Multiplexing and Switching

- **Multiplexing** - how links are shared between sessions

- **Switching** - how traffic is switched from input to output ports at nodes.

Conceptually multiplexing is very similar to medium access control.

- The main difference is with medium access control, users accessing the channel are geographically separate, so coordination and contention arise.
- With multiplexing the channel sharing is done at one location, namely in a switch, so contention and coordination are not as difficult.
- As with medium access control, multiplexing techniques can be divided into static and dynamic approaches (usually called statistical multiplexing).
- With static approaches each user is allocated a sub-channel, i.e. a fixed portion of the channel, while with dynamic approaches the allocation varies according to demand.

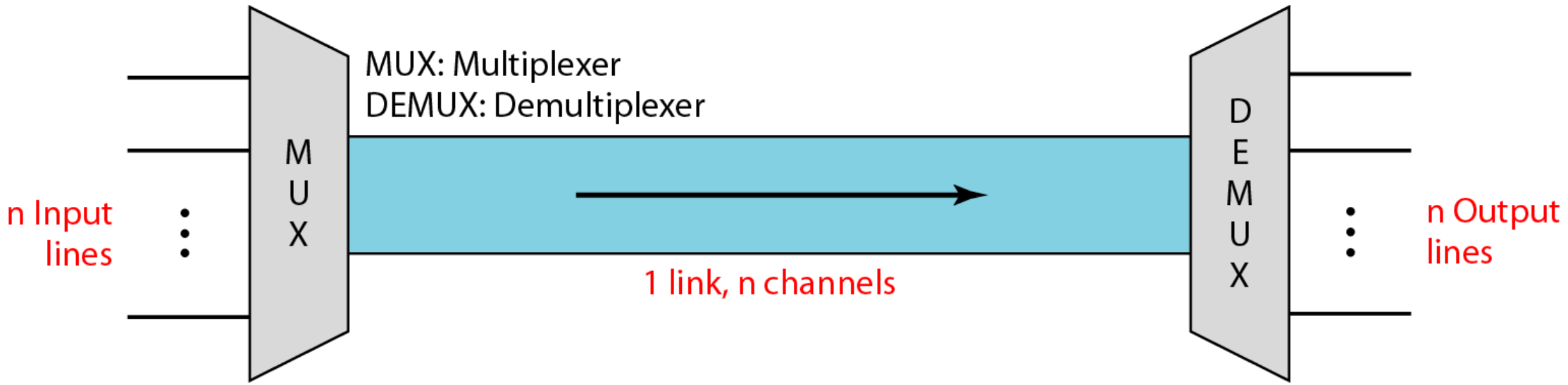
MULTIPLEXING

- Bandwidth utilization is the wise use of available bandwidth to achieve specific goals.
- Efficiency can be achieved by multiplexing; i.e., sharing of the bandwidth between multiple users.
- 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.

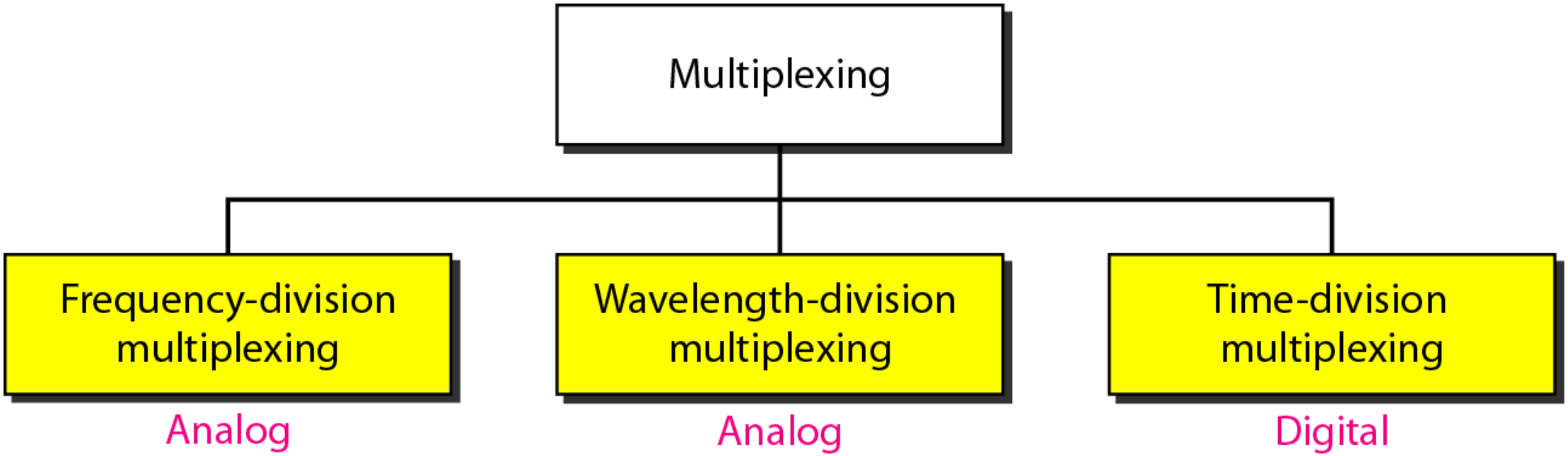
Types of Multiplexing

- Frequency-Division Multiplexing
- Wavelength-Division Multiplexing
- Time-Division Multiplexing
  - Synchronous Time-Division Multiplexing
  - Statistical Time-Division Multiplexing

Dividing a link into channels



Categories of multiplexing

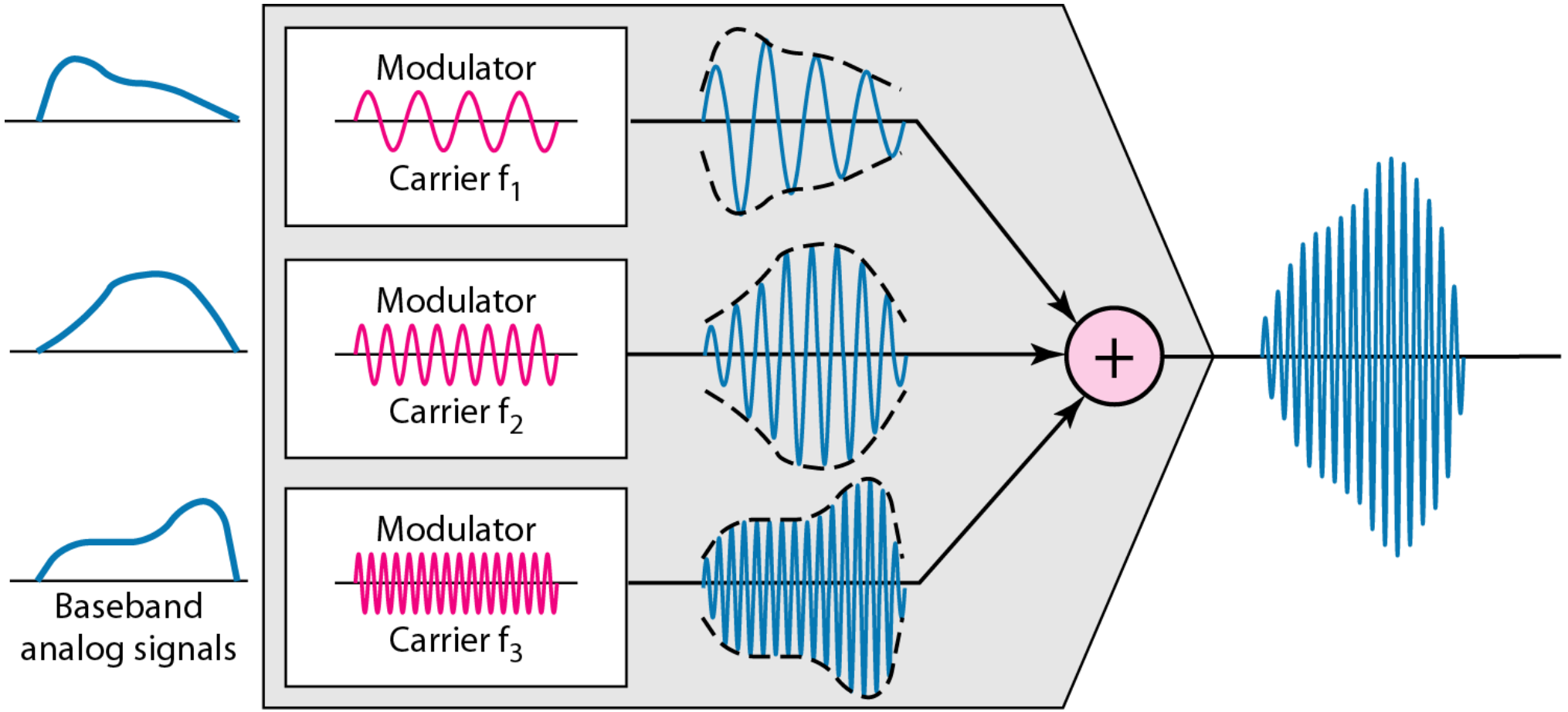


Frequency-division multiplexing (FDM)

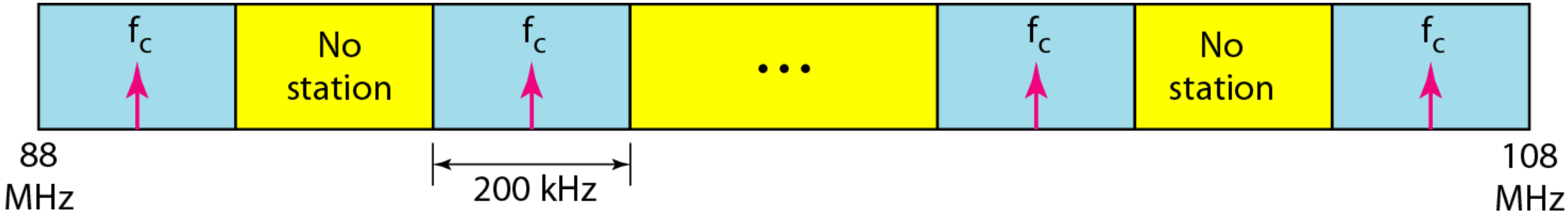
- The frequency spectrum of a link is divided up into disjoint bands and a separate band is assigned to each session.
- Useful bandwidth of medium exceeds required bandwidth of channel
- Each signal is modulated to a different carrier frequency
- Carrier frequencies are separated so signals do not overlap (guard bands)

  e.g. broadcast radio
- Channel allocated even if no data

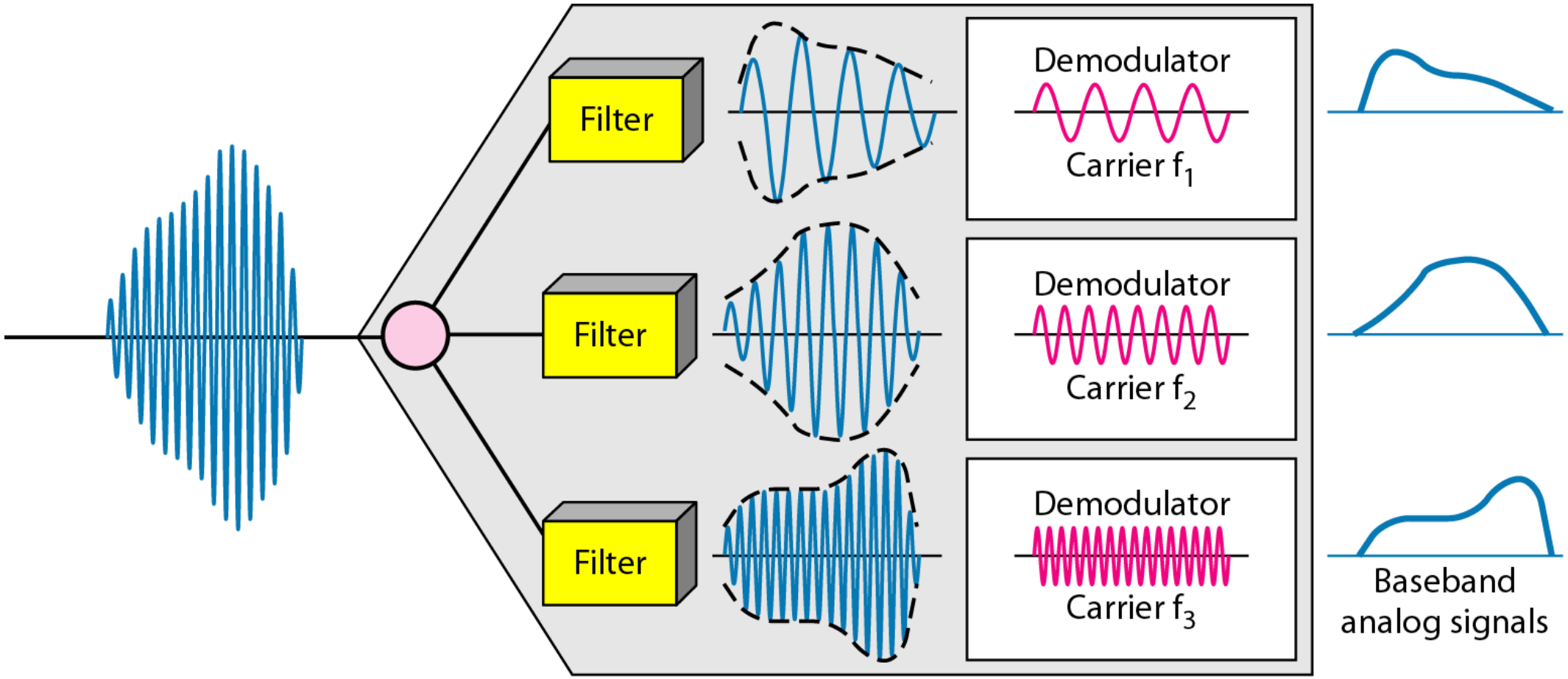
FDM process


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

FM



FDM demultiplexing example



Advantages of FDM:

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

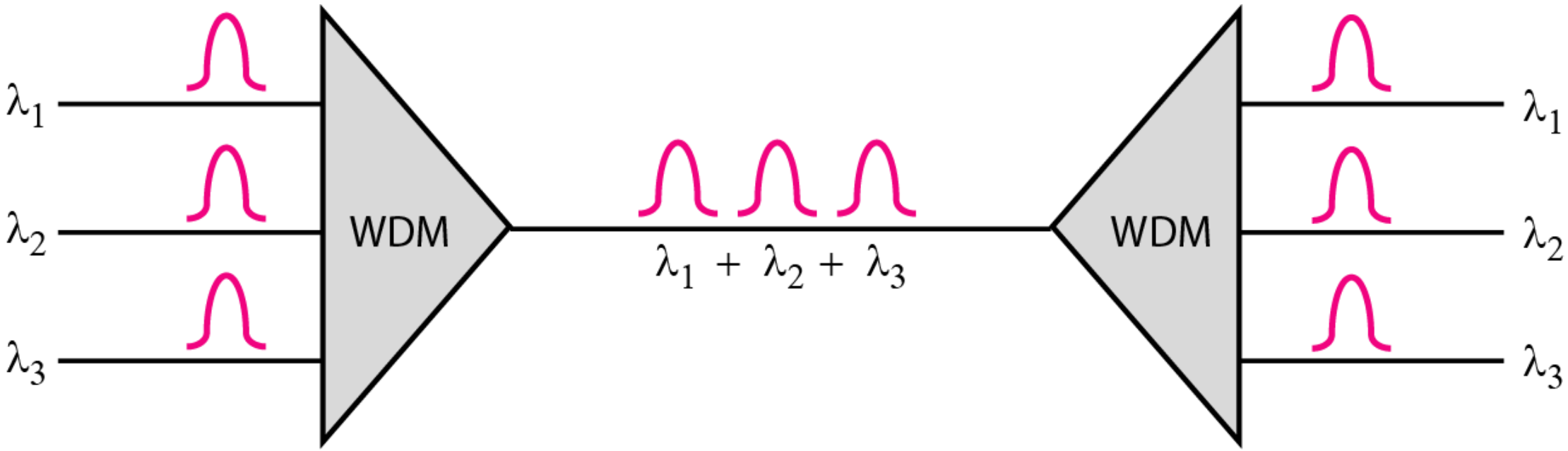
Disadvantages of FDM:

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

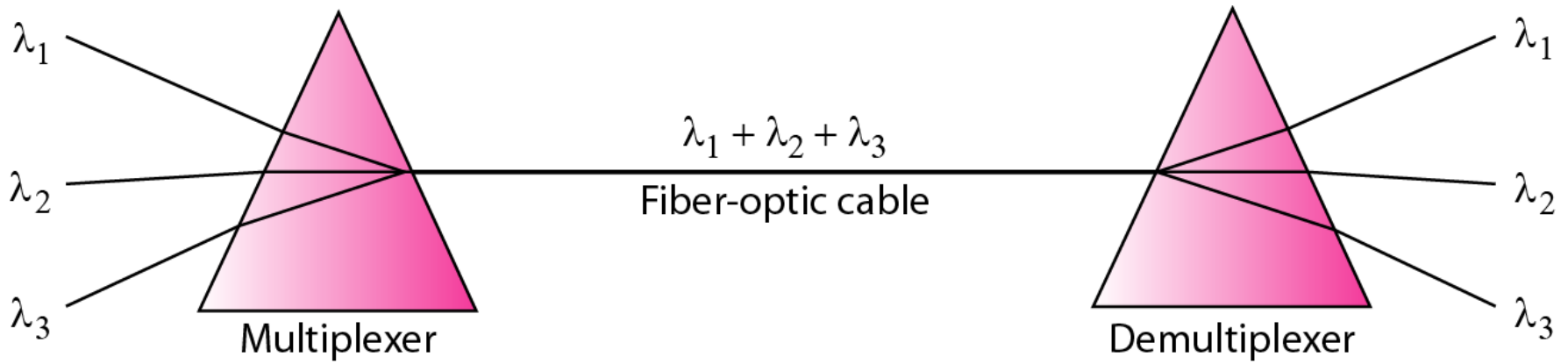
Wavelength-division multiplexing (WDM)

- WDM is an analog multiplexing technique to combine optical signals.
- When FDM is used in optical communication systems it is called WDM.
- In WDM systems, different sessions modulate light sources (LED's or lasers) at different wavelengths (frequencies) over the same fiber. These signals can then be separated using optical components such as diffraction gratings.
- Using WDM current systems can multiplex 40-128 channels onto single optical fiber at rates of 2.5 - 10 Gbps each.
- Low rate optical streams can be multiplexed together "all optically“ without any electrical conversion. This may also be done using passive optical components.
- Each WDM wavelength can be treated independently and used for analog or digital data. In many cases, WDM is combined with TDM.

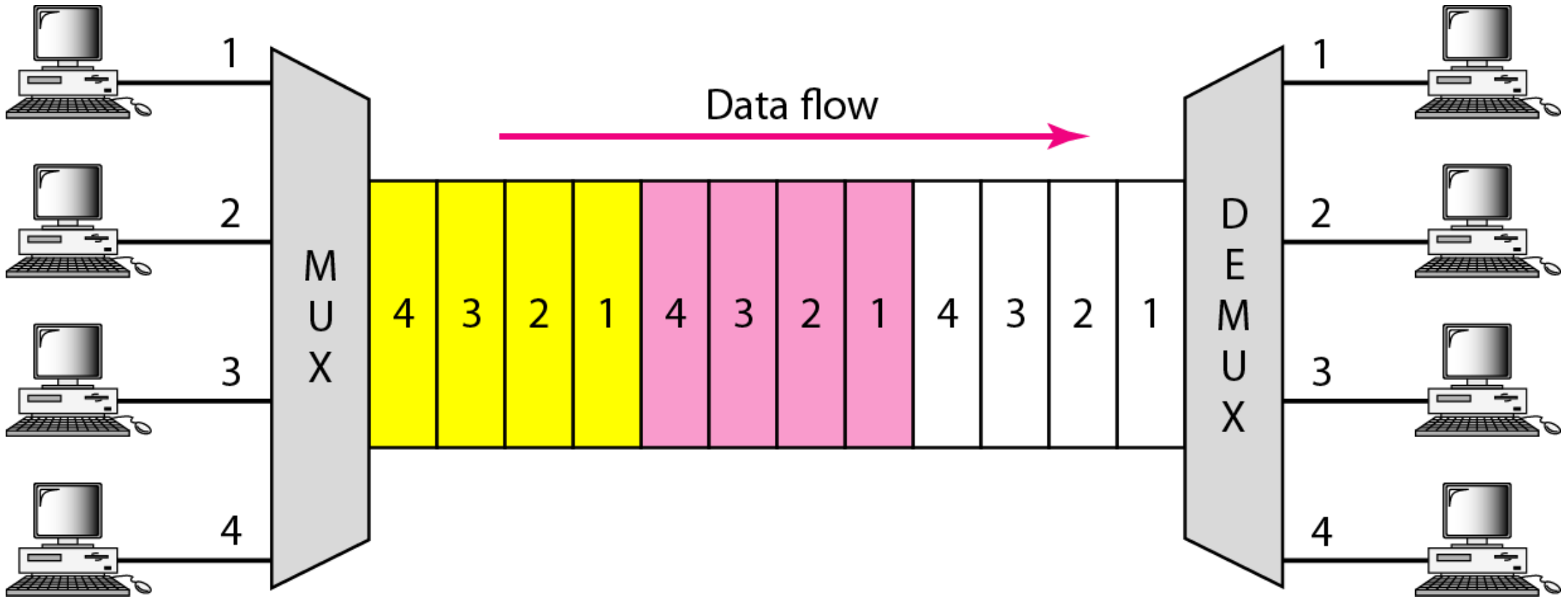
Wavelength-division multiplexing (WDM)



- *Prisms in wavelength-division multiplexing and demultiplexing*

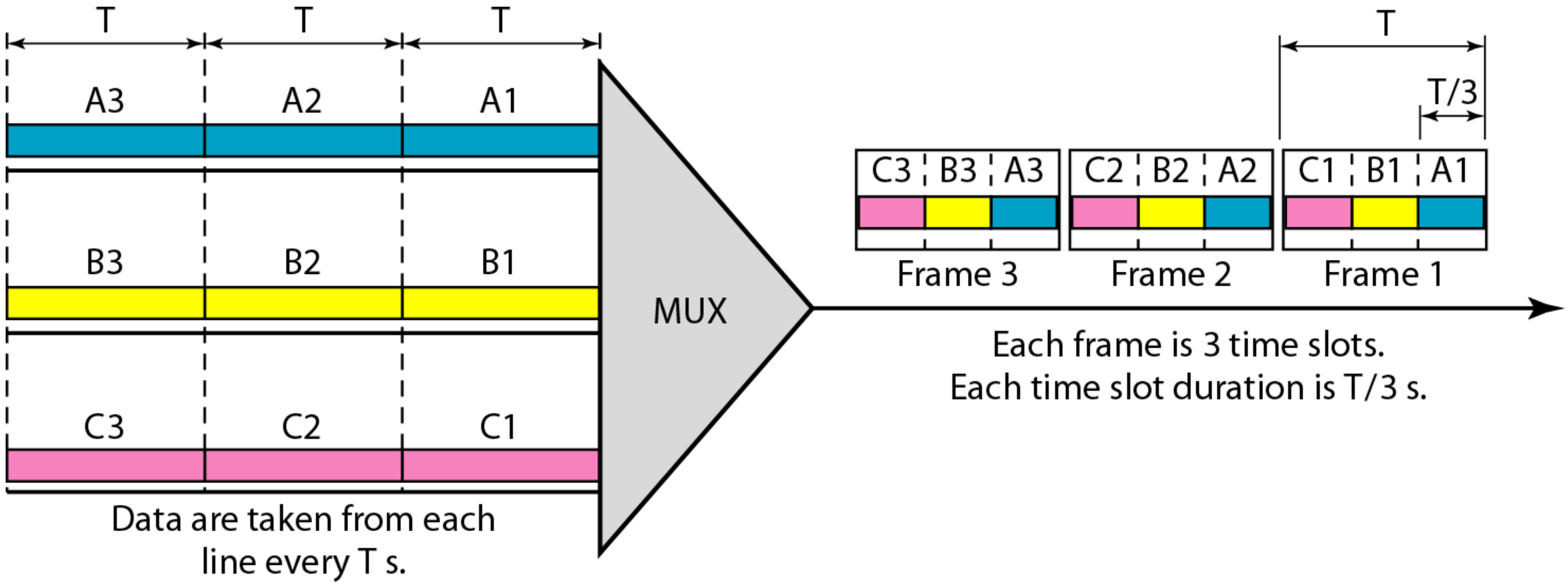


Time Division Multiplexing (*TDM*)



- TDM is a digital multiplexing technique for combining several low-rate digital channels into one high-rate one.
- Time is divided up into slots and each session is assigned a given set of slots in a cyclical order.
- Each slot could correspond to the time to transmit either a single bit or byte from a user or a fixed size packet. The sequence of time-slots, 1 per user is called a ***frame***.

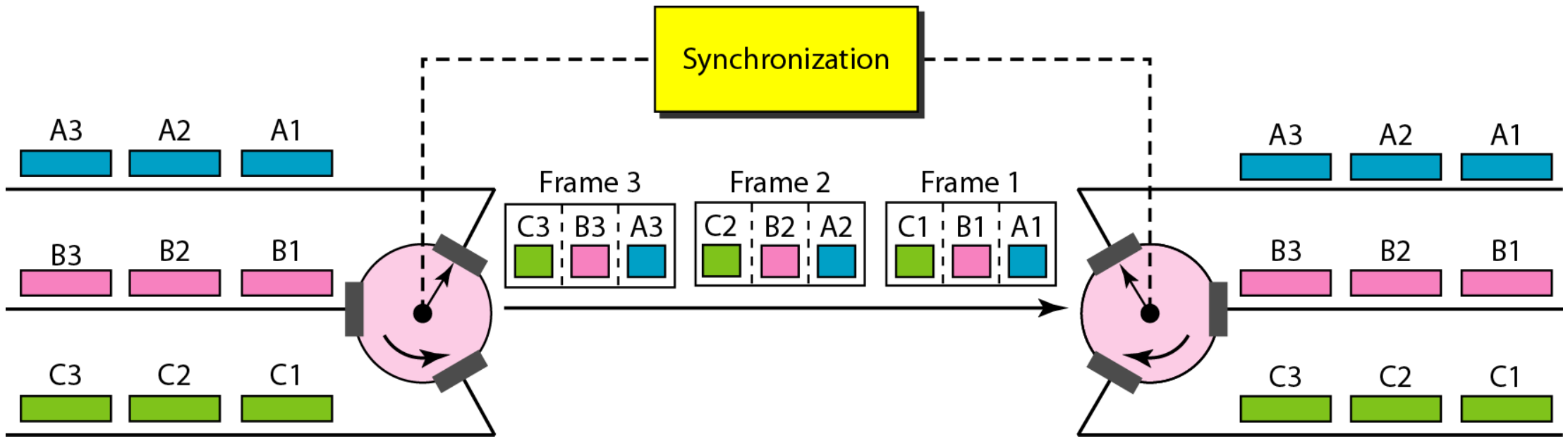
Synchronous time-division multiplexing



Synchronous Time Division Multiplexing

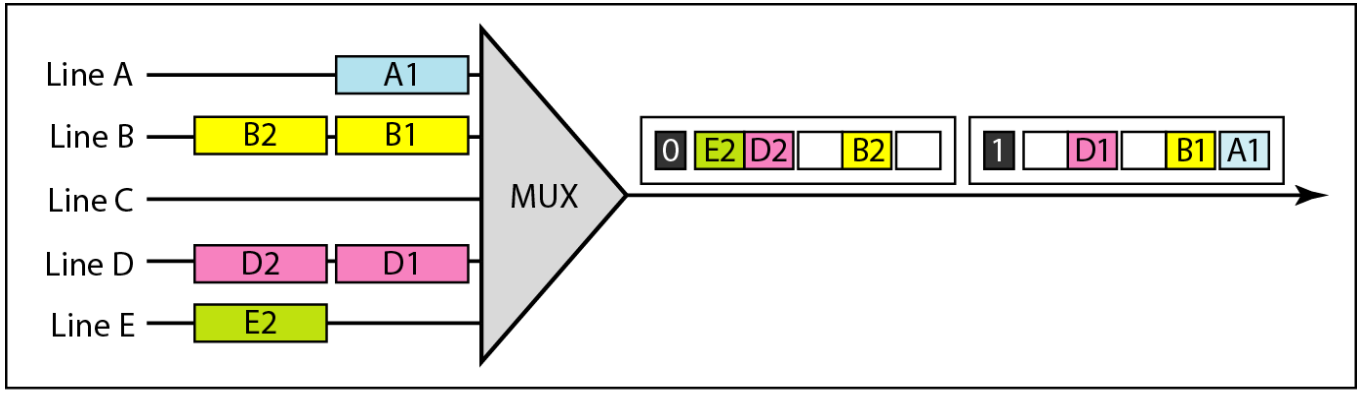
- Data rate of medium exceeds data rate of digital signal to be transmitted
- Multiple digital signals interleaved in time
- May be at bit level of blocks
- Time slots preassigned to sources and fixed
- Time slots allocated even if no data
- Time slots do not have to be evenly distributed amongst sources

- In synchronous TDM, the data rate of the link is *n* times faster, and the unit duration is *n* times shorter.
- Interleaving
  - The process of taking a group of bits from each input line for multiplexing is called interleaving.
  - We interleave bits (1 - n) from each input onto one output.

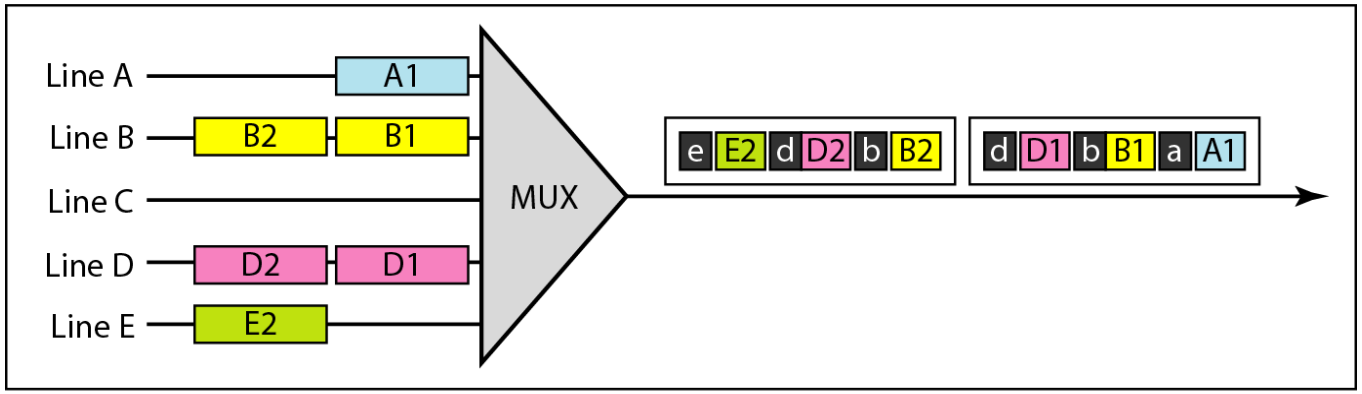

Synchronization
A3
A2
A1
B3
B2
B1
C3
C2
C1
Frame 3
C3
B3
A3
Frame 2
C2
B2
A2
Frame 1
C1
B1
A1
A3
A2
A1
B3
B2
B1
C3
C2
C1

Statistical TDM

- In Synchronous TDM many slots are wasted
- Statistical TDM allocates time slots dynamically based on demand
- Multiplexer scans input lines and collects data until frame full
- Data rate on line lower than aggregate rates of input lines



a. Synchronous TDM



b. Statistical TDM

Advantages of TDM

1. It uses a single link
2. It does not require precise carrier matching at both end of the links.
3. Use of the channel 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 is very high and causes problems
2. Initial cost is high
3. Technical complexity is more

SWITCHING

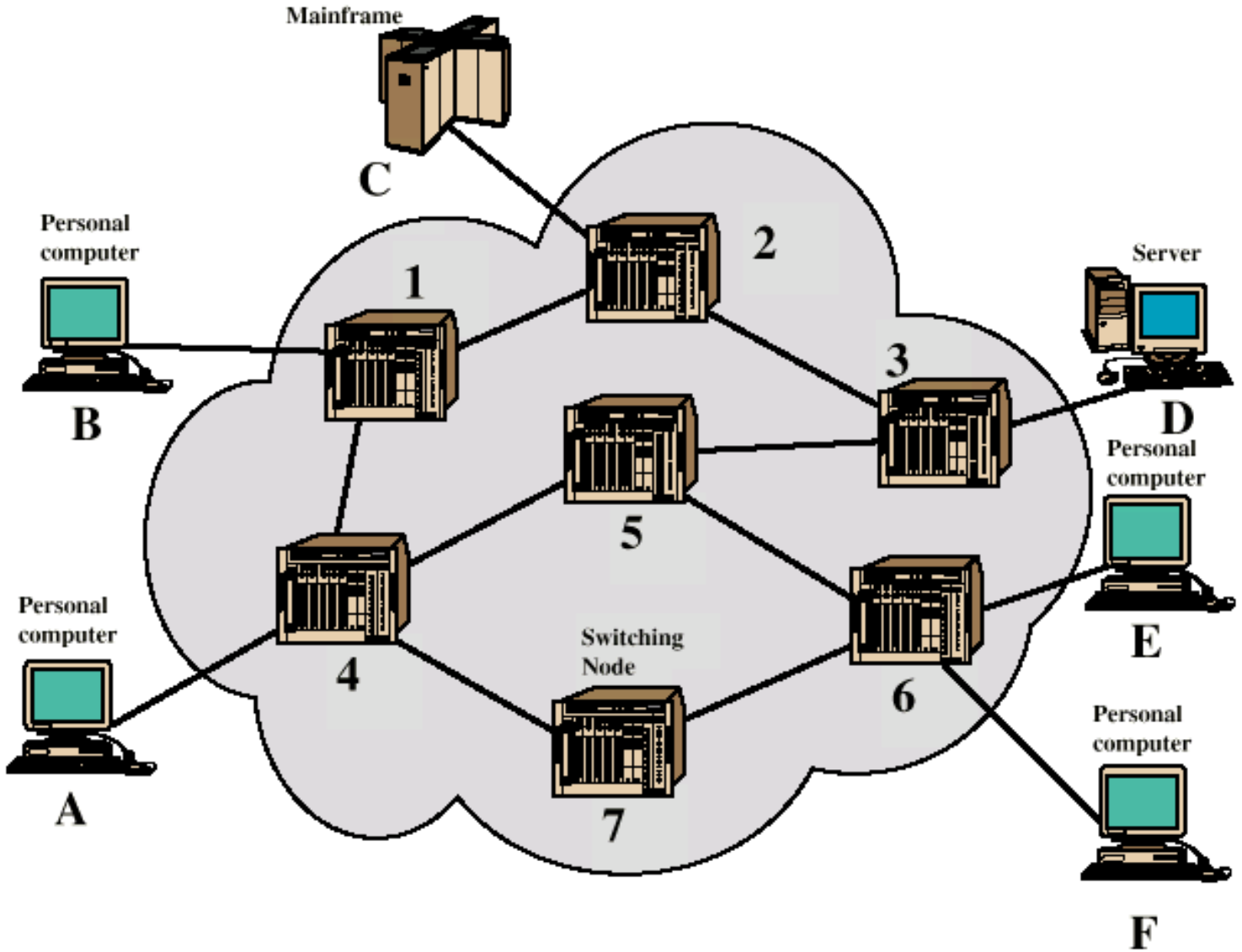
Switching Networks

- A collection of nodes and connections is a communications network
- Long distance transmission is typically done over a network of switched nodes
- Data routed by being switched from node to node
- Nodes not concerned with content of data
- End devices are stations
  - Computer, terminal, phone, etc.

Nodes

- Nodes may connect to other nodes only, or to stations and other nodes
- Node to node links usually multiplexed
- Network is usually partially connected
  - Some redundant connections are desirable for reliability

Simple Switched Network



SWITCHING

- How traffic is switched from input to output ports at nodes.
- The passage of a message from a source to a destination involves many decisions
- When a message reaches a connecting device, a decision needs to be made to select one of the output ports through which the packet needs to be send out.
- In other words, the connecting device acts as a switch that connects one port to another port.

Types of switching

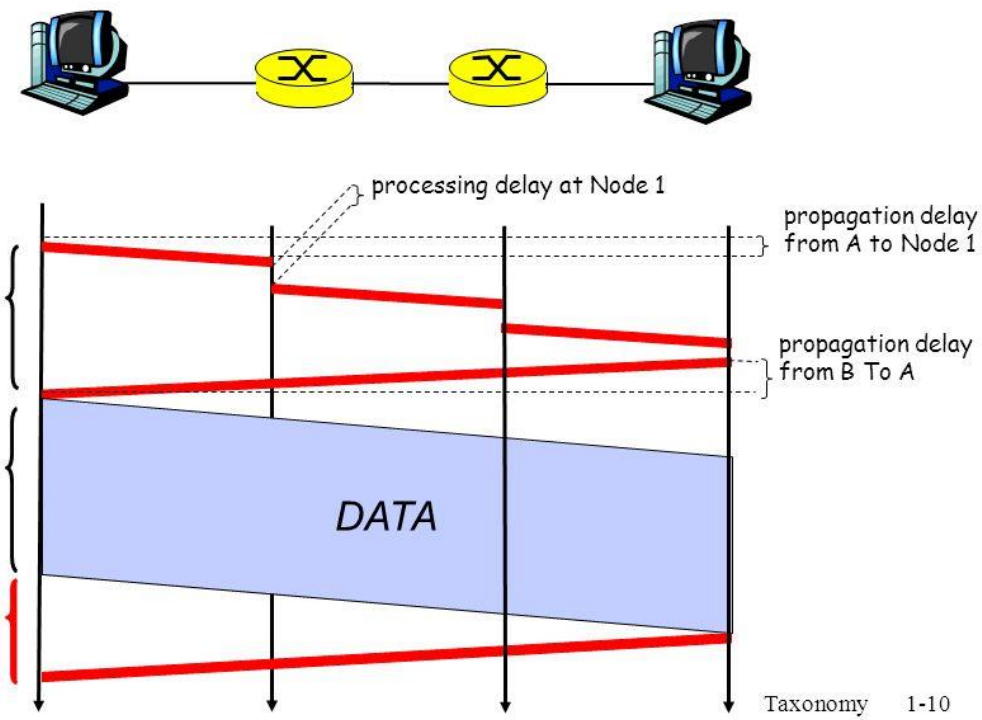
- Circuit switching and packet switching.

- Circuit switching is used with static multiplexing techniques, while packet switching is used primarily with statistical multiplexing.

Circuit Switching

- In circuit switching, the whole message is sent from the source to the destination without being divided into packets.
- Dedicated communication path between two stations
- Three phases
  - Establish
  - Transfer
  - Disconnect
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing

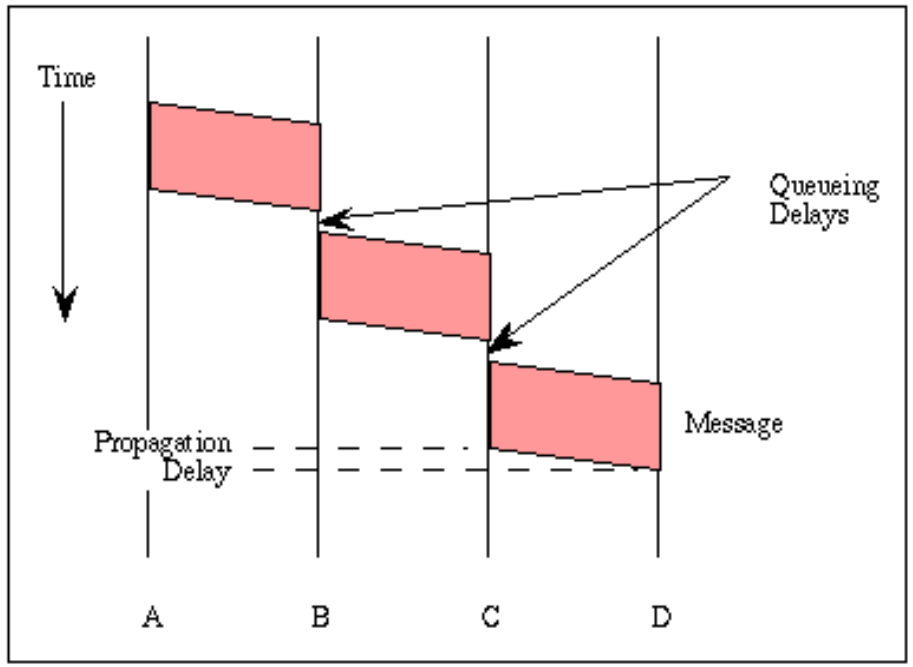
Circuit Switching in MultiHop Route



Circuit Switching - Issues

- Circuit switching is inefficient (designed for voice)
  - Resources dedicated to a particular call
  - Much of the time a data connection is idle
  - Data rate is fixed
    - Both ends must operate at the same rate
- Set up (connection) takes time
- Once connected, transfer is transparent

Message Switching



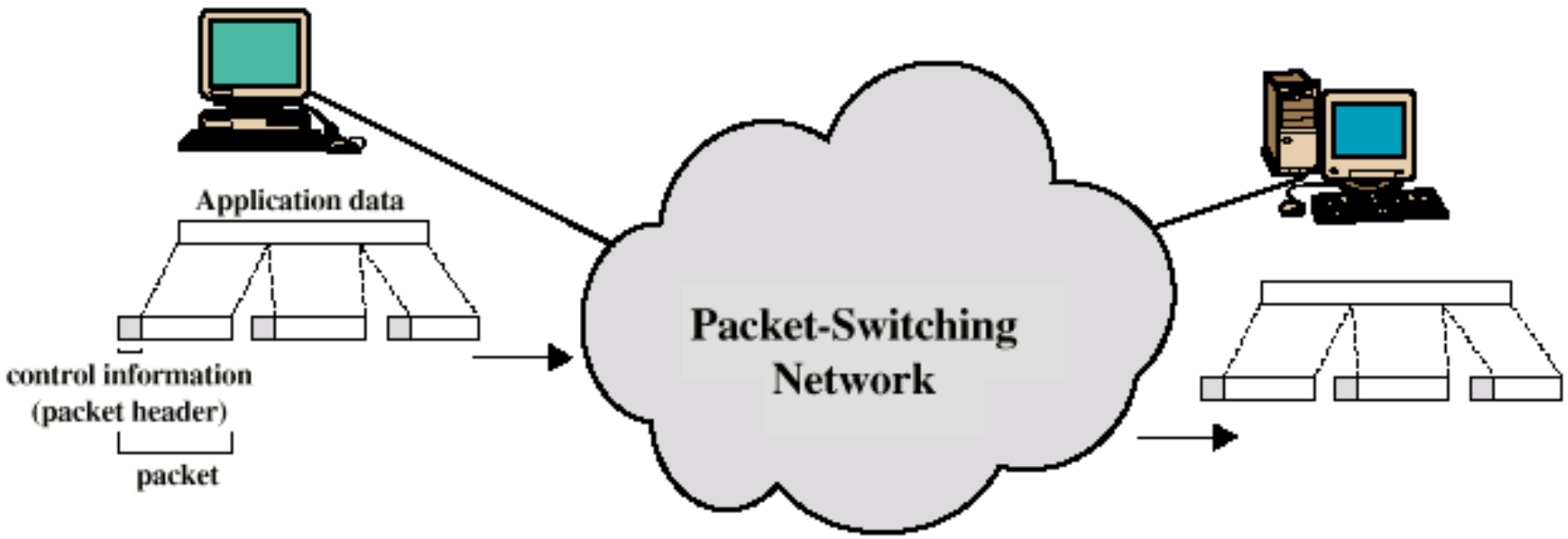
Packet Switching

- To improve the efficiency of transferring information over a shared communication line, messages are divided into fixed-sized, numbered **packets**
- Network devices called routers are used to direct packets between networks.

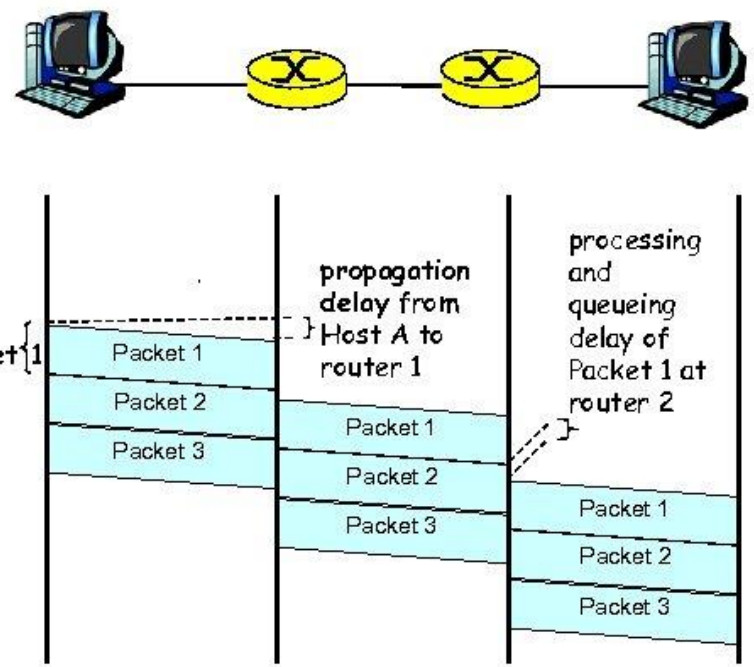
Basic Operation

- Data transmitted in small packets
  - Typically 1000 octets
  - Longer messages split into series of packets
  - Each packet contains a portion of user data plus some control info
- Control info
  - Routing (addressing) info
- Packets are received, stored briefly (buffered) and passed on to the next node
  - Store and forward

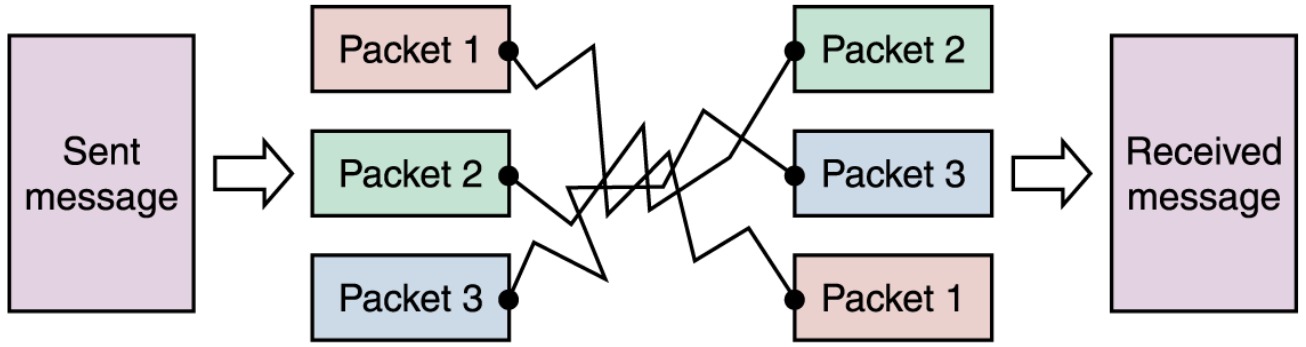
Use of Packets



Timing Diagram of Packet Switching



Packet Switching



Message is divided into packets

Packets are sent over the Internet by the most expedient route

Packets are reordered and then reassembled

Messages sent by packet switching