UNIT-4: ANALOG & DIGITAL COMMUNICATION SYSTEM

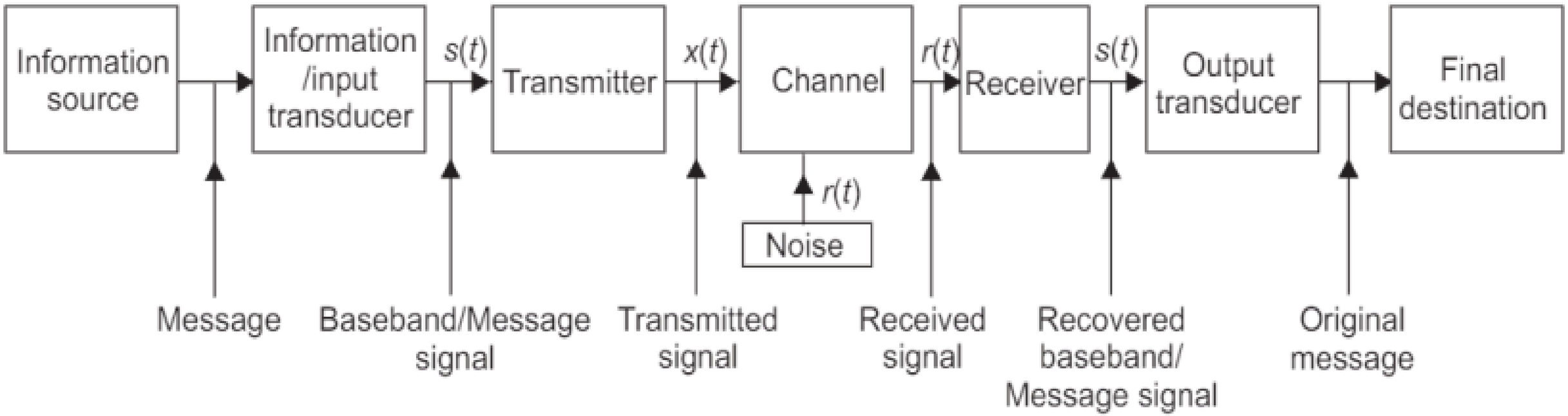
MODERN COMMUNICATION SYSTEM

- Communication is a process by which the information/message is transmitted from one point to another, from one person to another or from one place to another in the form of an electrical signals through some communication link.
- The process of communication involves sending, receiving and processing information in electrical form.

NEED FOR COMMUNICATION?

- **Speedy Transmission**: Requires only few seconds to communicate through electronic media due the technology available for quick transmission.
- **Wide Coverage**: The whole world has become a global village and communication around the globe requires just a second.
- **Low Cost**: Cost of an SMS is cheaper than sending a letter by post.
- **Exchange of feedback**: Instant exchange of feedback.
- **24/7 accessibility**: Can be accessed anytime.

General form of a Basic Communication System



Constituents of a Communication System:

- Information source and transducer.
- Transmitter.
- Channel or medium.
- Noise.
- Receiver.
- Output transducer and final destination.

Information Source and Transducer

- A communication system transmits information from an ***information source (message)*** *to* a ***destination***.

  Examples: Voice, Live scenes(video), music, written text, and e-mail.

- If the information produced by the source is not an electrical signal then we need to use a device called transducer.
- A *transducer is a device that* ***converts a non-electrical energy*** *into its corresponding* ***electrical energy*** called ***signal*** *and vice versa.*

  Example: Microphone: It converts the sound signals into corresponding electrical signals.

- The output signal produced by the transducer is called as baseband signal or message signal it is designated as s(t).
- In communication systems there are 2 types of signals: a) Analog Signal. b) Digital Signal.

ANALOG SIGNAL

- Analog signal is a continuous value signal which changes with respect to time.

  Example: Pure Sine Wave, Voice signal etc.

- These signals are used in analog devices and these type of signals are more affected by Noise.

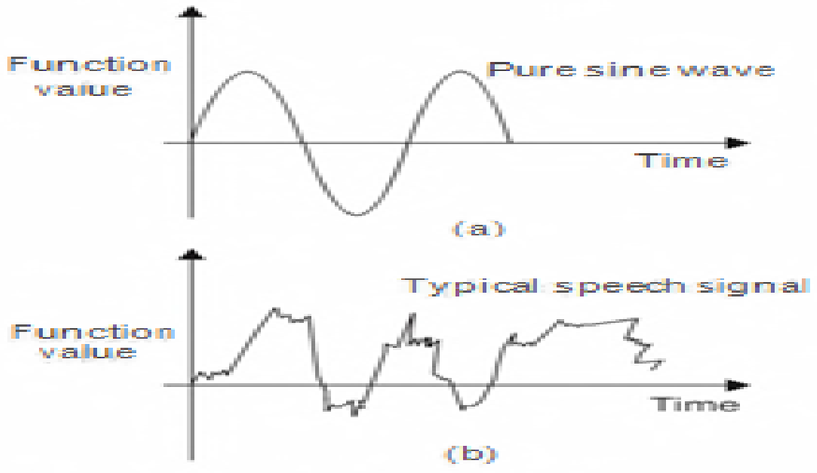


Fig. 1.2 Analog signals (a) Pure sine wave, (b) Typical speech signal

DIGITAL SIGNAL

- Digital signal consists of only 0’s & 1’s.
- An analog signal can be converted into digital signal using the process called Sampling & Quantization.
- An analog signal is converted into discrete time signal by the process called Sampling. The signal which is continuous in amplitude but discrete in time is called discrete signal.
- The discrete signal is then quantized and represented in the form of 0’s & 1’s.

TRANSMITTER

- The transmitter is a collection of electronic components and circuits that converts the electrical signal into a suitable signal for transmission over a given medium.
- Transmitters are made up of oscillators, amplifiers, tuned circuits, filters, modulators, frequency mixers, frequency synthesizers and other circuits.
- The base band signal and the output from the transducer is given as input to the transmitter.
- The transmitter section processes the signal prior to transmission.
- There are two options for processing signals prior transmission

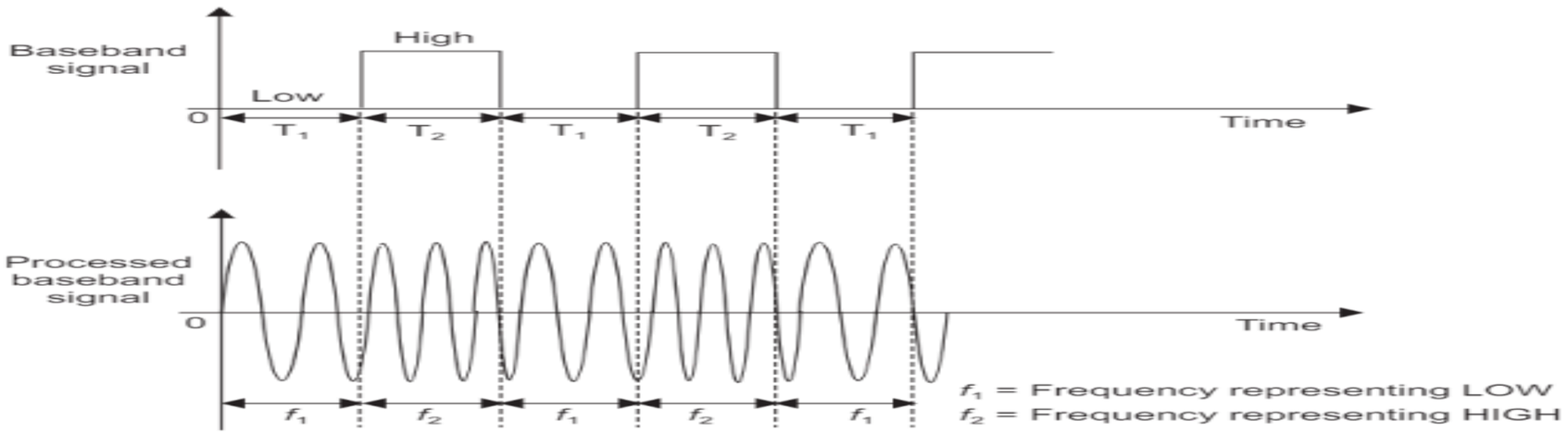
(i) Carrier communication system

The baseband signal which lies in the low frequency spectrum is translated to a higher frequency spectrum.

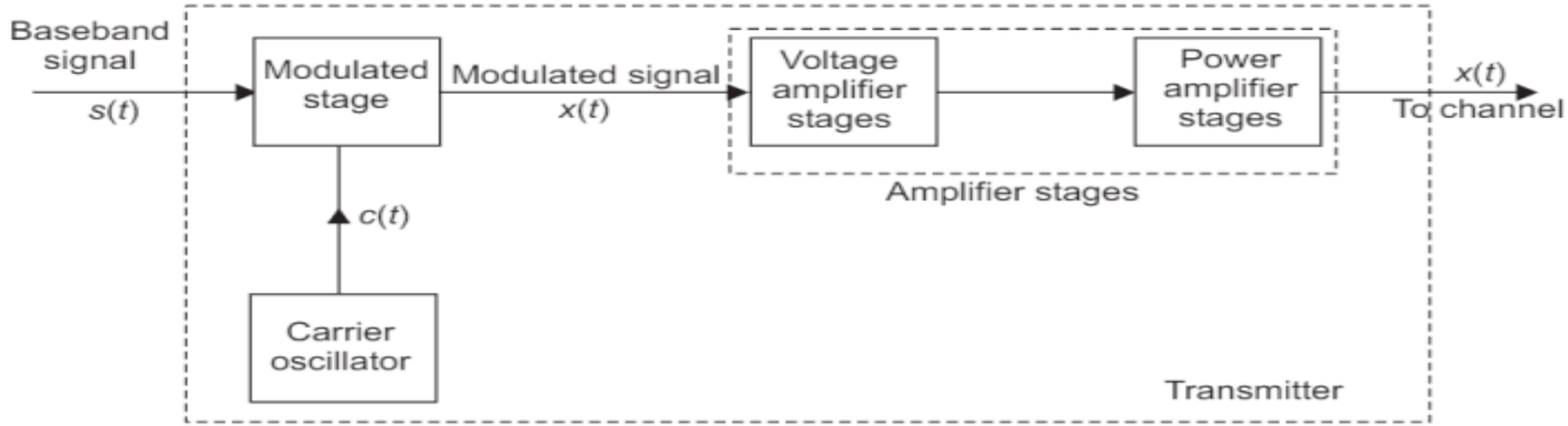
(ii) Baseband communication system.

The baseband signal is tra

Processing of a baseband Sig



Block Diagram of Analog Transmitter Section



- The baseband signal s(t) and carrier signal c(t) are applied as an input to the modulated stage.
- The carrier signal is varied in accordance with the message signal.
- If the amplitude of the carrier is varied with respect to message signal is called amplitude modulation.
- If the frequency of the carrier is varied with respect to message signal is called frequency modulation.
- The output signal of the modulated stage is called modulated signal x(t).
- The voltage of the modulated signal is amplified and fed to power amplifier stage.
- **Power Amplifier**: The power of the modulated signal is amplified thus it carries enough power to reach the receiver stage of the system. Finally the signal is passed over the

Frequency Range & It’s Application

Table 1.1: Classification of radio frequency (RF) spectrum alongwith the associated applications in communication systems.

Radio frequency range	Wavelength (meters)	Class	Applications
10–30 kHz	$3 \times 10^4 - 10^4$	Very Low Frequency (VLF)	Point-to-point communication (long distance)
30–300 kHz	$10^4 - 10^3$	Low Frequency (LF)	Point-to-point communication (long distance) and navigation
300–3000 kHz	$10^3 - 10^2$	Medium Frequency (MF)	Radio broadcasting
3–30 MHz	$10^2 - 10$	High Frequency (HF)	Overseas radio broadcasting, Point-to-point radio telegraphy, and telephony
30–300 MHz	$10 - 1.0$	Very High Frequency (VHF)	FM broadcast, television, and radar
300–3000 MHz	$1.0 - 0.1$	Ultra High Frequency (UHF)	Television and navigation
3000–30,000 MHz	$0.1 - 0.01$	Super High Frequency (SHF)	Radar navigation and radio relays

Communication Channel

- Communication channel is a medium through which the signals is sent from one place to another.
- Types of Medium:
  - Electrical Conductors.
  - Optical Media.
  - Free Space.
  - System Specific media (Eg: Water is a medium for SONAR)
- The transmission medium between the transmitter and the receiver is called a **Channel.**
- Noise gets added in the channel hence transmitted signal should have adequate power to withstand the **channel noise.**
- The channel characteristics also impose constraints on the **Bandwidth.**
- Bandwidth is a range of frequencies that is used for transmitting a signal.
- Depending on the physical implementations, one can classify the channels in the following two groups:
  - Hard wired (Hardware) channels.
  - Soft wired (Software) channels.

Hardwired (Hardware) Channels

- These are manmade structures which can be used as transmission medium. There are following three possible implementations of the hardware channels.
  - Transmission lines.
  - Waveguides.
  - Optical Fiber Cables (OFC).
- Transmission lines are not suitable for ultra high frequency (UHF) transmission.
- To transmit UHF range waveguides will be used.
- Optical fiber cables are highly sophisticated transmission media in which signals are transmitted in the form of light energy.

Soft-wired (Software) Channels

- Natural resources which can be used as the transmission medium for signals.

  Example: Air or Open space and Sea water.
- The signals are transmitted in the form of electromagnetic (EM) waves also called radio waves.
- Radio waves travel through open space at a speed equal to that of light.

NOISE

- Noise is defined as unwanted electrical energy of random and unpredictable nature.
- Noise is a highly undesirable part of a communication system, and has to be minimized.
- When noise is mixed with the transmitted signal, it rides over it and deteriorates its waveform.

Signal to Noise Ratio (SNR) and Noise factor (F)

- In judging the performance of the communication system and receiver the term SNR is used.
- The SNR is a simply a number that indicates the relative strengths of the signal and the noise.
- When the signal is strong and noise is weak, the SNR will be high and vice versa.

Measurement of SNR

Now, if P_s is signal power and P_n is noise power, then SNR expressed as S/N, is given as

$$\frac{S}{N} = \frac{P_s}{P_n}$$

If $P_s = V_s^2 R$ and $P_n = V_n^2 R$, then

$$\frac{S}{R} = \frac{P_s}{P_n} = \frac{V_s^2 R}{V_n^2 R} \qquad \ldots(2)$$

where V_s is signal voltage and V_n is noise voltage.

In addition, it is assumed that both the signal and noise powers are dissipated in the same resistor R. Therefore, SNR can be expressed in terms of decibels (dB) as

$$\left(\frac{S}{N}\right)_{dB} = 10 \log_{10}\left(\frac{V_s^2}{V_n^2}\right)$$

$$\left(\frac{S}{N}\right)_{dB} = 20 \log_{10}\left(\frac{V_s}{V_n}\right) \qquad \ldots(3)$$

For example, if, at a particular point in a circuit, the signal and noise voltages are given as 3.5 mV and 0.75 mV, respectively, SNR in dB is calculated as:

$$\left(\frac{S}{N}\right)_{dB} = 20 \log_{10}\left(\frac{3.5}{0.75}\right)$$

or

$$\begin{aligned} \text{SNR} &= 20 \log_{10}(4.66) \\ &= 13.38\ dB \end{aligned}$$

Clearly, the SNR of the circuit at the point is 13.38 dB.

Noise Factor and Noise Figure

$$F = \frac{\frac{S}{N} \text{ Power at the input terminals of the circuit}}{\frac{S}{N} \text{ Power at the output terminals of the circuit}}$$

Noise Calculation

- SNR is ratio of signal power, *S* to noise power, *N*.

$$SNR = 10 \log \frac{S}{N} dB$$

- Noise Factor, *F*

$$F = \frac{S_i / N_i}{S_o / N_o}$$

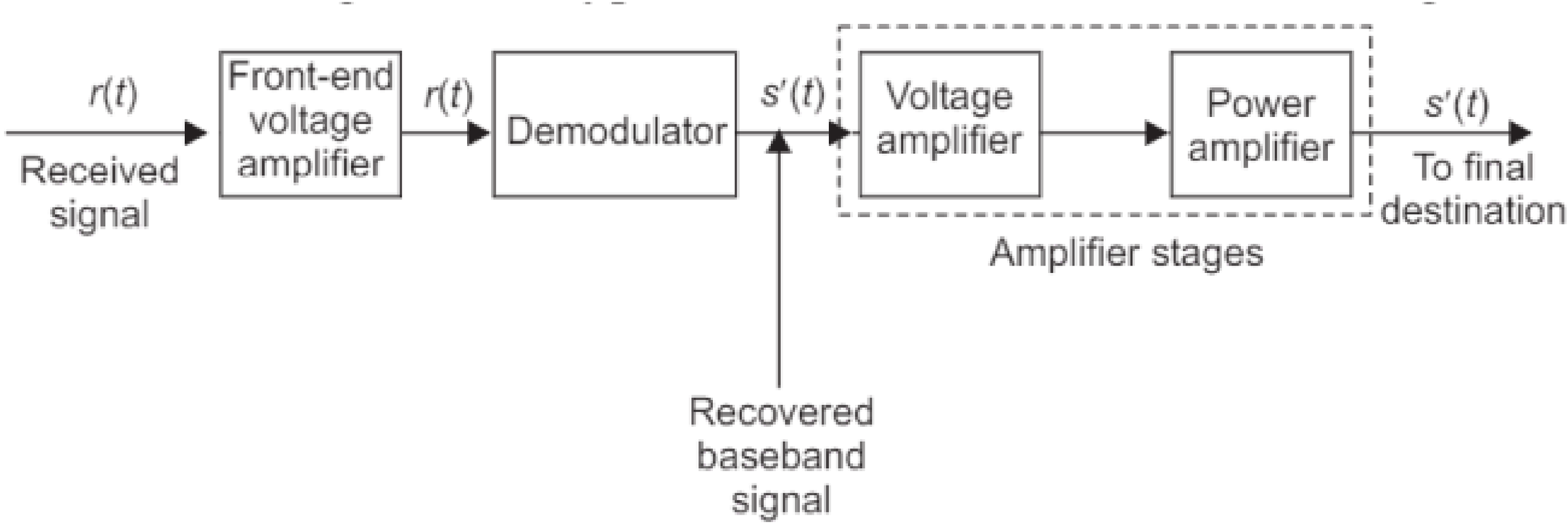
- Noise Figure, *NF*

$$NF = 10 \log F$$
$$= 10 \log \frac{S_i / N_i}{S_o / N_o} (dB)$$

RECEIVER

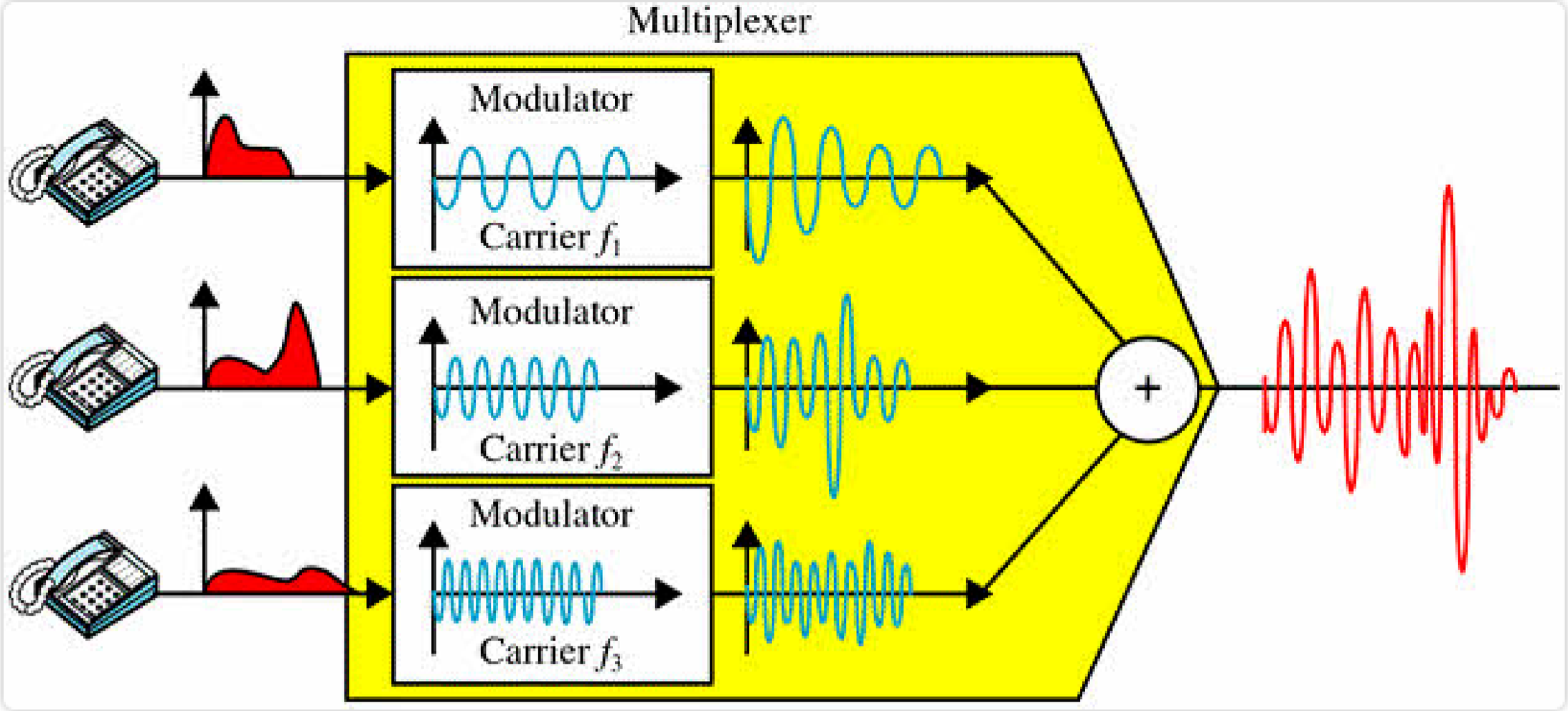
- The task of the receiver is to provide the original information to the user.
- The signal received by the receiver is r(t).
- This signal contains both the transmitted signal, x(t), and the noise, n(t), added to it during transmission.
- A receiver is a collection of electronic components and circuits that accepts the transmitted message from the channel and converts it back into a form which a human can understand.
- Receivers contain amplifiers, oscillators, mixers, tuned circuits and filters and a detector that recovers the original signal from the carrier.

Detailed block diagram of a Typical Receive Section

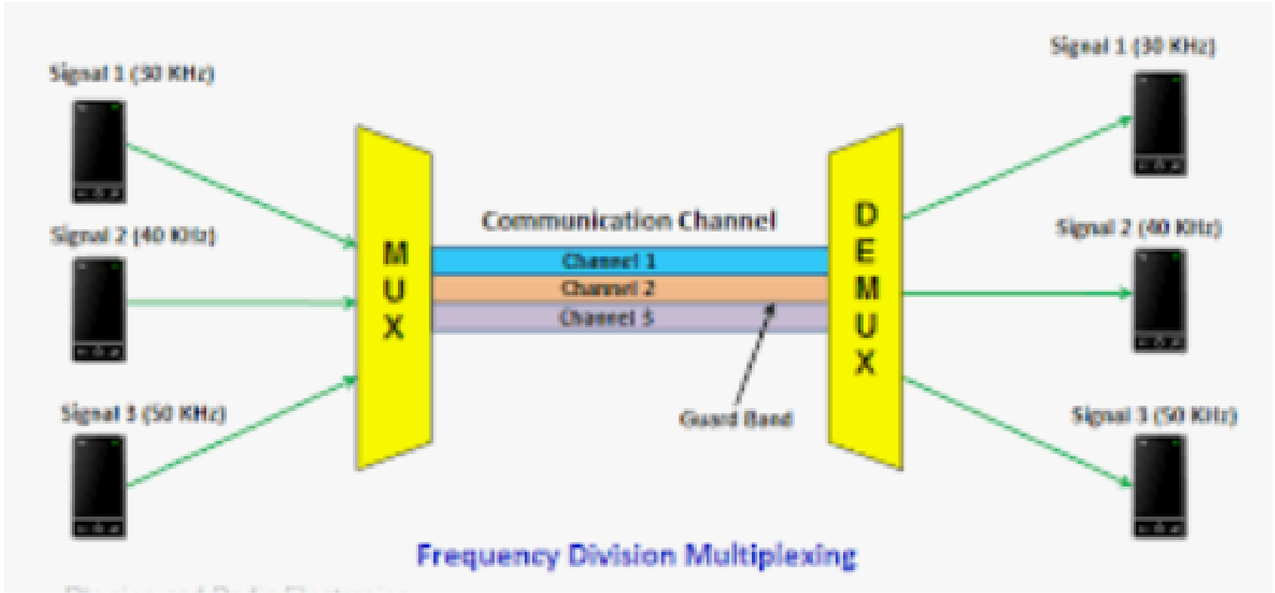


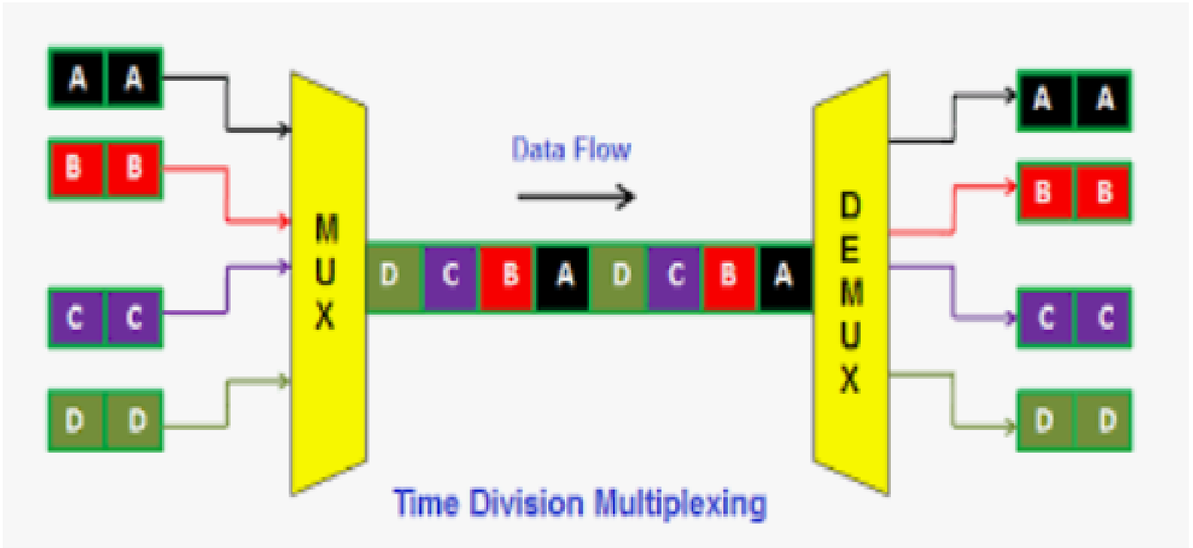
MULTIPLEXING

- Multiplexing is a process which allows more than one signal to be transmitted through a single channel.



TYPES OF MULTIPLEXING





Advantages of Multiplexing

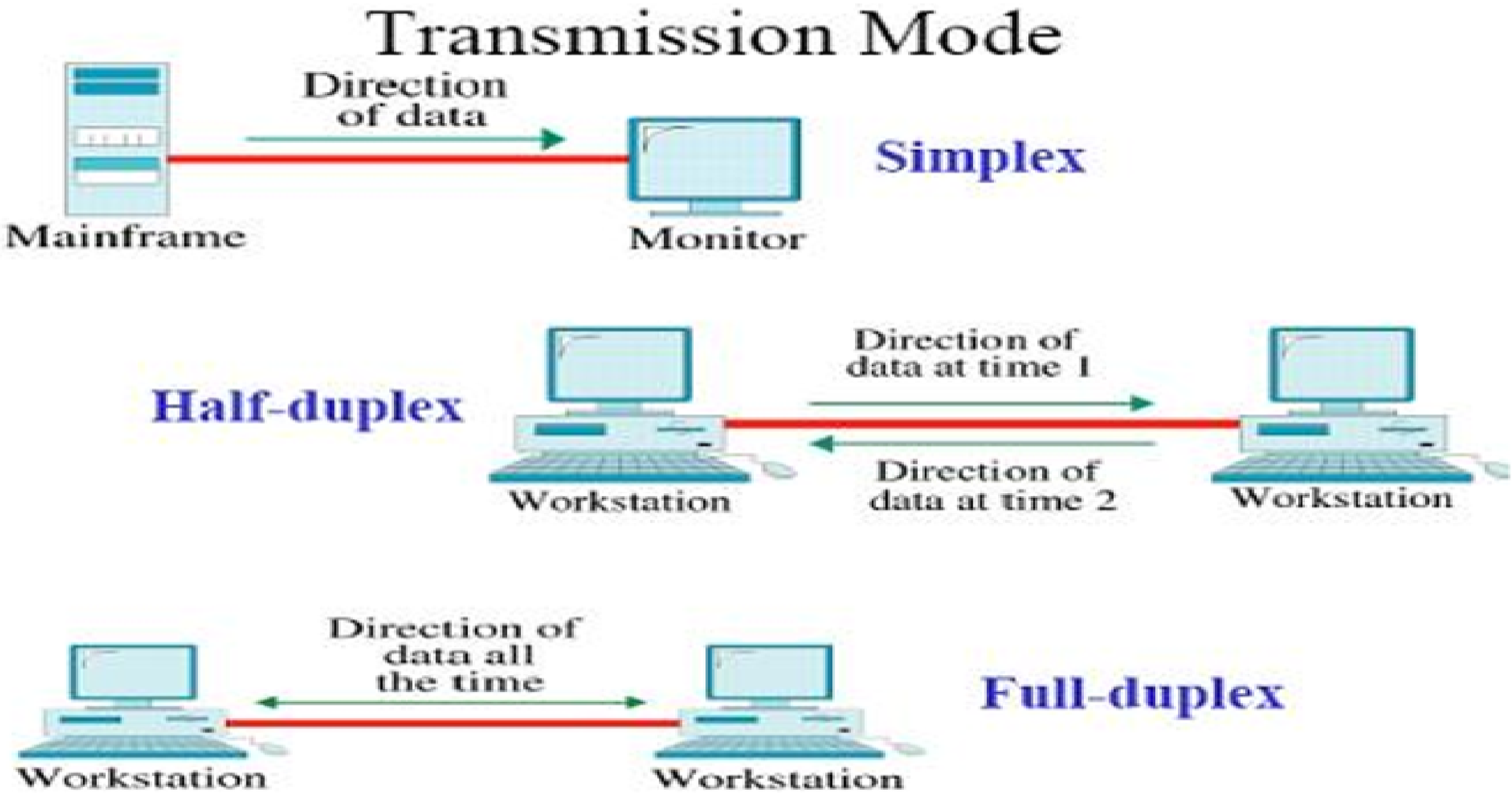
- Multiplexing allows the maximum possible utilization of the available bandwidth of the system.
- The use of multiplexing also makes the communication system economical because more than one signal can be transmitted through a single channel.

TYPES OF COMMUNICATION SYSTEMS

One may categorize communication systems based on their physical infrastructure and the specifications of the signals they transmit.

- Communication Systems based on Physical Infrastructure.
  - Line Communication Systems.
- Communication systems based on Signal specifications.
  - Analog/ Digital Communication systems.
  - Baseband/ Carrier Communication systems.

Communication Systems based on Physical Infrastructure



Communication Systems based on Signal Specifications

The signal specifications used to decide the type of communication include:

- Nature of baseband or information signal.
- Nature of the transmitted signal.

Based on the nature of the baseband signal.

- Analog communication systems.
- Digital communication systems.

Based on the nature of the transmitted signal.

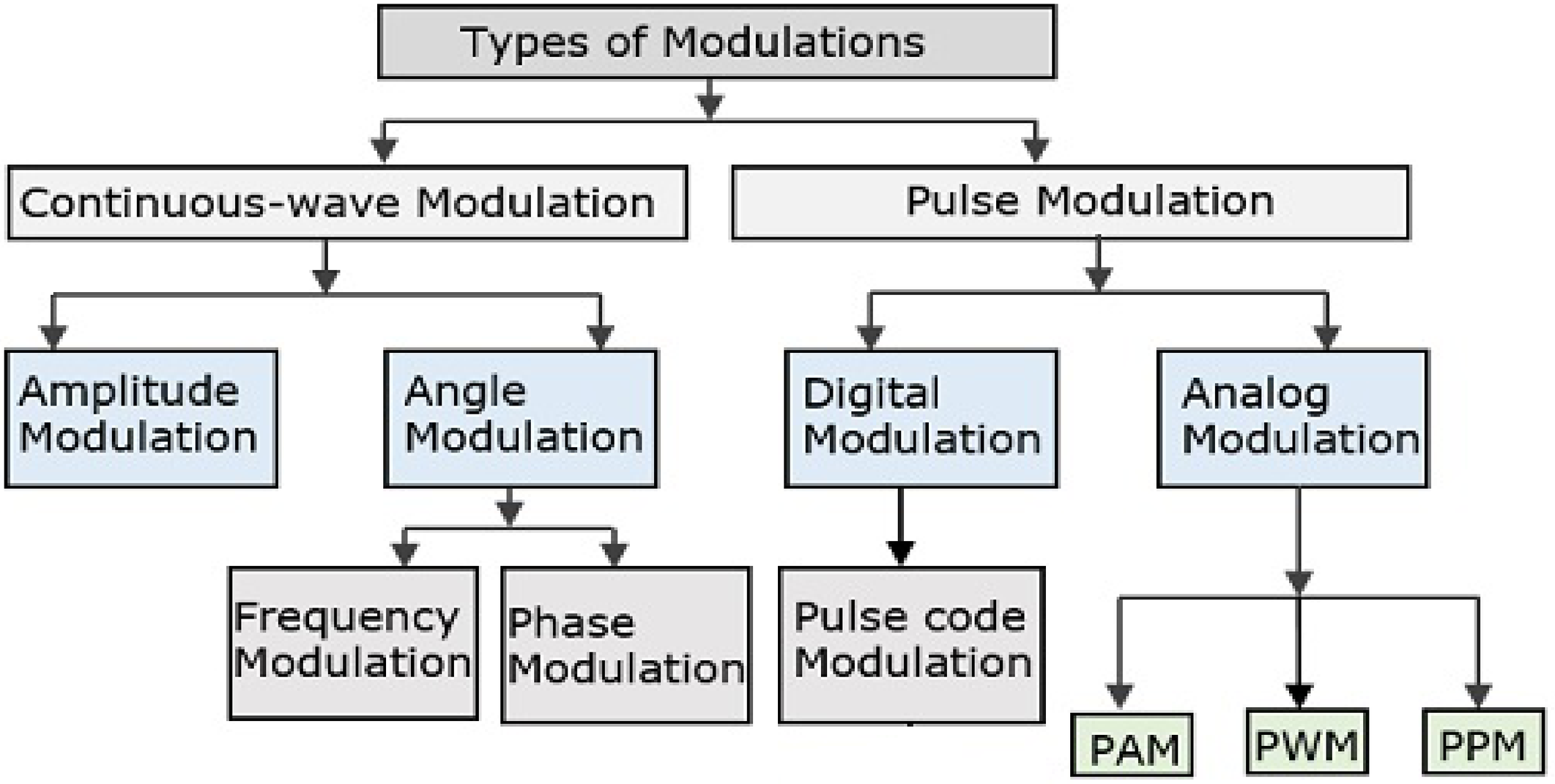
- The two systems can then be put under following categories:
  - Baseband communication system.
  - Carrier communication system.
- Thus, there are four types of communication system categories based on signal specification. These are:
  - Analog communication system.
  - Digital communication system.
  - Baseband communication system.
  - Carrier communication system.

Modulation

- Modulation – process of translating the low frequency baseband signal to higher frequency spectrum
- Process of changing the parameters of the carrier signal, in accordance with the instantaneous values of the modulating signal.

Need for Modulation

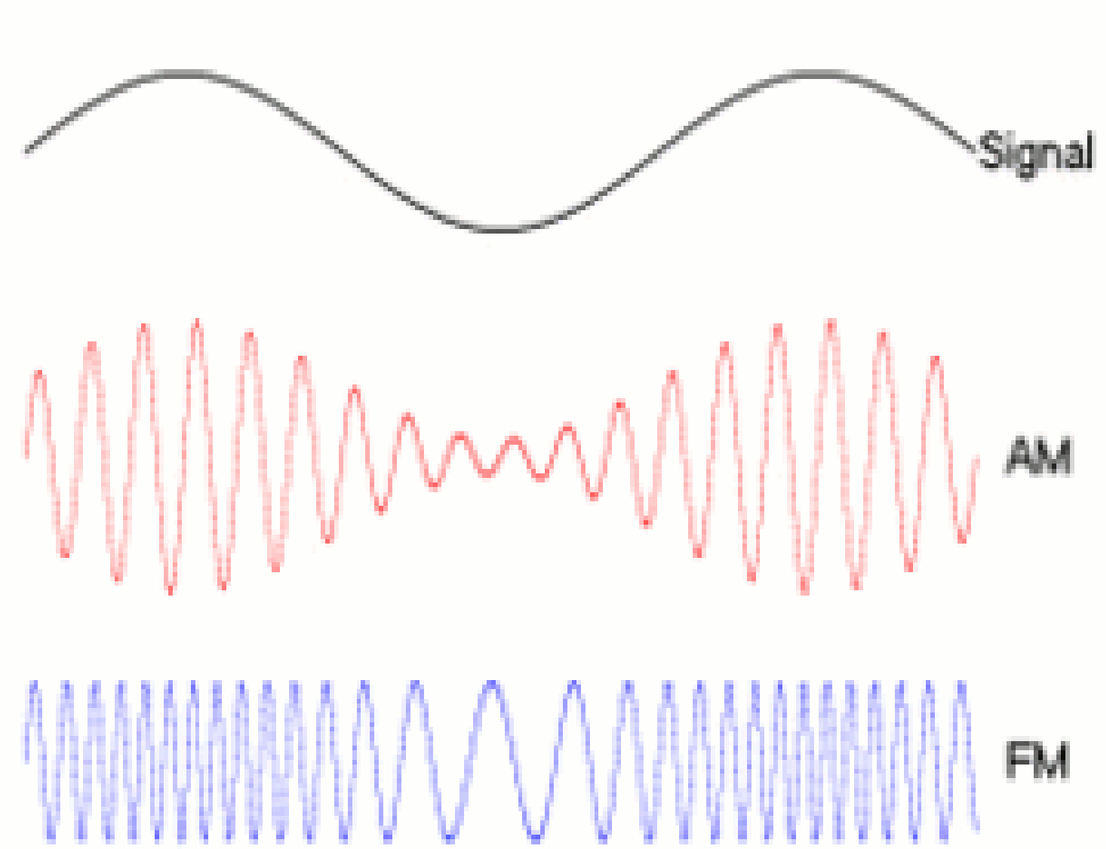
- Improves Quality of reception.
- Reduces Height of antenna.
- Options for Multiplexing.
- Bandwidth Extension.
- Increased Range of Communication.
- Reduced noise and interference.


Types of Modulations
Continuous-wave Modulation
Pulse Modulation
Amplitude Modulation
Angle Modulation
Digital Modulation
Analog Modulation
Frequency Modulation
Phase Modulation
Pulse code Modulation
PAM
PWM
PPM

Types of Analog (Continuous Wave) Modulation

Amplitude modulation

Frequency modulation



Amplitude Modulation

- Amplitude modulation (AM) -modulation technique in which the instantaneous amplitude of the carrier signal is varied in accordance with the instantaneous amplitude of the analog modulating signal to be transmitted
- Modulating signal - an analog baseband signal which is random and has a low frequency
- Carrier signal- a sinusoidal wave with high frequency
- Variations in amplitude of carrier signal represent the information

Amplitude Modulation

- It can be observed from the figure that the amplitude of the carrier wave is varied in accordance with the modulating signal while the frequency and phase of the carrier signal remains unchanged.
- Modulating signal seems to be superimposed on the carrier signal.
- Amplitude variations in the peak values of the carrier signal exactly replicates the modulating signal at different points of time which is known as an envelope.
- Modulation Index = A_m/A_c

Frequency Modulation

- Process of changing the frequency of the carrier signal in accordance with the instantaneous value of the modulating signal while keeping the amplitude and phase of the carrier constant.
- The original frequency of the carrier signal is called the center frequency denoted as .
- Frequency deviation (Δf) -The amount by which the frequency of the carrier wave changes or shifts above or below the center frequency.

$$\Delta f \propto m(t)$$

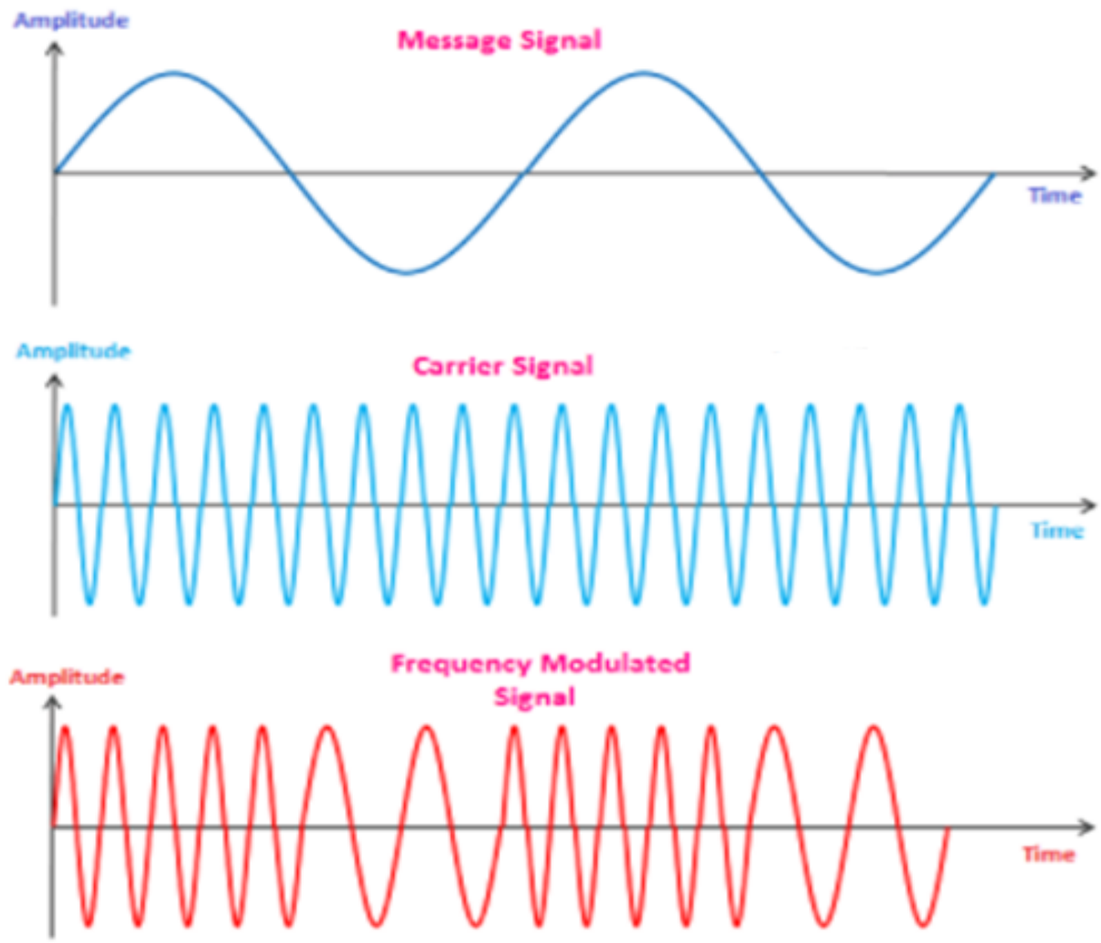
Frequency Modulation

- The total variation of frequency of FM wave from the lowest to highest is termed as carrier swing (CS)

$$CS = 2\times \Delta f$$

- Modulation Index:

=



CELLULAR WIRELESS NETWORKS

- The cellular technology was provided by researchers from BELL Laboratory in 1947.
- For a proper cellular communication it was determined that the larger geographical area must be subdivided into a small sections called cells which uses the concept of frequency reuse to increase the capacity of a wireless and mobile telephone channel.
- In a wireless communication, base stations will be used to provide a connection to all the mobile users within the coverage area and the Base Station(BS) must be connected to a central hub called Mobile Switching Center (MSC).
- As the number of users increases the infrastructure and antenna sites has to increase to provide better facility and quality of service (QOS).

Cellular Telephone System

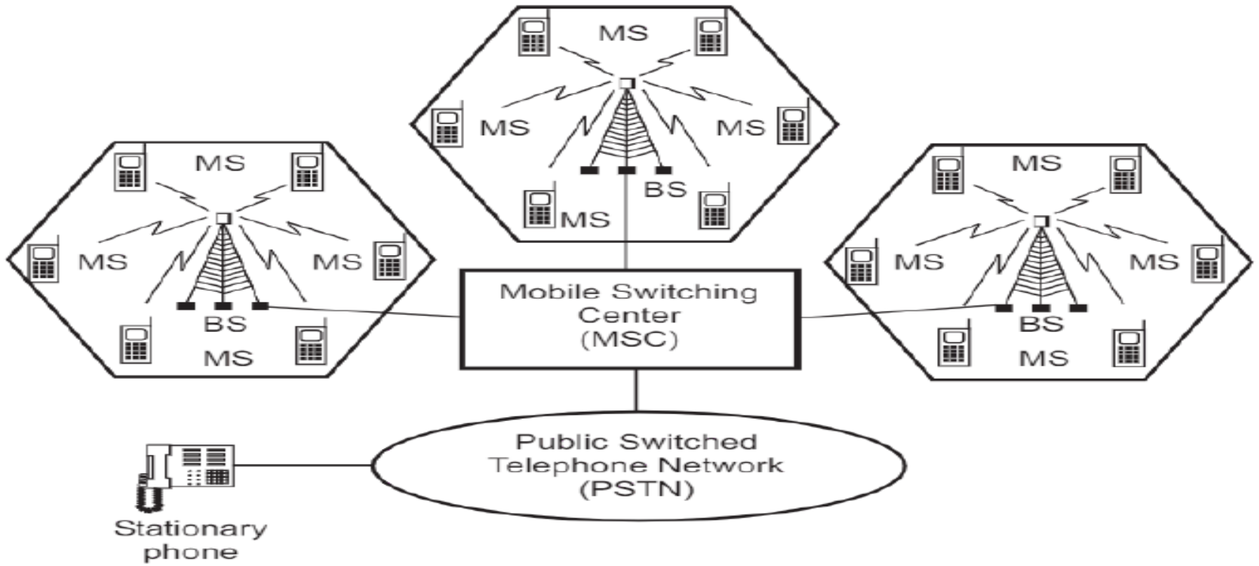


Fig. 8.1 Schematic diagram of a cellular telephone system

Cellular Telephone System

A cellular system comprises of following basic components:

- **Mobile Station (MS)**: This is the mobile handset, which is used by an user to communicate with another user.
- **Cell**: Each Cellular service area is divided into small regions called cell (5 to 20 KM).
- **Base Station (BS)**: Each cell contains an antenna, which is controlled by a small office.
- **Mobile Switching Center (MSC)**: Each base station is controlled by a switching office called mobile switching center.

Cellular Concept and Frequency Reuse

- The cellular concepts was introduced in 1970 and the fundamental principle of the cellular concept is to divide the coverage area into a number of smaller areas which are served by their own radio base station.
- Cells are allocated to these smaller areas in an intelligent way so as to minimize the interference and improve the performance and to cater the traffic loads.

Cellular Concept and Frequency Reuse

- The group of cells in a smaller areas are known as Clusters. Conversations can be handed off from cell to cell to maintain constant phone service as the user moves between cells.
- Cells can be sized according to the subscriber density and demand. As the demand grows cells can be added to accommodate the growth.
- Small sized cells can be used to meet the demand but it will increase the Co-Channel Interference (CCI). Thus it affects the QOS.

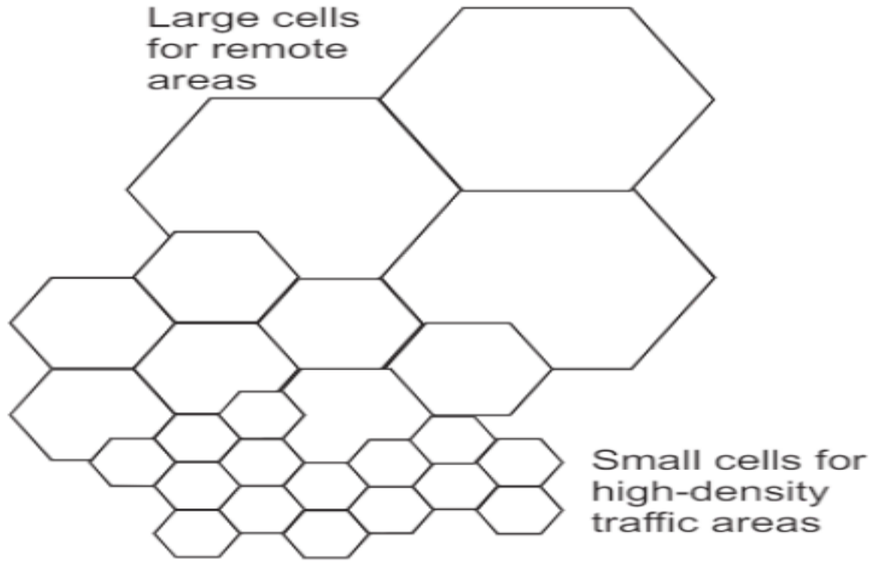


Fig. 8.2 Cellular concept in wireless and mobile networks

Frequency Reuse

- Frequency reuse is a concept in cellular radio system in which the total available channels are divided into a number of channel sets and each channel set is assigned to a cell.
- Below figure illustrates th

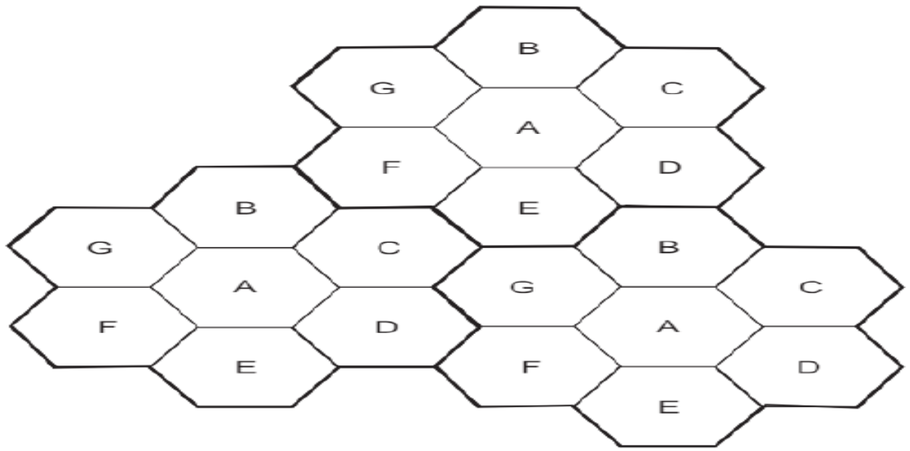


Fig. 8.3 Concept of frequency reuse

- As shown in the figure, cells with the same alphabets use the same channel set. The same set of channels can be reused in the another cell provided that the reuse distance D is fulfilled.
- T e

$$D = \sqrt{3N} \cdot R \qquad \ldots(1)$$

Where N is the number of channel sets (cells in a cluster) (in Fig. 8.2, $N = 7$), R is the radius of a cell.

Note:

- Mobile phone talks to a base station on a particular radio frequency. We don’t have enough frequencies to give each mobile a permanent frequency (like a wire). Hence frequency Reuse is necessary.
- Frequency Reuse is of 2 types
- Temporal

  If mobile is off, no frequency assigned to it.
- Spatial

  Mobiles in non-adjacent cells can use the same frequency.

Reduction of Interference

- Using same frequency channel in different cells will cause Co-Channel Interference (CCI).
- One way to overcome this effect is to maintain minimum distance between the two cells.
- Another way to control CCI is using cell sectoring. Cell sectoring is a method of decreasing the co-channel interference and enhancing system performance by using a directional antenna at the base station.
- The near end ratio interference can occur among the neighbouring channels. Therefore if one channel is assigned to a cell its adjacent channels cannot be assigned to the same cell and vice versa.

Transmitting & Receiving

Transmitting involves the following steps:

- A caller enters his phone number and presses the send button.
- The MS scans the band to select a free channel and sends a strong signal to send the dialed number.
- The BS relays the number to the MSC.
- The MSC in turn dispatches the request to all the base stations in a cellular system.
- The Mobile Identification Number (MIN) is then broadcast over all the forward control channels throughout the cellular system. It is known as paging.
- The MS responds by identifying itself over the reverse control channel.
- The BS relays the acknowledgment sent by the mobile station and informs the MSC about the handshake.
- The MSC assigns an unused voice channel to the call and call is established.

Receiver involves the following steps:

- All the idle mobile stations continuously listens to the paging signal to detect messages directed at them.
- When a call is placed to a mobile station, a packet is sent to the callers home MSC to find out where it is.
- A packet is sent to the base station in its current cell, which then sends a broadcast on the paging channel.
- The called MS responds on the control channel.
- In response, a voice channel is assigned and ringing starts at the MS.

Mobility Management

- A mobile station will be assigned a home network commonly known as location area. When a MS migrates out of its current BS into another a set of procedures need to be followed to maintain proper connectivity which is known as Handoff Management.
- An agent will be allotted to keep track of the current location of the MS and there will be a procedure need to followed to track the users current location which is referred as location Management.
- Handoff management and Location Management together referred as Mobility Management.

HANDOFF

- Each mobile station will be under the control of a cell and its base station.
- When a mobile station moves out of a cell the base station notices that the signal strength of mobile station is fading away and requests all the neighbouring base stations to report the strength they are receiving.
- The BS then transfers the ownership to the cell which is getting the strongest signal and MSC changes the channel carrying the call. This process is called handoff.
- There are two types of handoff:
  - **Hard Handoff:** In this method MS communicates with one BS. As the MS moves from say Cell A to Cell B, the communication between the MS and BS of cell A is first broken before communication is started between MS and BS of cell B. Hence the transition is not smooth.
  - **Soft Handoff:** In this method MS continues to talk with both Cell A & Cell B . As the MS moves from cell A to cell B at some point the communication is broken with the Cell A. Hence the transition is smooth.

First Generation (1G) Technology

- The original cellular networks, now named as 1G, provided analog traffic channels and were designed to be an extension of the public switched telephone networks.
- Users with brick - sized cell phones placed and received calls in the same fashion as landline subscribers.
- The most widely deployed 1G system was the Advanced Mobile Telephone Service (AMTS),developed by AT&T.
- The channels (frequency bands) carry the conversations in analog using Frequency Division Multiple Access (FDMA) .
- The number of channels is inadequate for many larger areas. It has low capacity, unreliable handoff, poor voice links, and no security at all.
- Since voice calls were played back in radio towers, making these calls susceptible to unwanted eavesdropping by third parties.

Second Generation (2G) Technology

- Second-generation (2G) systems were developed to provide higher - quality signals, higher data rates for support of digital services and greater capacity. Key differences between 1G and 2G networks are as below:

1. **Digital traffic channels**: The most notable difference between the two generations is that 1G systems are almost purely analog, whereas 2G systems are digital.

- In particular, 1G system is designed to support voice channels; digital traffic is supported only by the use of a modem that converts the digital data into analog form.
- 2G systems provide digital traffic channels. 2G systems readily support digital data, voice traffic is first encoded in digital form before transmitting.

2. **Encryption**: Because all of the user traffic, as well as control traffic, is digitized in 2G systems, it is a relatively simple matter to encrypt all of the traffic to prevent eavesdropping. All 2G systems provide this capability, whereas 1G system sends user traffic in the clear, providing no security.

3. **Error detection and correction**: The use of error detection and correction techniques in digital traffic stream of 2G systems is very easy. So, the result will be usually with fewer errors.

4. **Channel access**: In 1G system, each cell supports a number of channels. At any given time a channel is allocated to only one user. 2G systems also provide multiple channels per cell, but each channel is dynamically shared by a number of users using time division multiple

Global System for Mobile Communication (GSM)

- The first GSM system developed was GSM-900 (Phase 1). Phase-1 operates in 900 MHz band for voice only.
- Phase-2 (introduced in 1995) which included video and data communication services.
- GSM is a second generation (2G) cellular telephone system to solve the fragmentation problems inherent in 1G cellular telephone system in Europe.
- All European countries were using different cellular telephone standards before implementing GSM. Thus, it was impossible for a subscriber to use a single telephone set throughout Europe.
- GSM was the first totally digitized cellular telephone system which used the services of SS7 signaling and integrated services digital network.
- GSM became the worlds most popular standard with 22-50 million subscribers for new cellular telephone and communication equipment.

GSM System Architecture

- GSM Architecture contains 3 Sub-Syste
  - Mobile Station (MS).
  - Base Station Subsystem (BSS).
  - Network & Switching Subsystem(NSS).

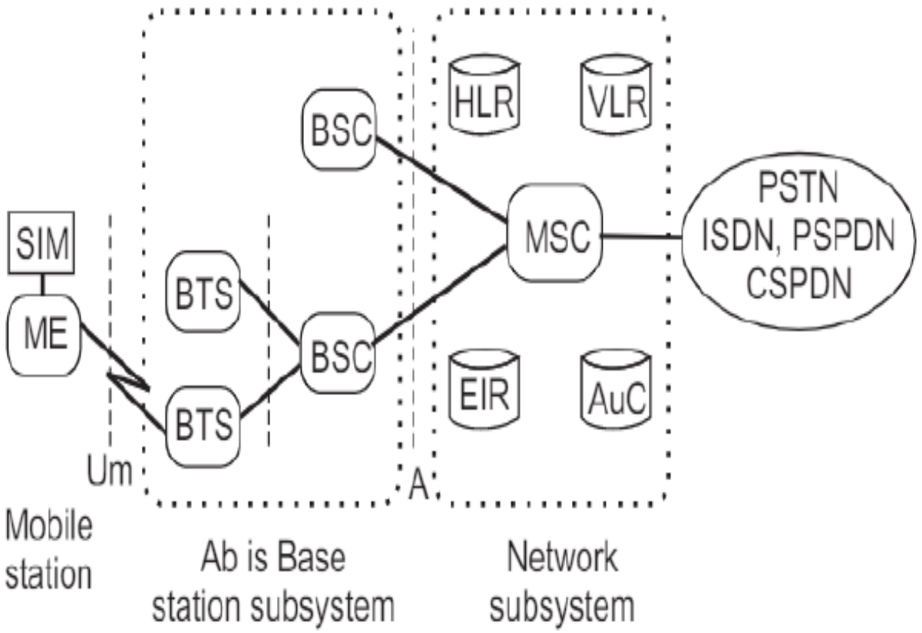


Fig. 8.11 GSM architecture

- Mobile Station:
  - The MS consists of the physical equipment used by subscriber to access a mobile network.
  - MS can be divided into two parts:
    - The first part is the Mobile equipment (ME) which contains the hardware and software to support radio and human interface functions.
    - The second part contains terminal/user- specific data in the form of a smart card known as Subscriber Identity Module (SIM).
    - The SIM card plugs into the first part of the MS and remains in for the duration of use. Without the SIM card, the MS is not associated with any user and cannot make or receive calls (except an emergency call if the network allows).

- Base Station Subsystem:
  - The BSS is the physical equipment that provides radio coverage to prescribed geographical areas, known as the cells. It contains equipment required to communicate with the MS.
  - BSS consists of base station controller (BSC) which performs the control action and a base transceiver station (BTS) where transmitting function is performed.
  - The BTS is the radio transmission equipment and it covers each cell.
  - BSS can serve several cells because it can have multiple BTS.
  - The BTS contains the Transcoder Rate Adapter Unit (TRAU) where the GSM-specific speech encoding and decoding is carried out.
- Network and Switching Subsystem:
  - The NSS includes the main switching functions of GSM, databases required for the subscribers, and mobility management.
  - Its main role is to manage the communications between GSM and other network users.
  - Within the NSS, the switching functions are performed by the MSC. Subscriber information relevant to provisioning of services is kept in the home location register (HLR). The other database in the NSS will be in the visitor location register (VLR).
  - The MSC monitors the mobility of its subscribers and manages necessary resources required to handle and update the location registration procedures and to carry out the handover functions.
  - The MSC is involved in the interworking functions to communicate with other networks such as Public Switched Telephone Network (PSTN) and ISDN.

- Home location register (HLR):
  - The HLR is the functional unit used for management of mobile subscribers.
  - Two types of information are stored in the HLR: subscriber information and part of the mobile information to allow incoming calls to be routed to the MSC for the particular.
  - The HLR stores International Mobile Subscriber Identity (IMSI), Integrated Services Digital Network (ISDN) number, VLR address, and subscriber data.
- Visitor Location Register (VLR):
  - The VLR is linked to one or more MSCs. The VLR is the functional unit that dynamically stores subscriber information when the subscriber is located in the area covered by the VLR.
  - When a roaming MS enters an MSC area, the MSC informs the associated VLR about the MS and the MS goes through a registration procedure.
  - The Steps in registration process is as follows:
    - The VLR recognizes that the MS is from another MN.
    - If roaming is allowed, the VLR finds the MS’s HLR in its home MN.
    - The VLR constructs a Global Title (GT) from the IMSI to allow signaling from the VLR to the MSs HLR via the PSTN/ISDN networks.
    - The VLR generates a Mobile Subscriber Roaming Number (MSRN) that is used to route incoming calls to the MS.
    - The MSRN is sent to the MS’s HLR.

Third Generation(3G) Technology

- The objective of the third generation (3G) wireless communication is to provide fairly high –speed wireless communications to support multimedia, data, and video in addition to voice. The dominant technology for 3G systems is CDMA. The design features of CDMA are:-

1. **Bandwidth:** An important design goal for all 3G systems is to limit channel usage to 5 MHz. But, a bandwidth of 5 MHz or more improves the receiver's ability to resolve multipath when compared to narrower bandwidths. On the other hand, available spectrum is limited by challenging needs, and 5 MHz is a reasonable upper limit that can be allocated for 3G.

2. **Data rate:** The data rates of 144 and 384 kbps are the usually supported by 3G network. Some 3G systems also provide support up to 2 Mbps for office use.

3. **Multirate:** The term multirate refers to the provision of multiple fixed-data-rate channels to a given user, in which different data rates are provided on different channels. The advantage of multirate is that the system can flexibly support multiple simultaneous applications from a given user.

- 3G system is accepted worldwide and the mobile subscriber can get services anywhere in the world. Universal mobile telecommunication system(UMTS) and

HIGH LEVEL ARCHITECTURE OF LTE

[FROM UNIVERSAL MOBILE TELECOMMUNICATION SYSTEM (UMTS) TO LONG-TERM EVOLUTION (LTE)]

- Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM and UMTS standards.
- In 2004, 3GPP began a study into the long term evolution of UMTS. The aim was to keep 3GPP's mobile communication systems competitive over timescales of 10 years and beyond, by delivering the high data rates and low latencies that future users would require.
- Following diagram shows the resulting architecture and the way in which that architecture developed from that of UMTS.

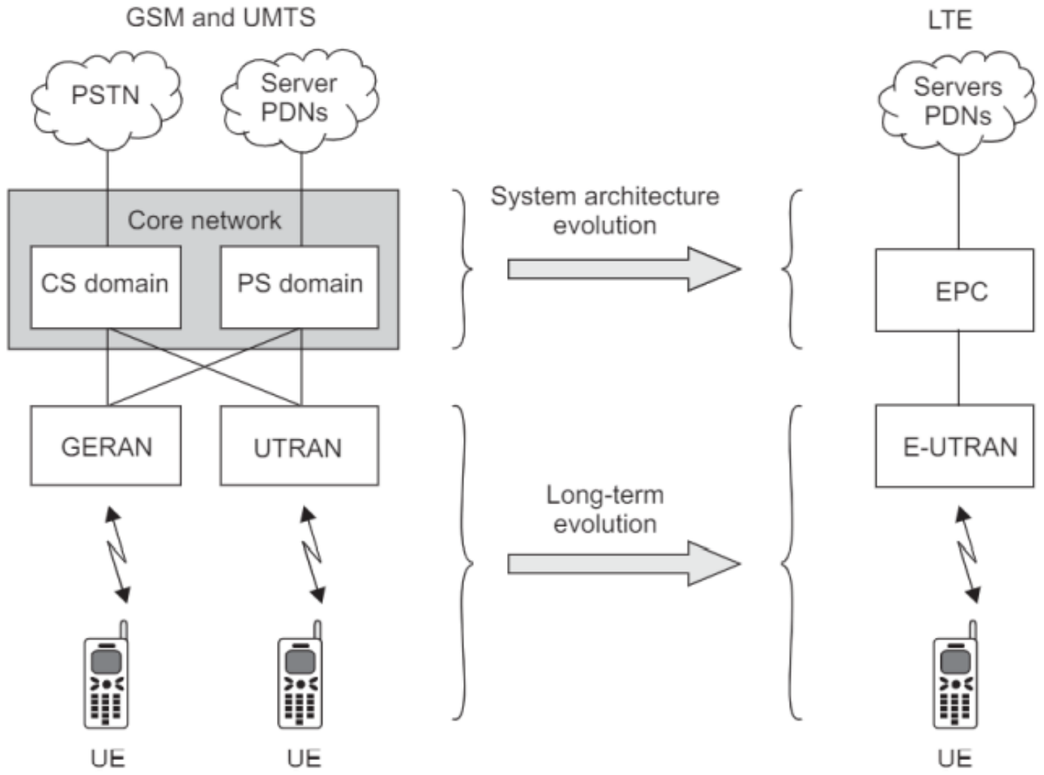


Fig. 8.14 Evolution of the system architecture from GSM and UMTS to LTE

- In the new architecture, the *evolved packet core* (EPC) is a direct replacement for the packet switched domain of UMTS and GSM.
- It distributes all types of information to the user voice as well as data using the packet switching technologies that have traditionally been used for data alone.
- There is no equivalent to the circuit switched domain. Instead, voice calls are transported using voice over IP.
- The *evolved LIMTS terrestrial radio access network* (E-UTRAN) handles the EPC's radio communications with the mobile, so is a direct replacement for the UTRAN.

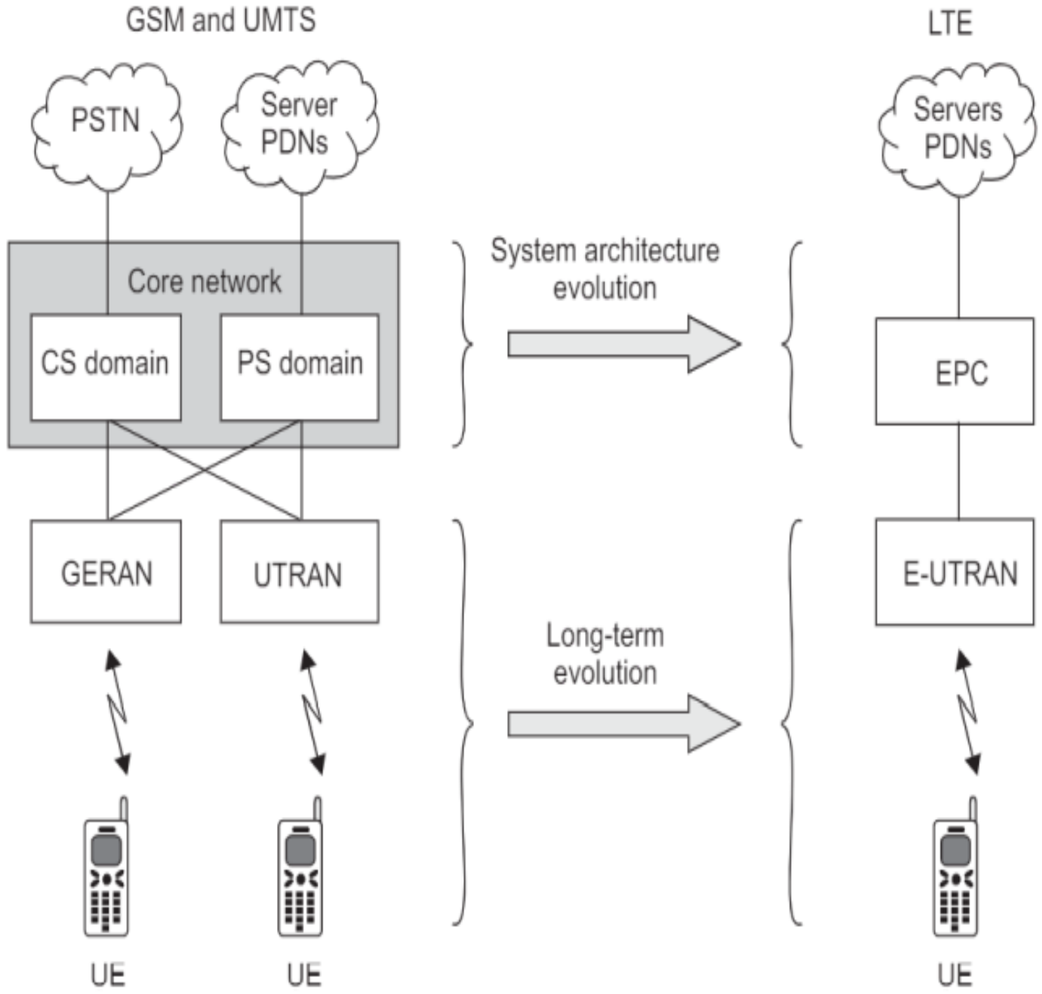


Fig. 8.14 Evolution of the system architecture from GSM and UMTS to LTE

FOURTH GENERATION(4G) TECHNOLOGY

- 4G is short for "fourth-generation" wireless telephone technology. It is the latest technology which is started to be used in many countries.
- LTE or Long Term Evolution is the brand name given to the efforts of 3GPP 4th Generation technology development efforts mostly in Europe and UMB (Ultra-Mobile Broadband) is the brand name for similar efforts by 3GPP2 in North America.
- **The High Level requirements for a 4G technology were identified as:**

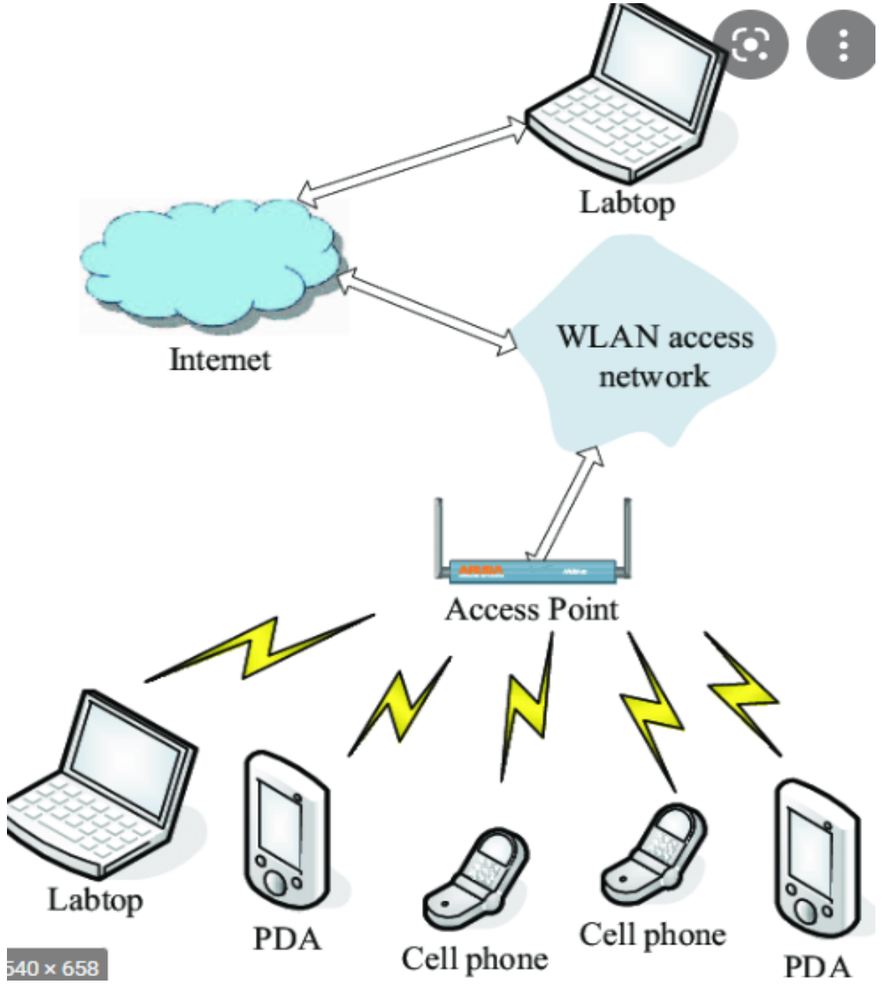
I. Higher spectral efficiency.
II. Reduced cost per bit.
III. Increased service provisioning by lowering the cost and increasing efficiency.
IV. Open interfaces as against closed technologies of the past.
V. Power consumption efficiency.
VI. Scalable and flexible usage of frequency bands.

- **The technical specifications approved by 3GPP for the LTE project include**

I. Orthogonal Frequency Division Multiplexing (OFDM)
II. Advanced antenna technologies such as MIMO (Multiple Input Multiple Output)

WIRELESS LAN (WLAN)

- LAN, which is simply a way of connecting computers together within a single organization, and usually in a single site.
- Wireless Local Area Network (WLAN) links two or more devices using a wireless communication method. It usually provides a connection through an Access Point (AP) to the wider internet.
- WLAN gives users the ability to move around within a local coverage area while still be connected to the network. Just as the mobile phone frees people to make a phone call from anywhere in their home, a WLAN permits people to use their computers anywhere in the network area.
- In WLAN, connectivity no longer implies attachment. Local areas are measured not in feet or meters, but miles or kilometers. An infrastructure need not be buried in the ground or hidden behind the walls, so we can move and change it at the speed of the organization.
- The major standards for WLANs are IEEE 802.11 and HIPERLAN.



WLAN Specifications

The IEEE 802.11 specifications were developed specifically for Wireless Local Area Networks (WLANs) by the IEEE and include four subsets of Ethernet-based protocol standards:

- 802.11
- 802.11a
- 802.11b
- 802.11g.

802.11

- 802.11 operated in the 2.4 GHz range and was the original specification of the 802.11 IEEE standard.
- This specification delivered 1 to 2 Mbps using a technology known as phase-shift keying (PSK) modulation.
- This specification is no longer used and has largely been replaced by other forms of the 802.11 standard.

802.11a

- 802.11a operates in the 5 - 6 GHz range with data rates commonly in the 6 Mbps, 12 Mbps, or 24 Mbps range. Because 802.11a uses the orthogonal frequency division multiplexing (OFDM) standard, data transfer rates can be as high as 54 Mbps.
- OFDM breaks up fast serial information signals into several slower sub-signals that are transferred at the same time via different frequencies, providing more resistance to radio frequency interference.
- The 802.11a specification is also known as Wi-Fi5, and though regionally deployed, it is not a global standard like 802.11b.

802.11b

- The 802.11b standard (also known as Wi-Fi) operates in the 2.4 GHz range with up to 11 Mbps data rates and is backward compatible with the 802.11 standard.
- 802.11b uses a technology known as complementary code keying (CCK) modulation, which allows for higher data rates with less chance of multi-path propagation interference
- The overall benefits include:
  - Up to twice the data rate of conventional 11 Mbps 802.11b standard products.
  - Greater WLAN coverage.
  - Improved security over standard 802.11b.

802.11g

- 802.11g is the most recent IEEE 802.11 draft standard and operates in the 2.4 GHz range with data rates as high as 54 Mbps over a limited distance.

Advantages of WLAN over Wired LAN

- **Installation**: Wireless LANs are very easy to install. There is no requirement for wiring every workstation and every room. This ease of installation makes wireless LANs inherently flexible. If a workstation must be moved, it can be done easily and without additional wiring, cable drops or reconfiguration of the network.
- **Portability**: If a company moves to a new location, the wireless system is much easier to move than ripping up all of the cables that a wired system would have snaked throughout the building

BLUETOOTH

- It is a Wireless Personal Area Network (WPAN) technology and is used for exchanging data over smaller distances. This technology was invented by Ericson in 1994.
- Maximum devices that can be connected at the same time are 7.
- Bluetooth ranges up to 10 meters. It provides data rates up to 1 Mbps or 3 Mbps depending upon the version.
- Bluetooth is a standard used in links of radio of short scope, destined to replace wired connections between electronic devices like cellular telephones, Personal Digital Assistants (PDA), computers, and many other devices.
- Bluetooth technology can be used at home, in the office, in the car, *etc.*
- This technology allows to the users instantaneous connections of voice and information between several devices in real time. The way of transmission used assures protection against interferences and safety in the sending of information. Between the principal characteristics, must be named the hardiness, low complexity, low consume and low cost.
- The Bluetooth is a small microchip that operates in a band of available frequency throughout the world. Communications can realize point to point and point multipoint.
- The standard Bluetooth operates in the band of 2,4 GHz. This band is available worldwide, however, the width of the band can differ in different countries.

Bluetooth Architecture — Piconets and Scatternets

The architecture of Bluetooth defines two types of networks:

1. Piconet
2. Scatternet

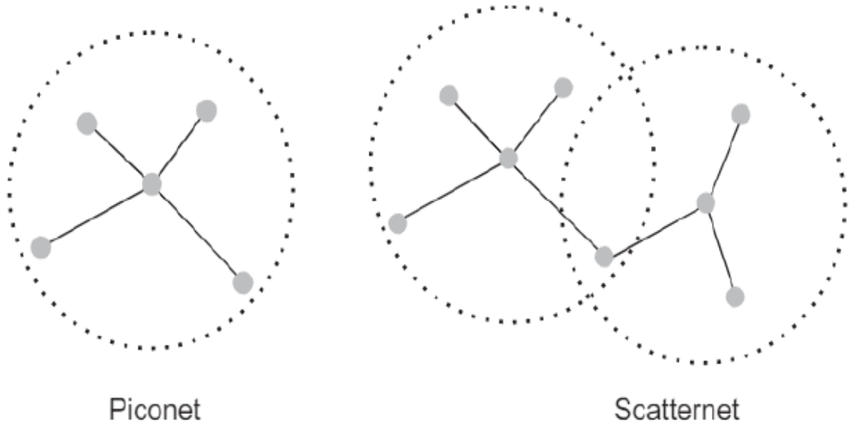


Fig. 8.18 Illustration of the concept of piconet and scatternet in bluetooth

Piconet:

- Piconet is a type of Bluetooth network that contains one primary node called master node and seven active secondary nodes called slave nodes. Thus, we can say that there are total of 8 active nodes which are present at a distance of 10 meters.
- The communication between the primary and secondary node can be one-to-one or one-to-many. Possible communication is only between the master and slave; Slave-slave communication is not possible.

Scatternet:

- It is formed by using various piconets.
- A slave that is present in one piconet can act as master or we can say primary in another piconet. This kind of node can receive message from master in one piconet and deliver the message to its slave into the other piconet where it is acting as a slave. This type of node is refer as bridge node.

- Up to seven slaves can be active and served simultaneously by the master.
- If the master needs to communicate with more than seven devices, it can do so by first instructing active slave devices to switch to low-power park mode and then inviting other parked slaves to become active in the piconet.
- This juggling act can be repeated, which allows a master to serve a large number of slaves.
  - Most envisioned Bluetooth applications involve local communication among small groups of devices.
  - A piconet configuration consisting of two, three, or up to eight devices is ideally suited to meet the communication needs of such applications.
  - When many groups of devices need to be active simultaneously, each group can form a separate piconet. The slave nodes in each piconet stay synchronized with the master clock and hop according to a channel-hopping sequence that is a function of the masters node address. Since channel-hopping sequences are pseudorandom, the probability of collision among piconets is small.
  - Piconets with overlapping coverage can coexist and operate independently. Nonetheless, when the degree of overlap is high, the performance of each piconet starts to degrade.
  - In some usage scenarios, however, devices in different piconets may need to communicate with each other.
  - Bluetooth defines a structure called *scatternet* to facilitate inter piconet communication. A scatternet is formed by interconnecting multiple piconets.