DATA COMMUNICATION TECHNOLOGIES

UNIT-3

SIGNAL ENCODING TECHNIQUES

- WHY?

  To Optimize the use of Transmission Media, (i.e) minimize the errors.

- ENCODING:

  It is the process coverting the data or given sequence of characters, symbols, alphabets, etc, into a specified format, for the secured transmission of data.

- DECODING is the reverse process of encoding which is to extract the information from the converted format.

SIGNAL ENCODING TECHNIQUES

Signal Encoding Techniques

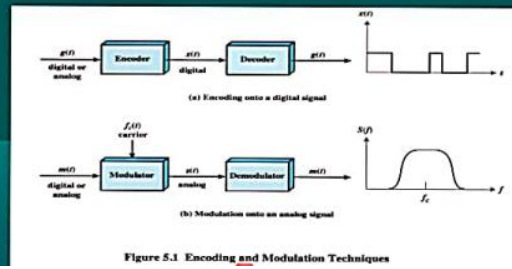
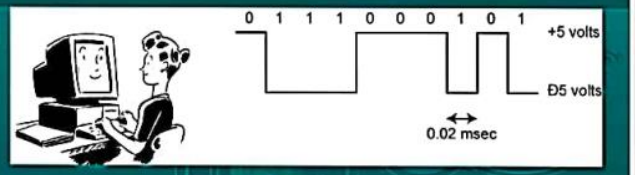


Figure 5.1 Encoding and Modulation Techniques

1. DIGITAL DATA, DIGITAL SIGNAL

Digital Data, Digital Signal

- Digital signal
  - discrete, discontinuous voltage pulses
  - each pulse is a signal element
  - binary data encoded into signal elements



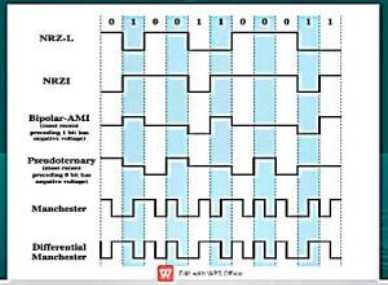
1.1 INTERPRETING SIGNALS

Interpreting Signals

- need to know
  - timing of bits - when they start and end
  - signal levels
- factors affecting signal interpretation
  - signal to noise ratio
  - data rate
  - bandwidth
  - encoding scheme

1.2 ENCODING SCHEMES

Encoding Schemes



1.3 NRZ-L

Nonreturn to Zero-Level (NRZ-L)

- two different voltages for 0 and 1 bits
- voltage constant during bit interval
  - no transition I.e. no return to zero voltage
  - such as absence of voltage for zero, constant positive voltage for one
  - more often, negative voltage for one value and positive for the other

NONRETURN TO ZERO INVERTED

Nonreturn to Zero Inverted

- nonreturn to zero inverted on ones
- constant voltage pulse for duration of bit
- data encoded as presence or absence of signal transition at beginning of bit time
  - transition (low to high or high to low) denotes binary 1
  - no transition denotes binary 0
- example of differential encoding since have
  - data represented by changes rather than levels
  - more reliable detection of transition rather than level
  - easy to lose sense of polarity

NRZ PROS & CONS

NRZ Pros & Cons

- Pros
  - easy to engineer
  - make good use of bandwidth
- Cons
  - dc component
  - lack of synchronization capability
- used for magnetic recording
- not often used for signal transmission

1.4 MULTILEVEL BINARY BIPOLAR- AMI

Multilevel Binary Bipolar-AMI

- Use more than two levels
- Bipolar-AMI
  - zero represented by no line signal
  - one represented by positive or negative pulse
  - one pulses alternate in polarity
  - no loss of sync if a long string of ones
  - long runs of zeros still a problem
  - no net dc component
  - lower bandwidth
  - easy error detection

MULTILEVEL BINARY PSEUDOTERNARY

Multilevel Binary Pseudoternary

- one represented by absence of line signal
- zero represented by alternating positive and negative
- no advantage or disadvantage over bipolar-AMI
- each used in some applications

MULTILEVEL BINARY ISSUES

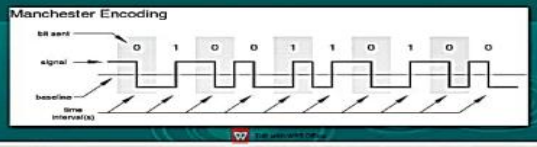
Multilevel Binary Issues

- synchronization with long runs of 0's or 1's
  - can insert additional bits, cf ISDN
  - scramble data (later)
- not as efficient as NRZ
  - each signal element only represents one bit
    - receiver distinguishes between three levels: +A, -A, 0
  - a 3 level system could represent $\log_2 3 = 1.58$ bits
  - requires approx. 3dB more signal power for same probability of bit error

MANCHESTER ENCODING

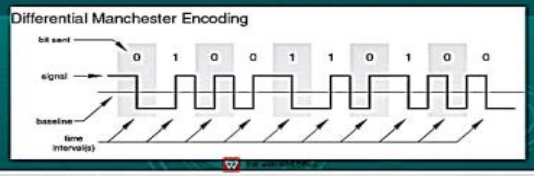
Manchester Encoding

- has transition in middle of each bit period
- transition serves as clock and data
- low to high represents one
- high to low represents zero
- used by IEEE 802.



Differential Manchester Encoding

- midbit transition is clocking only
- transition at start of bit period representing 0
- no transition at start of bit period representing 1
  - this is a differential encoding scheme
- used by IEEE 802.5



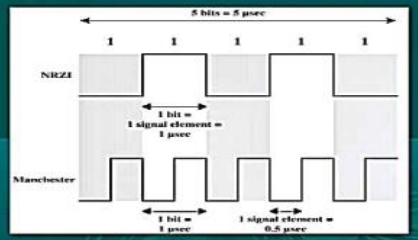
BIPHASE PROS & CONS

Biphase Pros and Cons

- Con
  - at least one transition per bit time and possibly two
  - maximum modulation rate is twice NRZ
  - requires more bandwidth
- Pros
  - synchronization on mid bit transition (self clocking)
  - has no dc component
  - has error detection

1.5 MODULATION RATE

Modulation Rate



SCRAMBLING

Scrambling

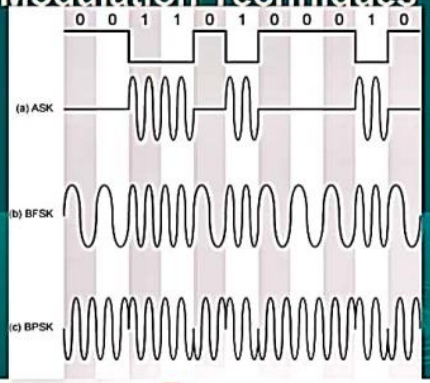
- use scrambling to replace sequences that would produce constant voltage
- these filling sequences must
  - produce enough transitions to sync
  - be recognized by receiver & replaced with original
  - be same length as original
- design goals
  - have no dc component
  - have no long sequences of zero level line signal
  - have no reduction in data rate
  - give error detection capability

2. DIGITAL DATA, ANALOG SIGNAL

Digital Data, Analog Signal

- main use is public telephone system
  - has freq range of 300Hz to 3400Hz
  - use modem (modulator-demodulator)
- encoding techniques
  - Amplitude shift keying (ASK)
  - Frequency shift keying (FSK)
  - Phase shift keying (PK)

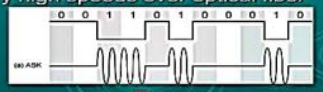
Modulation Techniques



2.1 ASK

Amplitude Shift Keying

- encode 0/1 by different carrier amplitudes
  - usually have one amplitude zero
- susceptible to sudden gain changes
- inefficient
- used for
  - up to 1200bps on voice grade lines
  - very high speeds over optical fiber



2.2 BFSK

Binary Frequency Shift Keying

- most common is binary FSK (BFSK)
- two binary values represented by two different frequencies (near carrier)
- less susceptible to error than ASK
- used for
  - up to 1200bps on voice grade lines
  - high frequency radio
  - even higher frequency on LANs using co-ax

Multiple FSK

- each signalling element represents more than one bit
- more than two frequencies used
- more bandwidth efficient
- more prone to error

2.3 BPSK

Phase Shift Keying

- phase of carrier signal is shifted to represent data
- binary PSK
  - two phases represent two binary digits
- differential PSK
  - phase shifted relative to previous transmission rather than some reference signal

Performance of Digital to Analog Modulation Schemes

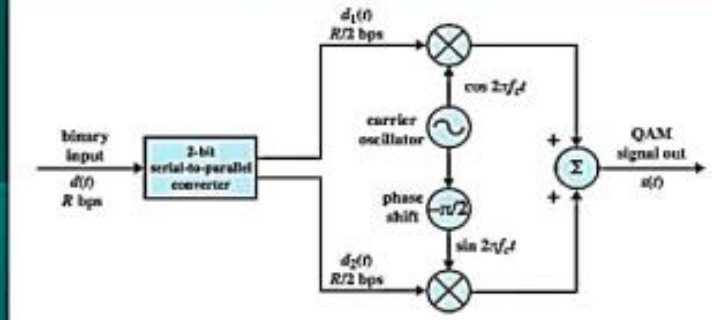
- bandwidth
  - ASK/PSK bandwidth directly relates to bit rate
  - multilevel PSK gives significant improvements
- in presence of noise:
  - bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK
  - for MFSK & MPSK have tradeoff between bandwidth efficiency and error performance

2.4 QAM

Quadrature Amplitude Modulation

- QAM used on asymmetric digital subscriber line (ADSL) and some wireless
- combination of ASK and PSK
- logical extension of QPSK
- send two different signals simultaneously on same carrier frequency
  - use two copies of carrier, one shifted 90
  - each carrier is ASK modulated
  - two independent signals over same medium
  - demodulate and combine for original binary output

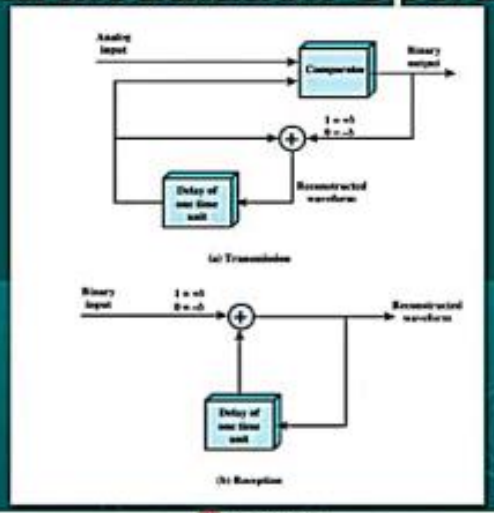
QAM Modulator



QAM Variants

- two level ASK
  - each of two streams in one of two states
  - four state system
  - essentially QPSK
- four level ASK
  - combined stream in one of 16 states
- have 64 and 256 state systems
- improved data rate for given bandwidth
  - but increased potential error rate

Delta Modulation Operation



3.3 PCM VS DELTA MODULATION

PCM verses Delta Modulation

- DM has simplicity compared to PCM
- but has worse SNR
- issue of bandwidth used
  - eg. for good voice reproduction with PCM
    - want 128 levels (7 bit) & voice bandwidth 4khz
    - need 8000 x 7 = 56kbps
- data compression can improve on this
- still growing demand for digital signals
  - use of repeaters, TDM, efficient switching
- PCM preferred to DM for analog signals

4. ANALOG DATA

ANALOG SIGNAL

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Analog Data, Analog Signals

- modulate carrier frequency with analog data
- why modulate analog signals?
  - higher frequency can give more efficient transmission
  - permits frequency division multiplexing (chapter 8)
- types of modulation
  - Amplitude
  - Frequency
  - Phase

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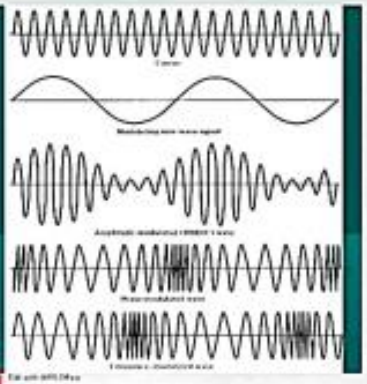
4.1 ANALOG MODULATION TECHNIQUES

Analog Modulation Techniques

- Amplitude Modulation
- Frequency Modulation
- Phase Modulation



DIGITAL DATA

TRANSMISSION TECHNIQUES

ASYNCHRONOUS & SYNCHRONOUS TRANSMISSION

Asynchronous and Synchronous Transmission

Timing problems require a mechanism to synchronize the transmitter and receiver
- receiver samples stream at bit intervals
- if clocks are not precisely aligned, drifting will sample at wrong time after sufficient bits are sent

Two solutions to synchronizing clocks:

asynchronous transmission	synchronous transmission
• avoid timing problems by not sending long, uninterrupted streams of bits	• a block of bits is transmitted in a steady stream without start and stop codes

1. ASYNCHRONOUS TRANSMISSION:

Asynchronous Transmission

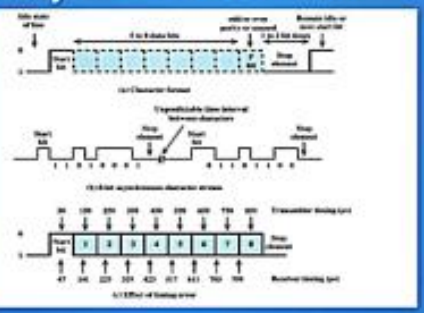
Data are transmitted one character at a time
- each character is 5 to 8 bits in length
- receiver has the opportunity to resynchronize at the beginning of each new character

Simple and cheap
- requires overhead of 2 or 3 bits per character (~20%)

The larger the block of bits, the greater the cumulative timing error

Good for data with large gaps (keyboard)

Asynchronous Transmission



2. SYNCHRONOUS TRANSMISSION

Synchronous Transmission

Block of bits transmitted in a steady stream without start and stop codes

Clocks must be synchronized to prevent drift
- can use separate clock line
- embed clock signal in data

Need to indicate start and end of block
- use preamble and postamble bit patterns

Frame is data plus preamble, postamble, and control information

More efficient than asynchronous for large blocks of data

3. ERROR:

Types of Error

An error occurs when a bit is altered between transmission and reception
- binary 1 is transmitted and binary 0 is received or binary 0 is transmitted and binary 1 is received

single bit errors
- isolated error that alters one bit but not nearby bits
- caused by white noise

burst errors
- contiguous sequence of B bits where first and last bits and any number of intermediate bits are received in error
- caused by impulse noise or by fading in wireless
- effects greater at higher data rates

ERROR DETECTION:

Error Detection

Regardless of design you will have errors
Can detect errors by using an error-detecting code added by the transmitter
- code is also referred to as check bits

Recalculated and checked by receiver
Still chance of undetected error
Parity
- parity bit set so character has even (even parity) or odd (odd parity) number of ones
- even number of bit errors goes undetected

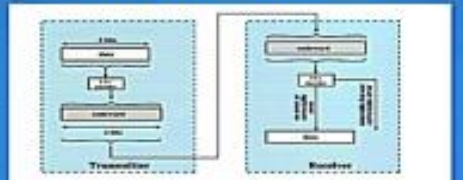
PARITY CHECK

Parity Check

The simplest error detecting scheme is to append a parity bit to the end of a block of data
If any even number of bits are inverted due to error, an undetected error occurs

PROCESS OF ERROR DETECTION:

Error Detection Process



4. CRC

Cyclic Redundancy Check (CRC)

One of most common and powerful checks
For block of *k* bits transmitter generates an *n* bit frame check sequence (fcs)
Transmits *k+n* bits which is exactly divisible by some predetermined number
Receiver divides frame by that number
- If no remainder, assume no error

ERROR CORRECTION

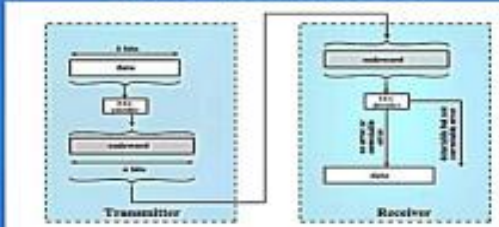
Error Correction

Correction of detected errors usually requires data block to be retransmitted
Not appropriate for wireless applications
- bit error rate is high causing loss of retransmissions
- propagation delay long (satellite) compared with frame transmission time, resulting in retransmission of frame in error plus many subsequent frames

Need to correct errors on basis of bits received codeword
- on the transmission end each k-bit block of data is mapped into an n-bit block (n > k) using a forward error correction (FEC) encoder

ERROR CORRECTION PROCESS

Error Correction Process



How Error Correction Works

Adds redundancy to transmitted message
- redundancy makes it possible to deduce original message despite some errors

Block error correction code

5. LINE CONFIGURATION

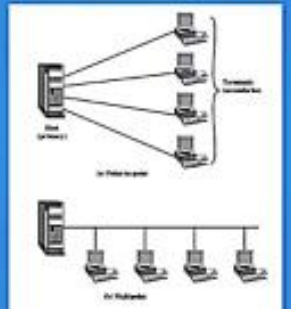
Line Configuration - Topology

topology
- refers to the physical arrangement of stations

point to point - two stations
- such as between two routers / computers

multi point - multiple stations
- traditionally mainframe computer and terminals
- now typically a local area network (LAN)

Line Configuration - Topology



DUPLEX

Line Configuration - Duplex

Data exchanges classified as half or full duplex

- Half duplex (two-way alternate)
  - only one station may transmit at a time
  - requires one data path
- Full duplex (two-way simultaneous)
  - simultaneous transmission and reception between two stations
  - requires two data paths
  - separate media or frequencies used for each direction

Summary

Asynchronous and synchronous transmission
- asynchronous
  data transmitted one character at a time
- synchronous
  block of bits transmitted in steady stream without start and stop codes

Error detection and correction
- single bit error and error burst
- error detecting codes
  parity and cyclic redundancy check (CRC)

Line configurations
- topology
- full duplex and half duplex

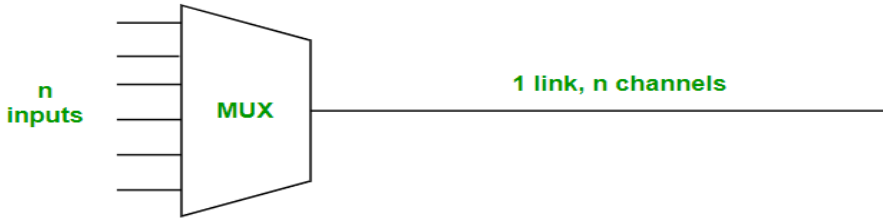
DATA COMMUNICATION & TECHNOLOGIES

UNIT-4

Multiplexing- Frequency-Division Multiplexing-Synchronous Time-Division Multiplexing- Statistical Time Division Multiplexing-Asymmetric Digital Subscriber Line- Spread Spectrum- The Concept of Spread Spectrum- Frequency Hopping Spread Spectrum-Direct Spectrum Spread Spectrum- Code-Division Multiple Access.

What is Multiplexing?

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.



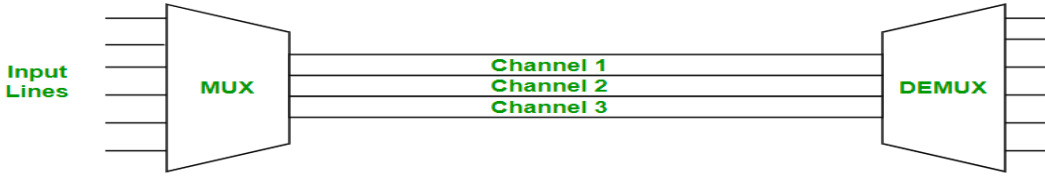
Types of Multiplexing

There are Five types of Multiplexing :

1. Frequency Division Multiplexing (FDM)
2. Time-Division Multiplexing (TDM)
3. Wavelength Division Multiplexing (WDM)
4. Code-division multiplexing (CDM)
5. Space-division multiplexing (SDM)

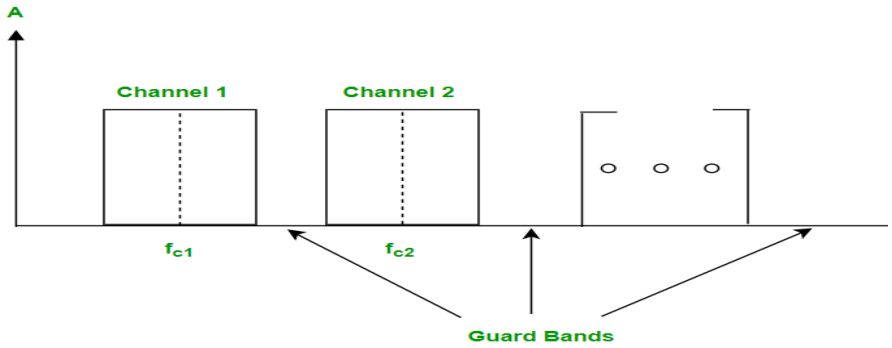
1. Frequency Division Multiplexing :

Frequency division multiplexing is defined as a type of multiplexing where the bandwidth of a single physical medium is divided into a number of smaller, independent frequency channels.



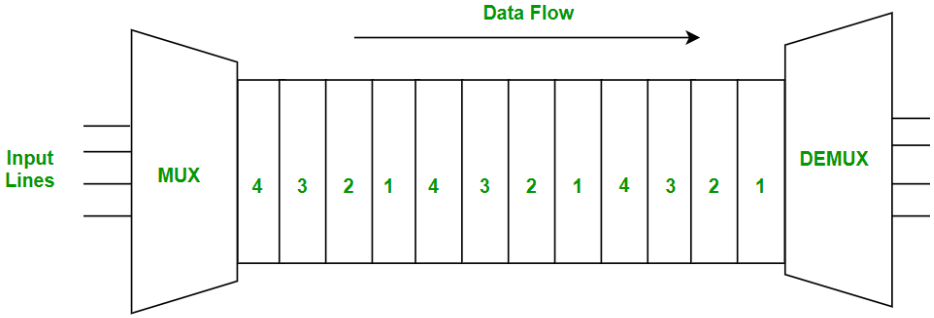
Frequency Division Multiplexing is used in radio and television transmission.

In FDM, we can observe a lot of inter-channel cross-talk, due to the fact that in this type of multiplexing the bandwidth is divided into frequency channels. In order to prevent the inter-channel cross talk, unused strips of bandwidth must be placed between each channel. These unused strips between each channel are known as guard bands.



2. Time Division Multiplexing :
Time-division multiplexing is defined as a type of multiplexing wherein FDM, instead of sharing a portion of the bandwidth in the form of channels, in TDM, time is shared. Each connection occupies a portion of time in the link.

In Time Division Multiplexing, all signals operate with the same frequency (bandwidth) at different times.



There are two types of Time Division Multiplexing :

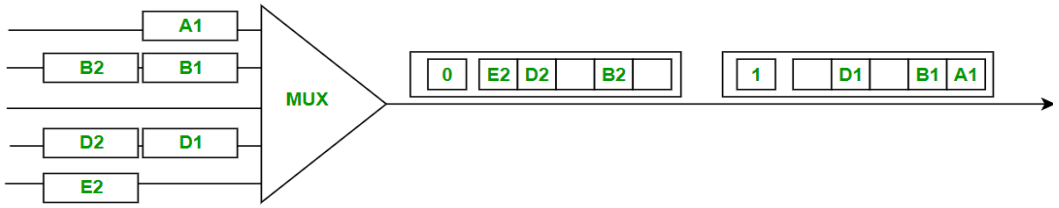
1. Synchronous Time Division Multiplexing
2. Statistical (or Asynchronous) Time Division Multiplexing

Synchronous TDM :

Synchronous TDM is a type of Time Division Multiplexing where the input frame already has a slot in the output frame. Time slots are grouped into frames. One frame consists of one cycle of time slots.

Synchronous TDM is not efficient because if the input frame has no data to send, a slot remains empty in the output frame.

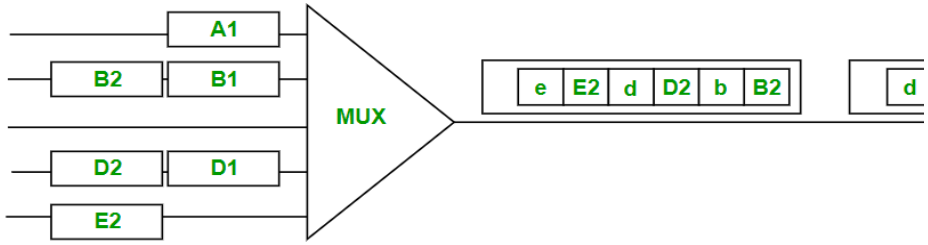
In synchronous TDM, we need to mention the synchronous bit at the beginning of each frame.



Statistical TDM :

Statistical TDM is a type of Time Division Multiplexing where the output frame collects data from the input frame till it is full, not leaving an empty slot like in Synchronous TDM.

In statistical TDM, we need to include the address of each particular data in the slot that is being sent to the output frame.



Statistical TDM is a more efficient type of time-division multiplexing as the channel capacity is fully utilized and improves the bandwidth efficiency.

3. Wavelength Division Multiplexing :

Wavelength Division Multiplexing (WDM) is a multiplexing technology used to increase the capacity of optical fiber by transmitting multiple optical signals simultaneously over a single optical fiber, each with a different wavelength. Each signal is carried on a different wavelength of light, and the resulting signals are combined onto a single optical fiber for transmission. At the receiving end, the signals are separated by their wavelengths, demultiplexed and routed to their respective destinations.

WDM can be divided into two categories: Dense Wavelength Division Multiplexing (DWDM) and Coarse Wavelength Division Multiplexing (CWDM).

DWDM is used to multiplex a large number of optical signals onto a single fiber, typically up to 80 channels with a spacing of 0.8 nm or less between the channels.

CWDM is used for lower-capacity applications, typically up to 18 channels with a spacing of 20 nm between the channels. WDM has several advantages over other multiplexing technologies such as Time Division Multiplexing (TDM). WDM allows for higher data rates and capacity, lower power consumption, and reduced equipment complexity. WDM is also flexible, allowing for easy upgrades and expansions to existing networks.

WDM is used in a wide range of applications, including telecommunications, cable TV, internet service providers, and data centers. It enables the transmission of large amounts of data over long distances with high speed and efficiency.

Wavelength Division Multiplexing is used on fiber optics to increase the capacity of a single fiber. It is an analog multiplexing technique. Optical signals from the different sources are combined to form a wider band of light with the help of multiplexers. At the receiving end, the De-multiplexer separates the signals to transmit them to their respective destinations.

4. Space-division multiplexing (SDM) :

Space Division Multiplexing (SDM) is a technique used in wireless communication systems to increase the capacity of the system by exploiting the physical separation of users.

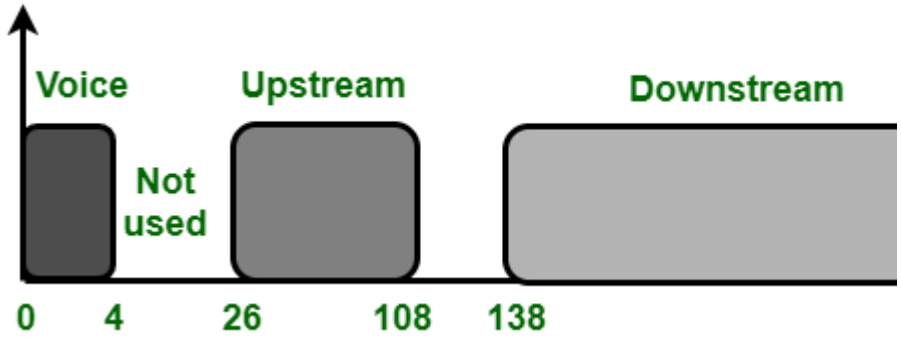
In SDM, multiple antennas are used at both the transmitter and receiver ends to create parallel communication channels. These channels are independent of each other, which allows for multiple users to transmit data simultaneously in the same frequency band without interference. The capacity of the system can be increased by adding more antennas, which creates more independent channels.

SDM is commonly used in wireless communication systems such as cellular networks, Wi-Fi, and satellite communication systems. In cellular networks, SDM is used in the form of Multiple Input

Multiple Output (MIMO) technology, which uses multiple antennas at both the transmitter and receiver ends to improve the quality and capacity of the communication link.

5. Code-division multiplexing (CDM) :
Code division multiplexing (CDM) is a technique used in telecommunications to allow multiple users to transmit data simultaneously over a single communication channel. In CDM, each user is assigned a unique code that is used to modulate their signal. The modulated signals are then combined and transmitted over the same channel. At the receiving end, each user's signal is demodulated using their unique code to retrieve their original data.

ADSL (ASYMMETRIC DIGITAL SUBSCRIBER LINE):
ADSL (Asymmetric Digital Subscriber Line) is the first technology of DSL technologies. It is just like 56K modem that is able to provide a higher speed of data in the downstream direction than in the upstream direction. That is the reason why its name is Asymmetric DSL. It divides bandwidth unevenly to meet the need of residential customers. As we know that business purposes require higher bandwidth so it is not suitable for them.



Bandwidth division in ADSL

Using Existing Local Loops :
It uses existing local loops. It is capable to reach data rate that is not possible by traditional modem it is just because of the use of twisted pair local loop i.e. capable of handling bandwidths up to 1.1 MHz, but there are the installations of filters at the end offices of the telephone company where the bandwidth limits of each loop are up to 4KHz. Without the filter, the 1.1 MHz is available for both data and voice communication.

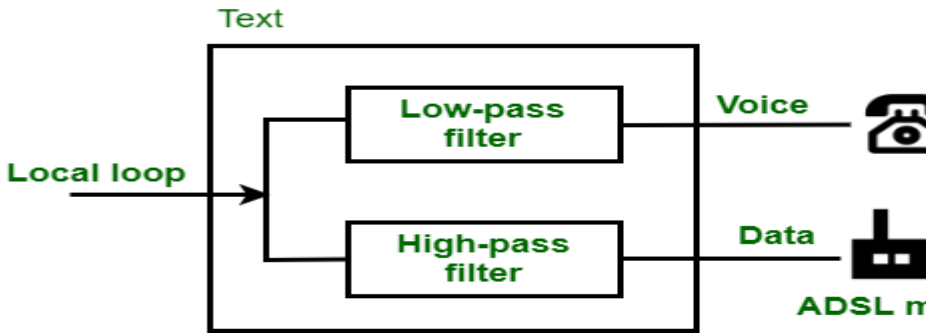
Adaptive Technology :
Unfortunately, 1.1 MHz is just a theoretical bandwidth. The factors like distance between residence and switching offices will affect the bandwidth due to reasons like the size of the cable, signal used and so on. Before setting up the data rate, the developers of this technology uses adaptive technology for this purpose. Thus, we can say that the data rate of ADSL technology is not fixed, it changes according to the conditions and the type of local loop used.

Discrete Multitone Technique :
The standard modulation technique for ADSL is Discrete Multitone Technique which combines both QAM and FDM. There is the availability of 1.104 MHz bandwidth. It is divided into 256 channels. The following is the distribution of bandwidth –

- **IDLE –**
  1 to 5 channels are not used and these will provide a gap between voice and data communication.
- **Upstream Data and Control –**
  Channel 6 to 30 are used for upstream data transfer and control. One channel is used for control and other 24 are used for data transfer.
- **Downstream Data and Control –**
  Channels 31 to 255 are used for downstream data transfer and

control. Like upstream in this also one channel is used for control and other 224 are used for data transfer.

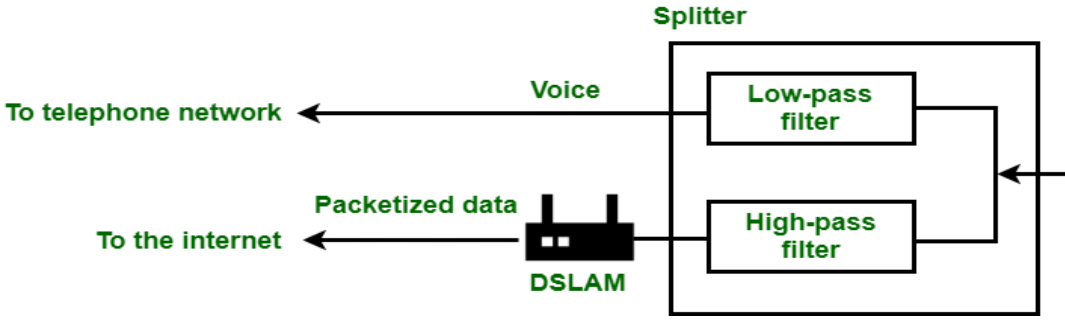
Customer Site : ADSL Modem
The ADSL Modem is installed at a customer's site. In this local loop connects to a splitter which is used to separate voice and data communication. Modulation and Demodulation are done using DMT and it creates separate downstream and upstream channels.



ADSL Modem

The splitter must be installed at the customer premises, from the telephone company. The voice line can be installed by the existing wiring in the house but the data line need to be installed by the professional. Due to this, the ADSL line becomes expensive.

Telephone Company Site : DSLAM
The view is different from the telephone company site. Instead of using ADSL modem, they are using DSLAM i.e. Digital Subscriber Line Multiplex. In addition to ADSL features, it has an additional feature to packetizes the data to is be sent to the internet. The following is the configuration of the DSLAM



DSLAM

Features Of ADSL :
- High speed internet access.
- Both internet and calling facilities.
- Fair prices.
- Real time access to information.

Asymmetric Digital Subscriber Line (ADSL) is a technology that allows high-speed digital data transmission over existing copper telephone lines. It is called "asymmetric" because it provides higher download speeds than upload speeds, which is suitable for applications such as web browsing, email, and streaming video.

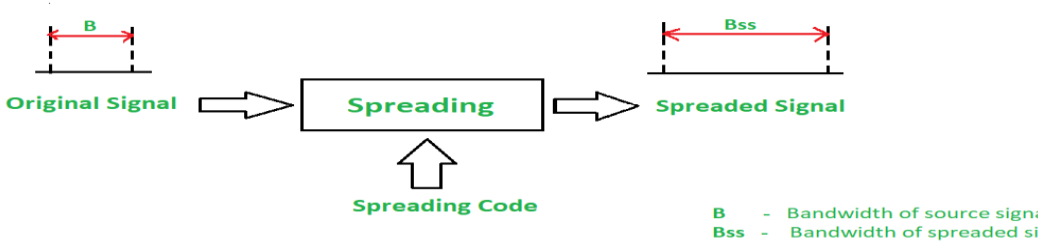
1. ADSL technology works by dividing the available bandwidth of a telephone line into separate channels, with each channel carrying a different type of traffic. The majority of the bandwidth is allocated to downstream traffic, which is data traveling from the internet to the user's device, while a smaller portion is allocated to upstream traffic, which is data traveling from the user's device to the internet.

2. ADSL uses a modulation technique called Discrete Multitone (DMT) to divide the available bandwidth into channels. DMT uses a complex algorithm to divide the bandwidth into hundreds of separate channels, each carrying a different frequency range. This allows ADSL to transmit data at high speeds while minimizing interference from other devices on the same telephone line.
3. One of the key advantages of ADSL is that it can provide high-speed internet access over existing telephone lines, which means that it is widely available in many areas where other types of broadband internet services may not be available. It also allows users to use their phone line for voice calls while simultaneously using the internet, without interfering with each other.
4. However, ADSL has some limitations. The maximum distance between the user and the telephone exchange can affect the speed and quality of the connection. In addition, the available bandwidth is shared among all users connected to the same telephone exchange, which can result in slower speeds during peak usage periods.

What is Spread Spectrum?

The increasing demand for wireless communications has problems due to limited spectrum efficiency and multipath propagation. The use of spread spectrum communication has simplified these problems. In the spread spectrum, signals from different sources are combined to fit into larger bandwidth.
Most stations use air as the medium for communication, stations must be able to share the medium without an interception and without being subject to jamming from a malicious intruder.
To achieve this, spread-spectrum techniques add redundancy means it uses extended bandwidth to accommodate signals in a protective envelope so that more secure transmission is possible.

The spread code is a series of numbers that looks random but are actually a pattern. The original bandwidth of the signal gets enlarged (spread) through the spread code as shown in the figure.



Spread Spectrum

Principles of Spread Spectrum process:

1. To allow redundancy, it is necessary that the bandwidth allocated to each station should be much larger than needed.
2. The spreading process occurs after the signal is created by the source.

Conditions of Spread Spectrum are:

1. The spread spectrum is a type of modulation where modulated signal BW is much larger than the baseband signal BW i.e. spread spectrum is a wide band scheme.
2. A special code (pseudo noise) is used for spectrum spreading and the same code is to be used to despread the signal at the receiver.

Characteristics of the Spread Spectrum are:

1. Higher channel capacity.

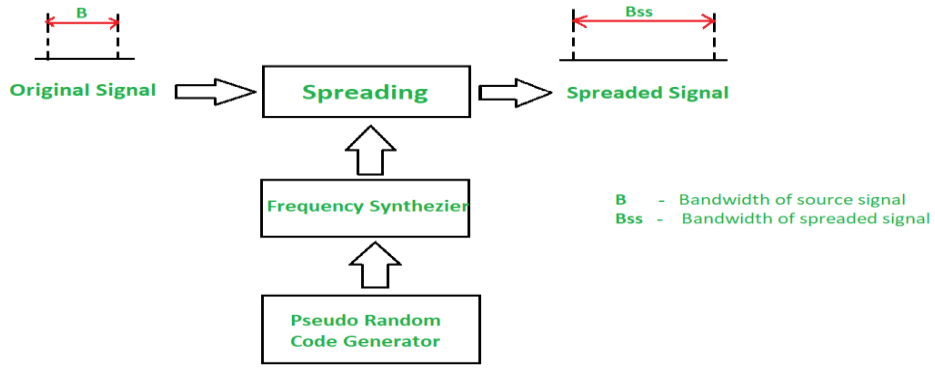
2. Ability to resist multipath propagation.
3. They cannot easily intercept any unauthorized person.
4. They are resistant to jamming.
5. The spread spectrum provides immunity to distortion due to multipath propagation.
6. The spread spectrum offers multiple access capabilities.

Two types of techniques for Spread Spectrum are:

1. Frequency Hopping Spread Spectrum (FHSS)
2. Direct Sequence Spread Spectrum (DSSS)

Frequency Hopping Spread Spectrum (FHSS):

In Frequency Hopping Spread Spectrum (FHSS), different carrier frequencies are modulated by the source signal i.e. M carrier frequencies are modulated by the signal. At one moment signal modulates one carrier frequency and at the subsequent moments, it modulates other carrier frequencies. The general block diagram of FHSS is shown in the below figure.



Frequency Hopping Spread Spectrum

A pseudorandom code generator generates Pseudo-random Noise of some pattern for each hopping period Th. The frequency corresponding to the pattern is used for the hopping period and is passed to the frequency synthesizer. The synthesizer generates a carrier signal of that frequency. The figure above shows the spread signal via FHSS.

Advantages of FHSS:

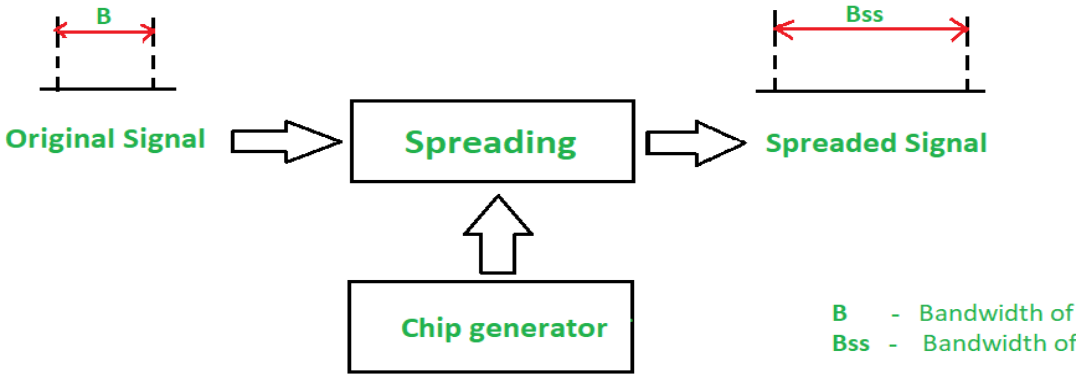
- Synchronization is not greatly dependent on distance.
- Processing Gain is higher than DSSS.

Disadvantages of FHSS:

- The bandwidth of the FHSS system is too large (in GHz).
- Complex and expensive Digital frequency synthesizers are required.

Direct Sequence Spread Spectrum (DSSS):

In DSSS, the bandwidth of the original signal is also expanded by a different technique. Here, each data bit is replaced with n bits using a spreading code called chips, and the bit rate of the chip is called as chip-rate. The chip rate is n times the bit rate of the original signal. The below Figure shows the DSSS block diagram.



Direct Sequence Spread Spectrum

In wireless LAN, the sequence with n = 11 is used. The original data is multiplied by chips (spreading code) to get the spread signal. The required bandwidth of the spread signal is 11 times larger than the bandwidth of the original signal.

Advantages of DSSS:

- The DSSS System combats the jamming most effectively.
- The performance of DSSS in presence of noise is superior to FHSS.
- Interference is minimized against the signals.

Disadvantages of DSSS:

- Processing Gain is lower than DSSS.
- Channel Bandwidth is less than FHSS.
- Synchronization is affected by the variable distance between the transmitter and receiver.

DMA: Code Division Multiple Access

CDMA stands for Code Division Multiple Access. It is *a channel access method used by several radio communication technologies*. It is a digital cellular technology and an example of multiple access. It is generally used for mobile communication.

Multiple access means that several transmitters can send information simultaneously over a single communication channel. In this system, different CDMA codes are assigned to different users, and the user can access the whole bandwidth for the entire duration. It optimizes the use of available bandwidth as it transmits over the entire frequency range and does not limit the user's frequency range.

Thus, CDMA allows several users to share a band of frequencies without undue interference between the users. It is used as an access method in many mobile phone standards.

CDMA technology was developed during World War II. It was developed by English allies to protect their wireless transmissions from jamming. When the war ended, Qualcomm patented this technology and made it commercially available. The first CDMA system was launched in September 1995 in Hong Kong by Hutchison Telephone Co.

Usage

- It is used in the Global Positioning System (GPS).
- It is used by several mobile phone companies (e.g., Qualcomm standard IS-2000, also known as CDMA2000)
- W-CDMA is used in UTMS 3G mobile phone standards.
- CDMA has been used in OmniTRACS satellite system for transportation.

Categories of CDMA

- Synchronous CDMA (orthogonal codes)
- Asynchronous CDMA (pseudorandom codes)

Difference between CDMA and GSM

The major difference between CDMA and GSM are given below.

Criteria	CDMA	GSM
Technology	CDMA is based on spread-spectrum technology, which makes the optimum use of available bandwidth.	GSM operates on the wedge spectrum. It uses both time division multiple access (TDMA) and frequency division multiple access (FDMA). TDMA provides multi-user access by cutting up the channel into different time slices, and FDMA provides multi-user access by separating the used frequency.
Security	CDMA is more secure than GSM.	GSM is less secure than CDMA.
Global reach	CDMA is used in the USA and some parts of Canada and Japan. CDMA is used only by 24% of users worldwide.	GSM is used in over 80% of the world network in over 210 countries. GSM is used by 76% of users worldwide.
Data Transfer Rate	CDMA has faster data transfer as compared to GSM.	GSM has slower data transfer as compared to CDMA.
Radiation exposure	CDMA phones emit less radiation than GSM phones.	GSM phones emit continuous wave pulses and emit almost 28 times more radiation than CDMA phones.

DATA COMMUNICATION & TECHNOLOGIES

How is CDMA operative?

- The cellular architecture of wireless CDMA networks is formed by cell clusters. In a cell cluster, each cell has a transceiver with the necessary transmitting power, and mobile units are scattered around the cell's coverage area. Every mobile unit has a transceiver, which is made up of a sensitive receiver and a low-power transmitter that operates in a wireless cellular environment. Access interference, fading, and multipath propagation are some features of the cellular environment.
- The quality of service (QoS) for CDMA systems is significantly influenced by the near-far (N-F) impact. A broadcast from a user who is near the base station can interfere with and overpower a weaker transmission signal from a user who is further away.
- In order to do this, CDMA network providers employ receivers that are immune to the N-F effect as well as stringent power management techniques.
- The CDMA channel has a nominal width of 1.23 MHz. Soft handoff is a technique used by CDMA networks to reduce signal loss as a handset moves from one cell to another. Spread spectrum and digital together allow for substantially more signals per unit of bandwidth than analogue modes do. Due to CDMA's compatibility with other cellular technologies, nationwide roaming is possible. In its single-channel and eight-channel configurations, the original CDMA technology, also known as CDMA One, only enables transmission speeds of up to 14.4 and 115 kilobits per second, respectively. W-CDMA and CDMA2000 send data at rates that are many times quicker.
- The CDMA2000 family of standards includes Single-carrier Radio Transmission Technology (1xRTT), Evolution-Data Optimized Release 0, EVDO Revision A, and EVDO Revision B. The physical layer multiplexing protocol CDMA is frequently confused with the CDMA2000 family of protocols, which Verizon and Sprint both support.

New 5g technology

Older protocols will be replaced by 5G cellular technology, and CDMA will lose even more significance as 5G wireless systems evolve. Data transfer speeds on cellular networks are expected to significantly increase with 5G, making them competitive.with fiber-optic networks. Beyond what is achievable with 4G, the technology provides better broadband capacity, reliability, and bandwidth. 5G is mainly powered by millimeter wave (MM wave) bands at 26, 28, 38, and 60 GHz. These frequency ranges allow for data transport rates up to 20 gigabits per second (Gbps). Massive multiple input, multiple outputs (MIMO) 64-256 antennas enable 5G to provide speeds that are at least ten times faster than those offered by 4G networks.

Low-band and mid-band 5G cellular technologies operate between 600 MHz and 6 GHz, with the majority operating between 3.5 and 4.2 GHz. The 3,100 to 3,550 MHz and 3,700 to 4,200 MHz 5G wireless frequency bands are already in use in the United States.

While Asia uses the 3,300-3,600 MHz, 4,400-4,500 MHz, and 4,800-4,990 MHz bands, Europe employs the 3,400-3,800 MHz range.

UNIT-5

Circuit Switching and Packet Switching- Switched Communication Networks-Circuit Switching Networks-Circuit Switching Concepts-Packet-Switching Principles.

Circuit Switching and Packet Switching:

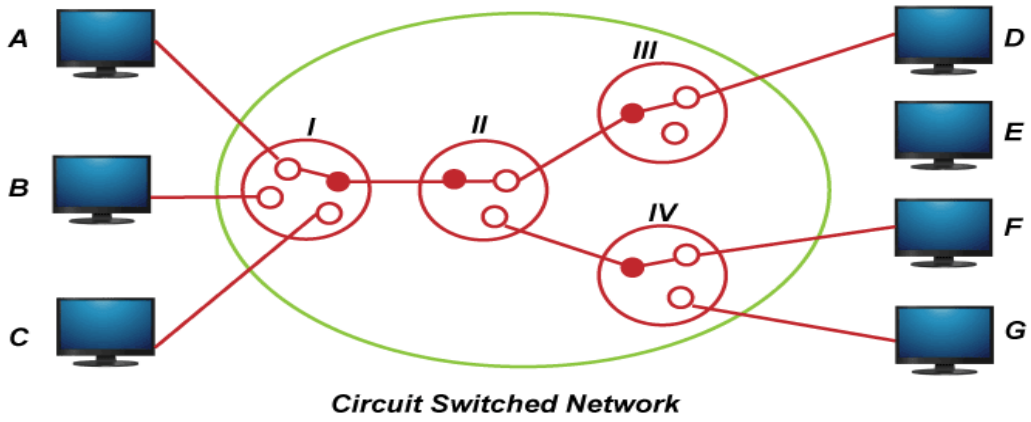
- *Circuit switching* was designed in 1878 to send telephone calls down a dedicated channel. It is a method that is used when a dedicated channel or circuit needs to be established.
- A channel used in circuit switching is kept reserved and applied only when the two users need to communicate.

- Circuit switching connections are classified into two categories half-duplex or full-duplex. Half-duplex communications can be allocated just one channel, while full-duplex interfaces can be assigned two channels.
- *Packet switching* is a method of grouping data that is transmitted over a digital network into packets. It is a connectionless network switching method. It never establishes any physical connection before the transmission starts. In the packet switching method, before the message is transmitted, it is divided into some manageable parts known as packets.
- In this method, each packet divided into two parts: a header and a payload. The header contains the addressing information of the packet. The payload contains the actual message.

Circuit switching Network:

A circuit-switched network is one of the simplest data communication methods in which a dedicated path is established between the sending and receiving device. In this physical links connect via a set of switches.

Following figure displays the working of circuit switched network.



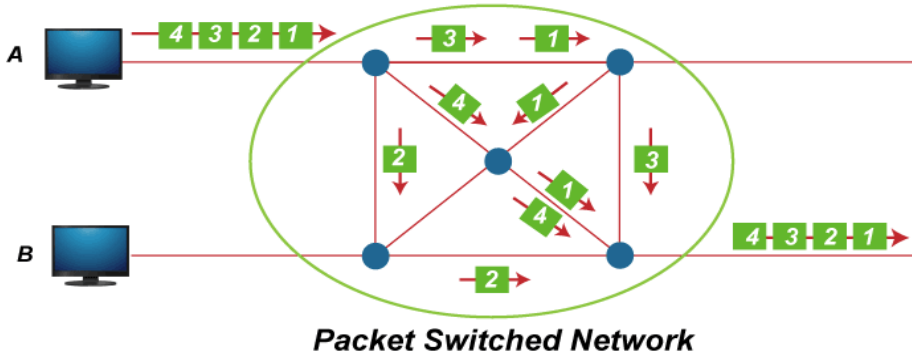
Circuit Switched Network

In the above figure it shows a circuit switched network in which computer connect via 4 switches with a point to point connections.

Packet switching Network:

In the Packet switching Network, the message is divide into packets. Each packet contains a header which includes the source address, destination address, and control information.

Following figure displays the working of packet switched network.



Packet Switched Network

In the above figure, it shows how a data gram approach is used to deliver four packets from station A to station D.

S.No	Parameter	Circuit switching Network	Packet switching Network
1	Path	In circuit switched network a dedicated path is created between two points by setting the switches.	In packet switched network no dedicated path is created between two points. Only the virtual circuit exists.
2	Store and forward transmission	In circuit switching there is no concept of store and forward transmission.	In virtual packet switched network, each node may store incoming packets and forward them after use.
3	Dedicated	The links that make a path in circuit switched network are	In the virtual circuit network, links that make a route can

		dedicated and cannot be used for other connections.	be dedicated with other connections.
4	Availability of Bandwidth	In circuit switching, bandwidth is fixed because it is reserved in advance.	In the virtual circuit network, require bandwidth is dynamic because it can be released as it is needed.
5	The route followed by packets	The route followed by packets is always the same.	The route followed by packets is may or may not be different.
6	Call setup	An in-circuit switching call setup is required.	In packet switching, call setup is not required.
7	Congestion	In circuit switching, congestion can	In packet switching, congestion can
		occur at set up time.	occur on every packet.
8	Wastage of Bandwidth	In circuit switching, bandwidth is fixed, unused bandwidth on an allocated circuit is wasted.	Other packets from an unrelated source may utilize unused bandwidth.
9	Charging	In circuit switching, users are charged based on time and the basis of distance.	In packet switching, users are charged based on time and number of bytes carried & not based on distance.
10	Application	Telephone network for bidirectional, real time transfer of voice signal.	Internet for datagram and reliable stream service between computers.

11	Layers	Circuit-switched network is implemented at the physical layer.	A virtual circuit network is implemented at the data link and a network layer.
12	Reliability	Circuit-switched is highly reliable.	In packet switching, low reliability, subject to congestion.
13	Overhead bits	In Circuit-switched network, no overhead bits after call setup.	In packet switching, Overhead bits in each packet.
14	Technologies or types	Circuit switching using two technologies ○ Time Division Switching ○ Space Division Switching	Packet Switching using two technologies ○ Datagram circuit approach ○ Virtual circuit Approach
15	Installation Cost	Circuit switching's initial cost is low.	Packet switching networks have high installation costs.
16	Protocols	Circuit switching requires simple protocols for delivery.	Packet switching requires complex protocols for delivery.
17	Addressing scheme	In Circuit switching, Hierarchical numbering plan scheme is used.	In Packet switching, Hierarchical address space is used.
18	End Terminal	In this telephone and modem is	In this computer is used as end terminal.

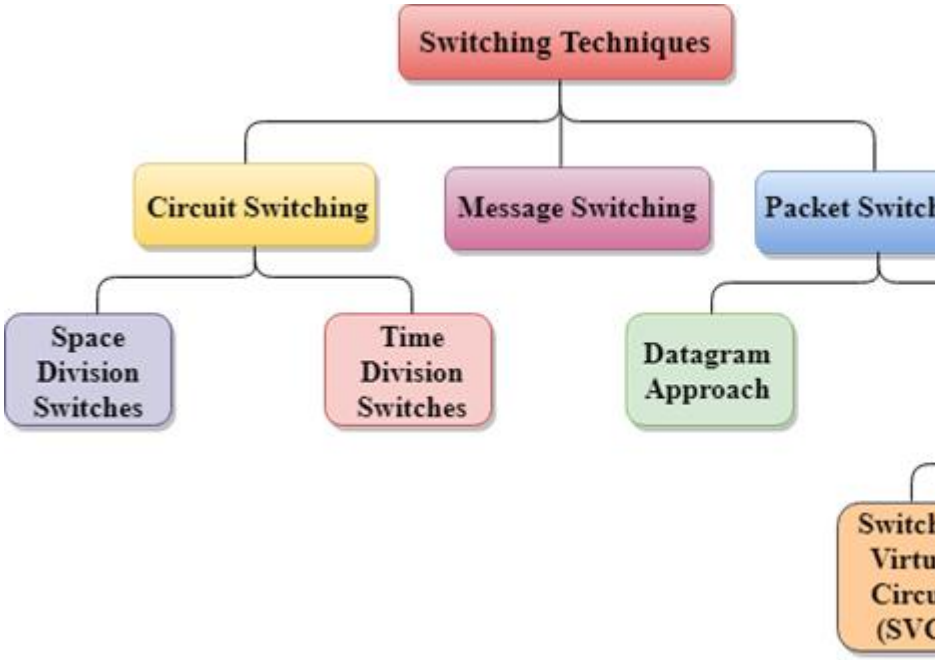
		used as end terminal.	
19	Information type	In this information type is Analog voice or PCM digital voices.	In this information type is binary information.
20	Multiplexing scheme	In circuit switching, circuit multiplexing is used.	In packet switching, packet multiplexing shared media access network in used.
21	Routing Scheme	In circuit switching, route selecting during set up.	In packet switching, each packet is routed independently.

SWITCHED COMMUNICATION NETWORKS:

In large networks, there can be multiple paths from sender to receiver. The switching technique will decide the best route for data transmission.

Switching technique is used to connect the systems for making one-to-one communication.

Classification Of Switching Techniques

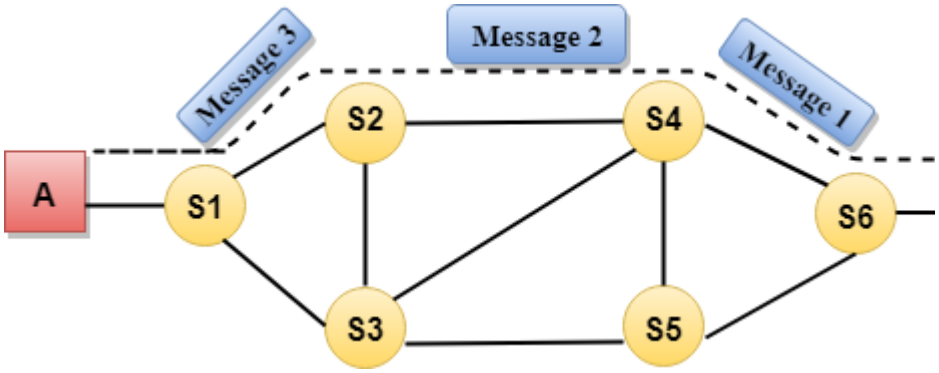


Circuit Switching

- Circuit switching is a switching technique that establishes a dedicated path between sender and receiver.
- In the Circuit Switching Technique, once the connection is established then the dedicated path will remain to exist until the connection is terminated.
- Circuit switching in a network operates in a similar way as the telephone works.
- A complete end-to-end path must exist before the communication takes place.
- In case of circuit switching technique, when any user wants to send the data, voice, video, a request signal is sent to the receiver then the receiver sends back the acknowledgment to ensure the availability of the dedicated path. After receiving the acknowledgment, dedicated path transfers the data.
- Circuit switching is used in public telephone network. It is used for voice transmission.
- Fixed data can be transferred at a time in circuit switching technology.

Communication through circuit switching has 3 phases:

- Circuit establishment
- Data transfer
- Circuit Disconnect



Circuit Switching can use either of the two technologies:

Space Division Switches:

- Space Division Switching is a circuit switching technology in which a single transmission path is accomplished in a switch by using a physically separate set of crosspoints.
- Space Division Switching can be achieved by using crossbar switch. A crossbar switch is a metallic crosspoint or semiconductor gate that can be enabled or disabled by a control unit.
- The Crossbar switch is made by using the semiconductor. For example, Xilinx crossbar switch using FPGAs.
- Space Division Switching has high speed, high capacity, and nonblocking switches.

Space Division Switches can be categorized in two ways:

- **Crossbar Switch**
- **Multistage Switch**

Crossbar Switch

The Crossbar switch is a switch that has n input lines and n output lines. The crossbar switch has n^2 intersection points known as **crosspoints.**

Disadvantage of Crossbar switch:

The number of crosspoints increases as the number of stations is increased. Therefore, it becomes very expensive for a large switch. The solution to this is to use a multistage switch.

Multistage Switch

- Multistage Switch is made by splitting the crossbar switch into the smaller units and then interconnecting them.
- It reduces the number of crosspoints.
- If one path fails, then there will be an availability of another path.

Advantages Of Circuit Switching:

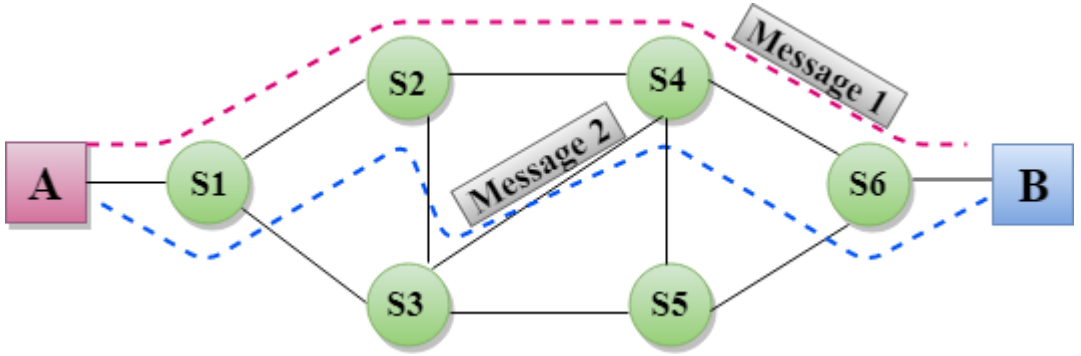
- In the case of Circuit Switching technique, the communication channel is dedicated.
- It has fixed bandwidth.

Disadvantages Of Circuit Switching:

- Once the dedicated path is established, the only delay occurs in the speed of data transmission.
- It takes a long time to establish a connection approx 10 seconds during which no data can be transmitted.
- It is more expensive than other switching techniques as a dedicated path is required for each connection.
- It is inefficient to use because once the path is established and no data is transferred, then the capacity of the path is wasted.
- In this case, the connection is dedicated therefore no other data can be transferred even if the channel is free.

Message Switching

- Message Switching is a switching technique in which a message is transferred as a complete unit and routed through intermediate nodes at which it is stored and forwarded.
- In Message Switching technique, there is no establishment of a dedicated path between the sender and receiver.
- The destination address is appended to the message. Message Switching provides a dynamic routing as the message is routed through the intermediate nodes based on the information available in the message.
- Message switches are programmed in such a way so that they can provide the most efficient routes.
- Each and every node stores the entire message and then forward it to the next node. This type of network is known as **store and forward network.**
- Message switching treats each message as an independent entity.



Advantages Of Message Switching

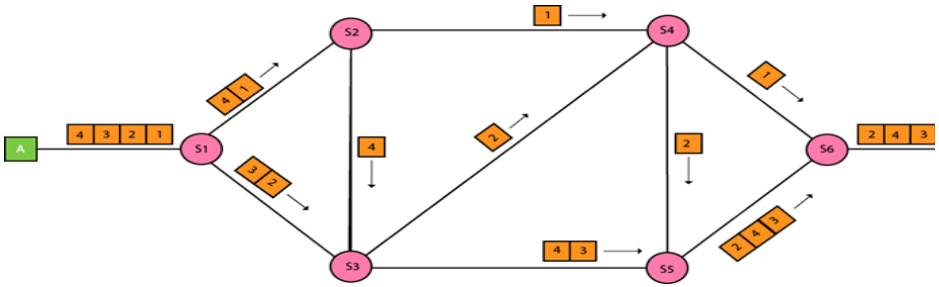
- Data channels are shared among the communicating devices that improve the efficiency of using available bandwidth.
- Traffic congestion can be reduced because the message is temporarily stored in the nodes.
- Message priority can be used to manage the network.
- The size of the message which is sent over the network can be varied. Therefore, it supports the data of unlimited size.

Disadvantages Of Message Switching

- The message switches must be equipped with sufficient storage to enable them to store the messages until the message is forwarded.
- The Long delay can occur due to the storing and forwarding facility provided by the message switching technique.

Packet Switching

- The packet switching is a switching technique in which the message is sent in one go, but it is divided into smaller pieces, and they are sent individually.
- The message splits into smaller pieces known as packets and packets are given a unique number to identify their order at the receiving end.
- Every packet contains some information in its headers such as source address, destination address and sequence number.
- Packets will travel across the network, taking the shortest path as possible.
- All the packets are reassembled at the receiving end in correct order.
- If any packet is missing or corrupted, then the message will be sent to resend the message.
- If the correct order of the packets is reached, then the acknowledgment message will be sent.



Approaches Of Packet Switching:

There are two approaches to Packet Switching:

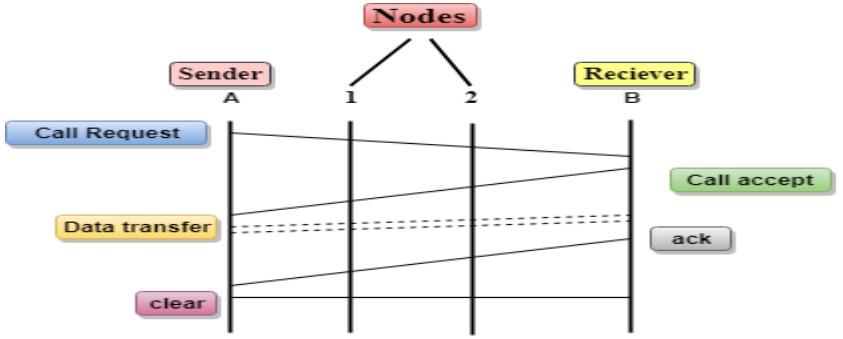
Datagram Packet switching:

- It is a packet switching technology in which packet is known as a datagram, is considered as an independent entity. Each packet contains the information about the destination and switch uses this information to forward the packet to the correct destination.
- The packets are reassembled at the receiving end in correct order.
- In Datagram Packet Switching technique, the path is not fixed.
- Intermediate nodes take the routing decisions to forward the packets.
- Datagram Packet Switching is also known as connectionless switching.

Virtual Circuit Switching

- Virtual Circuit Switching is also known as connection-oriented switching.
- In the case of Virtual circuit switching, a preplanned route is established before the messages are sent.
- Call request and call accept packets are used to establish the connection between sender and receiver.
- In this case, the path is fixed for the duration of a logical connection.

Let's understand the concept of virtual circuit switching through a diagram:



- In the above diagram, A and B are the sender and receiver respectively. 1 and 2 are the nodes.
- Call request and call accept packets are used to establish a connection between the sender and receiver.
- When a route is established, data will be transferred.
- After transmission of data, an acknowledgment signal is sent by the receiver that the message has been received.
- If the user wants to terminate the connection, a clear signal is sent for the termination.

Differences b/w Datagram approach and Virtual Circuit approach

Datagram approach	Virtual Circuit approach
Node takes routing decisions to forward the packets.	Node does not take any routing decision.
Congestion cannot occur as all the packets travel in different directions.	Congestion can occur when the node is busy, and it does not allow other packets to pass through.
It is more flexible as all the packets are treated as an independent entity.	It is not very flexible.

Advantages Of Packet Switching:

- **Cost-effective:** In packet switching technique, switching devices do not require massive secondary storage to store the packets, so cost is minimized to some extent. Therefore, we can say that the packet switching technique is a cost-effective technique.
- **Reliable:** If any node is busy, then the packets can be rerouted. This ensures that the Packet Switching technique provides reliable communication.
- **Efficient:** Packet Switching is an efficient technique. It does not require any established path prior to the transmission, and many users can use the same communication channel simultaneously, hence makes use of available bandwidth very efficiently.

Disadvantages Of Packet Switching:

- Packet Switching technique cannot be implemented in those applications that require low delay and high-quality services.

- The protocols used in a packet switching technique are very complex and requires high implementation cost.
- If the network is overloaded or corrupted, then it requires retransmission of lost packets. It can also lead to the loss of critical information if errors are nor recovered.

Principles of packet switching

Packet switching is a fundamental principle in data communication technology that enables the efficient and reliable transmission of data over networks. It involves breaking data into small, manageable units called packets and sending them independently across the network to their destination. Here are some key principles of packet switching:

1. Packetization: Packet switching divides data into smaller packets for transmission. Each packet consists of a header (containing control information) and a payload (actual data). Packetization allows efficient sharing of network resources and facilitates error detection and retransmission.
2. Store-and-Forward: In packet switching, each network node (routers or switches) receives a complete packet before it is forwarded to the next node. This store-and-forward mechanism ensures that packets are error-free and complete before they are

transmitted to the next hop.If errors are detected, the packet is discarded, and retransmission may be requested.

3. Addressing and Routing: Each packet contains addressing information in its header, specifying the source and destination addresses. Routers use this information to determine the next hop for forwarding the packet toward its destination. Routing algorithms, such as the popular IP (Internet Protocol) routing protocols, help determine the best path for packet delivery.

4. Statistical Multiplexing: Packet switching utilizes statistical multiplexing, which allows multiple packets from different sources to share the same network resources. Packets are transmitted over the network based on availability and bandwidth requirements, rather than allocating dedicated resources for each connection. This increases network efficiency and utilization.

5. Connectionless Communication: Packet switching is connectionless, meaning that each packet is treated independently and can take different paths to reach the destination. There is no need to establish a dedicated connection

before sending data. This provides flexibility and scalability for data transmission.

6. Error Detection and Correction: Packet switching incorporates error detection mechanisms to ensure data integrity. Commonly usedtechniquesinclude cyclic redundancy check (CRC) or checksum algorithms. Iferrorsare detected, the packet may be discarded, and a request for retransmission can be initiated.

7. Congestion Control: Packet switching networks employ various congestion control mechanisms to prevent network congestion and ensure fair sharing of resources. Congestion can occur when network nodes become overwhelmed with more packets than theycan handle. Techniques liketraffic shaping, queuing algorithms, and flow control help manage congestion and maintain network performance.