Dr. Vishwanath Karad MIT WORLD PEACE UNIVERSITY | PUNE

TECHNOLOGY, RESEARCH, SOCIAL INNOVATION & PARTNERSHIPS

Computer Networks (CET2005B)

School of Computer Engineering and Technology (SCET)

Computer Networks

Teaching Scheme
Theory: 3 Hrs / Week

Credits: 3 + 1 = 4
Practical: 2 Hrs / Week

Course Objectives:

1. Knowledge:

i. To understand the fundamentals of networking and data communications.

ii. To understand network & data link layer protocols.

2. Skills: i. To learn network layer protocols.

3. Attitude:

i. To explore services offered by the transport layer.

ii. To understand protocols of the application layer

Course Outcomes:

On completion of course, students should be able to

1. Identify characterizing features of transmission techniques.
2. Recall and Demonstrate working of flow control & error control protocols.
3. Select routing protocol to Develop fully-functional simulation to simulate its working.
4. Define connection oriented & connectionless transport layer protocols & build working applications based on it.
5. Choose application layer protocol and make use of it in a suitable environment.

Pre-requisites

- Programming and Problem Solving

Syllabus

1	**Fundamentals of networking and data communication (9 Hrs)** Analog Transmission: Analog-to-Analog conversion, Digital-to-Analog conversion, Digital Transmission: Digital-to-Digital conversion (line coding, block coding, scrambling), Analog-to-Digital conversion (Pulse Code Modulation, Delta Modulation) Types of Networks, Network Architectures, Network Topologies, Transmission media's, Networking devices, OSI Model, TCP/IP Reference Model, Ethernet standards.
2	**Data Link Layer: (9 Hrs)** Data Link Layer Services, Types of errors, Block coding, Error Control: Cyclic Redundancy Check (CRC) Code, Hamming Code, Checksum, sliding window Protocols: Selective Repeat (SR) & Go Back N (GBN), Channel allocation, Multiple Access Protocols: ALOHA, CSMA/CD, CSMA/CA, Ethernet Frame format.
3	**Network Layer (9 Hrs)** Services, Internet Protocol: Ipv4 & Ipv6, Classful Addressing, Classless Addressing, CIDR, Subnetting, NAT, ARP, RARP ICMP, Routing Algorithms: Distance-Vector (DV) Routing, Link State (LS) Routing, Routing in Internet: RIP, OSPF, BGP
4	**Transport Layer (9 Hrs)** Services, Multiplexing, demultiplexing. Sockets, UDP, RTP, TCP: Services, Features, Segment, TCP Connection (Three-Way Handshake), Flow control and buffering, Silly window syndrome, Congestion Control. Congestion Control (Leaky Bucket, Token Bucket), Quality of Service (QoS)
5	**Application Layer (9 Hrs)** Dynamic Host Control Protocol (DHCP), Hypertext Transfer Protocol (HTTP), FTP, TELNET, SMTP: POP3, IMAP, MIME, Domain Name System (DNS), SNMP.

Guidelines for CCA and LCA

Examination Scheme

Sr. No.	Examination Scheme	Marks
1.	Class Continuous Assessment (CCA)	30
2.	Laboratory Continuous Assessment (LCA)	30
3.	Term End Examination	40

Sr. No.	Laboratory Continuous Assessment: (30 Marks)	Marks
1.	Practical Performance	10
2.	Implementation	10
3.	End Term Practical/ Oral Examination	10

CCA Marks Distribution

Sr. No.	Class Continuous Assessment: (30 Marks)	Marks
1.	Mid Term Exam	15
2.	Active Learning	10
3.	Component	05

Lab Assignment

1. Design a simple network (LAN) with different topologies & test it using PING utility.
2. Analyze and test PCM modulation technique.
3. Design and configure a virtual LAN.
4. Write a program for error detection and correction codes using Hamming Codes
5. Write a program to implement subnetting to find subnet mask
6. Implement Static and Dynamic NAT Configuration with Packet Tracer
7. Set up a network - configure interfaces, IP addresses and routing protocols (RIP, OSPF, EIGRP, BGP).
8. Write a C program for wired network using TCP socket to demonstrate a) Chat Application (50% Students) b) Mathematical operations. (Remaining 50% Students) Show packet captured traces using Wireshark Packet Analyzer Tool.
9. UDP Socket Programming: (Language: C/C++/Python/Java)/ Write a C program for wired network using UDP socket to perform any one of the following operations.

   a. String Conversion from UpperCase to LowerCase. (50% Students)

   b. Reverse the String. (Remaining 50% Students) Show packet captured traces using Wireshark Packet Analyzer Tool.
10. Configure network using Dynamic Host Configuration Protocol (DHCP), DNA and Web server Use Ping utility to test connectivity.

Unit I: Fundamentals of networking and data communication

Analog Transmission: Analog-to-Analog conversion, Digital-to-Analog conversion, Digital Transmission: Digital-to-Digital conversion (line coding, block coding, scrambling), Analog-to Digital conversion (Pulse Code Modulation, Delta Modulation) Types of Networks, Network Architectures, Network Topologies, Transmission media's, Networking devices, OSI Model, TCP/IP Reference Model, Ethernet standards.

Learning Resources:

Text Books:

1. Behrouz A. Forouzan, 'Data Communications and Networking', 5th Edition, McGrawHill Publishing Company, ISBN 978-0-07-337622-6
2. Tanenbaum A. S., 'Computer Networks', Pearson Education, 5th Edition, ISBN-978-0-13-212695-3

Reference Books:

1. James F. Kurose and Keith W Ross 'Computer Networking, A Top-Down Approach', 5th Edition, Pearson Education, ISBN- 978-81-317-9054-0
2. W. Richard Stevens, Unix Network Programming, The Sockets Networking API, Vol 1, 3rd Edition, PHI Learning Pvt. Ltd.

Supplementary Reading:

1. William Stallings, 'Data and Computer Communications', 6th Edition, Prentice Hall of India Pvt.

Introduction

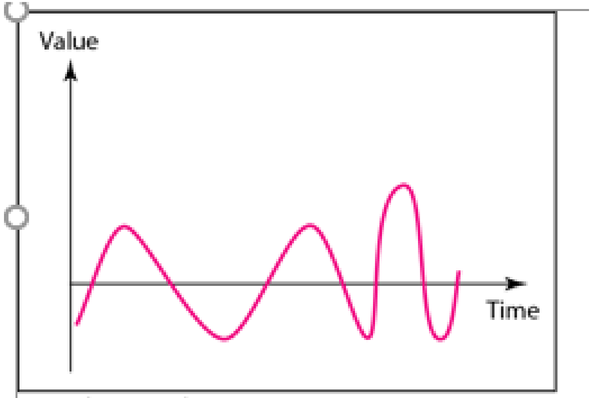
- **Data Communications Telecommunication** – means communication at a distance. (“tele”, greek word for “far”)
- **Data -** refers to information presented in whatever form is agreed upon by the parties creating and using the data
- **Data Communication -** exchange of data between two devices via some form of transmission medium such as a wire cable
- Data is a collection of facts. Information is how you understand those facts in context
- Data is unorganized, while information is structured or organized
- Data is not typically useful on its own, but information is
- Information depends on data

Analog and Digital Data

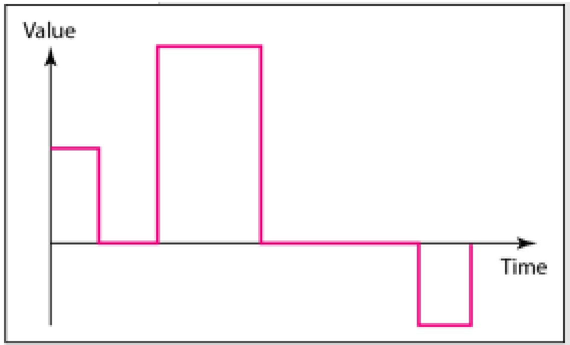
- The term analog data refers to information that is continuous
- Analog data, such as the sounds made by a human voice, take on continuous values can be captured by a microphone and converted to an analog signal or sampled and converted to a digital signal
- Digital data refers to information that has discrete states
- Digital data take on discrete values. For example, data are stored in the memory as 0s and 1
- They can be converted to a digital signal or modulated into an analog signal for transmission across a medium

Analog and Digital Signals

- **Signal** - A signal is an electromagnetic or electrical current that is used for carrying data from one system or network to another
- **An analog signal** is any continuous signal for which the time varying feature of the signal is a representation of some other time varying quantity i.e., analogous to another time varying signal.
- A **digital signal** is a signal that represents data as a sequence of discrete values; at any given time it can only take on one of a finite number of values.
- Discrete value 1 and 0



a. Analog signal



b. Digital signal

Difference between Analog and Digital Signals

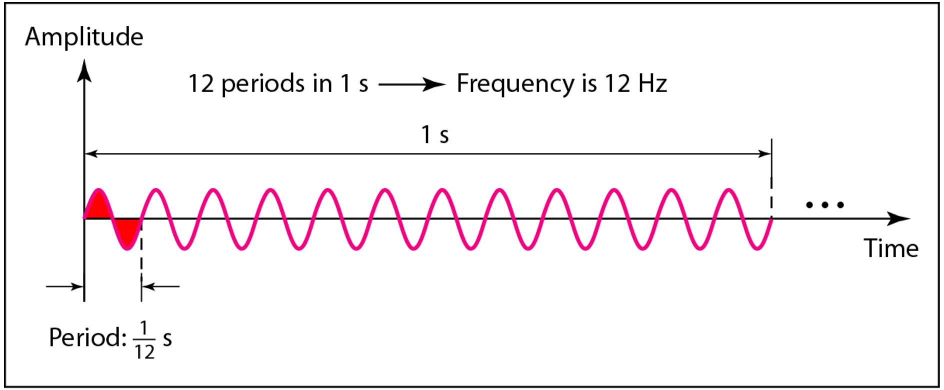
Analog Signals	**Digital Signals**
Analog signal is **continuous and time varying.**	Digital signal have **two or more states and in binary form.**
Troubleshooting of analog signals are difficult.	Troubleshooting of digital signals are easy.
An analog signal is usually in the form of **sine wave.**	An digital signal is usually in the form of **square wave.**
Easily affected by the noise.	These are stable and less prone to noise.
Analog signals use **continuous** values to represent the data.	Digital signals use **discrete** values to represent the data.
Accuracy of the analog signals may be affected by noise.	Accuracy of the digital signals are immune from the noise.
Analog signals may be **affected during data transmission.**	Digital signals are not affacted during data transmission.
Analog signals **use more power.**	Digital signals use less power.
Examples: **Human voice, natural sound**, Audio signal, Radio signal etc.	Examples: **Computers, optical drives, etc.**
Components like **resistors, Capacitors, Inductors, Diodes** are used in analog circuits.	Components like **transistors, logic gates, and micro-controllers** are used in Digital circuits.

Period and Frequencies

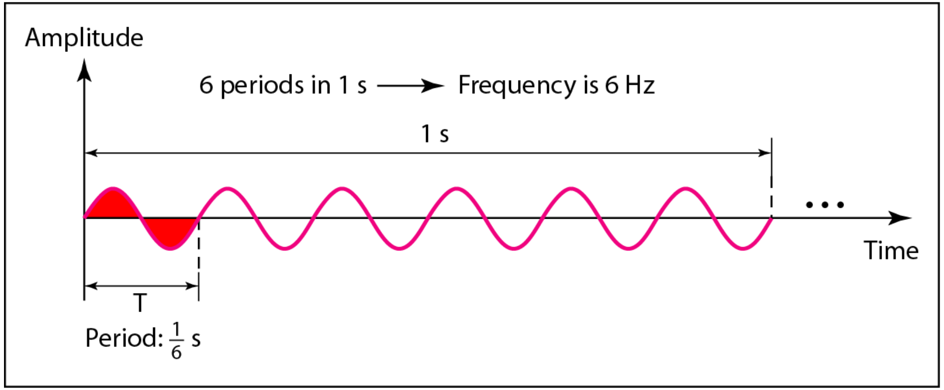
- Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.
- Frequency refers to the number of periods in 1 s

- Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \qquad \text{and} \qquad T = \frac{1}{f}$$



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Period and Frequencies

Example 1. The power we use at home has a frequency of 60 Hz. The period of this sine wave can be determined as follows:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166 \text{ s} = 0.0166 \times 10^3 \text{ ms} = 16.6 \text{ ms}$$

Example 2. The period of a signal is 100 ms. What is its frequency in kilohertz?

Solution

First we change 100 ms to seconds, and then we calculate the frequency from the period (1 Hz = 10^{-3} kHz).

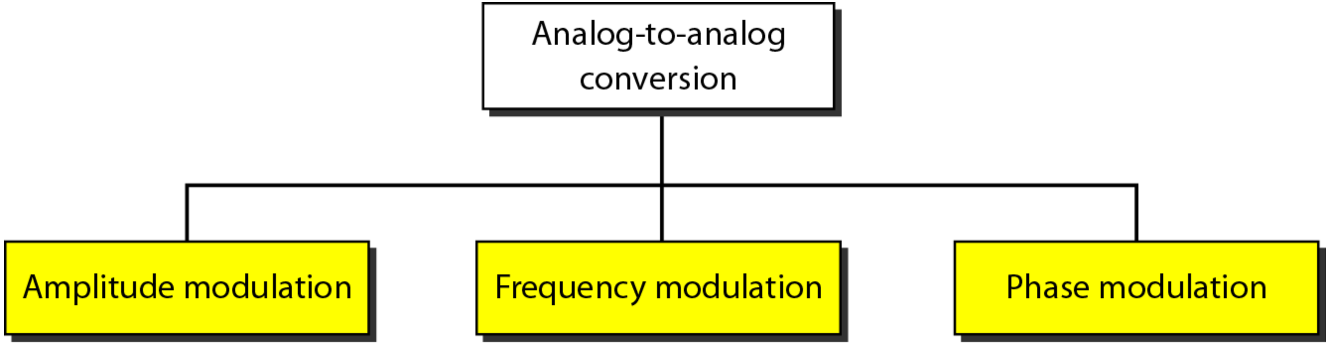
$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 10^{-1} \text{ s}$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}} \text{ Hz} = 10 \text{ Hz} = 10 \times 10^{-3} \text{ kHz} = 10^{-2} \text{ kHz}$$

Modulation

- Modulation is the process of altering one or more properties of a periodic waveform known as a carrier signal with respect to the modulation signal, which contains information to be transmitted
- Modulation is performed by the device known as a modulator, and this technique is mainly used to overcome the interference of the signal. Modulation techniques typically aid in long-distance communication
- Modulation is of two types
    1. Analog Modulation
    2. Digital modulation

Types of Analog-to-Analog modulation

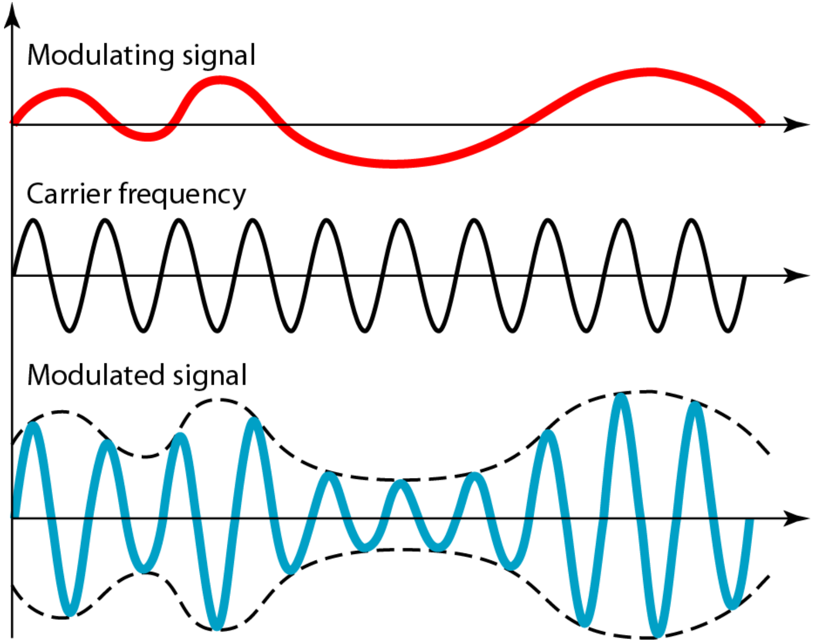


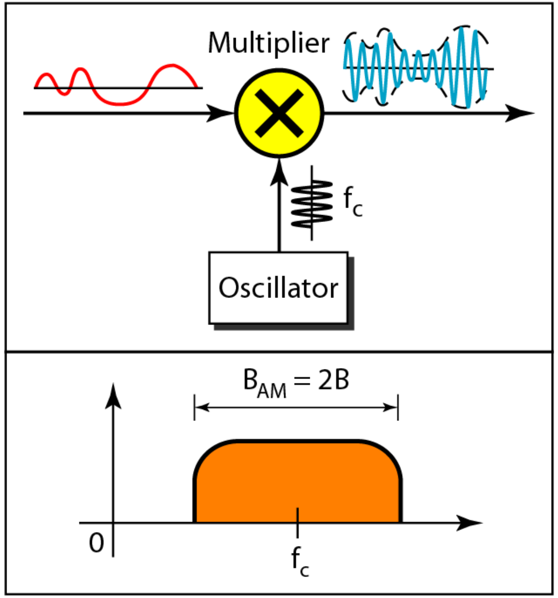
- **Amplitude Modulation**: Amplitude is varied keeping frequency and phase constant
- **Frequency Modulation:** Frequency is varied keeping amplitude and phase constant
- **Phase Modulation:** Phase is varied keeping amplitude and frequency constant

Amplitude Modulation

- Amplitude is varied keeping frequency and phase constant

An oscillator is a circuit which produces a continuous, repeated, alternating waveform without any input.





The total bandwidth required for AM can be determined from the bandwidth of the audio signal: $B_{AM} = 2B$.

Advantages and disadvantages of AM

Advantages of Amplitude Modulation

- Amplitude Modulation is easier to implement
- The components used in building the AM transmitter and AM receiver are very cheap
- It can be demodulated using a circuit consisting of very few components

Disadvantages of Amplitude Modulation

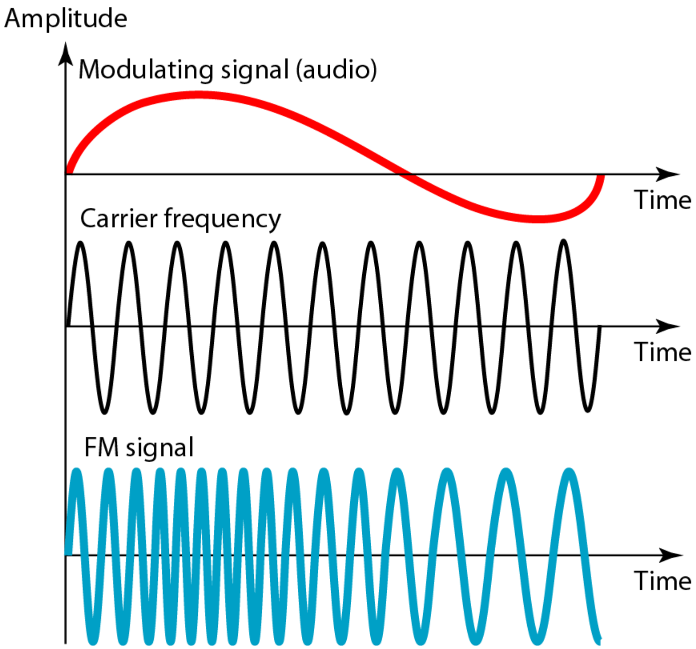
- Poor Performance due to noise
- Inefficient use of transmitter power
- It is not efficient in terms of its use of bandwidth, requiring a bandwidth equal to twice that of the highest frequency.

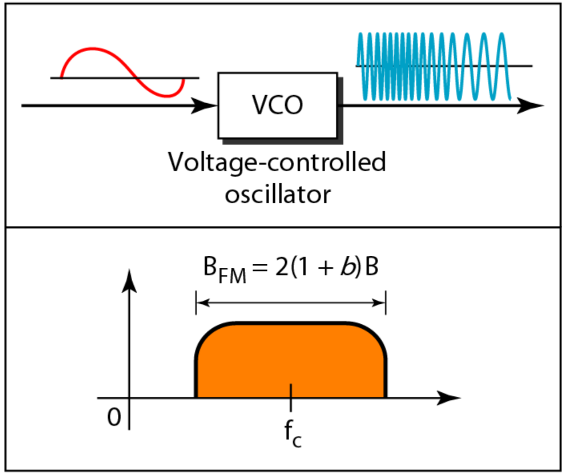
Applications of Amplitude Modulation

- Broadcast Transmissions
- Air-band radio
- Single sideband
- Quadrature amplitude modulation

Frequency Modulation

- Frequency modulation is the process by which the frequency of a carrier signal changes with respect to the modulating signal.





The total bandwidth required for FM can be determined from the bandwidth of the audio signal: $B_{FM} = 2(1 + \beta)B$. Where β is a factor depends on modulation technique with a common value 4.

Advantages and disadvantages of FM

Advantages of Frequency Modulation

- The amplitude of the frequency-modulated wave does not get affected.
- Large decrease in noise, hence increase in the signal to noise ratio.
- Noise may reduce by increasing the frequency deviation.
- Frequency allocation allows for a guard band which reduces adjacent channel interference.
- It operates in a very high frequency called VHF.

Disadvantages of Frequency Modulation

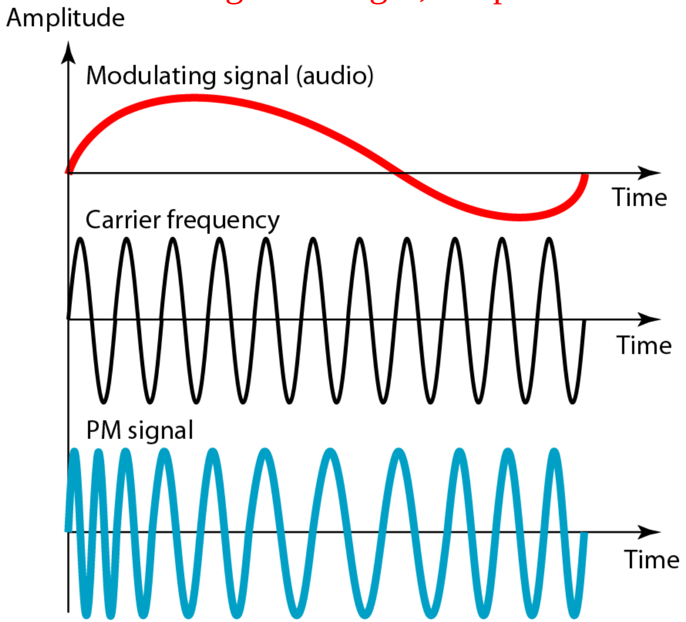
- FM cannot cover large areas.
- Transmitting and receiving equipment of frequency modulation is complex and expensive.
- A much wider channel tytpically 200 kHz is required by FM..
- The antennas for FM need to be closely placed for better signals.

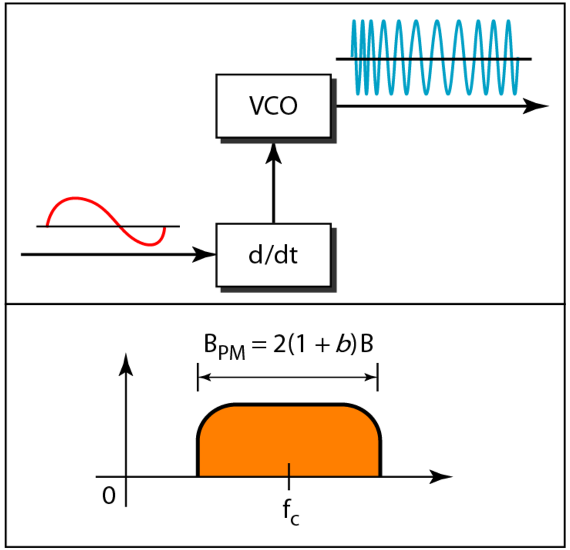
Applications of Frequency Modulation

- Telemetry, radar and seismic prospecting, EEG monitoring
- It is used in radio broadcasts
- It is used for audio frequency synthesis.

Phase Modulation

In PM transmission, the phase of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal. The peak amplitude and frequency of the carrier signal remain constant, but as the amplitude of the information signal changes, the phase of the carrier changes correspondingly.





In PM the instantaneous change in the carrier frequency is proportional to the derivative of the amplitude of the modulating signal. The total bandwidth required for PM can be determined from the bandwidth and maximum amplitude of the modulating signal: BPM = 2(1 + β)B. The value of β is lower in the case of PM.

Advantages and disadvantages of Phase Modulation

Advantages of Phase Modulation

- Phase modulation (PM) is a simple contrasted to Frequency modulation (FM)
- It has a higher transmitter efficiency.
- It has a higher noise immunity.

Disadvantages of Phase Modulation

- The system cost is quite expensive
- Phase ambiguity comes if we exceed its modulation index pi radian(180 degree).
- we need frequency multiplier to increase phase modulation index.

Applications of Phase Modulation

- widely used in the transmission of radio waves satellite transmission system
- Used in digital synthesizers for generating waveform and signal
- Wireless technologies such as GSM, Satellite television, and Wi-Fi.

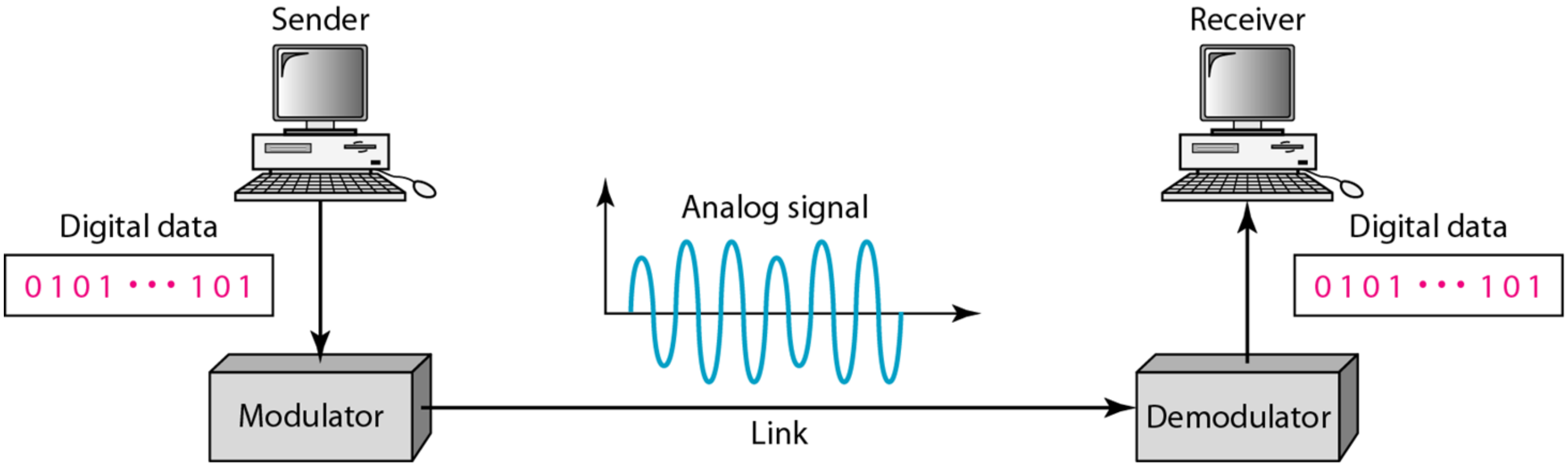
Comparision of AM and FM

Amplitude Modulation	Frequency Modulation
In amplitude modulation, the frequency and phase remain the same	In frequency modulation amplitude and phase remain the same
Its modulation index varies from 0 to 1	Its modulation index is always greater than one
It has only two sidebands	It has an infinite number of sidebands
It has simple circuit	It has complex circuit
The amplitude of the carrier wave is modified in order to send the data or information	The frequency of the carrier wave is modified in order to send the data or information
It requires low bandwidth in the range of 10 kHz	It requires high bandwidth in the range of 200 kHz
In AM received signal is of low quality	In FM received signal is of high quality
It operates in the medium frequency (MF) and high frequency (HF)	It operates in the very high frequency
It has poor sound quality	It has better sound quality

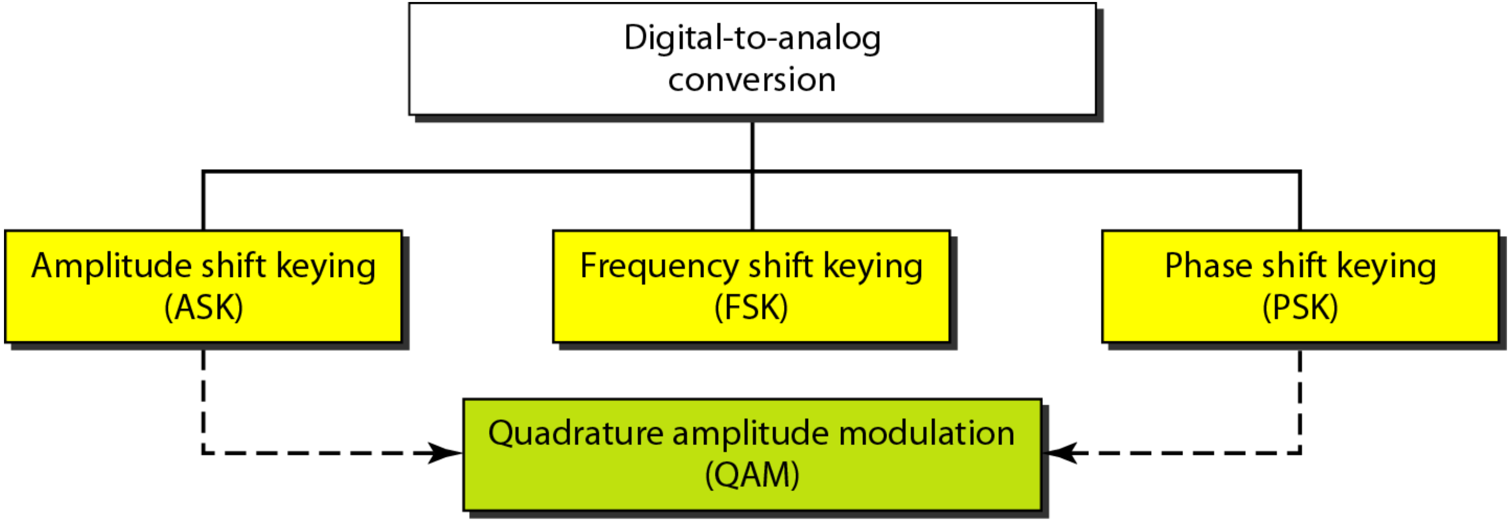
Digital-to-Analog conversion

Digital-to-Analog conversion

- Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data



Types of digital-to-analog conversion



- In amplitude shift keying (ASK), amplitude of a carrier is changed using the digital data.
- In Frequency shift keying (FSK), the frequency of a carrier is changed using the digital data.
- In phase shift keying (PSK), the phase of a carrier signal is changed to represent digital data.
- In quadrature amplitude modulation (QAM), both amplitude and phase of a carrier signal are changed to represent digital data

Data Rate(Bit Rate) and Signal Rate(Baud Rate)

- Bit rate (data rate) is the number of bits per second
- Baud rate (signal rate) is the number of signal elements per second.
- In the analog transmission of digital data, the baud rate is less than or equal to the bit rate
- The relationship between data rate and baud rate is given by following formula

$$S = N * (1/r) \text{ baud}$$

- Where N is the data rate(bps) and r is the number of data elements carried in one signal element. The value of r in analog transmission is $r = \log_2 L$, where L is type of signal element

Data Rate Versus Signal Rate

Bit Rate	Baud Rate
The number of bits per second is known as the bit rate.	The number of signal units per second is known as the baud rate.
Bit rate determines the number of bits travelled per second.	Baud Rate determines the number of times a signal's status changes.
Bit rate= baud rate x the count of bits per signal unit.	Baud rate= bit rate/ the number of bits per signal unit.
The focus is on computer efficiency.	On the other hand, data transmission over the channel is more concerned.
Bit Rate cannot determine the bandwidth.	It can determine the amount of bandwidth necessary to send the signal.

Example 3

An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

Solution

In this case, r = 4, S = 1000 (signal rate, or baud), and N (the bit rate) is unknown. We can find the value of N from

$$S = N \times \frac{1}{r} \qquad \text{or} \qquad N = S \times r = 1000 \times 4 = 4000 \text{ bps}$$

Example 4

An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

Solution

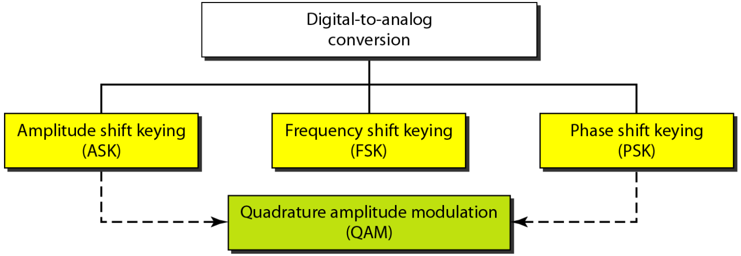
In this example, S = 1000 baud, N = 8000bps, and r and L are unknown. We find first the value of r and then the value of L.

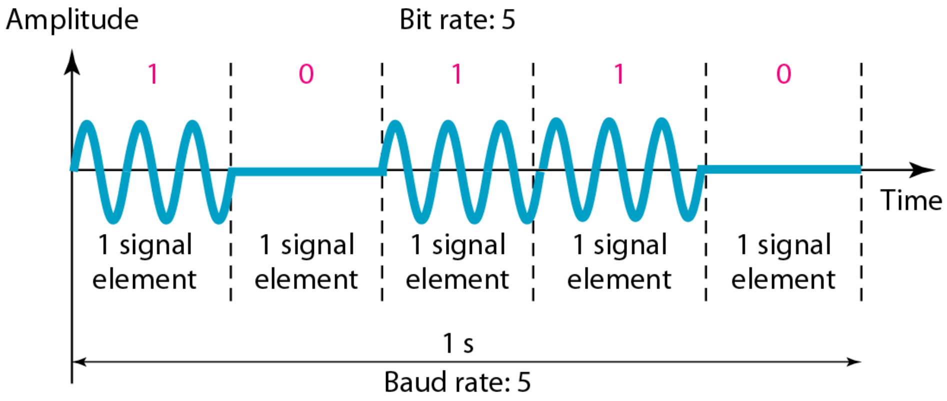
$$S = N \times \frac{1}{r} \quad \longrightarrow \quad r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}$$

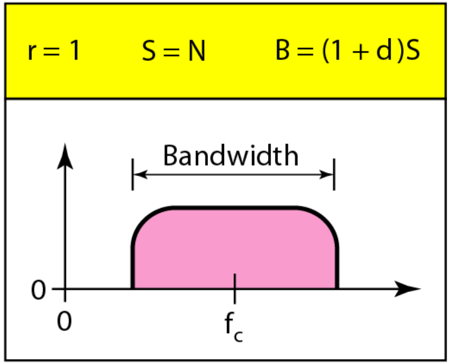
$$r = \log_2 L \quad \longrightarrow \quad L = 2^r = 2^8 = 256$$

Amplitude Shift Keying (ASK)

In amplitude shift keying, the amplitude of the carrier signal is varied to create signal elements. Both frequency and phase remain constant while the amplitude changes.







- ASK is normally implemented using only two levels. This is referred to as binary amplitude shift keying or on-off keying (OOK). The peak amplitude of one signal level is 0; the other is the same as the amplitude of the carrier frequency

Bandwidth of Amplitude Shift Keying (ASK)

- Carrier signal is only sine wave, the process of modulation produces a non periodic composite signal.
- Bandwidth is proportional to signal rate(baud rate).
- There is another factor involved called as d, which depends on modulation and filtering process. The value of d is between 0 and 1.
- Bandwidth can be expressed as shown

$$B = (1+d) * S$$

Where B is the bandwidth and S is the signal rate.

The middle of bandwidth is fc where carrier frequency is located.

Example 5

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate (N) if we modulated our data by using ASK with d = 1?

Solution

The middle of the bandwidth is located at 250 kHz. This means that our carrier frequency can be at f_c = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

Bandwidth = (1+d) * baud rate S

Don't want to know baud rate S, we want to know bit rate N, so substitute S = N * 1/r

Bandwidth = (1+d) * N * 1/r
100kHz = 2 N * 1/1 (given r=1 and d=1)
100kHz = 2N
N = 50 kbps

Amplitude Shift Keying (ASK)

Advantages

- It can be used to transmit digital data over optical fiber.
- The receiver and transmitter have a simple design which also makes it comparatively inexpensive.
- It uses lesser bandwidth as compared to FSK thus it offers high bandwidth efficiency.

Disadvantages

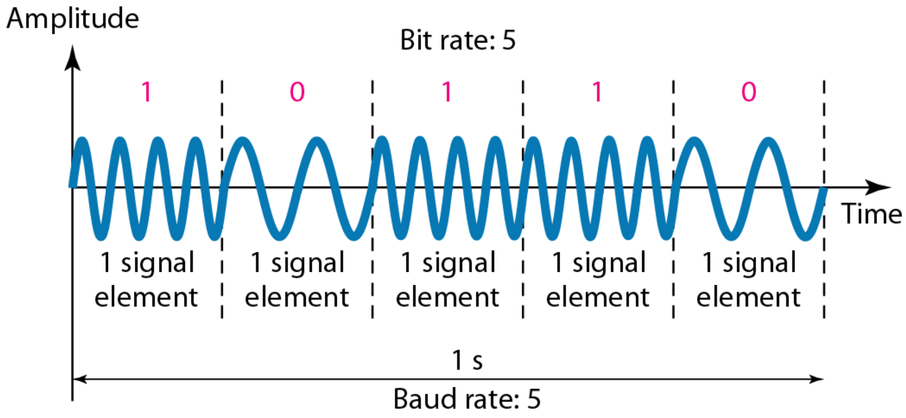
- It is susceptible to noise interference and entire transmissions could be lost due to this.
- It has lower power efficiency
- ASK techniques are not suitable for high bit rate data transmission

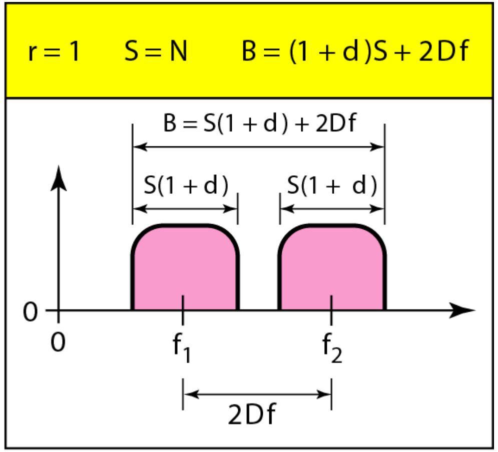
Applications

- Home automation devices.
- Industrial networks devices.
- Wireless base stations.

Frequency Shift Keying (FSK)

- In frequency shift keying, the frequency of the carrier signal is varied to represent
- data. The frequency of the modulated signal is constant for the duration of one signal element, but changes for the next signal element if the data element changes. Both amplitude and phase remain constant for all signal elements.
- Carrier signal are simple sine waves, but modulation creates a non periodic composite signal with continuous frequencies. We can say that FSK as two ASK signal with its own carrier frequencies (f1 or f2). The Difference between two frequencies is 2Df then the required bandwidth is   B= (1+d)*S + 2Df





Frequency Shift Keying (FSK)

Advantages

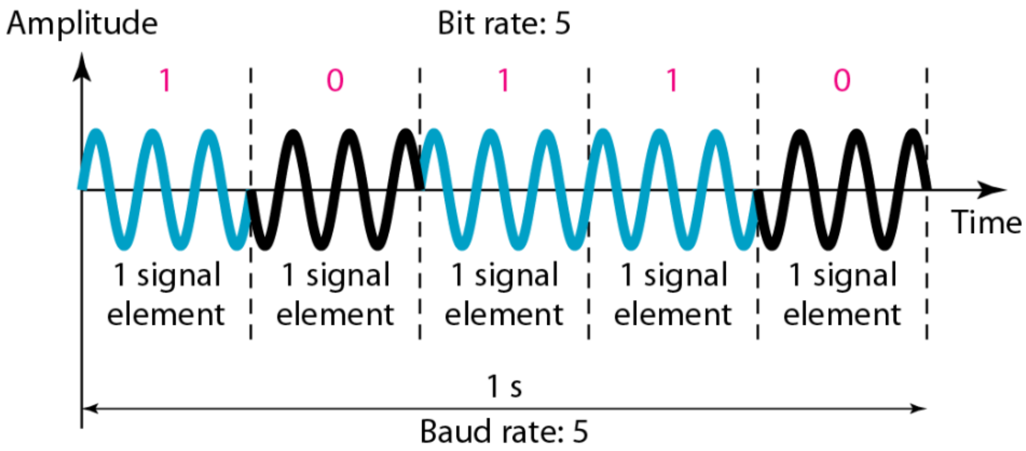
- The antenna size reduced.
- Avoid multiplexing of signals, decrease the SNR.
- Long-range communication can be possible.

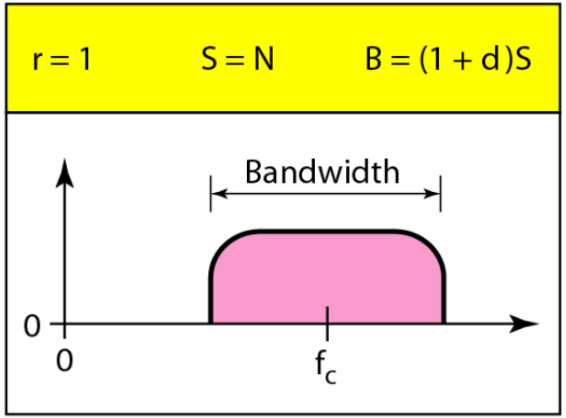
Disadvantages

- It uses larger bandwidth compare to ASK and PSK. Hence it is not bandwidth efficient.
- The bit error rate is less in AEGN channel than phase shift keying.

Phase Shift Keying (PSK)

- In phase shift keying, the phase of the carrier is varied to represent two or more different signal elements. Both peak amplitude and frequency remain constant as the phase changes.





d = 0 for PSK

- Bandwidth is same as that for binary ASK, but less than that for Binary FSK (BFSK). No Bandwidth is wasted for separating two carrier signal

Phase Shift Keying (PSK)

- Binary PSK is as simple as binary ASK with one big advantage-it is less susceptible to noise. In ASK, the criterion for bit detection is the amplitude of the signal; in PSK, it is the phase.
- Noise can change the amplitude easier than it can change the phase.
- In other words, PSK is less susceptible to noise than ASK. PSK is superior to FSK because we do not need two carrier signals.

Advantages

- It is more power efficient modulation technique compare to ASK and FSK.

Disadvantages

- It has lower bandwidth efficiency.

Quadrature Amplitude Modulation (QAM)

- Quadrature amplitude modulation is a combination of ASK and PSK.
- QAM uses two carriers, one in-phase and the other quadrature, with different amplitude levels for each carrier.

Bandwidth for QAM

- The minimum bandwidth required for QAM transmission is the same as that required for ASK and PSK transmission. QAM has the same advantages as PSK over ASK.

Advantages

- Efficient usage of bandwidth

Disadvantages

- QAM modulation is more susceptible to the noise
- Linear amplifier is needed which consumes more power

Applications

- Used in the radio communications
- Used in optical fiber systems to increase bit rates

Digital-to-Digital conversion
(line coding, block coding, scrambling)

Digital-to-Digital conversion

- Digital-to-digital conversion techniques, methods which convert digital data to digital signals.

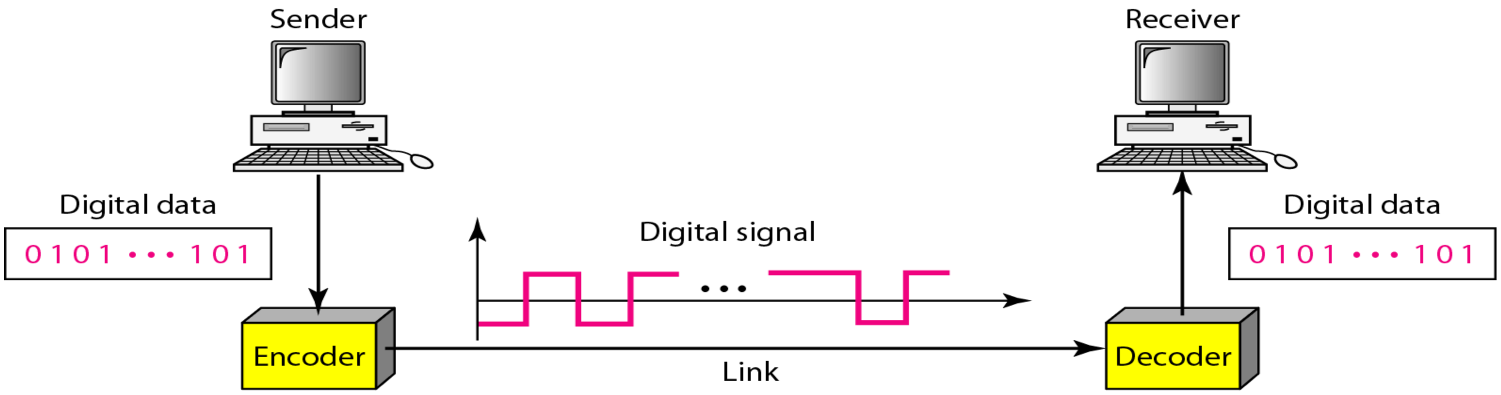
- The conversion involves **Three techniques:**

  1. **Line Coding**
  2. **Block Coding**
  3. **Scrambling**

Note: Line coding is always needed; block coding and scrambling may or may not be needed.

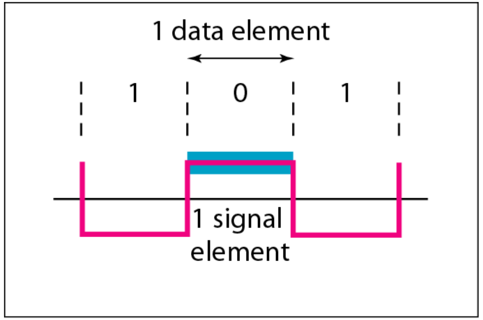
Line Coding

- **Line coding** is the process of converting digital data to digital signals.
- At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal.
- **High voltage** level **(+V)** could represent a **“1”** and a **low voltage** level **(0 or -V)** could represent a **“0”.**

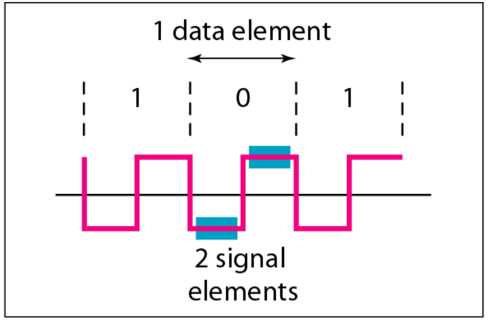


Line Coding

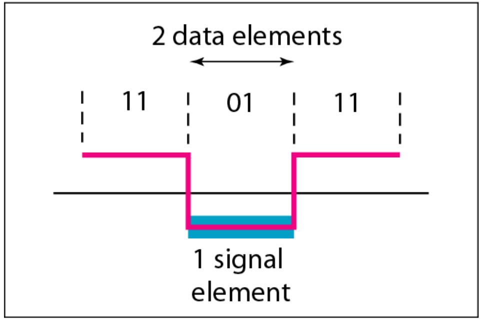
- We define a ratio r which is the number of data elements carried by each signal element.
- In part a of the figure, one data element is carried by one signal element (r = 1). In
- Part b, we need two signal elements (two transitions) to carry each data
- element (r = 1/2).
- In part c, a signal element carries two data elements (r = 2).
- In part d, a group of 4 bits is being carried by a group of three signal elements (r =4/3).



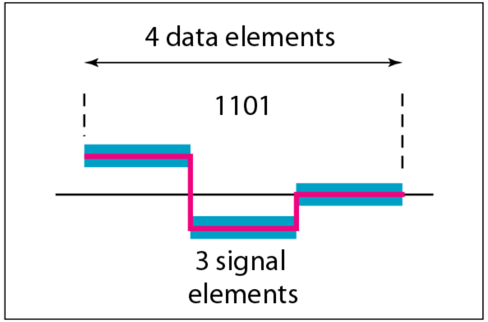
a. One data element per one signal element (r = 1)



b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$



c. Two data elements per one signal element (r = 2)



d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

Data Rate Versus Signal Rate

- The data rate defines the number of data elements (bits) sent in 1s.
- The unit is bits per second (bps).
- The signal rate is the number of signal elements sent in 1s. The unit is the baud.
- There are several common terminologies used in the literature.
- The data rate is sometimes called the bit rate; the signal rate is sometimes called the pulse rate, the modulation rate, or the baud rate.
- One goal: To increase the data rate while decreasing the signal rate.
- Increasing the data rate increases the speed of transmission; decreasing the signal rate decreases the bandwidth requirement.

Example 6

A signal is carrying data in which one data element is encoded as one signal element (r = 1). If the bit rate is 100 kbps, what is the average value of the baud rate if c is between 0 and 1? Assume that the **average value of c is 1/2**

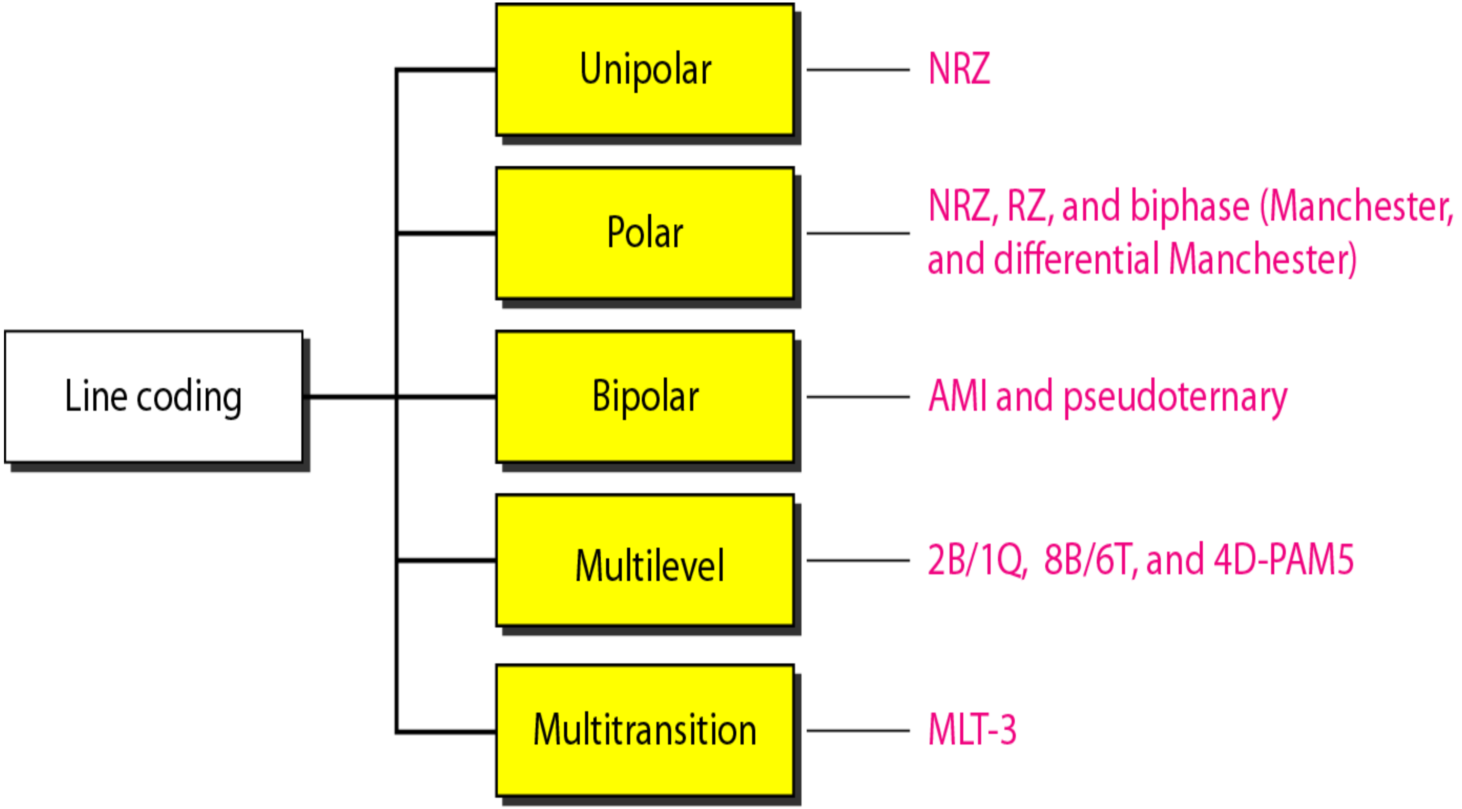
- **c is the case factor (worst, best & avg.) =1/2**

S = c x N x 1/r bauds

- **N is data rate =100 kbps=100,000**
- **r is the ratio between data element & signal element = 1/1**

$$\boxed{S = c \times N \times \frac{1}{r} = \frac{1}{2} \times 100{,}000 \times \frac{1}{1} = 50{,}000 = 50 \text{ kbaud}}$$

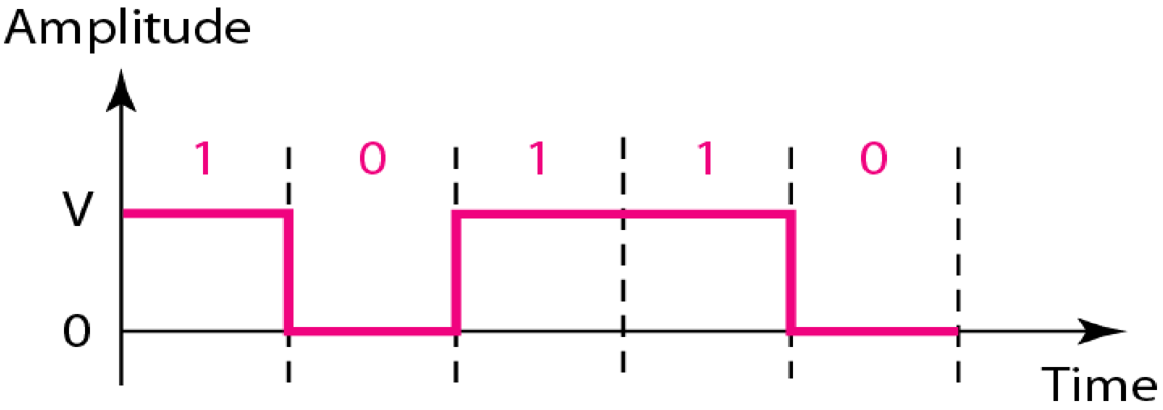
Line Coding Schemes



Unipolar NRZ scheme

- In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below. In ***Non-Return-to-Zero,*** the signal does not return to zero at the middle of the bit, *where* positive voltage defines bit 1 and the zero voltage defines bit 0.
- It is simple but costly in power consumption.

Sequence of bits=10110



Polar NRZ scheme

a. Non-Return-to-Zero (NRZ):

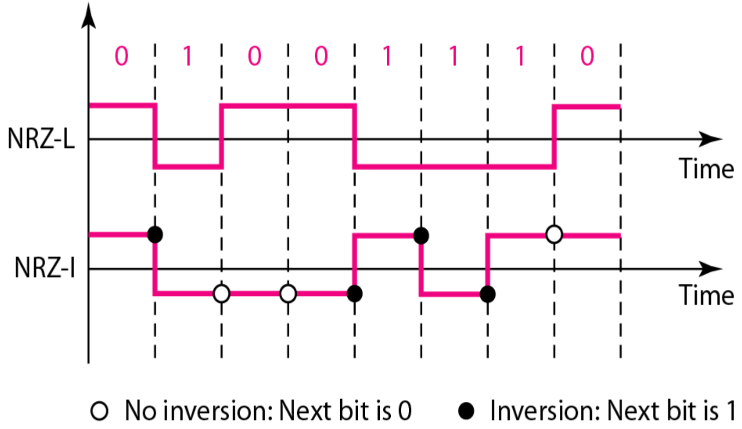
The voltages are on both sides of the time axis.

Polar NRZ scheme can be implemented with **two voltages.** E.g. +V for 1 and -V for 0.

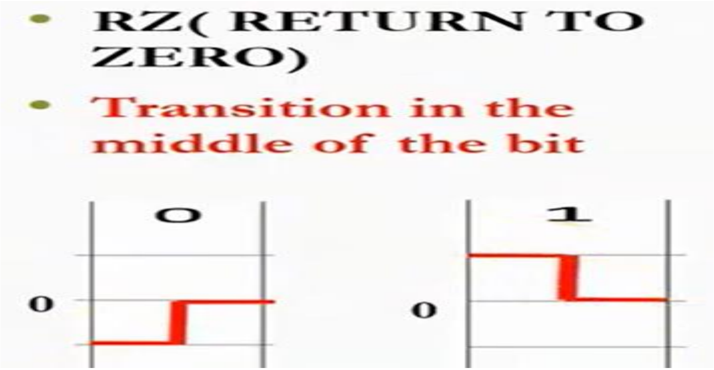
There are **two versions:**

1. NZR - Level (NRZ-L) - positive voltage for zero symbol and negative for the other.

2. NRZ - Inversion (NRZ-I) - the change or lack of change in polarity determines the value of a symbol. E.g. a “1” symbol inverts the polarity a “0” does not.

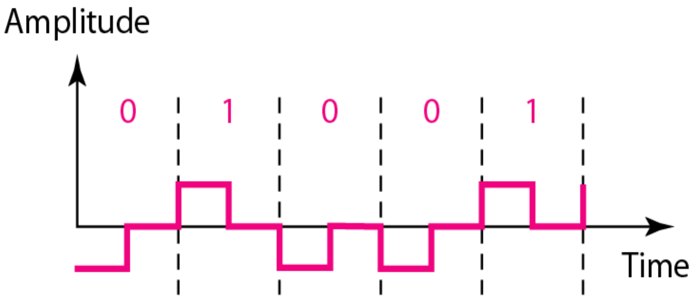


Polar RZ scheme



b. Return-to-Zero (RZ):

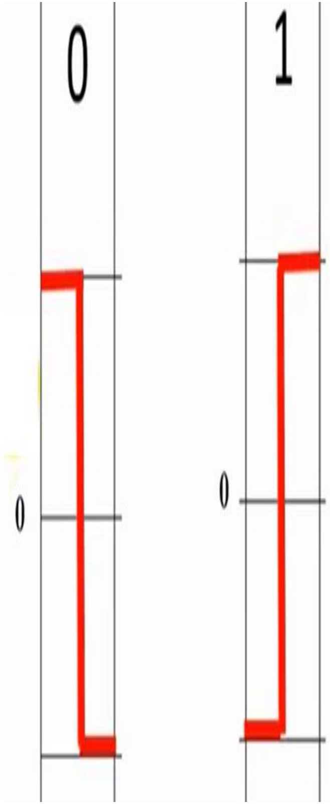
- This scheme uses **three voltage values. +, 0, -.**
- Each symbol has a **transition in the middle**. Either from high to zero or from low to zero.
- This scheme has more signal transitions (two per symbol), so requires a wider bandwidth.
- Problem is the complexity due to 3 signals.
- Not in use.



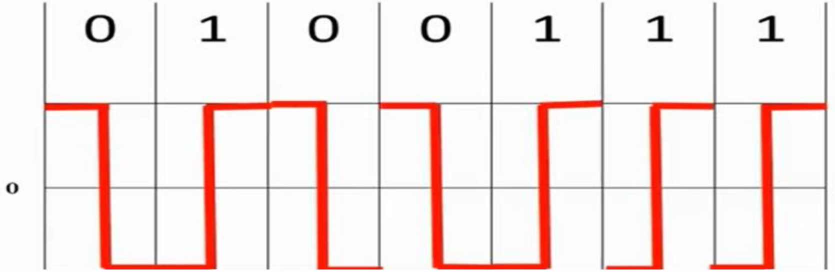
2. Polar Schemes : Manchester

BIPHASE

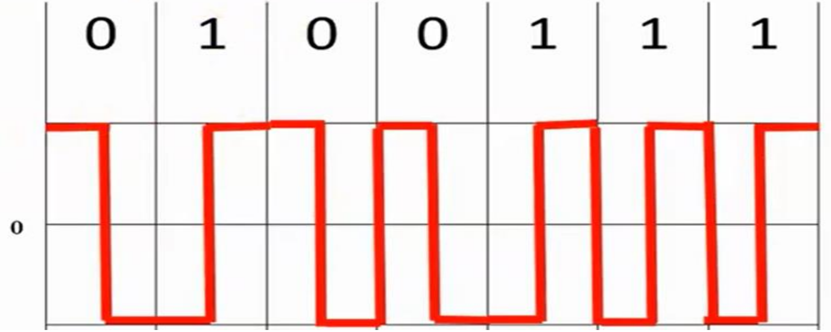
- MANCHESTER
- Combines the logic of RZ and NRZ-L
- 0: Positive to negative transition
- 1: Negative to positive transition



Example 1:
Data : 0 1 0 0 1 1 1

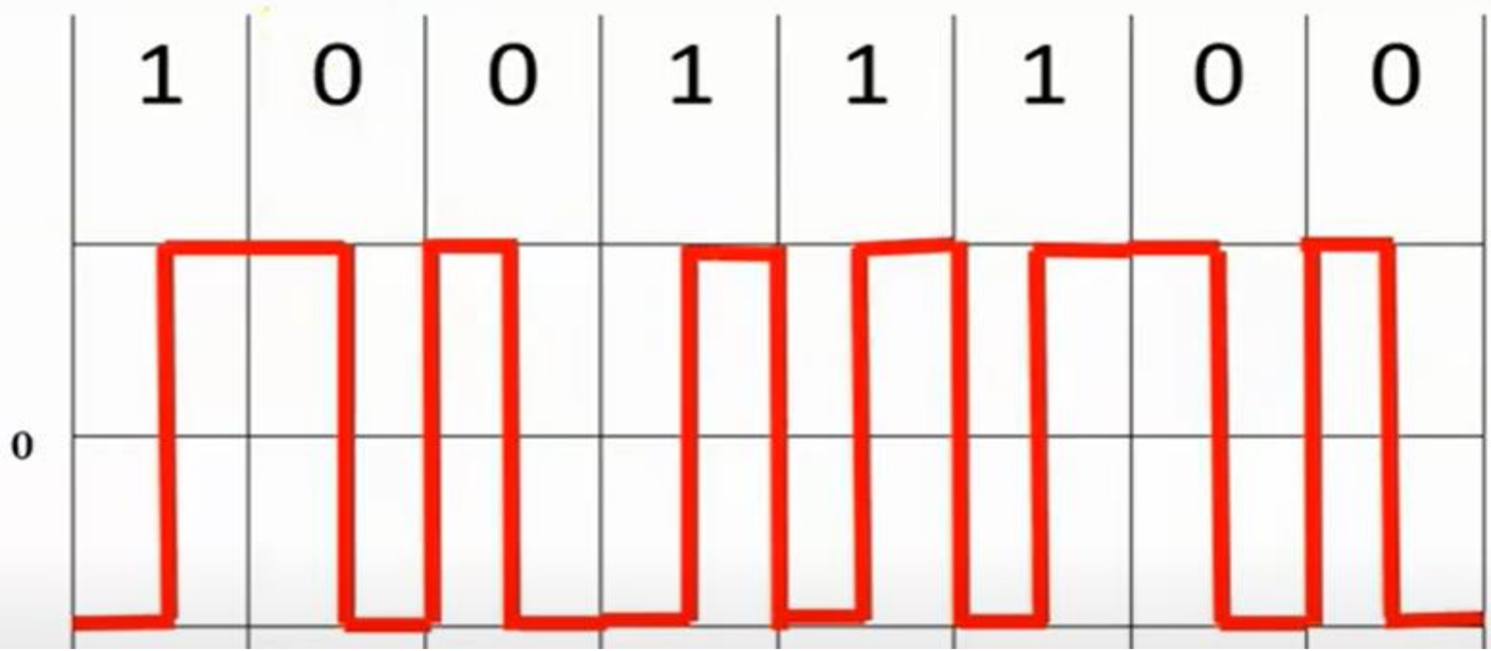


Example 1:
Data : 0 1 0 0 1 1 1



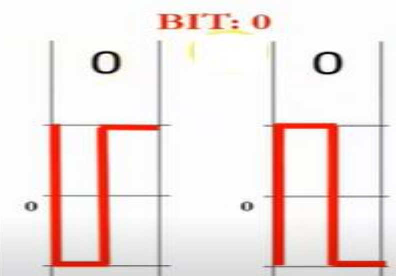
2. Polar Schemes : Manchester

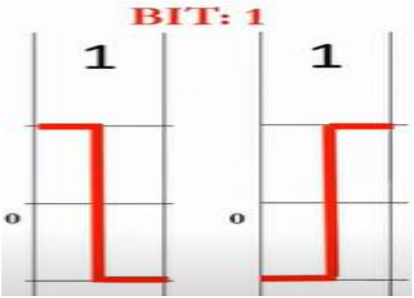
Data : 1 0 0 1 1 1 0 0



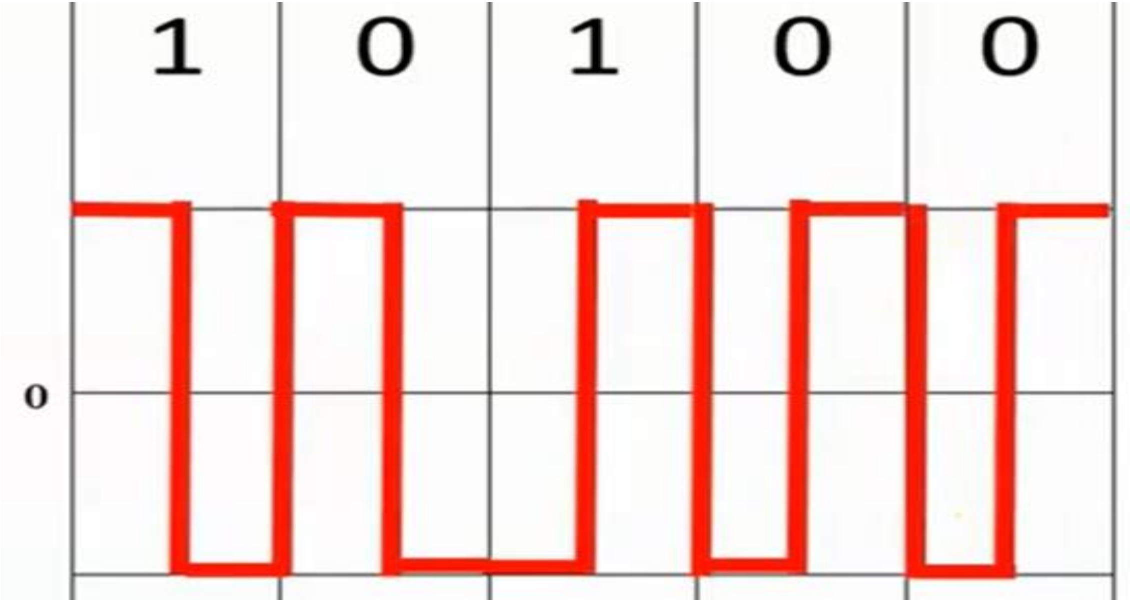
2. Polar Schemes : Differential Manchester

Combines the logic of RZ and NRZ-I

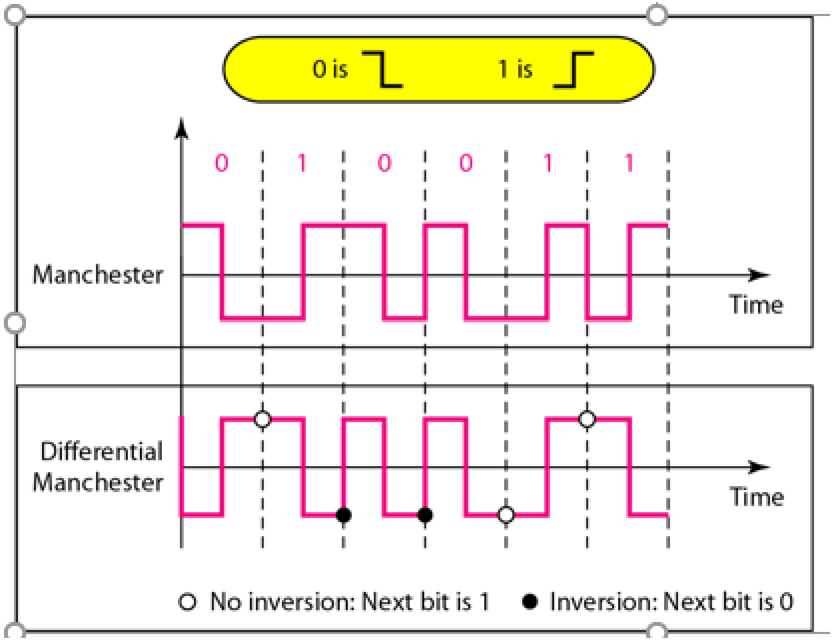




Example 1:
Data : 1 0 1 0 0

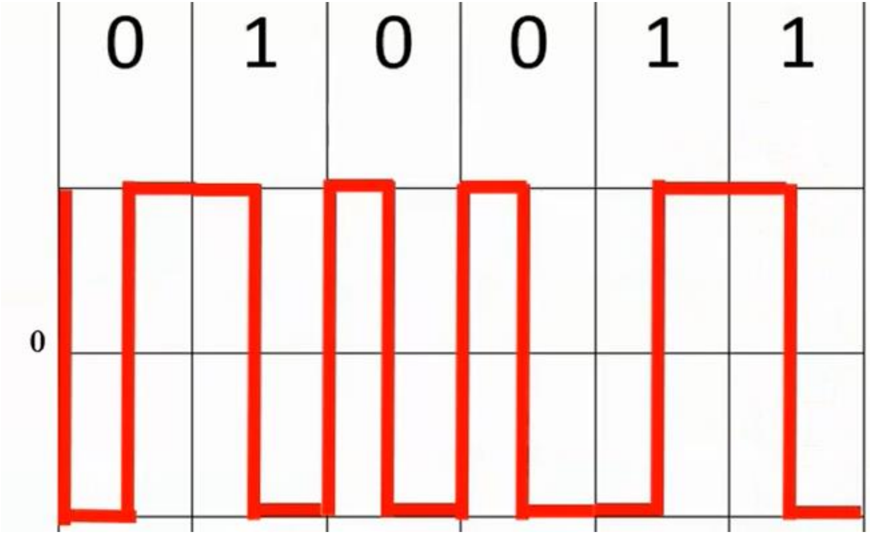


2. Polar Schemes : Differential Manchester



Example 2:

Data : 0 1 0 0 1 1



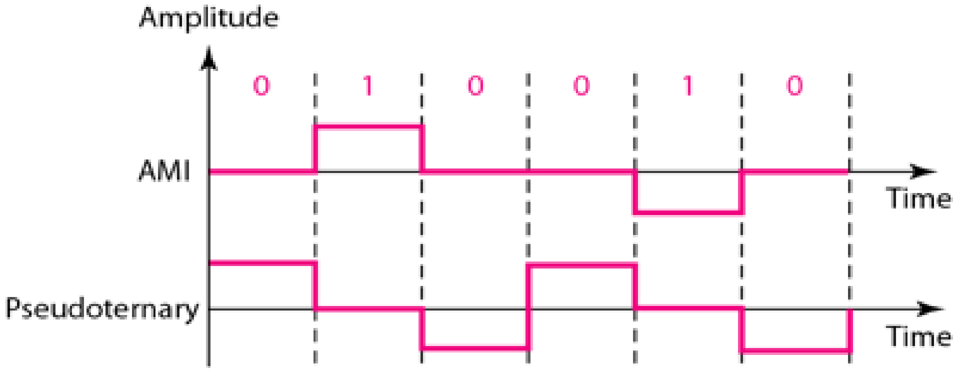
2. Polar Schemes : Differential Manchester

- In Manchester and differential Manchester encoding, the transition at the middle of the bit is used for synchronization

- The minimum bandwidth of Manchester and differential Manchester is 2 times that of NRZ.

3. Bipolar: Alternate Mark Inversion (AMI) and Pseudoternary

- Alternate Mark Inversion (AMI) and Pseudoternary.
- Mark means 1. So AMI means alternate 1 inversion.
- A neutral zero voltage represents binary 0. Binary 1s are represented by alternating positive and negative voltages.
- A variation of AMI encoding is called pseudoternary in which the 1 bit is encoded as a zero voltage and the 0 bit is encoded as alternating positive and negative voltages.



AMI is commonly used for long-distance communication, but it has a synchronization problem when a long sequence of O's (Zero) is present in the data.

Revision

BIPOLAR

AMI(ALTERNATE MARK INVERSION)

- 0 : zero voltage
- 1 : alternating positive and negative voltages

BIPOLAR

Pseudoternary

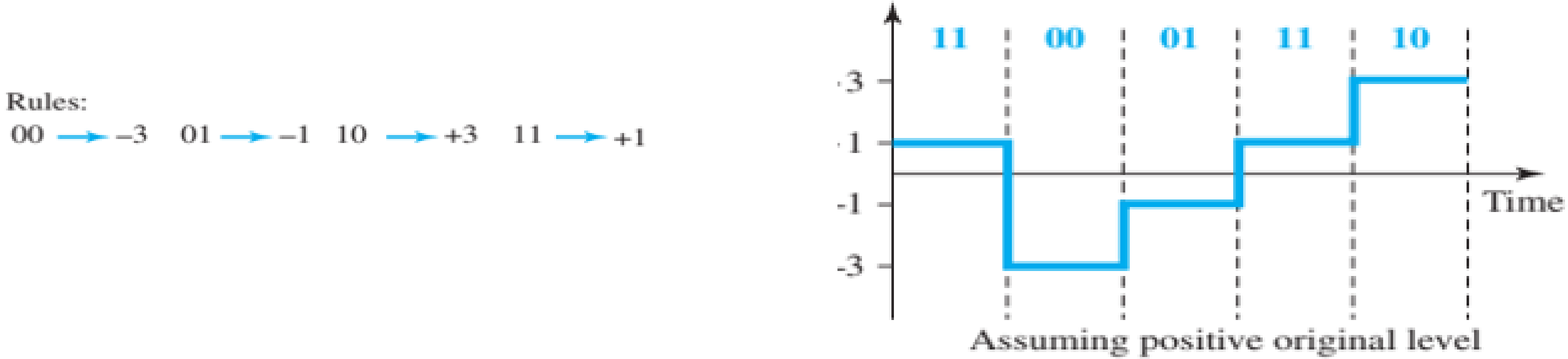
- 0 : alternating positive and negative voltages
- 1 : zero voltage

4. Multilevel Schemes

In *m*B*n*L schemes, a pattern of *m* data elements is encoded as a pattern of *n* signal elements in which $2^m \leq L^n$.

4. Multilevel Schemes

- The first *mBnL* scheme we discuss, **two binary, one quaternary (2B1Q),** uses data patterns of size 2 and encodes the 2-bit patterns as one signal element belonging to a four-level signal.
- In this type of encoding *m* = 2, *n* = 1, and *L* = 4 (quaternary).
- 2 times faster than by using NRZ-L
- There are no redundant signal patterns in this scheme because $2^2 = 4^1$.
- Used in DSL (Digital Subscriber Line) technology to provide a high-speed connection to the Internet by using subscriber telephone lines



5. Multitransition: MLT-3

The **multiline transmission, three-level (MLT-3) scheme uses** three levels (+*V*, 0, and -*V*) and three transition rules to move between the levels.

1. If the next bit is 0, there is no transition.

2. If the next bit is 1 and the current level is not 0, the next level is 0.

3. If the next bit is 1 and the current level is 0, the next level is the opposite of the last nonzero level.

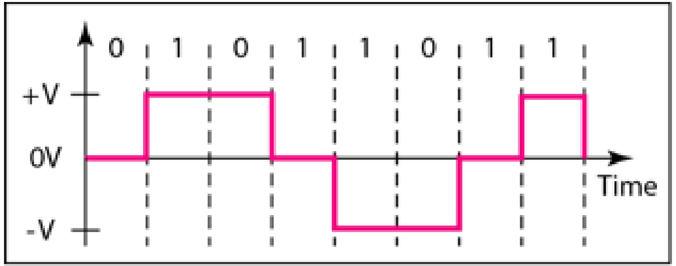
The three voltage levels (-*V*, 0, and +*V*) are shown by three states (ovals).

It turns out that the shape of the signal in this scheme helps to reduce the required bandwidth.

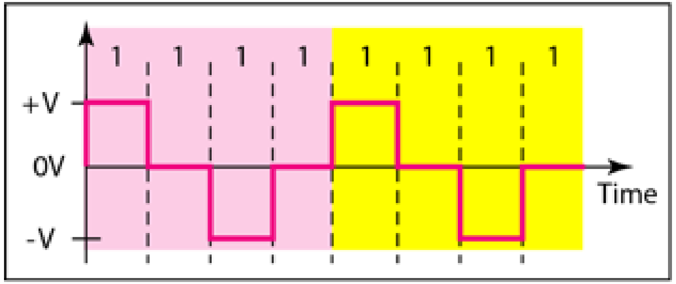
MLT-3 a suitable choice when we need to send 100 Mbps on a copper wire that cannot support more than 32 MHz.

1 = level change. 0 = no change.

5. Multitransition: MLT-3



a. Typical case



b. Worse case

Summary of line coding schemes

Category	*Scheme*	*Bandwidth (average)*	*Characteristics*
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization iflong Os or Is, DC
Unipolar	NRZ-L	$B = N/2$	No self-synchronization if long Os or 1s, DC
	NRZ-I	$B = N/2$	No self-synchronization for long aS, DC
	Biphase	$B = N$	Self-synchronization, no DC, high bandwidth
Bipolar	AMI	$B = NI2$	No self-synchronization for long os, DC
Multilevel	2BIQ	$B = N/4$	No self-synchronization for long same double bits
	8B6T	$B = 3N/4$	Self-synchronization, no DC
	4D-PAM5	$B = N/8$	Self-synchronization, no DC
Multiline	MLT-3	$B = N/3$	No self-synchronization for long Os

2. Block Coding

We need **redundancy** to ensure **synchronization** and to provide some kind of **inherent error detecting.**
Block coding can give us this **redundancy and improve the performance** of line coding.

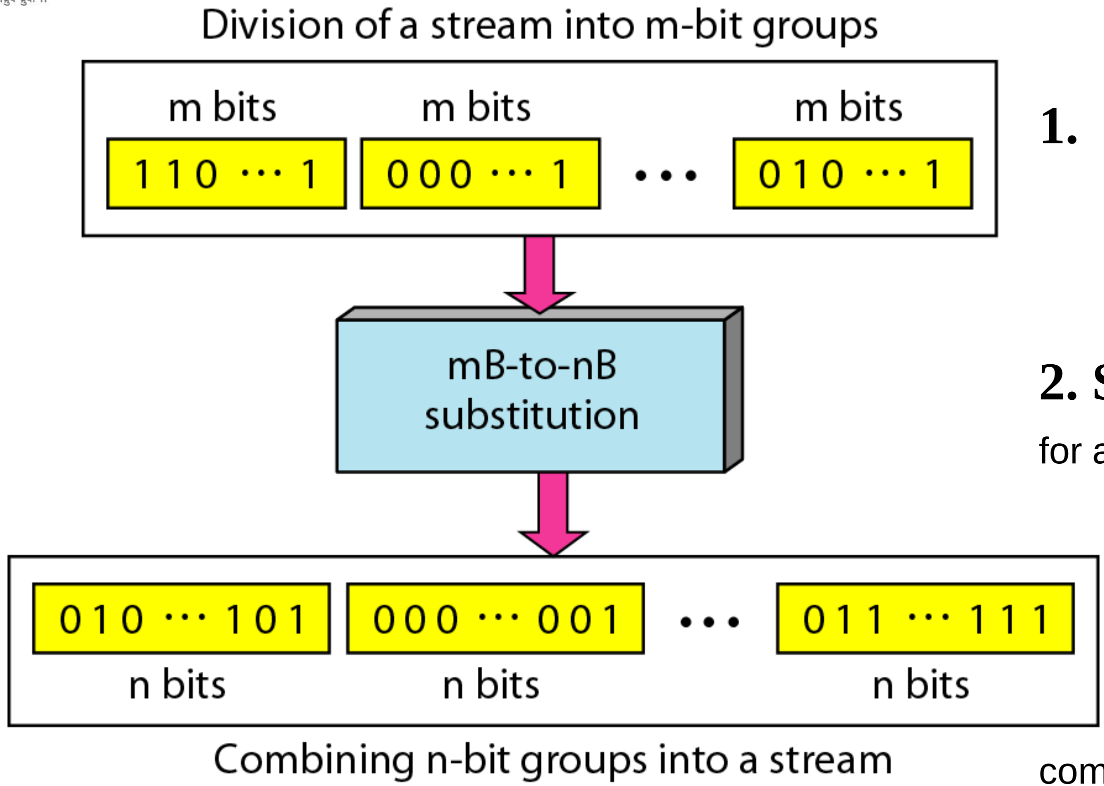
A technique of sending data in **a set of sequence.**

Block coding is done in three steps:

1. **Division**
2. **Substitution**
3. **Combination.**

Need to **add redundant** bits for padding, error checking

Block Coding

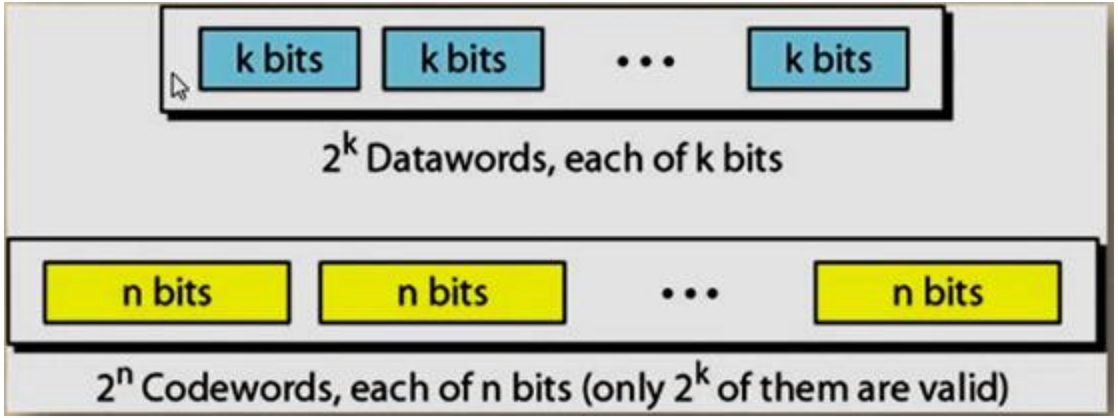


1. **Division (**a sequence of bits is divided into groups of *m* bits**)**

2. **Substitution (**substitute an m-bit group for an n-bit group.**)**

3. **Combination (**n-bit groups are combined together to form a stream**)**

Block Coding



- In block coding, we divide our message into blocks, each of k bits, called datawords.

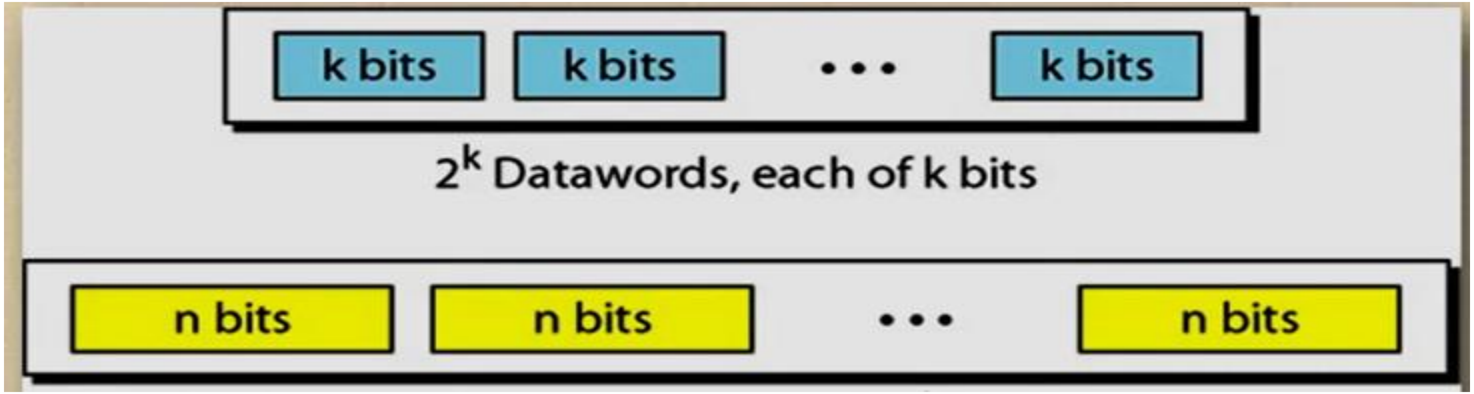
- We add r redundant bits to each block to make the length
  $n = k + r$.

- The resulting n-bit blocks are called codewords.

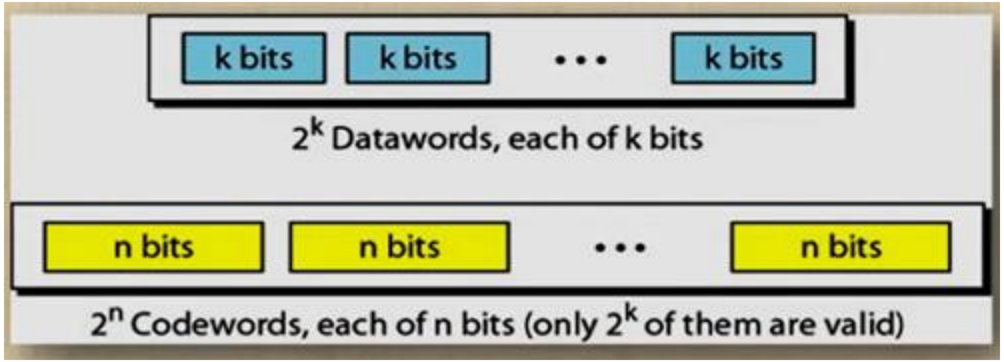
Block Coding

$110 + 11000010 \rightarrow 110\ 11000010$

- With k bits, we can create a combination of 2^k datawords; with n bits, we can create a combination of 2^n codewords.
- Since $n > k$, the number of possible codewords is larger than the number of possible datawords. The same dataword is always encoded as the same codeword. Other codewords are invalid or illegal.



Block Coding



For example, if $k = 4$ and $n = 5$, we have $2^4 = 16$ datawords and $2^5 = 32$ codewords. Here 16 out of 32 codewords are used for message transfer and rest are not used. Hence remainig codewords are considered as invalid codewords

Scrambling

- Earlier coding schemes **are not suitable for long distance because of DC component.**
- Scrambling is a technique to avoid **long sequence of 0’s** used to create a sequence of bits that has the required c/c’s for transmission - self clocking, no low frequencies, no wide bandwidth.
- It is implemented at the same time as encoding, the bit stream is created on the fly.
- It replaces ‘unfriendly’ runs of bits with a **violation code** that is easy to recognize and removes the unfriendly c/c.

Scrambling

a. B8ZS

Bipolar with 8 zero substitution

Replace 8 consecutive zeros

Case 1: If no 8 consecutive zeros

same as AMI

Bit 0: zero

Bit 1: alternating positive and negative voltage

Case 2: If 8 consecutive zeros

PREVIOUS VOLTAGE LEVEL	SUBSTITUTION
POSITIVE	0 0 0 + - 0 - +
NEGATIVE	0 0 0 - + 0 + -

The **V in the sequence denotes** ***violation*****,** this is a nonzero voltage that **breaks an AMI rule** of encoding (opposite polarity from the previous).

The **B in the sequence denotes** ***bipolar***, which means a **nonzero level voltage** in accordance with the AMI rule.

Scrambling

a. **B8ZS**

Case 1: If no 8 consecutive zeros

same as AMI

Bit 0: zero

Bit 1: alternating positive and negative voltage

Replace 8 consecutive zeros

Case 2: If 8 consecutive zeros

PREVIOUS VOLTAGE LEVEL	SUBSTITUTION
POSITIVE	0 0 0 + - 0 - +
NEGATIVE	0 0 0 - + 0 + -

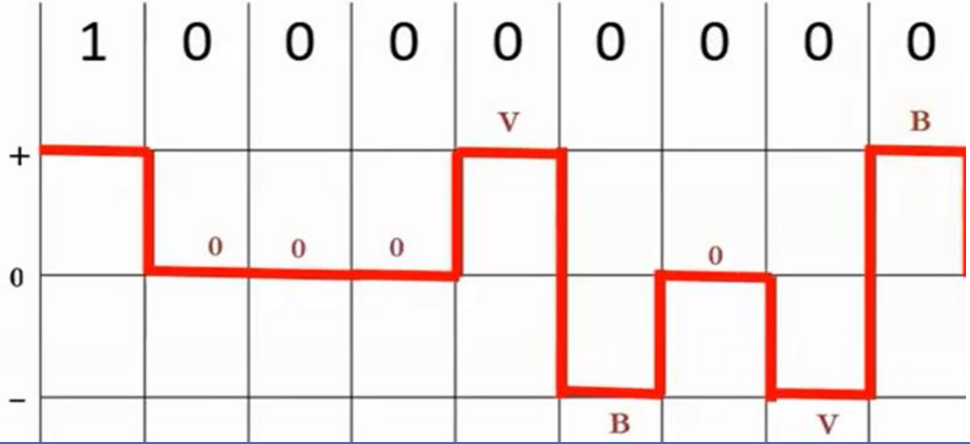
Example 1:

Data : 1 0 0 0 0 0 0 0 0

V: VIOLATION

B: BIPOLAR

0 0 0 V B 0 V B



Scrambling

a. **B8ZS**

Case 1: If no 8 consecutive zeros

same as AMI

Bit 0: zero

Bit 1: alternating positive and negative voltage

Replace 8 consecutive zeros

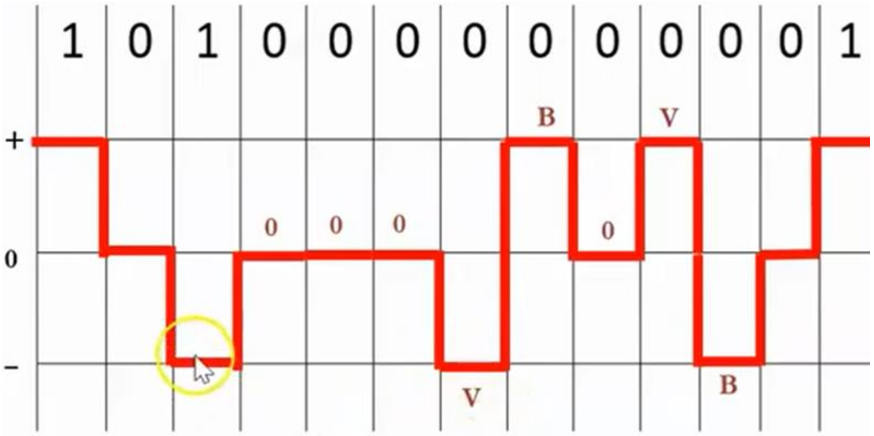
Case 2: If 8 consecutive zeros

PREVIOUS VOLTAGE LEVEL	SUBSTITUTION
POSITIVE	0 0 0 + - 0 - +
NEGATIVE	0 0 0 - + 0 + -

Example 2:

Data : 1 0 1 0 0 0 0 0 0 0 0 0 1

0 0 0 V B 0 V B



Scrambling

b. HDB3

High-Density Bipolar 3 -zero

Replace 4 consecutive zeros

Case 1: If no 4 consecutive zeros
same as AMI
Bit 0: zero
Bit 1: alternating positive and negative voltage

Case 2: If 4 consecutive zeros

Number of non-zero voltages	Previous voltage	Substitution
ODD	POSITIVE	0 0 0 +
	NEGATIVE	0 0 0 -
EVEN	POSITIVE	- 0 0 -
	NEGATIVE	+ 0 0 +

Number of non zero voltages after last substitution

Scrambling

b. HDB3

Replace 4 consecutive zeros

Case 1: If no 4 consecutive zeros

same as AMI

Bit 0: zero

Bit 1: alternating positive and negative voltage

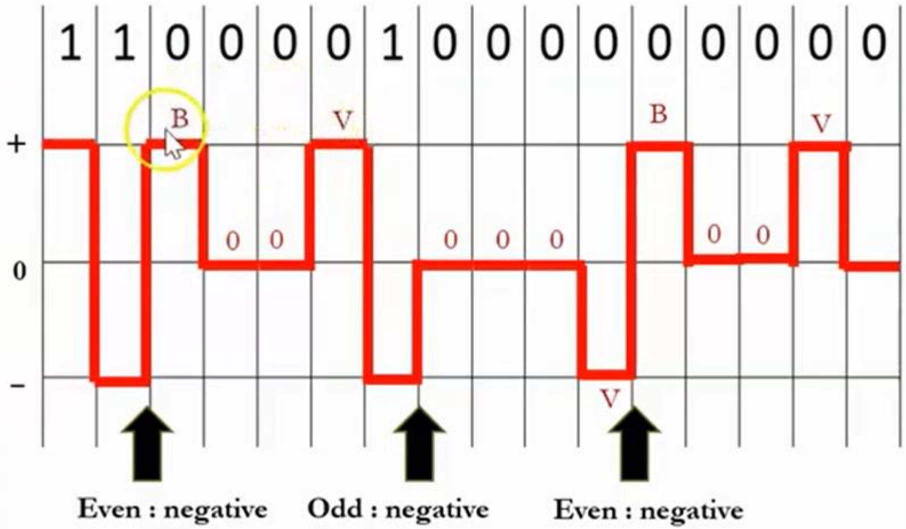
Case 2: If 4 consecutive zeros

Number of non-zero voltages	Previous voltage	Substitution
ODD	POSITIVE	0 0 0 +
	NEGATIVE	0 0 0 -
EVEN	POSITIVE	- 0 0 -
	NEGATIVE	+ 0 0 +

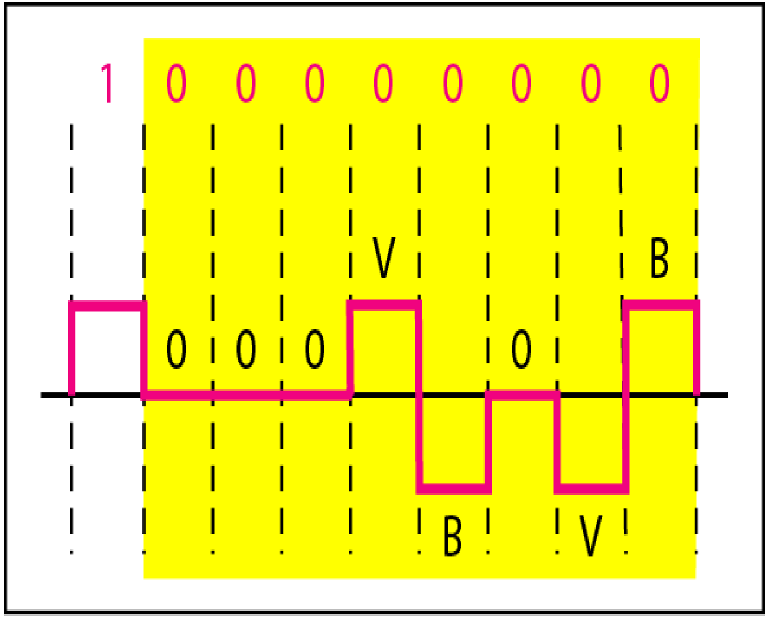
Number of non zero voltages after last substitution

Example 1:
Data : 1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0

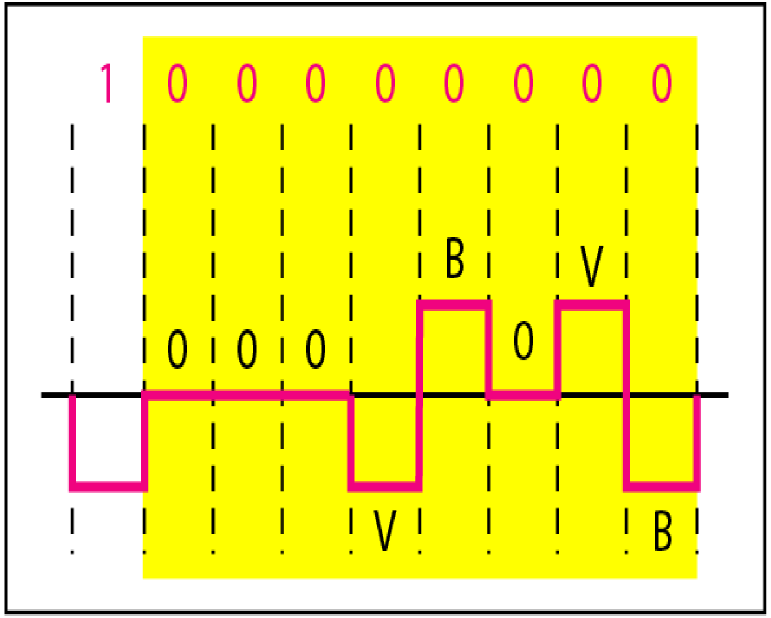
EVEN: B 0 0 V ODD : 0 0 0 V B: bipolar V:violation



Scrambling



a. Previous level is positive.



b. Previous level is negative.

Analog-to-Digital Conversion

Analog-to-Digital Conversion

- A **digital signal** is **superior** to **an analog signal.**
- It is more robust to noise and can easily be recovered, corrected and amplified. For this reason, it is better to change an analog signal to digital data.

Analog-to-Digital Conversion: Two techniques

1. Pulse Code Modulation (PCM) and

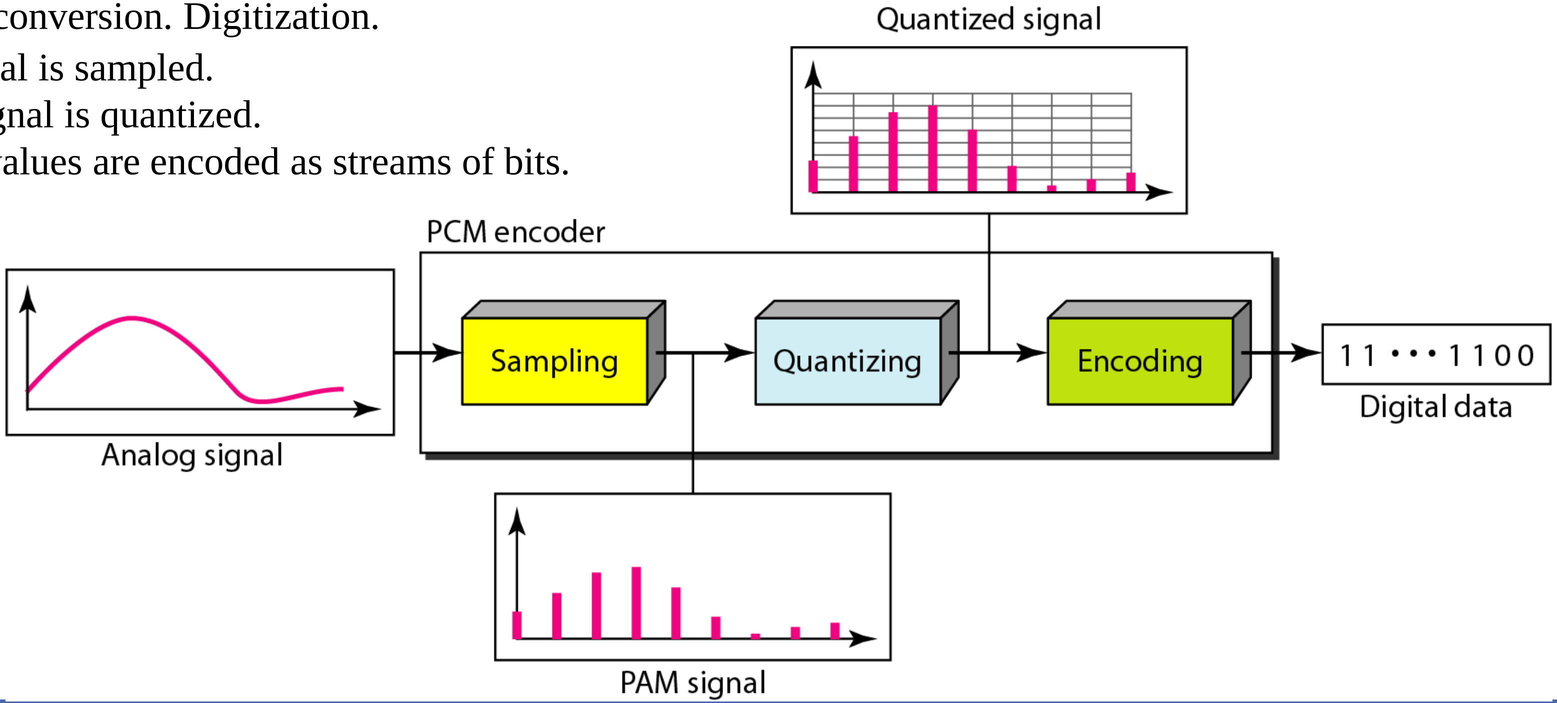
2. Delta Modulation(DM)

Components of PCM encoder

Pulse Code Modulation.

Analog to digital conversion. Digitization.

1. The analog signal is sampled.
2. The sampled signal is quantized.
3. The quantized values are encoded as streams of bits.



Three different sampling methods for PCM - Pulse Code Modulation, PAM – Pulse Amplitude Modulation = Sampling

According to the Nyquist theorem, the sampling rate must be at least 2 times the highest frequency contained in the signal.

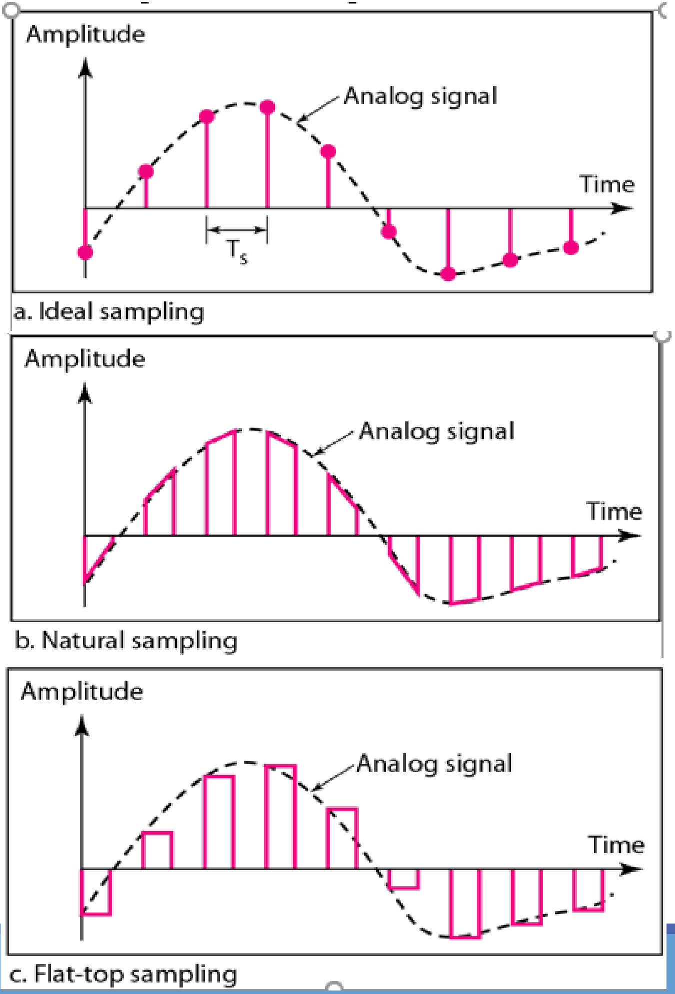
Analog signal is sampled every **Ts secs.** where *Ts* is the **sample interval or period.** The inverse of the sampling interval is called the **sampling rate or sampling frequency.**

There are 3 sampling methods:

1. Ideal - pulses from the analog signal are sampled. This is an **ideal sampling method** and cannot be easily implemented.

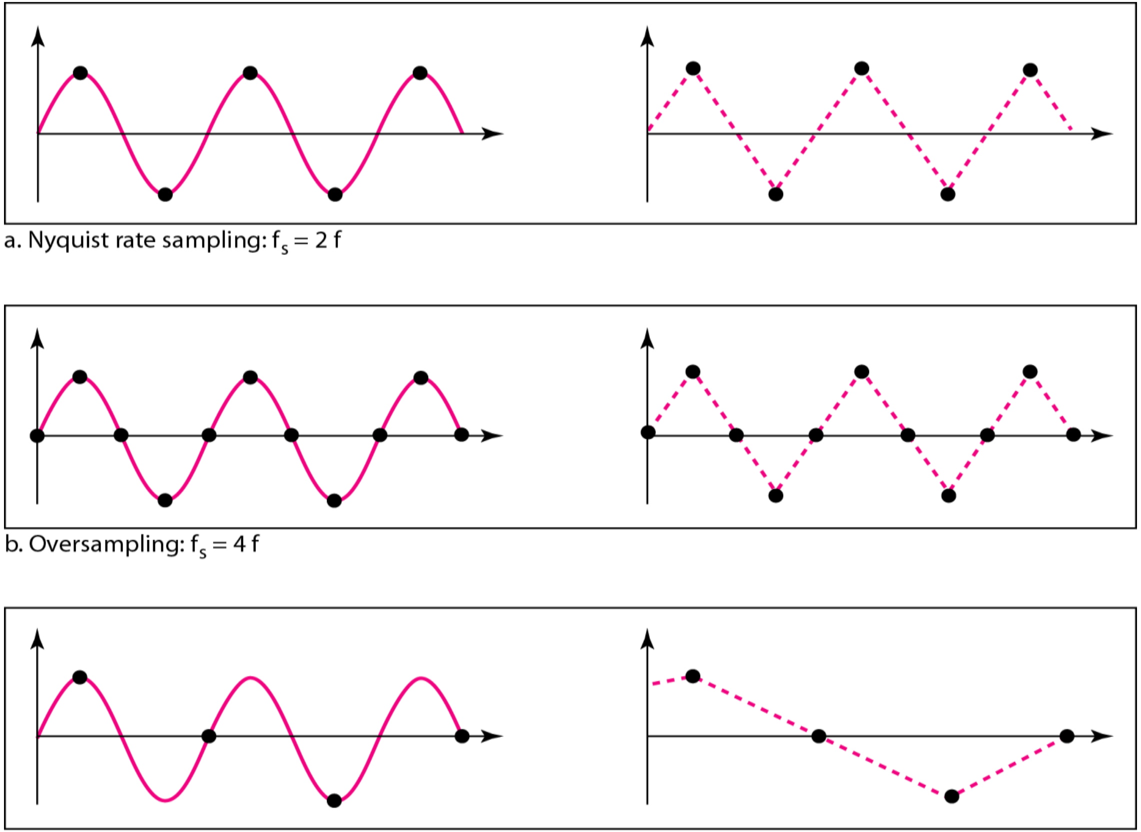
2. Natural - a pulse of short width with varying amplitude. A high-speed switch is turned on for only the small period of time when the sampling occurs. **The result is a sequence of samples that retains the shape of the analog signal.**

3. Flattop - The **most common sampling method**, called **sample and hold**, however, creates flat-top samples by using a circuit.



a. Ideal sampling
b. Natural sampling
c. Flat-top sampling

Example 7 *Recovery of a sampled sine wave*


a. Nyquist rate sampling: $f_s = 2f$

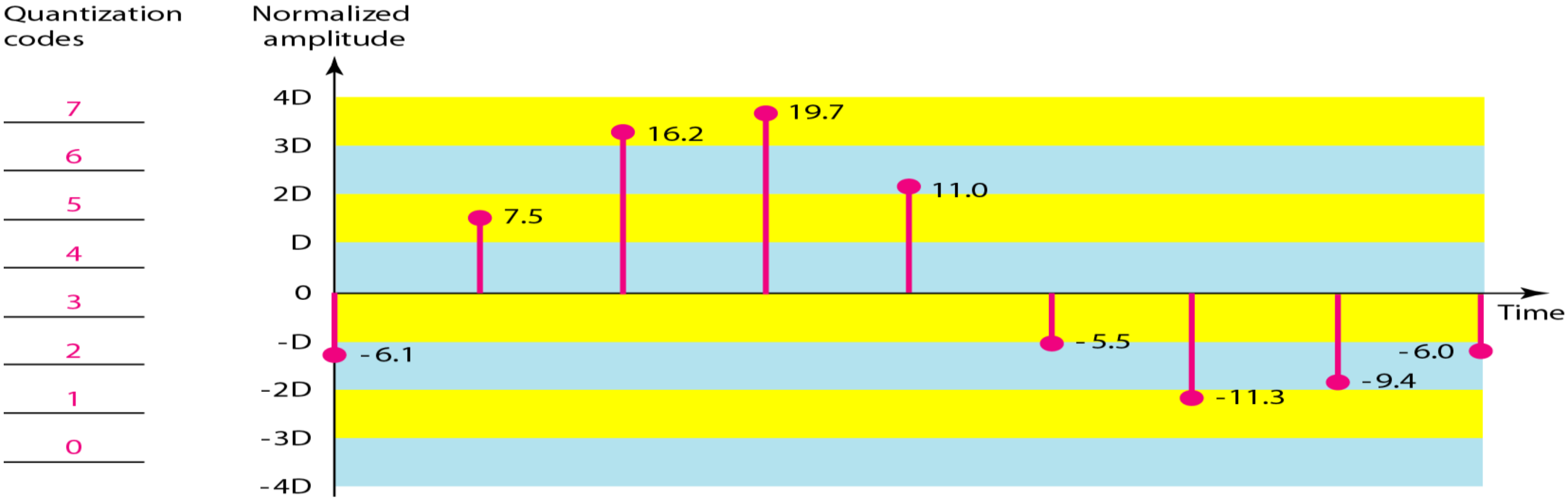
b. Oversampling: $f_s = 4f$

c. Undersampling: $f_s = f$

For an example of the Nyquist theorem, let us sample a simple sine wave at three sampling rates: $f_s = 4f$ (2 times the Nyquist rate), $f_s = 2f$ (Nyquist rate), and $f_s = f$ (one-half the Nyquist rate). Figure 4.24 shows the sampling and the subsequent recovery of the signal.

It can be seen that sampling at the Nyquist rate can create a good approximation of the original sine wave (part a). Oversampling in part b can also create the same approximation, but it is redundant and unnecessary. Sampling below the Nyquist rate (part c) does not produce a signal that looks like the ***original sine wave.***

Binary Encoding



Normalized PAM values	-1.22	1.50	3.24	3.94	2.20	-1.10	-2.26	-1.88	-1.20
Normalized quantized values	-1.50	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized error	-0.38	0	+0.26	-0.44	+0.30	-0.40	-0.24	+0.38	-0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

Quantization Steps

1. Assume we have a voltage signal with amplitudes V_{min}=-20V and V_{max}=+20V.
2. We want to use L=8 quantization levels.
3. Zone width $\Delta = (20 - -20)/8 = 5$
4. The 8 zones are: -20 to -15, -15 to -10, -10 to -5, -5 to 0, 0 to +5, +5 to +10, +10 to +15, +15 to +20
5. The midpoints are: -17.5, -12.5, -7.5, -2.5, 2.5, 7.5, 12.5, 17.5

Binary Encoding

- Each zone is then assigned a binary code.
- The number of bits required to encode the zones, or the number of bits per sample as it is commonly referred to, is obtained as follows:
  - $n_b = \log_2 L$
- Given our example, $n_b = 3$
- The 8 zone (or level) codes are therefore: 000, 001, 010, 011, 100, 101, 110, and 111
- Assigning codes to zones:
- 000 will refer to zone -20 to -15
- 001 to zone -15 to -10, etc.

PCM

Advantages

- Uniform transmission quality
- Compatibility of different class of traffic in network
- Integrated Digital Network
- Increased utilization of existing circuit.
- Good performance over poor transmission path.

Disavantages

- Large Bandwidth requires for transmission
- Noise and Crosstalk leaves low but attenuation will increase

Applications

- In Compact disk
- Digital Telephony
- Digital Audio applications

Example 8

We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample?

Solution

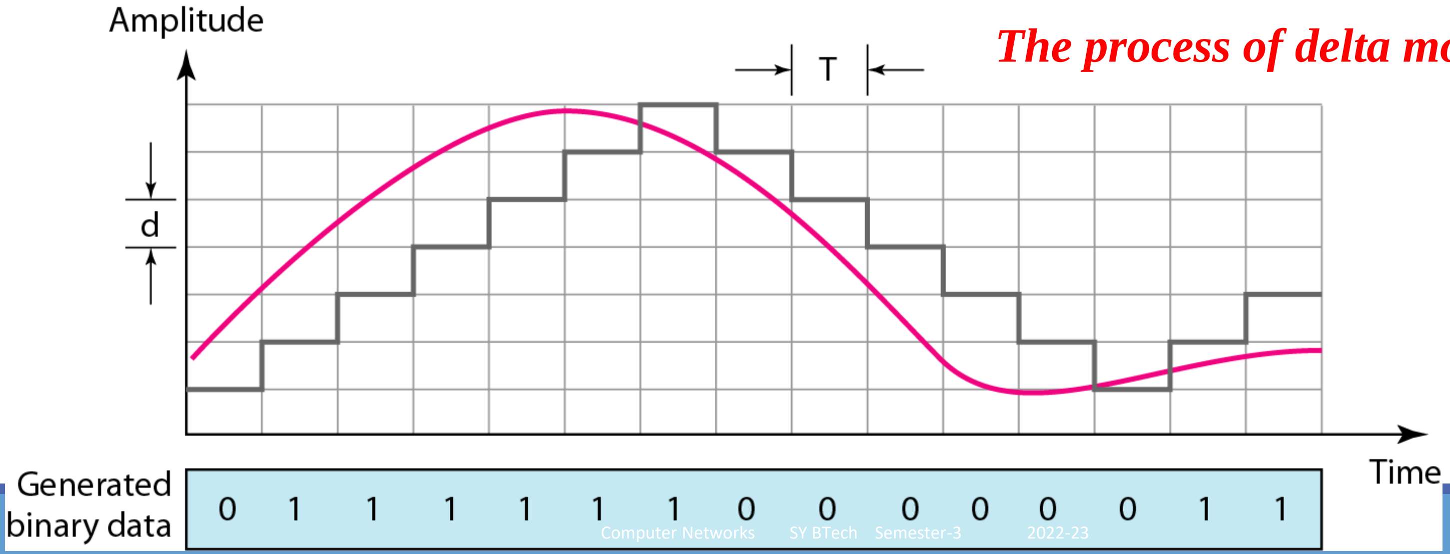
The human voice normally contains frequencies from 0 to 4000 Hz. So the sampling rate and bit rate are calculated as follows:

$$\text{Sampling rate} = 4000 \times 2 = 8000 \text{ samples/s}$$
$$\text{Bit rate} = 8000 \times 8 = 64{,}000 \text{ bps} = 64 \text{ kbps}$$

Delta Modulator

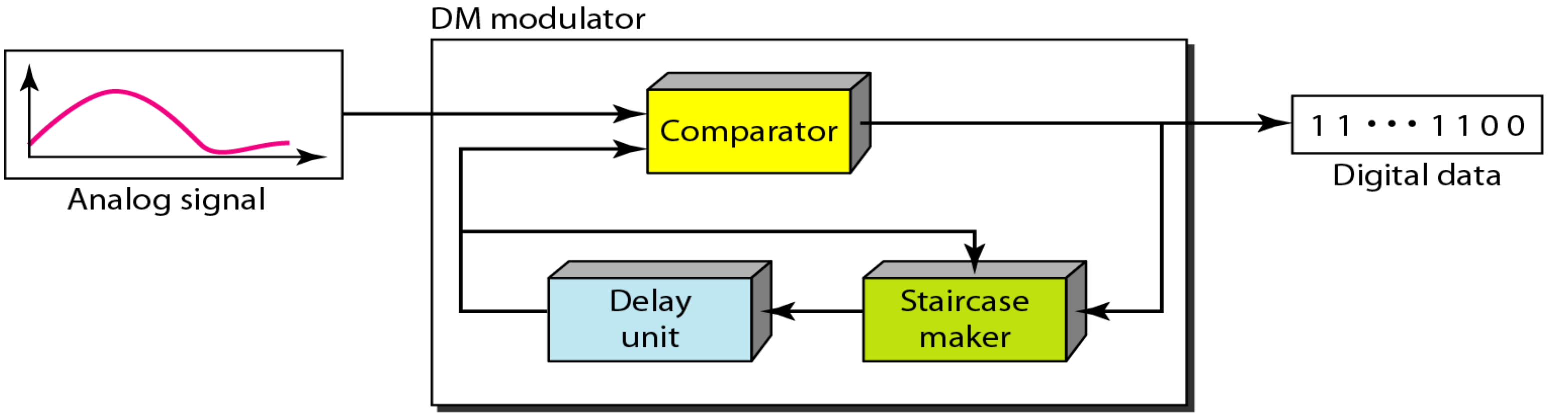
- PCM is a very complex technique. Other techniques have been developed to reduce the complexity of PCM.
- The simplest is delta modulation.
- PCM finds the value of the signal amplitude for each sample; DM finds the change from the previous sample.
- Note that there are no code words here; bits are sent one after another.

The process of delta modulation



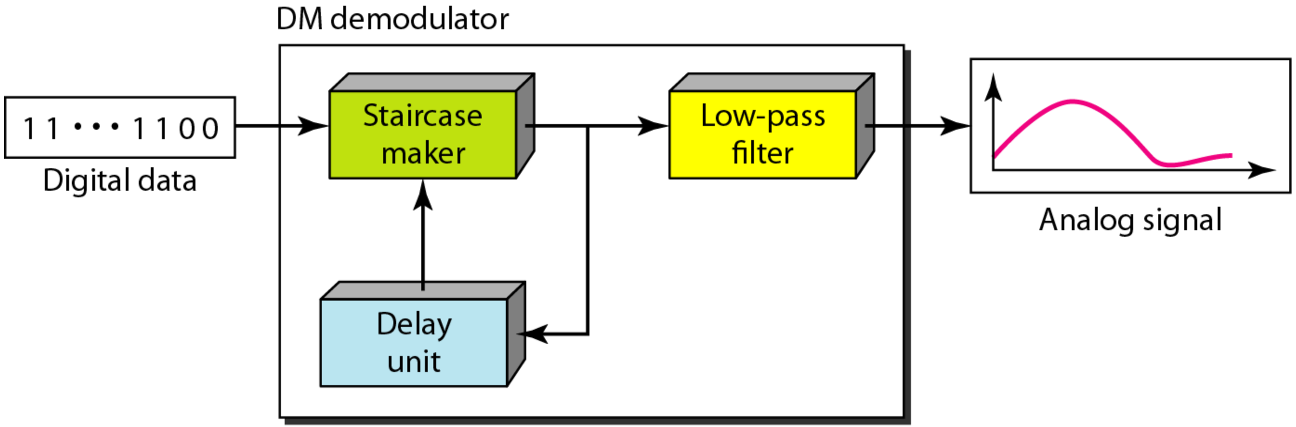
Delta modulation components

- Modulator: is used at the sender site to create a stream of bits from an analog signal.
- If the delta is positive, the process records a 1; if it is negative, the process records a 0.
- Base of comparison is required. Which is done by Staircase Maker.
- The modulator, at each sampling interval, compares the value of the analog signal with the last value of the staircase signal.
- Note that we need a delay unit to hold the staircase function for a period between two comparisons.



Delta demodulation components

- Demodulator: The demodulator takes the digital data and, using the staircase maker and the delay unit, creates the analog signal.
- Low-pass filter is used for smoothing.
- Adaptive DM: A better performance can be achieved if the value of δ is not fixed. In adaptive delta modulation, the value of δ changes according to the amplitude of the analog signal.
- Quantization Error: DM is not perfect. Quantization error is always introduced in the process. The quantization error of DM, however, is much less than that for PCM.



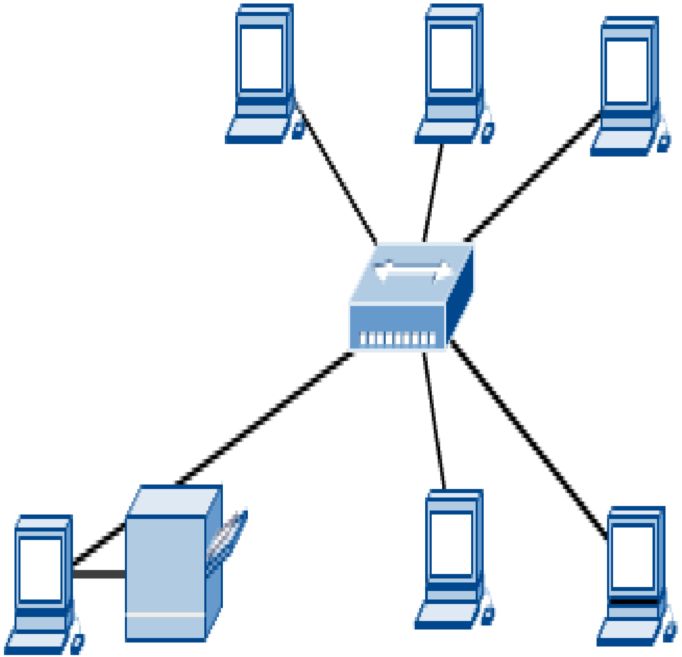
Types of Networks

Computer Networks

- Autonomous computers are network or a collection of networks that are all managed and supervised by a single entity or organization

- Two or more autonomous computers are connected

- Geographic location: anywhere



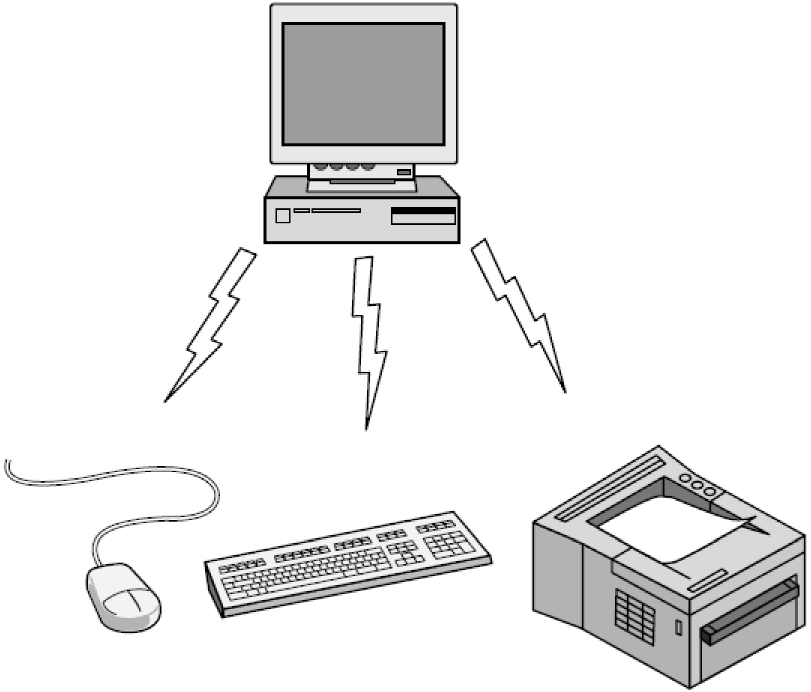
Types of Networks

Classification of interconnected processors:

- Personal area networks (PAN)
- Local area networks (LAN)
- Metropolitan area networks (MAN)
- Wide are networks (WAN)
- Ad-hoc network

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

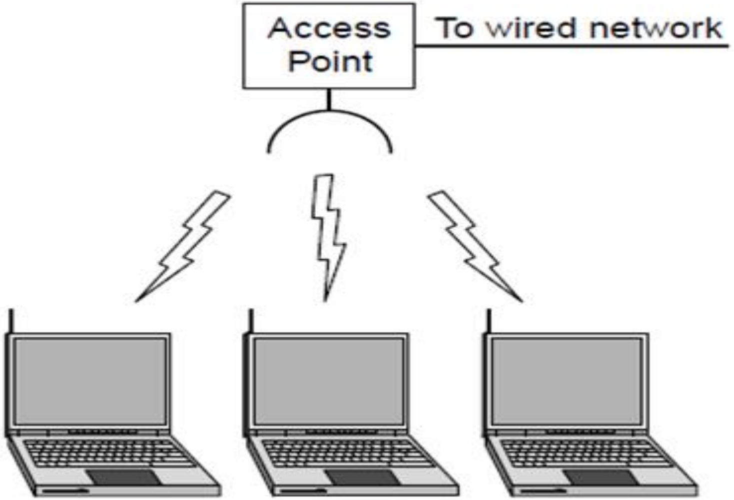
Personal Area Network (PAN)

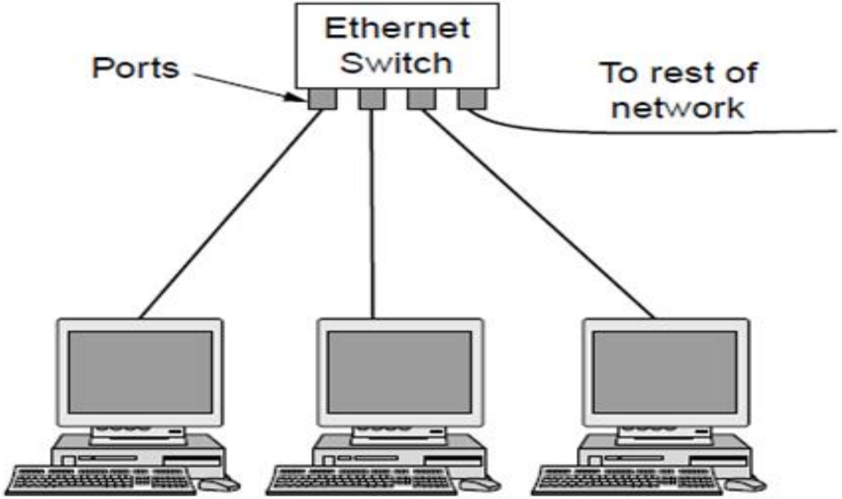


Local Area Network (LAN)

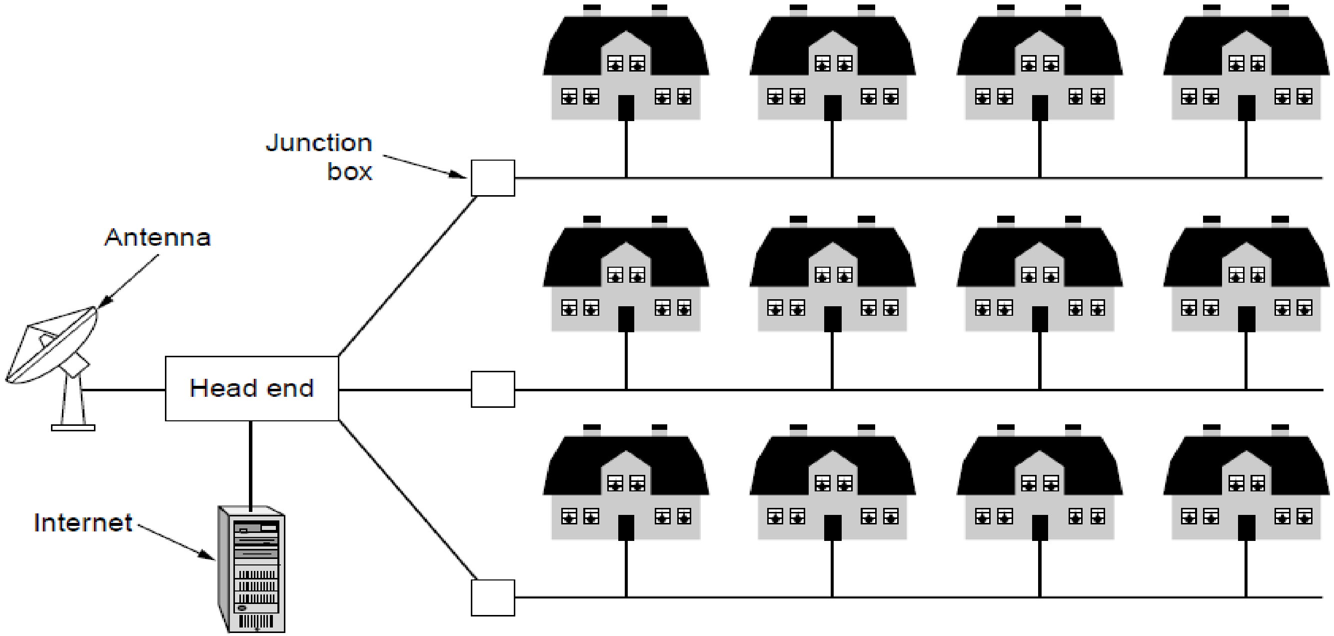
Wireless and Wired LAN

(a) 802.11 (b) Switched Ethernet



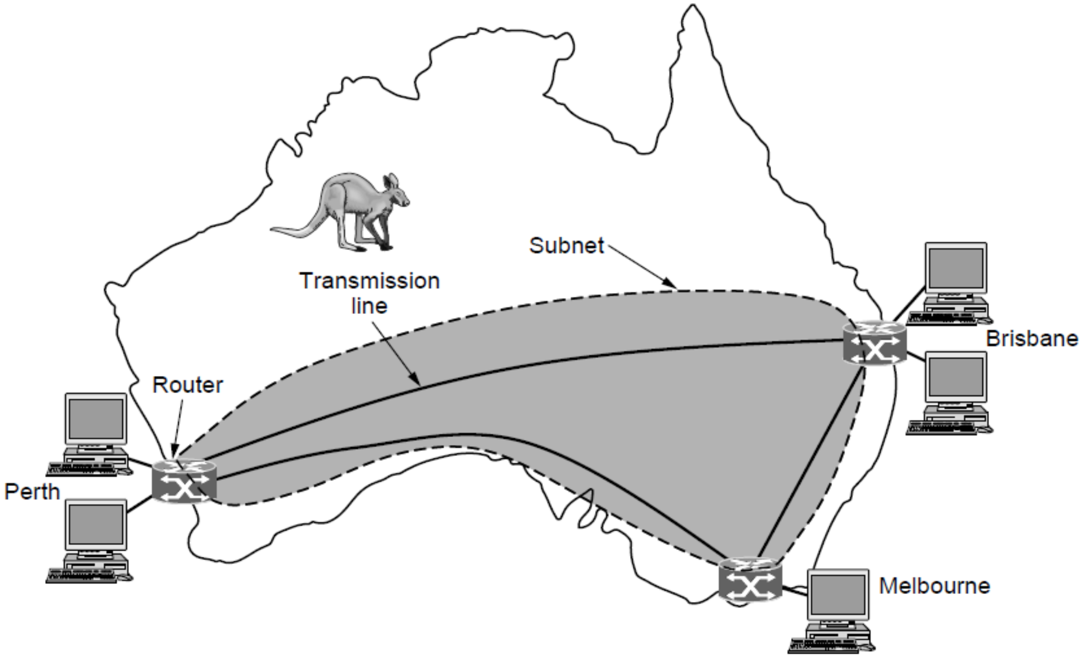


Metropolitan Area Network(MAN): based on cable TV

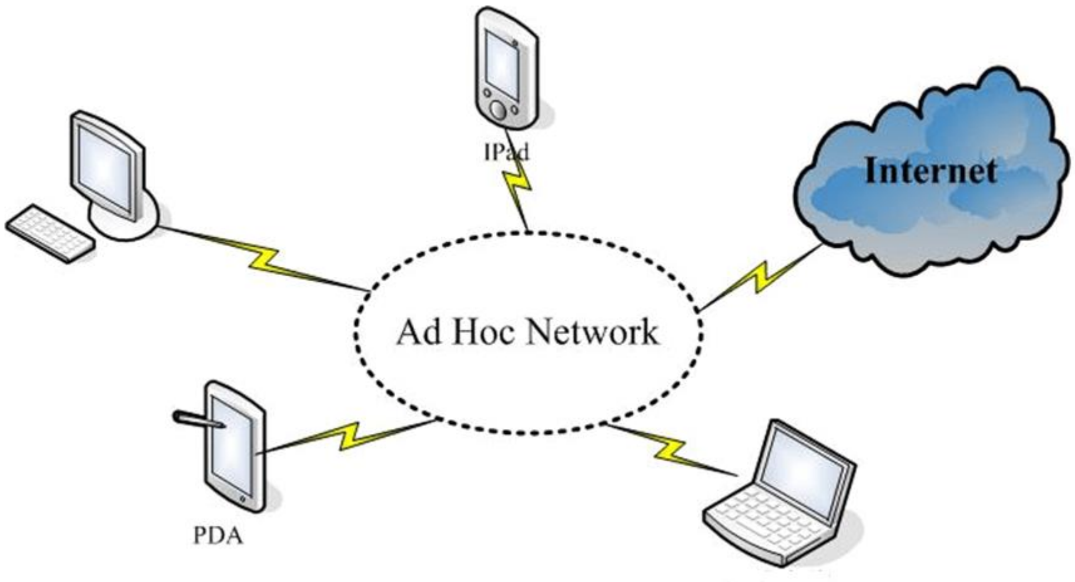


Wide Area Network (WAN)

WAN: connects three branch offices in Australia



Ad-hoc Network

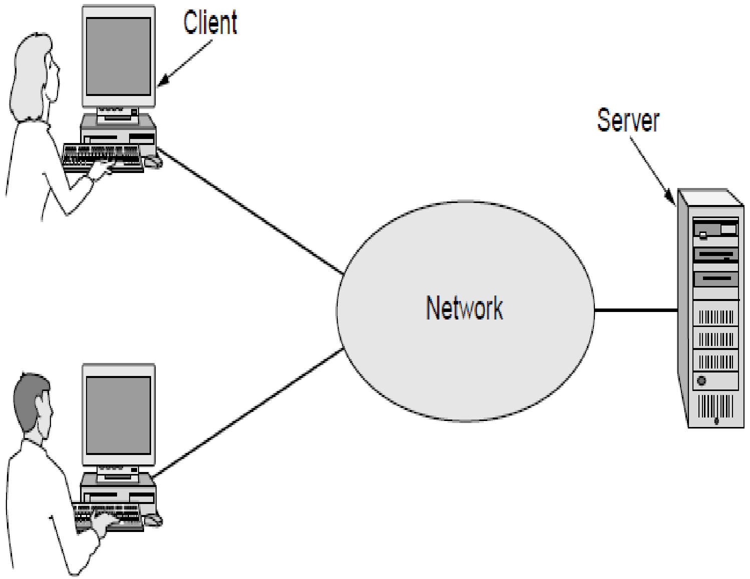


Comparision of LAN, MAN, WAN

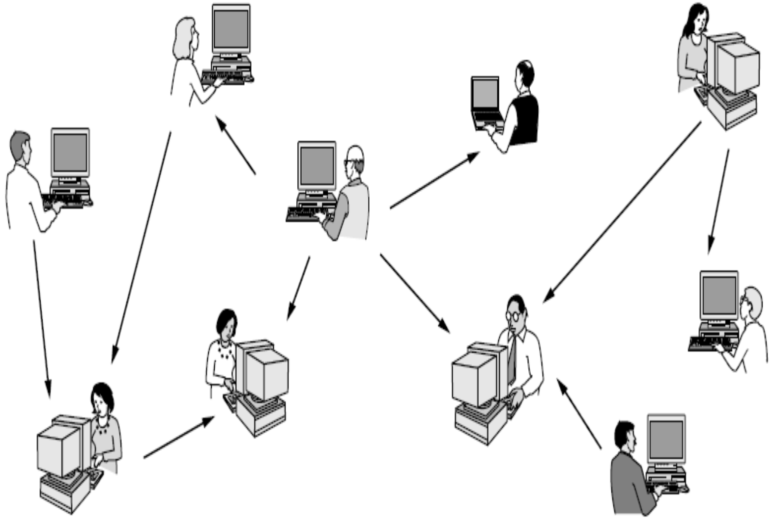
Sr.No.	Key	LAN	MAN	WAN
1	**Definition**	LAN stands for Local Area Network.	MAN stands for Metropolitan Area Network.	WAN stands for Wide Area Network.
2	**Ownership**	LAN is often owned by private organizations.	MAN ownership can be private or public.	WAN ownership can be private or public.
3	**Speed**	LAN speed is quiet high.	MAN speed is average.	WAN speed is lower than that of LAN.
4	**Delay**	Network Propagation Delay is short in LAN.	Network Propagation Delay is moderate in MAN.	Network Propagation Delay is longer in WAN.
5	**Congestion**	LAN has low congestion as compared to WAN.	MAN has higher congestion than LAN.	WAN has higher congestion than both MAN and LAN.
6	**Fault Tolerance**	Fault Tolerance of LAN is higher than WAN.	Fault Tolerance of MAN is lower than LAN.	Fault Tolerance of WAN is lower than both LAN and MAN.
7	**Maintenance**	Designing and maintaining LAN is easy and less costly than WAN.	Designing and maintaining WAN is complex and more costly than LAN.	Designing and maintaining WAN is complex and more costly than both LAN and MAN.

Uses of Computer Networks

- Business Applications



- Business Applications Home Applications: P2P having no fixed clients & servers



Uses of Computer Networks

- Mobile Users: Combinations of wireless networks and mobile computing

Wireless	Mobile	Typical applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in unwired buildings
Yes	Yes	Store inventory with a handheld computer

- Social Issues
  - Network neutrality
  - Digital Millennium Copyright Act
  - Profiling users
  - Phishing

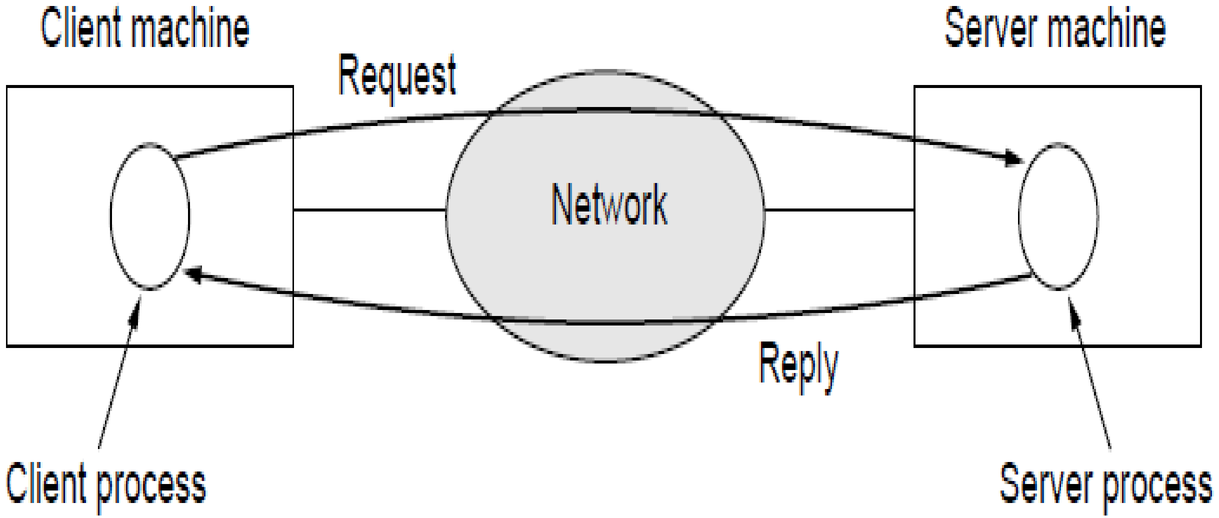
Network Architectures

Network Architectures

- Client-Server
- Peer-to-Peer
- Distributed Network
- Software Define Network

Client-Server Model

Client-server model: involves requests and replies

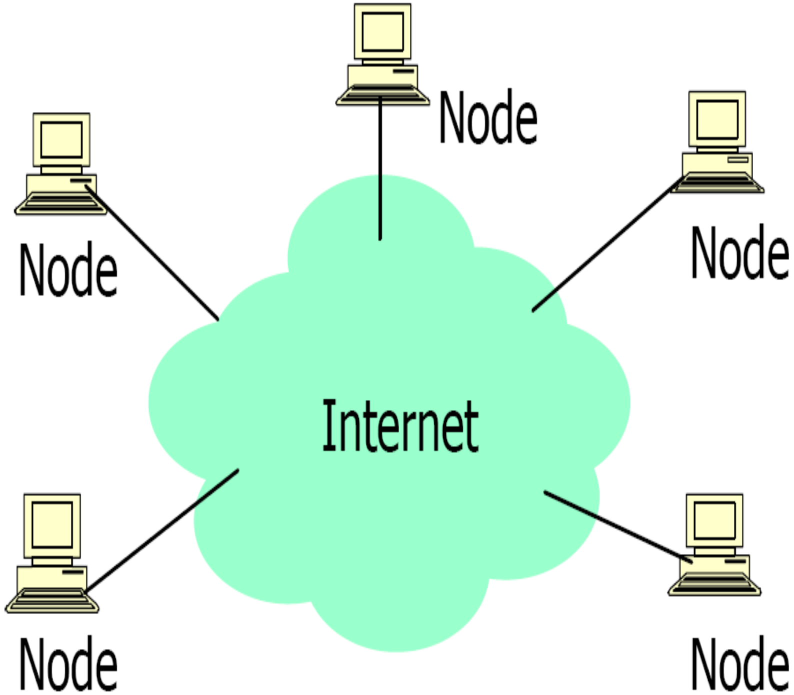


Peer-to-Peer Architecture

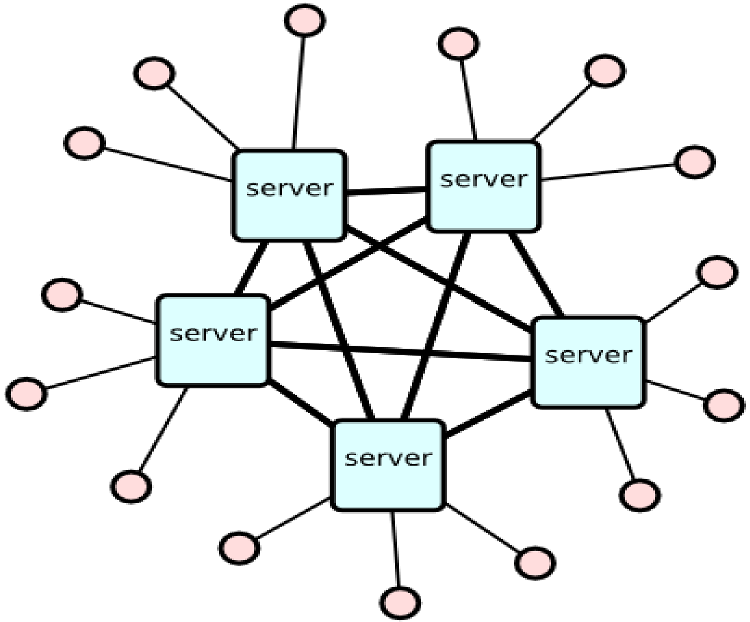
- All nodes acts as a clients and servers
- - Provides and consume data
- -Any node can initiate a connection

- No centralized data source

-The ultimate form of democracy on the Internet
-The ultimate threat to copy-right protection on the Internet

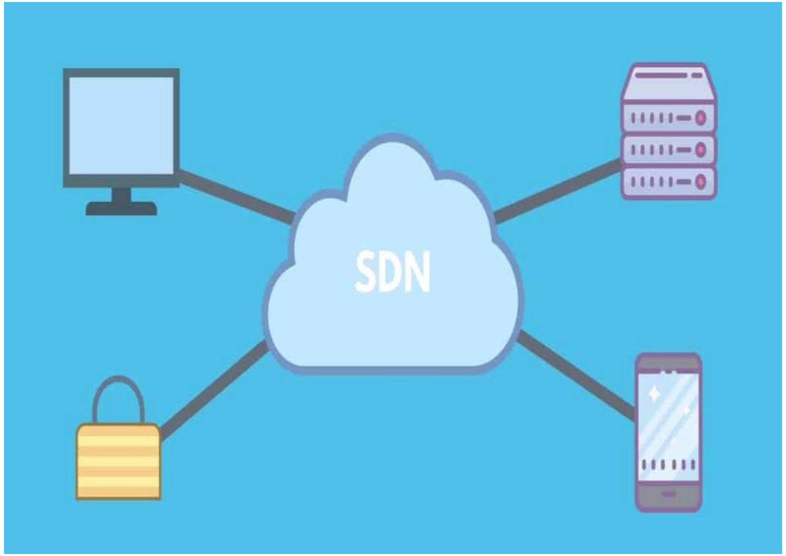


Distributed Network



Distributed networks are part of distributed computing architecture, in which enterprise IT infrastructure resources are divided over a number of networks, processors and intermediary devices

Software Define Network



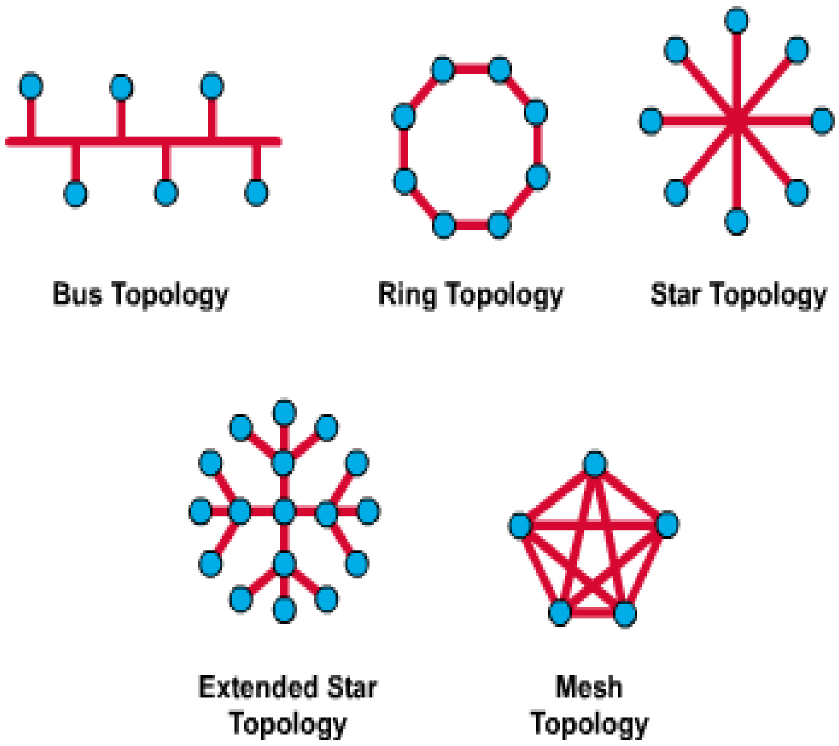
- Software-Defined Networking (SDN) is dynamic, manageable, cost-effective, and adaptable for the high-bandwidth, dynamic nature of today's applications
- This architecture decouples the network control and forwarding functions enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services

Network Topologies

Network Topologies

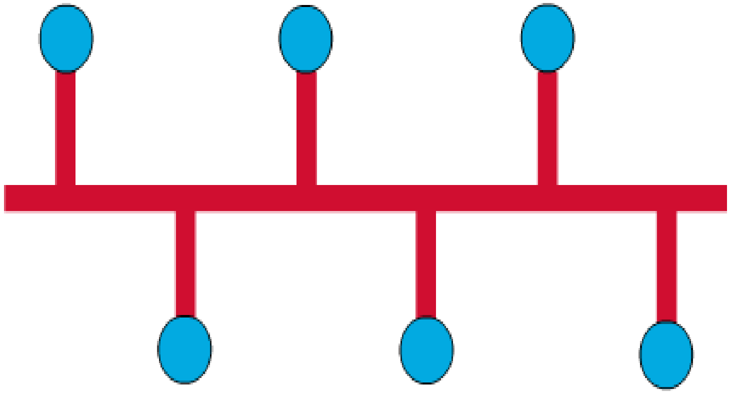
- Way of connection between computers, printers and other devices

- Layout of the wire and devices as well as the paths used by data transmissions



Bus Topology

- Commonly referred as a linear bus
- All the devices are connected by one single cable



Advantages

- It is easy to set up, handle, and implement.
- It is best-suited for small networks.
- It costs very less.

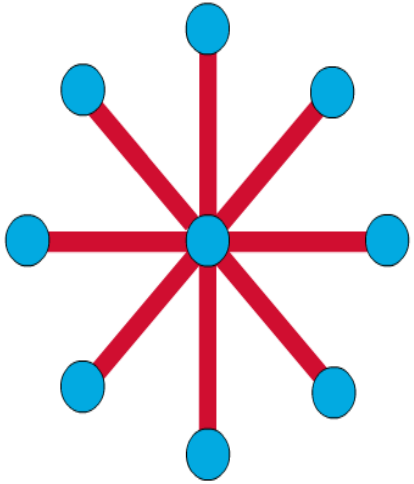
Disadvantages

- The cable length is limited - limits the number of network nodes
- When the number of devices connected to the bus increases, the efficiency decreases.
- A fault in the central bus leads to network failure.
- Each device on the network “sees” all the data being transmitted.

Star Topology

Star topology

- most commonly used architecture in Ethernet LANs
- resembles spokes in a bicycle wheel



Advantages of Star Topology

- Due to its centralized nature, the topology offers simplicity of operation.
- It also achieves isolation of each device in the network.
- Adding or removing network nodes is easy.
- Due to the centralized nature, it is easy to detect faults in the network devices.

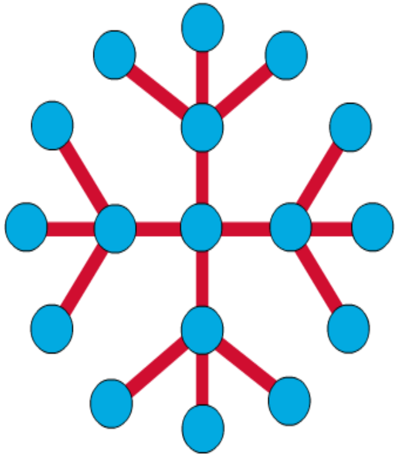
Disadvantages of Star Topology

- Network operation depends on the functioning of the central hub. Hence, central hub failure leads to failure of the entire network.
- Also, the number of nodes that can be added, depends on the capacity of the central hub.
- The setup cost is quite high.

Tree Topology

Extended star topology or tree topology

- significantly reduces the traffic on the wires by sending packets only to the wires of the destination host
- network devices that filter frames or packets like bridges, switches and routers



Advantages of Tree Topology

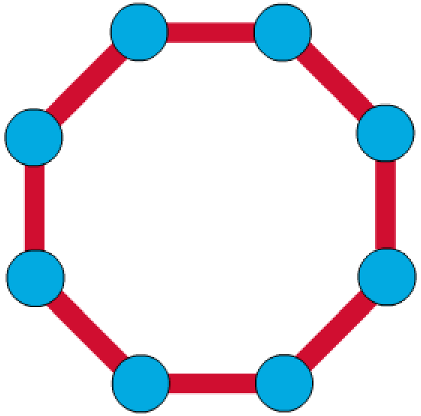
- The tree topology is useful in cases where a star or bus cannot be implemented individually.
- Fault identification is easy.
- The network can be expanded by the addition of secondary nodes. Thus, scalability is achieved.

Disadvantages of Tree Topology

- As multiple segments are connected to a central bus, the network depends heavily on the bus. Its failure affects the entire network
- Owing to its size and complexity, maintenance is not easy and costs are high
- Though it is scalable, the number of nodes that can be added depends on the capacity of the central bus and on the cable type.

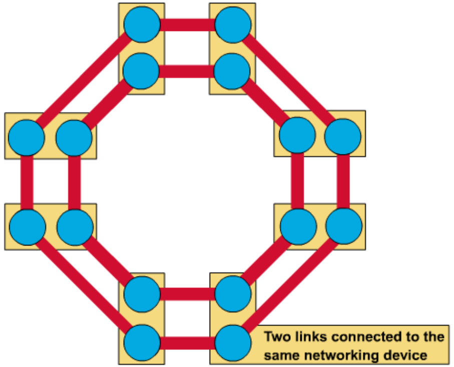
Ring Topology

- A frame travels around the ring, stopping at each node
- A Node wants to transmit data it adds the data as well as the destination address to the frame, which takes the data out of the frame
- Single ring – all the devices on the network share a single cable
- Dual ring – allows data to be sent in both directions



Advantages of Ring Topology

- A central server is not required
- The traffic is unidirectional and the data transmission is high-speed
- In comparison to a bus, a ring is better at handling load.
- The adding or removing of network nodes is easy.
- It is less costly than a star topology.

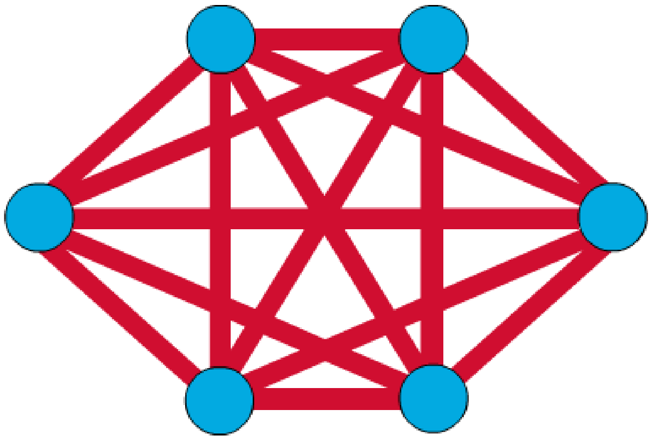


Disadvantages of Ring Topology

- The failure of a single node in the network can cause the entire network to fail
- The movement made to network nodes affect the entire network’s performance.

Mesh Topology

- Connects all devices (nodes) to each other for redundancy and fault tolerance
- Used in WANs to interconnect LANs and for mission critical networks like those used by banks and financial institutions
- Implementation is Expensive and difficult
- Advantages of Mesh Topology
- Possible to transmit data from one node to many other nodes at the same time.
- The failure of a single node does not cause the entire network to fail
- It can handle heavy traffic
- Easy to identify faults.



Disadvantages of Mesh Topology

- A lot of cabling is required.
- Costly setup and maintenance
- Administration of a mesh network is difficult

Comparison of network Topologies

Topology	Information Transfer	Setup	Expansion	Troubleshooting	Cost	Cabling Concerns
Star Each computer connects to a central connection device.	All information passes through the central network connection.	Each computer must be close to the central device. 100 meters maximum cable length. Up to 24 computers per network.	Add a new computer by plugging in a new cable from the computer to the connection device.	When one computer goes down, the rest of the network is unaffected. If the connection device goes down, then the network is down.	More expensive of the simple topologies, it requires costly connection device. Usually cheaper than a hybrid network.	Uses twisted pair cable. Requires large amounts of cable. No more than 100 meters from the computer to the connection device.
Bus Single cable connects everything.	One computer at a time sends information. Information goes along the cable and the computer accesses the information off the cable.	Connect the cable from one computer to the next and so on to the end. A terminator is placed at each end of the network.	To add a computer, you must shut down the network and disconnect the cable from the existing computers.	If one computer malfunctions, the entire network goes down.	A cheaper network since there is usually one continuous copper cable.	Single continuous cable connects the devices. Terminator is required at each end of the cable. Uses coaxial or twisted pair cabling.

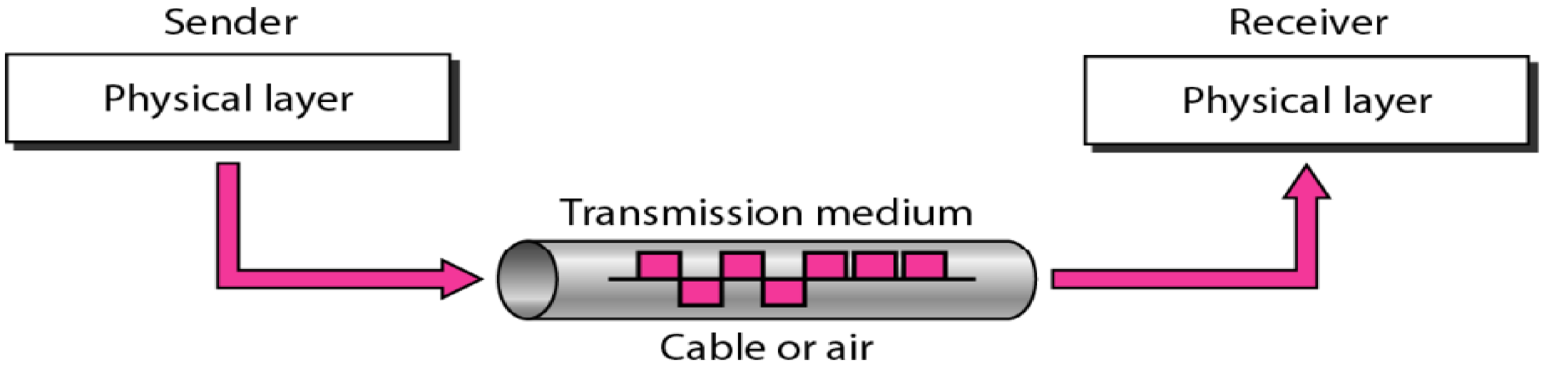
Comparison of network Topologies

Ring Single cable configured in a ring.	Information goes in one direction around the ring and passes along the ring until it reaches the correct computer.	Computers are located close to each other. Setup is easy. There is no connector. The ring has no beginning and no end.	Cable between the computers must be broken to add a new computer, so the network is down until the new device is back online.	If there's a break in the cable or an error in the network, information continues to transfer through the rest of the ring until reaching the point of the break. This makes troubleshooting easy.	One of the more expensive topologies due to high cable costs.	Requires more cabling than other topologies. Uses twisted pair.
Hybrid Mesh Combines two or more different structures.	Often used across long distances. Information transfer can happen in different ways, depending on the other topologies.	Often created when expanding an existing network. Can use a variety of connection devices.	Connection devices make combining different networks and different topologies easy.	Troubleshooting is most difficult in this topology because of the variety of technologies.	Expensive, large, and usually complicated.	Cabling depends on the types of networks. Can use twisted pair and coaxial cable. Also incorporates fiber optic cabling over long distances.

Transmission media's

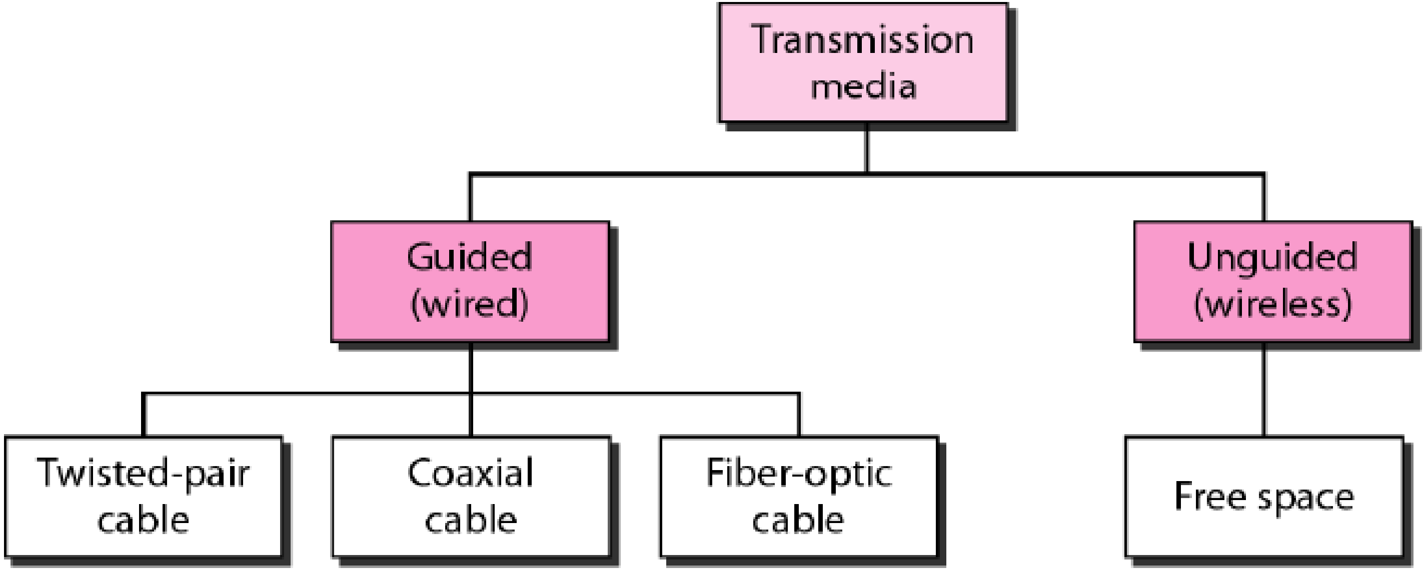
Transmission Media

- Transmission media is a communication channel that carries the information from the sender to the receiver.
- Transmission media is of two types are wired media and wireless media.
- Different transmission media have different properties such as bandwidth, delay, cost and ease of installation and maintenance.
- Transmission media are located below the physical layer



Transmission medium and physical layer

Classification of Transmission Media

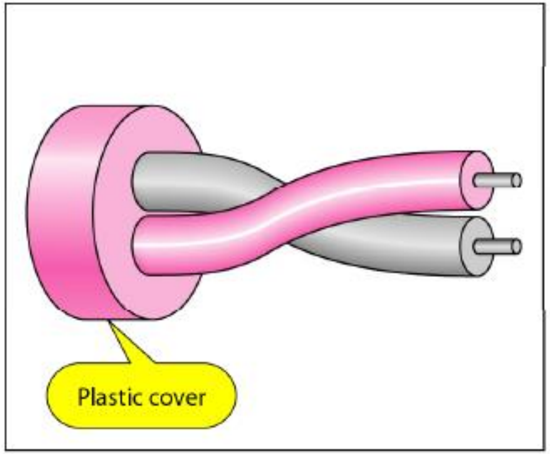


Twisted-pair cable

- A twisted pair consists of two conductors basically copper based with its own plastic insulation, twisted together.
- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference. The receiver uses the difference between the two.

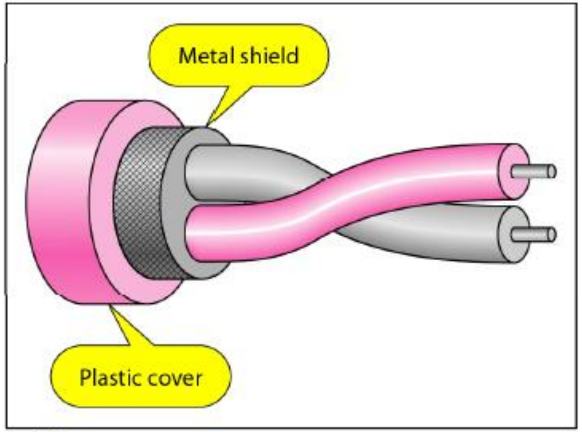
Twisted-pair cable

UTP cable



a. UTP

STP cable



b. STP

The most common twisted-pair cable used in communications is referred to as **unshielded twisted-pair (UTP**). IBM has also produced a version of twisted-pair cable for its use called **shielded twisted-pair (STP).** STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors. Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive.

Twisted-pair cable

UTP cable

Advantages Of Unshielded Twisted Pair:

- It is cheap.
- Installation of the unshielded twisted pair is easy.
- It can be used for high-speed LAN.

Disadvantage:

- This cable can only be used for shorter distances because of attenuation..

STP cable

Characteristics Of Shielded Twisted Pair:

- An installation of STP is easy.
- It has higher capacity as compared to unshielded twisted pair cable.
- It is shielded that provides the higher data transmission rate.

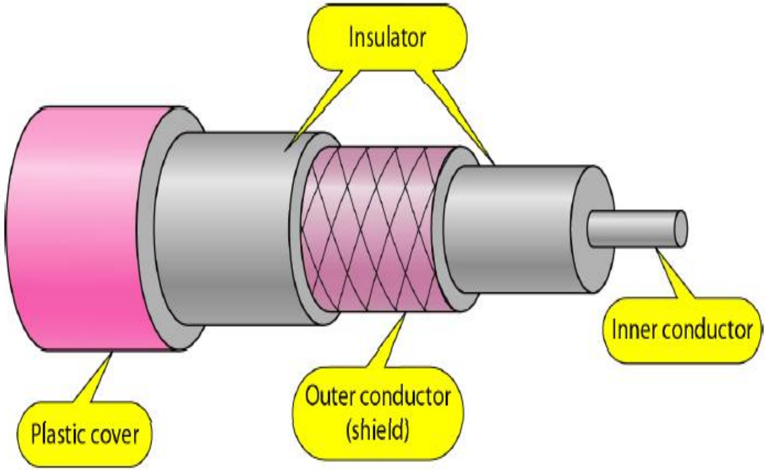
Disadvantages

- It is more expensive as compared to UTP
- It has a higher attenuation rate.

Categories of unshielded twisted-pair cables

Category	Specification	Data Rate (Mbps)	Use
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

Coaxial Cable



- Coaxial cable (Coax) is very commonly used for example, TV wire is usually a coaxial cable.
- Coaxial - contains two conductors parallel to each other.
- It has a higher frequency as compared to Twisted pair cable.
- The inner conductor of the coaxial cable is made up of copper, and the outer conductor is made up of copper mesh.

Advantages Of Coaxial cable:

- The data can be transmitted at high speed.
- It has better shielding as compared to twisted pair cable.
- It provides higher bandwidth.

Applications

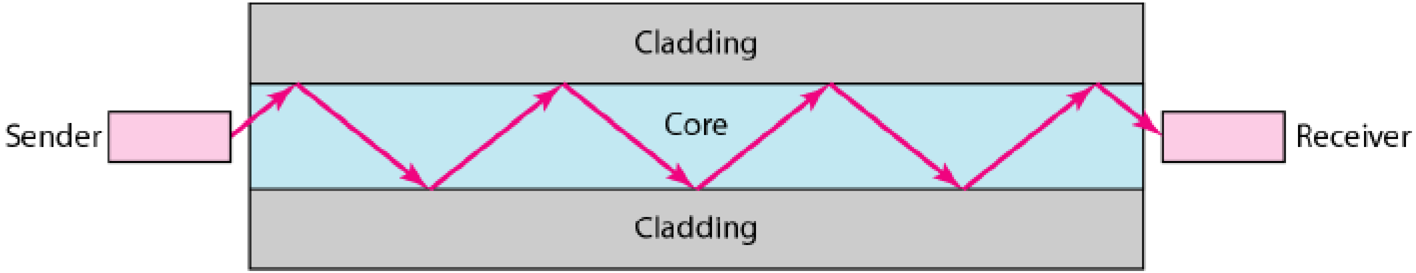
- was widely used in analog telephone networks
- Cable TV networks
- Can carry 10,000 voice signals.
- Traditional Ethernet LANs

Disadvantages of Coaxial cable:

- It is more expensive as compared to twisted pair cable.
- If any fault occurs in the cable causes the failure in the entire network.

Fiber-Optic Cable

- Fibre optic cable is a cable that uses electrical signals for communication.
- Fibre optic is a cable that holds the optical fibres coated in plastic that are used to send the data by pulses of light.
- The plastic coating protects the optical fibres from heat, cold, electromagnetic interference from other types of wiring.
- Fibre optics provide faster data transmission than copper wires.



Fiber-Optic Cable

Advantages of Fiber-optic cable

- **Higher bandwidth:** The fiber optic cable provides more bandwidth as compared copper.
- Fiber optic cable carries the data in the form of light. This allows the fibre optic cable to carry the signals at a higher speed.
- **Less signal attenuation:** Fiber-optic transmission distance is significantly greater than that of other guided media.
- **Immunity to electromagnetic interference:** Electromagnetic noise cannot affect fiber-optic cables.
- **Resistance to corrosive materials:** Glass is more resistant to corrosive materials than copper.
- **Light weight:** Fiber-optic cables are much lighter than copper cables.
- **Greater immunity to tapping:** Fiber-optic cables are more immune to tapping than copper cables.

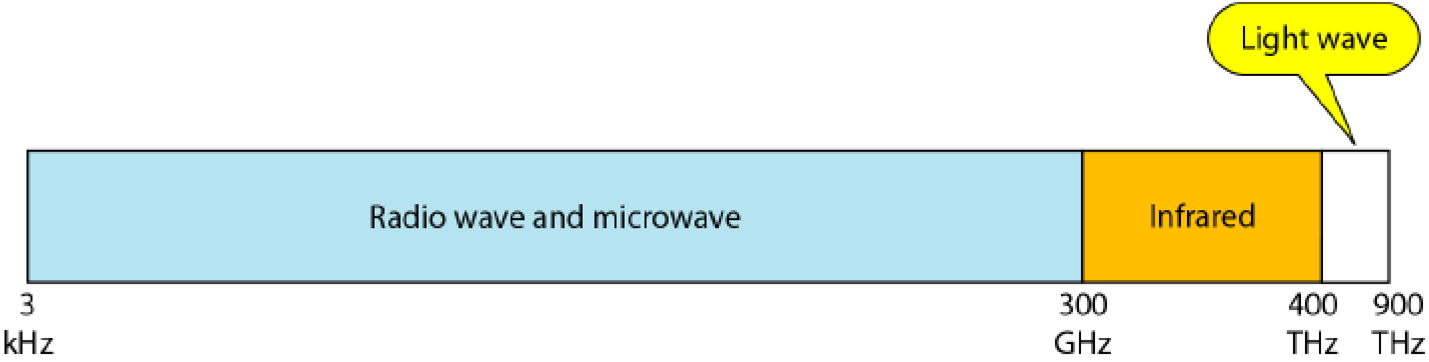
Disadvantages of Fiber-optic cable

- **Installation and maintenance:** Its installation and maintenance require expertise that is not yet available everywhere.
- **Unidirectional light propagation:** Propagation of light is unidirectional.
- **Cost:** The cable and the interfaces are relatively more expensive than those of other guided media.

UNGUIDED MEDIA: WIRELESS

- An unguided transmission transmits the electromagnetic waves without using any physical medium. Therefore it is also known as wireless transmission.

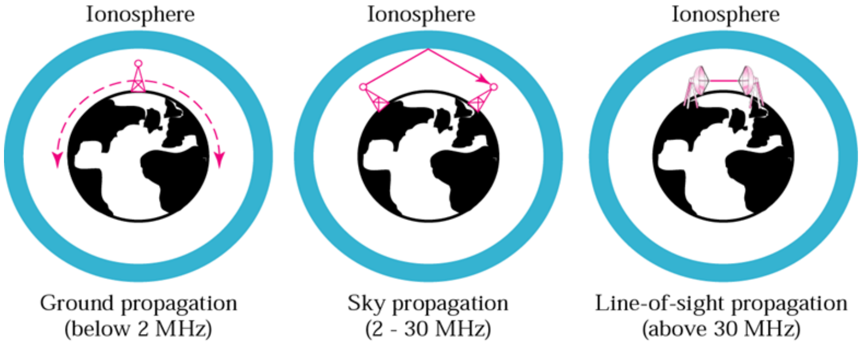
- Figure shows the part of the electromagnetic spectrum, ranging from 3 kHz to 900 THz, used for wireless communication.



Electromagnetic spectrum for wireless communication

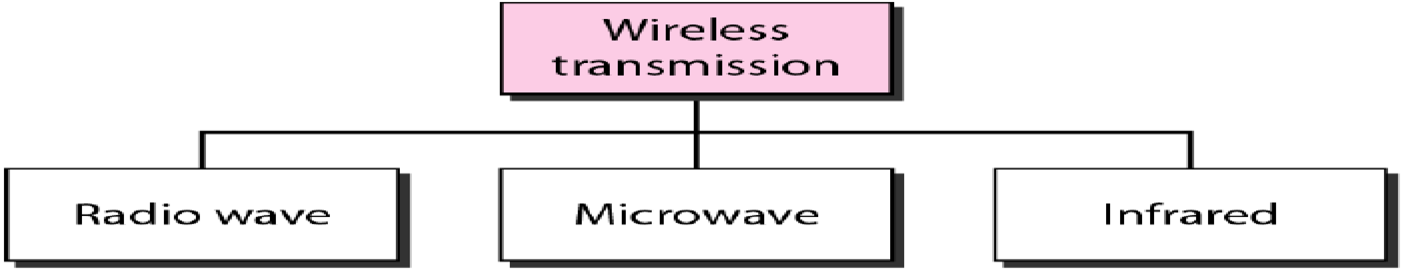
UNGUIDED MEDIA: WIRELESS

- Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation
- In ground propagation, radio waves travel through the lowest portion of the atmosphere, touching the earth.
- In sky propagation, higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to earth.
- In line-of-sight propagation, very high-frequency signals are transmitted in straight lines directly from
- antenna to antenna



Electromagnetic spectrumfor wireless communication

UNGUIDED MEDIA: WIRELESS



Radio Waves

- Radio waves are the electromagnetic waves that are transmitted in all the directions of free space.
- Radio waves are omnidirectional, i.e., the signals are propagated in all the directions.
- Electromagnetic waves ranging in frequencies between 3Khz to 1 Ghz are called radio waves

Applications Of Radio waves:

- Radio waves are used for multicast communications, such as radio and television, and paging systems.

Microwaves

- Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves.
- Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned.
- The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas.

Applications:

- Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs

Infrared

- Frequencies from 300 GHz to 400 THz
- Used for short-range communication

Applications:

- Infrared waves are used for short-range communications such as those between a PC and a peripheral device.
- TV remote operation
- They can also be used for indoor LANs.

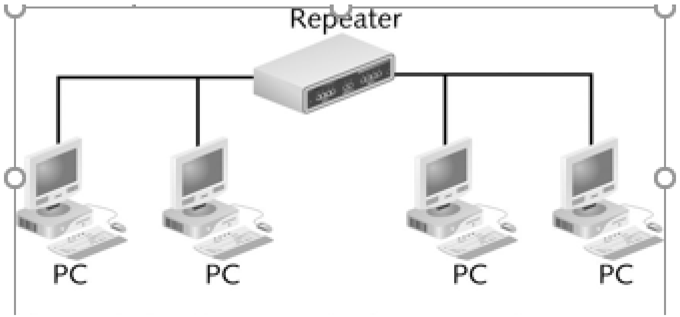
Networking Devices

Networking Devices

- Networking devices are Repeaters, Hubs, Bridges, Switches, Routers and Gateways

Repeater:

- A repeater operates at the physical layer.
- A repeater receives a signal and, before it becomes too weak or corrupted, regenerates the original bit pattern.
- A repeater is a regenerator, not an amplifier.



Hub:

- Hub is used to connect devices to the same network.
- Hubs cannot filter data, so data packets are sent to all
- connected devices

Networking Devices

Bridge

- A bridge operates at data link layer
- It is also used for interconnecting two LANs working on the same protocol.

Switch

- A switch is a data link layer device
- It is an intelligent network device that can be conceived as a multiport network bridge.
- It uses MAC addresses to send data packets to selected destination ports
- Switches can perform some error checking before forwarding data

Router

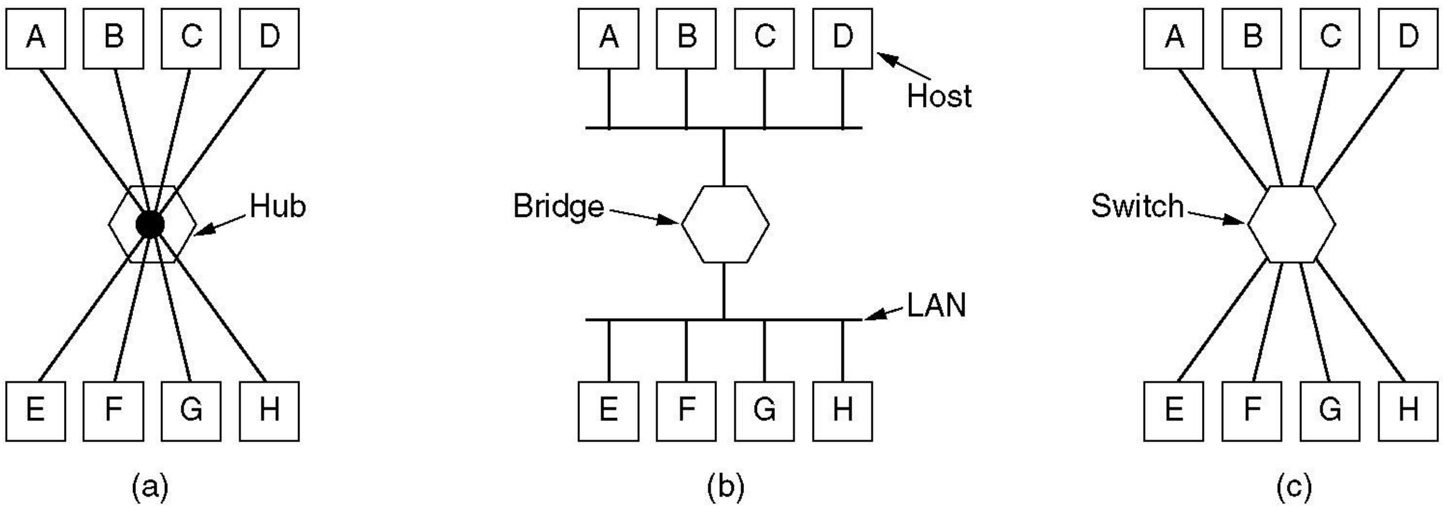
- Routers operate at the Network Layer (Layer 3)
- Interconnect IP networks

Gateway:

- A gateway is simply a device or hardware that acts as a "gate" between the networks. We can also define it as a node that acts as an entry for other network nodes

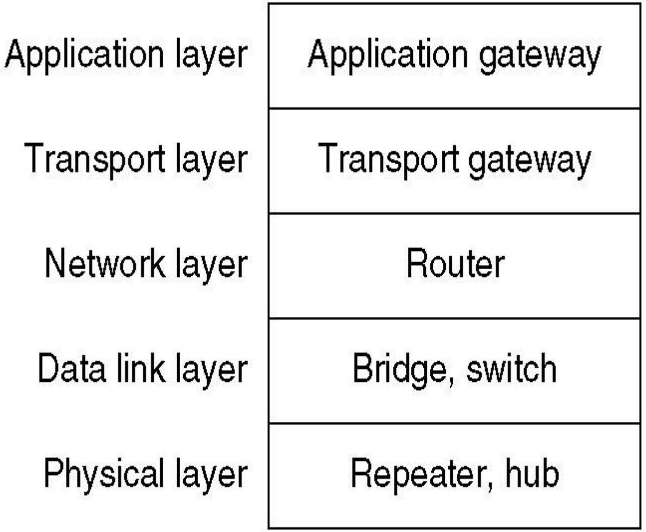
Networking Devices

(a) Hub (b) Bridge (c) Switch

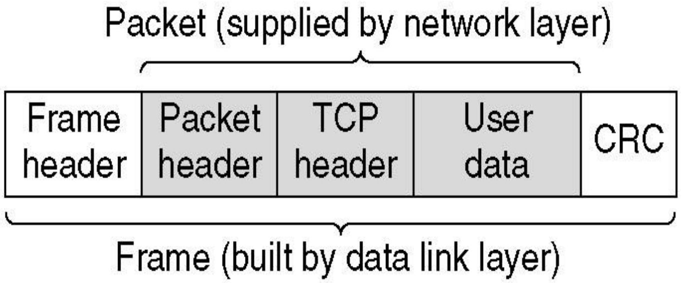


Layer wise Networking Devices

(a) Layer wise devices (b) Frames, packets and headers



(a)



(b)

Comparison of network devices

HUB	SWITCH	ROUTER
Hub is a broadcast device.	The switch is a multicast device.	The router is a routing device.
Hub works in the physical layer of OSI model.	The switch works in data link layer.	The router works in the network layer of OSI model.
Hub is used to connect devices to the same network.	The switch is used to connect devices to the network.	The router is used to connect two different networks.
Hub sends data in the form of bits.	The switch sends data in the form of frames.	The router sends data in the form of packets.
Hub works in half duplex.	The switch works in full duplex.	The router works in full duplex.
Only one device can send data at a time.	Multiple devices can send data at a time.	Multiple devices can send data at a time.
Hub does not store any MAC address of a node in the network.	It uses MAC addresses	It uses IP Addresses

OSI Reference and TCP/IP Model

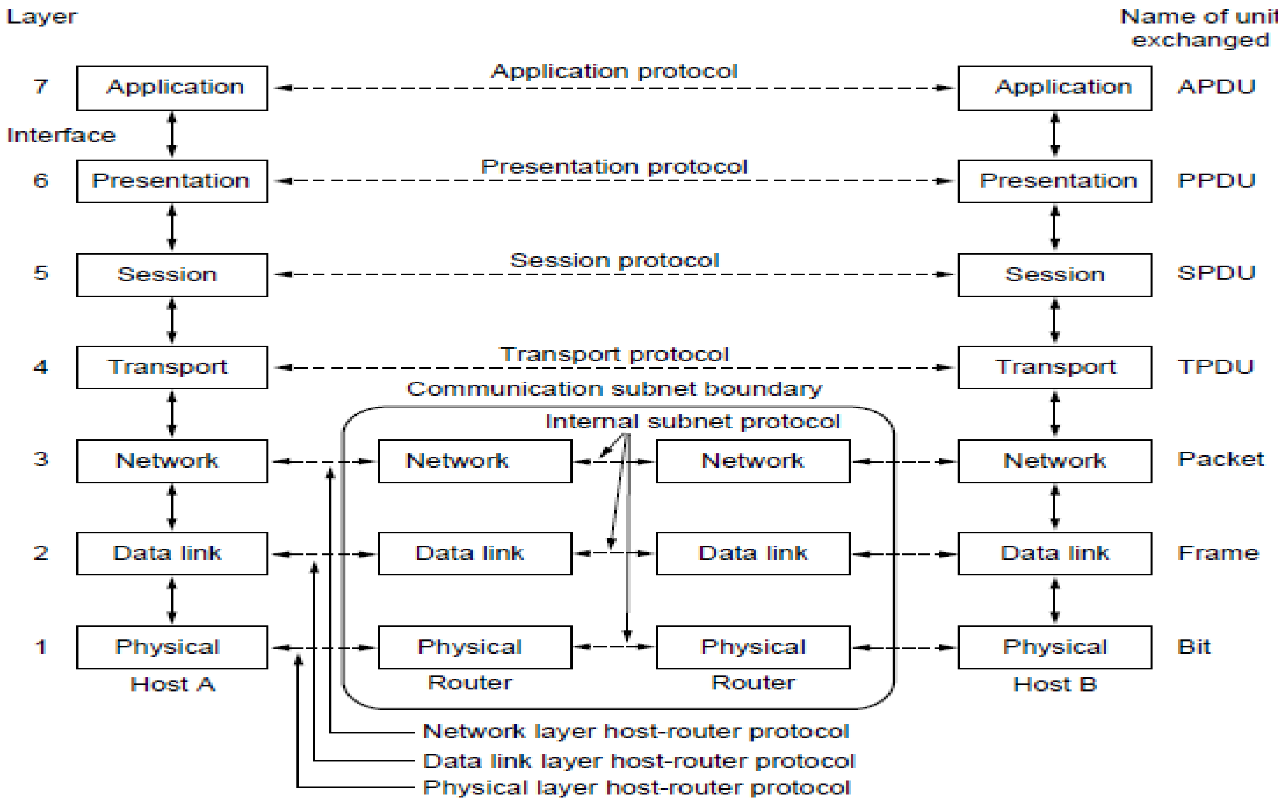
OSI Reference Model

Principles for the seven layers of OSI Model:

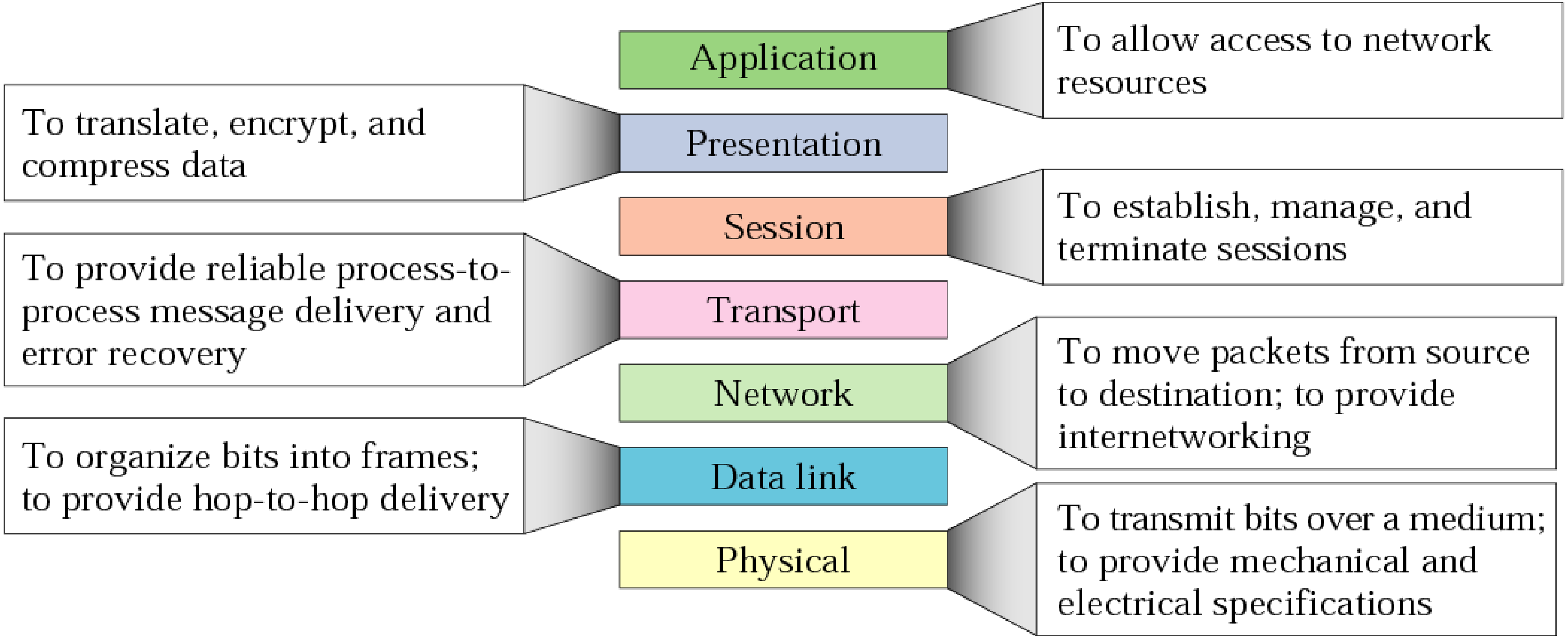
- Layers created for different abstractions
- Each layer performs well-defined function
- Function of layer chosen with definition of international standard protocols in mind
- Minimize information flow across interfaces between boundaries
- Number of layers optimum

OSI Reference Model

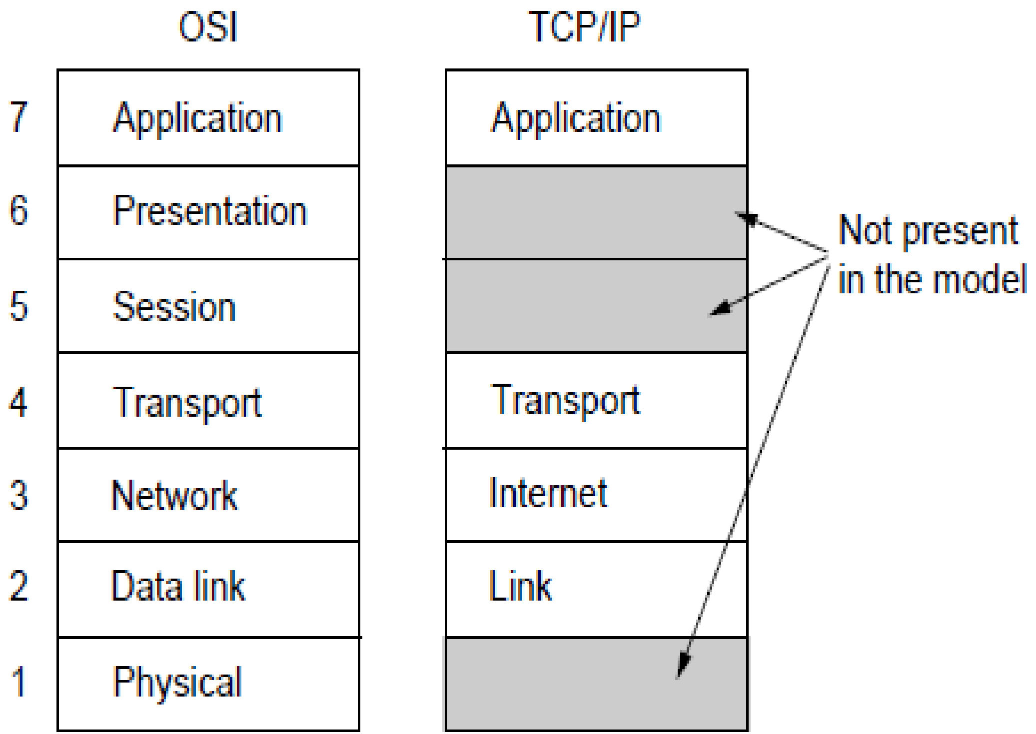
- Application layer
- Presentation layer
- Session layer
- Transport layer
- Network layer
- Data link layer
- Physical layer



Summery of duties for each layer of OSI Model

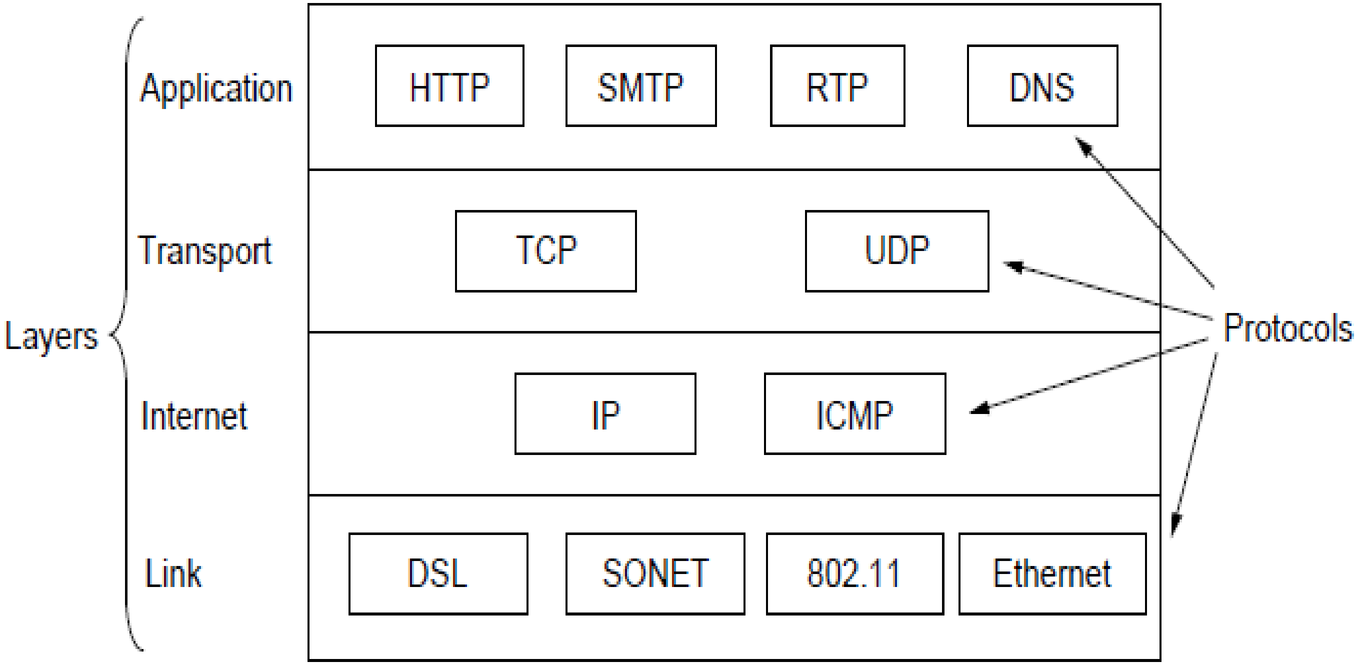


TCP/IP Model

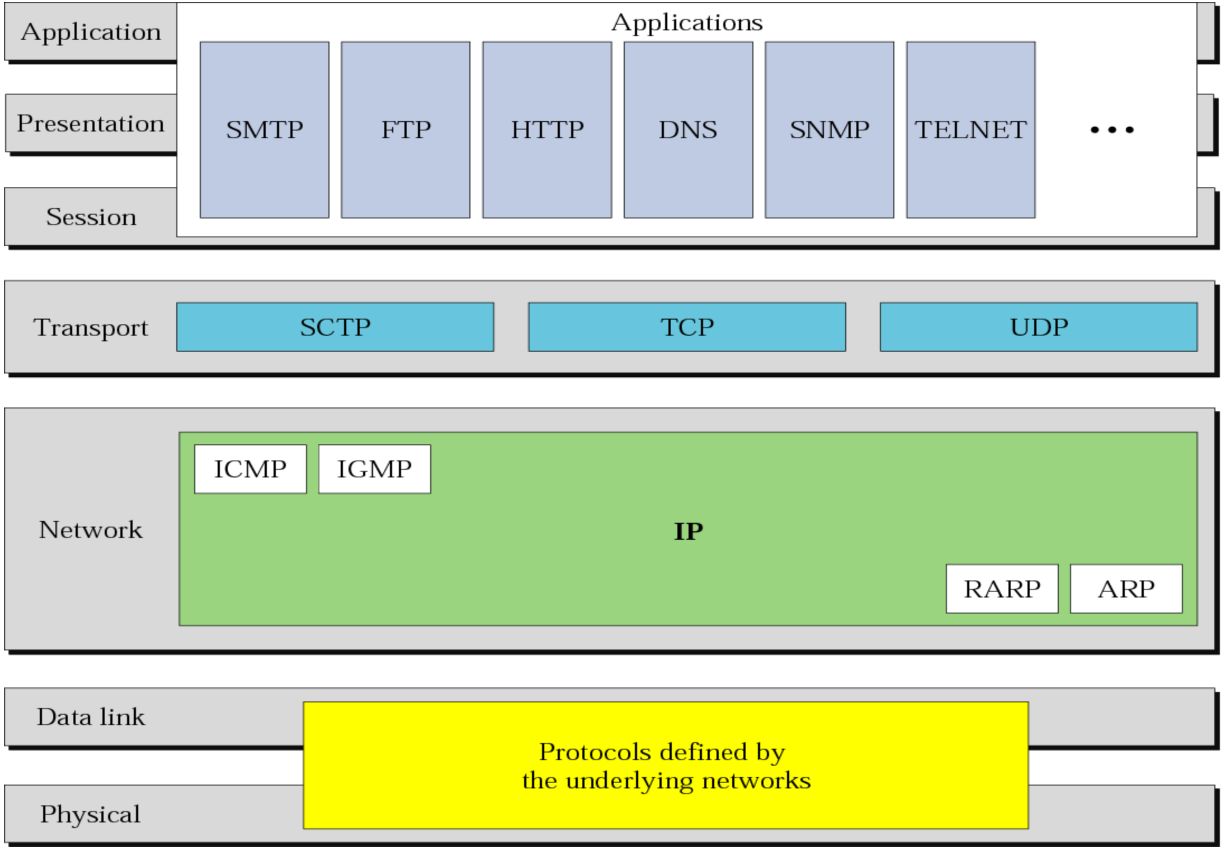


OSI
TCP/IP
7
Application
6
Presentation
5
Session
4
Transport
3
Network
2
Data link
1
Physical
Application
Transport
Internet
Link
Not present in the model

TCP/IP Model: Protocols



TCP/IP and OSI model



Comparison of OSI & TCP/IP Reference Models

OSI(Open System Interconnection)	TCP/IP(Transmission Control Protocol / Internet Protocol)
1. OSI is a generic, protocol independent standard, acting as a communication gateway between the network and end user.	1. TCP/IP model is based on standard protocols around which the Internet has developed. It is a communication protocol, which allows connection of hosts over a network.
2. In OSI model the transport layer guarantees the delivery of packets.	2. In TCP/IP model the transport layer does not guarantees delivery of packets. Still the TCP/IP model is more reliable.
3. Follows vertical approach.	3. Follows horizontal approach.
4. OSI model has a separate Presentation layer and Session layer.	4. TCP/IP does not have a separate Presentation layer or Session layer.
5. Transport Layer is Connection Oriented.	5. Transport Layer is both Connection Oriented and Connection less.

OSI(Open System Interconnection)	TCP/IP(Transmission Control Protocol / Internet Protocol)
6. Network Layer is both Connection Oriented and Connection less.	6. Network Layer is Connection less.
7. OSI is a reference model around which the networks are built. Generally it is used as a guidance tool.	7. TCP/IP model is, in a way implementation of the OSI model.
8. Network layer of OSI model provides both connection oriented and connectionless service.	8. The Network layer in TCP/IP model provides connectionless service.
9. OSI model has a problem of fitting the protocols into the model.	9. TCP/IP model does not fit any protocol
10. Protocols are hidden in OSI model and are easily replaced as the technology changes.	10. In TCP/IP replacing protocol is not easy.
11. OSI model defines services, interfaces and protocols very clearly and makes clear distinction between them. It is protocol independent.	11. In TCP/IP, services, interfaces and protocols are not clearly separated. It is also protocol dependent.
12. It has 7 layers	12. It has 4 layers

Ethernet Standards

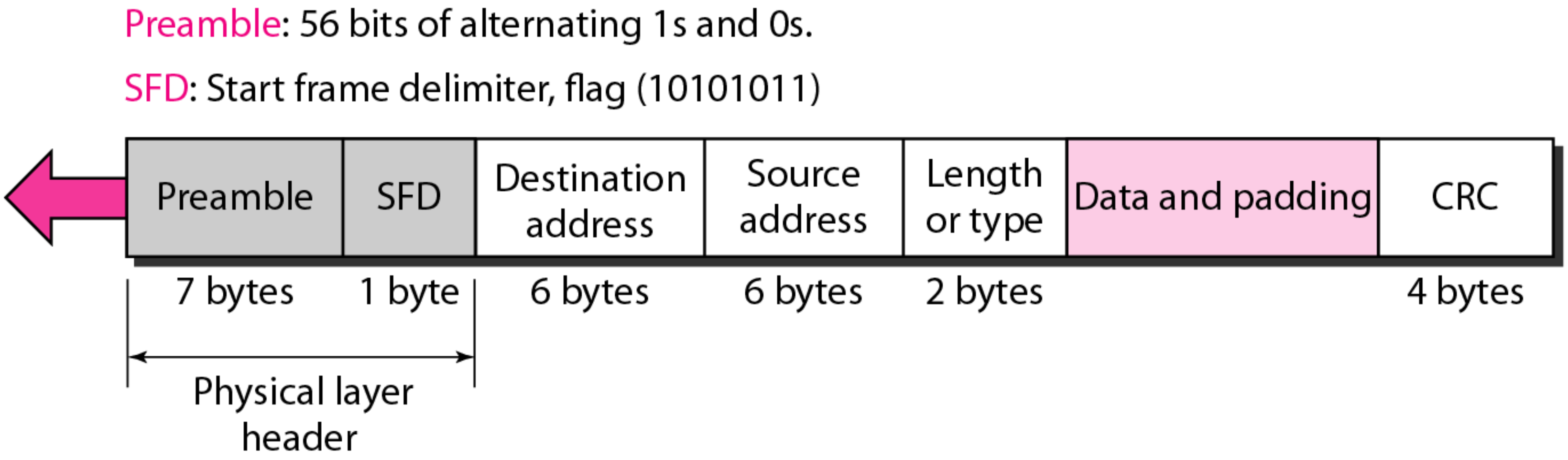
Ethernet Standards

- Ethernet: It is a LAN protocol that is used in Bus and Star topologies and implements CSMA/CD as the medium access method

- Original (traditional) Ethernet developed in 1980 by three companies: Digital, Intel, Xerox (DIX).

- In 1985, the Computer Society of the IEEE started a project, called Project 802, to set standards to enable intercommunication among equipment from a variety of manufacturers. Current version is called IEEE Ethernet

802.3 MAC frame

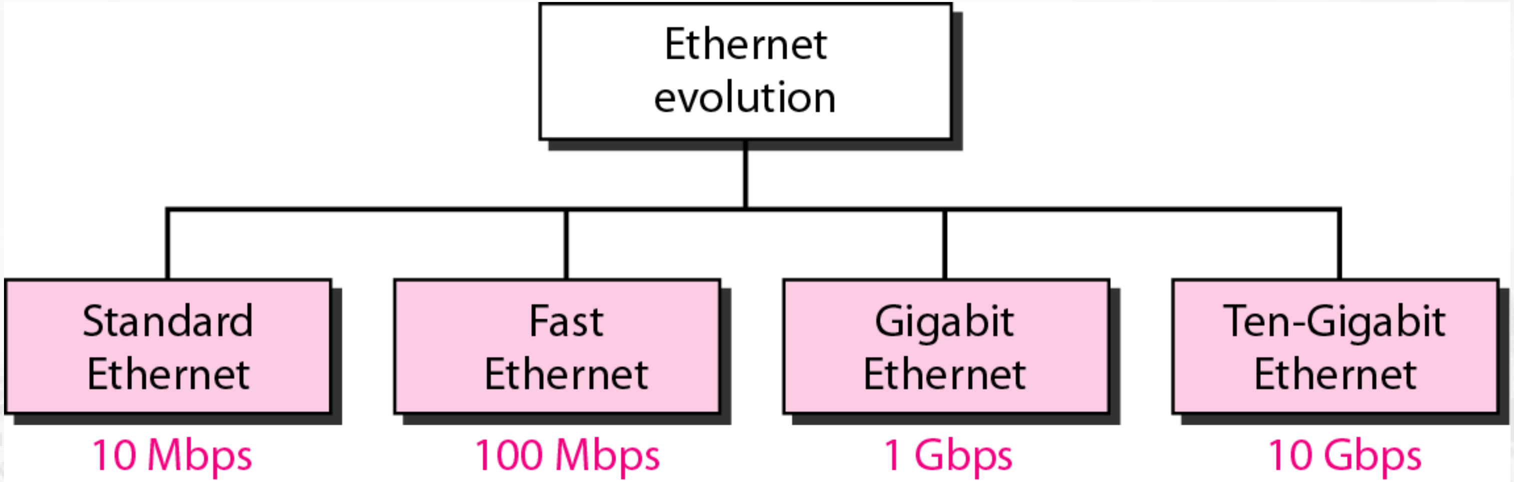


Ethernet address

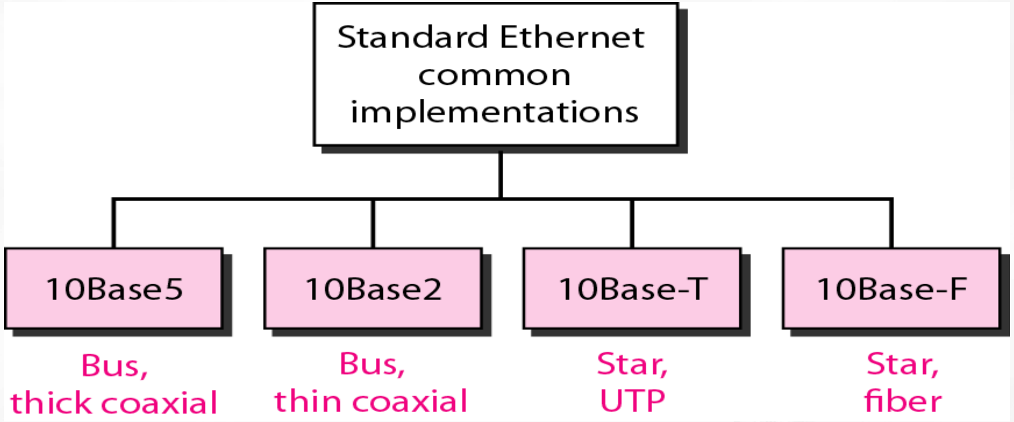
06-01-02-01-2C-4B

- Six bytes = 48 bits
- Flat address not hierarchical
- Burned into the NIC ROM
- First three bytes from left specify the vendor. Cisco 00-00-0C, 3Com 02-60-8C and the last 24 bit should be created uniquely by the company
- Destination Address can be:
  - Unicast: second digit from left is even (one recipient)
  - Multicast: Second digit from left is odd (group of stations to receive the frame – conferencing applications)
  - Broadcast (ALL ones) (all stations receive the frame)
- Source address is always Unicast

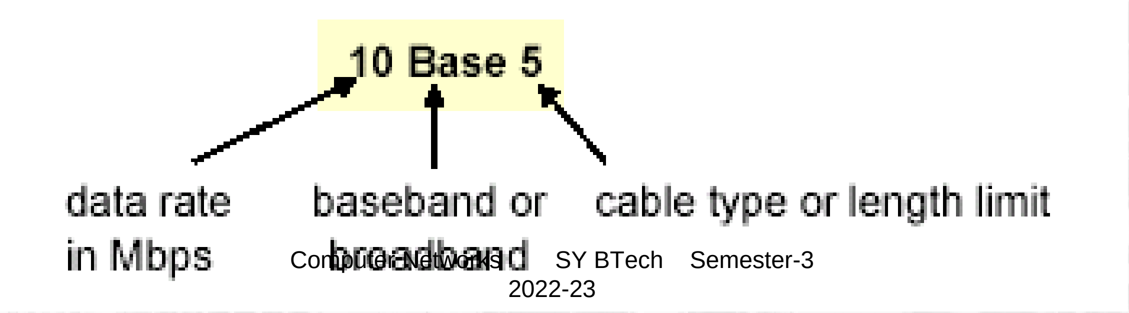
Ethernet evolution through four generations



Categories of traditional Ethernet



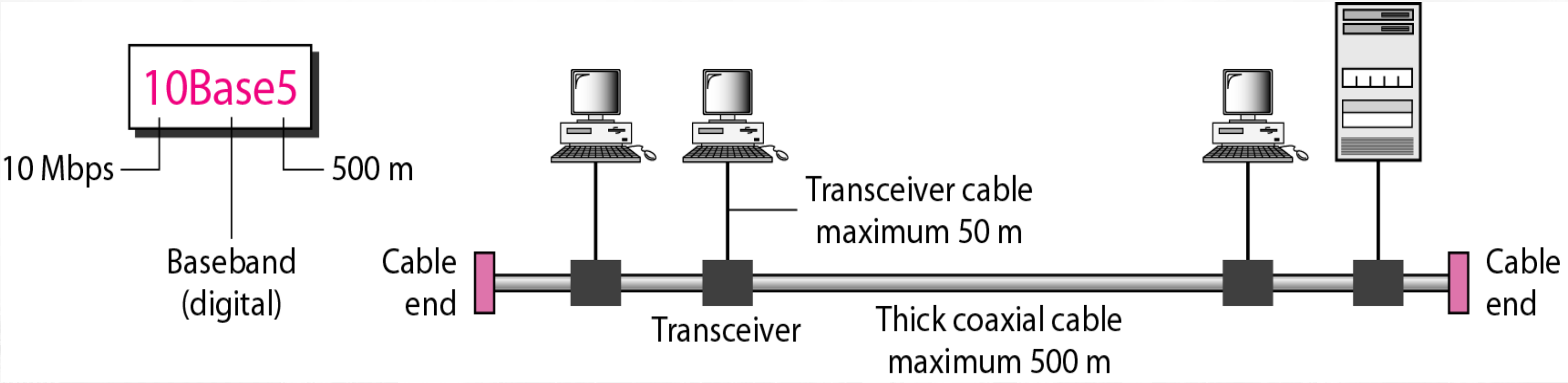
- <data rate><Signaling method><Max segment length or cable type>



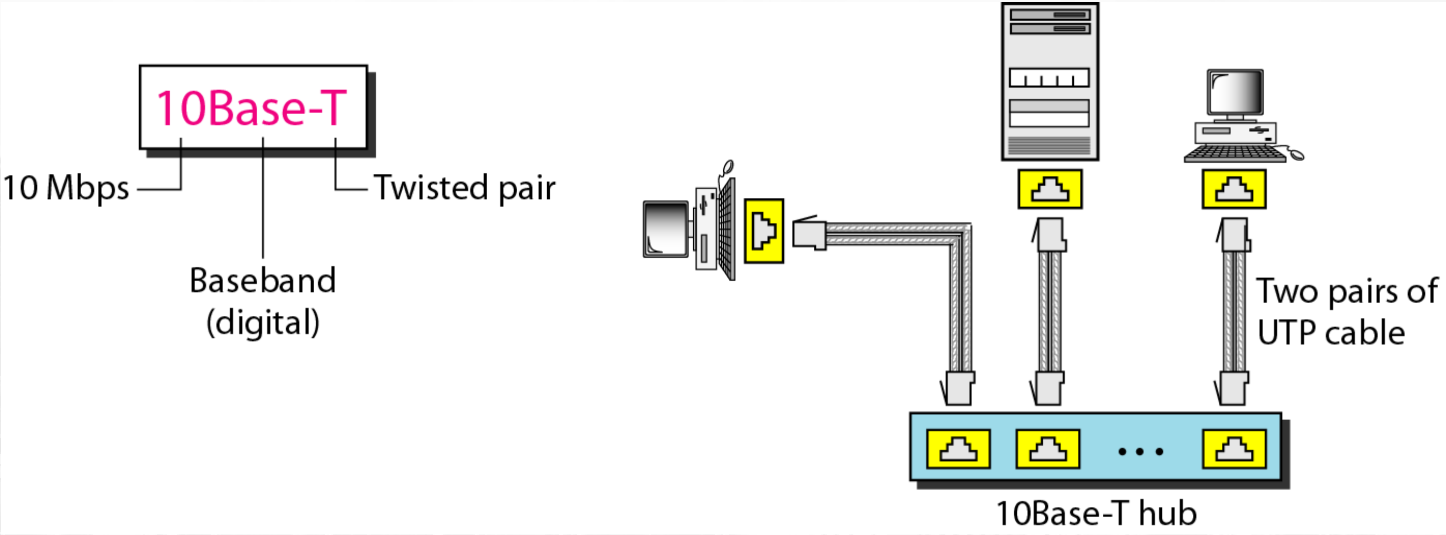
IEEE 802.3 Cable Types

Name	Cable Max.	Max Cable Segment Length	Nodes /segment	Toplogy
10Base5	thick coax	500 meters	100	Bus
10Base2	thin coax	185 meters	30	Bus
10BaseT	twisted pair	100 meters	1	Star
10BaseF	Fiber Optic	2Km	1	Star

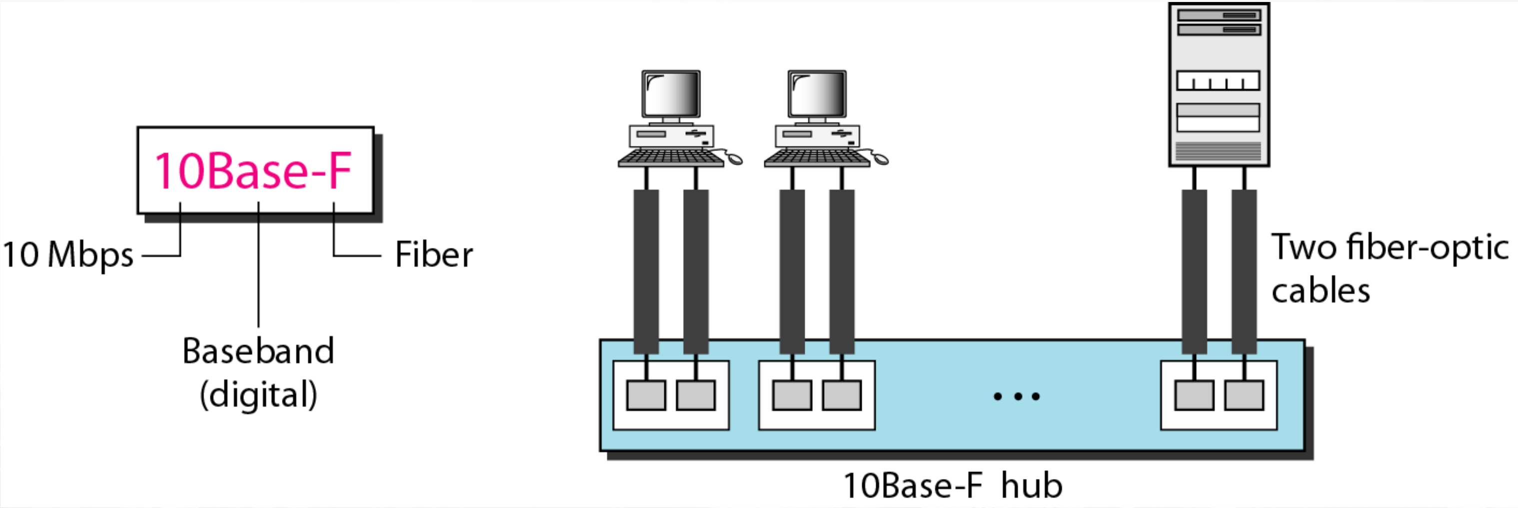
10Base5 implementation



10Base-T implementation



10Base-F implementation



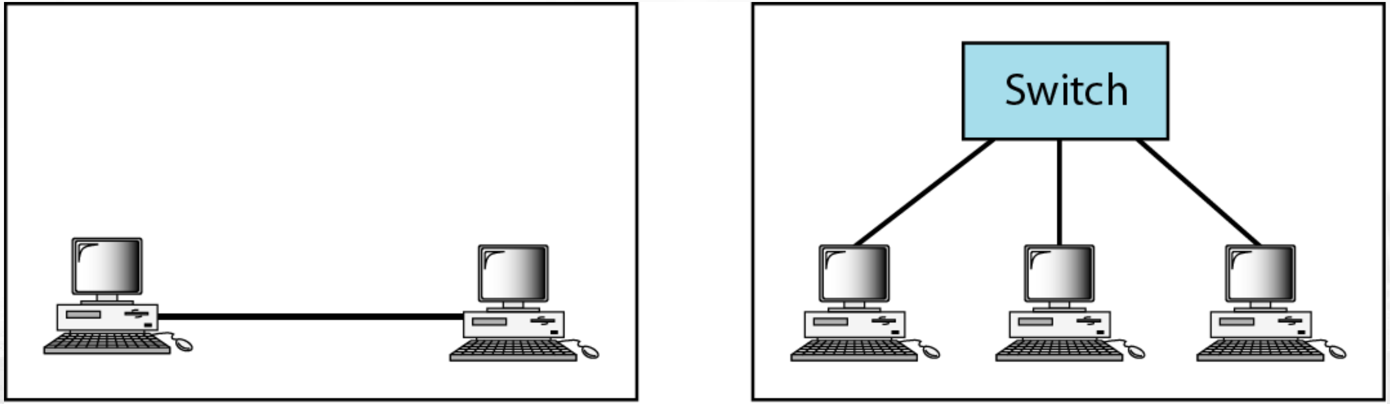
Fast Ethernet

1. Upgrade the data rate to 100 Mbps.
2. Make it compatible with Standard Ethernet.
3. Keep the same 48-bit address.
4. Keep the same frame format

- media: twisted pair (CAT 5) or fiber optic cable (no coax)
- Star-wire topology
  - Similar to 10BASE-T

Name	Cable	Max. segment	
100Base-T4	Twisted pair	100 m	**CAT 3**
100Base-TX	Twisted pair	100 m	**CAT 5**
100Base-FX	Fiber optics	2000 m	

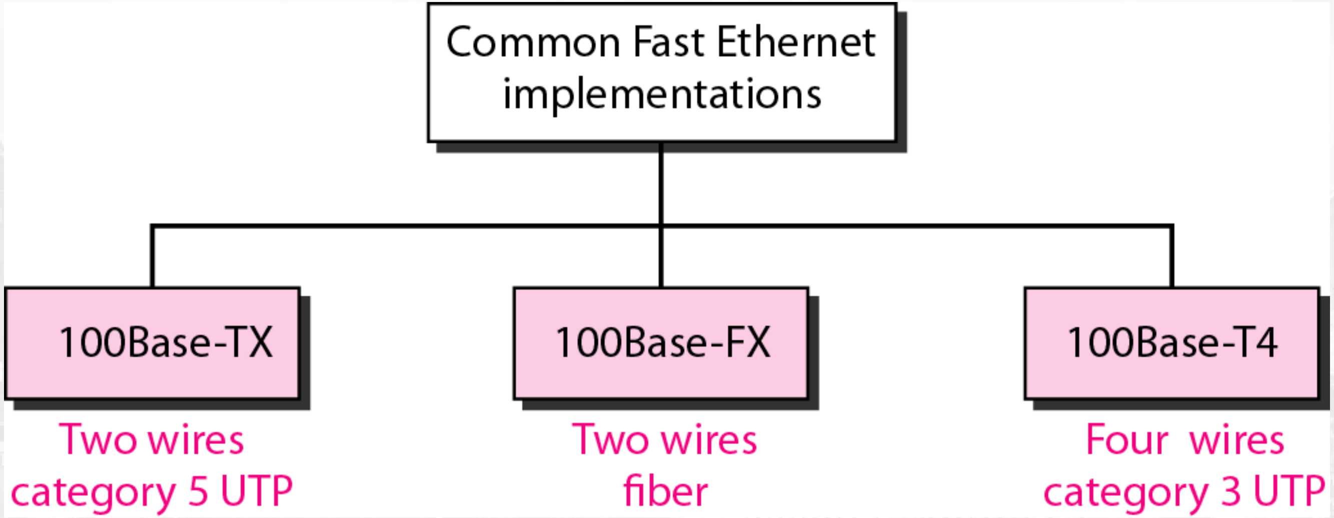
Fast Ethernet topology



a. Point-to-point

b. Star

Fast Ethernet implementations

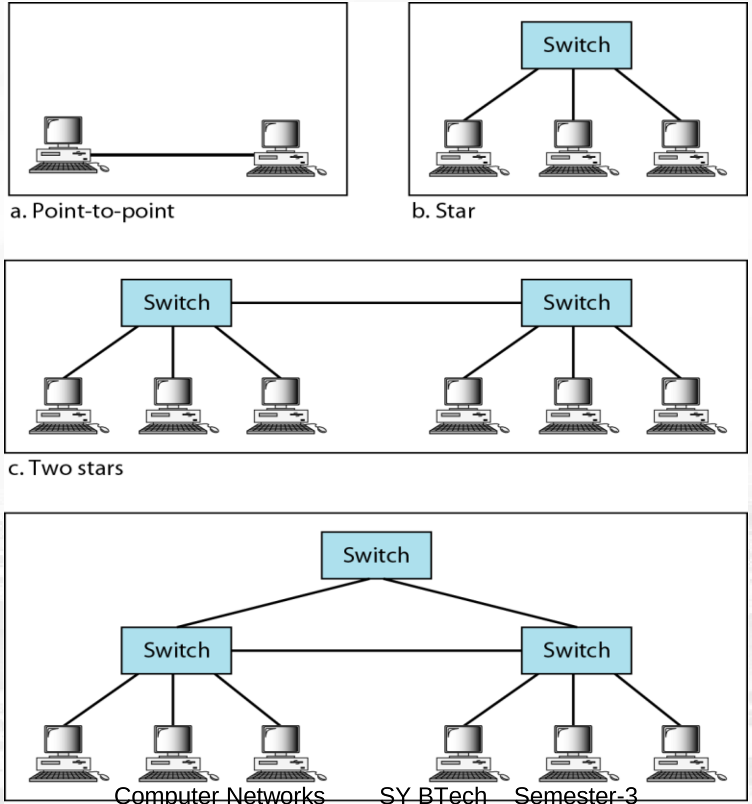


Gigabit Ethernet

1. Upgrade the data rate to 1 Gbps.
2. Make it compatible with Standard or Fast Ethernet.
3. Use the same 48-bit address.
4. Use the same frame format.
5. Keep the same minimum and maximum frame lengths.
6. Support autonegotiation as defined in Fast EthernetOperates in full/half duplex modes mostly full duplex

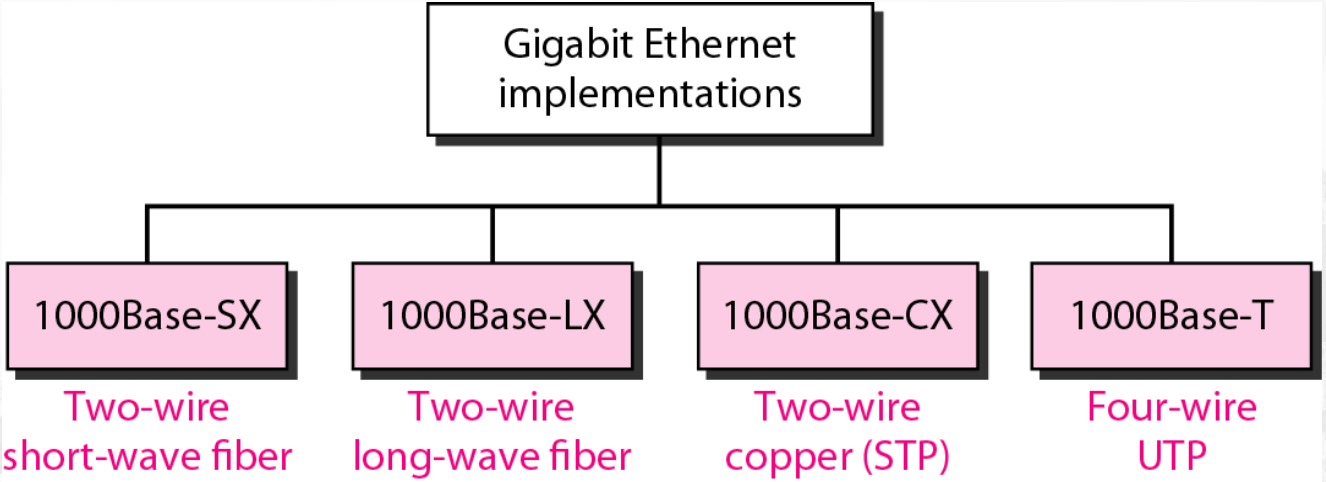
Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

Topologies of Gigabit Ethernet



a. Point-to-point
b. Star
c. Two stars
d. Hierarchy of stars

Gigabit Ethernet implementations



Sample Questions

1. What is the difference between analog and digital signal?
2. An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?
3. Explain AM, FM and PM with advantages and disadvantages.
4. Compare AM and FM, Bit rate and Baud rate.
5. Explain ASK, FSK and PSK with advantages and disadvantages.
6. Explain Line coding schemes with examples.
7. Explain PCM with its advantages and disadvantages.
8. List and explain types of networks along with its advantages.
9. Explain in detail star and bus topologies with advantages and disadvantages.
10. Explain point-to-point and broadcast network with examples.
11. Differentiate LAN, MAN and WAN
12. Compare Guided and unguided media. What are advantages of Fiber optic cable.
13. Write a short note on wireless media
14. What is the difference between Hub, Switch, and Router?
15. Explain TCP/IP Model with neat diagram,
16. Explain various types of networks based on their sizes?
17. Name the different types of network topologies and brief their advantages?
18. What are the Advantages of Fiber Optics?
19. Compare OSI Model and TCP/IP model
20. Explain Frame format. Write a note on classification of ethernet evolution.

Thank You

Any Questions