Module V

Cellular Wireless Networks - Introduction, cellular telephone system, cellular concept and frequency reuse. Wireless Network Topologies - First Generation (1G) Technology, Second Generation (2G) Technology, GSM Communications, GSM System architecture, Third Generation (3G) Technology, CDMA Technology, High-level architecture of LTE, Fourth Generation (4G) Technology, Wireless LAN, Bluetooth, Bluetooth Architecture.

Satellite Communication – Elements of Satellite Communication, Types of satellites – GEO, LEO, MEO.

Optical Fiber Communication - A fiber optic Communication system.

Microwave Communication – Introduction, Frequency modulated microwave communication system.

Cellular Wireless Networks

Introduction:

To provide wireless communication within a particular geographic region, an integrated network of base stations must be installed to provide sufficient radio coverage to all the mobile users. The key principles of cellular telephone were provided in 1947 by the researchers at bell telephone laboratories and other telecom companies throughout the world. For cellular communications, it was determined that the large geographic area must be subdivided into small sections, called cells.

In this chapter, we are going to discuss the concept of *cells* and *frequency reuse, wireless network topologies* and *different generations of mobile communication systems.* Later, in this chapter, concepts Bluetooth and WLAN will also be discussed so that the readers can actually know about the technologies they are using in their everyday life.

Cellular Telephone System

As shown in Fig. 5.9.1, a cellular system comprises the following basic components:

- **Mobile Stations (MS):** Mobile handsets, which is used by a user to communicate with another user
- **Cell**: Each cellular service area is divided into small regions called cell (5 to 20Km)
- **Base Stations (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

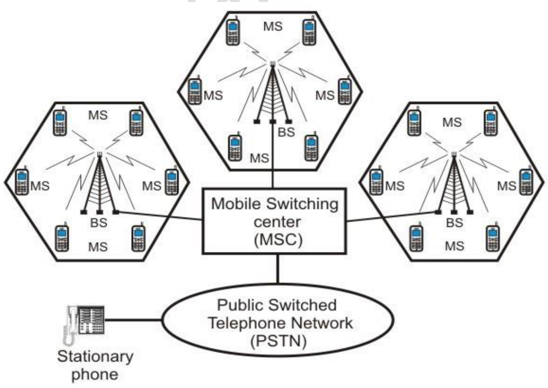


Figure 5.9.1 Schematic diagram of a cellular telephone system

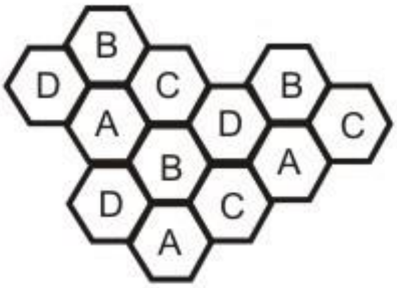
Frequency Reuse Principle

Cellular telephone systems rely on an intelligent allocation and reuse of channels. Each base station is given a group of radio channels to be used within a cell. Base stations in neighbouring cells are assigned completely different set of channel frequencies. By limiting the coverage areas, called *footprints*, within cell boundaries, the same set of channels may be used to cover different cells separated from one another by a distance large enough to keep interference level within tolerable limits as shown in Fig. 5.9.2. Cells with the same letter use the same set of frequencies, called *reusing cells*. N cells which collectively use the available frequencies (S = k.N) is known as cluster. If a cluster is replicated

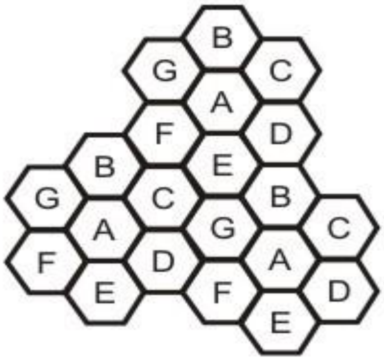
M times within a system, then total number duplex channels (capacity) is C= M.k.N= M.S.

Reuse factor:

Fraction of total available channels assigned to each cell within a cluster is 1/N. Example showing reuse factor of ¼ is shown in Fig. 5.9.2 (a) and Fig. 5.9.2(b) shows reuse factor of 1/7.



(a)



(b)

Figure 5.9.2 (a) Cells showing reuse factor of 1/4, (b) Cells showing reuse factor of 1/7

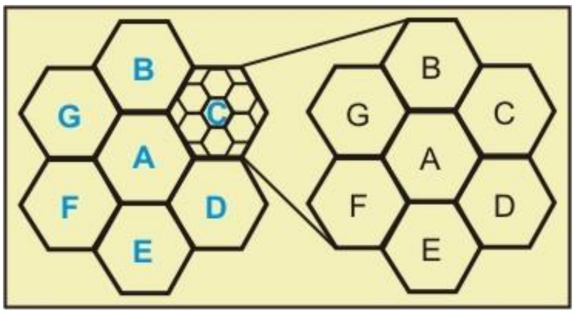


Figure 5.9.3 A cell is replaced by a cluster as demand increases

As the demand increases in a particular region, the number of stations can be increased by replacing a cell with a cluster as shown in Fig. 5.9.3. Here cell C has been replaced with a cluster. However, this will be possible only by decreasing the transmitting power of the base stations to avoid interference.

Frequency Reuse:

Frequency reuse is the core concept of the cellular mobile radio system. The total available channels are divided into a number of channel sets (Actually, frequency reuse pattern is equally to the number of channel sets). Each channel set is assigned to a cell. Cells are assigned a group of channels that is completely different from neighbouring cell.

Figure 5.9.2 illustrates the concept of frequency reuse. Cells with the same alphabet use the same channel set. The same set of channels can be reused in another cell provided that the reuse distance Dis fulfilled (Fig. 8.3). The reuse distance is the minimum separation of identical channels that have the same carrier frequency, at which there is acceptable interference

$$D = \sqrt{3N}.R$$

Where N is the number of channel sets (cells in a cluster), R is the radius of a cell.

Reduction of Interference

Reusing an identical frequency channel in different cells is limited by co-channel interference between cells, and the co-channel interference can become a major problem. One way to reduce co-channel interference (CCI) is to keep the separation between two co-channel cells by a sufficient distance. Another way for controlling CCI is to use directional antennas at the base station (BS), and we call it cell sectoring. The adjacent channel interference, coming from neighbouring channels and next channels, is another consideration in channel assignment. The adjacent channel interference depends on the separation of two adjacent channels, the characteristic of receiver filters, and the distance of two adjacent channel users. 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 and Receiving

Basic operations of transmitting and receiving in a cellular telephone network are discussed in this section.

Transmitting involves the following steps:

- A caller enters a 10-digit code (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 number entered.
- The BS relays the number to the MSC
- The MSC in turn dispatches the request to all the base stations in the 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 acknowledgement sent by the mobile and informs the MSC about the handshake.
- The MSC assigns an unused voice channel to the call and call is established.

Receiving involves the following steps:

- All the idle mobile stations continuously listen 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 callee's 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 callee MS responds on the control channel.
- In response, a voice channel is assigned and ringing starts at the MS.

Mobility Management

A MS is assigned a home network, commonly known as location area. When an MS migrates out of its current BS into the footprint of another, a procedure is performed to maintain service continuity, known as *Handoff management*. An agent in the home network, called *home agent*, keeps track of the current location of the MS. The procedure to keep track of the user's current location is referred to as *Location management*. Handoff management and location management together are referred to as *Mobility management*.

Handoff: At any instant, each mobile station is logically in a cell and under the control of the cell's base station. When a mobile station moves out of a cell, the base station notices the MS's signal fading away and requests all the neighbouring BSs to report the strength they are receiving. The BS then transfers ownership to the cell getting the strongest signal and the MSC changes the channel carrying the call. The process is called *handoff*. There are two types of handoffs;

Hard Handoff and Soft Handoff. In a *hard handoff*, which was used in the early systems, a MS communicates with one BS. As a MS moves from cell A to cell B, the communication between the MS and base station of cell A is first broken before communication is started between the MS and the base station of B. As a consequence, the transition is not smooth. For smooth transition from one cell (say A) to another (say B), an MS continues to talk to both A and B. As the MS moves from cell A to cell B, at some point the communication is broken with the old base station of cell A. This is known as *soft handoff*.

Roaming: Two fundamental operations are associated with Location Management; *location update* and *paging*. When a Mobile Station (MS) enters a new Location Area, it performs a location updating procedure by making an association between the foreign agent and the home agent. One of the BSs, in the newly visited Location Area is informed and the home directory of the MS is updated with its current location. When the home agent receives a message destined for the MS, it forwards the message to the MS via the foreign agent. An authentication process is performed before forwarding the message.

WIRELESS NETWORK TOPOLOGIES

Wireless network topology is defined as the configuration in which a mobile terminal (MT) communicates with other mobile terminals. Basically, there are two types of topologies used in wireless networks as follows:

Ad-Hoc Network Topology:

Ad-hoc wireless networks do not need any infrastructure to work. Each node can communicate directly with other nodes, so no base station is necessary. These networks are primarily used by military and also in a few commercial applications for voice and data transmission. This topology is suitable for rapid deployment of a wireless network in a mobile or fixed environment

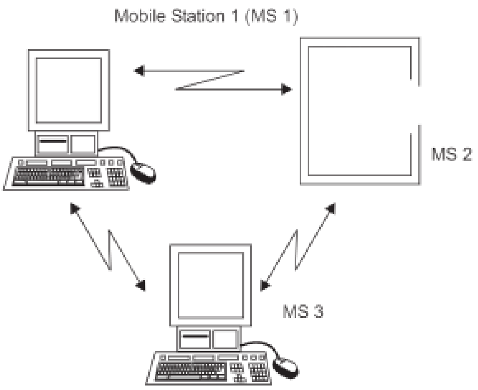


Fig. 8.4 Single hop ad-hoc network

Figure 8.4 shows a single-hop, ad-hoc network where every user terminal has the functional capability of communicating directly with any other user terminal. Nodes within an ad-hoc network can only communicate if they can reach each other physically, i.e., if they are within each other's radio range or if other nodes can forward the message.

In some ad-hoc networking applications, where users may be distributed over a wide area, a given user terminal may be able to reach only a portion of the other users in the network due to the transmitter signal power limitations. In this situation, user terminals will have to cooperate in carrying messages across the network between widely separated stations. These networks are called multi hop ad-hoc networks as shown in Fig. 8.5.

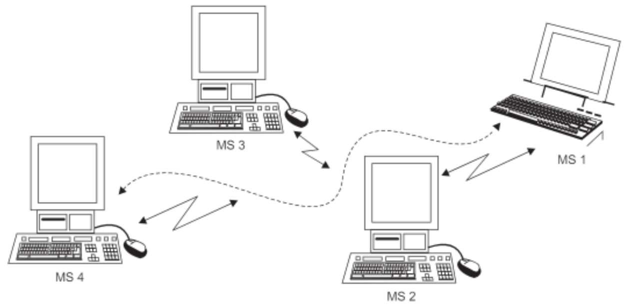


Fig. 8.5 Multi hop ad-hoc network

Infrastructure Network Topology:

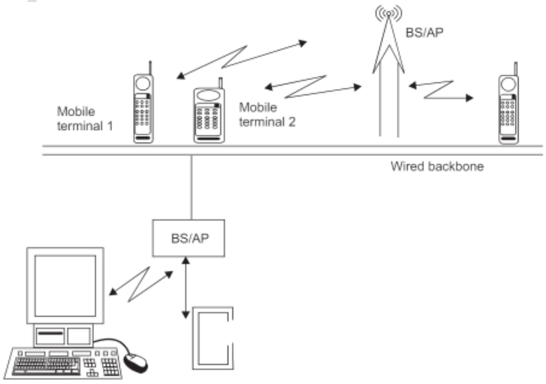


Figure 8.6 Infrastructure network topology

In this topology, there is a fixed infrastructure that supports the communication between the mobile terminals and between mobile and fixed terminals. This topology is often designed for large coverage areas and multiple base stations (BS) or access point (AP) operations. Figure 8.6 shows the basic operation of an infrastructure network with a single base station. Base station (BS) serves as the hub of the network and mobile terminals are located at different positions at the ends of spokes. Any communication from one wireless station user to another comes through the base station. Thus, we can say that the hub is involved in managing the user access to the network.

First Generation System

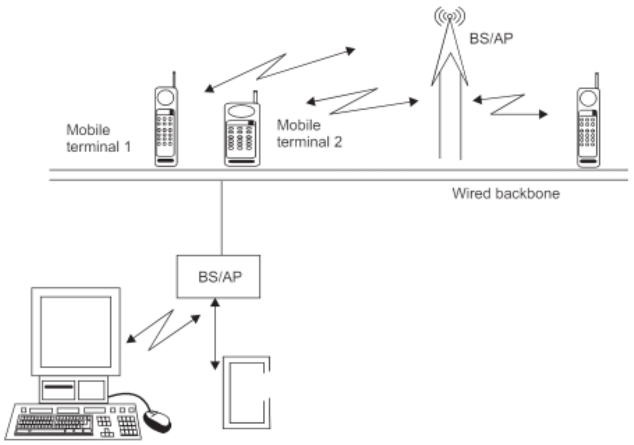


Figure 8.6 Infrastructure network topology

Figure 5.9.8 Frequency bands used in AMPS system

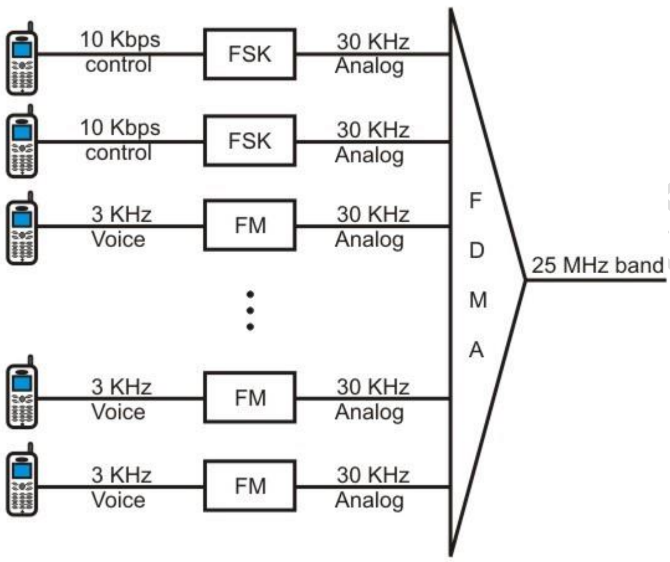
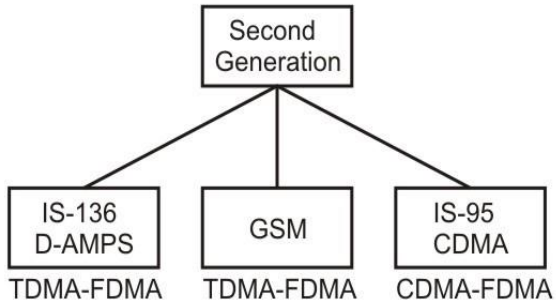


Figure 5.9.9 FDMA medium access control technique used in AMPS

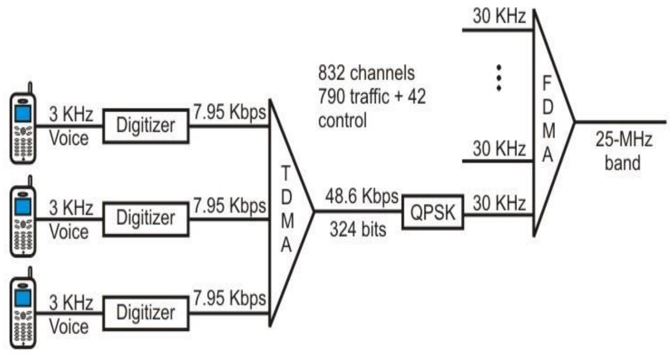
The first generation was designed for voice communication. One example is Advanced Mobile Phone System (AMPS) used in North America. AMPS is an analog cellular phone system. It uses 800 MHz ISM band and two separate analog channels; forward and reverse analog channels. The band between 824 to 849 MHz is used for reverse communication from MS to BS. The band between 869 to 894 MHz is used for forward communication from BS to MS. Each band is divided in to 832 30-KHz channels as shown in Fig. 5.9.8. As each location area is shared by two service providers, each provider can have 416 channels, out of which 21 are used for control. AMPS uses Frequency Division Multiple Access (FDMA) to divide each 25-MHz band into 30-KHz channels as shown in Fig. 5.9.9.

Second Generation

The first-generation cellular network was developed for analog voice communication. To provide better voice quality, the second generation was developed for digitized voice communication. Three major systems were evolved, as shown in Fig. 5.9.10



D-AMPS: D-AMPS is essentially a digital version of AMPS and it is backward compatible with AMPS. It uses the same bands and channels and uses the frequency reuse factor of 1/7. 25 frames per second each of 1994 bits, divided in 6 slots shared by three channels. Each slot has 324 bits-159 data, 64 control, 101 error-correction as shown in Fig. 5.9.11. As shown in the figure, it uses both TDMA and FDMA medium access control techniques.



GSM: The Global System for Mobile (GSM) communication is a European standard developed to replace the first-generation technology. Uses two bands for duplex communication. Each voice channel is digitized and compressed to a 13Kbps digital signal. Each slot carries 156.25 bits, 8 slots are multiplexed together creating a FDM frame, 26 frames are combined to form a multiframe, as shown in Fig. 5.9.12. For medium access control, GSM combines both TDMA and FDMA. There is large amount of overhead in TDMA, 114 bits are generated by adding extra bits for error correction. Because of complex error correction, it allows a reuse factor as low as 1/3.

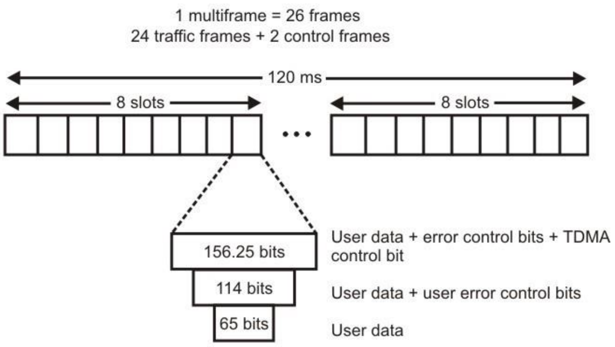


Figure 5.9.12 Multiframe components

IS-95 CDMA: IS-95 is based on CDMA/DSSS and FDMA medium access control technique. The forward and backward transmissions are shown in Fig. 5.9.13 and Fig. 5.9.14, respectively.

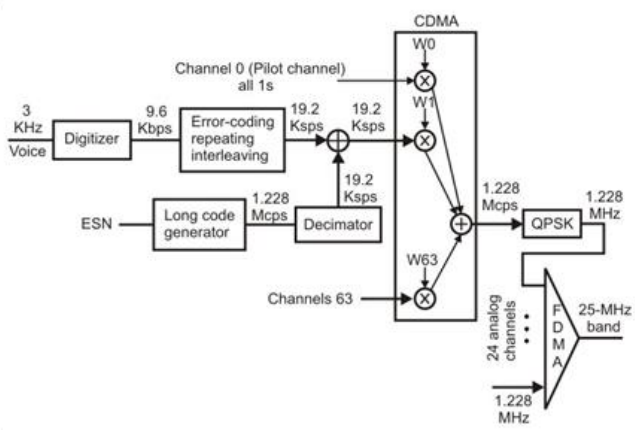


Figure 5.9.13 Forward transmission in IS-95 CDMA

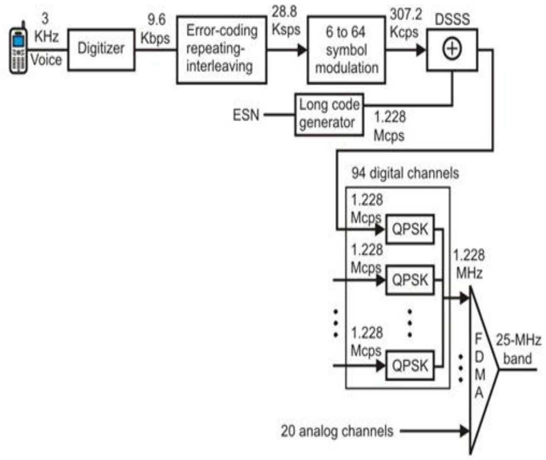


Figure 5.9.14 Backward transmission in IS-95 CDMA

GLOBAL SYSTEM FOR MOBILE (GSM) COMMUNICATIONS

Most of the existing systems were operated at different frequencies and all were analog. In 1982, conference of European Posts and Telegraphs (CEPT) formed a study group named Group Special Mobile GSM to study development of a Pan European Public and Mobile Telephone System using ISDN. The responsibility of GSM was transferred to European Telecommunicators Standard Institute (ETSI) in 1989. And the Phase-I was published in 1990. GSM provided its subscriber with good quality privacy and security, it began its services in Germany in1991 and by 1993, 33 GSM networks were installed in 22 countries.

GSM System Architecture

The system architecture of GSM is shown in the Fig. 8.11. It consists of three major subsystems that interact with each other and with the subscribers through specified network interfaces. The three subsystems are as follows:

- Mobile station (MS)
- Base station subsystem (BSS)
- Network and switching subsystem (NSS)

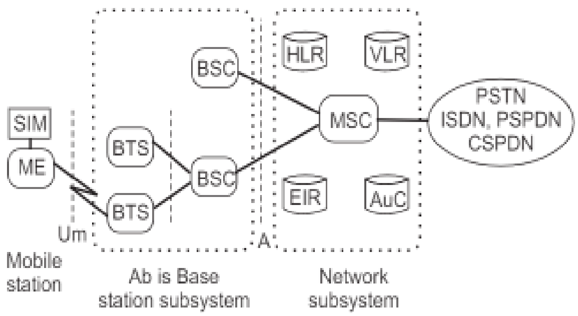


Fig. 8.11 GSM architecture

Mobile station (MS): The MS consists of the physical equipment used by the subscriber to access a mobile network for offered telecommunication services. Functionally, the MS includes a Mobile Terminal (MT) and, depending on the services it can support, various Terminal Equipment (TE), and combinations of TE and Terminal Adaptor (TA) functions (the TA acts as a gateway between the TE and the MT). Various types of MS, such as the vehicle mounted station, portable station, or handheld station, are used Basically, a 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), which can effectively be considered a sort of logical terminal.

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 possibly an emergency call if the network allows). The SIM card is issued by the mobile service provider after subscription, while the first part of the MS would be available at retail shops to buy or rent.

An MS has a number of identities including the International Mobile Equipment Identity (IMEI), the International Mobile Subscriber Identity (IMSI), and the ISDN number. The IMSI is stored in the SIM. The SIM card contains all the subscriber-related information stored on the users side of the radio interface.

Base Station Subsystem (BSS): 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. Functionally, a BSS consists of a control function carried out by the base station controller (BSC) and a transmitting function performed by the BTS. The BTS is the radio transmission equipment and covers each cell. A BSS can serve several cells because it can have multiple BTSs. The BTS contains the Transcoder Rate Adapter Unit (TRAU). In TRAU, the GSM-specific speech encoding and decoding is carried out, as well as the rate adaptation function for data

Network and Switching Subsystem (NSS): 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 is the visitor location register (VLR). The MSC performs the necessary switching functions required for the MSs located in an associated geographical area, called an MSC area.

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. The interworking functions of the MSC depend upon the type of the network to which it is connected and the type of service to be performed.

Home location register (HLR): The HLR is the functional unit used for management of mobile subscribers. The number of HLRs in a PLMN varies with the characteristics of the PLMN. 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 MS. Any administrative action by the service provider on subscriber data is performed in the HLR. The HLR stores IMSI, MS 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; the MS goes through a registration procedure. The registration procedure for the MS includes these activities

- 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 signalling 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 third generation systems support high speed packet switched data (up to 2Mbps). In fact GPRS is considered to be a transition step from second generation cellular systems to third generation cellular systems.

The 3G systems are accepted world-wide and the subscriber is able to get the mobile services from anywhere in the world without replacing his handset or SIM card. The subscriber also gets the same environment and services in the visiting network as in his home network also being independent of the terminal. Apart from this, the modern generation cellular system provide with the framework to build various kind of services (like VPN and conferencing) on the top of core cellular networks. Currently the 3G cellular systems are being evolved from the existing cellular networks. Despite the efforts of standardization, UMTS (Universal Mobile Telecommunication System) and CDMA-2000 are the two main 3G networks which are being used. Both these systems use CDMA technology. The UMTS system is being promoted by ETSI (European Telecommunication Standards Institute) and is a successor of GSM while CDMA 2000 is successor of IS-95.

CDMA TECHNOLOGY

CDMA offers several advantages over FDMA and TDMA. Error control coding, spreading of the spectrum, soft handoffs and strict power control are some of those advantages. CDMA is primarily an air-interface and access technique that is based on direct sequence - spread spectrum (DS-SS). The air interface is significantly different in the case of CDMA compared with TDMA technique. The core fixed network infrastructure of CDMA supports the wireless interface is very similar to the structure of the GSM core network.

Both IS-136 and IS-95 use CDMA as the air interface and the access method. In CDMA, all user data, the control channel and signalling information are transmitted on the same frequency at the same time. Also, CDMA employs powerful error control codes. The quality of voice is also improved and the multipath and fading problems are also reduced in CDMA technology.

Capacity of a Mobile Telecommunication System

In 1948, Claude Shannon discovered a theoretical limit on the data rate that can be achieved from any communication system. We will write it in its simplest form, as follows:

$$C = B \log_2 (1+SINR)$$

Here, SINR is the *signal to interference plus noise ratio*, in other words the power at the receiver due to the required signal, divided by the power due to noise and interference. B is the bandwidth of the communication system in Hz, and C is the *channel capacity* in bits s^{-1}. It is theoretically possible for a communication system to send data from a transmitter to a receiver without any errors at all, provided that the data rate is less than the channel capacity. the signal to interference plus noise ratio in decibels (dB):

$$\text{SINR (dB)} = 10 \log_{10}(\text{SINR})$$

From Universal Mobile Telecommunication System (UMTS) To Long-Term Evolution (LTE)

High Level Architecture of Long-Term Evolution (LTE)

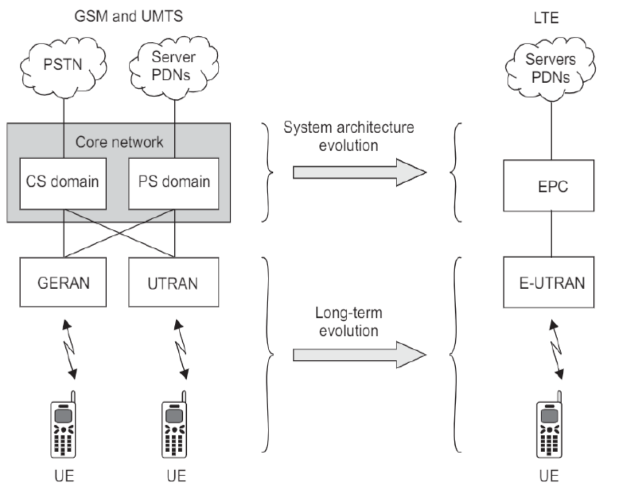


Fig. 8.14 Evolution of the system architecture from GSM and UMTS to LTE

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. Fig. 8.14 shows the resulting architecture and the way in which that architecture developed from that of UMTS. 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 UMTS terrestrial radio access network* (E-UTRAN) handles the EPC's radio communications with the mobile, so is a direct replacement for the UTRAN. The mobile is still known as the user equipment, though its internal operation is very different from before. The new architecture was designed as part of two 3GPP work items, namely *system architecture evolution* (SAE), which covered the core network, and *long term evolution* (LTE), which covered the radio access network, air interface and mobile. Officially, the whole system is known as the *evolved packet system* (EPS), while the acronym LTE refers only to the evolution of the air interface. Despite this official usage, LTE has become a colloquial name for the whole system, and is regularly used in this way by 3GPP. We will use LTE in this colloquial way

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:

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

The technical specifications approved by 3GPP for the LTE project include the use of Orthogonal Frequency Division Multiplexing (OFDM). It specifies downlink peak speeds of 326Mbps and uplink peak speeds of 86Mbps, both in a 20 MHz bandwidth. It also mandates the round trip latency between the base station and handsets to IO-milliseconds.

The LTE-advanced is now de facto 4G mobile communications system, and it is likely to remain so. It does not have a serious competitor in sight. To understand LTE-A, it is better to have a look at LTE first. LTE is a very different system from UMTS, as both its architecture and the technologies used are either new or greatly enhanced versions of the old entities. In this section we will first have a look at LTE architecture, and then we will discuss the radio access network (RAN), the new OFDM air interface, and the core network. The final section presents the LTE-A enhancements to LTE. We present a brief overview of an LTE—A system.

LYE-A System Architecture

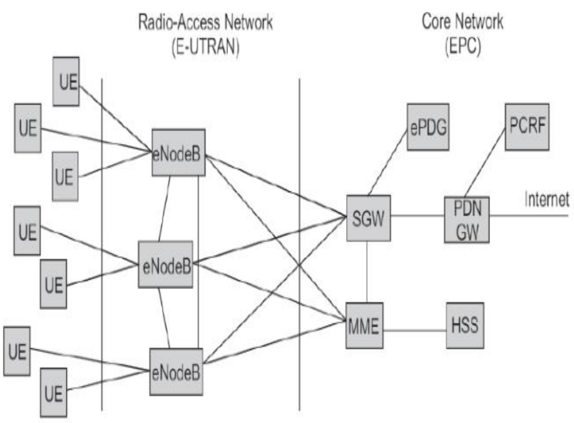


Fig. 8.15 LTE system architecture

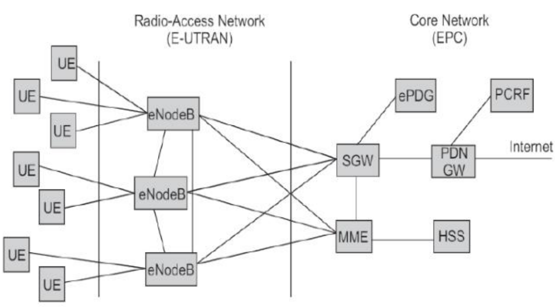


Fig. 8.16 ULTRAN system architecture

Figure 8.15 gives a high-level description of the LTE-A network architecture. Readers who are more familiar with 2G/3G networks may notice the simplicity of the LTE-A architecture. In the old GSM there were base transceiver stations (BTS), and base station controllers (BSC), and in UTRA networks (see Fig. 8.16) we have NodeBs and radio network controllers (RNC), and several different entities in the core network

WIRELESS LAN (WLAN)

To know about WLAN, first we need to know the definition of 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. This 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 kilometres. 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, and 802.IIg.

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. 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 LAN 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 easierto move than ripping up all of the cables that a wired system would have snaked throughout the building

BLUETOOTH

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

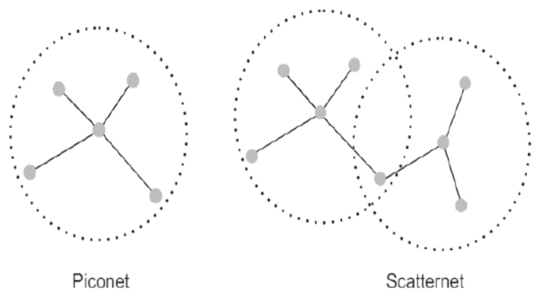


Fig. 8.18 Illustration of the concept of piconet and scatternet in Bluetooth

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.

Bluetooth defines a structure called *scatternet* to facilitate inter piconet communication. A scatternet is formed by interconnecting multiple piconets. As shown on the right side of Fig. 8.18, the connections are formed by *bridge nodes,* which are members of two or more piconets. A bridge node participates in each member piconet on a time-sharing basis. After staying in a piconet for some time, the bridge can turn to another piconet by switching to its hopping sequence. By cycling through all member piconets, the bridge node can send and receive packets in each piconet and also forward packets from one piconet to another.

Applications of Bluetooth

Most common applications of Bluetooth are as follows:

- Wireless control of and communication between a mobile phone and a hands-free headset.
- Wireless networking between PCs in a confined space and where little bandwidth is required.
- Wireless communications with PC input and output devices, the most common being the mouse, keyboard and printer.
- Transfer of files between devices.
- Replacement of traditional wired serial communications in test equipment, GPS receivers, medical equipment, bar code scanners, and traffic control devices.
- Sending small advertisements from Bluetooth enabled advertising hoardings to other, discoverable, Bluetooth devices.
- Dial-up internet access on personal computer or PDA using a data-capable mobile phone as a modem.

Satellite Communication –

Elements of Satellite Communication, Types of satellites – GEO, LEO, MEO

INTRODUCTION

The outer space has always fascinated people on the earth and communication through space evolved as an offshoot of ideas for space travel. In the area of satellite communications, the technology has been responsive to the imaginative dreams. Hence it is also expected that technological innovations will lead the evolution of satellite communications towards the visions of today. Satellites are specifically made for telecommunication purpose. They are used for mobile applications such as communication to ships, vehicles, planes, hand-held terminals and for TV and radio broadcasting. Satellites orbit around the earth Fig. 9.1(a). Depending on the application, these orbits can be circular or elliptical. Satellites in circular orbits always keep the same distance to the earth's surface.

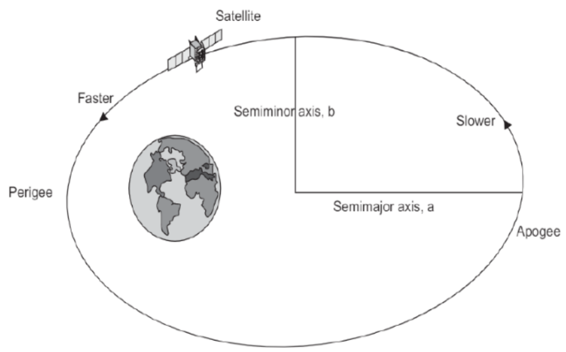


Fig. 9.1 *(a)* Satellite orbit around the Earth

Moon is the natural satellite, of course, but the idea of manmade communications satellites came from Sir Arthur C. Clark in 1945. The Soviets launched the first manmade satellite, *Sputnik 1,* in 1957. The first communications satellite (a simple reflector) was the U.S. *Echo 1* in 1960. The first "geosynchronous" satellite, *Syncom,* went up in 1962. There are now over 5000 operational satellites in orbit, most of which are large commercial (mostly communications) satellites.

It governs all the activities and transmissions happening in the satellite communication. Configuration of an earth station will also be discussed in detail to make the readers understand about the basic control and handling of the satellites

ELEMENTS OF SATELLITE COMMUNICATION

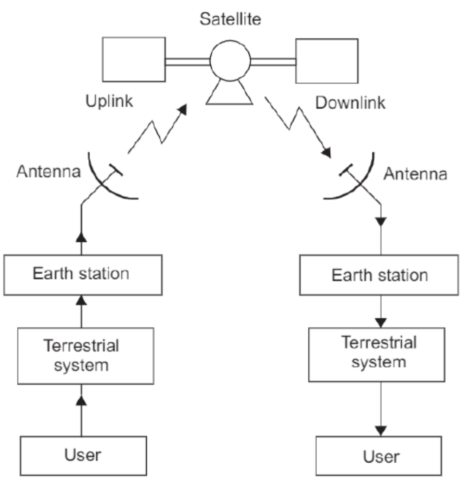


Fig. 9.4 Basic elements of a satellite communication system

The basic elements of a satellite communication system are shown in the Fig. 9.4. Basic elements are:

User: The user generates the baseband signal that proceeds through a terrestrial network and transmitted to a satellite at the earth station

Satellite: The satellite consists of a large number of repeaters **in** the space that perform the reception of modulated RF carrier in its uplink frequency spectrum from all the earth stations in the present networks, amplifiers. They retransmit them back to the earth stations in the down link frequency spectrum. To avoid interference, downlink and uplink frequency spectrums should be separate and different

Terrestrial network: This is a network on the ground which carries the signal from user to earth station. It can be a telephone switch or a dedicated link between the user and the earth station

Earth Station: It's a radio station located on the earth and used for relaying signals from satellites. It governs all the activities and transmissions happening in the satellite communication

TYPES OF SATELLITES (BASED ON ORBITS)

Geostationary Earth Orbit (GEO) Satellites

GEO satellites are synchronous with respect to earth. Looking from a fixed point from Earth, these satellites appear to be stationary. These satellites are placed in the space in such a way that only three satellites are sufficient to provide connection throughout the surface of the Earth. The orbit of these satellites is circular. There are three conditions which lead to geostationary satellites. Lifetime expectancy of these satellites is 15 years.

- The satellite should be placed 37,786 kms (approximated to 36,000 kms) above the surface of the earth
- These satellites must travel in the rotational speed of earth, and in the direction of motion of earth, that is eastward.
- The inclination of satellite with respect to earth must be 00.

Geostationary satellite in practical is termed as geosynchronous as there are multiple factors which make these satellites shift from the ideal geostationary condition.

- Gravitational pull of sun and moon makes these satellites deviate from their orbit. Over the period of time, they go through a drag. (Earth's gravitational force has no effect on these satellites due to their distance from the surface of the Earth.)

- These satellites experience the centrifugal force due to the rotation of Earth, making them deviate from their orbit.

- The non-circular shape of the earth leads to continuous adjustment of speed of satellite from the earth station.

These satellites are used for TV and radio broadcast, weather forecast and also, these satellites are operating as backbones for the telephone networks

Low Earth Orbit (LEO) Satellites

These satellites are placed 500-1500 kms above the surface of the earth. As LEO satellites circulate on a lower orbit, hence they exhibit a much shorter period that is 95 to 120 minutes. LEO systems try to ensure a high elevation for every spot on earth to provide a high quality communication link. Each LEO satellite will only be visible from the earth for around ten minutes. Using advanced compression schemes, transmission rates of about 2,400 bit/scan be enough for voice communication. LEOs even provide this bandwidth for mobile terminals with omni• directional antennas using low transmit power in the range of 1W. The delay for packets delivered via a LEO is relatively low. Smaller footprints of LEOs allow for better frequency reuse, similar to the concepts used for cellular networks. LEOs can provide a much higher elevation in polar regions and better global coverage. These satellites are mainly used in remote sensing and mobile communication services (due to lower latency).

Disadvantages:

- The biggest problem of the LEO concept is the need for many satellites if global coverage is to be reached.

- Several concepts involve 50–200 or even more satellites in orbit. The high number of satellites combined with the fast movements resulting in a high complexity of the whole satellite system.

- The short time of visibility with a high elevation requires additional mechanisms for connection handover between different satellites.

- One general problem of LEOs is the short lifetime of about five to eight years due to atmospheric drag and radiation.

Medium Earth Orbit (MEO) Satellites

MEO satellites can be positioned somewhere between LEOs and GEOs, both in terms of their orbit and due to their advantages and disadvantages. Using orbits around 10,000 km, the system only requires a dozen satellites which is more than a GEO system, but much less than a LEO system. These satellites move more slowly relative to the Earth's rotation allowing a simpler system design (satellite periods are about six hours). Depending on the inclination, a MEO can cover larger populations, so requiring fewer handovers.

Disadvantages:

- Due to the larger distance to the earth, delay increases to about 70–80 ms.

- These satellites need higher transmit power and special antennas for smaller footprints.

A FIBER-OPTIC COMMUNICATION SYSTEM

A generalized configuration of a fiber-optic communication system is shown in Fig. 10.15. A brief description of each block in this figure will give us an idea of the prime components employed in this system

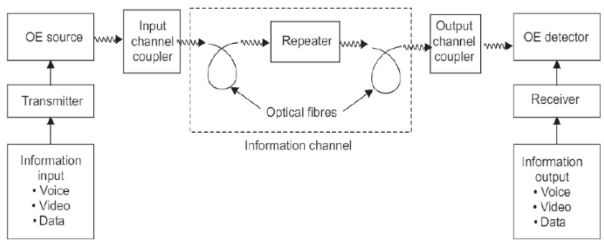


Fig. 10.15 Generalized configuration of a fiber-optic communication system

Information Input

The information input may be in any of the several physical forms, *e.g.,* voice, video, or data. Therefore an input transducer is required for converting the non-electrical input into an electrical input. For example, a microphone converts a sound signal into an electrical current, a video camera converts an image into an electric current or voltage, and so on. In situations where the fiber-optic link forms a part of a larger system, the information input is normally in electrical form. The information input must be in the electrical form for onward transmission through the fiber-optic link.

Transmitter

The transmitter (or the modulator, as it is often called) comprises an electronic stage which (i) converts the electric signal into the proper form and (ii) impresses this signal onto the electromagnetic wave (carrier) generated by the optoelectronic source. The modulation of an optical carrier may be achieved by employing either an analog or a digital signal. An analog signal varies continuously and reproduces the form of the original information input, whereas digital modulation involves obtaining information in the discrete form. In the latter, the signal is either on or off, with the *on* state representing a digital 1 and the *off* state representing a digital 0. These are called *binary digits* (or bits) of the digital system. The number of bits per second (bps) transmitted is called the *data rate.* If the information input is in the analog form, it may be obtained in the digital form by employing an analog-to-digital converter.

Optoelectronic Source

An optoelectronic (OE) source generates an electromagnetic wave in the optical range (particularly the near-infrared part of the spectrum), which serves as an information carrier Common sources for fiber-optic communication are the light-emitting diode (LED) and the injection laser diode (ILD). Ideally, an optoelectronic source should generate a stable single frequency electromagnetic wave with enough power for long-haul transmission. However, in practice, LEDs and even laser diodes emit a range of frequencies and limited power.

Channel Couplers

In the case of open channel transmission, for example, the radio or television broadcasting system, the channel coupler is an antenna. It collects the signal from the transmitter and directs this to the atmospheric channel. At the receiver end again the antenna collects the signal and routes it to the receiver. In the case of guided channel transmission, *e.g.,* a telephone link, the coupler is simply a connector for attaching the transmitter to the cable.

In fiber-optic systems, the function of a coupler is to collect the light signal from the optoelectronic source and send it efficiently to the optical fiber cable. Several designs are possible. At the end of the link again a couplers required to collect the signal and direct it onto the photodetector.

Fiber-optic Information Channel

In communication systems, the term 'information channel' refers to the path between the transmitter and the receiver. In fiber-optic systems, the optical signal traverses along the cable consisting of a single fiber or a bundle of optical fibers. An optical fiber is an extremely thin strand of ultra-pure glass designed to transmit optical signals from the optoelectronic source to the optoelectronic detector. In its simplest form, it consists of two main regions:

(i) a solid cylindrical region of diameter 8-100 um Called the core

(ii) a coaxial cylindrical region of diameter normally 125 m called the cladding.

The refractive index of the core is kept greater than that of the cladding. This feature makes light travel through this structure by the phenomenon of total internal reflection. In order to give strength to the optical fiber, it is given a primary or buffer coating of plastic, and then a cable is made of several such fibers. This optical fiber cable serves as an information channel.

For clarity of the transmitted information, it is required that the information channel should have *low attenuation* for the frequencies being transmitted through it and a large light-gathering capacity.

Repeater

As the optical signals propagate along the length of the fiber, they get attenuated due to absorption, scattering, *etc.,* and broadened due to dispersion. After a certain length, the cumulative effect of attenuation and dispersion causes the signals to become weak and indistinguishable. Therefore, before this happens, the strength and shape of the signal must be restored. This can be done by using either a regenerator or an optical amplifier.

Optoelectronic Detect

The reconversion of an optical signal into an electrical signal takes place at the OE detector. Semiconductor *p-i-n* or avalanche photodiodes are employed for this purpose. The photocurrent developed by these detectors is normally proportional to the incident optical power and hence to the information input. The desirable characteristics of a detector include small size, low power consumption, linearity, flat spectral response, fast response to optical signals, and long operating life.

Receiver

For analog transmission, the output photocurrent of the detector is filtered to remove the de bias that is normally applied to the signal in the modulator module, and also to block any other undesired frequencies accompanying the signal. After filtering, the photocurrent is amplified if needed. These two functions are performed by the receiver module.

For digital transmission, in addition to the filter and amplifier, the receiver may include decision circuits. If the original information is in analog form, a digital-to-analog converter may also be required.

The design of the receiver is aimed at achieving high sensitivity and low distortion. The *signal-to-noise ratio* (SNR) and *bit-error rate* (BER) for digital transmission are important factors for quality communication.

Information Output

Finally, the information must be presented in a form that can be interpreted by a human observer. For example, it may be required to transform the electrical output into a sound wave or a visual image. Suitable output transducers are required for achieving this transformation. In some cases, the electrical output of the receiver is directly usable. This situation arises when a fiber-optic system forms the link between different computers or other machines.

Microwave Communication

INTRODUCTION

'Microwaves' is a descriptive term finds its origin in the frequencies used for its communication. The term microwaves used to identify *em* waves in the frequency spectrum ranging approximately from 1 GHz (10^9 Hz) to 30 GHz. This corresponds to wavelengths from 30 cm to 1 cm. Sometimes higher frequencies (extending upto 600 GHz) are also called microwaves. These waves present several interesting and unusual features not found in other portions of *e,,,* frequency spectrum. These features make 'microwaves' uniquely suitable for several useful applications.

A significant advantage associated with the use of microwaves for communications is their large bandwidth. A 10% bandwidth at 3 GHz implies availability of 30 MHz spectrum. This means all the radio, television and other communications that are transmitted in the frequency spectrum from DC to 300 MHz can be accommodated in a 10% bandwidth around 3 GHz. Since the lower frequency part of the radio spectrum is getting crowded, there is a trend to use more and more of microwave region (and beyond) for various different services. The high frequencies used in the microwave communication environment makes it very different compared to the low frequency communications.

At such high frequencies of operation, it is possible to focus the radio energy concentrated into a beam, with a much less bandwidth compared to low-frequency communication systems. There are other advantages associated with the small wavelengths at microwave frequencies. Unlike lower radio frequencies, these waves are not reflected and practically not absorbed by the ionosphere. Another reason for the microwaves to operate as such a high frequency is the availability of the spectrum in that range. The low frequency spectrum is generally used for *omni directional* (all directions) broad coverage systems and is not generally available (only low tens of kHz is licensed). Omni directional coverage systems generally include a transmitting antenna, which broadcasts in all directions.

MICROWAVE COMMUNICATIONS

Microwave communications are widely used for telephone networks, in broad cast and television systems and several other communication application by services, railways, *etc.* Now, we study the basic operation of a *frequency modulated microwave communication system.*

Frequency Modulated Microwave Communication System

FM microwave systems, when equipped with suitable multiplexing technology are capable of carrying hundreds of voice and data channels. In addition to point-to-point communications. the FM microwave systems can also be extended to broadcasting television audio signals.

The baseband input signal can be anything from a FDM voice channel to a TDM channel or from a composite video signal to a wideband data signal. The baseband signal is first applied to the preemphasis network that, in general, provides extra amplification to high frequency baseband signals. When the signal coming out of the preemphasis circuit is applied to the FM modulator, the low frequencies get frequency modulated by the intermediate Frequency (IF) carrier and the high frequencies get phase modulated. This ensures a more uniform SNR (signal to noise ratio) throughout the frequency range. The IF frequencies are generally in the range of 60-80 MHz. The modulated output from the FM deviator is passed through the IF amplifier to the mixer. The mixer then converts the signal to microwave frequencies. Using the mixer instead of the multiplier preserves the modulation index and also limits the bandwidth. The output of the mixer is passed through the band pass filter to band limit the signal and then to the channel-combining network. Finally, the signal is fed to the transmitter antenna.

Figure 11.17 shows the simplified transmitter block diagram of a microwave FM transmitter

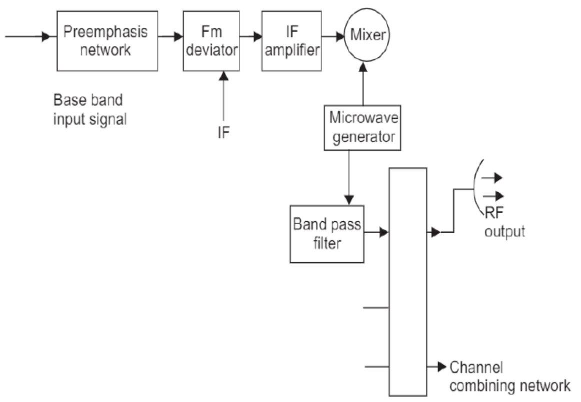


Fig. 11.17 Block diagram of FM transmitter

Figure 11.18 shows the need for repeaters and how a virtual line of sight is maintained between the transmitter and the receiver using repeaters.

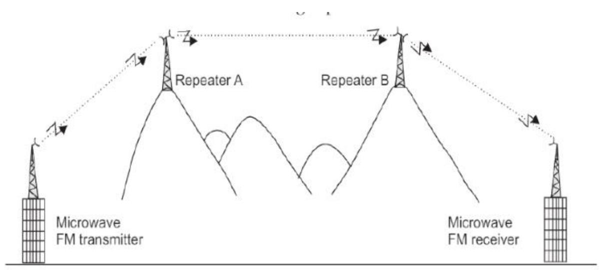


Fig. 11.18 Virtual line of sight for microwave FM transmission using Repeaters

If the distance between the transmitter and the receiver is less than the maximum distance that ensures the reliable reception of the FM signal, then the communication system does not need any other intermediate station. However, there should be a line of sight path maintained for reliable transmission and reception. If either if there two conditions is not met, then the system needs intermediate stations that can receive the signal, process it (possibly amplify)

and retransmit the signals. These intermediate stations are called the repeaters, since their objective is to repeat the signal that they receive (possibly with some amplification) in the direction of the next repeater or the receiver. In Fig. 9.18, the transmitter and the receiver are not in direct line of sight with each other de to the obstructive intermediate terrain (which is caused by the mountains). However, by appropriately placing the repeaters, a virtual line of sight is achieved along the path transmitter-repeater A-repeater B-receiver.

In Fig. 11.19, the RF signal picked by the receiving antenna is passed to the channel separation network, which separates the individual channels. The bandpass filter then filters out any frequencies that fall outside the bandwidth of the required signal. The mixer employs the same RF oscillator frequency as used at the transmitter and converts the RF signal to the IF band. The FM detector demodulates the signal which is then passed to the deemphasis network. The de-emphasis network applies inverse functionality of the preemphasis network at the transmitting end, to finally restoring the original baseband signal.

Figure 11.19 shows the microwave FM receiver block diagram.

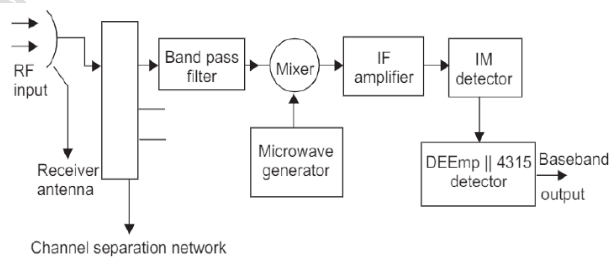


Fig. 11.19 Block diagram of FM receiver