Multiplexing

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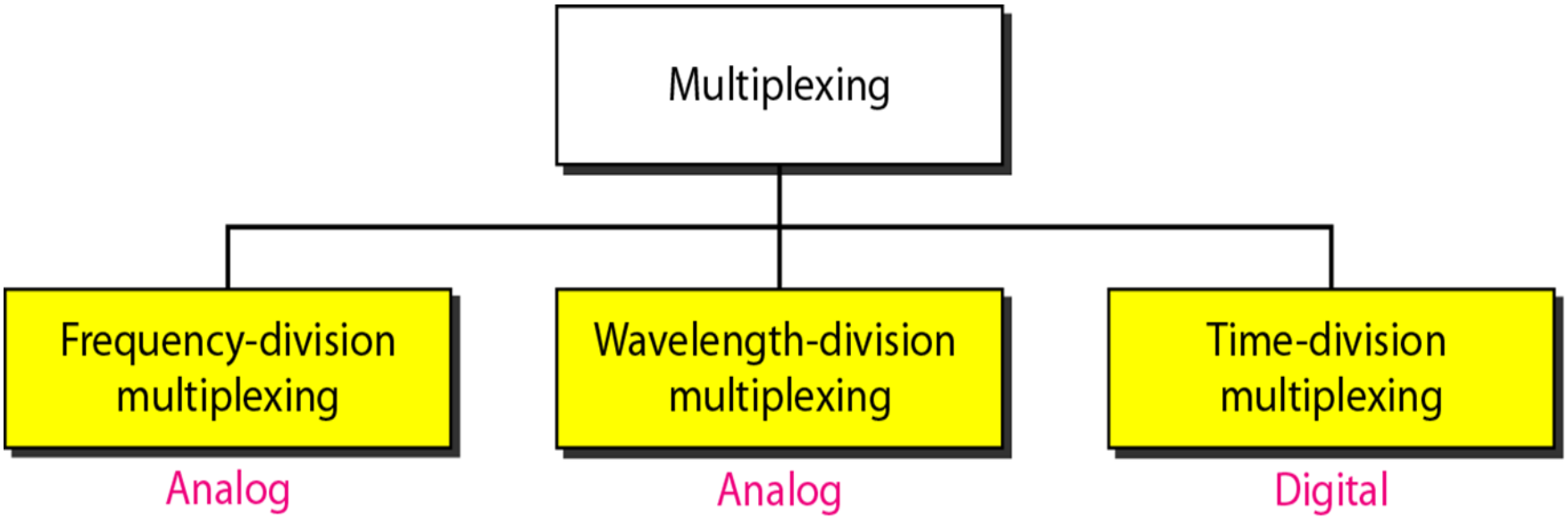
Multiplexing

Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared. Multiplexing is the set of techniques that allows the (simultaneous) transmission of multiple signals across a single data link. As data and telecommunications use increases, so does traffic.


Multiplexing
Frequency-division multiplexing
Wavelength-division multiplexing
Time-division multiplexing
Analog
Analog
Digital

Frequency Division Multiplexing (FDM)

- **Frequency Division Multiplexing (FDM)** is a technique of dividing total bandwidth available in a communication medium is into a series of non-overlapping frequency bands, each of which can carry a separate signal.
- Operation similar to radio broadcasting where a number of stations are broadcast simultaneously on different frequencies. One only needs to tune radio to capture the station or frequency.

Frequency Division Multiplexing

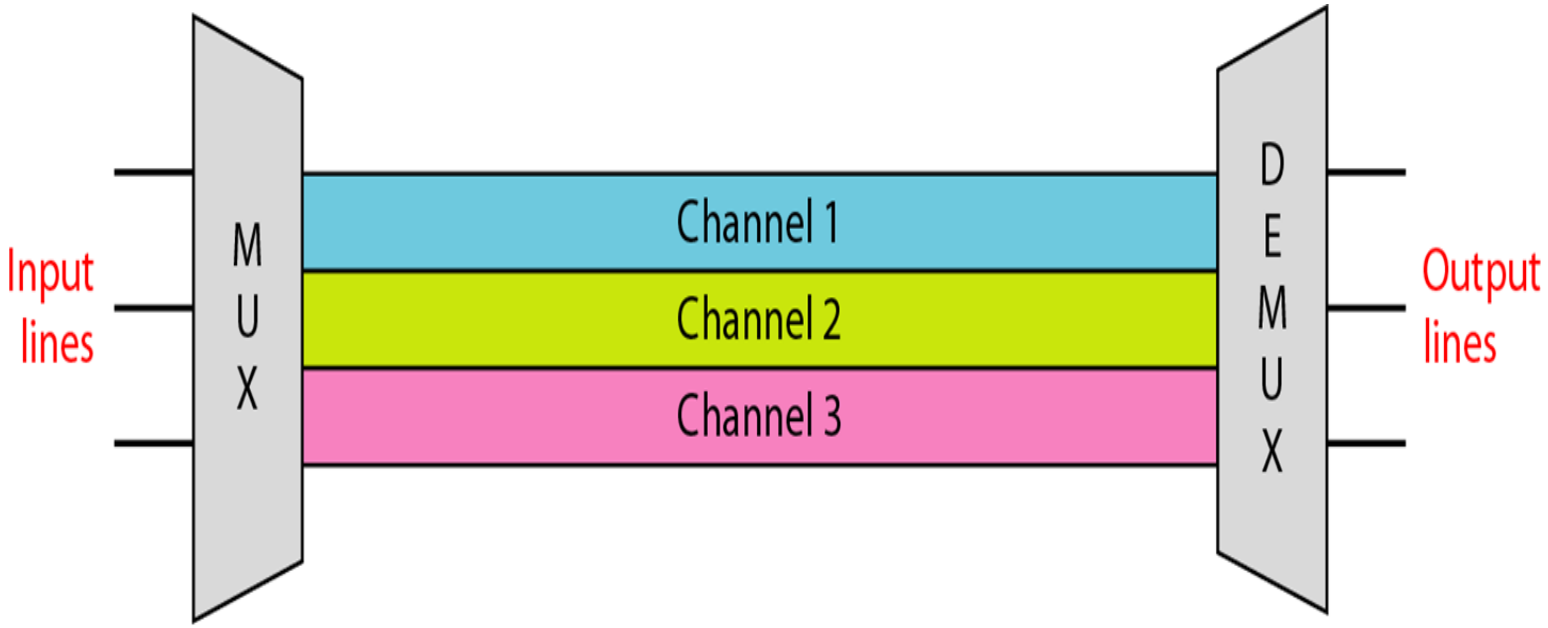
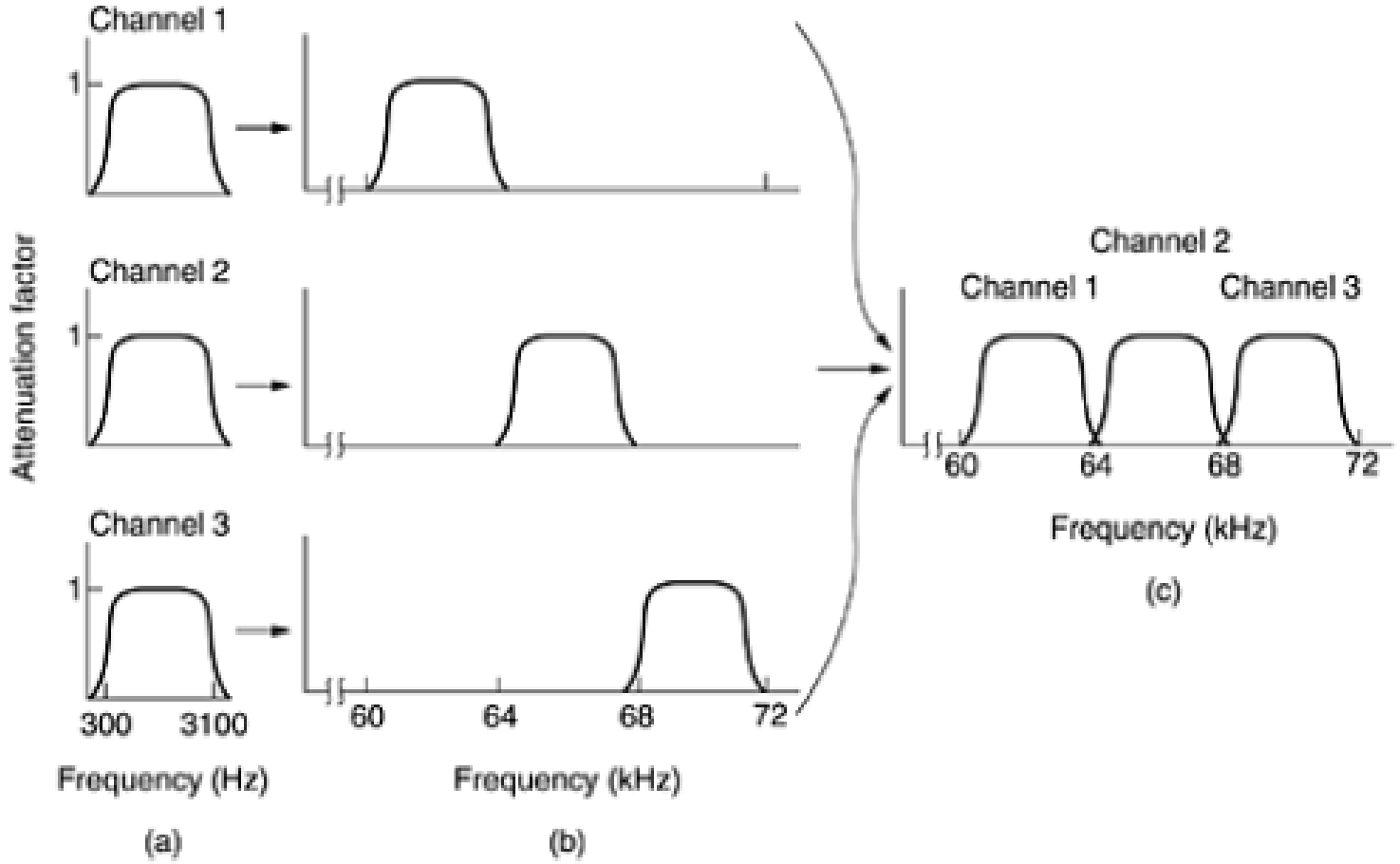


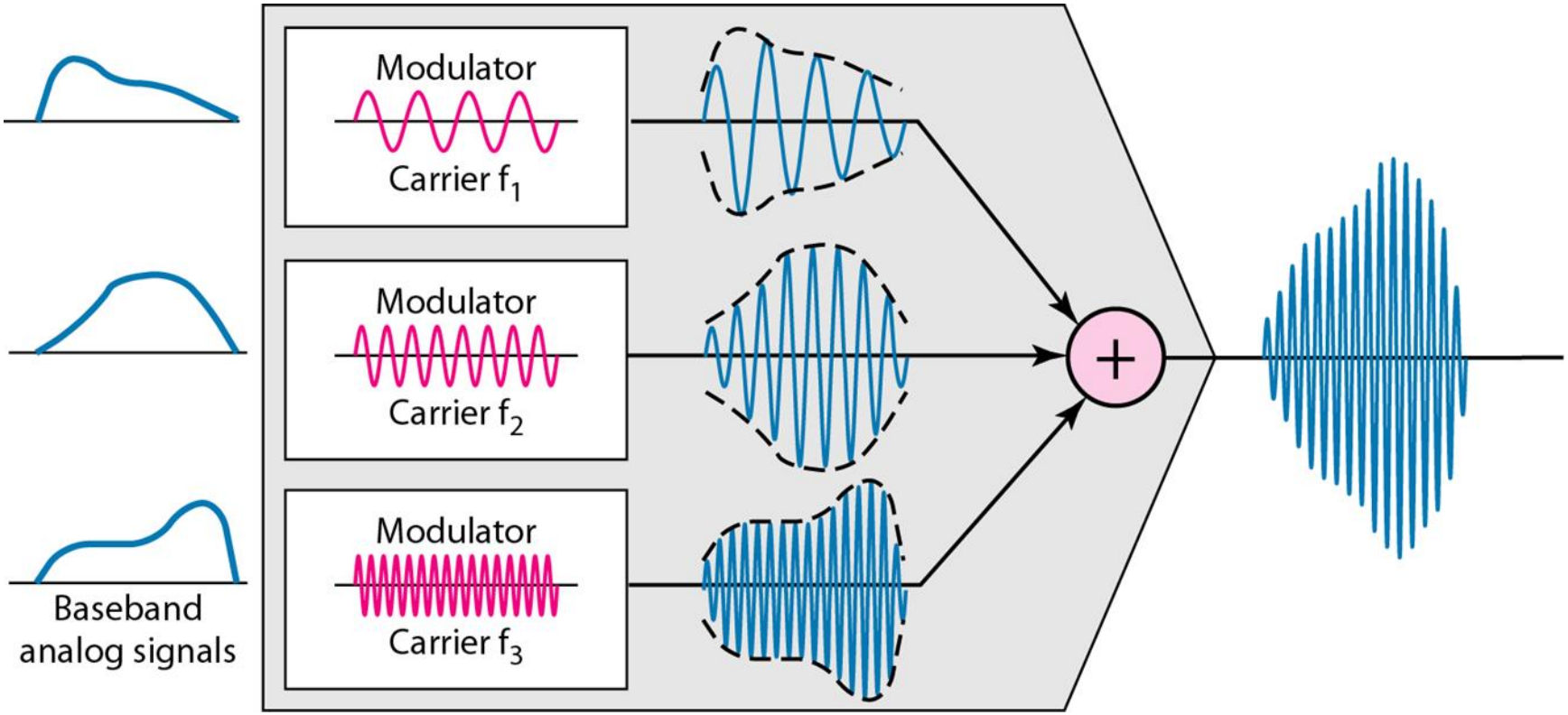
Figure Frequency division multiplexing. (a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.



Explanation of the Fig. (see last slide)

Figure shows how three voice-grade telephone channels are multiplexed using FDM. Filters limit the usable bandwidth to about 3100 Hz per voice-grade channel. When many channels are multiplexed together, 4000 Hz is allocated to each channel to keep them well separated. First the voice channels are raised in frequency, each by a different amount. Then they can be combined because no two channels now occupy the same portion of the spectrum. Notice that even though there are gaps (guard bands) between the channels, there is some overlap between adjacent channels because the filters do not have sharp edges. This overlap means that a strong spike at the edge of one channel will be felt in the adjacent one as nonthermal noise.

FDM Process


Modulator
Carrier f_1
Modulator
Carrier f_2
Modulator
Carrier f_3
+
Baseband
analog signals

FDM: Merits & Demerits

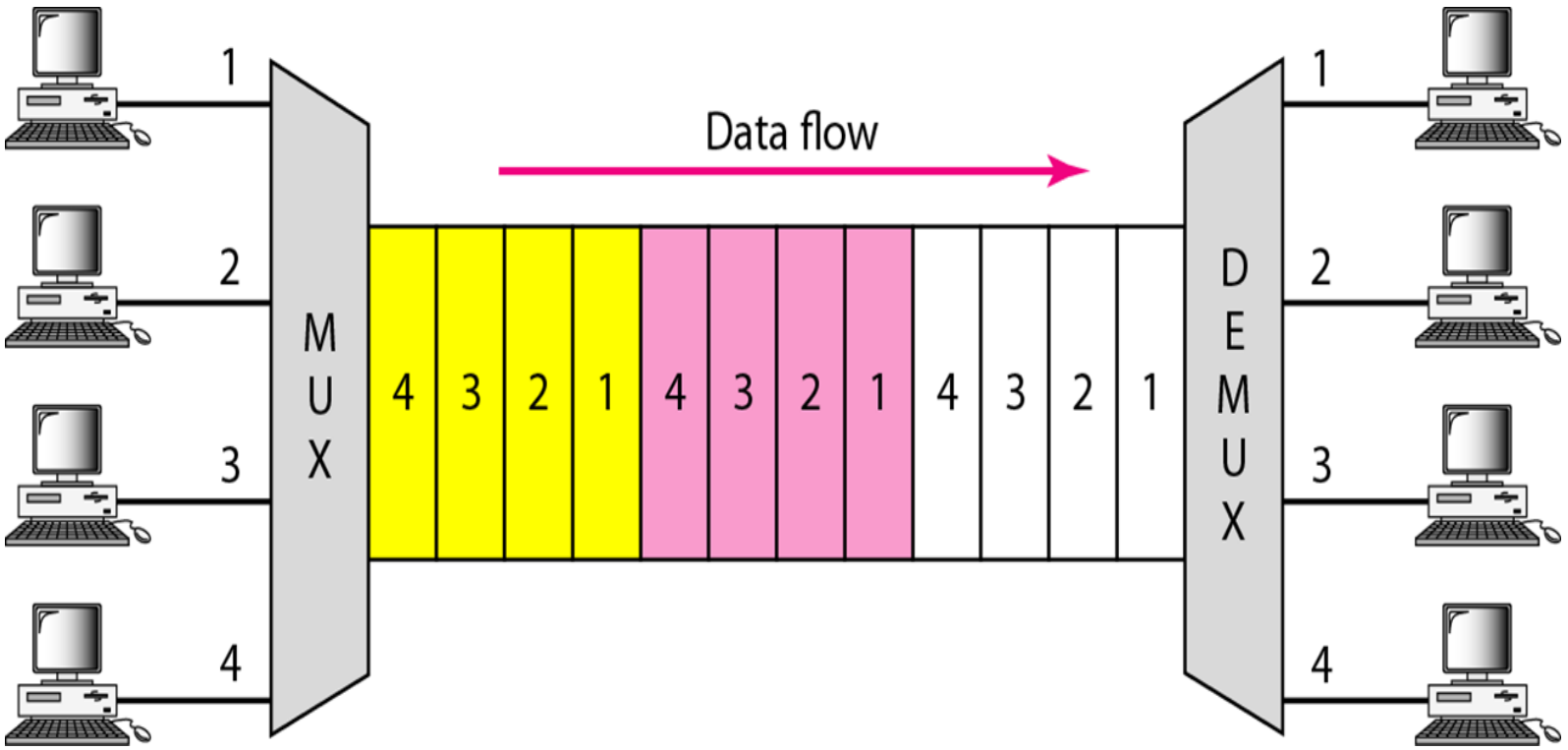
- Advantages of FDM:
  - The users can be added to the system by simply adding another pair of transmitter modulator and receiver demodulators.
  - FDM system support full duplex information (Both side simultaneous Communication) flow which is required by most of application.

- Disadvantages of FDM:
  - In FDM system, the initial cost is high. This may include the cable between the two ends and the associated connectors for the cable.
  - A problem with one user can sometimes affect the others.
  - Each user requires a precise carrier frequency for transmission of the signals.

Time Division Multiplexing

- TDM is a digital multiplexing technique for combining several low-rate digital channels into one high-rate one.
- Each user of the channel is allotted a small time interval during which it may transmit a message.
- So total time available in the channel is divided and each user is allocated a time slot.
- Data from each user is multiplexed into a frame which is transmitted over the channel.
- In TDM, user's messages are buffered as they received and read from the buffer during its time slot to make a frame.
- So each user can use the full channel bandwidth.
- Channel capacity is fully utilized in TDM by interleaving a number of messages belonging to different users into one long message.
- This message sent through the physical channel must be separated at the receiving end.
- Individual chunks of message sent by each user should be reassembled into a full message.

TDM



Uses of TDM

- The PDH (Plesiochronous Digital Hierarchy) system, also known as the PCM (Pulse Code Modulation) systems.
- The synchronous digital hierarchy (SDH) / synchronous optical networking (SONET) network transmission standards.
- TDM can be further extended into the time division multiple Channel (TDMA) scheme, where several stations connected to the same physical medium, for example sharing the same frequency channel, can communicate. Application examples include the widely used GSM telephone system.

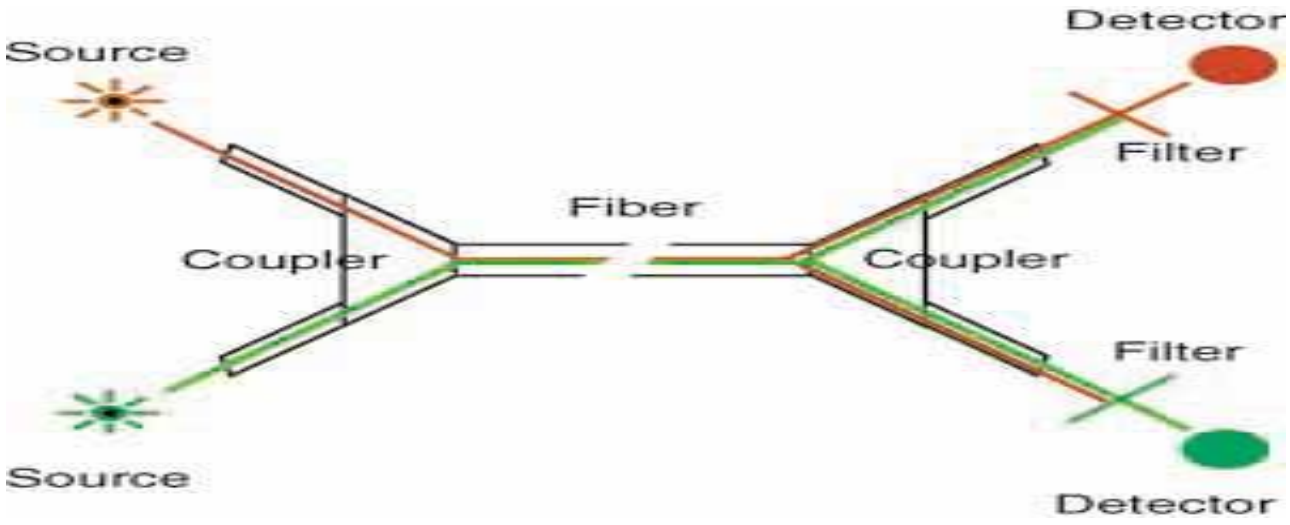
TDM: Merits & Demerits

- Advantages of TDM
  - It uses a single link.
  - It does not require precise carrier matching at both end of the links.
  - Use of the channel capacity is high.
  - Each to expand the number of users on a system at a low cost.
  - There is no need to include identification of the traffic stream on each packet.

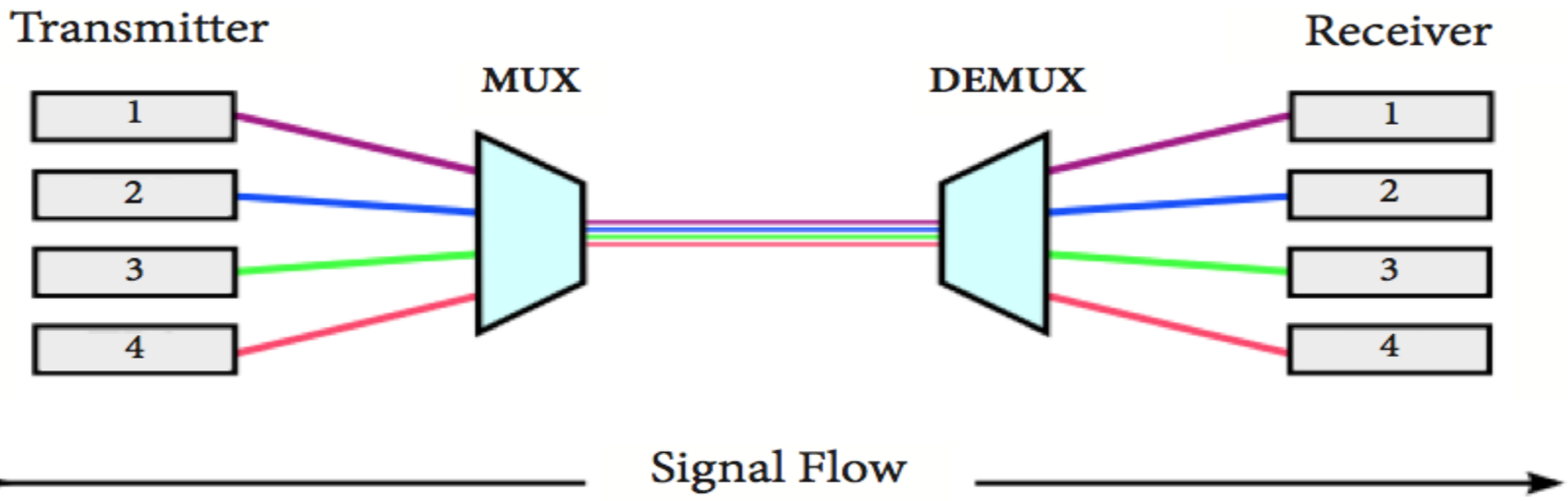
- Disadvantages of TDM:
  - The sensitivity to other user is very high and causes problems.
  - Initial cost is high.
  - Technical complexity is more.

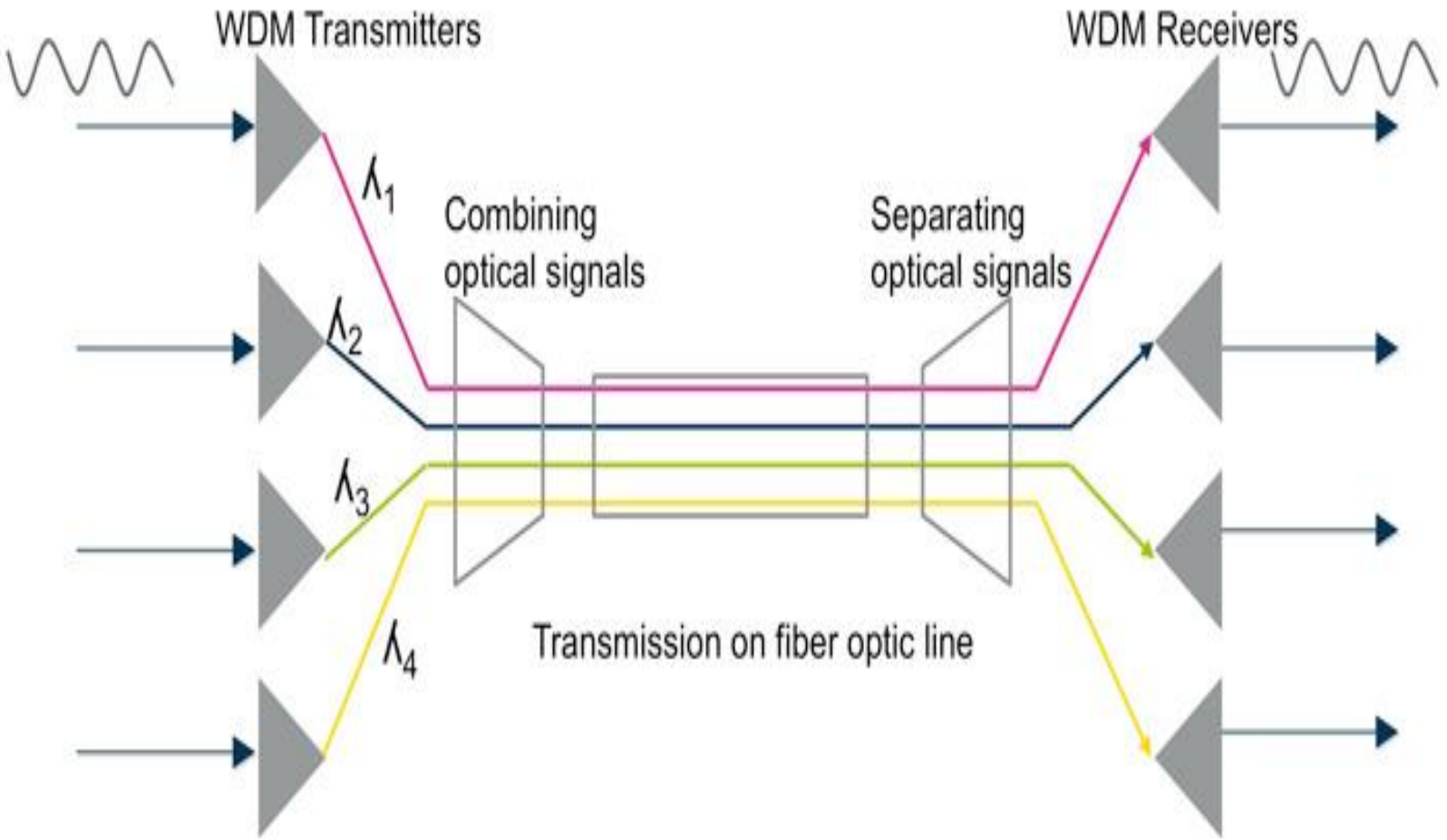
Wavelength Division Multiplexing (WDM)

- WDM is the basic technology for Optical Networking.
- It is a technique for using a fibre (or optical device) to carry many separate and independent optical channels.
- Wavelength Division Multiplexing (WDM) is the same as frequency division, except that the terminology is used for optical frequencies.
- Each communication channel is allocated to a different frequency and multiplexed onto a single fibre.
- At the destination wavelengths are spatially separated to different receiver locations.



Wavelength Division Multiplexing (WDM)




WDM Transmitters
WDM Receivers
λ1
λ2
λ3
λ4
Combining
optical signals
Separating
optical signals
Transmission on fiber optic line

WDM - Types

Coarse WDM (CWDM)

- WDM systems with fewer than eight active wavelengths per fiber.
- CWDM is defined by wavelengths.
- CWDM is for short-range communications, so it employs wide-range frequencies with wavelengths spread far apart.
- Standardized channel spacing permits room for wavelength drift as lasers heat up and cool down during operation.
- CWDM is a compact and cost-effective option when spectral efficiency is not an important requirement.

WDM - Types

Dense WDM (DWDM)

- DWDM is defined in terms of frequencies.
- DWDM is for systems with more than eight active wavelengths per fiber.
- DWDM is designed for long-haul transmission, with wavelengths packed tightly together.
- DWDM systems must also use precision lasers that operate at a constant temperature to keep channels on target.
- DWDM dices spectrum finely, fitting 40-plus channels into the same frequency range used for two CWDM channels.
- DWDM's tighter wavelength spacing fits more channels onto a single fiber, but cost more to implement and operate.

TDM: Merits & Demerits

- Merits
  - Full duplex transmission is possible.
  - Easier to reconfigure.
  - Optical components are similar and more reliable.
  - It provides higher bandwidth.
  - This could be the best approach as it is simple to implement.
  - High security
- Demerits
  - Cross phase modulation and Four wave mixing (FWM) are the major limitations.
  - Cost of system increases with addition of optical components.
  - Difficulty in wavelength tuning, difficulty in cascaded topology.

Home-Work

- Discuss the methods:
  - FDMA
  - TDMA
  - WDMA

END