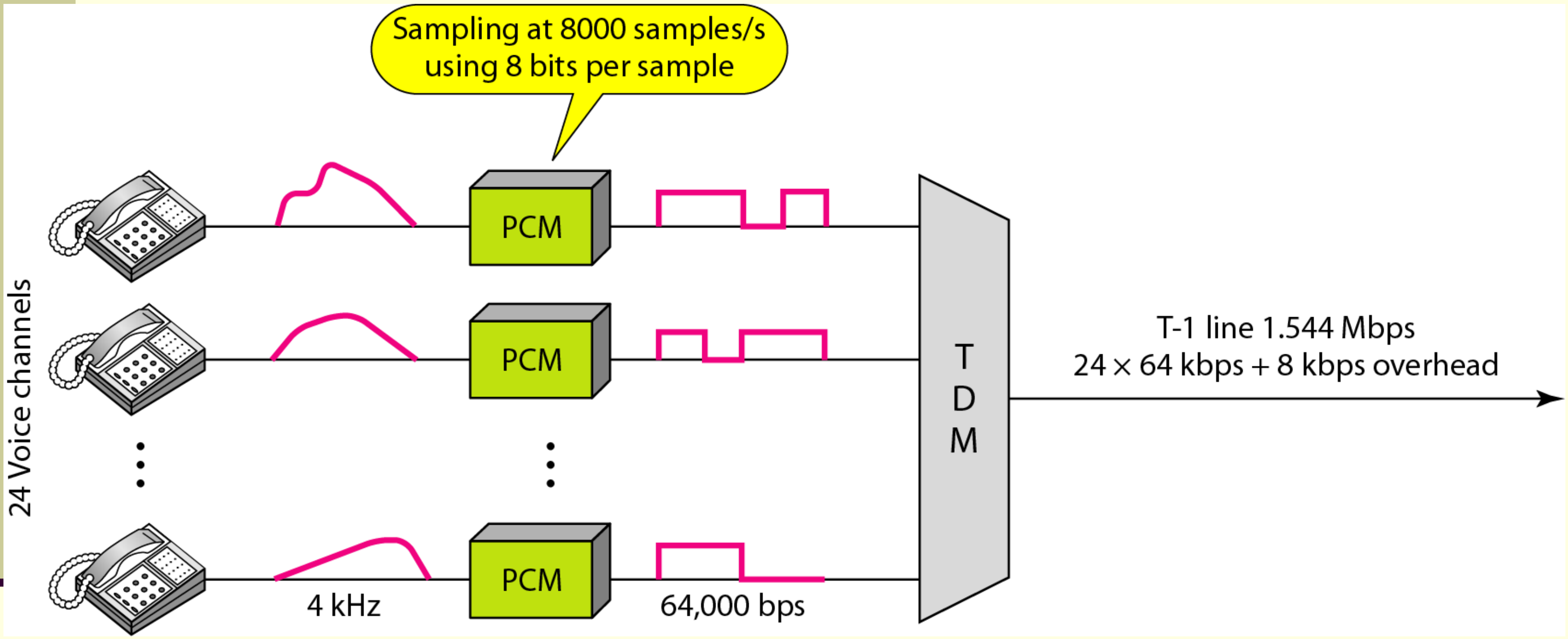
T-1 line for multiplexing telephone lines



T-1 frame structure



T-1 line for multiplexing telephone lines



A Word about Data Rates

- Bandwidth of telephone analog channel is about 4KHz, so when digitizing (PCM):

  DS0=8000 samples/sec * 8 bits = 64Kbits/second

- Common data rates supported by telcos in North America:
  - Modem: rate improved over the years
  - T1/DS1: 24 voice channels plus 1 bit control & synchronization per sample

    T1= (24 * 8 + 1) * 8000 = 1.544 Mbits/second

- Common data rates supported in the world:
  - E1/DS1: 30 voice channels plus 2 control & synchronization channels per sample

    E1= 32 * 8 * 8000 = 2.048 Mbits/second

Synchronous Time Division Multiplexing

Synchronous Time Division Multiplexing

Three types popular today:

- T-1 multiplexing (the classic)
- E-1 multiplexing
- ISDN multiplexing
- SONET (Synchronous Optical NETwork)

Asynchronous TDM

- By eliminating unused slots
  - statistical TDM takes less time to send the same amount of data
- Figure illustrates how a statistical TDM system sends the data from Figure in only 8 slots instead of 12

Asynchronous TDM

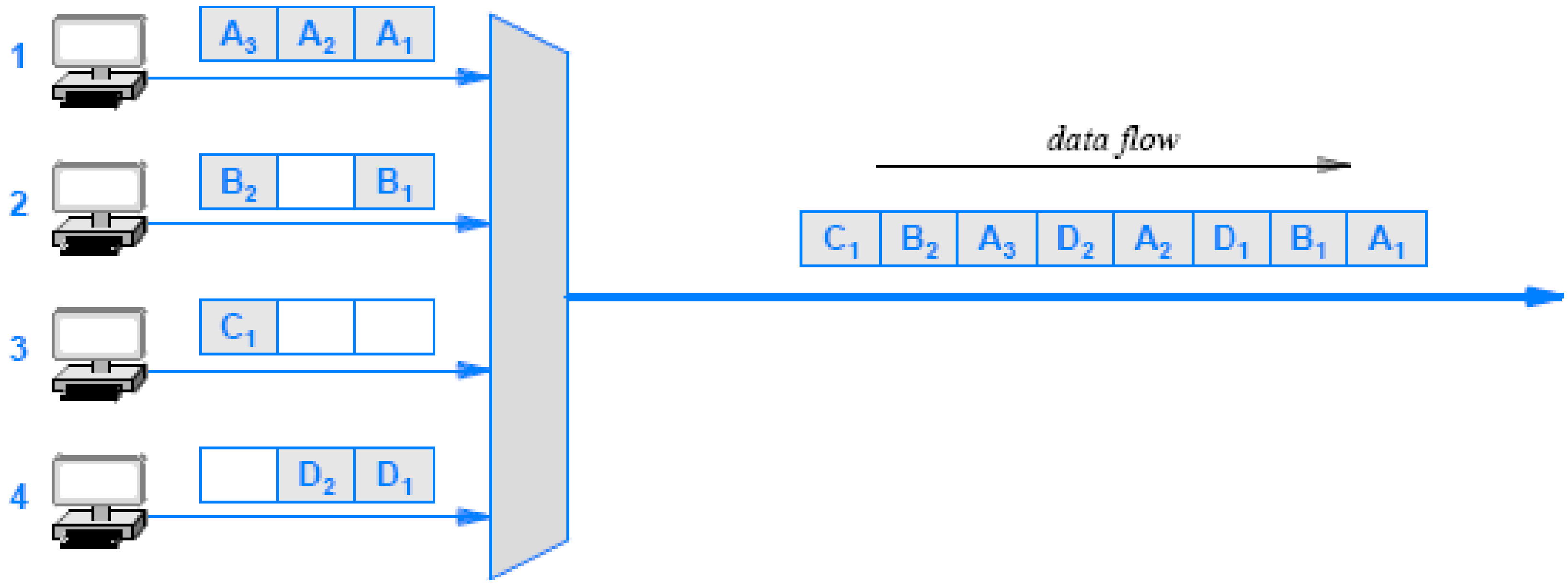


Figure 11.13 Illustration that shows how statistical multiplexing avoids unfilled slots and takes less time to send data.

Asynchronous 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.
- Like synchronous TDM, asynchronous TDM allows a number of lower-speed input lines to be multiplexed to a single higher-speed line. However, in asynchronous TDM the total speed of the input lines can be greater than the capacity of the link.

Advantages of TDM

1. It uses a single links.

2. It does not require precise carrier matching at both end of the links.

3. Use of capacity is high.

4. Each to expand the number of users on a system at a low cost.

5. There is no need to include identification of the traffic stream on each packet

Disadvantages of TDM

1.The sensitivity to other user problem is high.

2. Initial cost is high.

3. Technical complexity is more.

Commparison Synchronous & Asnchronous TDM

- Works by the multiplexor giving exactly the same amount of time to each device connected to it.

- Therefore, the use of Synchronous TDM does not guarantee maximum line usage and efficiency.

- Synchronous TDM is used in T1 and E1 connections.

Commparison Synchronous & Asnchronous TDM

- Is a more flexible method of TDM. With Asynchronous TDM the length of time allocated is not fixed for each device but time is given to devices that have data to transmit.

- This may require more processing by the multiplexor and take longer, however, the time saved by efficient and effective bandwidth utilization makes it worthwhile.

- TDM allows more devices than there is physical bandwidth for.
- This type of TDM is used in Asynchronous Transfer Mode (ATM) networks

Comparison TDM VS FDM

Difference No. 1

TDM: Total available time is divided into several user

FDM: total frequency bands are divided into several users

Difference No. 2

FDM:A multiplex system for transmitting two or more signals over a common path by using a different frequency band for each signal.

TDM: Transmission of two or more signals on the same path, but at different times.

Difference No. 3

TDM:TDM imply partitioning the bandwidth of the channel connecting two nodes into finite set of time slots

FDM:The signals multiplexed come from different sources/transmitters.

Comparison TDM VS FDM

Difference No. 4
TDM provides much better flexibility compared to FDM.

Difference No. 5
FDM proves much better latency compared to TDM.