Bandwidth Utilization

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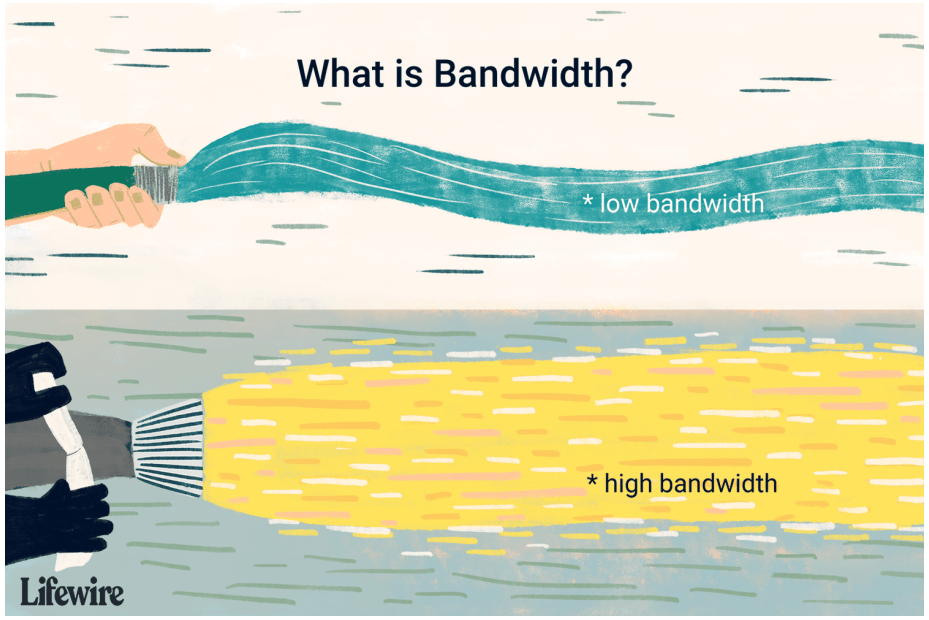
Bandwidth

Bandwidth is measured as the amount of data that can be transferred from one point to another within a network in a specific amount of time.

Bandwidth also refers to a range of frequencies used to transmit a signal. This type of bandwidth is measured in hertz (Hz) and is often referenced in signal processing applications.



Expressing bandwidth

Typically, bandwidth is expressed as a bitrate and measured in bits per second (bps)

Nowadays we mostly use Mbps, Gbps, Tbps etc

K = kilo = 1,000 bits

M = mega = 1,000 kilo = 1,000,000 bits

G = giga = 1,000 mega = 1,000,000,000 bits

T = tera = 1,000 giga = 1,000,000,000,000 bits

Mbps and MBps: The Real Difference

Understanding the difference between bits and bytes is useful when discussing internet technologies and digital gadgets. It can also be helpful when dealing with tech support or customer service.

Mbps	MBps
Mbps refers to mega**bits** per second	**MB**ps refers to mega**bytes** per second
Measures data speed. If you're looking for an internet provider, all the speeds will use bits	Measures data volume or storage capacity
A byte is the smallest storage slot in terms of memory. Bytes are generally measured in hard drives, SSDs, USB sticks, and system memory.	A byte is a collection of eight bits
The value is either "1" or "0" but can also signify "on" and "off"	1 byte = 8 bits
Mega**bits** per second **(Mbps)** indicates how fast a network or internet connection is.	Mega**bytes** per second **(MB)** indicates the rate a file is downloaded or uploaded.

Conversions in between data transfer rates

Example : Convert 10 MBps into Mbps.

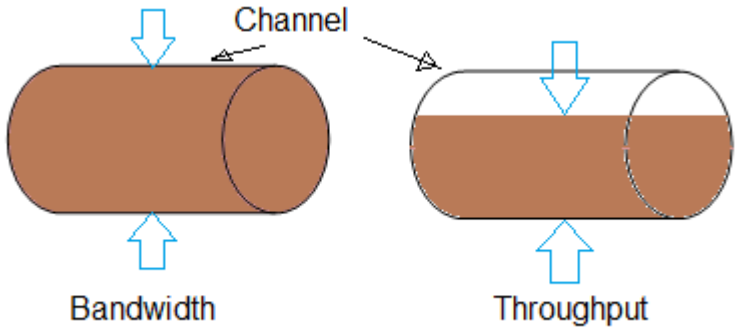
10 MBps = 80 Mbps (1 Byte = 8 bits)

Exercise.

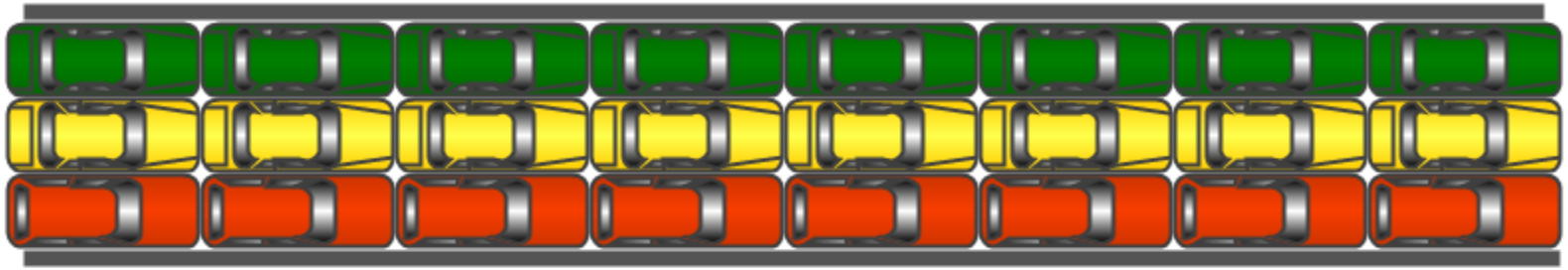
1. Convert 3 GBps into MBps
2. Convert 3.2 Mbps into Kbps
3. Convert 7 MBps into Kbps

Bandwidth vs Throughput

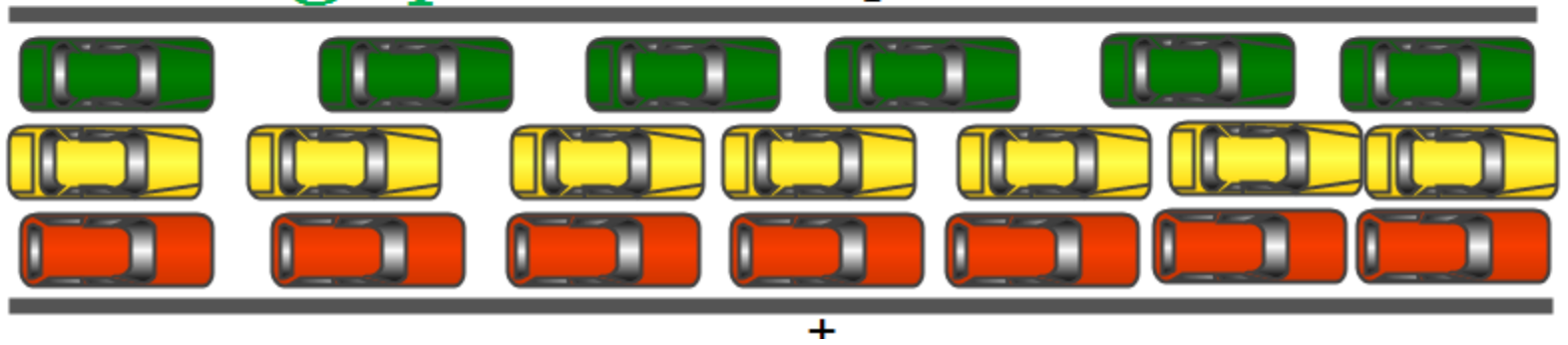
Bandwidth	Throughput
Bandwidth is a theoretical measure of how much data could be transferred from source to destination.	Throughput is an actual measure of how much data is successfully transferred from source to destination.
Mainly refers to a theoretical peak value.	Refers to an achieved value.



Bandwidth 24 Cars per second



Throughput 20 Cars per second



Wired bandwidth standards for connections

Dialup Modem	56 kbps
T1 (Digital leased landline connection)	1.544 Mbps
E1 (Digital leased landline connection European)	2.048 Mbps
Asynchronous DSL	4 Mbps
Ethernet	10 Mbps
T3 (Digital leased landline connection)	44.763 Mbps
VDSL	55 Mbps
VDSL 2	100 Mbps
Fast Ethernet	100 Mbps

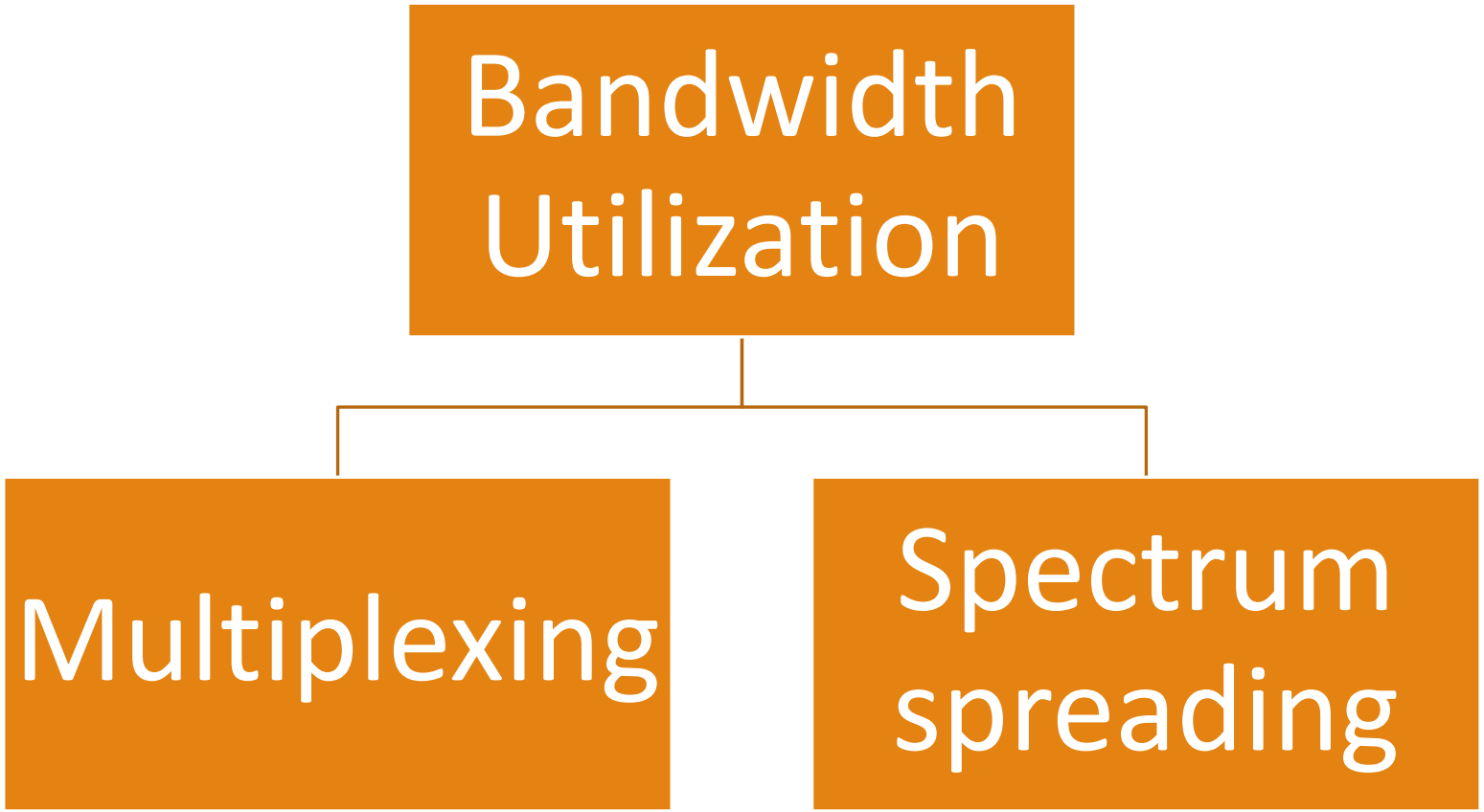
OC3 (Ficer optic leased landline connection)	155 Mbps
OC 12 (Ficer optic leased landline connection)	622 Mbps
Gigabit Ethernet	1000 Mbps or 1 Gbps
VSDL 2 Vplus	300 Mbps
10 Gigabit Ethernet	10 Gbps
100 Gigabit Ethernet	100 Gbps

Wireless network standard maximum download speeds

802.11b	11 Mbps
802.11g	54 Mbps
802.11n	600 Mbps
802.11ac	600 Mbps
3G - HSPA	7.2 Mbps
3G - HSPA+	21 Mbps
3G - DC-HSPA+	42 Mbps
4G - LTE	100 Mbps
5G (proposed)	1 Gpbs (or higher)

Bandwidth Utilization

- In real life, we have links with limited bandwidths.
- The wise use of these bandwidths has been, and will be, one of the main challenges of electronic communications.
- Sometimes we need to combine several low-bandwidth channels to make use of one channel with a larger bandwidth.
- Sometimes we need to expand the bandwidth of a channel to achieve goals such as privacy and antijamming.


Bandwidth Utilization
Multiplexing
Spectrum spreading

Multiplexing

Multiplexing is a method by which multiple analog or digital signals are combined into one signal over a shared medium.

Goal→ efficiency

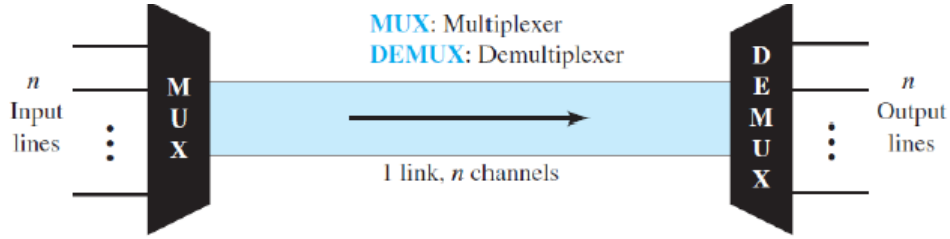
allow the simultaneous transmission of multiple signals across a single data link.

Applied in

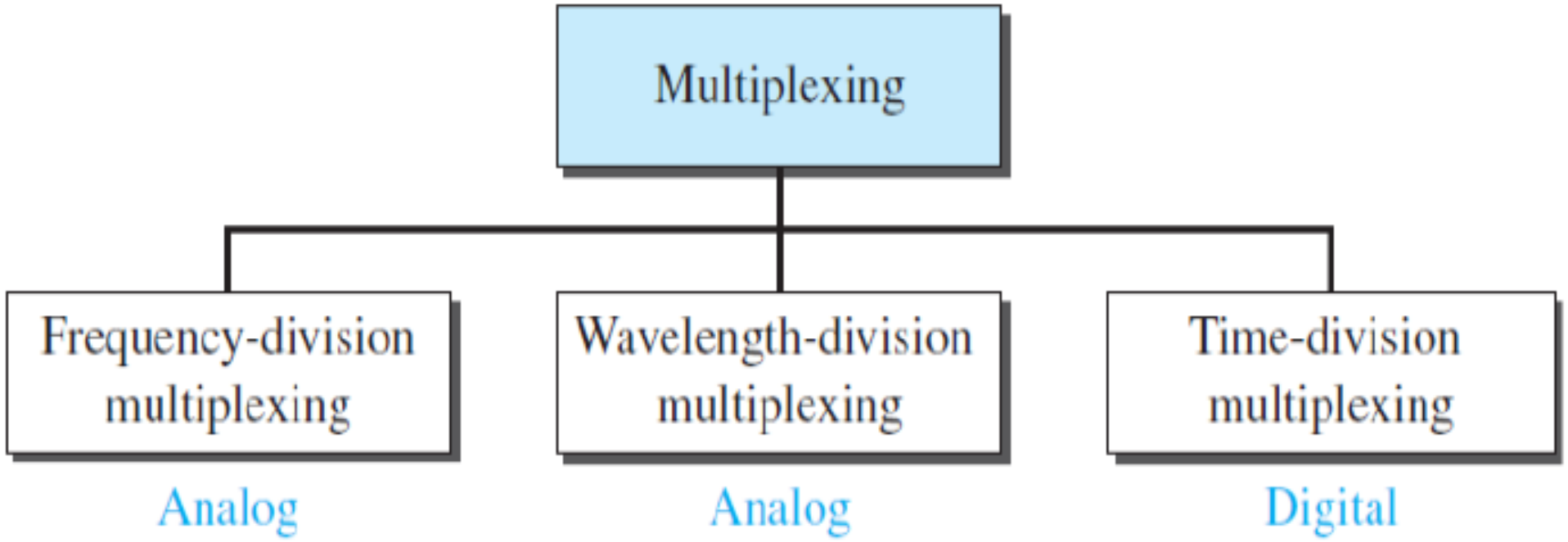
- Telecommunication
- Broadcasting (Analog, Digital)
- Video Processing
- Satellite Communication

Multiplexing cont.

- Multiplexer (MUX)
  - combines (multiplexes) data from the n input lines and transmits over a higher capacity data link.
- Demultiplexer (DEMUX)
  - accepts the multiplexed data stream, separates (demultiplexes) the data according to channel, and delivers them to the appropriate output lines.



Categories of Multiplexing



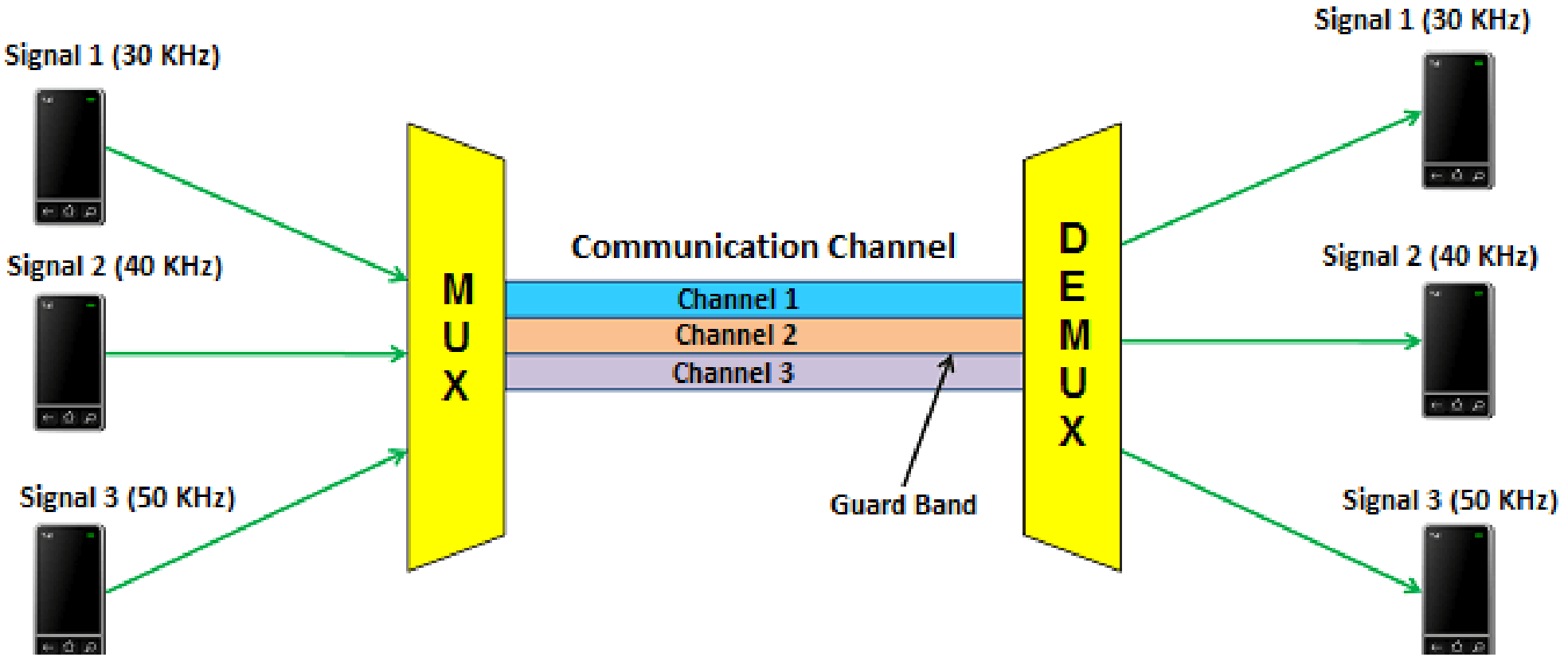
Frequency Division Multiplexing (FDM)

- FDM is an analog multiplexing technique that combines analog signals
- Can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted
- This technique uses various frequencies to combine streams of data, for sending them on a communication medium, as a single signal

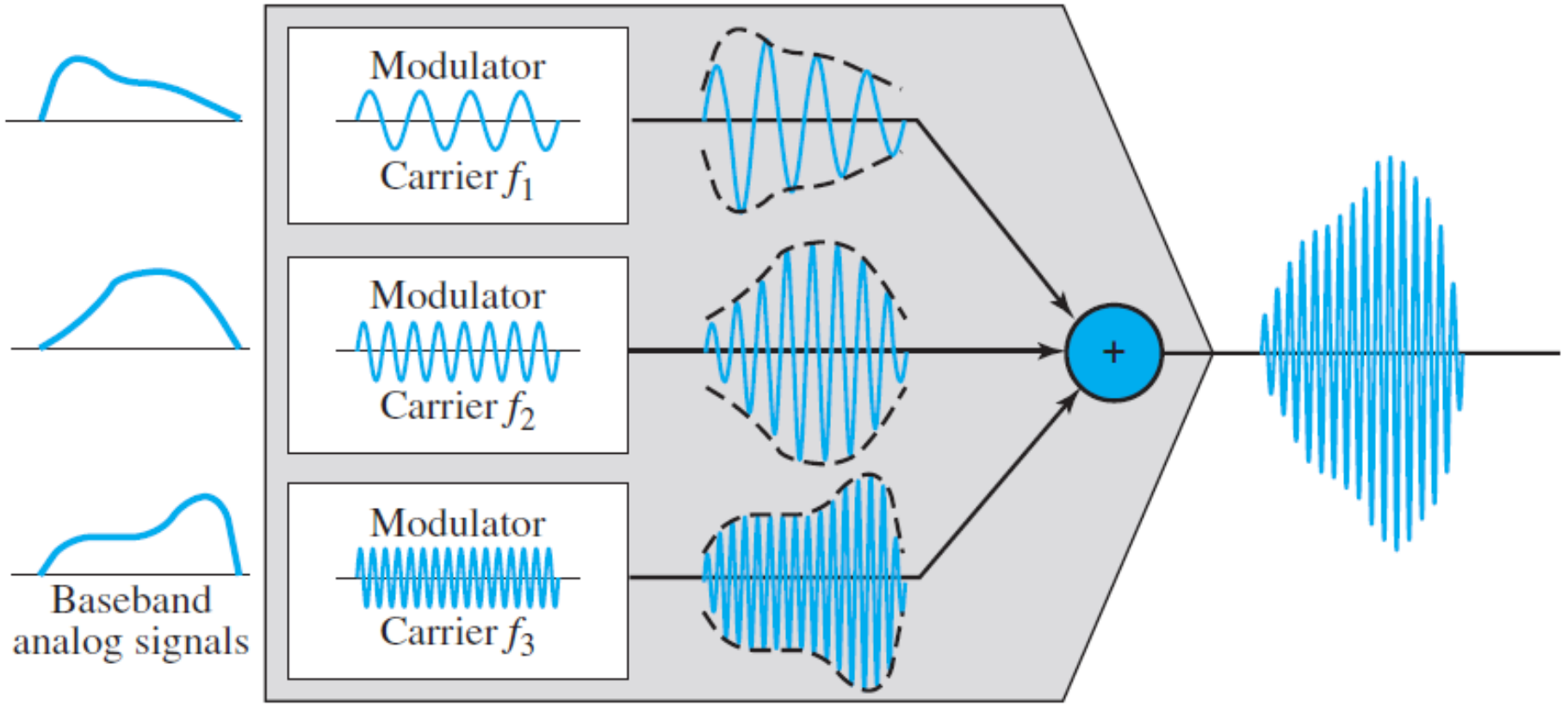
Used in

- radio and television broadcasting
- mobile or satellite stations
- cable television

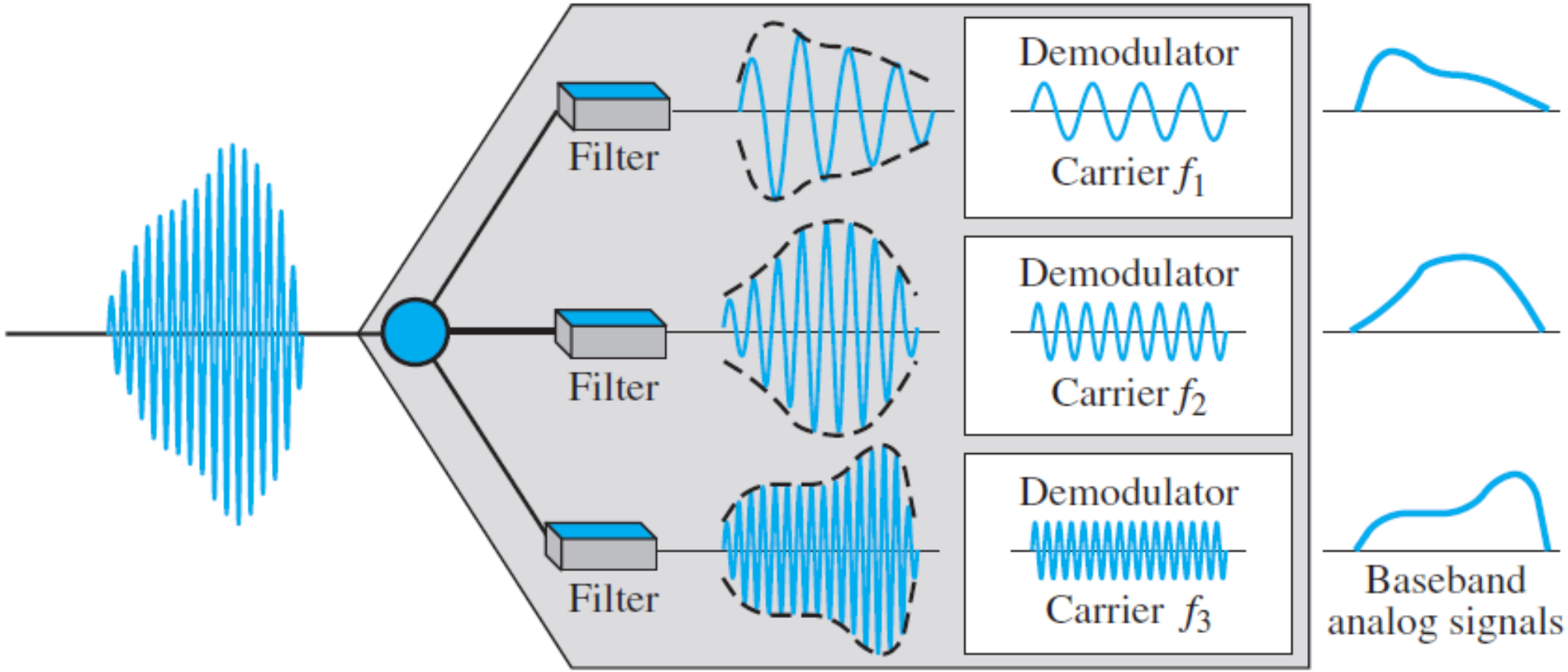
Frequency Division Multiplexing (FDM) cont.



Frequency Division Multiplexing Process Multiplexing



Frequency Division Multiplexing Process Demultiplexing



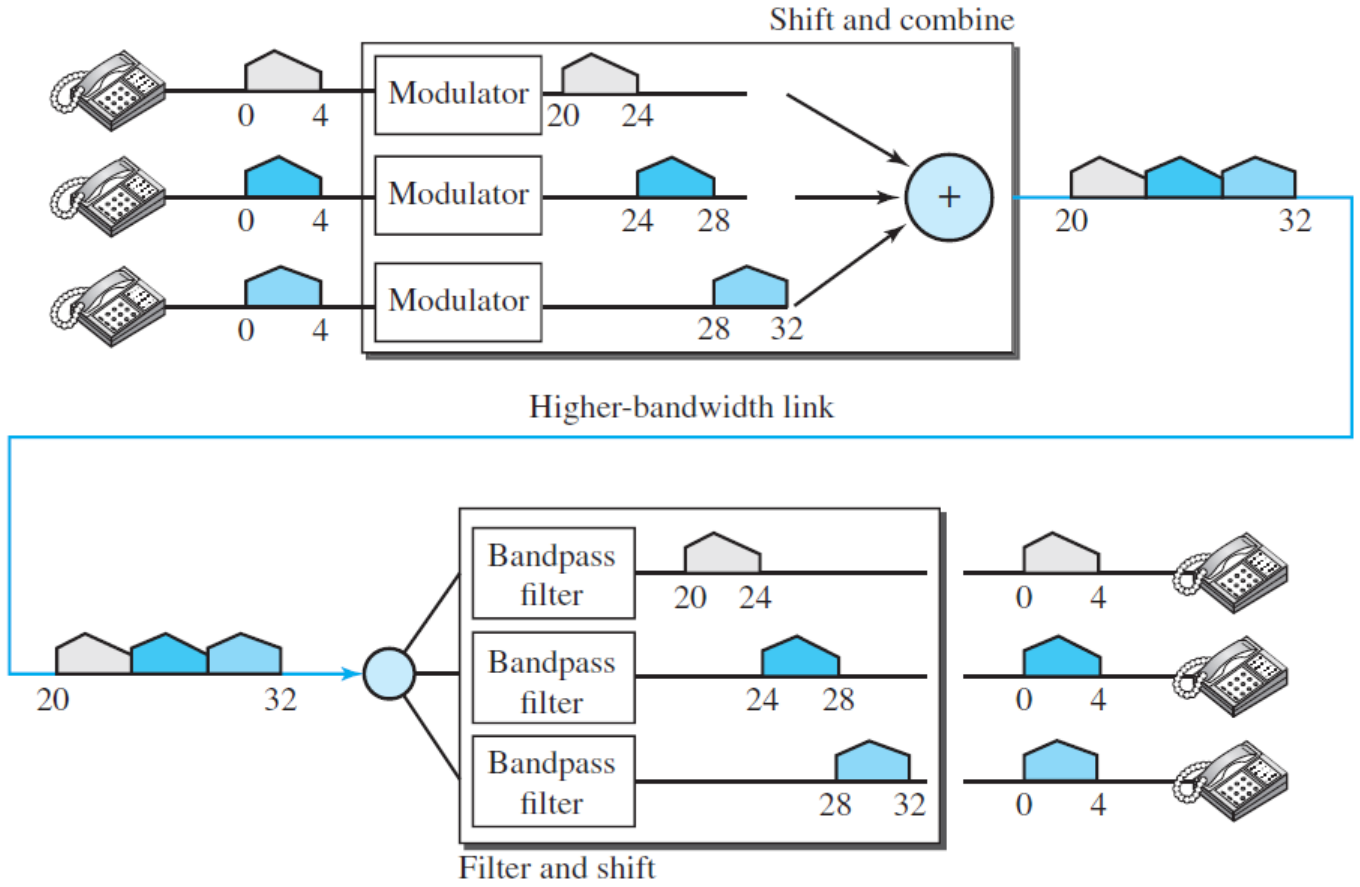
Example

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 Assume there are no guard bands

Solution


Shift and combine
Modulator
Modulator
Modulator
0
4
20
24
28
32
+
Higher-bandwidth link
Bandpass filter
Bandpass filter
Bandpass filter
Filter and shift

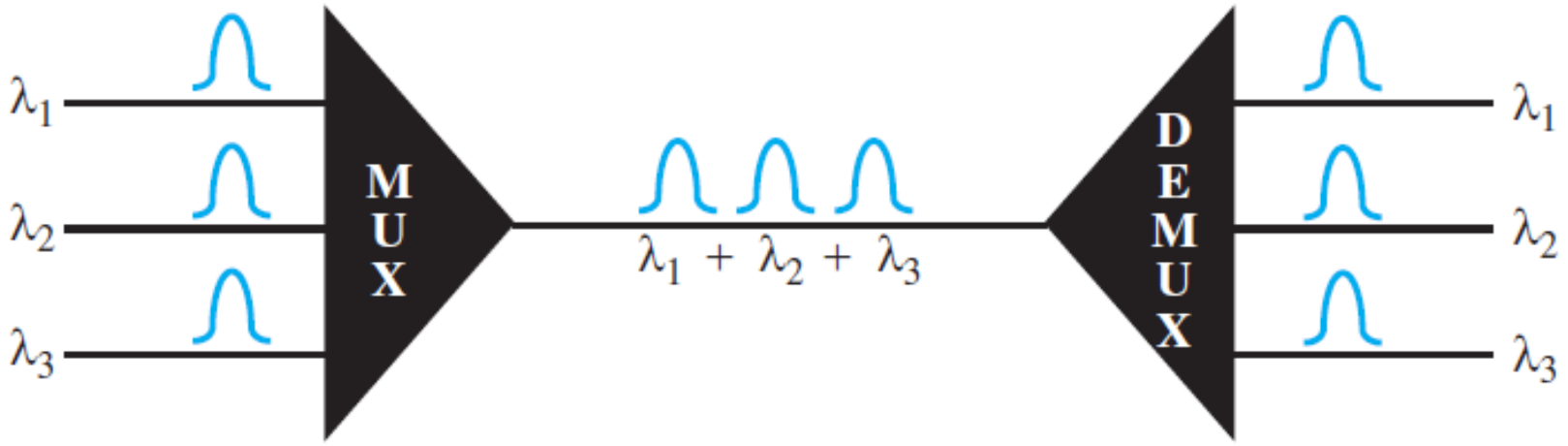
Question

Five channels, each with a 100 kHz bandwidth, are to be multiplexed together

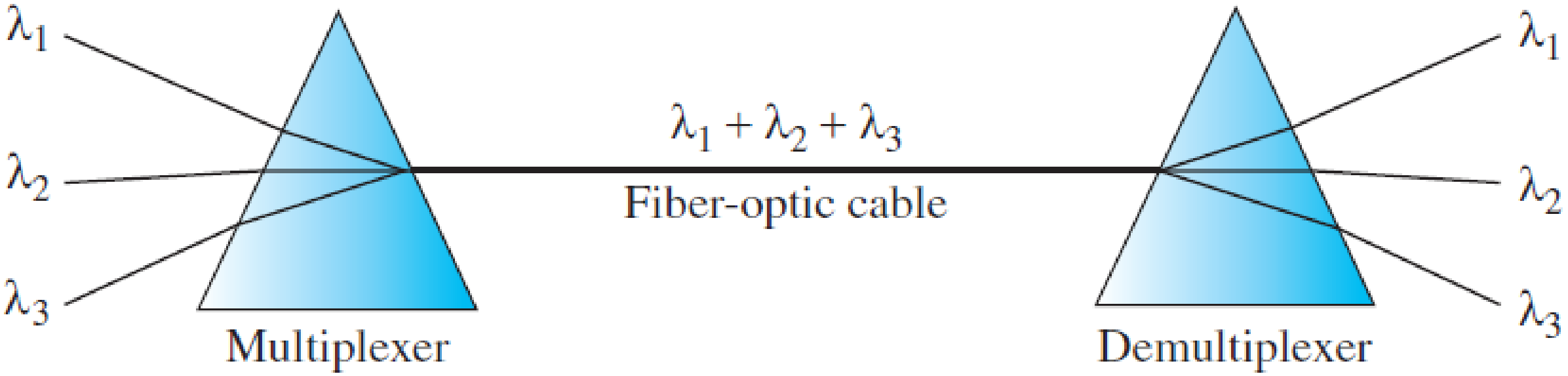
What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

Wavelength Division Multiplexing (WDM)

- WDM is an analog multiplexing technique to combine optical signals.
- designed to use the high data rate capability of fiber optic cable.

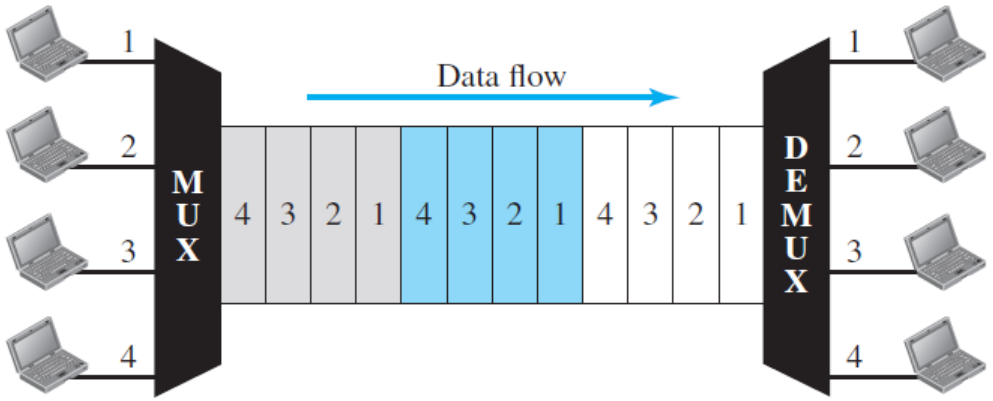


Wavelength Division Multiplexing (WDM) cont.



Time Division Multiplexing (TDM)

- TDM is a digital multiplexing technique for combining several low rate channels into one high-rate one.
- Each connection occupies a portion of time in the link.



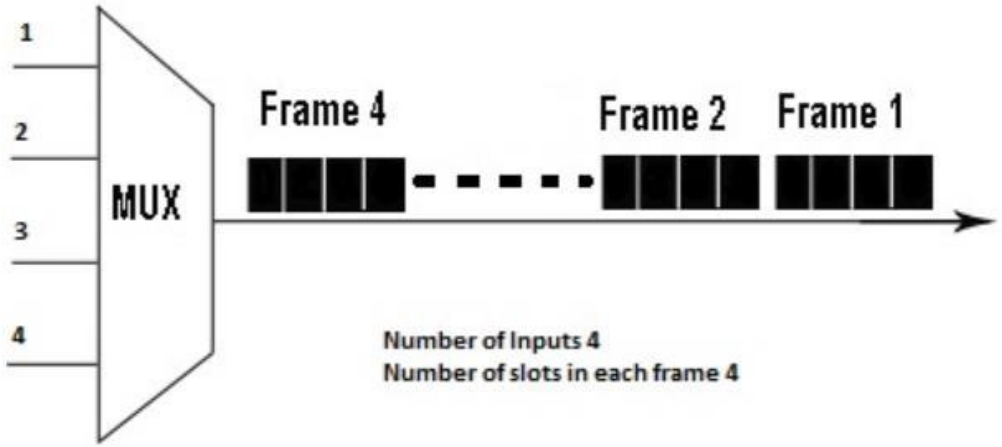
Time Division Multiplexing (TDM) Types

1. Synchronous time division multiplexing
2. Asynchronous time division multiplexing
3. Interleaving time division multiplexing
4. Statistical time division multiplexing

1. Synchronous time division multiplexing

Synchronous time division multiplexing assigns a fixed time slot to each connected device, whether the device transmits data or not.

Number of slots in the frame Number of inputs.



1. Synchronous time division multiplexing cont.

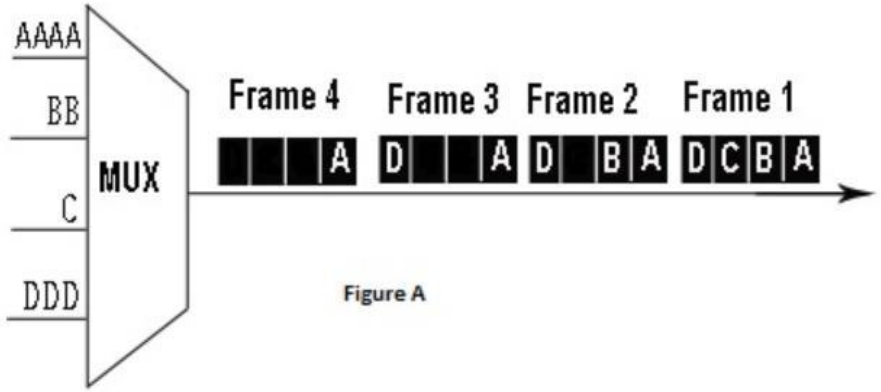


Figure A

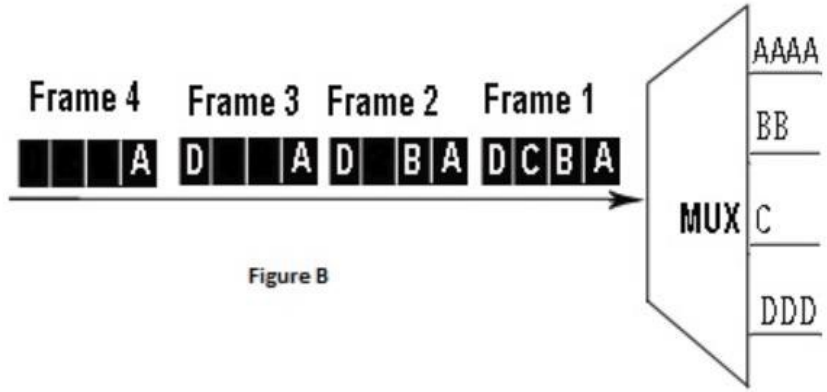
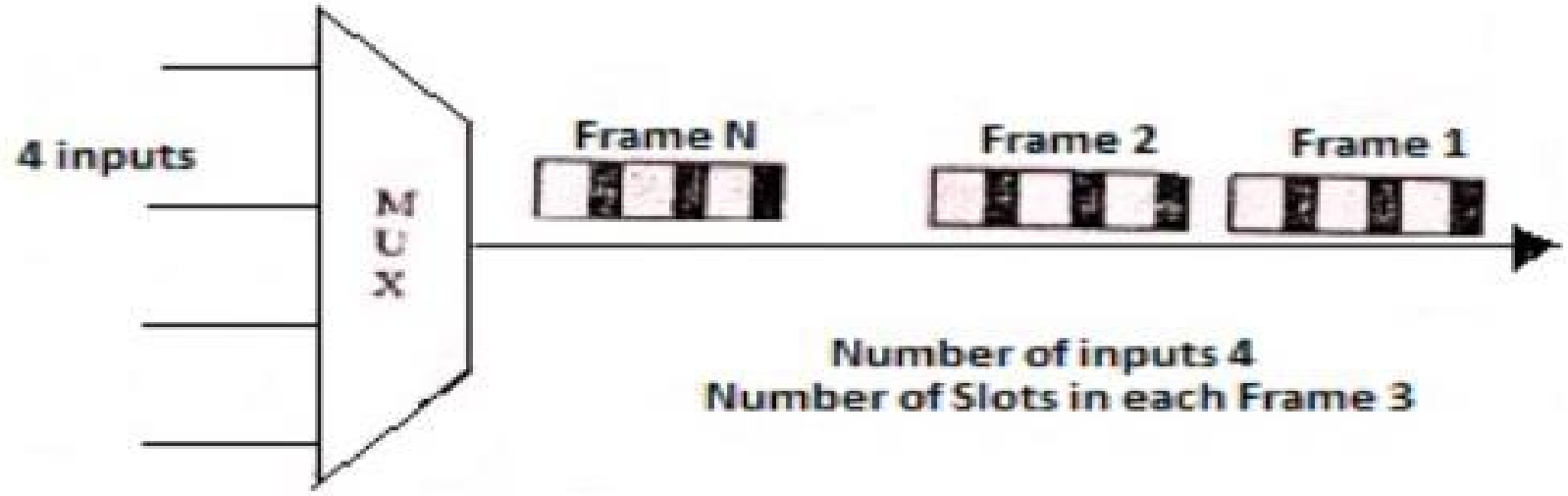


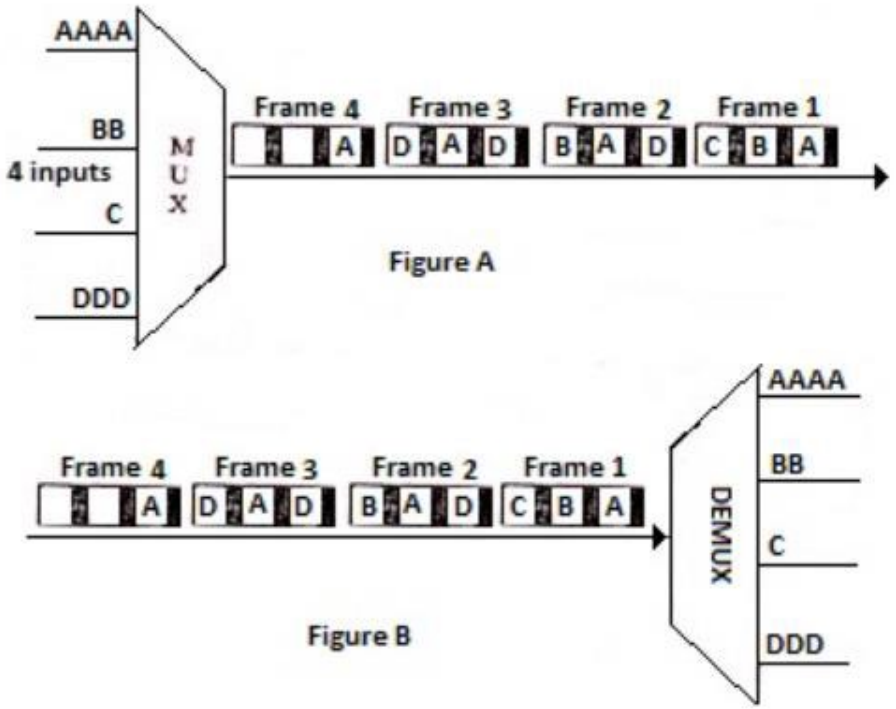
Figure B

2. Asynchronous time division multiplexing

- Each slot in a frame is not dedicate to a fix input device
- A frame contains fixed number of time slots Number of slots in a frame is not necessary to be equal to the number of input devices



2. Asynchronous time division multiplexing cont.



3. Interleaving time division multiplexing.

The TDM can be imagined like two speedy rotary switches on the multiplexing demultiplexing surface

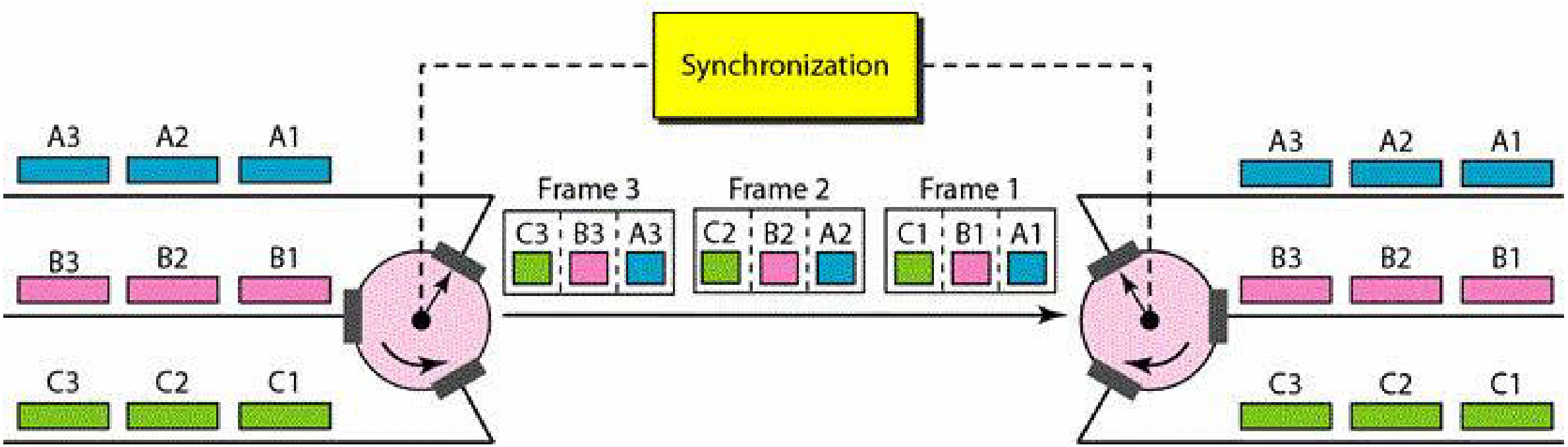
These switches can be rotated synchronized in reverse directions.

Once the switch releases at the surface of multiplexer ahead of a connection, then it has a chance of sending a unit into the lane.

Similarly, once the switch releases at the surface of de multiplexer ahead of a connection a chance to receiving a unit from the lane.

This procedure is named as interleaving.

3. Interleaving time division multiplexing cont.



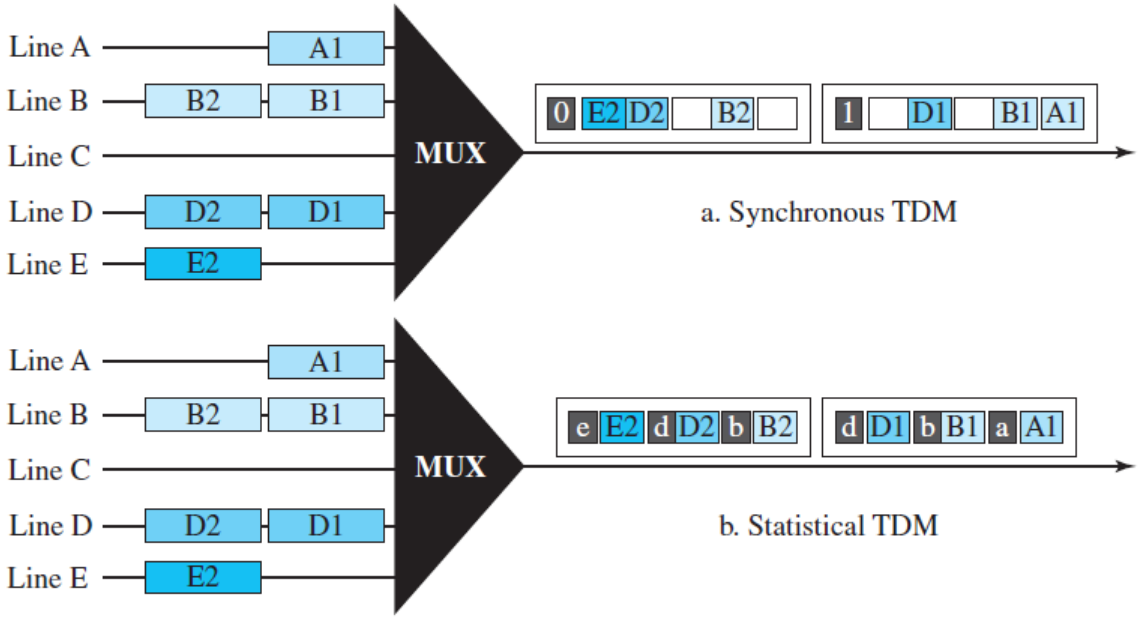
4. Statistical time division multiplexing.

In statistical time division multiplexing, slots are dynamically allocated to improve bandwidth efficiency.

number of slots in each frame < 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.

4. Statistical time division multiplexing cont.



Spectrum spreading

Spread spectrum is designed to be used in wireless applications

In wireless applications, all stations use air (or a vacuum) as the medium for communication

Stations must be able to share this medium without interception by an eavesdropper and without being subject to jamming from a malicious intruder

To achieve these goals, spread spectrum techniques add redundancy they spread the original spectrum needed for each station.

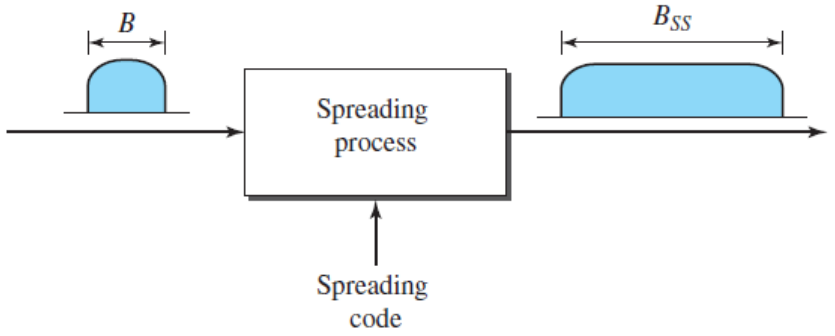
Spectrum spreading cont.

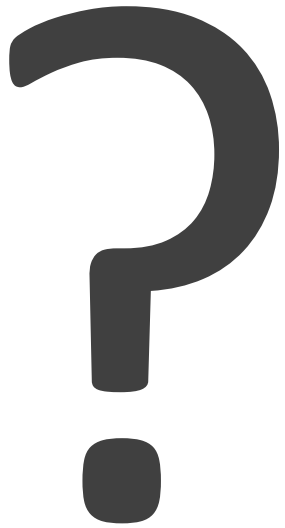
required bandwidth for each station = B

Expanded by spread spectrum = Bss

Bss > B

The expanded bandwidth allows the source to wrap its message in a protective envelope for a more secure transmission.





Thank you