Chapter-1

Principles of Wireless Communication

1.1 HISTORY OF WIRELESS COMMUNICATION

We know that wireless networking has emerged as its own discipline over the past decade. Wireless communication can be used for cellular voice telephony, wireless access to the internet, wireless home networking etc., wireless networks have profoundly impacted our life-style. After a decade of exponential growth, today's wireless industry is one of the largest industries in the world. The use of light for wireless communications reaches back to ancient times. In former times, the light was either modulated using mirrors to create a certain light on/light off pattern. All optical transmission systems suffer from the high frequency of the carrier light as every little obstacle shadows the signal rain and fog make communication almost impossible. At that time it was not possible to focus light as efficiently as can be done today by means of a laser, so actual wireless communication did not actually started until the discovery of electromagnetic waves and the development of the equipment to modulate them. It all started with Michael Faraday demonstrating EM waves induction in 1831 and James C. Maxwell (1831-79) laying the theoretical foundations for electromagnetic fields with his famous equations. And finally, Heinrich hertz (1857-94) was the first to demonstrate the wave character of electrical transmission through space (1886), thus proving Maxwells equations. Today we are using that HZ. After that Nikala Tesla (1856-1943) soon increased the distance of EM waves.

The ability to communication with people on the move has evolved remarkably since Guglielmo Marconi first demonstrated radio's ability to provide continuous contact with ships sailing the English channel. We can say that the name, which is most closely connected with the success of wireless communication, is certainly that of Guglielmo Marconi (1874-1937). He gave the first demonstration of wireless telephony in 1895 using long wave transmission with very high transmission power (>200 kW). In 1907, the first commercial transatlantic connections were set up. Huge base stations using up to 30 hundred meter high antennas were used on both sides of the Atlantic ocean. The first radio broadcast took place in 1906 when Reginold A. Fessenden (1866-1932) transmitted voice and music for Christmas. In 1915, the first wireless voice transmission was set up between Newyork and Sanfrancisco. The 1st commercial radio station started in 1920, but at that time sender and receiver required huge antennas and high transmission power. Again in 1920 Marconi developed short waves, using short waves it is possible to send short radio waves around the world bouncing at the ionosphere, now a days also we are using this technique. After 1906 when vacuum tube is involved, distance between transmitter and receiver is reduced. One of the first 'mobile' transmitters was on board a Zeppelin in 1911. As early as 1926, the first telephone in a train was available on the Berlin—Hamburg line, and the first car radio was

commercially available in 1927. John L. Baird (1880-1946) transmitted TV across the Atalantic and demonstrated colour TV, and first teleteaching started in 1932 from CBS station. At that time for all wireless communication amplitude modulation techniques is used, due to lot of interference quality of transmission is very poor. One high step forward in this respect was the invention of frequency modulation in 1933 by Edwin H. Armstrong (1890-1954). Now a days both AM and FM is used for TV broadcasting (AM for picture and FM for sound).

Many national and international projects started in the area of wireless communications after the 2nd world war. The first wireless network is started in 1958 by Germany, on carrier frequency of 160 MHz. Connection setup was only possible from the mobile station, but it is not possible to transfer a call from one base station to other (*i.e.*, handoff is not possible).

In 1972 a wireless network started using same 160 MHz carrier known as B-Netz by Germany. By using this network it is possible to initiate the connection setup, from a station in the fixed telephone network, if the current location of the mobile receiver had to be known. At the same time, the northern European countries of Denmark, Finland, Norway, and Sweden setup one wireless network by using 450 MHz carrier known as Nordic mobile telephone (NMT) system, NMT at 900 MHz started in 1986. After 1982 European countries decided to develop a pan-European mobile phone standard.

The new system is designed by using new spectrum of 900 MHz, provide seamless handover of a telephone call from on network provider to another while crossing national boundaries (which is known as interstate Roaming) and it offer both voice and data service with fully digital transmission. All above criteria are the foundation of Group special mobile (GSM).

After 1983 Ist generation mobile technology started by US known as advance mobile phone system (AMPS). AMPS carrier frequency is 850 MHz and it is an analog mobile phone systems. In 1984 our basic telephones at homes become wireless by development of standard CT1 (cordless telephones). By using AMPS handoffs between different cells is possible and all AMPS MSC's are connected with signaling system-7 protocol. Also MSC's are able to locates its mobile user automatically within the whole network supported by that MSC's. This analog network was switched off in 2000. By using AMPS we can transmit voice, fax, data (via modem), X.25 protocol and email.

In 1987 system CT2 started which is successor of CT1, was embodied into British standards and lator adopted by ETSI for Europe (ETS, 1994), it uses the spectrum at 864 MHz and offers a data channel at a rate of 32 K bit/S. Basic digital systems started in 1990s. In 1991, ETSI adopted the standard **digital European** cordless telephone (DECT) for digital cordless telephony (ETSI, 1998). DECT technology works at a spectrum of 1880-1900 MHz with a range of 100-500 m, it support nearly 120 duplex channels and data transmission rate is 1.2 M bit/S. Some other features of DECT are voice encryption authentication etc. New DECT is known as **Digital** enhanced cordless telecommunications. After many years of discussions and field trials, **GSM** was standarlized in a document of more than, 5,000 pages in 1991. GSM is the most successful digital mobile telecommunication system in the world today. It is used by over 800 million people in more than 190 countries. For a second generation fully digital system, the **group special mobile (GSM)**.

In 1992, GSM changed its name to the Global system for mobile communications for marketing reasons. The setting of standards for GSM is under the aegis of the European Technical Standards Institute

(ETSI). GSM was first introduced into the European market in 1991. By the end of 1993, several non-European countries in South America, Asia and Australia had adopted GSM and the technically equivalent offshoot, DCS 1800, which supports personal communication system (PCS) in the 1.8 GHz to 2.0 GHz radio bands recently created by governments throughout the word.

GSM is a 2nd generation (2G) cellular system standard that was developed to solve the fragmentation problems of the first cellular system in Europe. Basic aim of GSM was to provide a mobile phone system that allows users to roam throughout Europe and provide voice services compatible to ISDN and other PSTN systems.

GSM was the world's first cellular system to specify digital modulation and network level architectures and services, GSM has initially been deployed in Europe user 890-915 MHz for uplinks and 935-960 MHz for downlinks, this system is also known as GSM 900. Other version of GSM is known as GSM 1800 MHz (1710-1785 MHz uplink, 1930-1990 MHz downlink) also known as **DCS (Digital Cellular System) 1800.** GSM system used by US is GSM 1900 MHz (1850-1900 MHz uplink, 1930-1990 MHz downlink) also known as PCS-1900 (Personal Communication Services). A GSM system that has been introduced in several European countries for railroad systems is GSM rail (GSM-R, 2002), (EISI 2002) Main application of GSM-R is the control of trains, switches, gates and signals.

GSM provides facility like full international roaming, automatic location services, authentication encryption on the wireless link, efficient interoperation with ISDN systems and high audio quality. Also it provides services like short message (SMS) with upto 160 alphanumeric characters, Fax group 3, and data services at 9.6 K bit/S have been integrated. Know a days over 70% of world's wireless market is under control of GSM.

But in most populated areas where user densities is high it is found that analog AMPS technology used in US and digital GSM technology at 900 MHz in Europe are not sufficient. To solve this problem in the US different companies developed different new, more bandwidth–efficient technology to operate side-by-side with AMPS in the same frequency band, and three new technology developed.

1. Analog narrowband AMPS (IS-88, TIA, 1993*a*).
2. TDMA (IS-136, TIA-1996).
3. CDMA (IS-95, TIA-1993*b*).

The Europeans countries agreed to use GSM in the 1800 MHz spectrums this system is also known as DCS 1800 digital cellular system. GSM-1800 system having better voice quality due to newer speech codes. GSM is also available in the US as GSM-1900 (also called PCS 1900) using spectrum at 1900 MHz like the newer versions of the TDMA and CDMA systems. During the development of new technology Europe is concentrated up on standards of technology but US believes in market forces. So while all European countries working on common standard and roaming is possible in other countries also, but US still struggles with many incompatible systems.

HIPERLAN (High performance radio local area network) started in 1996. On ETSI standard HIPERLAN type should operate at 5.2 GHz and should offer data rates of upto 23.5 Mbit/S.

In 1997, the IEEE standard 802.11 started and it is popular than HIPERLAN. It works at the license free Industrial Science Medical (ISM) band at 2.4 GHz and Infrared offering 2 M bit/S in the beginning (Up to 10 M bit/S with proprietary solutions already at that time). In 1998 mobile communication via

satellites started with the Iridium system (Iridium, 2002). After introduction of Iridium technology, very small and portable mobile satellite telephones using data services started. In consists of 66 satellites in low earth orbit and uses the 1.6 GHz band for communication with the mobile phone. Universal mobile telecommunications system (UMTS) started in 1998 by European countries as the European proposal for the International Telecommunication Union (ITU) **IMT-2000** (International mobile telecommunications). Initially UMTS combines GSM network technology with more bandwidth efficient CDMA solutions. The IMT-2000 recommendations define a common worldwide framework for future mobile communication at 2 GHz (ITU, 2002). This includes a framework for services, satellite communication network architecture, strategies for developing countries requirements of the radio interface, spectrum considerations, security and management frameworks, and different transmission technique. The IEEE standard 802.11 (IEEE 1999) specifies the most famous family of WLANs in which many products are available.

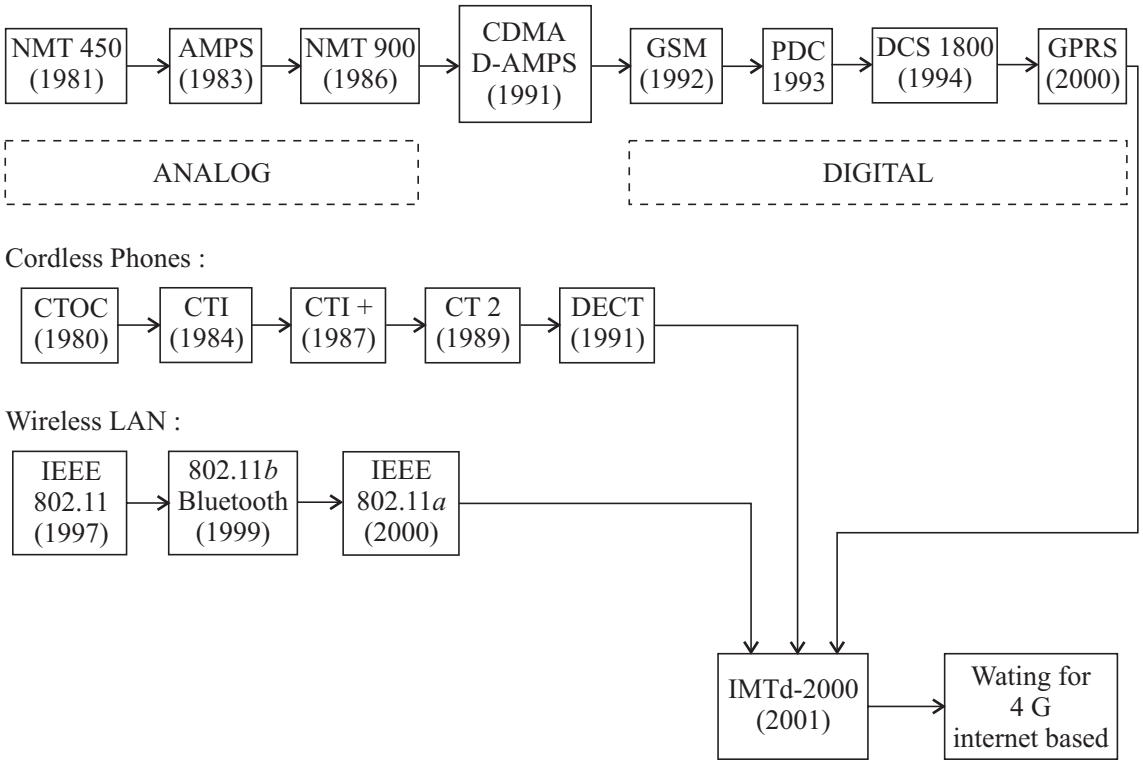
As the standard's number indicates, this standard belongs to the group of 802.X LAN standards *e.g.*, 802.3 Ethernet on 802.5 Token ring. This standard specifies the physical and medium access layer adopted to the special requirement of wireless LAN's, but offers the same interface as the others to higher layers to maintain interoperability, with standard 802.11 the subscription presents the enhancements of the original standard for higher data rates, 802.11*a* (up to 54 Mbit/S at 5 GHz) and 802.11*b* (11 Mbit/S).

In 1998 five companies (Ericsson, Intel, IBM, Nokia, Toshiba) founded the Bluetooth consortium with the goal of developing a single-chips low, cost radio-based wireless network technology. Known as Special Interest Group (SIG), many other companies and research institutions joined this group. Main goal of this group was the development of mobile phones, laptops, notebooks, headsets etc. including Bluetooth technology, by the end of 1999. In 2001, the first products hit the mass market, and many mobile phones, laptops, PDAs video cameras etc. equipped with Bluetooth technology today. The IEEE 802.11*b* offering 11 M bit/S at 2.4 GHz. The same spectrum is used by Bluetooth, a short range technology to set-up wireless personal area networks with gross data rates loss than 1 M bit/S. The WAP (wireless application protocol (WAP) started at the same time as *i*-male in Japan. But WAP did not succeed in the beginning *i*-male soon became a tremendous success.

In 2000 higher data rates packet-oriented transmission for GSM (HSCSD, GPRS) started. The third generation of mobile communication started in 2001 in Japan with the FDMA services, in Europe with several field trials and in Korea with cdma 2000. IEEE started new WLAN standard, 802.11*a* operating of 5 GHz and offering gross data rates of 54 Mbit/S. In 2002 new WLAN developments followed. Example are 802.11*g* which provide 54 Mbit/S at 2.4 GHz and many new Bluetooth applications.

Now we are waiting for 4G technology no one knows exactly what the new generation of mobile and wireless system will look like, but, there are strong indications that it will be widely internet based the system will use internet protocols and internet applications. By using 4G technology it may possible when your washing machine will send an e-mail to your cell phone informing you about the washing information. Suppose you are driving and cannot read the e-mail. Your car audio will connected to your cell-phone, using Bluetooth and you may read your e-mail. You can then dictate your e-mail reply, just in case want to modify the program. And when you reach home, you will find your laundry all done while you are away. Block diagram given below described some of standards network described above.

Cellular phones:



Now a development of new technology in wireless and mobile communication systems has slowed down, but already developed technology like GSM and CDMA have still a huge market potential. Now middle and lower class people are also using mobile phone. Wireless technology is built in many moving vehicle, wireless LAN and wireless data communication is also popular in many areas. Fig. 1.1 and Fig. 1.2 shows that increasing number of subscribers to mobile phone service provider and cellular subscriber per region GSM word, 2002.

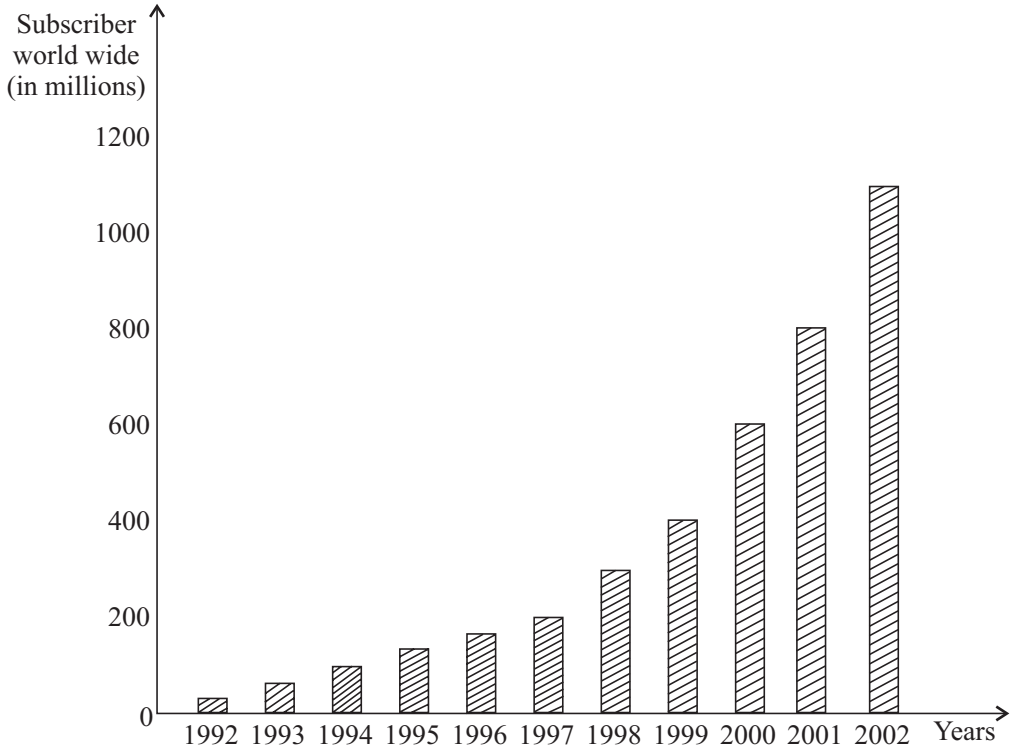


Fig. 1.1. *Mobile phone service subscribers* (*Worldwide on missions*)

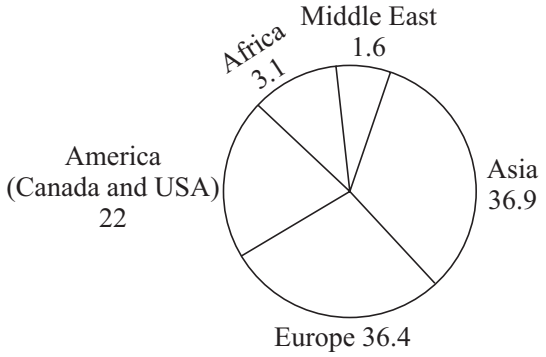


Fig. 1.2. *Cellular subscriber worldwide after 2002*

From above history we can say that. After a decade of exponential growth, today's wireless industry is one of the largest industries in the world.

At present time over two billion people subscribe to cellular services, and over 300 billion GSM short message are exchanged yearly, and the penetration of the cellular telephone in India exceeded 80%, the highest in the world. In response to this growth, a number of universities and other educational institutions have started wireless research and teaching programs and a number of engineers and scientists are re-educating themselves, in this fields. In 1995, when wireless networking was an emerging discipline, the principal author, alongwith Allen levesque, wrote the first comprehensive text book in wireless information networks that addressed cellular and PCS systems as well as mobile data and wireless LANs. Here I am trying to write comprehensive text book on wireless networks that provides a deeper understanding of the issues specific to the wireless networks.

Frequencies for Radio Transmission

For radio transmission we require different frequency bands. Each frequency band having its own application, advantages and disadvantaged. Table 1.1 shows different frequency range of radio transmission.

Table 1.1 : The radio spectrum

Frequency Band	*Range*	*Media*	*Applications*
1. Very low frequency (VLF)	3 to 30 kHz (1 mm)	Twisted pair	Long distance point to point communication
2. Low frequency (LF)	30-300 kHz (10 km)	Coaxial cable	Radio navigation
3. Medium frequency (MF)	0.3 to 3 MHz (100 m)	Coaxial cable	Broadcasting marine
4. High frequency (HF)	3-30 MHz (100 m)	Coaxial cable	Radio telephony
5. Very high frequency (VHF)	30-300 MHz (1 m)	Coaxial, air	FM broadcasting, TV, mobile, radio navigation
6. Ultra high frequency (UHF)	0.3 to 3 GHz (1 mm)	Unguided (Air)	TV, mobile, Radio navigation and Radar
7. Supper high frequency (SHF)	3 to 30 GHz (10 mm)	Unguided (Air)	Multi channel telephony links Radar or Satellite communication
8. Infrared	0.3 to 300 THz (100 m)	Optical transmission	Wireless LAN, TV remote
9. UV	above 300 THz	Optical transmission	Medical purpose

We know that wavelength λ is directly related with frequency *f*.

$\lambda = c/f$ $C = 3.10^8$ m/s and known as speed of light in vacuum.

For landline communication frequencies of up to several hundred kHz are used for distances up to some km with twisted pair upper wires, while frequencies of several hundred MHz are used with coaxial cable. For optical communication using fiber optics frequency ranges of several hundred THZ but one typically refers to the wavelength which is 1500 nm / 1350 nm (infrared).

VLF and LF frequency ranges are used for radio transmission like submarines, because they can penetrate into water and can fallow the earth's surface. MF and HF frequency ranges are basically used for transmission of hundreds of radio stations either as Amplitude Modulation (AM) between 520 kHz and 1605.5 kHz, and short wave between 5.9 MHz and 26.1 MHz, or as frequency modulation (FM) between 87.5 MHz and 108 MHz for these ranges are fixed by national regulation and vary from country to country. Short waves are typically used for radio transmission around the world like BBC radio enabled by reflection at the ionosphere. But high transmitting power about 500 kw is required.

VHF and UHF ranges are used for TV transmission. For analog TV transmission 174-230 MHz and 470-790 MHz frequency rangers are used. For digital TV transmission 470-862 MHz frequency ranges are used. For mobile phone using analog technology frequency range (450-465 MHz) is used for digital mobile communication like GSM frequency ranges 890-960 MHz and 1710-1880 MHz is used. For digital cordless telephones frequency range is 1880-1900 MHz and for 3G cellular systems fallowing the UMTS standard 1900-1980 MHz, 2020-2025 MHz, 2110-2190 MHz are used. By using VHF and UHF size of antennas become small, which is a big advantages.

SHF are used for directed microwave links (2-40 GHz) and for satellite services in C-band (4 and 6 GHz) Kv-band (11 and 14 GHz) or Ka band (19 and 29 GHz). Fiber optical links using Infrared (IR) is also used for wireless communication. It is also used for WLAN and to connect different building via laser links.

Table 1.2 : Major mobile radio standards in North America

Standard	*Type*	*Multiple Access*	*Modulation*	*Channel Bandwidth*	*Frequency Band*	*Years of Introduction*
AMPS	Cellular	FDMA	FM	30 kHz	824-894 MHz	1983
NAMPS	Cellular	FDMA	FM	10 kHz	824-894 MHz	1992
USDC	Cellular	TDMA	Π/4–QPSK	30 kHz	824-894 MHz	1991
CDPD	Cellular	FH/Packet	GMSK	30 kHz	824-894 MHz	1993
IS-95	Cellular	CDMA	QPSK/	1.25 MHz	824-894 MHz	1993
	PCS		BPSK		1.8-2.0 GHz	
FLEX	Paging	Simplex	4-FSK	15 kHz	Several	1993
DCS-1900	PCS	TDMA	GMSK	200 kHz	1.85-1.99 GHz	1994
(GSM)						
PACS	Cordless/	TDMA/	Π/4	300 kHz	1.85-1.99 GHz	1994
	PCS	FDMA	DQPSK			

Table 1.3 : Major mobile radio standards in Europe and Japan

Standard	*Multiple Access*	*Year of Introduction*	*Channel Bandwidth*	*Frequency Band*	*Modulation*	*Type*
ETACS	FDMA	1985	25 kHz	900 MHz	FM	Cellular
NMT-450	FDMA	1981	25 kHz	450-470 MHz	FM	Cellular
NMT-900	FDMA	1986	12.5 kHz	890-960 MHz	FM	Cellular
GSM	TDMA	1990	200 kHz	890-960 MHz	GMSK	Cellular/PCS
CT_2	FDMA	1989	100 kHz	864-868 MHz	GFSK	Cordless
DECT	TDMA	1993	1.728 MHz	1880-1900 MHz	GFSK	Cordless
DCS-1800	TDMA	1993	200 kHz	1710-1880 MHz	GMSK	Cordless/PCS

Japan

Standard	*Multiple Access*	*Year of Introduction*	*Channel Bandwidth*	*Frequency Band*	*Modulation*	*Type*
JTACS	FDMA	1988	25 kHz	860-925 MHz	FM	Cellular
PDC	TDMA	1993	25 kHz	810-1501 MHz	Π/4-DQPSK	Cellular
NTACS	FDMA	1993	12.5 kHz	843-925 MHz	FM	Cellular
NTT	FDMA	1979	12.5 kHz	280 MHz	FSK	Paging
PHS	TDMA	1993	300 kHz	1998-1907 MHz	Π/4-DQPSK	Cordless

1.2 INTRODUCTION TO WIRELESS COMMUNICATION

Mobile telephone services began in the 1940s and were called MTSs (Mobile telephone systems or manual telephone systems), because all calls were handled by an operator MTS systems utilized frequency modulation and were generally assigned a single carrier frequency in the 35 MHz to 45 MHz range that was used by both the mobile unit and the base station. The mobile unit used a push-to-talk (PTT) switch to activate the transceiver. Depressing the PTT button turned the transmitter on and the receiver off, whereas releasing the PTT turned the receiver on and the transmitter off. Placing a call from a MTS mobile telephone was similar to making a call through a manual switchboard in the public telephone network. When the PTT switch was depressed, the transmitter turned on and sent a carrier frequency to the base station, illuminating a lamp on a switchboard. After the calling party verbally told the operator the telephone number they wished to call the operator connected the mobile unit with a patchcard to a trunic circuit connected to the appropriate public telephone network distention office. Because there was only one carrier frequency, the conversation was limited to half-duplex operation and only one conversation could take place at a time.

In 1964, the improved mobile telephone system (IMTS) was introduced, which used several carrier frequencies and could, therefore, handle several simultaneous mobile conversations at the same time IMTS subscribers was assigned a regular PSTN telephone number, therefore, callers could reach on IMTS mobile phone by dialing the PSTN directly, eliminating the need for an operator.

Because of their high cost, limited availability and narrow frequency allocation, early mobile telephone systems were not widely used. However, in recent years factors such as technological advancements, wider frequency spectrum, increased availability and improved reliability have stimulated a phenomenal increase in people's desire to talk on the telephone from virtually anywhere, at any time, regardless of whether it is necessary, safe or productive.

Now a days mobile telephone stations are small handsets, easily carried by a person in their pocket or parse. Earlier, the form **Mobile** is **defined as any radio transmitters, receiver, or transceiver that could be moved while in operation.**

The contemporary definition of mobile has come to mean proving at high speed, such as in a boat, airplane, automobile, or at low speed such as in the pocket of a pedestrian. So **Actual definition of mobile telephone is :**

Any wireless telephone capable of operating while moving at any speed, battery powered, and small enough to be easily carried by a person. (*e.g.*, a cellular telephone in a fast moving vehicle).

Portable : The term portable described a relatively small radio unit that was handheld, battery powered, and easily carried by a person moving at waking speed. (*e.g.*, a walkie-talkie or cordless telephone inside a home).

Subscriber : The term subscriber is often used to describe a mobile or portable user because in most mobile communication systems, each user pays a subscription fee to use the system, and each user's communication device is called a **subscriber unit.** In general, the collective group of users in a wireless system, are called **users** or **mobiles**, even though many of the users may actually use portable terminals.

Cellular telephone is similar to two-way mobile radio in that most communications occurs between base stations and mobile units.

Base stations : Base stations are fixed-position transceivers with relatively high-power transmitters and sensitive receivers. It is used for a radio communication with mobile stations. Base stations are located at the center or on the edge of a coverage region and consist of radio channels and transmitter and receiver antennas mounted on a tower. Cellular telephones communicates directly with base stations. Cellular telephone is best described by painting out the primary difference between and two-way mobile radio. Two-way mobile radio systems operate half duplex and use PTT transceivers. With PTT transceivers, depressing the PTT button turns on the transmitter and turns off the receiver, whereas releasing the PTT buffer turn on the receiver and turns off the transmitter. With two-way mobile telephone, all transmissions (unless scrambled) can be heard by any listener with a receiver tuned to that channel. Hence, two-way mobile radio is a one-to-many radio communications system.

On the other hand, cellular telephone offers full-duplex transmissions and operates much the same way as the standard wire line telephone service provided to homes and businesses by local telephone companies. Mobile telephone is a one-to-one system that permits two-way simultaneous transmissions and, for privacy each cellular telephone is assigned a unique telephone number. Coded transmissions from the base stations activate only the intended receiver. With mobile telephone, a person can virtually call anyone with a telephone number whether it be through a cellular or a wire line service. Cellular telephone systems offer a relatively high user capacity within a limited frequency spectrum providing a significant innovation in solving inherent mobile telephone communications problems, such as spectral congestion and user capacity. Cellular telephone systems replaced mobile systems serving large areas

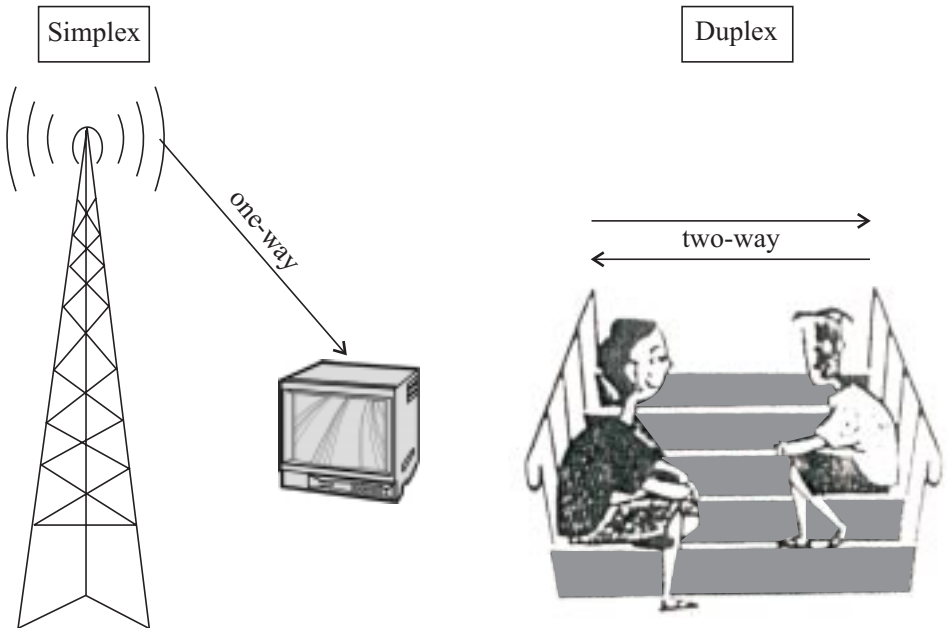
(cells) operating with a single base station and a single high-power transmitter with many smaller areas (cells), each with its own base station and low-power transmitter. Each base station is located a fraction of the total channels available to the systems, and adjacent cells are assigned different groups of channels to minimize interference between cells. When demand for service increases in a given area, the number of base stations can be increased, providing an increase in mobile unit capacity without increasing the radio-frequency spectrum.

1.3 MOBILE COMMUNICATIONS : BASIC CONCEPTS

From ancient to modern times, mankind has been looking for means of long distance communications. For centuries, letters proofed to be the most reliable way to transmit information.

Technical improvements in the 19th century simplified long distance communications: Telegraphy, and later on telephony. Both techniques were wire line.

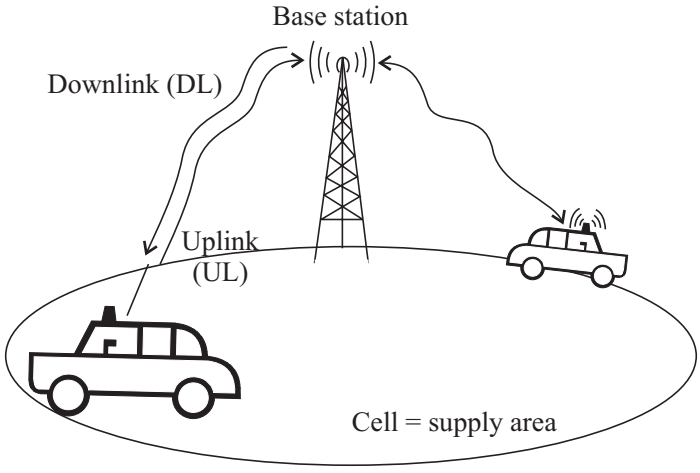
In 1873, J.C. Maxwell laid the foundation of the electro-magnetic theory by summarising empirical results in four equations, which are still valid today. Still, several decades passed by, till Marconi made economic use of this theory by developing devices for wireless transmission of Morse signals (about 1895). Already 6 years later, the first transatlantic wireless transmission of Morse signals took place. Voice was transmitted the first time in 1906 (R. Fesseden), and one of the first radio broadcast transmission 1909 in New York.



Transmission Techniques

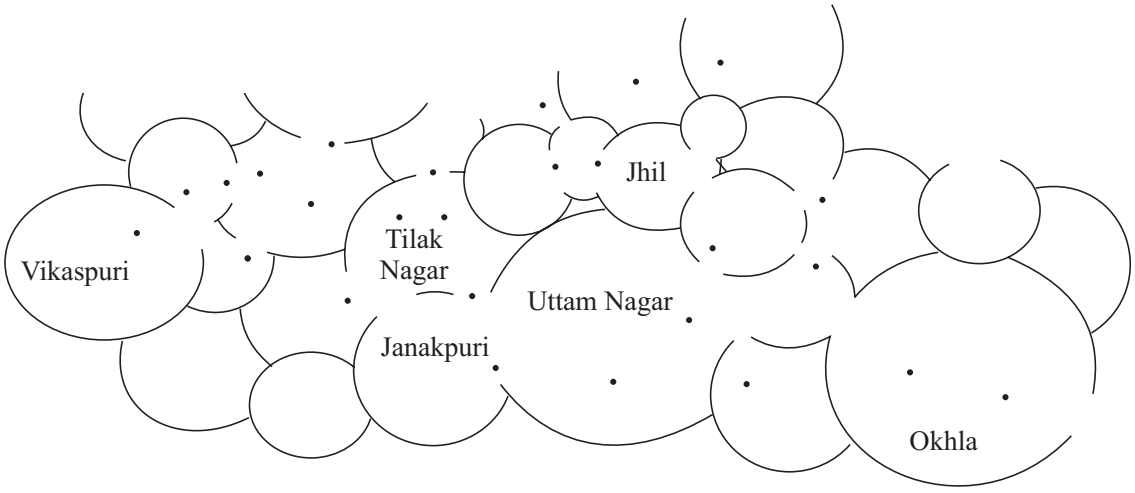
The economically most successful wireless application in the first half of the 20th century was radio broadcast. There is one transmitter, the so-called radio station. Information, such as news, music, etc. is transmitted from the radio station to the receiver equipment, the radio device. This type of one-way transmission is called **simplex transmission.** The transmission takes place only in one direction, from the transmitter to the receiver. When we take a human conversation, a technical solution is required, where the information flow can take place in two directions. This type of transmission is called **duplex transmission.** Walky-talky was already available the early 30s. This systems already allowed a transmission of user data in two directions, but there was a limitation: The users were not allowed to transmit at the same time. In other words, you could only receive or transmit user information. This type of transmission is therefore often called semi-duplex transmission. For telephony services, a technical solution is required, whereby subscribers have the impression that they can speak (transmit) and her (receive) simultaneously. This type of transmission solution is regarded as full duplex transmission.

The first commercial wireless car phone telephony service started in the late 1940 in St. Louise, Missouri (USA). It was a car phone services, because at that time, the mobile phone equipment was bulky and heavy. Actually, in the start-up, it filled the whole back of the car. But it was a real full duplex transmission solution. In the 50s, several vehicle radio systems were also installed in Europe. These systems are nowadays called **single cell systems.** The user data transmission takes place between the mobile phone and the **base station (BS).** A base station transmits and receives user data. While a mobile phone is only responsible for its user's data transmission and reception, a base station is capable to handle the calls of several subscribers simultaneously. The transmission of user data from the base station to the mobile phone is called **downlink (DL),** the transmission from the mobile phone to the base station uplink (UL direction). The area, where the wireless transmission between mobile phones and the base station can take place, is the base stations supply area, called cell.



Single cell system

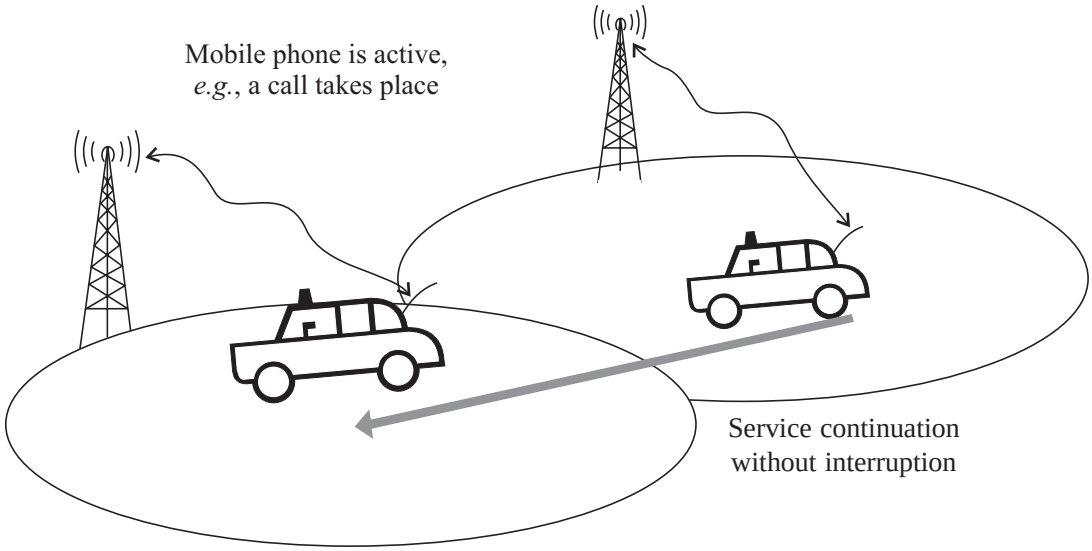
Single cell systems are quite limited. The more and more distant the subscriber is from the base station, the lower the quality fo the radio link. If the subscriber is leaving the supply area of the cell, no communication is possible any more. In other words, the mobile communication service was only available within the cell. In order to overcome this limitation, **cellular systems** were introduced. A cellular mobile communication system consists of several cells, which can overlap. By doing so, a whole geographical area can be supported with the mobile communication service.



Cellular system

But what happens when a subscriber moves during a call from one cell to another cell? It would be very annoying, if the call were dropped. If the subscriber is leaving a call, and in parallel is entering a new cell, then the system makes new radio resources available in the neighbouring cell, and then the call is handed over from on cell to the next one. By doing so, service continuation is guaranteed, even when the subscriber is moving. The process is **called handover (HO)** handoff**.**

A handover takes place during a call, *i.e.*, when the mobile phone is the active (dedicated) mode. A mobile phone can also be in the idle mode. In this case, the mobile phone is switched on, but no resources were allocated to it and the base station to allow user data transmission. In tis mode, the mobile phone is still listening to information, broadcasted by the base station. Why?



Handover

Image, there is a mobile terminated call. The mobile phone is then **paged** in the cell, informed about the situation, that there is a mobile terminated call. But a cellular system may consist of hundreds of cells. If the network does not know, in which cell the mobile phone is located, it must be paged in all of them. This costs resources on the radio interface, especially when millions of mobile phones must be paged in the supply area of a mobile operator. Therefore, the operator of a cellular mobile communications system groups cells in administrative units called **location areas (LA).** A mobile phone is paged in only one location area.

But how does the cellular system know, in which location area the mobile phone is located? And how does the mobile phone know? In every cell, system information is continuously transmitted. The system information includes the location area information. In the idle mode, the mobile phone is listening to this system information. If the subscriber moves hereby from one cell to the next cell, and the new cell belongs to the same location areas, the mobile stays idle. If the new cell belongs to a new location area, then the mobile phone has to become active. It starts a communication with the network, informing, it about it new location. This is stored in databases within the mobile network, and if there is a mobile terminated call, the network knows where to page the subscriber. The process, where the mobile phone informs the network about its new location is called **Location Update** Procedure (LUP). See detail in chapter 4.

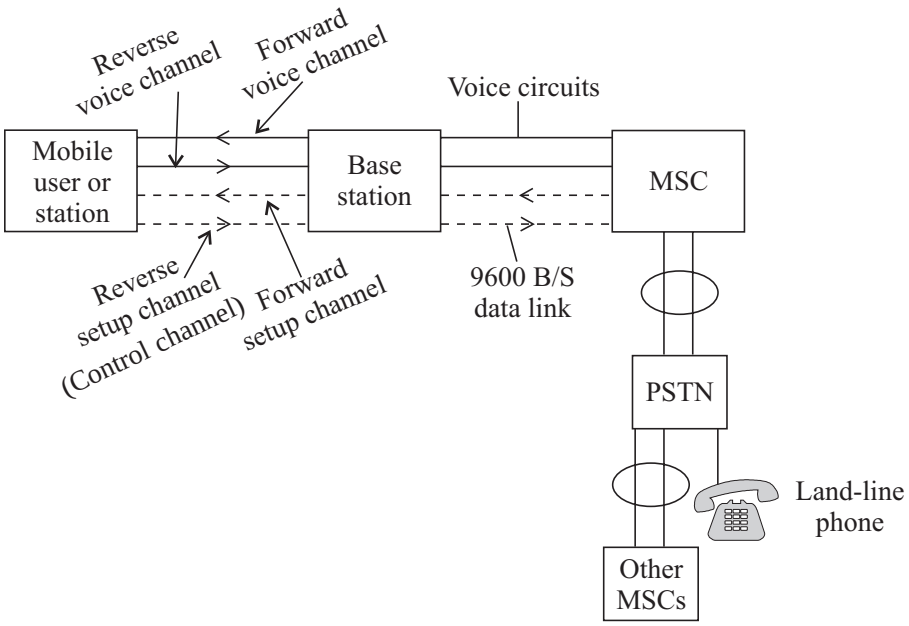


Fig. 1.3. *Basic cellular systems*

Basic cellular telephone systems : The key principles of **cellular telephone** also known as cellular radio were uncovered in 1947 by researchers at Bell Telephone Caborateries and other telecommunications companies throughout the world when they developed the basic concepts and theory at cellular telephone. It was determined that by subdividing a relatively large geographic market area called a coverage zone into small sections called cells. A cellular telephone system provides a wireless connection to the PSTN for any user location within the radio range of the system. Cellular systems accommodates a large number of users over a large geographic area, within a limited frequency spectrum cellular radio systems provide high quality service that is often comparable to that of the landline telephone systems.

Fig. 1.3 shows the basic cellular systems which consists of mobile stations, base stations and a mobile switching center (MSC) also known as mobile telephone switching office (MTSO). It is responsible for connecting all mobiles to the PSTN in a cellular system.

1.4 DEFINITIONS OF TERMS USED IN WIRELESS COMMUNICATIONS

1. **Mobile stations (MS) :** The mobile station (MS) communicates the information with the user and modifies it to the transmission protocols of the air interface to communicate with the BSS. The user information is communicated with the MS through a microphone and speaker for the speech, keypad and display for short messaging, and the cable connection for other data terminals. The mobile stations has two elements.

(*a*) **Mobile equipment (ME) :** It is a piece of hardware that the customer purchases from the equipment manufacturer of their dealers (Nokia, Samsung etc.) This hardware piece contains all the components needed for the implementation of the protocols to interface with the user and the air-interface to the base stations. The components include speaker, microphone, keypad and the radio modem. So we can say that, the ME is an expensive piece of hardware.

(*b*). **Subscriber identity module (SIM) :** This is a smart card issued at the subscription times identifying the specifications for a user such as address and type of service. The calls in the GSM are directed to the SIM rather than the terminal. SMS are also stored in the SIM card. SIM card is not used in CDMA. A SIM card carries every user's personal information which enables a number of useful applications.

Mobile stations may be hand-hold personal units (portables) or installed in vehicles (mobiles).

2. **Base station :** Already defined.
3. **Mobile switching center :** A MSC is the hardware part of the wireless switch that can communicate with PSTN switches using the signaling system-7 (SS-7) protocol, as well as other MSCs in the coverage area of a service provider. The MSC also provides the specific information on the status of the mobile terminals. It provides for communications with other wired and wireless networks as well as support for registration and maintenance of the connection with the mobile stations. It is a switching centre which coordinates the routing of calls in a large service area. In a cellular radio systems, the MSC connects the cellular base stations and the mobiles to the PSTN. It is also known as mobile telephone switching office (MTSO).
4. **Channels :** It is a range of frequency allotted to particular service or systems. Basically two types of channels are used in wireless communication.

   (*a*) **Control channel :** Radio channel used for transmission of call setup, call request, call initiation, and other beacon or control purposes.

   (*b*) This is again divided into two parts forward control channel (FCC) and reverse control channel (RCC).

   Forward channel : Radio channel used for transmission of information from the base station to the mobile.

   Reverse channel : Radio channel used for transmission of information from the mobile to base station.

   (*c*) **Voice channel :** Radio channel used for voice or data transmission.
5. **Page :** A brief message which is broadcast over the entire service area, usually in a simulcast (apposite to broad cast) fashion by many base station at the same time.
6. **Handoff :** It is defined as the transferring a call (mobile stations) from are channel or base station to another base station.

7. **Roamer :** A mobile station which operates in a service area (market) other than that from which service has been subscribed.
8. **Transceiver :** A device capable of simultaneously transmitting and receiving radio signals.

Mobile radio transmission systems may be divided into basic three categories :

1. **Simplex system :** It is a communication system which provide only one-way communication (*i.e.*, communication is possible in only one direction) for example radio, TV and paging system.
2. **Half duplex :** It is a communication system which allow two-way communication by using the same radio channel for both transmission and reception. A any given time, the user can only either transmit or receive information.

   Ex–Walkie-talkie *i.e.*, "push to talk" and "release-to-listen" fundamentals are used.
3. **Full duplex :** It is a communication system which allow simultaneous two-way communication. By providing two simultaneous but separate channels (frequency division duplex or FDD) or adjacent time slots on a single radio channel (time division duplex or TDD) for communication to and from user.

Introduction to multiple access techniques : By using multiple access techniques many mobile users can share simultaneously a finite amount of radio spectrum. By using sharing spectrum technique cellular system capacity can increases. Because we can simultaneously allocate the available bandwidth or the available amount of channels to multiple users.

Duplexing : Duplexing means simultaneously transmission and reception. Like in conventional telephone systems. It is possible to talk and listen simultaneously.

(*a*) **Frequency division duplexing (FDD) :** Frequency division duplexing (FDD) provides two distinct bands of frequencies for every user. The forward band provides traffic from the base station to the mobile and the reverse band provides traffic from the mobile to the base station. In FDD any duplex channel actually consists of two simplex channels forward and reverse channel and duplexer is used inside each subscriber unit and base station to allow simultaneous bidirectional radio transmission and reception for both the subscriber unit and the base station on the duplex channel pair. The frequency separation between each forward and reverse channel is constant throughout the system, regardless of the particular channel being used.

(*b*) **Time division duplexing (TDD) :** Here both forward and reverse links are provided on time sharing basis. In TDD, multiple users share a single radio channel by talking turns in the time domain.

Each users are allowed to access the channel in assigned time slots, and each duplex channel has both a forward time slot and a reverse time slot to facilitate bidirectional communication. If the time difference between forward and reverse time slot is small, then the transmission and reception data appears simultaneously to the users at both the subscriber unit and on the base station side Fig. 1.4 show the FDD and TDD techniques.

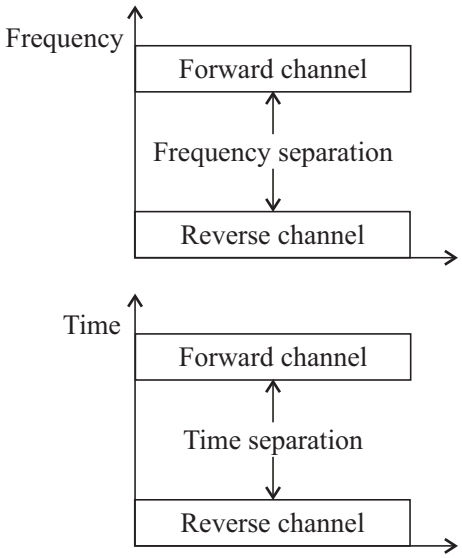


Fig. 1.4. *FDD and TDD*

1.5 BASIC CELLULAR SYSTEM ARCHITECTURE AND CALL PROCEDURE

For every cellular service provider (Like in India AIRTEL, HUTCH, CELL-ONE etc.) a limited geographical area is alloted known as **coverage zone** for that service provides. For example a particular company got permission to provide his cellular services in Delhi they, cannot provide his services in Faridabad, Gurgaon or other border areas. So Delhi is coverage zone for that service provider.

Coverage zone is divided into small geographical areas known as **cell.** Generally each area is divided into Hexagonal–shaped cells that fit together to form a **honeycomb pattern** as shown in fig. 1.5 the hexagon shape was chosen because it provides the most effective transmission by approximating a circular pattern while dominating gaps inherently present between adjacent circles. A cell is defined by its physical size and more importantly, by the size of its population and traffic patterns. The number of cells per system and the size of the cells are not specifically defined by the FCC and has been left to the service providers to establish in accordance with anticipated traffic patterns. The physical size of a cell varies, depending on number of user and calling patterns. Large cells known as macrocells typically have a radius between 1 mile and 15 miles with base station transmit powers between 1w and 6w. The smallest cells is known as the microcells typically have a radius at 1500 feet or less with base station transmit powers between 0.1w and 1w.

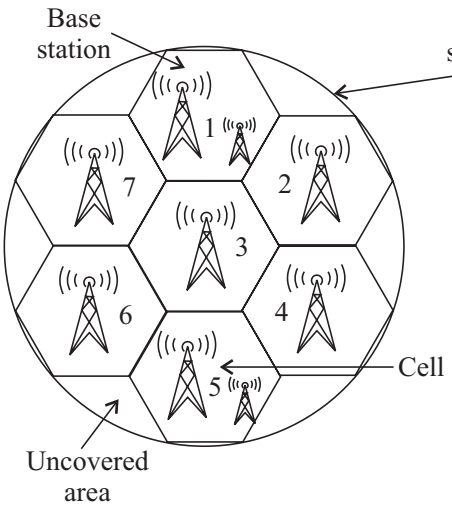


Fig. 1.5. (*a*) *Honeycomb cell pattern using aonagonal cell*

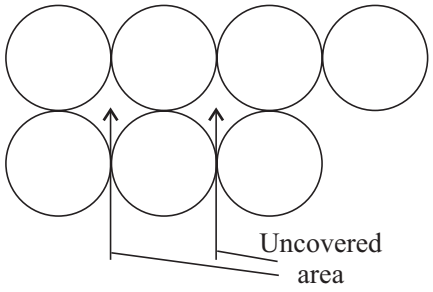


Fig. 1.5. (*b*) *More uncovered area in case of circular cell*

Each cell having number of base stations depending upon the number of users. The base station consist of several transmitting and receiving antennas which simultaneously handle full duplex communications and generally connected on long towers which support several transmitting and receiving antennas. Base station work as a bridge between mobile user and MSC. Each base station is allocated a portion of the total number of channels available to the entire system, and nearby base stations are assigned different groups of channels so that the interference between base stations and the mobile users under control of any base stations it minimized.

All base stations are connected with each other by microwave links (wireless media or may connected with landline) mobile users are also connected with base stations by microwave links. Base station nearest to the MSC is connected with landline to the MSC (See fig. 1.6).

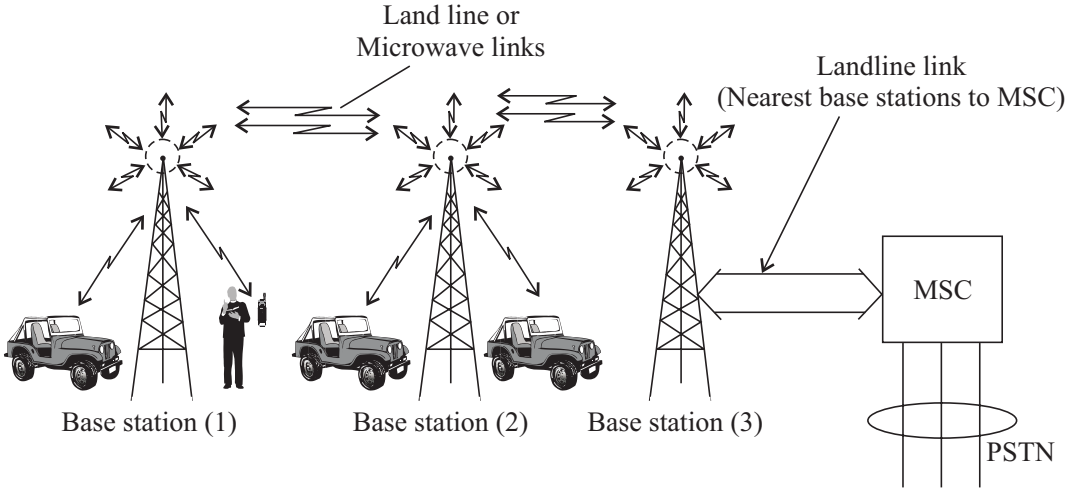


Fig. 1.6. *Interconnection of mobile networks*

The MSC is the hardware part of the wireless switch that can communicate with PSTN switches using the signaling system-7 (SS-7) protocol, as well as other MSCs in the coverage area of a service provider. The MSC coordinates the activities of all the base stations and connects the entire cellular system to the PSTN. Generally an MSC can handles 100,000 cellular subscribers and 5,000 simultaneous conversations at a time, and accommodates all billing and system maintenance functions, as well. The MSC also provides to the network the specific information on the status of the mobile terminals. Every service providers have its own MSC for example in India, mobile service providers like, AIRTEL, HUTCH, IDIA etc. have its own MSCs.

MSC is connected to landline phones, or other MSC via PSTN (Through MTNL or BSNL network). That is MSCs of all service providers connected to each other through PSTN or SS-7 protocols. For example MSC of AIRTEL is connected with MSCs of other service providers like HUTCH, CELL-ONE etc. thorough PSTN or SS-7 protocol. For exchange location, validation, and call signaling information. MSC maintains all mobile related information and controls each mobile handoff. It also performs all of the network management functions, such as call handling and processing billing location management and fraud detection.

1.6 CALL PROCEDURE

Within a cellular telephone system, three types of calls can take place involving mobile cellular telephones.

1. **Mobile (cellular)-to-wireline (PSTN) (see Fig. 1.7)**

   For example from AIRTEL MOBILE to landline number 0129-2265678 (BSNL no.)

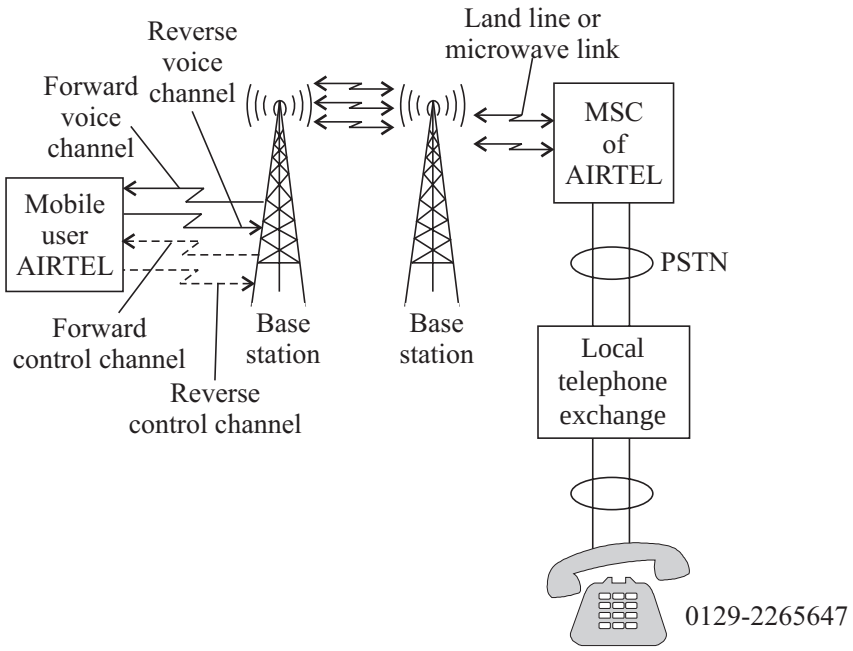


Fig. 1.7. *Call handling procedure for mobile to landline*

Suppose you are calling from user mobile from Saket, New Delhi to your friend in Faridabad. and AIRTEL MSC is in Okhla New Delhi.

Step 1 : Suppose a mobile user is using mobile service provider AIRTEL SIM card and his mobile is in switch off condition. Now when mobile user turned on his cellular phone, it first scans the group of forward control channels to determine the one with the strangest signal, and then monitors that control channel until the signal drops below a usable level. Now it again scans the control channels in search of the strongest base station signal. In this example it will select its home network *i.e.,* AIRTEL.

> **Note :** *When a service provider start his services a limited geographical area and bandwidth is allocated to that service provider.*

Limited geographical area is known as cell and total available bandwidth is divided into number of voice and control channels, 95% of total available channel is used as a voice channel and remaining 5% is used as a control channel.

Now the mobile subscriber enters the wireline telephone number with area code (*i.e.*, 0129-2265678) into the mobile system memory using a standard Touch-tone keypad. The subscriber then depresses a send key, which transmits the called number as well as **mobile identification** number (MIN), which is mobile user telephone number over a reverse control channel (broadcast as a paging message) to the nearest base station-1 (BS-1), BS-1 transmitter antenna transmit these number to BS-2 and so on up to BS-*n* which is nearest to the MSC of AIRTEL (Okhla New Delhi) and from BS-*n* it is transferred to the MSC.

Step 2 : The MSC (or MTSO) uses either standard call progress signals or the SS-7 protocol to locate a switching path through the PSTN to the destination party. After path of local BSNL exchange is found (which is Okhla BSNL exchange) then MSC transfer this number to the BSNL exchange.

Step 3 : Then MSC instructs the base station to move the call to an unused voice channel within the cell (Generally between 10 to 60 voice channels, just one control channels are used in each cell's base station), and instructs the mobile unit to tune to that channel.

Step 4 : Base station signals the mobile to change frequencies to an unused forward and reverse voice channel pair.

Step 5 : After the base station receives verification that the mobile unit has tuned to the selected channel and it has been determined that the called number is on hook, the base station transmit another data message called alert message on forward voice channel to instruct the mobile telephone to ring while the wireline caller receives a standard ringing signal.

Step 6 : If a suitable switching path is available to the wireline telephone number, the call is completed when the wireline party goes off hook (*i.e.*, answers the telephone).

2. **Mobile (cellular)-to-mobile (Cellular) : (See Fig. 1.8)**

(Within same service provider, suppose cell-one to cell-one)

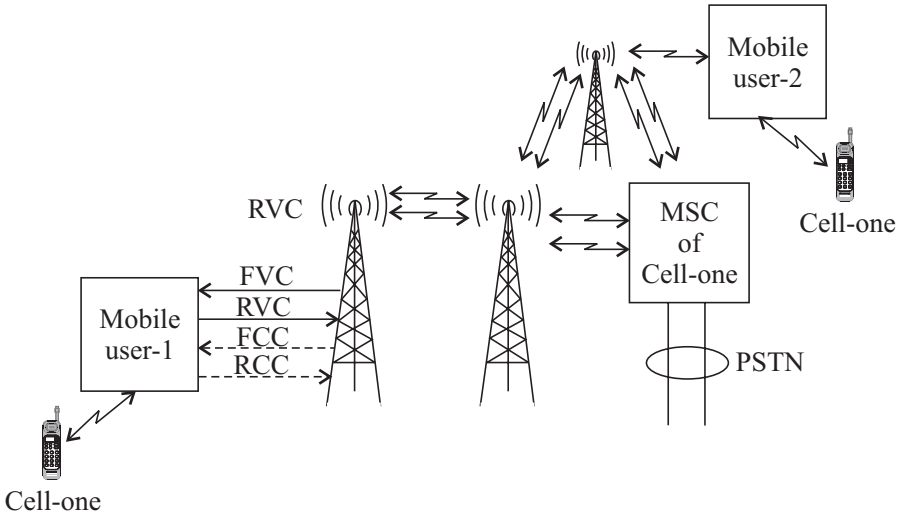


Fig. 1.8. *Call procedure mobile-to-mobile* (*same service provider*)

Step 1 : Call initiation process is same as it would for a mobile-to-wireline call.

Step 2 : The base station receives call's (user-1) identification number (MIN number) and destination telephone number through a reverse control channel, which are then forwarded to MSC.

Step 3 : MSC sends a page command to all base stations to locate the destination party which may be anywhere in or out of the service area. The mobile identification number (MIN), which is the subscribers telephone number is then broadcast as a paging message over all other forward control channels through the cellular system. The mobile (user 2) receives the paging message sent by the base station which it monitors, and responds by identifying itself over the reverse control channel.

Step 4 : Once the destination mobile unit is located, the destination base station sends a page request through a forward control channel to the user-2 to determine if the unit is on or off hook (*i.e.*, busy or free). After receiving a positive response to the page the base station relays the acknowledgment sent by the mobile and informs the MSC of the handshake.

Step 5 : Then, the MSC instructs the base station to move the call to an unused voice channel within the cell, so idle user channels are assigned to both mobile units. And call progress tones, are applied in both directions (ring and ring-back). Actually the base station signals the mobile to change frequencies to an unused forward and reverse voice channel pair, and another data message called call progress tone or call alert tone is transmitted over the forward voice channel to instruct the mobile telephone to ring thereby instructing the mobile user to answer the phone.

Step 6 : When the user-1 mobile system notice that the called party has answered the telephone, the switches terminate the call progress tones, and the conversation begins. If mobile user wishes to initiate a call and all user channels are busy, the switch sends a directed retry command, instructing the subscriber's unit to reatempt the call through a neighboring cell.

- If the system cannot allocate user channels through a neighboring cell, the switch transmits an intercept message to the calling mobile unit over the control channel.
- If the called party is off hook, the calling party receives a busy signal.
- If the called number is invalid, the calling party receives a recorded message announcing that the call cannot be processed.

3. **Mobile-to-mobile between different service providers :**

   Example – Airtel to hutch. (Fig. 1.9)

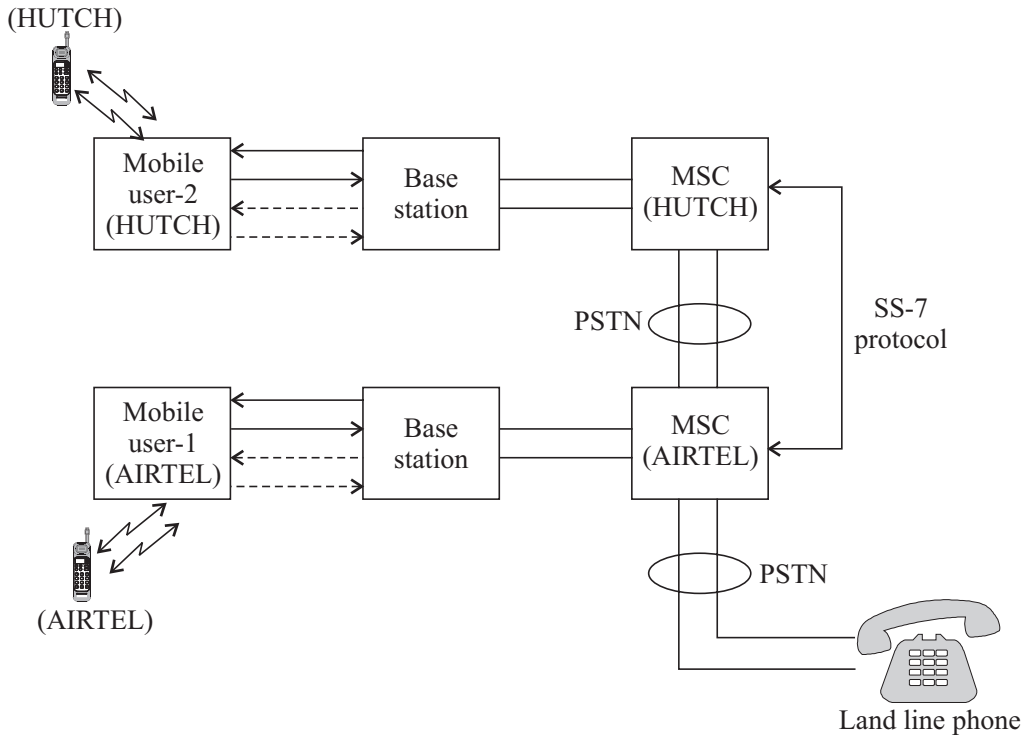


Fig. 1.9. *Call procedure mobile-to-mobile* (*between different service provider*)

Step 1 and **Step 2** is same as previous example.

Step 3 : Here user-1 is AIRTEL subscriber and user-2 is HUTCH subscriber when AIRTEL MSC (source MSC) received destination mobile number from its nearest base station, it is found that destination number is HUTCH mobile number (starting digits of mobile nos. is service provider identification number in India 91 is country code, 9868 is TRUMP 9891 is IDEI 9431 is cell-one etc.) MSCs of all service provider colleneted together via PSTN or SS-7 protocol. So in our example when MSC of AIRTEL able to know that this HUTCH number it inform HUTCH MSC that your call is coming search your user.

Step 4 : Then all HUTCH base stations broadcast destination MIN number on forward control channel, destination user (user-2) reply on reverse control channel.

Step 5 : HUTCH MSC inform AIRTEL MSC that user is found then AIRTEL MSC inform its base station and connection establishment take place according to previous example.

4. **From wireline (PSTN)-to-Mobile (cellular) call procedures**

   From : From BSNL Land line to Airtel mobile (Fig. 1.10)

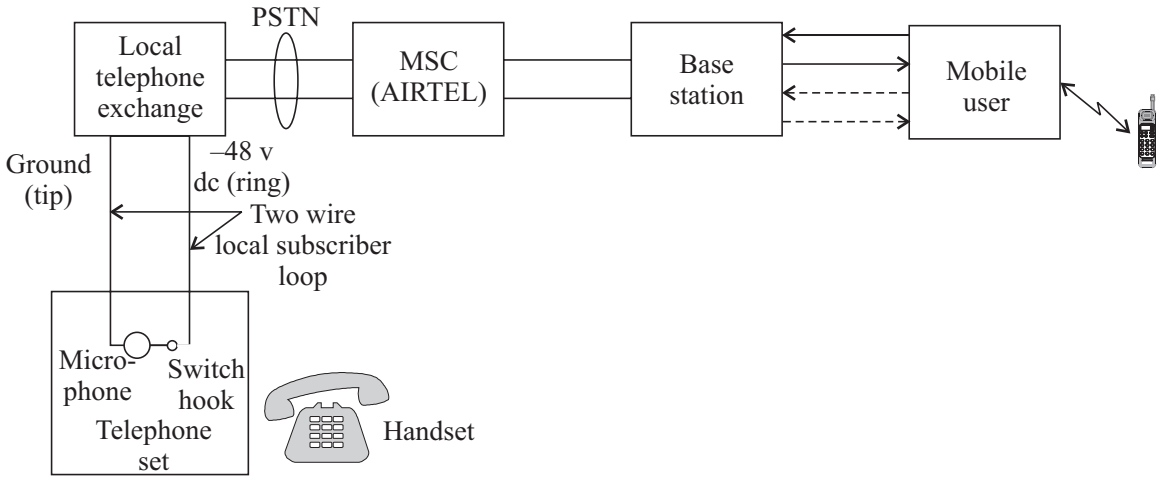


Fig. 1.10. *Call procedure from wireline-to-mobile*

Telephone set is connected to a local exchange switching machine. A basic telephone set requires only two wires (one pair) from the telephone company (BSNL or MTNL) to operate. Again, the pair of wires connecting a subscriber to the closest telephone office is called the local loop. One wire on the local loop is coded the tip, and other is called the ring. When device is off-hook (–48 V) is supply through wire and loop is completed and user receive dial-tone. Then we dial destination mobile number

Step 1 : The wireline telephone goes off hook to complete the loop, receive a dial tone and then inputs the mobile unit's telephone number. The telephone number is transferred from the PSTN switch to the cellular network switch (MSC) that services the destination mobile number.

Step 2 : The MSC of Airtel receives the incoming call from the PSTN, translates the received digits and locates the base station nearest the mobile user, which determines if the mobile user is free or busy.

Other process are same as above.

1.7 CORDLESS TELEPHONES

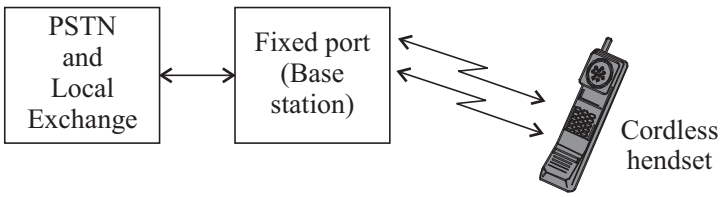


Fig. 1.11**(*a*).** *Block diagram of cordless phone*

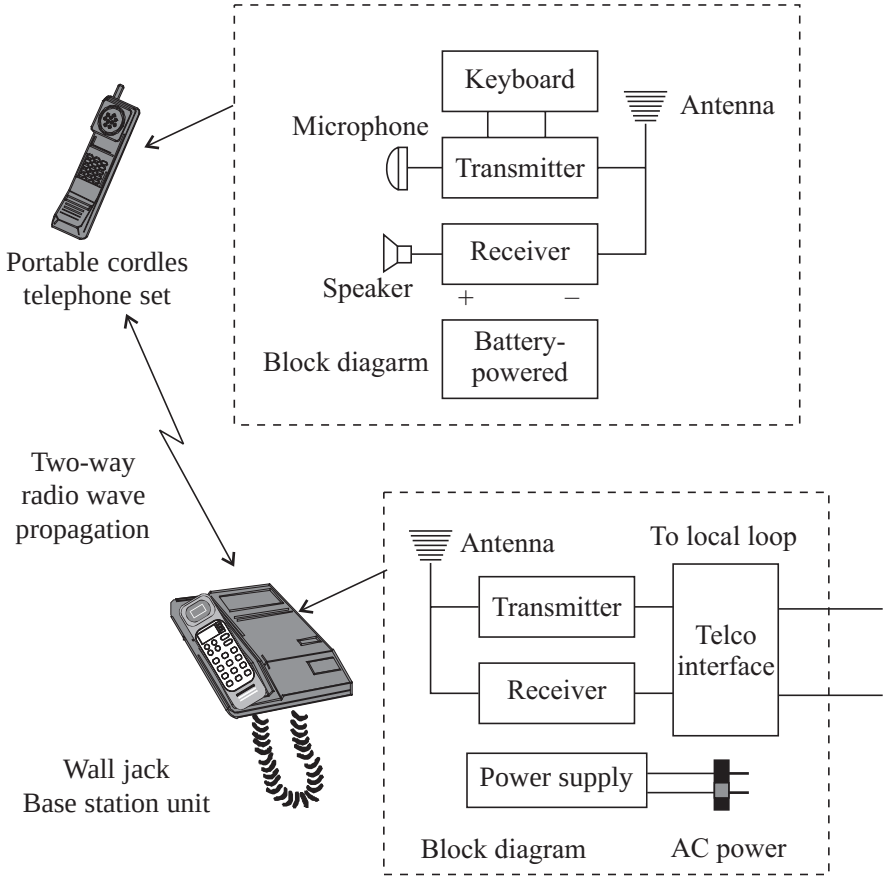


Fig. 1.11(b). *Cordless telephone system*

Cordless telephones are simply telephones that operate without cords attached to the handset. Cordless telephones originated around 1980 and were quite primitive by today's standards, Cordless telephone system are full duplex communication systems that use radio to connect a portable handset to a dedicated base station, which is then connected to a dedicated telephone line with a specific telephone number on the PSTN. They originally occupied a narrow band of frequencies near 1.7 MHz, just above the AM broadcast band and used the 117V AC, 50-60 Hz household power line (USA) for an antenna. These early units used frequency modulation (FM) and were poor quality and susceptible to interference from fluorescent lights and automobile ingestion systems. In 1984, the FCC reallocated cordless telephone service to the 46-MHz to 49-MHz band. In 1990, the FCC extended cordless telephone service to the 902 MHz to 928 MHz band, which appreciated a superior signal-to-noise radio. It transmit and receives over narrow band FM (NBFM) channel spaced 30 kHz to 100 kHz apart, depending on the modulation and frequency band used. In 1998, the FCC expanded service again to the 2-4 GHz band.

In essence a cordless telephone a full-duplex, battery-powered portable radio transceiver that communicates directly with a stationary transceiver located somewhere in the subscriber's home or office. Basic cordless telephone is shown in Fig. 1.11 (*a* and *b*). The base station is an ac-powered stationary radio transceiver connected to the local loop through a cord and telephone company interface unit. The interface unit functions in much the same way as a standard telephone set in that its primary function is to interface the cordless telephone with the local loop while being transparent to the user. Therefore, the base station is capable of transmitting and receiving both supervisory and voice signals over the subscribe loop in the same manner as a standard telephone. The base station must also be capable of relaying voice and control signals to and from the portable telephone set through the wireless transceiver. Portable telephone set is a battery powered, two-way radio capable of operating in the full duplex mode.

In first generation cordless telephone systems (In 1980), the portable unit communicates only to the dedicated base unit and only over distance of a few tens of meters. Early cordless telephones operate solely as extension telephones to a transceiver connected to a subscriber line on the PSTN and are primarily for in home use.

Modern cordless telephones allow subscribers to use their handsets at many outdoor locations within urban centers now a days cordless telephones are sometimes combined with paging receivers so that a subscriber may first be paged and then respond to the page using the cordless telephone. Cordless telephone systems provide the user with limited range and mobility, as it is usually not possible to maintain a call if the user travels outside the range of the base station. Normally base stations provide coverage ranges up to a few hundred meters.

1.8 PAGING SYSTEMS

Paging systems are simplex wireless communications systems send brief messages to a subscriber depending on the type of service, the message may be either a numeric message, an alphanumeric message, or a voice message. Paging transmitters relay radio signals and messages from wire-line and cellular telephones to subscribers carrying portable receivers. Simplified and basic block diagram of paging system is shown in Fig. 1.12 (*a*) and (*b*).

The infrastructure used with paging systems is somewhat different than the one used for cellular telephone system. This is because standard paging systems are one way, with signals transmitted from the paging system to portable pager and never in the reverse direction. There are narrow–, mid–, and wide-area pages also known as local, regional, and national. Narrow-area paging systems operate only within a building or building complex, mid-area pagers cover an area of several square miles, and wide-area pagers operate worldwide. Most pagers are mid-area where one centrally located high-power transmitter can cover a relatively large geographic area, typically between 6 and 10 miles in diameter.

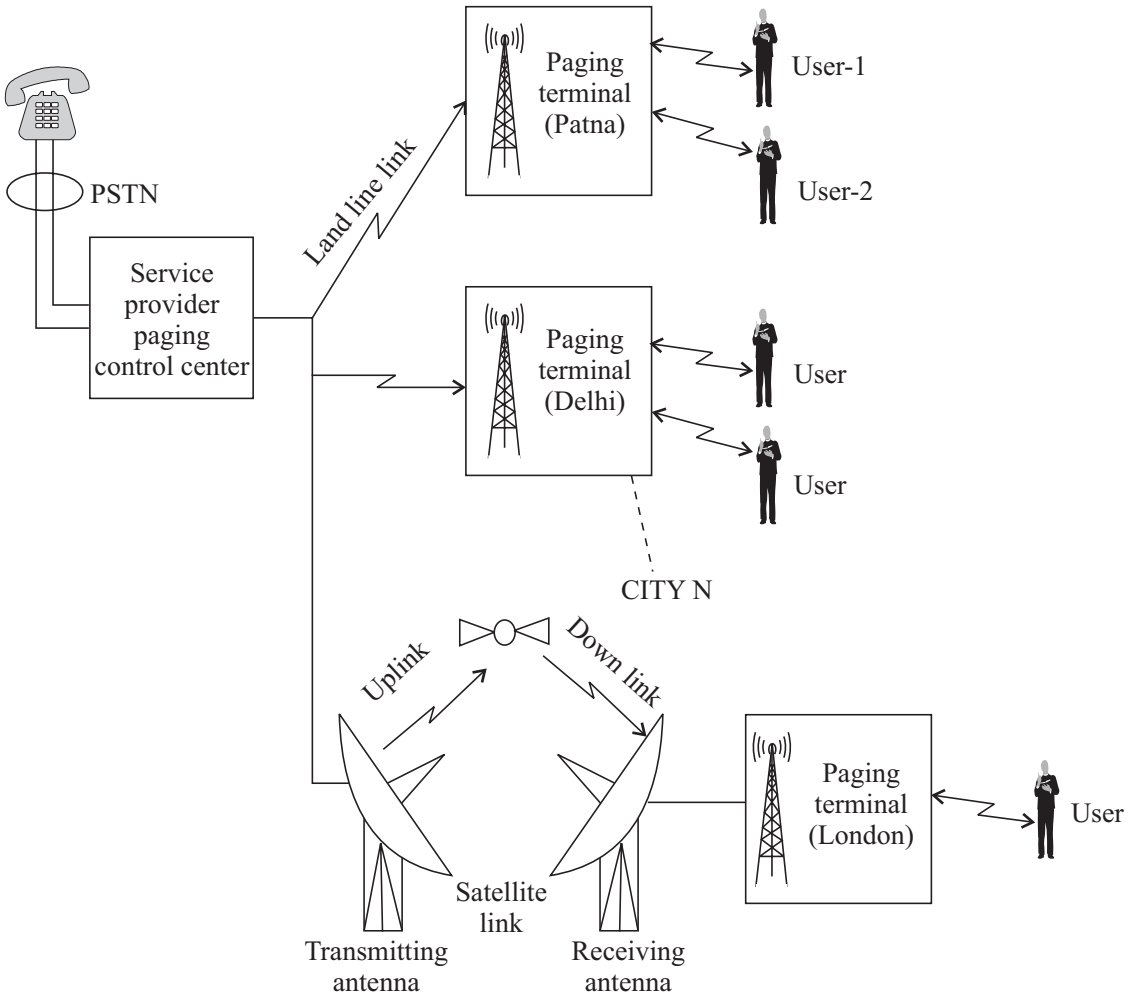


Fig. 1.12(a). *Basic paging system*

Paging procedure : To send message a person carrying a pager, first we have to dial the telephone number assigned by his service provider which is company paging center number. The paging center of that company receives the call and responds with a query requesting the pager number of that person you wish to send messages also you have to tell your messages. Then paging center operator enter that pager number. After the number is entered, a terminating signal is appended to the number, which is usually the # sign. The caller then hangs up. The paging systems converts the pager number to a digital code and transmits in the form of a digitally encoded signal over a wireless communications system. The signal may be simultaneously sent from more than one radio transmitter (some times called simulcasting or broadcasting), as is necessary in a wide-area paging systems. If the paged person is within range of a broadcast transmitter, the targeted pager will receive the message. The message includes a notification

signals, which either produces an audible beep or causes the pager to vibrate and the number the paged unit should call shown on an alphanumeric display. Some newer paging units are also capable of displaying messages as well as the telephone number of the paging party, paging systems vary widely in their complexity and coverage area. While simple paging systems may cover a limited range of 2 to 5 km or may even by on fixed to within individual buildings, wide area paging systems can provide worldwide coverage.

Early paging systems used FM, however now a days paging systems use FSK or PSK. Pages typically transmit bit rates between 200 bps and 6400 bps with the carrier frequency bands of, 138 MHz to 175 MHz, 267 MHz to 284 MHz, 310 MHz to 330 MHz, 420 MHz to 470 MHz and several frequency slots within the 900-MHz band. Each portable pager is assigned a special code called cap code, which include a sequence of digitals or a combination of digits and letters. The cap code is broadcast alongwith the paging party's telephone number. If the portable paging unit is within range of the broadcasting transmitter, it will receive the signal, demodulate it, and recognize its cap code. Once the portable pager recognizes the cap code. The callback number and perhaps a message will be displayed on the unit. Alphanumeric messages are generally limited to between 26 and 40 characters in length.

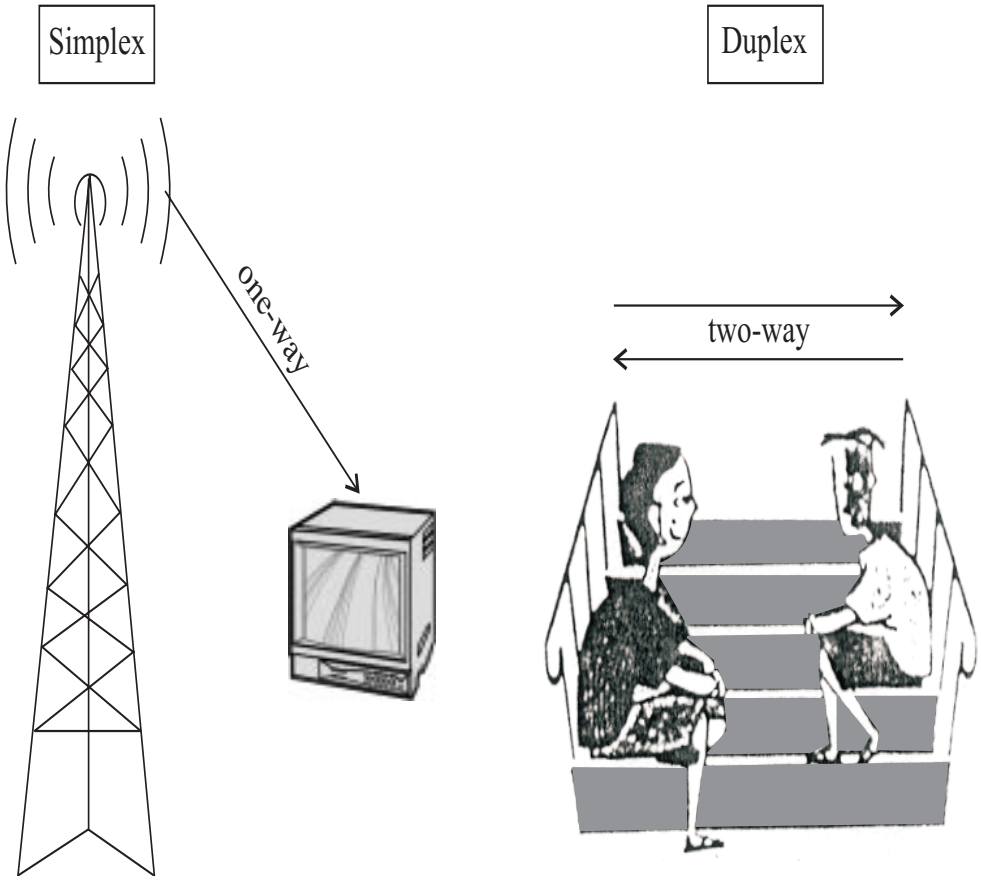


***Fig. 1.12*(*b*).** *Simplified block diagram of a standard simplex paging system*

1.9 INTRODUCTION TO HANDOFF'S AND ROAMING

1. **Handoff :** We know that one of the most important features of a cellular system is its ability to transfer calls that are already in progress from one base station to another as the mobile user moves from cell to cell within the cellular network. The base station transfer includes converting the call to an available channel within the new cell's allocated frequency subset. The transfer of a mobile user from one base stations' to another base station is called a handoff (or handover). Handoofs should be performed as infrequently as possible and be completely transparent to the subscriber *i.e.*, the subscriber cannot perceive that their facility has been switched.

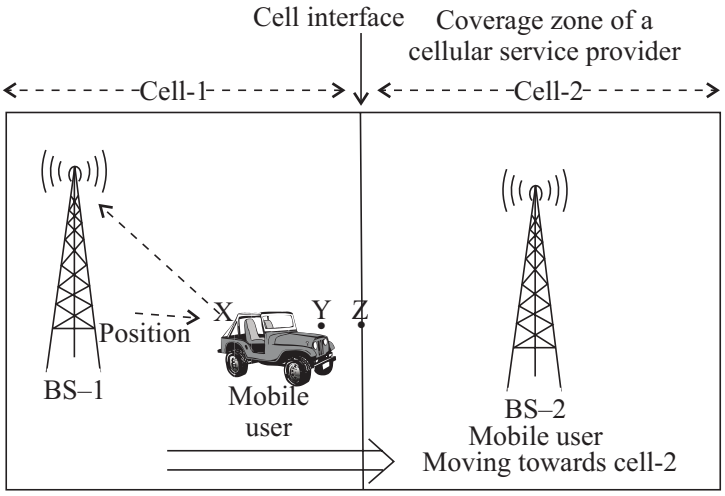


Fig. 1.13. *Handoff procedure*

Suppose one service provider divided its coverage zone into two parts: cell-1 and cell-2 (*i.e.*, number of cell is 2) and each cell having one base station. Now suppose a mobile user is moving on high speed vehicle from cell-1 towards cell-2. (See Fig. 1.3). When mobile user is at position X it is connected with base station-1 (BS-1) and its signal strength is full, when it moves to point Y its signal level start reducing because transmitting antennas of BS-1 is not able to transmit full signal strength due to its maximum power transmissions limitations, (Maximum up to point Z).

In first generation analog cellular systems signal strength measurements are made by the base stations and supervised by the MSC. Each base station constantly monitors the signal strength of all of its reverse voice channels to determine the relative location of each mobile user with respect to the base station tower. In addition to measuring the received signal strength (RSS) of calls in progress within the cell, one extra receiver in each base station is used to scan and measure signal strengths of mobile users which are in neighboring cells and it is known as **locator receiver.** The locator receiver is controlled by the MSC.

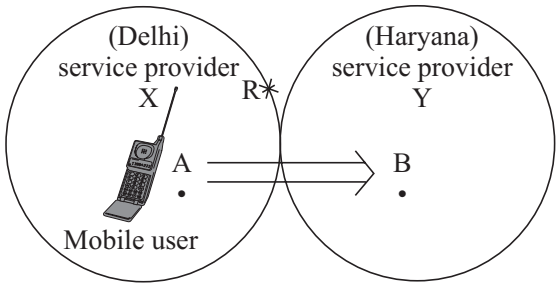
In second generation system **Mobile assisted handoff** (MAHO) techniques are used. Here every mobile unit measures the received power from surrounding base stations and continually reports the

results of these measurement to the serving base station. A handoff is initiated when the power received from the base station of a neighboring cell begins to exceed the power received from the current base station by a certain level or for a certain period of time.

Now in our example when mobile user is at point Y its mobile unit found that power level of signal decreases from minimum level. Then mobile user send its power level to the nearest base station (Mobile unit send its power level to base stations an every 6 sec.) then base station inform to the MSC that signal level of particular user is decreases. Then MSC locate nearest base station which is having strong signal level (*i.e.*, base station-2), and provide free voice and control channel from BS-2 *i.e.*, call is transfer to the base station-2. This process is known as **handoff** or **handover.**

Note : All above steps must be completed before user reached at point Z. Because BS-1 is not able to transmit power after point Z and call is disconnected. So handoff (transfer of call from BS-1 to BS-2) must be completed before call is disconnected and user is not able to know that his calls is transferred to another base stations.

Roaming : A mobile station which operates in 4 service area (market) other than that from which services has been subscribed is known as roaming.



Suppose one mobile user uses services of service provider X (Let AIRTEL) which provide his cellular services in Delhi. Let mobile user is going from Delhi to Mathura. When he reached at Faridabad (position A), his mobile power level start decreasing (*i.e.*, strength of signal stars decreasing now MSC of Airtel searching for another base station for handoff but no more base station connected with Airtel (Delhi) MSC, because his services is limited for Delhi only. Now MSC of Airtel search for service provider whose services are available in Haryana. Suppose it selects cell-one (depends on the agreements between service provider to provide services to their home user when they are on roaming). Then MSC X (Airtel) sends the handoff request (known as intersystem handoff) to MSC Y (cell-one) through a dedicated line between MSC X and MSC Y and MSC Y makes a complete handoff during the call conversation. So cell-one provide services to Airtel-user, but MSC of Airtel must provide all user details to the service provider cell-one (Y) *i.e.*, particular user is my authorised and he is a registered user, then service provider Y provide his services and service provider X must pay call charges or roaming charges to service provider Y (*i.e.*, why call charges on roaming is more).

Until the early 1990s, US cellular customers that roamed between different cellular systems had to register manually each time they entered a new market during long distance travel. For that roaming technique, user is required to call an service provider to request registration. But in 1991, US cellular carriers implemented the network protocol standard IS-41 to allow different cellular systems to automatically accommodate subscribers who roam into their coverage region. This is known as

incorporator roaming. Due to IS-41 it is possible to allow MSCs of different services providers to pass information about their subscribers to other MSCs on demand.

Dropped call : After the call establishment if a call is disconnected before it is properly terminated by user. Call establishment means that the call is setup completely by the setup channels. If there is a possibility of a call drop due no available voice channels, this is counted as a blocked call not a dropped call. If there is a possibility that a call will drop due to the poor signal of the assigned voice channel, this is considered a dropped call. This can happen when the mobile or portable units are at a standstill and due to unavailability of voice channel strong control channel becomes of weak voice channel due to weak voice channel call is dropped after establishment.

Call drop rate may be higher due to :

(*a*) The subscriber unit not functioning properly (needs repair).

(*b*) The user operating the portable unit in a vehicle.

(c) The user not knowing how to set the best reception from to portable cannot.

Questions

1. Write short history of wireless communication.
2. Compare two-way mobile radio and cellular telephone.
3. Describe the difference between a cellular telephone, service area and a cell.
4. Suppose a mobile user whose mobile number is 09868147638 is calling to other mobile user explain call initiation and call handling process.
5. What do you mean by the terms ‘handoff’ and ‘roaming’?
6. Explain different types of channel used for wireless communication.
7. Draw the block diagram of basic wireless communication system and explain functions of each block.
8. Why is PSTN required for wireless communication?
9. Describe the term ‘cell’ and ‘cellular’.