Switching and Multiplexing

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Switching and Multiplexing

Switching

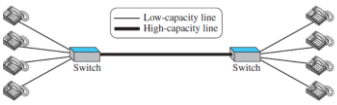
- An internet is a switched network in which a switch connects at least two links together.
- A switch needs to forward data from a network to another network when required.
- The two most common types of switched networks
  - Circuit switched networks
  - Packet switched networks

Switching and Multiplexing

Circuit Switched Network

- In a circuit switched network, a dedicated connection, called a circuit, is always available between the two end systems the switch can only make it active or inactive
- Figure shows a very simple switched network that connects four telephones to each end

3 *A circuit-switched network*



Switching and Multiplexing

Circuit Switched Network

- We have used telephone sets instead of computers as an end system because circuit switching was very common in telephone networks in the past, although part of the telephone network today is a packet switched network

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Circuit Switched Network

Advantages

- **Guaranteed bandwidth:** Provides a dedicated path for communication, ensuring that bandwidth is guaranteed for the duration of the call.
- **Low latency:** Provides low latency because the path is predetermined, and there is no need to establish a connection for each packet.
- **Predictable performance:** Because the bandwidth is reserved, and there is no competition for resources.
- **Suitable for real-time communication:** Suitable for real-time communication, such as voice and video, because it provides low latency and predictable performance.

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Circuit Switched Network

Disadvantages

- **Inefficient use of bandwidth:** Because the bandwidth is reserved for the entire duration of the call even when no data is being transmitted.
- **Limited scalability:** Because the number of circuits that can be established is finite which can limit the number of simultaneous calls that can be made.
- **High cost:** Because it requires dedicated resources, such as hardware and bandwidth for the duration of the call.

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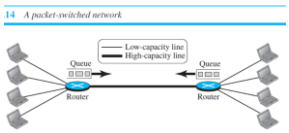
Packet Switched Network

- Communication between the two ends is done in blocks of data called packets
- Figure shows a small packet switched network that connects four computers at one site to four computers at the other site



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Packet Switched Network

- A router in a packet switched network has a queue that can store and forward the packet
- Now assume that the capacity of the thick line is only twice the capacity of the data line connecting the computers to the routers
- If packets arrive at one router, when the thick line is already working at its full capacity, the packets should be stored and forwarded in the order they arrived.

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Packet Switched Network

Advantages

- **Efficient use of bandwidth:** Because bandwidth is shared among multiple users and resources are allocated only when data needs to be transmitted.
- **Flexible**: Flexible and can handle a wide range of data rates and packet sizes.
- **Scalable:** Highly scalable and can handle large amounts of traffic on a network.
- **Lower cost:** Less expensive than circuit switching because resources are shared

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Packet Switched Network

Disadvantages of Packet Switching

- **Higher latency:** Higher latency than circuit switching because packets must be routed through multiple nodes which can cause delay.
- **Limited QoS:** Provides limited QoS guarantees. It means that different types of traffic may be treated equally.
- **Packet loss:** Result in packet loss due to congestion on the network or errors in transmission.

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Circuit Switching	Packet Switching
A dedicated communication path is established between the sender and receiver before data transmission.	Data is divided into packets, which are sent independently over the network and reassembled at the destination.
Connection-oriented	Connection-less (mostly)
Data transmission is Continuous and ordered	Data transmission is Packet-based and may arrive out of order
Fixed bandwidth is reserved for the entire duration of communication.	Bandwidth is dynamically shared among multiple users.
Low delay once the circuit is established, but high setup time.	Lower setup time, but packets may experience variable delays.
Poor scalability due to dedicated resources.	Highly scalable due to resource sharing.
Traditional telephone networks (PSTN).	Internet, VoIP, and most modern communication networks.

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MULTIPLEXING

- Multiplexing is the transmission of information from more than one source to more than one destination over the same transmission medium.
- **Multiplexing** is the sharing of a medium or bandwidth. It is the process in which multiple signals coming from multiple sources are combined and transmitted over a single communication/physical line.

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MULTIPLEXING

There are three types of Multiplexing

- Time-Division Multiplexing (TDM)
- Frequency Division Multiplexing (FDM)
- Wavelength Division Multiplexing (WDM)

Switching and Multiplexing

Time Division Multiplexing (TDM)

- A multiplexing technique by which multiple data signals can be transmitted over a common communication channel in different time slots is known as **Time Division Multiplexing (TDM)**.
- It allows the division of the overall time domain into various fixed length time slots.
- A single frame is said to be transmitted when it's all signal components gets transmitted over the channel.
- Each user is allotted a particular a time interval called time slot or time slice during which the data is transmitted by that user.

Switching and Multiplexing

Time Division Multiplexing (TDM)

- Each sending device takes control of entire bandwidth of the channel for fixed amount of time.
- In TDM, data rate capacity of the transmission medium should be greater than the data rate required by sending or receiving devices.
- In TDM, all the signals to be transmitted are not transmitted simultaneously. Instead, they are transmitted one-by-one.
- Each signal will be transmitted for a very short time.

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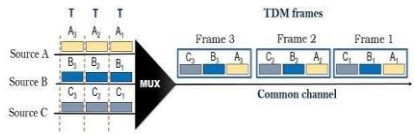
Time Division Multiplexing (TDM)

- The TDM system can be used to multiplex analog or digital signals, however it is more suitable for the digital signal multiplexing.



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Time Division Multiplexing (TDM)

Time Division Multiplexing Types

- Synchronous TDM
- Asynchronous or Statistical TDM

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Synchronous TDM

- In synchronous TDM, each device is given same **time slot** to transmit the data over the link, irrespective of the fact that the device has any data to transmit or not.
- Synchronous TDM, total speed of various input lines should not exceed the capacity of path.
- Each device places its data onto the link when its **time slot** arrives i.e. each device is given the possession of line turn by turn.
- If any device does not have data to send then its time slot remains empty.
- The various time slots are organized into **frames** and each frame consists of one or more time slots dedicated to each sending device.

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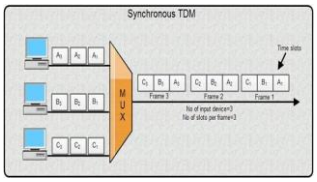
Synchronous TDM

- If there are **n** sending devices, there will be **n** slots in frame i.e. one slot for each device.



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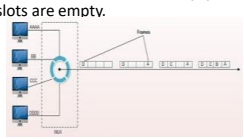
Synchronous TDM

Disadvantages

- The channel capacity cannot be fully utilized.
- Some of the slots go empty in certain frames. As shown in fig only first two frames are completely filled. The last three frames have 6 empty slots. It means out of 20 slots in all, 6 slots are empty.
- This wastes the l/4th capacity of links.



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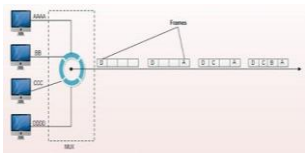
Synchronous TDM

Disadvantages

- The capacity of single communication line that is used to carry the various transmissions should be greater than the total speed of input lines.



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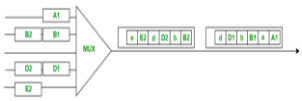
Statistical TDM

- Output frame collects data from the input frame till it is full, not leaving an empty slot like in Synchronous TDM.
- Asynchronous TDM is called so because is this type of multiplexing, time slots are not fixed i.e. the slots are flexible.
- Here, the total speed of input lines can be greater than the capacity of the path.



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Statistical TDM

- In synchronous TDM, if we have **n input lines** then there are **n slots** in one frame. But in asynchronous it is not so.
- In asynchronous TDM, if we have n input lines then the frame contains not more than m slots, with m less than n **(m < n).**
- In asynchronous TDM, the number of time slots in a frame is based on a statistical analysis of number of input lines.
- In this system slots are not predefined, the slots are allocated to any of the device that has data to send.

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Statistical TDM:

- The multiplexer scans the various input lines, accepts the data from the lines that have data to send, fills the frame and then sends the frame across the link.
- If there are not enough data to fill all the slots in a frame, then the frames are transmitted partially filled.

Advantages of TDM:

- Full available channel bandwidth can be utilized for each channel.
- Intermodulation distortion is absent.
- TDM circuitry is not very complex.

Disadvantages of TDM:

- Synchronization is essential for proper operation.

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Frequency Division Multiplexing (FDM)

- ***FDM*** is a scheme in which **numerous signals are combined for transmission on a single communications line or channel.**
- It is ***analog*** multiplexing technique.
- In this, a number of signals are transmitted at the same time, and each source transfers its signals in the allotted frequency range.
- There is a suitable frequency gap between the 2 adjacent signals to avoid over-lapping.
- Since the signals are transmitted in the allotted frequencies so this decreases the probability of collision.

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Frequency Division Multiplexing (FDM)

- The ***frequency spectrum*** is divided into several logical channels, in which every user feels that they possess a particular bandwidth.
- A number of signals are sent simultaneously at the same time allocating separate frequency bands or channels to each signal.
- It is used in **radio** and **TV** transmission.
- Therefore to avoid interference between two successive channels **Guard bands** are used.

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Frequency Division Multiplexing (FDM)

Application of FDM

- In the first generation of mobile phones, FDM was used.
- The use of FDM in television broadcasting
- FDM is used to broadcast FM and AM radio frequencies.
- Similarly FM broadcasting uses a bandwidth of 88 to 108 MHz

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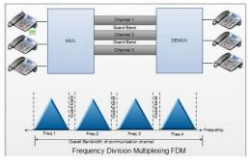
Frequency Division Multiplexing (FDM)

Advantages of FDM

- A large number of signals (channels) can be transmitted simultaneously.
- FDM does not need synchronization between its transmitter and receiver for proper operation.
- Demodulation of FDM is easy.
- Due to slow narrow band fading only a single channel gets affected.



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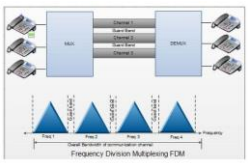
Frequency Division Multiplexing (FDM)

Disadvantages of FDM:

- The communication channel must have a very large bandwidth.
- Intermodulation distortion takes place.
- Large number of modulators and filters are required.
- FDM suffers from the problem of crosstalk.



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Wavelength-Division Multiplexing (WDM)

- ***WDM*** is a technique of multiplexing multiple optical carrier signals through a single optical fibre channel by varying the wavelengths of laser lights.
- WDM allows communication in both the directions in the fibre cable.

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Wavelength-Division Multiplexing (WDM)

Concept and Process

- In **WDM**, the optical signals from different sources or (transponders) are combined by a multiplexer, which is essentially an optical combiner.
- They are combined so that their wavelengths are different.
- The combined signal is transmitted via a single optical fibre strand.
- At the receiving end, a demultiplexer splits the incoming beam into its components and each of the beams is send to the corresponding receivers.

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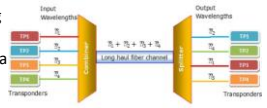
Wavelength-Division Multiplexing (WDM)

- **Example:** It has 4 optical signals having 4 different wavelengths.
- Each of the four senders generates data streams of a particular wavelength.
- The optical combiner multiplexes the signals and transmits them over a single long-haul fibre channel.
- At the receiving end, the splitter demultiplexes the signal into the original 4 data streams.



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Wavelength-Division Multiplexing (WDM)

Categories of WDM: Based upon the wavelength, WDM can be divided into two categories

- **Course WDM (CWDM)**: CWDM generally operates with ***8 channels*** where the spacing between the channels is ***20 nm*** (nanometres) apart.
  - It consumes less energy than DWDM and is less expensive. However, the capacity of the links, as well as the distance supported, is lesser.
- **Dense WDM (DWDM)**: In DWDM, the number of multiplexed channels much larger than CWDM.
  - It is either ***40 at 100GHz spacing*** or ***80 with 50GHz spacing***. Due to this, they can transmit the huge quantity of data through a single fibre link.
  - DWDM is generally applied in core networks of telecommunications and cable networks.

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Wavelength-Division Multiplexing (WDM)

Advantages of WDM

- Enhanced capacity as full-duplex transmission is also possible with a single fibre.
- WDM is inherently easier to reconfigure (i.e. adding of removing channels)
- Usage of optical components makes it simpler, more reliable and often less costly.

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Wavelength-Division Multiplexing (WDM)

Disadvantages of WDM

- Signals cannot be placed so close in the wavelength spectrum that they interfere with each other.
- The overall signal strength should be approximately the same for each wavelength which may not be possible.
- Light waves carrying WDM are limited to a two-point circuit or a combination of many two-point circuits that can go only where the cable goes.

Thank you!