CS010 404

Signals and Communication Systems

Module 4 – Multiplexing

Dept. of Computer Science and Engineering

Module 4: Syllabus

Multiplexing:-
Time Division Multiplexing(TDM)-
Frequency Division Multiplexing(FDM)-
Wavelength Division multiplexing(WDM)
Switching:- Circuit, Packet and Message Switching Schemes,
Case Study:- SONET(Basic ideas only)-
Datagrams and virtual Circuits Digital Transmission:- Analog to Digital Converter(ADC), Serial and parallel Transmission- Simplex, Half Duplex and Full Duplex Transmissions.

Multiplexing

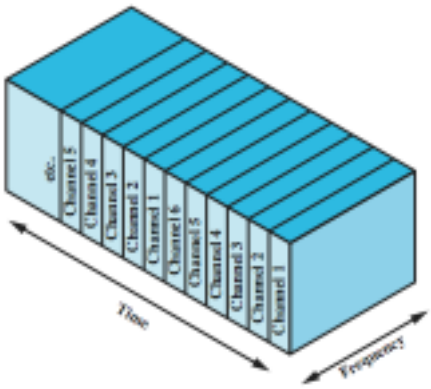
It was impossible to get a conversation going, everybody was talking too much.

- Yogi Berra

Multiplexing

- Multiplexing
  - A process where multiple analog message signals or digital data streams are combined into one signal over a shared medium
  - Combination of independent source signals into a composite signal suitable for transmission over a common channel
- Types
  - Time division multiplexing (TDM)
  - Frequency division multiplexing (FDM)
- Optically
  - Time division multiplexing
  - Wavelength division multiplexing (WDM)

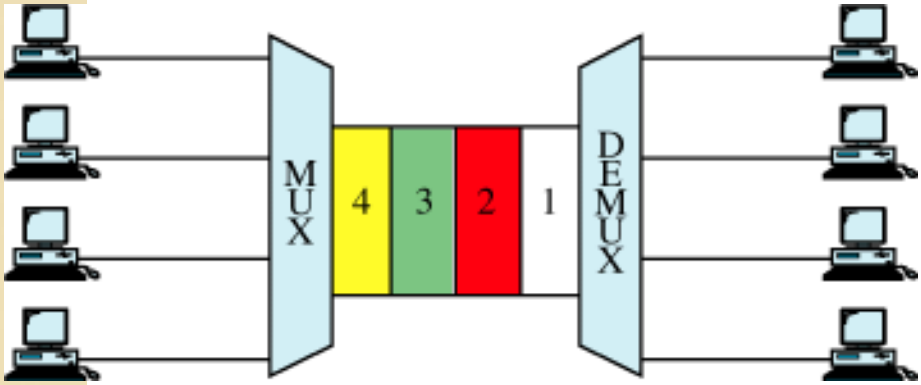
Synchronous Time Division Multiplexing



(b) Time division multiplexing

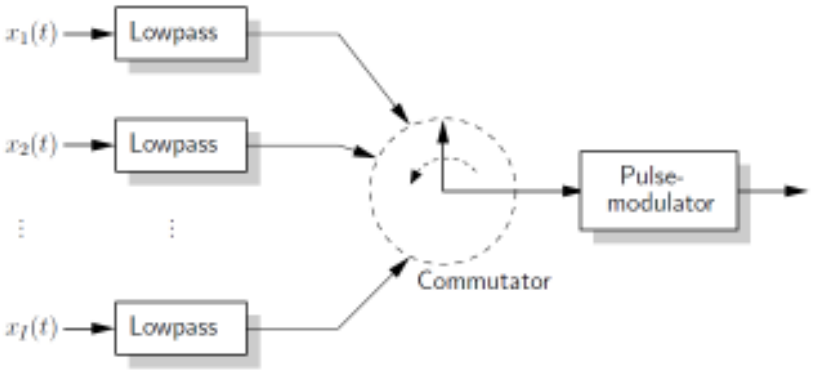
TDM

Individual signals are separated by allocating them to different time slots within a sampling interval.
– Used with (digital) pulse modulation

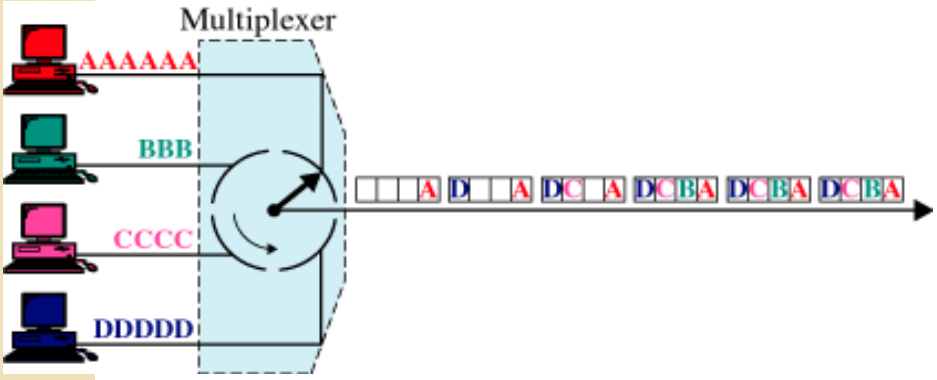


TDM-Time Division Multiplexing

- TDM is based on the sampling theorem.
- Transmission of one band-limited message signal engages transmission
- Channel occupied for only a fraction of the sampling interval.
- Time interval between adjacent samples is cleared for use by other message signals.

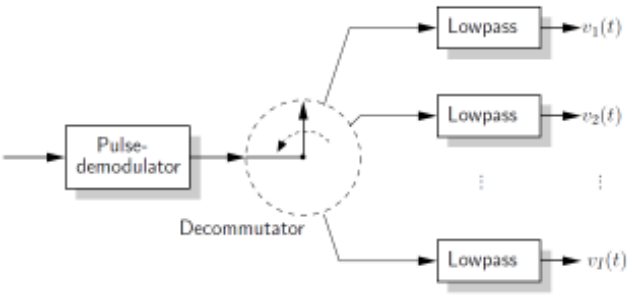


TDM - Multiplexing

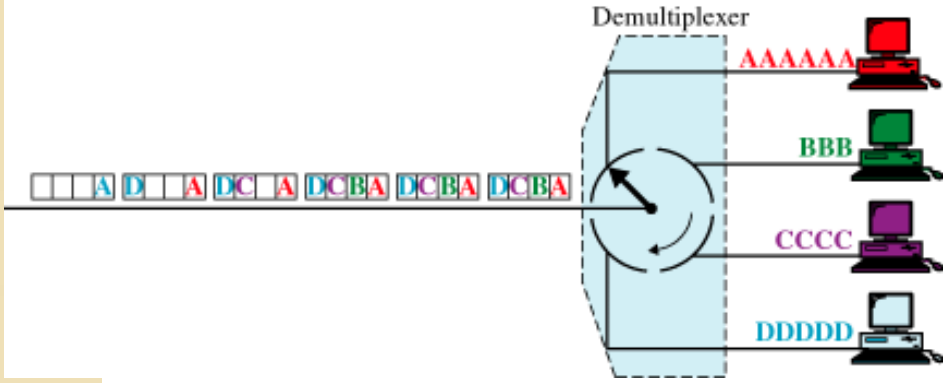


TDM, Demultiplexing

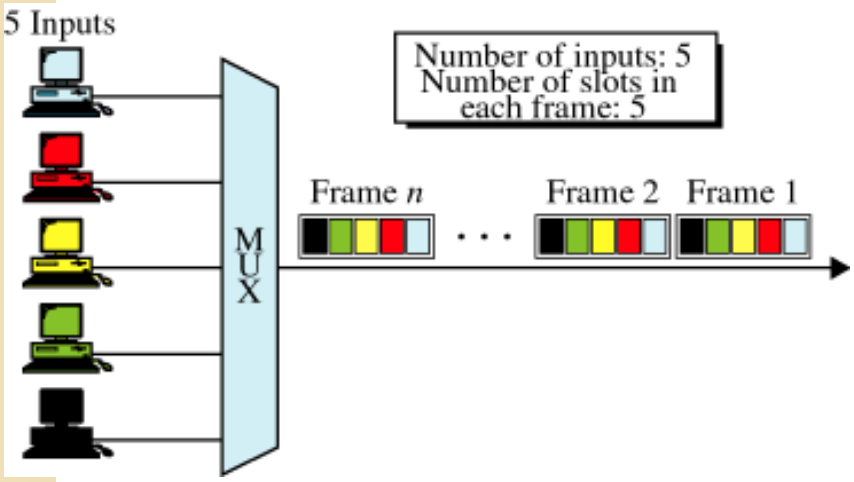
- Pulse demodulator produces narrow samples
- Decommutator distributes samples
- Lowpass filtering to reconstruct message signal
- Timing synchronization between commutator and decommutator is critical
- Appropriate choice of pulse shape and pulse demodulation to avoid intersymbol interference



TDM, Demultiplexing



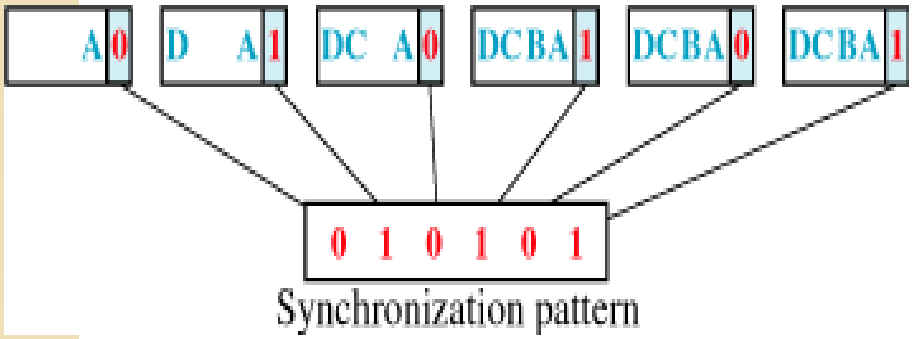
Synchronous TDM



Framing

- No flag or SYNC chars bracketing TDM frames
- Must still provide synchronizing mechanism between source and destination clocks
- Added digit framing is most common
  - one control bit added to each TDM frame
  - identifiable bit pattern used as control channel
  - alternating pattern 101010…unlikely to be sustained on a data channel
  - receivers compare incoming bits of frame position to the expected pattern

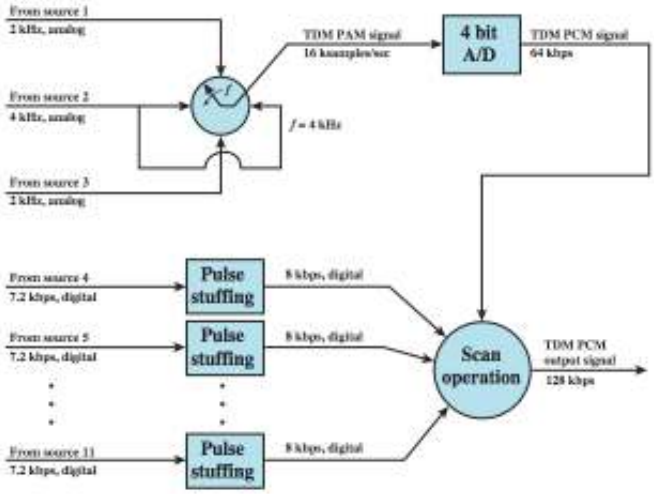
Framing Bits



Pulse Stuffing

- Have problem of synchronizing data sources
- With clocks in different sources drifting
- Also issue of data rates from different sources not related by simple rational number
- Pulse Stuffing a common solution
  - Have outgoing data rate (excluding framing bits) higher than sum of incoming rates
  - Stuff extra dummy bits or pulses into each incoming signal until it matches local clock
  - Stuffed pulses inserted at fixed locations in frame and removed at demultiplexer

TDM Example



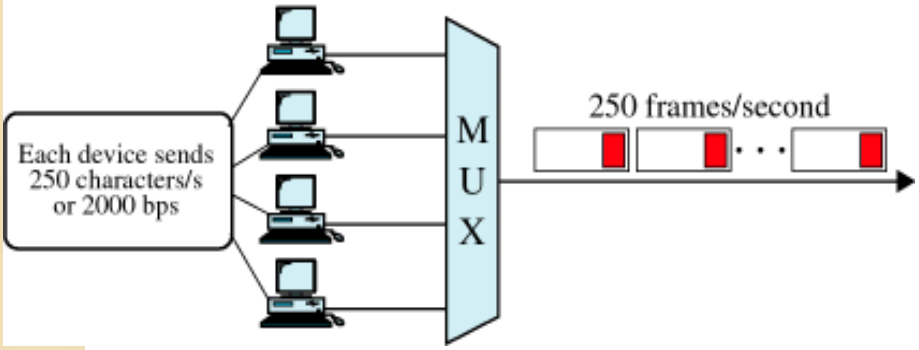
Problem - Data Rate

We have 4 sources, each creating 250 characters/sec.
If the interleaved unit is a character and
1 synchronization bit is added to each frame, find

(a) The data rate of each source
(b) Duration of each character in each source
(c) Frame rate
(d) Duration of each frame
(e) Number of bits in each frame
(f) Data rate for the link

Problem - Data Rate

8250 bps = 250 frames/second x 33 bits/frame
or
8250 bps = 4 x 2000 bps + 250 synchronization bps



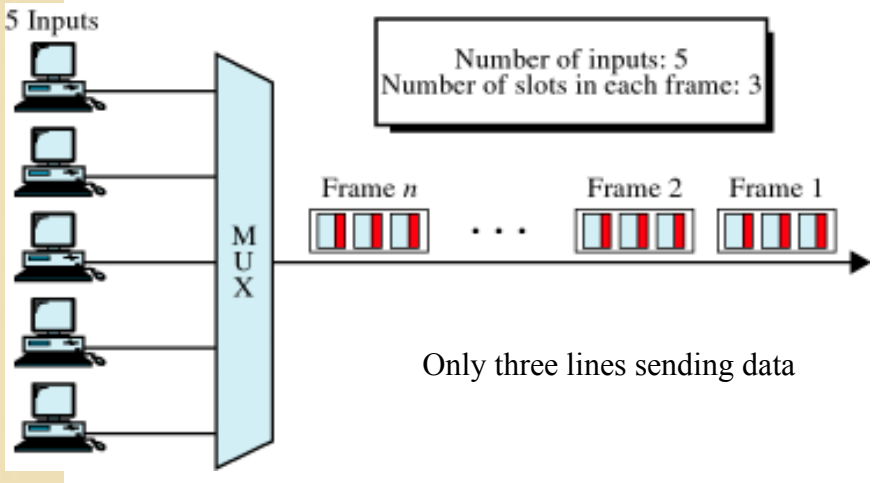
Statistical TDM

- In Synch TDM many slots are wasted
- Statistical TDM allocates time slots dynamically based on demand
- Multiplexer scans input lines and collects data until frame full
- Line data rate lower than aggregate input line rates
- May have problems during peak periods
  - must buffer inputs

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 is full
- line data rate lower than aggregate input line rates
- may have problems during peak periods
  - must buffer inputs

Asynchronous TDM



Only three lines sending data

Frames and Addresses

Only three lines sending data

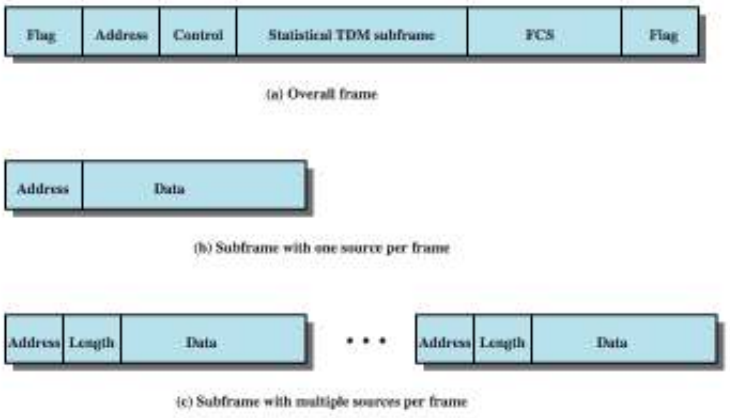
Frames and Addresses

Only four lines sending data

Frames and Addresses

All five lines sending data

Statistical TDM Frame Format

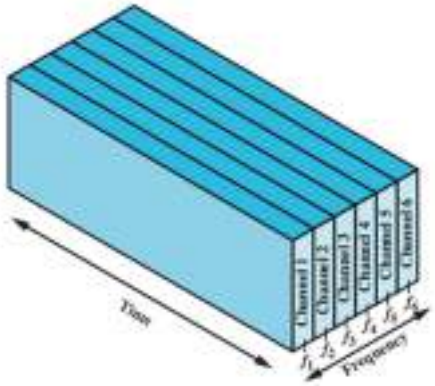


Frequency Division Multiplexing (FDM)

Individual signals are separated by allocating them to different frequency bands.

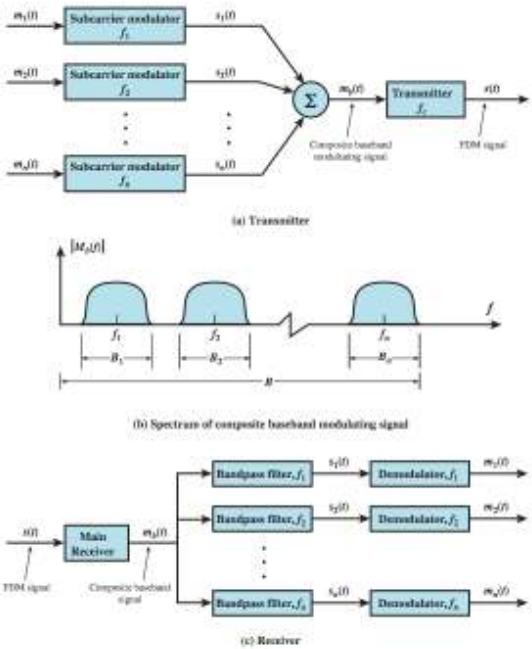
– Used with sinusoidal carrier-wave modulation

– Examples: wired telephony and telegraphy



(a) Frequency division multiplexing

FDM System Overview

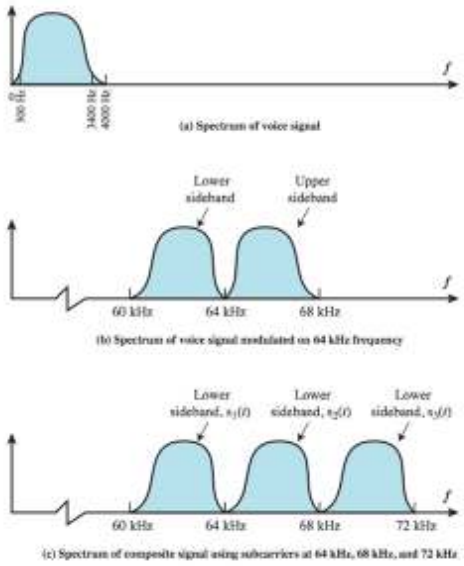


(a) Transmitter

(b) Spectrum of composite baseband modulating signal

(c) Receiver

FDM Voiceband Example



Wavelength Division Multiplexing (WDM)

Multiple beams of light at different frequencies

Carried over optical fiber links

- commercial systems with 160 channels of 10 Gbps
- lab demo of 256 channels 39.8 Gbps

Architecture similar to other FDM systems

- multiplexer consolidates laser sources (1550nm) for transmission over single fiber
- optical amplifiers amplify all wavelengths
- demultiplexer separates channels at destination

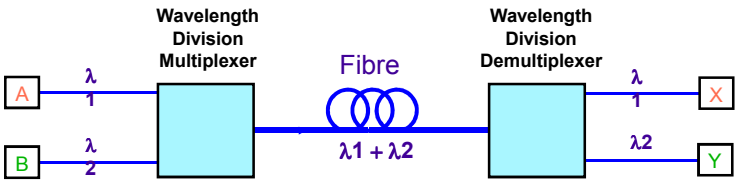
Dense Wavelength Division Multiplexing (DWDM)

- use of more channels more closely spaced

TDM to WDM

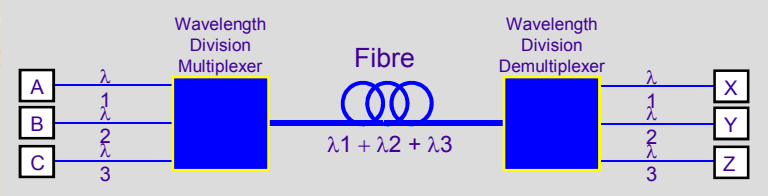
- TDM (Time Division Multiplexing)
  - Slotting of channels → simultaneous users
  - Increasing bit rate to maximize utilization of given bandwidth
- WDM (Wavelength Division Multiplexing)
  - Use of optical fibers to achieve higher speeds
  - Utilize wavelengths to multiplex users
  - Allow continuous channel allocation per user
  - Increases the effective bandwidth of existing fiber

WDM Overview



- Multiple channels of information carried over the same fibre, each using an individual wavelength
- A communicates with X and B with Y as if a dedicated fibre is used for each signal
- Typically one channel utilises 1320 nm and the other 1550 nm
- Broad channel spacing, several hundred nm
- Recently WDM has become known as Coarse WDM or CWDM to distinguish it from DWDM

WDM Overview



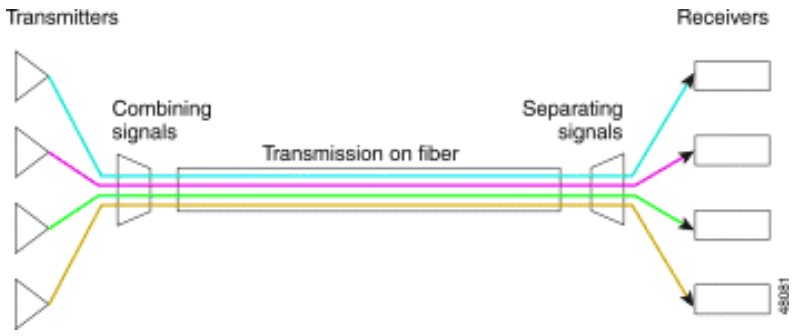
- Multiple channels of information carried over the same fibre, each using an individual wavelength
- Attractive multiplexing technique
  - High aggregate bit rate without high speed electronics or modulation
  - Low dispersion penalty for aggregate bit rate
  - Very useful for upgrades to installed fibres
  - Realisable using commercial components, unlike OTDM
- Loss, crosstalk and non-linear effects are potential problems

Types of WDM

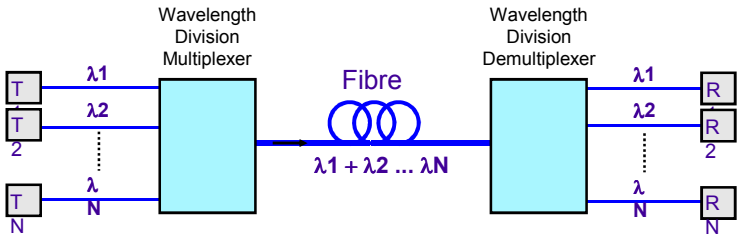
	Coarse WDM (includes WWDM)	WDM	DWDM (includes ultra dense WDM)
Channel Spacings	Large, from 1.6 nm (200 GHz) to 25 nm	1310 nm lasers used in conjunction with 1550 nm lasers	Small, 200 GHz and less
Number of bands used	O,E,S,C and L	O and C	C and L
Cost per channel	Low	Low	High
Number of channels delivered	17-18 at most	2	Hundreds of channels possible
Best Application	Short-haul, Metro	PON	Long-haul

What is DWDM ?

- Definition
  - Dense wavelength division multiplexing (DWDM) is a fiber-optic transmission technique that employs light wavelengths to transmit data parallel-by-bit or serial-by-character



Simple DWDM System



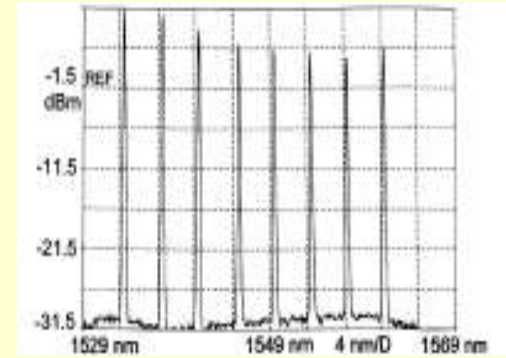
Multiple channels of information carried over the same fibre, each using an individual wavelength

Unlike CWDM channels are much closer together

Transmitter T_1 communicates with Receiver R_1 as if connected by a dedicated fibre as does T_2 and R_2 and so on

Source: Master 7_4

Sample DWDM Signal



Multiplexer Optical Output Spectrum for an 8 DWDM channel system, showing individual channels

Source: Master 7_4

DWDM Advantages

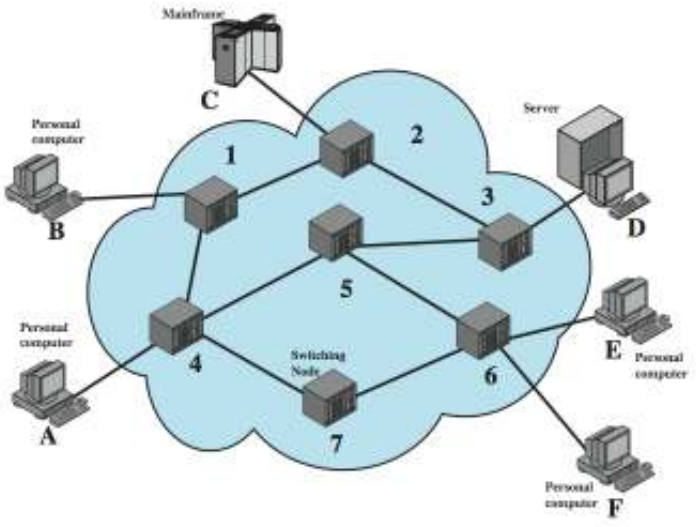
- Greater utilization of fibre capacity
- Easier network expansion
  - No new fibre needed
  - Just add a new wavelength
  - Incremental cost for a new channel is low
  - No need to replace many components such as optical amplifiers
- DWDM systems capable of longer span lengths - ~ 100 km

Circuit Switching and Packet Switching

He got into a District Line train at Wimbledon Park, changed on to the Victoria Line at Victoria and on to the Jubilee Line at Green Park for West Hampstead. It was a long and awkward journey but he enjoyed it.

—*King Solomon's Carpet*, Barbara Vine (Ruth Rendell)

Switched Network



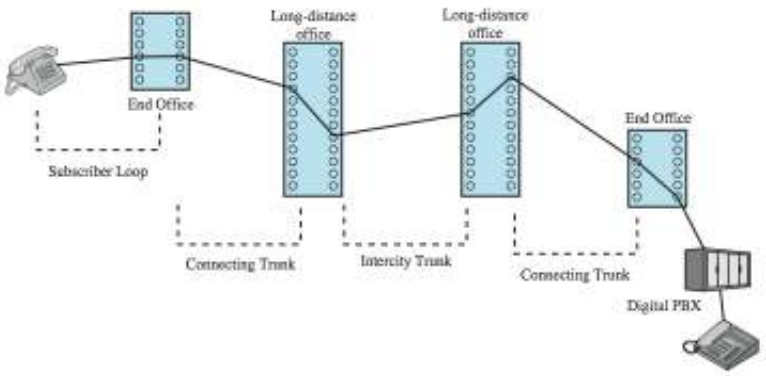
Nodes

- A collection of nodes and connections is a communications network
- Nodes may connect to other nodes only, or to stations and other nodes
- Network is usually partially connected
  - some redundant connections are desirable
- Have Three different switching technologies
  - Message switching
  - Circuit switching
  - Packet switching

Circuit Switching

- A circuit-switched communication network is made of a set of switches connected by physical links in which each link is divided into n channels using TDM or FDM
- Uses a dedicated communications path established for duration of conversation comprising a sequence of physical links with a dedicated logical channel
- eg. telephone network

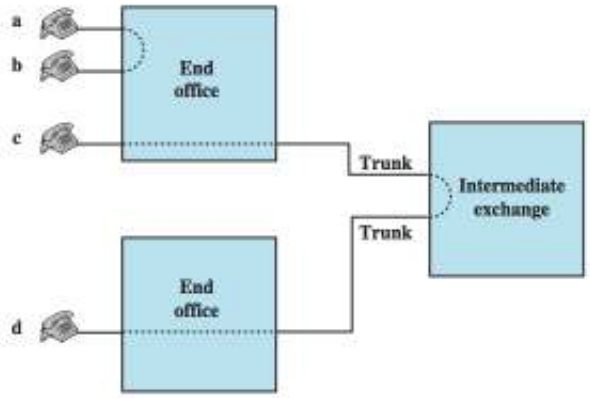
Public Circuit Switched Network



Circuit Switching

- Uses a dedicated path between two stations
- Has three phases
  - Establish
  - Transfer
  - Disconnect
- Inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent

Circuit Establishment



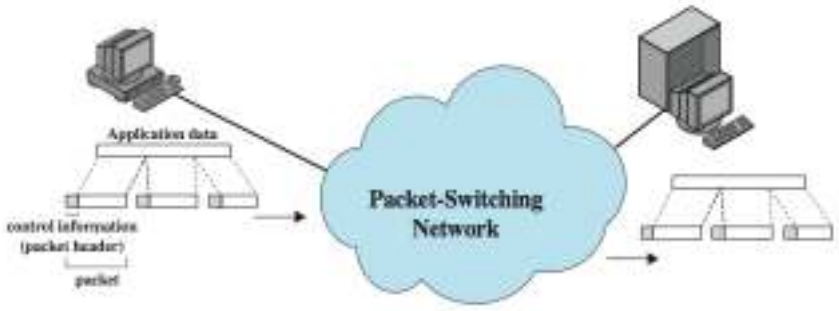
Blocking or Non-blocking

- Blocking network
  - May be unable to connect stations because all paths are in use
  - Used on voice systems
- Non-blocking network
  - Permits all stations to connect at once
  - Used for some data connections

Packet Switching

- Circuit switching was designed for voice
- Packet switching was designed for data
- Transmitted in small packets
- Packets contains user data and control info
  - User data may be part of a larger message
  - Control info includes routing (addressing) info
- Packets are received, stored briefly (buffered) and past on to the next node

Packet Switching



Packet switching Advantages

- Line efficiency
  - single link shared by many packets over time
  - packets queued and transmitted as fast as possible
- Data rate conversion
  - stations connects to local node at own speed
  - nodes buffer data if required to equalize rates
- Packets accepted even when network is busy
- Priorities can be used

Circuit Vs Packet Switching

- Performance depends on various delays
  - propagation delay
  - transmission time
  - node delay
- Range of other characteristics, including:
  - transparency
  - amount of overhead

Switching Techniques

- Station breaks long message into packets
- Packets sent one at a time to the network
- Packets can be handled in two ways
  - Datagram
  - Virtual circuit

Datagram

Each packet is treated independently, with no reference to packets that have gone before

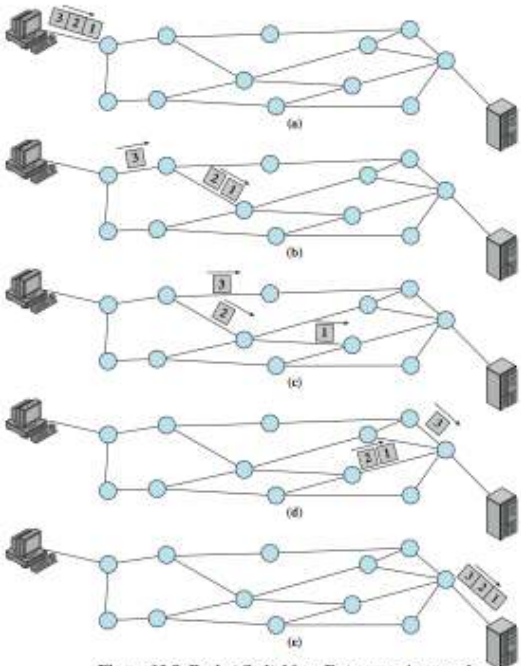


Figure 10.9 Packet Switching: Datagram Approach

Virtual Circuit Diagram

A preplanned route is established before any packets are sent. Once the route is established, all the packets between a pair of communicating parties follow this same route through the network.

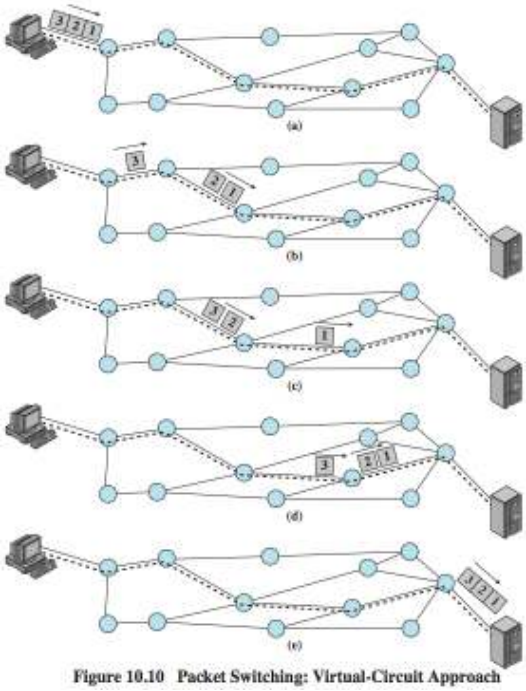


Figure 10.10 Packet Switching: Virtual-Circuit Approach

Virtual Circuits Vs Datagram

- Virtual circuits
  - network can provide sequencing and error control
  - packets are forwarded more quickly
  - less reliable
- Datagram
  - no call setup phase
  - more flexible
  - more reliable

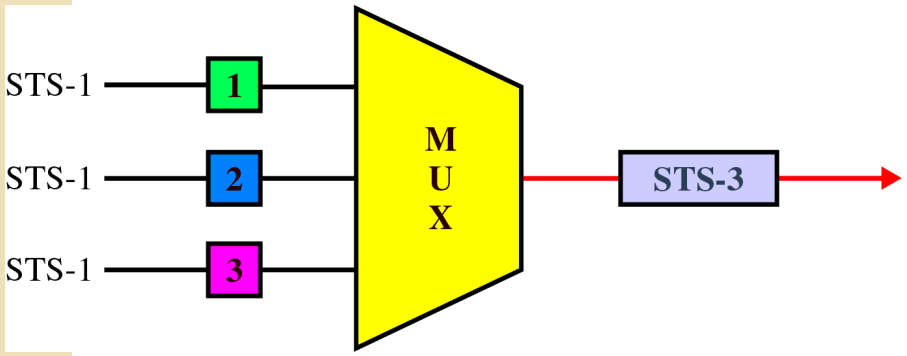
SONET/SDH

- SONET is a standard for connecting fiber-optic transmission systems
- Synchronous Optical Network (ANSI)
- Synchronous Digital Hierarchy (ITU-T)
- Utilizes high speed capability of optical fiber
- Defines hierarchy of signal rates
  - Synchronous Transport Signal level 1 (STS-1) or Optical Carrier level 1 (OC-1) is 51.84Mbps
  - Carries one DS-3 or multiple (DS1 DS1C DS2) plus ITU-T rates (e.g., 2.048Mbps)
  - Multiple STS-1 combine into STS-N signal
  - ITU-T lowest rate is 155.52Mbps (STM-1)

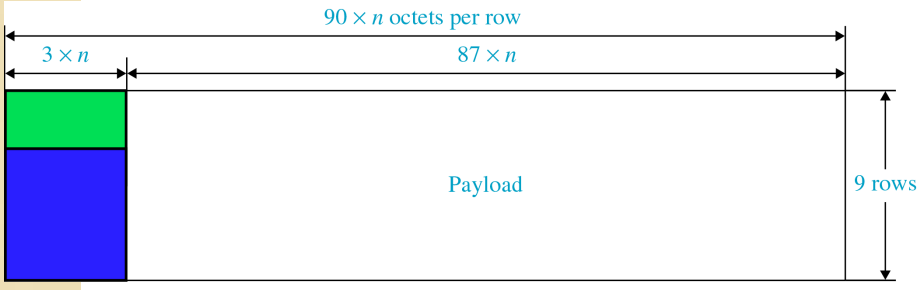
SONET

- SONET uses TDM
- Uses byte-interleaved multiplexing that can work on data streams of different rates
- Entire optical bandwidth is time-shared with different incoming data streams
- Need Synchronous operation
- SONET is controlled by a master clock with an accuracy of about 1 part in 10^9
- Thus bits of data sent over a SONET line are at extremely precise intervals

STS Multiplexing



STS-n



90 x 9 = 810 octets

STS-1 Frame

- Basic SONET building block is the STS-1 frame
- Analog Voice signal is digitized using PCM at a rate of 8000 samples per second.
- Hence frames must repeat 8000 times per second (125 micro-seconds per frame)