Bandwidth Utilization (Part 1): WDM and TDM

Course Code: COE 3201 Course Title: Data Communication

Dept. of Computer Engineering
Faculty of Engineering

Lecture: 09

Lecture Outline

1. Wavelength-division multiplexing (WDM)
2. Time-division multiplexing (TDM)
3. Synchronous TDM

Wavelength-division multiplexing (WDM)

- Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable.
- The optical fiber data rate is higher than the data rate of metallic transmission cable but using a fiber-optic cable for a single line wastes the available bandwidth.
- WDM allows us to combine several lines into one.

- WDM is conceptually the same as FDM, except that the multiplexing and demultiplexing involve optical signals transmitted through fiber-optic channels.
- The idea is the same: We are combining different signals of different frequencies.
- The difference is that the frequencies are very high.
- Figure 6.10 gives a conceptual view of a WDM multiplexer and demultiplexer.
- Very narrow bands of light from different sources are combined to make a wider band of light. At the receiver, the signals are separated by the demultiplexer.

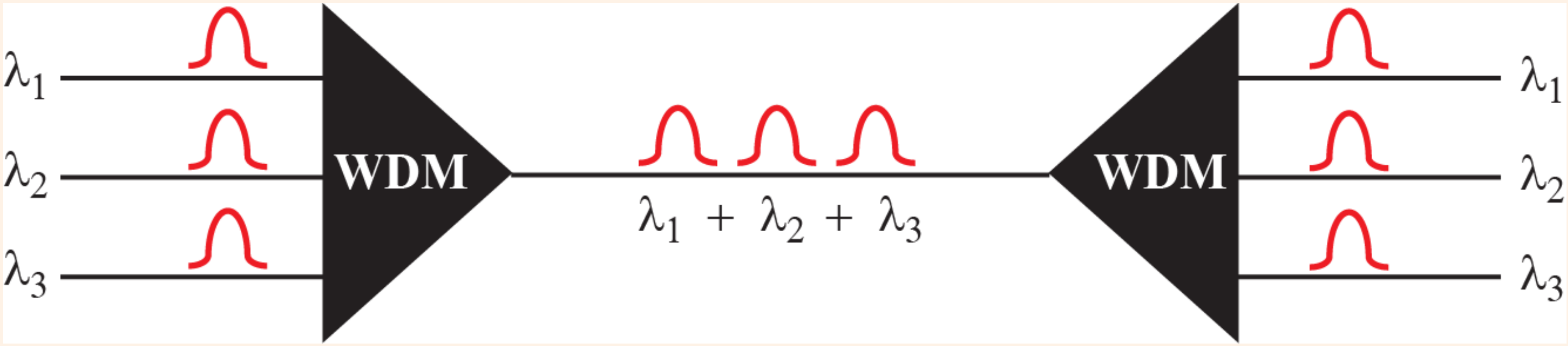


Figure 6.10: Wavelength-division multiplexing

- Although WDM technology is very complex, the basic idea is very simple.
- We want to combine multiple light sources into one single light at the multiplexer and do the reverse at the demultiplexer.
- The combining and splitting of light sources are easily handled by a prism.

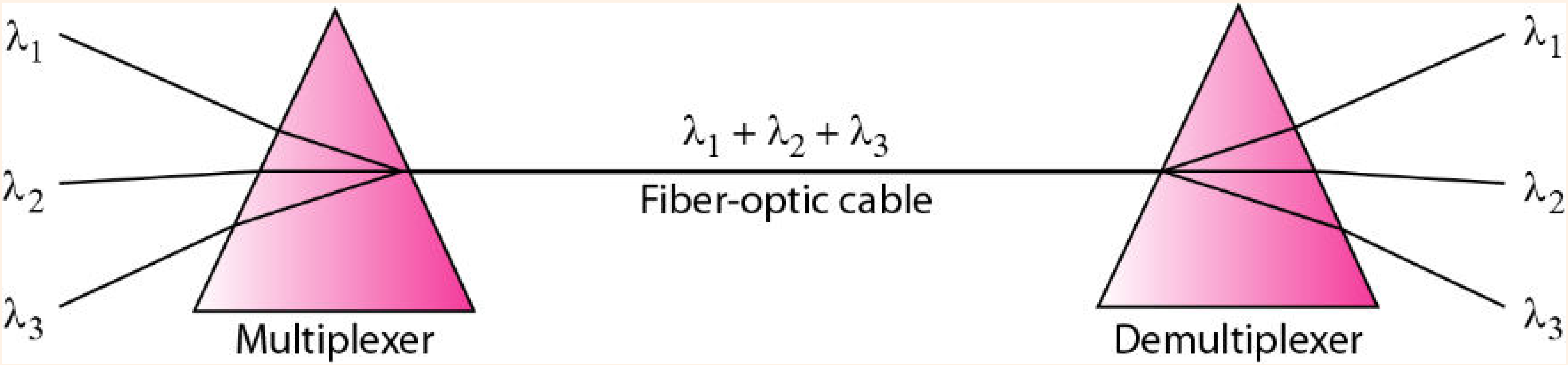


Figure 6.11: Prisms in wave-length division multiplexing

Time-division multiplexing (TDM)

- Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link.
- Instead of sharing a portion of the bandwidth as in FDM, time is shared. Each connection occupies a portion of time in the link.
- Figure 6.12 gives a conceptual view of TDM.
- Note that the same link is used as in FDM; here, however, the link is shown sectioned by time rather than by frequency.

- In the figure, portions of signals 1, 2, 3, and 4 occupy the link sequentially.

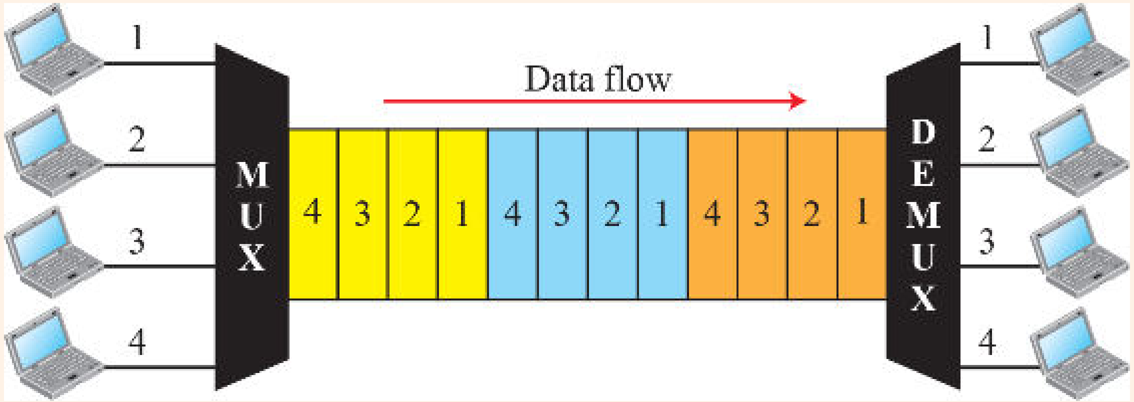
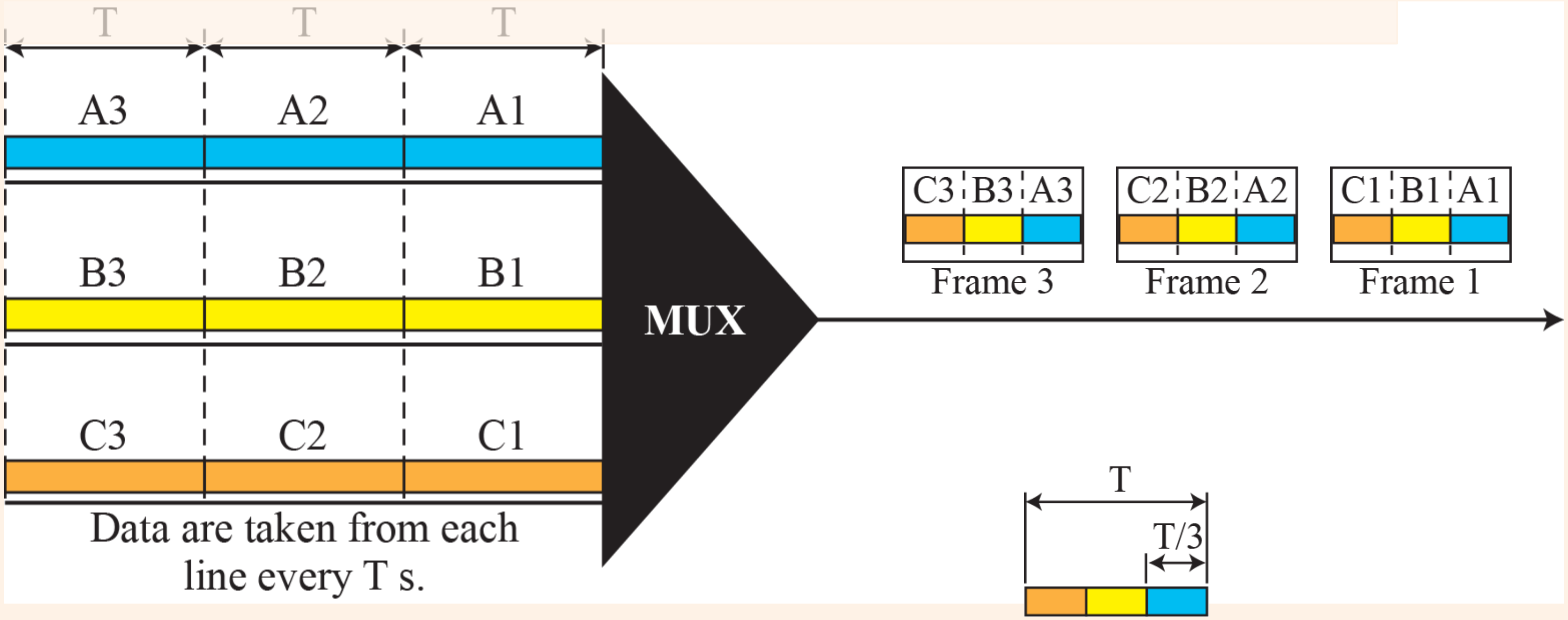


Figure 6.12: TDM

Synchronous TDM

- We can divide TDM into two different schemes: **synchronous** and **statistical**.
- In synchronous TDM, each input connection has an allotment in the output even if it is not sending data.
- Time Slots and Frames: In synchronous TDM, the data flow of each input connection is divided into units, where each input occupies one input time slot. Each input unit becomes one output unit and occupies one output time slot. However, the duration of an output time slot is n times shorter than the duration of an input time slot.

Synchronous TDM



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

Figure 6.13: Synchronous time-division multiplexing

Synchronous TDM

Example 6.5: In Figure 6.13, 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 1. each input slot, 2. each output slot, and 3. each frame?

Solution: We can answer the questions as follows:
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.

Synchronous TDM

Example 6.5: Figure 6.14 shows synchronous TDM with a data stream for each input and one data stream for the output. The unit of data is 1 bit. Find (a) the input bit duration, (b) the output bit duration, (c) the output bit rate, and (d) the output frame rate.

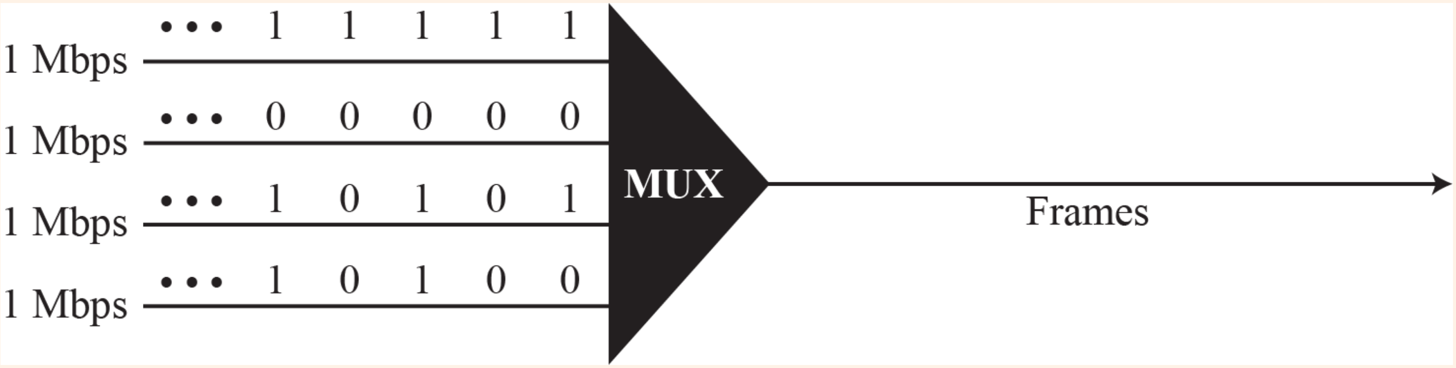


Figure 6.14: Example 6.6

Synchronous TDM

Solution

We can answer the questions as follows:

1. The input bit duration is the inverse of the bit rate: 1/1 Mbps = 1 μs.
2. The output bit duration is one-fourth of the input bit duration, or 1/4 μs.
3. The output bit rate is the inverse of the output bit duration, or 1/(1/4) μs or 4 Mbps. This can also be deduced from the fact that the output rate is 4 times as fast as any input rate; so the output rate = 4 × 1 Mbps = 4 Mbps.
4. The frame rate is always the same as any input rate. So the frame rate is 1,000,000 frames per second. Because we are sending 4 bits in each frame, we can verify the result of the previous question by multiplying the frame rate by the number of bits per frame.

Synchronous TDM

Example 6.5: 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.

Solution

We can answer the questions as follows:

1. The duration of 1 bit before multiplexing is 1/1 kbps, or 0.001 s (1 ms).
2. The rate of the link is 4 times the rate of a connection, or 4 kbps.
3. The duration of each time slot is one-fourth of the duration of each bit before multiplexing, or 1/4 ms or 250 μs. Note that we can also calculate this from the data rate of the link, 4 kbps. The bit duration is the inverse of the data rate, or 1/4 kbps or 250 μs.
4. The duration of a frame is always the same as the duration of a unit before multiplexing, or 1 ms. We can also calculate this in another way. Each frame in this case has four time slots. So the duration of a frame is 4 times 250 μs, or 1 ms.