Different Generations of Cellular Networks System

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Topic

Different Generations of Cellular Networks System

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Today's world is going very hastily towards wireless equipments especially in computer networking devices, home accessories, mobile phones etc. Among theses communication gadgets, cellular telephony is growing fastest. Cellular phones now provide the services of personal computers as well as provide Internet connectivity.

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CHAPTER 1

Introduction to Wireless Communication

Wireless Communication is the buzz word in today's technology world. Especially the cellular communication plays the vital role in worldwide infrastructure. Analog systems were the first generation (1G) cellular systems that introduced the wireless communication (only voice telephony) but with larger handsets and uneven voice quality declined their use quickly by the introduction of digital technology in the form of second generation (2G) standards such as GSM and CDMA*One*. By utilizing digital technology, cell phones and network infrastructure could be made cheaper over time, enabling better network service levels and more capable phones. Wireless networks are slowly developing from 1G analog system to 3G high-speed digital networks and now going towards 4G. Every country in the entire world is at a different phase of building networks to support 3G's next generation, data centric applications, such as online games, fast internet access, multimedia messaging, and online shopping [7].

A cellular network allows cellular subscribers to move anywhere in the country and remain connected to Public Switched Telephone Network (PSTN) via their mobile phones. A cellular network has a hierarchical structure and is formed by connecting the following generic components:

- Mobile Station (MS) or Mobile Phone (MP) ,
- Base Station (BS) and
- Mobile Switching Centre (MSC).

The BS serves is a cell, which could be a few kilometers in diameter. The cells when grouped together form a cluster and all BSs within a cluster are connected to a MSC using landlines. The MSC stores information about the subscribers located within the cluster and is responsible for directing calls to them. Generally rural areas have few subscribers as compared to urban areas. If each cell has fixed number of channels the cell size in urban area would have to be smaller to accommodate more channels. However, reducing the size too much would result in using similar channel frequency to be located closer to each other causing co-channel interference [1].

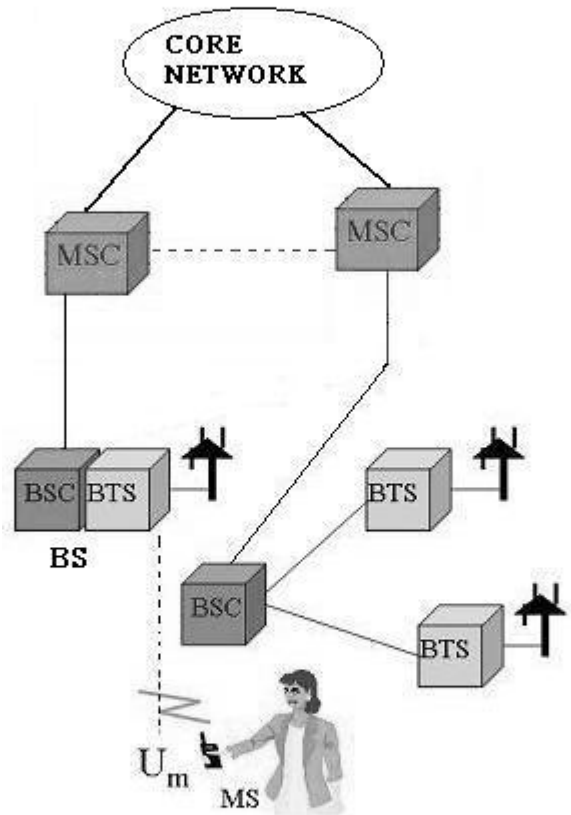


Figure 1.1a Cellular Network & Figure 1.1b Base Stations (BS)

1.1 **Basic information of Wireless terms**

Wireless Network provides the access information over a various set of wireless and wired networks. It uses the radio frequency (RF) spectrum for transmitting and receiving the voice, data and video signals for interactions [53]. Wireless networks technology is universally used in LAN, MAN and WAN. Some of the technologies are:

- *Wireless LAN (WLAN)*: A WLAN is one in which a mobile user can connect to a local area network (LAN) through a wireless (radio) connection. A standard, IEEE 802.11, specifies the technologies for wireless LANs [55].

- *Wireless Application Protocol (WAP)*: WAP allows mobile users with wireless devices to easily and instantly access of Internet and interact with information and services [1].
- *Wireless ISP (WISP* : A WISP is an Internet service provider (ISP) that allows subscribers to connect to a server at designated hot spots (access points) using a wireless connection such as Wi-Fi. This type of ISP offers broadband service and allows subscriber computers, called stations, to access the Internet and the Web from anywhere within the zone of coverage provided by the server antenna. This is usually a region with a radius of several kilometers [55].
- *Wireless Local Loop (WLL)*: A form of wireless access that utilizes radio to connect fixed end users to the PSTN and provide standard telephone services.
- *Wireless IP (WIP)*: The packet data protocol standard for sending wireless data over the Internet [1].
- *Wireless Fidelity (Wi-Fi)*: Wi-Fi is a term for certain types of WLAN that use specifications in the 802.11 family. The term Wi-Fi was created by an organization called the Wi-Fi Alliance, which oversees tests that certify product interoperability [55].
- *Wireless ATM (W-ATM)*: Wireless Asynchronous Transfer Mode network [1].
- *Wireless Data Forum (WDF)*: An industry group dedicated to promoting wireless data [1].
- *Wideband Code-Division Multiple Access (W-CDMA)*: A wireless technology that allows for high quality data transmission at high-speeds. W-CDMA is a 3G technology that requires a lot of bandwidth and isn't estimated to hit the market for several years [29].
- *Wireless Intelligent Network (WIN-4)*: The architecture of the wireless switched network that allows carriers to provide enhanced and customized services for mobile telephones [8] [53].

1.2 **History and Evolution of Wireless Communication**

The history of wireless communication is as old as the history of mankind. Even in the ancient era, people used primeval communication systems, which can be categorized as wireless. For examples smoke signals, flashing mirrors, flags, fires, etc. This concluded that the ancient Greeks utilized the communication system comprising a collection of observation stations on hilltops, with each station visible from its neighboring one. Upon receiving a message from a neighboring station, the station personnel repeated the message in order to relay it to the next neighboring station. Using this system messages were exchanged between pairs of stations far apart from one another [1] [14].

Throughout the world, wireless communication is experiencing phenomenal growth encompassing and transforming every aspect of our lives, creating an “always connected” society. The demand from businesses and consumers for easier, more mobile access to information has led to an explosion of groundbreaking wireless technologies [45].

1.2.1 **Wireless Issues and Trends**

In Today’s world, not only the wireless industry experiencing record growth in the number of wireless devices but also growth in the number of applications attempting to reach out to the wireless world. From mobile commerce and banking, information services and messaging including email, Short Message Service (SMS), Multimedia Messaging Service (MMS), Instant Messaging (IM), and Voice Instant Messaging (VIM), the list of business critical applications with interfaces to wireless devices will continue to expand rapidly [2].

1.2.2 **Constant, real-time access**

Over the next decade, consumers will make mobile devices natural extensions of themselves as they seek constant, real-time access to the information they need and want right here. Aided by faster transmission speeds and battery power boosts, this personal touch will evident in trends that include the increased use of more location based services and innovative new wireless devices [7].

According to the research, advanced 2.5G and 3G cellular networks are only the beginning as other technologies, including WLAN, Bluetooth, radio frequency identification (RFID) and even ultra wideband (UWB) technologies are deployed. Even the family car will be wirelessly enabled. Cumulative revenues garnered through the global adoption of these technologies, excluding cellular, will likely exceed $33 billion by 2007 [1].

1.2.3 **Wireless networking top trend**

Wireless technology will also play a key role in transforming the platforms that mobile, home and business users interact with. The combination of broadband access and wireless LANs in the home will create a renewed focus on alternate form factors, such as tablets, suitable for a range of access needs and locations. From security issues for enterprise WLANS to the threat that Wi-Fi presents to carriers spending big bucks on competing 3G networks, wireless networking will be the top technology trend [1] [2].

1.3 **Early Mobile Technology**

The first public mobile telephone system is known as Mobile Telephone System (MTS), was introduced in 25 cities in the United States in 1946 but due to technological limitations, the mobile transceivers of MTS were very big and could be carried only by vehicles. MTS was an analog system meaning that it processed voice information as a continuous waveform. This waveform was then used to modulate and demodulate the radio frequency (RF) carrier. The system was half-duplex that is at a specific time the user could either speak or listen. To switch between the two modes, users had to push a specific button on the terminal [1].

MTS utilized a Base Station (BS) with a single high-power transmitter that covered the entire operating area of the system. If extension to a neighboring area was needed, another BS had to be installed for that area. Due to power limitations, mobile units transmitted not directly to the BS but to receiving sites scattered along the system's operating area. These receiving sites were connected to the BS and relayed voice calls to it. In order to place a call from a fixed phone to an MTS terminal, the caller first called a special number to connect to an MTS operator. The caller informed the operator of the mobile subscriber's number. Then the operator searched for an idle channel in order to relay the call to the mobile terminal. When a mobile user wanted to place a call, an idle channel was seized through which an MTS operator was notified to place the call to a specific fixed telephone. Thus, in MTS calls were switched manually [1] [53].

An advancement of MTS in 1960s called Improved Mobile Telephone System (IMTS). IMTS utilized automatic call switching and full duplex support, thus remove the intermediation of the operator in a call and the need for the push to talk button [1].

1.3.1 **Analog Cellular Telephony**

Analogy Cellular Telephony is based on analog system that is, it processed voice information as continuous waveform. This is the first generation of cellular systems and was designed in the late 1960s and due to regulatory delays, their deployment started in the early 1980s. The first service trial of a fully operational analog cellular system was deployed in Chicago in 1978. The first commercial analog system in the United States known as Advanced Mobile Phone System (AMPS) went operational in 1982 offering only voice transmission. Similar systems were used in other parts of the world, such as Total Access Communication System (TACS) in the United Kingdom, Italy, Spain, Austria, Ireland. MCS-L1 in Japan and Nordic Mobile Telephony (NMT) in Nordic countries. All these standards utilize frequency modulation (FM) for speech and perform handover decisions for a mobile at the BSs based on the power received at the BSs near the mobile. The available spectrum within each cell is partitioned into a number of channels and each call is assigned a dedicated pair of channels [1] [14].

1.3.2 **Digital Cellular Telephony**

Analog cellular systems were the first step for the mobile telephony industry. Despite their significant success, they had a number of disadvantages that limited performance. These disadvantages were alleviated by the second generation (2G) of cellular systems. Digital system describes electronic technology that generates, stores, and processes data in terms of two states: positive and non-positive. Positive is represented by the number 1 and non-positive by the number 0. Thus, data transmitted or stored with digital technology is expressed as a string of 0's and 1's bit(s). A number of 2G systems have been deployed in various parts of the world. 2G systems can also send data at very low speeds. Therefore 2Gs upgrades launched called 2.5G that support higher data speeds [1] [14].

1.4 **Mobile Satellite Networks**

Mobile satellite networks refer to services of satellite planned for use with mobile and portable wireless telephones. Initially, the first sign to satellite communication systems was introduced in the mid of 1940s by Arthur Clarke. After no more than 40 years, satellites have emerged to be a significant industry. The satellite industry has enjoyed an enormous growth offering services such as data, paging, messaging, voice, TV broadcasting and a number of mobile services. The introduction of high-bandwidth fiber based links changed this and the biggest application of satellites turns out to be as a wireless local loop technology with great coverage [1] [35]. There are a number of issues that favor the use of satellites and briefly summarized it below:

- *Mobility*: Satellites favor the applications that demand mobility, whereas fiber networks are limited in this sense.
- *Broadcasting*: Satellites offer the capability of easy broadcasting of messages to a very large number of ground stations. This is easier than implementing broadcasting on a wired network.
- *Hostile environments*: Satellites can easily provide coverage to areas where installation of wires is either very difficult or costs a lot.
- *Rapid deployment*: By satellites, a network can be deployed far more quickly than a wired-based one.

1.4.1 **Satellite Communications Characteristics**

Satellite communications typically comprises of two main units, the satellite itself and the Earth Station (ES). The satellite, which is also called the space segment of the system, essentially acts as a wireless repeater that picks up uplink signals (signals from the ES to the satellite) from an ES and, after amplification, transmits them on the downlink (from the satellite to the ES) to, possibly more than one, other ESs. The uplink occupies a different frequency band than that of the downlink. There may existence more than one uplink channel. Thus, satellites typically contain many transponders, each of which contains receiver antennae and circuitry in order to listen to more than one uplink channel at the same time. Satellite communication systems have a number of characteristics that differentiate them both from wired and other kinds of wireless links [1] [6] [35]. These characteristics are briefly summarized below:

- *Wide coverage*: Due to the high altitudes used by satellites, their transmissions can be picked up from a wide area of the Earth’s surface. The area of coverage of a satellite is known as its footprint.

- *Noise*: Due to the large distances between the ESs and the satellite make the received signal very weak, typically in the order of a few hundred of picowatts.
- *Broadcast capability*: Satellites are an inherently broadcast device that is transmission can be picked up by an arbitrary large number of ESs within the satellite's footprint without an increase in either the cost or complexity of the system.
- *Long transmission delays*: Due to the high altitude of satellite orbits, the time required for a transmission to reach its destination is substantially more than that in other communication systems.
- *Transmission costs independent of distance*: In satellite systems, the cost of a message transmission is fixed and does not depend on the distance traveled.

1.4.2 **Applications of Satellite Communications**

There are number of applications where satellite communication systems are involved. An indicative list is briefly outlined below.

- *Voice telephony*: Satellite is a system for interconnecting the telephone networks of different countries and continents. Although the alternative of cables also exists, satellite use for interconnecting transoceanic points has sometimes been preferred rather than installing submarine cables.
- *Cellular systems*: Satellite coverage can be overlaid over cellular networks to provide support in cases of overload. When cells in the cellular network experience overload, the satellite can use a number of its channels to serve the increased traffic in the cell.
- *Worldwide coverage systems*: Satellite systems can provide connectivity even to places where no infrastructure exists, such as deserts, oceans, deserted areas, etc.
- *Connectivity for aircraft passengers*: Aircraft can be equipped with transceivers that can use such satellites to provide connectivity to passengers while airborne.
- *Internet access*: Satellite communication systems possess a number of characteristics that enable them to effectively provide efficient Internet access to globally scattered users.
- *Global Positioning Systems (GPS)*: The well-known GPS system offers the ability to determine the exact coordinates of the GPS receiver. This is achieved with the help of multiple satellites through triangulation [1].

1.4.3 Satellite Communication Systems

Satellite communication system consists of two main parts, the ground segment and the space segment. The ground segment consists of gateway stations; a network control center (NCC) and operation control centers (OCCs). NCCs and OCCs deal with network management and control of satellite orbits. The space segment comprises the satellites themselves, which are often classified by the orbit they use. Thus, satellite orbits are an essential characteristic of a satellite communication system [1] [6]. They are characterized by the following properties:

- *Apogee*: The orbit's farthest point from the Earth.
- *Perigee*: The orbit's closest point to the Earth.
- *Orbital period*: This is the time to go around the Earth once when in this orbit and is determined by the apogee and perigee.
- *Inclination*: This stands for the angle between the orbital plane and the equatorial plane of Earth.

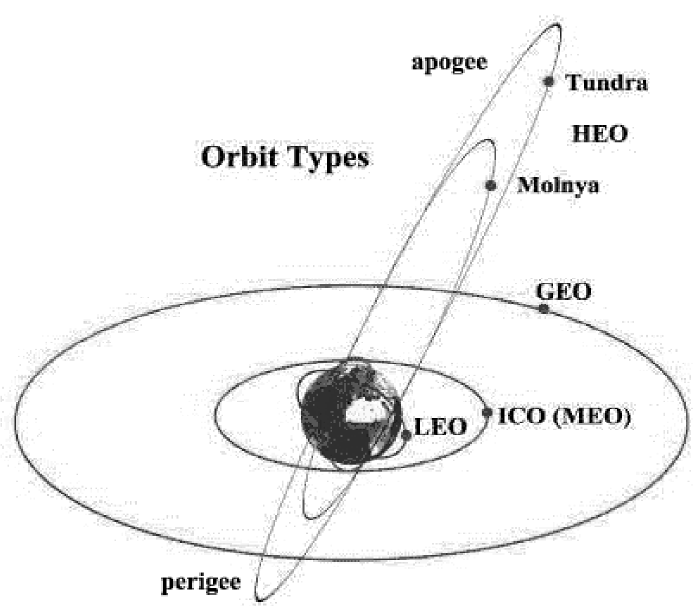


Figure1.2 Low, middle and geosynchronous circular earth orbits [55]

1.4.3.1 Low Earth Orbit (LEO)

Low Earth Orbit (LEO), that lies in the area between 100 and 1000 km above the Earth's surface. The small radius of a LEO orbit gives it a small period of rotation T, typically between 90 and 120 min that of course translate into a high orbiting speed. The main characteristics of LEO orbits are the following:

- *Low deployment costs*: Lower orbits are easier to reach by rocket systems. This translates into reduced cost for satellite deployment.
- *Very short propagation delays*: Due to their low distance from the Earth's surface, LEO systems exhibit very short propagation delays.
- *Very small path loss*: Lower orbits are characterized by a smaller path loss and LEO based systems have low power requirements.
- *Short lifetime*: The Earth's atmosphere extends to thousands of kilometers above its surface and becomes thinner with increasing height. At the altitudes of LEO systems, friction with atmospheric molecules is more intense than in higher orbits.
- *Small Line of Site (LoS) times*: LEO systems are characterized by angular orbiting speeds. This is problematic from the point of view of time the satellite remains visible from a given location on the Earth's surface. This means that terminals will need to possess steer able antennae in order to track the satellites as they move [1] [55].

1.4.3.2 **Medium Earth Orbit (MEO)**

Medium Earth Orbit (MEO), that lies in the area between 5000 and 15,000 km above the Earth's surface. These orbits are higher than those of LEO systems, thus the orbital period T also increases and typically the value of T is several hours. At such distances, the characteristics considered as advantages of LEO systems, fade to become disadvantages for MEO systems. Similarly, the disadvantages of LEO systems become advantages for MEO systems. Some of them are briefly summarized below:

- *Moderate propagation delay*: Although not much higher than that of LEO systems, the propagation delay in MEO systems is higher.
- *Greater lifetime*: The atmosphere is thinner at higher orbits. Thus, MEO systems experience lower friction with atmospheric molecules, a fact that translates into higher lifetimes.

- *Increased coverage*: The relatively high orbits of MEO systems give them an increased footprint. Compared with lower orbits, fewer satellites are needed to achieve worldwide coverage.

Theoretically, MEO satellites can be deployed as high as 35,000 km or more. However, few MEO satellites use orbits above 10,000 km. This is due to the fact that at distances greater than this, deployment costs and propagation delay become significant without additional advantages. The most well-known system that uses MEO orbits is the Global Positioning System (GPS) [1] [55].

1.4.3.3 **Geosynchronous Earth Orbit (GEO)**

The Geosynchronous Earth Orbit (GEO) was discovered by Arthur Clark. If a satellite is placed at approximately 36,000 km above the Earth’s surface, then its angular velocity will be the same as that of the Earth. The satellite rotates at an inclination of 908, which means that it remains in the same spot above the Equator. In such a case the satellite will appear to remain fixed at the same position in the sky. This is very useful for communications systems since ESs antennae do not have to track the satellite as it moves but rather remain focused on a specific point.

The Geosynchronous Earth Orbit has a period of 23 hours and 56 minutes, not 24 hours. This is because Earth makes a complete rotation around its axis in 23 hours and 56 minutes. On the other hand, 24 hours is the duration of the so-called solar day, which stands for the duration of a complete rotation of the Earth relative to the Sun. This difference of about 4 minutes stems from the Earth’s motion around the Sun. Due to this motion; Earth has to rotate slightly more than 3608 so that a given place on its surface points exactly towards the Sun. Consequently GEO satellites have an orbital period of 23 hours and 56 minutes to match the angular speed of the Earth. The main characteristics of GEO:

- *No atmospheric friction*: At such a high altitude, atmospheric friction is nearly nonexistent. As a result GEO satellites remain in orbit for a very long time.
- *Wide coverage*: Due to their high altitude, GEO systems exhibit a wide coverage. By using three GEO satellites spaced 1208 from one another, almost worldwide coverage can be achieved with obvious advantages for multicasting applications.

- *High deployment costs*: Due to the high altitude of GEO systems, the construction of rockets in order to deploy or reach the satellite for repair is high.
- *High propagation delay*: The high altitude of the geostationary orbit incurs a significant propagation delay. This causes problems for applications that require low delays, such as voice-related and interactive applications. Typical values of this delay for GEO systems are between 250 and 280 ms.
- *High path loss*: The high altitude of the geostationary orbit also translates into increased path loss. This translates into a need for increased transmission power and antennae sizes, which of course makes the construction of portable, low-cost mobile devices that communicate with GEO satellites difficult [1] [55].

1.4.4 **Elliptical Orbits**

Apart from the LEO, MEO and GEO orbits, which are all very close to circular, there are satellites that employ elliptical orbits. The elliptical nature of the orbit results in a variation of both the altitude and the speed of the satellite. Near the perigee, the satellite altitude is much lower than that near the apogee. The opposite applies for the orbital speed. Near the perigee the speed is much higher than that near the apogee. As a result, from the point of view of an observer on the surface of the Earth, an elliptical-orbit satellite remains visible for only a small period of time near the perigee but for a long period of time near the apogee. Elliptical-orbit satellites combine the low propagation delay property of LEO systems and the stability of geostationary systems. Thus, such a satellite has the properties of a LEO system near the perigee of its orbit (low delay, low LOS times) and the properties of a geostationary system near the apogee (high LOS times, high propagation delays). Elliptical-orbit satellites are obviously easier to access near their apogee because their high LOS times and low speeds permits ESs to track them without having to perform very frequent antenna readjustments. Thus, systems that employ such orbits have found use in systems that provide high LOS times for regions of the Earth far in the north or south [1] [6].

Since such areas cannot be effectively serviced by geostationary satellites as they orbit above the equator, elliptical orbits can provide high LOS times for such areas. This approach was followed by the former USSR in the Molniya satellites; since most of USSR is located far too north for geostationary satellite coverage; three elliptical-orbit satellites at an inclination of 63.48 have been used. The orbits were chosen in such a way so that at least one satellite covered the entire region of the country at any time instant [1] [55].

1.4.5 Examples of Satellite based Mobile Telephony Systems

In the late 1980s, satellite systems appeared to be a promising approach for constructing telephony systems with worldwide coverage. At that time, conventional cellular telephony was not very widespread and its cost was relatively high. These facts made room for satellite based systems. Here we study two examples of satellite based mobile telephony systems: Iridium and Globalstar. Iridium was an ambitious project aiming for worldwide coverage using a dense constellation of LEO satellites. Globalstar, which on the other hand had a better fate than Iridium, is a simpler system and its coverage also depends on the existence of ES [1].

1.4.5.1 Iridium

The Iridium project was initiated by Motorola in the early 1990s. The project aimed to offer coverage to every place on the planet through a dense constellation of LEO satellites. The Iridium satellites employ significantly richer functionality than simple bent-pipe satellites by enabling intra-satellite communication for relaying of control signaling and phone calls. The project initially called for use of 77 LEO satellites. This was the fact that gave it the name Iridium, since Iridium is the chemical element with an atomic number of 77. Despite the fact that the number of satellites was later reduced to 66, the name Iridium stayed probably due to the fact that the marketing people preferred it to Dysprosium, which is the chemical element with an atomic number of 66. This decision did not seem to favor the project’s fate, as Iridium was finally abandoned for economic reasons in 2000. The Iridium system comprised four main components: the satellite constellation, the system control facilities, the gateways and the subscriber units [35].

1.4.5.2 Globalstar

Globalstar is a satellite-based telephony system that aims to enable users to talk from virtually anyplace in the world. However, the word ‘virtually’ has a definite meaning. This is due to the fact that contrary to Iridium, which enables true worldwide coverage through the use of ISLs for call routing, the operation of Globalstar depends on the presence of a Globalstar gateway in range of the satellite that serves the user. This is because gateways are necessary in order to connect users, since no ISLs are used, as in Iridium. On the other hand, it constitutes an advantage in terms of cost and system simplicity.

Since typical Globalstar gateways can have a range of many kilometers, few such stations are needed to support the system. When every gateway is operational, Globalstar can cover most of the Earth’s surface, except for the regions in the middle of the oceans where ESs deployment is not possible or costs a lot and those near the poles, for reasons that are described later. The Globalstar system comprises three main components: the satellite constellation, the gateways and the subscriber units [1].

1.4.6 **Asia Cellular Satellite System**

Asia Cellular Satellite System (ACeS) is a joint cellular telephone and satellite wireless system that provides digital service to mobile phone and computer users in the Asia Pacific Region. Adding mobile satellite communication to the terrestrial Global System for Mobile (GSM) communication system, ACeS is billed as the first integrated satellite GSM system in the world. Users with Ericsson dual-mode terminals will be able to roam within the region switching as necessary between cellular service and satellite service [14].

ACeS is probably be available in an area from Indonesia in the South; Papua, New Guinea in the East; Japan in the North; and Pakistan in the West, an area with a combined population of three billion. ACeS makes it possible for many people to have communication services for the first time. ACeS has signed over 19 roaming service agreements with GSM operators. ACeS subscribers are provided with a GSM subscriber identify module (SIM) and a network access code that can be used outside the region or within the region when blockages of satellite signals occur [55].

1.5 **Introduction to Wireless Technologies**

From 1G to 3G, there are many technologies invented in different countries, some of the most popular technologies are:

1.5.1 **AMPS**

Advanced Mobile Phone Service (AMPS) is a standard system for analog signal cellular telephone service in the United States and is also used in other countries. It is based on the initial electromagnetic radiation spectrum allocation for cellular service by the Federal Communications Commission (FCC) in 1970. Introduced by AT&T in 1983, AMPS became and currently still is the most widely deployed cellular system in the United States. AMPS allocates frequency ranges within the 800 and 900 Megahertz (MHz) spectrum to cellular telephone [2] [9].

1.5.2 **D-AMPS**

Digital Advanced Mobile Phone Service (D-AMPS) is a digital version of AMPS. D-AMPS is now called Interim Standard 136 (IS-136) from the Electronics Industries Association and Telecommunication Industries Association (EIA/TIA) is the original analog standard for cellular telephone phone service in the United States. D-AMPS adds time division multiple access (TDMA) to AMPS to get three channels for each AMPS channel, tripling the number of calls that can be handled on a channel [1] [16].

1.5.3 **CDMA*One* (IS-95)**

IS-95 is the 2G system also known as CDMA*One* was standardized and the first commercial systems were deployed in South Korea and Hong Kong in 1995, followed by deployment in the United States in 1996. IS-95 utilizes Code Division Multiple Access (CDMA). In IS-95, multiple mobiles in a cell whose signals are distinguished by spreading them with different codes simultaneously use a frequency channel. Thus, neighboring cells can use the same frequencies, unlike all other standards discussed so far. IS-95 is incompatible with IS-136 and its deployment in the United States started in 1995. Both IS-136 and IS-95 operate in the same bands with AMPS. IS-95 is designed to support dual mode terminals that can operate either under an IS-95 or an AMPS network. IS-95 supports data traffic at rates of 4.8 and 14.4 kbps. An extension of IS-95, known as IS-95b or cdmaTwo, offers support for 115.2 kbps by letting each phone use eight different codes to perform eight simultaneous transmissions [1] [2].

1.5.4 **GSM**

Global System for Mobile communication (GSM) is a digital mobile telephone system that is widely used in Europe and other parts of the world. GSM uses a variation of TDMA and is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1800 MHz frequency band [14] [22].

1.5.5 **HSCSD**

High Speed Circuit Switched Data (HSCSD) is circuit switched wireless data transmission for mobile users at data rates up to 38.4 Kbps, four times faster than the standard data rates of the GSM communication standard in 1999. HSCSD is comparable to the speed of many computer modems that communicate with today's fixed telephone networks. HSCSD is an evolutionary technology on the way to Universal Mobile Telecommunications Service (UMTS) [25].

1.5.6 **GPRS**

General Packet Radio Services (GPRS) is a packet based wireless communication service that promises data rates from 56 up to 114 Kbps and continuous connection to the Internet for mobile phone and computer users. The higher data rates will allow users to take part in video conferences and interact with multimedia Web sites and similar applications using mobile handheld devices as well as notebook computers. GPRS is based on GSM communication and will complement existing services such circuit-switched cellular phone connections and the SMS [21] [23].

1.5.7 **CDMA2000**

CDMA2000 is a 3G mobile telecommunications standard and a successor to 2G CDMA. CDMA2000 is also known as IMT-CDMA Multi-Carrier (1xRTT or 3xRTT) is a version of the IMT-2000 standard developed by the International Telecommunication Union (ITU). It can support mobile data communications at speeds ranging from 144 Kbps to 2 Mbps [30] [55].

1.5.8 **W-CDMA**

Wideband CDMA (W-CDMA) is a wideband spread-spectrum 3G mobile telecommunication air interface that utilizes CDMA is a 3G mobile communications standard allied with the GSM standard. W-CDMA can support mobile voice, data, and video communications at up to 2 Mbps [29] [55].

1.5.9 **UMTS**

Universal Mobile Telecommunications System (UMTS) is one of the 3G mobile phone technologies. It uses W-CDMA as the fundamental standard is standardized by the 3G Partnership Project (3GPP). UMTS is sometimes marketed as 3GSM, emphasizing the combination of the 3G nature of the technology [56].

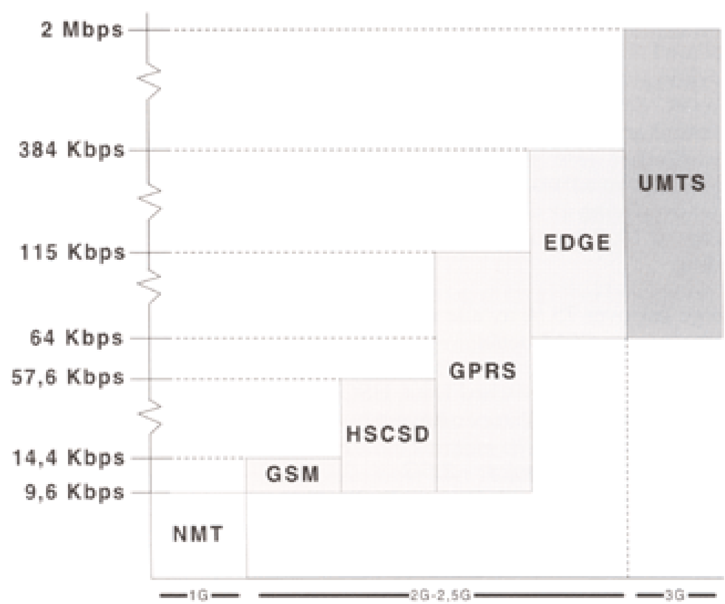


Figure 1.3 Speed Range of different technologies [65]

1.6 **Summary of Chapter**

In this chapter, I just introduced the wireless terminology. Basically, Wireless Communication is uses radio waves to carry signals and messages across distances. Wireless communications systems use devices called transmitters to generate radio waves. A microphone or other mechanism converts messages, like sounds or other data, into electronic impulses. The transmitters change, or modulate, the radio waves so they can carry the impulses, and then transmit the modulated radio signals across distances. Radio receivers pick up these signals and decode them back into the original messages.

Wireless communications allow people greater flexibility while communicating because they do not need to remain at a fixed location, such as a home or office. Wireless technologies make communications services more readily available than traditional wire-based technology which requires the installation of wires. These technologies are also useful for communicating in remote locations, such as highways, mountains, jungles, or deserts, where telephone service might not available. Wireless services allow communicating while a person in a car, airplane, or other moving vehicle. Police, fire, and other emergency departments use two-way radio to communicate information between vehicles that are already responding to emergency calls, which saves valuable time. Construction and utility workers frequently use hand held radios for short range communication and coordination. Many businesspeople use wireless communications, particularly cellular radio telephones, to stay in contact with colleagues and clients while traveling.

Satellite network plays keen role in wireless communication on Earth. The orbits of satellite systems are LEO, MEO, GEO and elliptical orbits. LEO and MEO orbits are characterized by relatively short propagation delays. They form constellations that orbit the Earth at a speed greater than its rotation speed. GEO satellites rotate at geostationary orbit over the equator. GEO systems experience higher propagation delays than LEO and MEO systems. However, they have the advantage of rotating at a speed equal to that of the Earth's rotation, thus eliminating the need to track the satellite as it moves. The Iridium and Globalstar, voice-oriented satellite systems were highlighted. Iridium, which was abandoned in 2000 for economic reasons targets worldwide coverage through a LEO constellation of 66 satellites, orbiting at 11 different planes with six satellites per plane.

In the last part of chapter some wireless technologies introduced like 1G is AMPS, 2G are D-AMPS, CDMA*One* and GSM, 2.5G are HSCSD and GPRS, 3G are CDMA2000, W-CDMA and UMTS.

CHAPTER 2

First Generation of Cellular Technology (1G)

The first cellular technology is known as first generation (1G) technology. The era of cellular telephony began with the introduction of the 1G cellular systems based on analog transmission. The analog cell phones were introduced in the later 1970s and continued until being replaced by 2G cell phones that are digital but 1G still in use in most part of the world. 1G system is now considered technically primitive but this does not change the fact that a large number of people use analog cellular phones and analog cellular infrastructure that is found all over the United States, Canada and some other parts of the world including Pakistan. The reason why 1G system is considered primitive is due to the fact that:

- *Encryption not used*: Analog signaling does not permit encryption schemes. Due to this problem, user identification numbers can be stolen and used to place illegal calls, which are charged to the user [9].
- *Low-grade call qualities*: Analog traffic is effortlessly corrupted by interference which results in poorer call quality [1].
- *Spectrum inefficiency*: In analog systems, each radio frequency (RF) carrier is dedicated to a single user, regardless of whether the user is active or not. This is the reason for the inefficient spectrum usage compared to later cellular systems [1].

The rest of the chapter examines two 1G cellular technologies named Advanced Mobile Phone System (AMPS) which is widely use in the North America and Nordic Mobile Telephony (NMT) that use in Nordic countries, Eastern Europe and Russia [1] [57].

2.1 **Advanced Mobile Phone System (AMPS)**

Advanced Mobile Phone Service (AMPS) is the technology of 1G mobile system developed by Bell Labs in the late 1970s and start operating commercially in early 1980s. AMPS is a standard analog signal cellular telephone service in the United States and are also used in other countries (like in Pakistan, Instaphone and Paktel using AMPS). It is based on the electromagnetic radiation spectrum allocation for cellular service by the Federal Communications Commission (FCC) in 1970. Introduced by AT&T in 1983, currently AMPS still widely deployed cellular system in the United States and Canada. It was designed to offer mobile telephone traffic services via a number of 30 kHz channels between the Mobile Stations (MSs) and the BSs of each cell. The latter is a 3 kHz signal that is carried over the AMPS channels via analog transmission [9].

AMPS assign frequency ranges within the 824 and 894 MHz spectrum to cellular telephone. Each service provider can use half of the 824-849 MHz range for receiving signals from cellular phones and half the 869-894 MHz range for transmitting to cellular phones. The bands are divided into 30 kHz sub-bands, called channels. These 30 kHz channels are used to carry voice traffic. The receiving channels are called reverse channels and the sending channels are called forward channels. The division of the spectrum into sub-band channels is achieved by using frequency division multiple access (FDMA). In a certain geographical region, two operators can exist and a different set of channels is assigned to each operator. For example, the two channel sets, A and B bands, comprise channels ‘A’ from 1 to 333 and ‘B’ from 334 to 666. Channels from 313 to 333 and from 334 to 354 are the control channels of bands ‘A’ and ‘B’, respectively. Thus, each operator has 312 voice channels and 21 control channels at its disposal. Each control channel can be associated with a group of voice channels, thus each set of voice channels can be split into groups of 16 channels, each group controlled by a different control channel [1].

The signals received from a transmitter cover an area is known as a cell. If a user moves out of the cell's area into a neighboring cell, the user begins to pick up the new cell's signals without any apparent transition. The signals in the adjacent cell are sent and received on different channels than the previous cell's signals to so that the signals don't interfere with each other. The analog service of AMPS has been updated with digital cellular service by adding to FDMA a further subdivision of each channel using time division multiple access (TDMA) and technology called Digital-AMPS. Although AMPS started for the North American, they are now used internationally with over 75 million subscribers [9] [13] [14].

2.2 **Nordic Mobile Telephony (NMT)**

Nordic Mobile Telephony (NMT) is an analog telephony has established by the telecommunication authorities in Nordic countries (Sweden, Norway, Finland, and

Denmark). NMT systems have also been deployed in other European and Asian countries. There are two versions of this technology; the first operates in the area around 450 MHz called NMT 450 and the second operates around 900 MHz called NMT 900 [1]. An NMT is made up of four basic parts:

- Mobile Telephone Exchange (MTX)
- Home Location Register (HLR), integrated in MTX or as a separate node
- Base Station (BS)
- Mobile Station (MS)

The MTX and HLR control the system and include the interface to the Public Switched Telephone Network (PSTN). This interface can be made at local or international gateway levels. BSs are permanently connected to the MTX and are used to handle radio communication with the mobile stations. BSs also supervise radio link quality via supervision tones. The set of BSs that are connected to the same MTX form an MTX service area, which in turn can be divided into subareas called Traffic Areas (TAs). The maximum number of BSs stations in a TA can be as high as 256. MSs can be vehicle-mounted, transportable or hand-portable. In order to set up a call to a mobile, a paging signal must be sent out in parallel from all BSs in the TA in which the mobile station resides, instead of being sent out on all BSs in the service area. The aim of this approach is to reduce call set-up time and system load. A number of network elements may also exist. These are Combined NMT/GSM Gateway (CGW), Mobile Intelligent Network (MIN) and Authentication Register (AR) [1]. CGW is a gateway that can interrogate an NMT HLR and a GSM HLR. This is an optional feature for GSM MSCs that demands no new hardware. The HLR is used to store data about every subscriber, its services and location. In large networks where subscriber numbers are high, HLRs are preferably utilized as separate nodes, whereas in small networks, HLRs can be integrated with MTXs. The signaling protocol between MTSs and HLRs is according to CCITT Number 7 standard. Finally, The MIN adds intelligence to the network in order to enable introduction of new, customized services [1].

The radio network consists of cells, each having a Calling Channel (CC) and a set of Traffic Channels (TC). In order to enable frequency reuse, adjacent BSs obviously employ different operating frequencies. The frequency reuse schemes that are typically employed divide the available frequencies among groups of 7, 12, or 21 cells. The reuse plan is then built up by repeating these groups by trying to optimize the distance between BSs that employ the same frequency. In order to adjust to variable traffic intensities, cell size may change correspondingly. Radio coverage is provided in the cells by placing BSs either at (a) the center of the cell or (b) at a corner of the cell (omni cells or sector cells). The latter option gives the advantage of using one BS for several cells, thus reducing the number of BSs used and obviously deployment costs. The coverage of a BS ranges from 15 to 60 km for NMT 450 and from 2 to 30 km for NMT 900, depending on the BS placement height and the actual environment [1] [10] [12].

System	*Uplink operating frequency range*	*Downlink operating frequency range*	*Channel Bandwidth*	*Usable channel Bandwidth*
AMPS	824 – 849 MHz	869 – 894 MHz	30 KHz	24 KHz
NMT	453 – 457.5 MHz	463 – 467.7 MHz 935 – 960 MHz	25 KHz	9.4 KHz

Table 2.1 Bandwidths for AMPS and NMT systems

2.3 **Worldwide 1G Cellular System**

Below is the brief information about 1G cellular system that uses worldwide:

2.3.1 **United States and Canada**

The first commercial cellular system in the United States is called AMPS, started operation in 1982 offering only voice communication. AMPS technology has been very successful and millions of AMPS subscribers in the United States and Canada. AMPS has also been deployed in Central and South America, Australia and some other parts of the world [1] [14].

2.3.2 **Europe**

In European countries, several 1G systems have been deployed. In which:

- Total Access Communications System (TACS) in the United Kingdom, Italy, Spain, Austria and Ireland.
- Nordic Mobile Telephone (NMT) in Nordic countries.

- C-450 in Germany and Portugal.
- Radiocom 2000 in France.
- Radio Telephone Mobile System (RTMS) in Italy.

The most popular systems are TACS and NMT, which together accounted for over 50% of analog cellular subscribers in 1995 [14].

2.3.3 **Japan**

- In Japan, 56 MHz is allocated to analog cellular systems (860-885 / 915-940 MHz and 843-846 / 898-901 MHz). The first Japanese analog cellular system was the Nippon Telephone and Telegraph (NTT) system, which began operation in the Tokyo metropolitan area in 1979. The system utilized 600 duplex channels (spaced 25 kHz apart), which were realized via transmission in the 925-940 MHz (uplink) and 870-885 MHz (downlink) bands [14].

2.4 **Summary of Chapter**

The period of cellular technology began with the introduction of the first generation (1G) of cellular systems. Such systems served mobile telephone calls via analog transmission of voice traffic only that is transmission in a continuous waveform. Despite the fact that 1G system are considered technologically primitive today but the considerable number of people still use analog cellular phones and analog cellular infrastructure is found several parts of the world. This chapter described the Advanced Mobile Phone System (AMPS) and Nordic Mobile Telephony (NMTS) 1G cellular systems. AMPS divides the frequency spectrum into several channels, each in 30 kHz wide. These channels are either speech or control channels. Speech channels utilize frequency modulation, while control channels can use Binary Frequency Shift Keying (BFSK) at a rate of 10 kbps. Both data messages and frequency tones are used for AMPS control signaling and two operators can be collocated in the same geographical area. There are two versions of NMT. The first operates in the area around 450 MHz and the second operates in the area around 900 MHz. These variants are known as NMT 450 and NMT 900, respectively. NMT successively use mostly in the European countries.

CHAPTER 3

Second Generation of Cellular Technology (2G)

The development started of cellular technology by 1G of cellular systems in the late 1970s. The growth of technology has enabled the industry to move towards second generation (2G) systems which is the heir of 1G system. 2G systems updated many insufficiencies of 1G system. 1G technology is purely based on analog technology while 2G introduced first time digital technology [1] [58]. The advantage of digital technology is:

- Digital technology provides encryption in which digitized traffic can easily encrypted to provide privacy and security.
- Use of error correction, in digital systems is applied for error detection and error correction techniques to the user traffic.

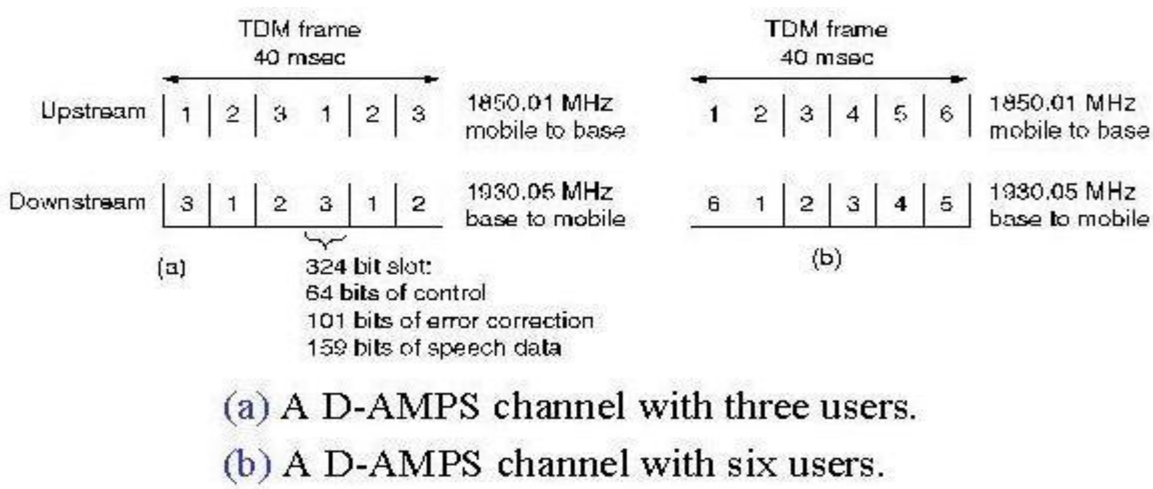
In this chapter, 2G standard technologies illustrated in which D-AMPS which is advanced form of the AMPS, CDMA*One* (IS-95) which is the only 2G system based on code division multiple access (CDMA) and the Global system for Mobile Communications (GSM).

3.1 **Digital AMPS (IS-136)**

Digital Advanced Mobile Phone Service (D-AMPS) is a digital version of 1G AMPS technology. D-AMPS is Interim Standard-136 (IS-136) from the Electronics Industries Association and Telecommunication Industries Association (EIA/TIA). D-AMPS adds time division multiple access (TDMA) to AMPS to get three channels for each AMPS channel, tripling the number of calls that can be handled on a channel. Both D-AMPS and AMPS are now used in many countries. Although AMPS and D-AMPS originated for the North American cellular telephone market, they are now used worldwide with over 74 million subscribers [16].

D-AMPS maintain the 30-kHz channel spacing of AMPS and is actually an overlay of digital channels over AMPS. D-AMPS was designed in a way that enables manufacturing of dual mode (AMPS and D-AMPS) terminals. Thus, the development of D-AMPS has led to a hybrid standard. This is necessary to accommodate roaming subscribers, given the large embedded base of AMPS equipment [1].

The main difference between AMPS and D-AMPS is that the overlays digital channels over the 30 kHz carriers of AMPS. Each such digital channel can support three times the users that are supported by AMPS with the same carrier. Therefore, D-AMPS can be seen as an overlay on AMPS that steals some carriers and changes them to take digital traffic. Apparently, this does not affect the underlying AMPS network, which can continue to serve regular AMPS users. In fact, each D-AMPS MS initially accesses the network via the traditional AMPS analog control channels. Then the MS can make a request to be assigned a digital channel and if such a channel is available, it is allocated to the D-AMPS MS; otherwise the MS will operate in AMPS mode. As far as handoffs are concerned, D-AMPS supports Mobile Assisted Handoff (MAHO). MSs make measurements of the signal strength from various neighboring BSs and report these measurements to the network, which uses this information to decide whether a handoff will be performed, and to which BS. The difference with AMPS is that in AMPS, MSs do not perform signal strength measurements. Rather these measurements are made by the BSs.



(a) A D-AMPS channel with three users.

(b) A D-AMPS channel with six users.

Figure 3.1 D-AMPS channel

D-AMPS supports voice as well as data services. Supported speeds for data services are up to 9.6 kbps. Large IS-136 networks include Cingular Wireless and US Cellular in the United States, and Rogers Wireless in Canada. Cingular and Rogers Wireless are upgrading their existing IS-136 networks to GSM and GPRS, while US Cellular is migrating most of their network to cdma2000. Rogers Wireless removed all 1900 MHz IS-136 in 2003, and is slowly doing the same with their 800 MHz spectrum as the equipment fails. In Pakistan Instaphone recently updated their setup from AMPS to D-AMPS 800 MHz [1] [16].

3.2 **CDMA*One* (IS-95)**

CDMA*One* (IS-95) is the first CDMA based digital cellular standard founded by Qualcomm. CDMA*One* is also known as TIA/EIA-95. In CDMA*One*, multiple mobiles in a cell, whose signals are distinguished by spreading them with different codes, concurrently use a frequency channel. CDMA*One* is mismatched with IS-136 and its deployment in the United States started in 1995. Both IS-136 and CDMA*One* operate in the same bands with AMPS. It is designed to support dual mode terminals that can operate either under CDMAOne network or an AMPS network. *CDMAOne* supports data traffic at rates of 4.8 and 14.4 kbps.

The CDMA system used for IS-95 is very different as CDMA uses a form of modulation known as direct sequence spread spectrum (DSSS). Here a signal is generated that spreads out over a wide bandwidth. A code known as a spreading code is used to perform this action. By using a group of codes known as orthogonal codes, it is possible to pick out a signal with a given code in the presence of many other signals with different orthogonal codes. In fact many different baseband signals with different spreading codes can be modulated onto the same carrier to enable many different users to be supported. By using different orthogonal codes interference between the signals is minimal. Conversely when signals are received from several mobile stations, the base station is able to isolate each one as they have different orthogonal spreading codes. In fact the system has been likened to hearing many people in a room speaking different languages. Despite a very high noise level it is possible to pick out the person speaking your own language English or Urdu for example. The advantage of using CDMA over FDMA and TDMA is that it enables a greater number of users to be supported [1].

Unlike the more traditional cellular systems where neighboring cells use different sets of channels, a CDMA system re-uses the same channels. Signals from other cells will be appear as interference, but the system is able to extract the required signal by using the correct code in the demodulation and signal extraction process. Often more than one channel is used in each cell and this provides additional capacity because there is a limit to the amount of traffic that can be supported on each channel [18].

Today, there are two versions of IS-95, called IS-95A and IS-95B. The IS-95A protocol employs a 1.25-MHz carrier, operates in radio frequency bands at either 800 MHz or 1.9 GHz, and supports data speeds of up to 14.4 Kbps. IS-95B can support data speeds of up to 115 kbps by bundling up to eight channels [1] [19].

3.3 **Global System for Mobile Communications (GSM)**

Global System for Mobile Communications (GSM) is the most popular standard for mobile phones in all over the world. GSM phones are used by over billions of people across more than 200 countries. GSM is a digital mobile telephone system that is initially used in Europe and then other parts of the world. GSM uses a variation of time division multiple access (TDMA) and is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at the 900 or 1800 or 1900 MHz frequency band [1].

The European Community (now called European Union) formed a study group called the Groupe Special Mobile later renamed to Global System for Mobile Communications in 1992. GSM comes from the initials of the group’s name had the task of studying and developing a European public land mobile system. The proposed system had to meet certain criteria:

- Good speech quality
- Low terminal and service cost
- Reliable in voice and data transmission
- ISDN Compatibility
- Hold for International roaming
- Ability to support handheld terminals
- Support of new services and facilities
- Spectral efficiency

GSM job was transferred to the European Telecommunication Standards Institute (ETSI), and phase I of the GSM specifications was published in 1990. Commercial deployment of GSM systems started in 1991, and by 1993 there were 36 GSM networks in 22 countries around Europe. GSM is the most popular 2G technology and it had 1 million new subscribers every week [15]. This popularity is not only due to its performance but also due to the fact that it is the only 2G standard in Europe. This existence of one standard boosted the cellular industry in Europe, contrary to the situation in the United States, where several different 2G systems have been deployed thus leading to an uneven market [4].

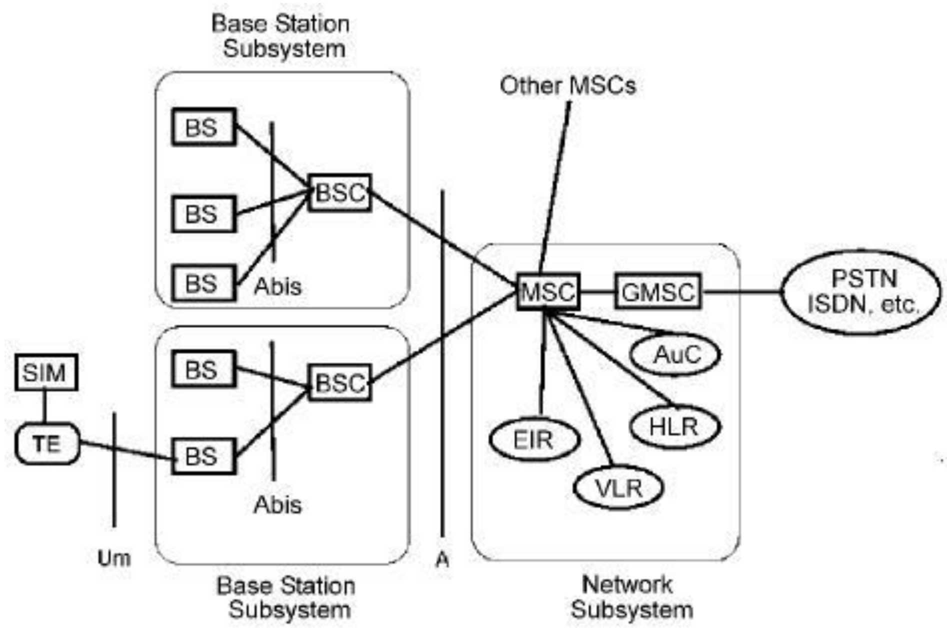


Figure 3.2 GSM Network Architecture [1]

GSM was standardized in Europe and it has been deployed in a large number of countries worldwide including our country. There are four versions of the GSM system, depending on the operating frequency. The system that operates at 900 MHz was the first to be used. The operating frequency was chosen at 900 MHz in order to reuse the spectrum used by European TACS systems. The next GSM variants to appear were those operating at 1800 MHz in Europe and 1900 MHz in North America. These variants are known as Digital Communications Network (DCN) and Personal Communications System (PCS), respectively, but they are essentially GSM operating at another frequency. The fourth variant operates at 450 MHz in order to provide a migration path from the 1G NMT standards that uses this band to 2G GSM systems. The primary service supported by GSM is voice telephony. Speech is digitally encoded and transmitted through the GSM network as a binary bit stream. For emergency situations, an emergency service is supported by dialing a certain three-digit number (usually 112). GSM also offers a variety of data services. It allows users to send and receive data, at rates up to 9600 bps. Data can be exchanged using a variety of access methods and protocols, such as X.25. A modem is not required between the user and GSM network due to the fact that GSM is a digital network. Other data services include Group 3 facsimile. GSM also supports the Short Message Service (SMS) and Cell Broadcast Service (CBS). Finally, GSM supports a number of additional services, such as call forward (call forwarding when the mobile subscriber is unreachable by the network), call barring of outgoing or incoming calls, caller identification, call waiting, multiparty conversations, etc.

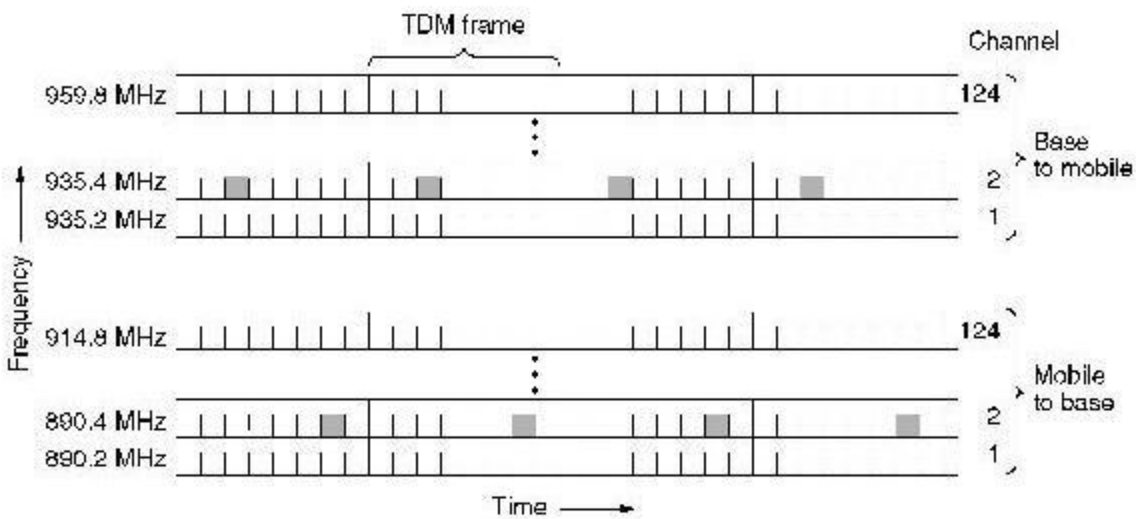


Figure 3.3 GSM 124 Frequency channels having 8 slot each TDM System

GSM was designed having interoperability with ISDN and the services provided by GSM are a subset of the standard ISDN services. Speech is the most basic and most important teleservice provided by GSM. In addition, various data services are supported with user bit rates up to 9.6 kbps. Specially equipped GSM terminals can connect with PSTN, ISDN, Packet Switched and Circuit Switched Public Data Networks, through several possible methods, using synchronous or asynchronous transmission. Other GSM services include a cell broadcast service, where messages such as traffic reports, are broadcast to users in particular cells. A service unique to GSM, the Short Message Service, allows users to send and receive point-to-point alphanumeric messages up to a few tens of bytes. It is similar to paging services, but much more comprehensive, allowing bi-directional messages, store-and-forward delivery, and acknowledgement of successful delivery.

Supplementary services enhance the set of basic teleservices. In the Phase I specifications, supplementary services include variations of call forwarding and call barring, such as Call Forward on Busy or Barring of Outgoing International Calls. Many more supplementary services, including multiparty calls, advice of charge, call waiting, and calling line identification presentation will be offered in the Phase 2 specifications. GSM has over 150 million users worldwide and is available in 120 countries, according to the GSM Association. Since many GSM network operators have roaming agreements with foreign operators, users can often continue to use their mobile phones when they travel to other countries [1] [4] [15] [22].

GSM variant	*Uplink Frequency*	*Downlink Frequency*
GSM 900	890 – 915 MHz	935 – 960 MHz
GSM 1800	1710 – 1785 MHz	1805 – 1880 MHz
GSM 1900	1850 – 1910 MHz	1930 – 1990 MHz

Table 3.1 GSM Variant

3.4 **Summary of Chapter**

The period of mobile telephony as we know it today is captured by second generation cellular technology. In this chapter, I discussed following technologies in which D-AMPS, the advancement in 1G AMPS and 2G TDMA system that is used in North America and other countries. D-AMPS operates in the 800 MHz band and an overlay over the analog AMPS network. It maintains the 30-kHz channel spacing of AMPS and uses AMPS carriers to deploy digital channels. Each such digital channel can support three times the users that are be supported by AMPS with the same carrier. Digital channels are organized into frames, with each frame comprising six slots. The actual channel a user sees comprises of one or two slots within each frame. D-AMPS can be seen as an overlay on AMPS that steals some carriers and changes them to carry digital traffic.

CDMA*One* is 2G technology, based on original CDMA. It is a fully digital standard that operates in the 800 MHz band, like AMPS. In CDMA*One*, multiple mobiles in a cell, whose signals are distinguished by spreading them with different codes, concurrently use a frequency channel. Thus, neighboring cells can use the same frequencies, unlike all other standards discussed so far. CDMA*One* supports data traffic at rates of 4.8 and 14.4 kbps.

A most popular 2G technology that widely used all over the world named Global System for Mobile Communications (GSM). Four variants of GSM exist, operating at 900 MHz, 1800 MHz, 1900 MHZ and 450 MHz. It is a fully digital standard and manages channel access via a TDD mechanism that splits the available bandwidth in the time domain. The resulting access method is actually a hierarchy of slots, frames, multiframes and hyperframes. Apart from voice services, GSM also offers data transfer services. The data speeds a user sees are typically round 9.6 kbps.

CHAPTER 4

2.5 Generation of Cellular Technology (2.5G)

2.5G is the technology that lies between 2G and 3G. The term "second and a half generation" is used to describe 2G systems that have implemented a packet switched domain in addition to the circuit switched domain. It does not necessarily provide faster services because bundling of timeslots is used for circuit switched data services as well. While the terms 2G and 3G are officially defined while 2.5G is not. It was invented for marketing purposes only. 2.5G provides some of the benefits of 3G and can use some of the existing 2G infrastructure in GSM and CDMA networks. The generally renowned 2.5G technology is GPRS. Some protocols, such as EDGE for GSM and CDMA2000 for CDMA, officially qualify as 3G services because they have a data rate of above 144 kbps, but are considered by most to be 2.5G services because they are several times slower than real 3G services [1] [55]. Some of the technologies that are considering 2.5G explained below.

4.1 **High Speed Circuit Switched Data (HSCSD)**

High Speed Circuit Switched Data (HSCSD) is a simple improvement in GSM. Against GSM, it provides more than one time slot per frame to a user, therefore data rates increase. HSCD allows a phone to use two, three or four slots per frame to achieve rates of 57.6, 43.2 and 28.8 kbps, respectively. Support for asymmetric links is also provided, meaning that the downlink rate can be different from that of the uplink. A problem with HSCSD is the fact that it decreases battery life, due to the fact that increased slot use makes terminals spend more time in transmission and reception modes. On the other hand, due to the fact that reception requires significantly less consumption than transmission, HSCSD can be efficient for web browsing, which involves much more downloading than uploading. It is a development of Circuit Switched Data (CSD). The difference comes from the ability to use different coding methods and even multiple time slots to increase data throughput [24].

The first innovation in HSCSD was to allow different error correction methods to be used for data transfer. The error correction used in GSM is designed to work at the limits of coverage and in the worst case that GSM will handle. This means that a large part of the GSM transmission capacity is taken up with error correction codes. HSCSD provides several levels of possible error correction which can be deployed according to the quality of the radio link. This means that in the best conditions 14.4Kbps can be put through a time slot which, under CSD, would normally only carry 9.6Kbps [25].

The second innovation in the HSCSD radio interface was the possibility to use multiple time slots at the same time. This allows an increase in maximum transfer rates up to 57.6 Kbps and, even in the bad radio conditions where the highest level of error correction has to be used, will still lead to a four times speed increase over CSD. HSCSD require the time slots being used to be fully reserved for a single user. It is possible that either at the beginning of the call, or at some point during a call, it will not be possible for the user's full request to be satisfied since the network is often configured so that normal voice calls take precedence over additional time slots for HSCSD users. The user is then charged, often at a rate higher than a normal phone call, and sometimes multiplied by the number of time slots allocated, based on the period of time that the user has a connection active. This makes HSCSD relatively expensive in many GSM networks and so, packet-switched GPRS which typically has lower pricing is becoming more common than HSCSD connections [1] [25].

Apart from the fact that the full allocated bandwidth of the connection is available for the HSCSD user, HSCSD also has an advantage in GSM systems in terms of lower average radio interface latency than GPRS. This is because the user of a HSCSD connection does not have to wait for permission to send a packet from the network [1] [24].

4.2 **General Packet Radio Service (GPRS)**

General Packet Radio Service (GPRS) is standard of 2.5G wireless communications which is a packet based wireless communication service that promises data rates from 56 to 114 Kbps and continuous connection to the Internet for mobile phone and computer users. The higher data rates will allow users to take part in video conferences and interact with multimedia web sites and similar applications using mobile handheld devices as well as notebook computers. GPRS is based on GSM communication and will complement existing services such circuit switched cellular phone connections and the Short Message Service (SMS). It supports a wide range of bandwidths in which efficient use of limited bandwidth and particularly suited for sending and receiving small bursts of data, like e-mail and Web browsing and also large size of data [2] [23]. GPRS upgrades GSM data services providing:

- *Point-to-Point (PTP) service*: Internetworking with the IP protocols and X.25 networks.
- *Point-to-Multipoint (PT2MP) service*: Point-to-multipoint multicast and point-to-multipoint group calls.
- *Anonymous service*: Anonymous access to predefined services.
- *Future enhancements*: Flexible to add new functions, such as more capacity, more users, new accesses, new protocols, new radio networks [1] [14].

GPRS will also harmonize Bluetooth, a newly standard of wireless radio connections. In addition to the Internet Protocol (IP), GPRS supports X.25, a packet based protocol that is used mainly in Europe. GPRS is an evolutionary step toward Enhanced Data GSM Environment (EDGE) and Universal Mobile Telephone Service (UMTS) [1].

4.3 **Enhanced Data rates for Global Evolution (EDGE)**

Enhanced Data rates for Global Evolution (EDGE) is a digital mobile phone technology which works as a secure improvement to 2G and 2.5G networks. This technology is working in TDMA and GSM networks. EDGE (also called EGPRS) is a superset to GPRS and can function on any network with GPRS deployed on it. In addition to Gaussian Minimum Shift Keying (GMSK) EDGE uses 8 Phase Shift Keying (8PSK) for its upper five of the nine modulation and coding schemes. EDGE is producing a 3bit word for every change in carrier phase. This effectively triples the gross data rate offered by GSM. EDGE, like GPRS, uses a rate adaptation algorithm that adapts the modulation and coding scheme (MCS) used to the quality of the radio channel, and thus the bit rate and robustness of data transmission. It introduces a new technology not found in GPRS, Incremental Redundancy, which, instead of retransmitting disturbed packets, sends more redundancy information to be combined in the receiver. This increases the probability of correct decoding [27].

It can carry data speeds up to 384 kbps in packet mode and will thus meet the International Telecommunications Union's requirement for a 3G network, and has been accepted by the ITU as part of the IMT-2000 family of 3G standards. It also enhances the circuit data mode called HSCSD, increasing the data rate of this service also. EDGE is being introduced into GSM networks around the world in 2003, initially in North America.

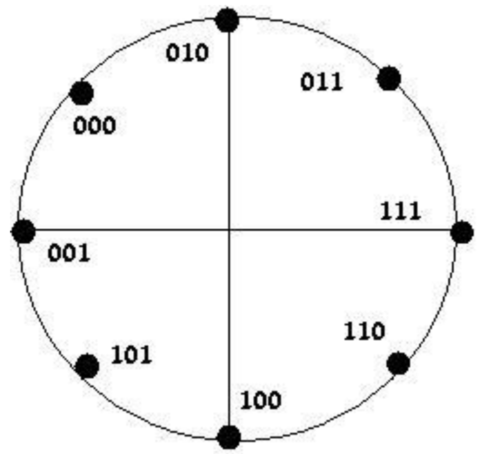


Figure 4.1 8 PSK

EDGE is keenly supported by GSM operators in United States than anywhere else in the world because GSM and GPRS have a strong competitor that is CDMA2000. Most other GSM operators view UMTS as the ultimate upgrade path and either plan to omit EDGE overall or use it outside the UMTS coverage area. However, the high cost and slow uptake of UMTS have made some western European GSM operators reevaluate EDGE as an interim upgrade [1] [27].

Even though EDGE needs no hardware changes to be made in GSM core networks, base stations must be modified. An EDGE compatible transceiver unit must be installed and base station system needs to be upgraded to support EDGE. New mobile terminal hardware and software is also required to decode and encode using the new shift keying scheme. EDGE provides Enhanced GPRS (EGPRS) which can be used for any packet switched applications such as an Internet connection. High-speed data applications such as video services and other multimedia benefit from EGPRS increased data capacity. The status of EDGE as to if it is 2G or 3G depends on implementation [1].

4.4 **CdmaTwo (CDMA*One*b or IS-95b)**

An advancement of *CDMAOne* is known as CDMA*One*b or cdmaTwo, presents support of 115.2 kbps by letting each phone use eight different codes to perform eight simultaneous transmissions. Therefore, CDMA*One*b actually allows more than one simultaneous CDMA transmission by the same station. On the uplink, an MS is initially assigned a fundamental channel code. When the MS has data to transmit, it uses the fundamental channel code to set up a channel in order to request additional codes from the BS. The BS informs the MSC and it is up to the MSC to coordinate access among other active mobiles. If the MSC decides to grant additional codes to the MS, it relays a supplemental channel assignment message (SCAM) to the MS via the BS. The SCAM indicates up to seven supplemental channel codes that will be used by the MS. Each of the assigned supplemental channel codes is based on a shift of the fundamental channel code. On the downlink, the MSC informs the MS that it should prepare to receive a data burst by transmitting a SCAM message. In this message, the MSC indicates the number of channel codes (up to eight) as well as the actual Walsh codes to be used for each channel [1].

4.5 **Summary of Chapter**

In this chapter, I discuss about the technologies that comes in between 2G and 3G known as 2.5G. Some of 2.5G are: High-Speed Circuit-Switched Data (HSCSD) was an enhancement to earlier Circuit Switched Data (CSD) standard, the original data transmission system of the GSM system is the circuit switched wireless data transmission for mobile users which is four times faster than the standard data rates of the GSM communication standard.

General Packet Radio Services (GPRS) is also a wireless communication service that based on the same principle as that of HSCSD but the difference is that GPRS is packet switched while GSM and HSCSD are circuit switched. This means that a GSM or HSCSD terminal that browses the Internet at 14.4 kbps occupies a 14.4 kbps circuit for the entire duration of the connection. GPRS packet-based service should cost users less than circuit-switched services since communication channels are being used on a shared use, as packets are needed basis rather than dedicated only to one user at a time.

Enhanced Data Rates for GSM Evolution (EDGE) is the only IMT-2000 air interface standard, based on TDMA technology. In starting stages, EDGE was not supposed to be a competitor for the CDMA based standards. Using same bandwidth and channel structure as

GSM, its original purpose was to be the upgrade for networks supporting GPRS and HSCSD.

An advancement of CDMA*One* is called CDMA*One*b or cdmaTwo, offers support for 115.2 kbps by letting each phone use eight different codes to perform eight simultaneous transmissions. Thus, CDMA*One*b actually allows more than one concurrent CDMA transmission by the same station.

CHAPTER 5

Third Generation of Cellular Technology (3G)

The current wireless technology is the third generation (3G). 3G presents the capability to transfer voice that is telephone call and data such as downloading or uploading information, exchanging email, audio, video and instant messaging etc. The evolution from 2G to 3G is characterized by revolutionary change of focus from voice to mobile multimedia services with the simultaneous support of several QoS classes in a single radio interface. Third generation systems can also provided higher data rates, thus enabling a much broader range of services. The following types of services have been identified:

- Better voice services including applications like video conferencing and voice mail.
- Low data rate services supporting messaging, e-mail.
- Data rate services for file transfer and Internet access at rates of 64 to144 Kbps.
- High data rate services to support high-speed packet and circuit-based network access, and to support high-quality video conferencing at rates higher than 64 Kbps.
- Multimedia services that provide concurrent video, audio, and data services to support advanced interactive applications.
- Multimedia services, also capable of supporting different quality of service requirements for different applications [1] [2] [28].

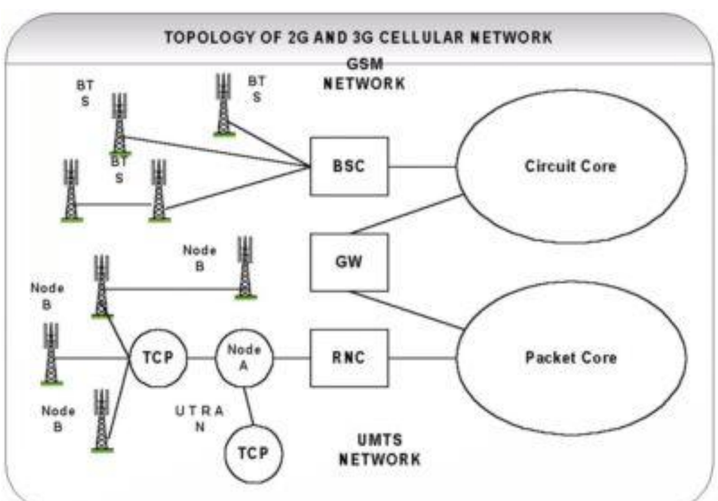


Figure 5.1 Circuit and Packet switch Networks

The International Telecommunication Union (ITU) defined the vision for a 3G cellular system, at first called Future Public Land Mobile Telecommunications System (FPLMTS) and later renamed International Mobile Telecommunications-2000 (IMT-2000) in 1985. ITU has two major points for the 3G wireless system, global roaming and multimedia services. The World Administrative Radio Conference (WARC'92) identified 1,885 to 2,025 and 2,110 to 2,200 MHz as the frequency bands that should be available worldwide for the new IMT-2000 systems. These bands will be allocated in different ways in different regions and countries. A common spectral allocation along with a common air interface and roaming protocol design throughout the world can accomplish the global roaming capability. To support simultaneously new multimedia services that require much higher data rates and better QoS than only voice services, the 3G wireless systems visualize:

- Higher data rate a service which is up to 384 Kbps for mobile users, and 2 Mbps for fixed users, increasing to 20 Mbps.
- Increased spectral efficiency and capacity.
- Flexible air interfaces as well as more flexible resource management [1] [17].

Compatibility with 2G systems is also one of the main goals of 3G systems. Different initiatives tried to unify the different proposals submitted to ITU in 1998 from ETSI for Europe, Association of Radio Industries and Broadcasting (ARIB) and Telecommunications Technology Council (TTC) for Japan, and American National Standard Institute (ANSI) for the United States [1] [28] [55].

Third generation mobile and wireless networks plan to fulfill the demands of future services. 3G systems will offer global mobile multimedia communication capabilities in a seamless and efficient manner. Users will be able to use a single device in order to enjoy a wide variety of applications. The term 3G is usually accompanied by some abstraction, as sometimes different people mean different things when they refer to it. 3G was originally defined to characterize any mobile standard that offered performance quality at least equal to that of ISDN (144 kbps). 3G systems will provide at least 144 kbps for full mobility applications in all cases, 384 kbps for limited mobility applications in macro and microcellular environments and 2 Mbps for low mobility applications particularly in the micro and picocellular environments. Those speeds are enough for the support of future mobile multimedia applications. It should be noted that speeds similar to those of ISDN are offered by some of the 2.5G standards (GPRS, IS-95B). However, these speeds occur under ideal channel conditions and only match the lower speeds of 3G systems [1] [28]. Some key characteristics of 3G systems are:

- Support for both symmetric and asymmetric traffic.
- Packet switched and circuit switched services support, such as Internet (IP) traffic and high performance voice services.
- Support for running several services over the same terminal simultaneously.
- Backward compatibility and system interoperability.
- Support for roaming.
- Ability to create a personalized set of services per user, which is maintained when the user moves between networks belonging to different providers. This concept is known as the Virtual Home Environment (VHE).
- Standardization for 3G systems was initiated by the ITU in 1992. The outcome of the standardization effort, called International Mobile Telecommunications 2000 (IMT-2000), comprises a number of different 3G standards. Each of these standards was submitted by one or more national Standards Developing Organizations (SDO).
- The plurality of standards aims to achieve smooth introduction of 3G systems so that backward compatibility with existing 2G standards is maintained. In order to facilitate the development of a smaller set of compatible 3G standards, several international projects were created, like the Third Generation Partnership Proposal (3GPP) and 3GPP2 [1] [11].

The plan of 3G networks is towards union of services that is 3G services will combine telephony, the Internet and multimedia services into a single device. The first advice for 3G networks was made in 1992, the Internet was still a tool for the academic and technical society and multimedia applications were much simpler than those of the present day. As a result, the need to support Internet and multimedia was not directly identified in those days. However, this has changed over the years and the present 3G standards will provide efficient support for advanced Internet services like web browsing and high performance multimedia applications [1] [5].

Numerous standards bodies throughout the world have submitted proposals to the ITU on UMTS and IMT-2000. In 1997, Japan's major standards body, the Association for Radio Industry and Business (ARIB), became the driving force behind a 3G radio transmission technology known as wideband-CDMA (W-CDMA). In Europe, the European Telecommunications Standards Institute (ETSI) Special Mobile Group (SMG) technical subcommittee has complete responsibility for UMTS standardization [1].

5.1 **Wideband Code Division Multiple Access (W-CDMA)**

Wideband Code Division Multiple Access (W-CDMA) is a wideband spread spectrum 3G mobile communication air interface that utilizes code division multiple access (CDMA) is a 3G mobile communications standard associated with the GSM. W-CDMA is the technology behind UMTS. Networks using W-CDMA are a form of cellular network [29].

W-CDMA was developed by ETSI NTT DoCoMo as the air interface for 3G network FOMA. Later NTT Docomo submitted the specification to ITU as a candidate for the international 3G standard known as IMT-2000. The ITU eventually accepted W-CDMA as part of the IMT-2000 family of 3G standards. Later, W-CDMA was selected as the air interface for UMTS, the 3G successor to GSM [1] [55].

W-CDMA is compatible with the present 2G GSM networks prevalent in Europe and parts of Asia. W-CDMA will require bandwidth of between 5 MHz and 10 MHz, making it a suitable platform for higher capacity applications. It can be overlaid onto existing GSM, TDMA (IS-36) and IS95 networks. Subscribers are likely to access 3G wireless services initially via dual band terminal devices. W-CDMA networks will be used for high-capacity applications and 2G digital wireless systems will be used for voice calls [29].

W-CDMA is the second 3G air interface standard based on CDMA technology. Difference to the requirement for synchronous operation of the base stations in CDMA2000, inherited from its CDMA*One* ancestor, W-CDMA is an asynchronous scheme. This enables easier installation and integration of indoor W-CDMA components with outdoor infrastructure. During the 3G standardization process, several Standard Development Organizations (SDOs) submitted W-CDMA proposals. The 3GPP W-CDMA standard is based on the ETSI and ARIB WCDMA proposals with the main parameters in the uplink and downlink from the

ETSI and ARIB proposals, respectively. The ETSI proposal for the 3G W-CDMA standards is also known as the Universal Mobile Telecommunications Subsystem (UMTS). Despite the fact that the WCDMA proposal to ITU was developed first by ETSI, Japan developed its W-CDMA standard more quickly. As a result, trial WCDMA system deployments began in Japan in 2000 [1].

In the W-CDMA specification, the term wideband indicates use of a wide carrier and it uses a 5 MHz carrier that is four times of CDMA*One* and 25 times of GSM. The use of a wider carrier aims to provide support for high data rates. However, using wider carriers requires more available spectrum. This poses a significant difficulty in cases of spectrum shortage, as is the case with North American operators [1] [29].

WCDMA based systems also coexist with older generation systems if the equivalent spectrum can be spared. The two lower layers of the radio interface protocol architecture of WCDMA. It consists of the physical layer and the data link control (DLC) layer. The DLC layer is split into the following sublayers: Medium Access Control (MAC), Radio Link Control (RLC), Packet Data Convergence Protocol (PDCP) and Broadcast and Multicast Control (BMC). The physical layer offers different transport channels to the MAC sublayer. MAC offers different logical channels to the Radio Link Control (RLC) sublayer of Layer 2 [1].

The W-CDMA physical layer suggests information transfer services to MAC and higher layers. It introduces an air interface based on direct spread CDMA over a 5 MHz channel bandwidth. The original W-CDMA proposals called for a chip rate of 4.096 Mcps, however, in order to enable easy manufacturing of terminals supporting both W-CDMA and CDMA2000, this rate was later reduced by organizational activities to 3.84 Mcps. This is the chip rate for the DS mode of CDMA2000 and is also very close to the 3.68 Mcps rate of multicarrier CDMA2000. W-CDMA supports a number of physical channels for the uplink and downlink. These channels serve as a means of transmitting the data carried over logical channels. W-CDMA uses 10 ms frames and has two operating modes, FDD and TDD, for use with paired and unpaired bands, respectively. The TDD mode is especially useful for European providers, due to the existence of unpaired frequency bands in Europe. The basic structure of TDD and FDD WCDMA radio interface protocol architecture frames is the same; however, TDD frames contain switching points for uplink/downlink traffic separation. The ratio of uplink and downlink slots within a frame can vary in order to support asymmetric traffic requirements with downlink and uplink ratios ranging from 15/1 up to 1/7. FDD mode requires the allocation of two frequency bands, one for the uplink and another for the downlink. FDD advantages are the ability to transmit and receive at the same time [1].

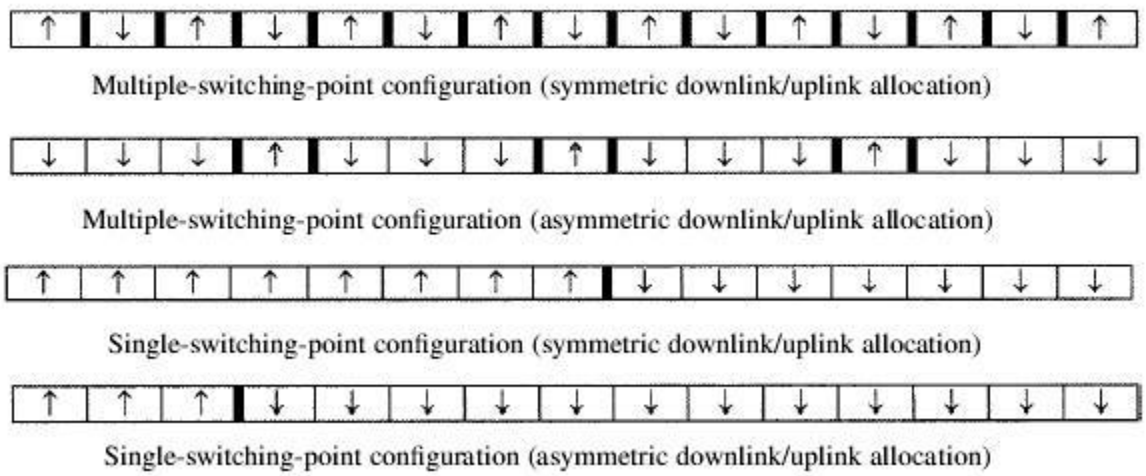


Figure 5.2 Switching Point Configurations

FDD is not very efficient in allocating the available bandwidth for all types of services. Consider the example of Internet access. Such a service requires more throughputs on the downlink than on the uplink. Of course by adjusting the spreading factor, FDD makes it possible to use only the required data rate, however, trading uplink capacity for downlink is not possible [1] [55].

TDD uses the same frequency band both for uplink and downlink by allocating time slots to each direction. Therefore, FDD can efficiently allocate capacity between the uplink and downlink and offer support to asymmetric traffic demands. However, it requires better time synchronization than FDD in order to guarantee that mobile and base station transmissions never overlap in the time domain. The asynchronous nature of base station operation must be taken into consideration when designing soft handover algorithms for W-CDMA. In an effort to support increased capacities through Hierarchical Cell Structures (HCS), W-CDMA also employs a new handover method, called interfrequency handover. In HCS several different frequency carriers are simultaneously used inside the same cell in an effort to serve increased demands in hot spots. To perform handover in HCS situations, the mobile station needs to possess the ability to measure the signal strength of an alternative carrier frequency while still having the connection running on the current frequency. Two methods for interfrequency measurements exist for WCDMA: The first, called dual receiver mode, is used when antenna diversity is employed. It uses different antenna branches for estimating different frequency carriers. The second, called slotted mode uses compression of transmitted data to save time for measurements on alternative frequency carriers. The W-CDMA physical layer provides two types of packet access using random access and dedicated (user) channels. Random access is based on a slotted ALOHA approach and is used only on the uplink for short infrequent bursts. The random access method is more efficient in terms of overhead, as the channel is not maintained between bursts. Dedicated access serves more frequent bursts both on the uplink and downlink. The W-CDMA physical layer provides broadcasting and paging capabilities to the upper layers [1] [55]. Briefly summarize the main W-CDMA physical channels.

- *Wideband*: A 5 MHz channel provides support for increased capacity. W-CDMA has double the capacity of narrowband CDMA in urban and suburban environments.
- *Spreading*: Orthogonal Variable Spreading Factors (OVSFs) are used for channel separation. These factors range from 4 to 256 in the FDD uplink, from 4 to 512 in the FDD downlink, and from 1 to 16 in the TDD uplink and downlink. Depending on the spreading factor (SF), it is possible to achieve different data rates.
- *Adaptive antenna support*: Support for adaptive antenna arrays improves spectrum efficiency and capacity by optimizing antenna performance for each mobile terminal.
- *Channel coding and interleaving*: Depending on the BER and delay requirements, different coding schemes may be applied. Convolutional coding, turbo coding or no coding at all is supported. In order to randomize transmission errors, bit interleaving is also performed.
- Downlink/Uplink coherent demodulation and fast power control.
- Support for downlink transmits diversity and multiuser detection techniques. Downlink (Forward Link) Physical Channels
- *Physical Synchronization Channel (PSCH)*: The PSCH provides timing information and is used for handover measurements by the mobile station.
- *Downlink Dedicated Physical Channel (Downlink DPCH)*: Within one downlink DPCH, data and control information generated at layer 2 and layer 1, respectively, are

transmitted in a time-multiplexed manner. The downlink DPCH can thus be seen as a time multiplex of a Downlink Dedicated Physical Data Channel (DPDCH) and a Downlink Dedicated Physical Control Channel (DPCCH).

- *Common Pilot Channel (CPICH)*: CPICH is used as a reference channel for downlink coherent detection and fast power control support.
- *Primary and Secondary Common Control Physical Channel (P-CCPCH, S-CCPCH) and Physical Downlink Shared Channel (PDSCH)*: These are used to carry data and control traffic [1].

Uplink (Reverse Link) Physical Channels

- *Uplink Dedicated Physical Data Channel (Uplink DPDCH)*: This channel is used to carry the data generated at layer 2 and above.
- *Uplink Dedicated Physical Control Channel (Uplink DPCCH)*: This channel is used to carry control information, such as power control commands, generated at layer 1. Layer 1, control information consists of known pilot bits to coherent detection; transmit power control commands, etc.
- *Physical Random Access Channel (PRACH) and Physical Common Packet Channel (PCPCH)*: These channels are used to carry user data traffic. The WCDMA random access scheme is based on a slotted ALOHA technique. More than one random access channel can be used if demand exceeds capacity.
- *Physical Uplink Shared Channel (PUSCH) (TDD mode)*: This channel is used to carry user data traffic [1].

Real-World Implementations

The world's first commercial W-CDMA service was launched by NTT DoCoMo in Japan in 2001. J-Phone Japan (now Vodafone) soon followed by launching their own W-CDMA based service, now branded "Vodafone Global Standard" and claiming UMTS compatibility. Beginning in 2003, Hutchison Whampoa gradually launched their upstart UMTS networks (simply called 3) worldwide. Vodafone launched several UMTS networks in Europe in February 2004. Vodafone also has plans to launch UMTS networks in other countries, including Australia and New Zealand. AT&T Wireless (now a part of Cingular Wireless) has deployed UMTS in several cities. TeliaSonera opened W-CDMA service in Finland October 13th 2004 with speeds up to 384 kbps.

Most Western European GSM providers plan to offer UMTS sometime in the future, though few have committed to an actual timeline. Some of them have begun launching UMTS networks at the end of 2003.

5.2 **Universal Mobile Telecommunications System (UMTS)**

Universal Mobile Telecommunications System (UMTS) is one of the 3G mobile phone technologies. It uses W-CDMA as the underlying standard, is standardized by the 3GPP, and represents the European to the ITU IMT-2000 requirements for 3G Cellular radio systems. UMTS is sometimes marketed as 3GSM, emphasizing the combination of the 3G nature of the technology and the GSM standard which it was designed to succeed. UMTS supports up to 1920 kbps data transfer rates, although typical users can expect performance of around 384 kbps in a heavily loaded real world system. However, this is still much greater than the 14.4 kbps of a single GSM error-corrected data channel or multiple 14.4 kbps channels in HSCSD, and offers the first prospect of practical inexpensive access to the World Wide Web on a mobile device and general use of MMS. The precursor to 3G is the now widely used GSM mobile telephony system, referred as 2G. There is also an evolution path from 2G, called GPRS, also known as 2.5G. GPRS supports a much better data rate (up to a maximum of 140.8 kbps, though typical rates are closer to 56 kbps) and is packet based rather than connection oriented. It is deployed in many places where GSM is used [1] [55].

In future current UMTS networks may be upgraded with high-speed downlink packet access (HSDPA), This will make a downlink transfer speed of up to 10 Mbps possible. Marketing material for UMTS has emphasized the possibility of mobile videoconferencing, although there is actually a mass market for this service remains untried [1].

Real-world implementations

The first UMTS network in the world went live in 2001 on the Isle of Man operated by *Manx Telecom*. The next launched network was simply called 3 and went live in the United

Kingdom in 2003. 3 is an upstart 3G network primarily owned by Hutchison Whampoa and its partners. Its partners vary depending on the country. It soon launched other UMTS networks worldwide that to-date includes Australia, Austria, Denmark, Hong Kong, Italy, Portugal, Republic of Ireland and Sweden. Most major western European GSM operators plan to upgrade to UMTS in the future, since it is closely allied with the GSM 2G standards. In December 2003, T-Mobile launched UMTS in Austria, with trials in the UK and Germany. In February 2004, Vodafone had a wide-scale UMTS launch in several European markets, including, UK, Germany, Netherlands and Sweden. In Portugal, UMTS was launched just before the Euro 2004 begun. The first UMTS network in Africa was launched on the island of Mauritius in November 2004, followed by Vodacom's launch of 3G services in South Africa in December 2004 [1].

Since merging with AT&T Wireless, Cingular has announced plans to begin deployment of UMTS along with HSDPA in 2005. Unlike the initial AT&T deployment of UMTS, Cingular's expanded (and eventually, nationwide) deployment of UMTS will run on both of their existing 1900 MHz and 850 MHz frequencies. T-Mobile USA has stated they have no plans to deploy UMTS until 2007 [1] [26].

5.3 **Freedom of Mobile Multimedia Access (FOMA)**

Freedom of Mobile Multimedia Access (FOMA) is the 3G services being started by Japanese mobile phone operator NTT DoCoMo. FOMA was the world's first W-CDMA 3G service when launched in 2001. FOMA's alternative of the technology is currently incompatible with standard UMTS; including Vodafone Japan's 3G service and hence does not provide global roaming. Originally FOMA handsets where big, had poor battery life and the network had poor coverage. Of course it didn't sell very well but with the introductions of attractive handsets and better coverage, sales have soared. In January 2005, FOMA has close to 10 million subscribers and is the fastest growing cell phone network in Japan [55].

5.4 **CDMA2000**

CDMA2000 is a 3G mobile telecommunications standard that is approved by radio interfaces for the ITU's IMT-2000 standard and a successor to 2G CDMA (IS-95, branded *CDMAOne*). The underlying signaling standard is known as IS-2000. CDMA2000 is an incompatible competitor of the other major 3G standard W-CDMA. CDMA2000 is a registered trademark of the Telecommunications Industry Association (TIA-USA) in the United States, not a generic term like CDMA. TIA has branded their 2G CDMA standard (IS-95) as *CDMAOne* [1].

Among 2G systems only the IS-95 family, also called CDMA*One*, is based on CDMA technology. This is a significant advantage for IS-95 providers since upgrades to 3G CDMA based systems will only require software and minor hardware changes to the existing CDMA based networks. CDMA2000 comprises a family of backwards compatible standards, a fact that enables smooth transition of 2G CDMA based networks to 3G networks. Although CDMA2000 can be used as the air interface of pure 3G network installations that use the IMT-2000 spectrum, its main advantage is the ability of overlaying CDMA2000 and IS-95 2G systems in the same spectrum. This is a very important aspect for IS-95 providers in North America due to fact that the spectrum specified by ITU for IMT-2000 is already in use in these areas. Thus, one can see the reason for CDMA2000 backward compatibility: North American providers will offer 3G services by deploying an overlay of CDMA2000 and IS- 95 in the same bands [1] [30].

The two lower layers of the radio interface protocol architecture of CDMA2000. The specification provides protocols and services that correspond to the two lower layers of the OSI model. In the next sections, we cover issues related to the physical (layer 1) and data link layer (layer 2) operation and briefly present the main channels of each layer [1].

The original CDMA2000 specification contained two spreading modes, multicarrier and Direct Spread (DS). However, the ongoing harmonization work stated that WCDMA should be used as the DS mode, thus putting an end to work on CDMA2000 DS. There are two non-DS CDMA2000 modes, 1X and 3X. The 1X mode uses a single *CDMAOne* carrier, while 3X is a multicarrier system. This means that CDMA2000 terminals and base stations based on 3X will use three of the 1.25-MHz wide IS-95 carriers. 1X and 3X are the two modes currently standardized, although modes such as 6X, 9X and 12X may be standardized in the future. As far as carrier chip-rates are concerned, a multicarrier transmission using N *CDMAOne* carriers de-multiplexes the message signal into N information signals and spreads each of these on a different carrier, at a chip rate of 1.2288 Mcps per-carrier. In this approach, each carrier has an IS-95 signal format [1] [2].

1X is the simplest version of CDMA2000. Despite the use of only one IS-95 carrier, 1X approximately doubles the voice capacity of *CDMAOne* systems and provides average rates for data services up to 144 kbps. This performance gain is attributed to the enhancements of CDMA2000 layers 1 and 2 over the corresponding layers of *CDMAOne*. High Data Rate (HDR) is an enhancement of 1X for data services. Instead of Quadrature Phase Shift Keying (QPSK) used by 1X and 3X, HDR uses the more efficient 16-Quadrature Amplitude Modulation (16-QAM) which codes four bits per transmitted symbol, thus offering speeds up to 621 kbps. However, in cases of heavy interference, HDR modulation drops down to the more robust 8-PSK or QPSK, a fact that decreases the data rates offered [1].

3X, also known as IS-2000-A, is an enhancement of 1X that uses three *CDMAOne* carriers for a total bandwidth of approximately 3.75 MHz. It offers greater capacities than 1X and can support data rates up to 2 Mbps. This performance increase is accomplished by multicasting the downlink traffic over the three 1.25 MHz carriers. Due to the terminal complexity induced by multicarrier transmission, 3X uses direct spreading for uplink transmission, which produces a wideband signal that matches the rate of the downlink signaling. This rate is slightly lower than the 3.84 Mcps rate of the WCDMA-compatible. The CDMA2000 protocol stack CDMA2000 DS mode. The CDMA2000 physical layer is an enhancement over the corresponding layer of *CDMAOne*. It supports a number of physical channels for the uplink and downlink. Physical channels can either belong to a specific mobile (dedicated channels), or be of shared access among many mobile stations (common channels). In the remainder of this section, after presenting some of the main characteristics of CDMA2000 downlink and uplink, we briefly summarize the main CDMA2000 physical channels [1] [30].

5.5 **Time Division Synchronous Code Division Multiple Access (TD-SCDMA)**

Time Division Synchronous Code Division Multiple Access (TD-SCDMA) is a 3G mobile telecommunications standard, being pursued in the People's Republic of China by the Chinese Academy of Telecommunications Technology (CATT), Datung and Siemens, in an attempt to develop home-grown technology and not be dependent on Western technology . It is based on spread spectrum CDMA technology. The launch of an operational system is projected in 2005 [1] [31].

5.6 **Comparison between CDMA2000 and W-CDMA**

CDMA2000, also known as IMT-CDMA Multi-Carrier or 1xRTT, is a code-division multiple access (CDMA) version of the IMT-2000 standard developed by the International Telecommunication Union (ITU). The CDMA2000 standard is third generation (3G) mobile wireless technology [30].

W-CDMA, an ITU standard derived from Code-Division Multiple Access (CDMA), is officially known as IMT-2000 direct spread. W-CDMA is also third generation (3G) mobile wireless technology that promises much higher data speeds to mobile and portable wireless devices than commonly offered in today's market [29].

CDMA2000 can support mobile data communications at speeds ranging from 144 Kbps to 2 Mbps. Versions have been developed by Ericsson and Qualcomm. As of mid 2003, the CDMA Development Group reports that more than 50 CDMA2000 networks have been deployed [30].

W-CDMA can support mobile, portable voice, images, data, and video communications at up to 2 Mbps (local area access) or 384 Kbps (wide area access). The input signals are digitized and transmitted in coded, spread-spectrum mode over a broad range of frequencies. A 5 MHz-wide carrier is used, compared with 200 kHz-wide carrier for narrowband CDMA [29]. Comparison between these technologies is given in table 5.1.

	W-CDMA	*Cdma2000 (1x / 1xEV-DO)*
Bandwidth	5 MHz	1.25 MHz
Spreading Chip rate	3.84 Mcps	1.2288 Mcps for 1xRTT
Power control frequency	1500 Hz up/down	1xRTT: 800 Hz up/down 1xEV-DO: no DL PC
Network Signaling	GSM	IS-41, GSM
Base station Synchronization	Not needed (Asynchronous)	Yes (Synchronous) via GPS

Cell search	3-step approach via primary, secondary search code and CPICH	Sync through time-shifted short code correlation
Downlink Pilot	CDM common (CPICH) TDM dedicated (bits in DPCH)	1xRTT: CDM common 1xEV-DO: TDM common
User separation	CDM / TDM (shared channel)	1xRTT: CDM 1xEV-DO: TDM
2G interoperability	GSM-UMTS handover (Multi-mode terminals)	1xRTT backward compatible

Table 5.1 Differences between W-CDMA and CDMA2000

5.8 Summary of Chapter

The aim of third generation (3G) wireless networks is to provide proficient support for voice, video and high bit-rate data services. The better capabilities of 3G networks call for use of additional spectrum. In 1992, 3G standardization originated by ITU. The result of the standardization effort, IMT-2000, comprises a number of different 3G standards for the air interface. ITU decided not to define the protocol that will be used inside the fixed part of a 3G network in order to allow for flexible evolution of 3G systems. Apart from supporting traditional voice calls, 3G systems will offer support for file transfer, web browsing, multimedia and videoconferencing applications. The requirements of those applications in terms of capacity span the entire range of the data rates offered by 3G systems, from several kbps, up to 2 Mbps. Several 3G service classes have been identified based on capacity demands. In this chapter we covered third generation wireless networks by focusing on a number of issues:

- W-CDMA (Wideband Code Division Multiple Access) is a wideband spread spectrum 3G mobile telecommunication air interface that utilizes code division multiple access (CDMA), is a 3G mobile communications standard allied with the GSM standard. W-CDMA was developed by ETSI NTT DoCoMo. W-CDMA can support mobile, portable voice, images, data, and video communications at up to 2 Mbps.
- UMTS (Universal Mobile Telecommunications System) is 3G mobile phone technology. It is marketed as 3GSM, emphasizing the combination of the 3G nature

of the technology and the GSM standard which it was designed to succeed. UMTS supports up to 1920 kbps data transfer rates.

- FOMA (Freedom of Mobile Multimedia Access) is the brand name for the 3G services being offered by Japanese mobile phone operator NTT DoCoMo.
- CDMA2000, one of the approved radio interfaces for the ITU's IMT-2000 standard, and a successor to 2G CDMA (IS-95, branded *CDMAOne*). The underlying signaling standard is known as IS-2000. CDMA2000 can support mobile data communications at speeds ranging from 144 Kbps to 2 Mbps.

CHAPTER 6

Cellular technology in Pakistan and future prospect of 4G Technology

Today, the 1G, 2G, 2.5G and 3G technologies is widely using in the entire world and researcher continue working on latest communication methods. 4G is the fourth generation which is the successor of 3G and is a wireless access technology is to provide high speed mobile wireless access with a very high data transmission speed as a local area network (LAN) connection. It provides fastest communication of audio, video, images, data and voice via packet switching as well as little bit circuit switching methods.

Below is the detail information about the present infrastructure of cellular networks and mobile service providers in Pakistan. Also discuss latest wireless technology news and future prediction about 4G.

6.1 **Scope of Cellular and Wireless Network in Pakistan**

In Pakistan, communication industry is growing very rapidly especially by the twenty first century, mobiles, calling cards and local wireless companies growth break the record of selling of normal fixed line telephone which is provided by Pakistan Telecommunication Company Limited (PTCL).

Pakistan Telecommunication Authority (PTA) is the government sector controlling all communication system in our country. Through its consistent and well calculated policies has bought about phenomenal progress in this sector and has transformed the country into investors' paradise. The arrival of heavy investment was occasioned because of the fact that PTA had issued various telecom licenses during the year 2004 to foreign and local telecom investors [45]. Cellular companies already operating in the country have significantly reduced their tariffs in view competitive environment. These operators also expanded their infrastructure to compete with the newly inducted parties. The government also reduced activation charges from Rs. 2000 to lower than Rs. 500 to facilitate the users and boosting growth of cell phone connections. The companies had withdrawn roaming charges through out the country. Owing to these measures, an increase of 173 percent was visible in mobile sector and total number of cell phone users reached to 7.9 million by the end of 2004. Existing mobile companies had provided more than 5.5 million new connections during the year. The mobile teledensity has crossed 5.14 percent in Pakistan and according to conservative estimates number of mobile phone users would touch the figure of 15 million by December 2005 [37].

Numerous new licenses were also issued to national and multinational companies providing fixed line telecommunication services to end PTCL monopoly in basic telephony during the year 2004. PTA awarded 12 Long Distance & International (LDI) licenses, 76 Fixed Local Loop (FLL) licenses to 34 operators and 90 Wireless Local Loop (WLL) licenses to 15 companies. The process fetched as much as 14 billion plus through auction of spectrum for WLL, and the initial processing fee for award of these licenses. Fixed line telephone tariffs were reduced substantially to give relief to consumers. Charges for new connection in rural and urban areas were decreased by 73% and 44% respectively. Similarly, NWD call charges were reduced by 25% and ISD charges by 24% [45].

Year	*Total (approximately)*
1996	68,000
1997	135,000
1998	196,100
1999	265,600
2000	306,500
2001	742,600
2002	1,698,550
2003	2,404,400
Jan, 2004	5,022,900
July, 04	5,842,000
Dec, 04	7,805,000
Mar, 05	9,995,000
Dec, 05 (expectably)	15,000,000

Table 6.1 Cellular Subscribers

Above table provides the users of cellular subscribers (approximately) since 1996 till March 2005 and expectations till December 2005. The extraordinary growth can be attributed to series of events that have taken place during the last two years. This includes award of license to two new mobile companies thus creating competitive environment for existing operators. The trend of rising cell phone subscription is a result of convenience and competition. They hope the trend would continue with the arriving of new cellular firms. Cellular service in Pakistan was started in early 1990, currently there are five mobile operators accessible named Paktel, Instaphone, Mobilink, Ufone and Telenor.

Phenomenal growth of cellular industry in Pakistan besides strategic location of the country has convinced the investors to establish mobile phone industries within this country. So far the cell phones being used in Pakistan are imported from different countries. However, some mobile phone companies in collaboration with some leading software houses in Pakistan are on their way to set up mobile producing projects in Pakistan. Hopefully, this trend may open new doors for investment, employment, exports and development in Pakistan [59].

6.2 **Cellular Companies in Pakistan**

In Pakistan, millions of people have the mobile phones for availing the services of voice, short messaging, GPRS, MMS, WAP etc. Also cellular phones play a vital role in business industries and due to e-banking facility provided by different banks, a lot of people interested to use cellular phones. Cellular companies are increasing and their tariffs decreasing and network coverage almost available nationwide especially in major business centers like Karachi, Lahore, and Islamabad. GSM technology uses in Pakistan and from five out of four operators are providing cellular services with GSM technology.

Frequency Allocation Board is clearing the 3G spectrum and will complete this task by the end of 2005. Thereafter, spectrum in the 3G Bands of 2100 MHz will be made available for auction. The 3G licenses will include a minimum urban coverage requirement and performance bond to ensure the spectrum is utilized in a manner beneficial to the country. The PTA will specify the License conditions. The 3G spectrum will be sold by auction. Both the Licensed mobile cellular operators and the new parties interested in 3G licenses will be able to participate in the process. According to an estimation, Mobilink leads the market share with 3.805 million subscribers while Ufone has 1.3 million subscribers followed by Instaphone with 0.544 million and Paktel with 0.488 million subscribers. Below is briefly summarized the mobile companies in Pakistan [62].

6.2.1 **Paktel Limited** www.paktel.com

Paktel that launched the cellular technology and introduced first time in Pakistan mobile telephony system. Paktel provided the basic one-to-one voice communication, short messaging service (SMS), picture messages, polyphonic ring-tones, conference calling, call forwarding and a host of other marvelous services.

Paktel is the only cellular company that provides AMPS and GSM mobile telephony. First they launched AMPS in later 1980s then in 2004 they introduced GSM. PTA had renewed license of pioneer cellular company of Pakistan, Paktel for next 15 years and allowed it to launch its GSM operation. With the operation of existing and new companies the customers would get varied choices and enhanced quality of service at cheaper rates [45] [49].

6.2.2 **Instaphone**

Instaphone started mobile telephony in 1991. In 2002-03, Instaphone holds honor of pioneering coverage of 185 cities. It provided their customers calling party pays, one year free incoming call, roam free incoming, SMS services and international SMS services. International SMS to more than 550 CDMA, TDMA & GSM operators worldwide. Its cellular infrastructure is based on TDMA 800 MHz technology (AMPS), which ensures customers access to real digital benefits, including congestion free environment, Instant connectivity, Optimum sound clarity, call privacy and enhanced battery life. Recently, they upgraded their networks toward 2G technology that is D-AMPS having better support in voice and data as compare with 1G AMPS [45] [50].

6.2.3 **Mobilink Pakistan** www.mobilinkgsm.com

Mobilink (subsidiary of Orascom Telecom) is the market leader in providing highest level in the communications service in Pakistan. It is the first cellular service provider in Pakistan to operate on a GSM 900/1800 MHz technology and now it is available more than 300 cities.

Mobilink GSM started operations in the year 1994 and from then on it has shown enormous growth. At the time when it entered the market it was a small player in the cellular market of Pakistan and now it is the market leader both in terms of growth as well as having the largest subscriber base in Pakistan.

Its popularity also increased by short message service center that allows Vehicle Tracking and Fleet Management services that are being provided by Tracker (Pvt.) Ltd., under the brand name of C-Track, a company licensed by Pakistan Telecom Authority (PTA). Tracker currently operates from Karachi but can provide these facilities at all those locations where GSM coverage is available [45] [46] [47].

6.2.4 **Ufone** www.ufonegsm.com.pk

Ufone, a subsidiary of Pakistan Telecommunication Company Limited (PTCL), is the only Pakistani owned cellular service operator in Pakistan. It started its operations from Islamabad on 29th January 2001. With a total current investment of over $350 Million, including a recent contract of $161 Million for expansion & capacity for 2004-05, they believe in solid commitment to growth, security & reliability.

Ufone is also operating on GSM 900 MHz technology and provides first time in Pakistan, GPRS, High speed data MMS, WAP services. SMS, free incoming, no roaming charge and it is available more than 225 cities in Pakistan [45] [48].

6.2.5 **Telenor (Pvt.) Ltd** www.telenor.com.pk

Telenor is newly Norway based cellular company that obtained the license for providing GSM (operating on 1800 MHz) services in Pakistan in April 2004, and has launched its services commercially in Islamabad, Rawalpindi and Karachi on March 15, 2005. Now its services available in some other cities like Lahore, Faisalabad and Hyderabad.

Telenor is operating on 3G GSM technology (3GSM). Telenor is proud to build mobile communication infrastructure in Pakistan and looks forward to combining its experience in mobile technology with the local Pakistani high level of competence [45] [51] [63].

6.2.6 **Warid Telecom (Pvt.) Ltd**. www.waridtel.com

Warid Telecom is the U.A.E based company, is going to launch its nationwide 3GSM network in the mid of 2005 provide to the demand for better quality mobile services. As the mobile market in Pakistan is undergoing significant growth and the potential of market is further evident from the limited existing coverage areas, capacity constraints and continued aggressive expansion by the current telecom operators. With new entrants, customers will be provided with more choices, better quality of services, cheaper rates and many new innovative products, which Warid Telecom wishes to pioneer.

In addition to its mobile services, Warid Telecom will be launching a Long Distance & International and Wireless Local Loop business shortly. This service will provide international termination of traffic into Pakistan, alternative affordable nationwide and international voice telephony and data & value added services [52].

6.3 **Design Goals for 4G and Related Research Issues**

The purpose of 4G systems is to capture the market in 2010 and beyond, there is time for 4G research and standards development. Right now, no 4G standard has been defined and only assumptions have been made regarding the structure and operation of 4G systems. Research efforts agree more or less on the following goals:

- *System interoperability*: 4G and future systems should bring something that is missing from their predecessors: flexible interoperability of the various kinds of existing wireless networks, such as satellite, cellular wireless, WLAN, PAN and systems for wireless access to the fixed network. On the other hand, this can be thought of as an ability to roam between multiple wireless and mobile standards [1] [43] . We can identify the three possible configurations described below:
    - *Multimode terminals*. This choice provides for more development of older generation systems and has also been applied in the past.
    - *Overlay network*: Users will use the 4G network through the access points (AP) of an overlay network. Upon connection with a terminal, an AP will select the wireless network to which the terminal will be connected.

    - *Common access protocol*: This choice calls for use of one or two standard access protocols by the wireless networks. A possible option is for the wireless networks to use either ATM cells with additional headers or W-ATM cells.
- *Terminal bandwidth and battery life*: Terminals of next generation networks will be characterized by a wide range of supported bandwidths, ranging from several kbps to about 100 Mbps or beyond.
- *Packet switched fixed network*: The 4G architecture will use a connectionless packet switching fixed network to interconnect the several different wireless networks.
- *Advanced base stations*: Base stations of future generation networks will utilize smart antennas to increase system capacity. Base stations will employ self configuring functionality in an effort to reduce operating costs.
- *Higher data rates*: 3G systems will have capacity limit of 2 Mbps. Although more than enough for the application demands of the years to come, 3G systems will most likely need to evolve in order to meet the mobile application demands of the next decades. 4G systems aim to provide support for such applications.
- In order to support the higher data rates new air interfaces will obviously be introduced. An ideal air interface should be spectrum efficient and provide the flexibility to offer different bit rates.
- Orthogonal Frequency Division Multiplexing (OFDM) is an air interface that can meet such requirements and is expected to be greatly used in the wireless systems [1] [2] [44].

6.4 **Orthogonal Frequency Division Multiplexing (OFDM)**

Orthogonal Frequency Division Multiplexing (OFDM) is a type of multicarrier modulation that splits the message to be transmitted into a number of parts. The existing spectrum is also split into a large number of low-rate carriers and the parts of the message are simultaneously transmitted over a large number of low-rate frequency channels. By recalling that the phenomenon that dominates the error behavior of wireless channels is fading; fading is frequency-selective; and delay spread must be very long to cause significant interference to a carrier, one can realize the inherent robustness of OFDM to fading. Thus, by splitting a message into parts and slowly sending (due to low-carrier bandwidths) these parts in parallel over a number of low-rate carriers, signal reflections due to multipath propagation will probably be late at the receiver only by a small amount of a bit time. This, together with the fact that overall message transmission is made over a large number of low-rate carriers in the same time, results in a high-capacity, multipath-resistant link [1] [44].

OFDM resembles FDMA in that they both split the available bandwidth into a number of carriers. The obvious difference of course is that FDMA is a multiple access technique whereas OFDM is a form of multicarrier transmission. Difference concerns efficiency: FDMA is inefficient in terms of spectrum utilization, since it wastes a significant amount of bandwidth as guard interval between neighboring channels in order to ensure that they do not interfere with one another. This bandwidth overhead allows signals from neighboring channels to be filtered out correctly at the receiver. TDMA systems which allow a single user to utilize the entire channel capacity for a specific time period are also subject to a bandwidth overhead since TDMA systems need to be synchronized. As a result, guard time periods occur at the beginning of each user's slot in order to compensate for synchronization problems between stations. Thus, TDMA systems also waste some bandwidth to ensure their proper operation [1] [64].

Such bandwidth overheads are not desirable in future generations of wireless systems. This is because spectrum is expected to be a scarce resource, and given a certain amount of spectrum this will need to be utilized to the highest extent possible in order to accommodate as many users as possible. OFDM tries to solve this problem by significantly reducing the amount of wasted spectrum by dividing the message to be transmitted into a number of frequency carriers and spacing these carriers very close to each other. In order to ensure that OFDM carriers do not interfere, they are made orthogonal to one another. Orthogonality ensures that although carriers are very close in frequency and their spectra overlap, messages in different carriers do not interfere with one another since detection for one carrier is made at the point where all other carriers are null [61] [64].

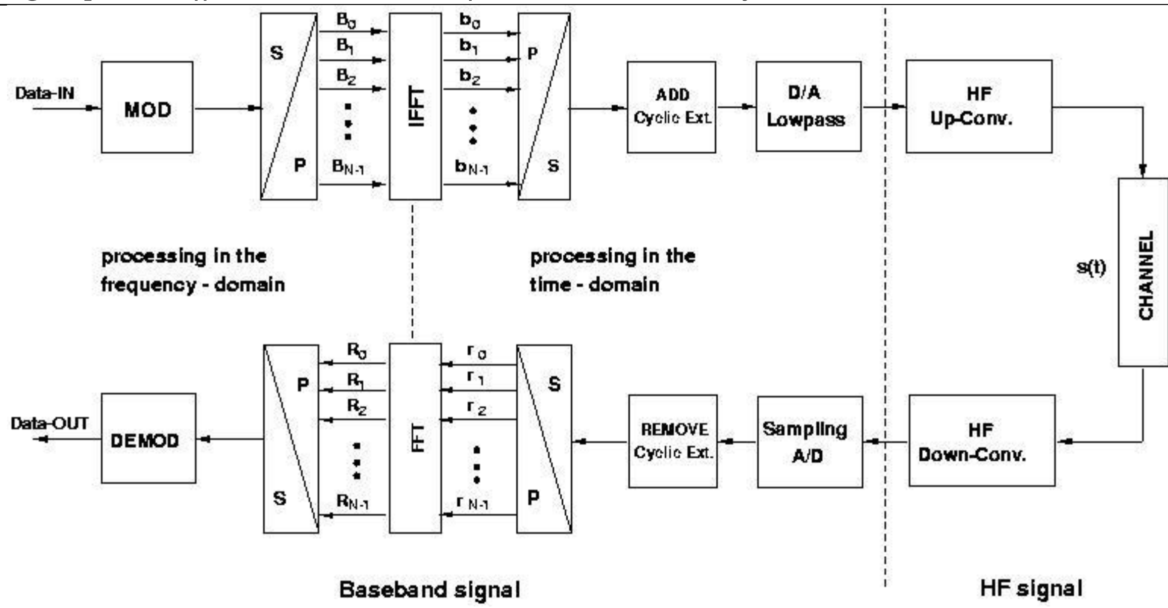


Figure 6.1 OFDM System

In an OFDM system, detection is performed in the frequency domain. The actual signal transmission, however, occurs in the time domain. To better understand this, Figure 6.1 illustrates the operation of a simple OFDM system [1]. OFDM transmission and reception comprise the following states:

- *Transmitter*: serial to parallel conversion. The data stream to be transmitted takes the form of the word size required for transmission. For instance, if QPSK is used, the stream is split into data words of two bits each. Then each data word is assigned to a different carrier.
- *Transmitter*: modulation of each carrier. The data word that forms the input of each carrier is modulated.
- *Transmitter*: Inverse Fourier Transform (IFT). After the actual contents of the various frequency carriers have been defined, the contents of these carriers form the input to an IFT in order to obtain a representation of the OFDM signal in the time domain. The IFT can be performed using the Fast Fourier Transform (FFT), which nowadays can be implemented at low cost.
- *Transmitter*: Digital to Analog Conversion (DAC). The output of the IFT is converted into an analog form suitable for radio transmission.

- *Receiver:* In order to receive the message, the receiver performs the reverse operation to the transmitter. It digitizes the received signal and performs an FFT on the received signal in order to obtain its representation in the frequency domain [1].

6.5 **Researches and Predictions about 4G technologies**

The next generation of mobile communication entrance, which is expected start in the year 2015, the need for transmission capacities for voice, data, image and multimedia is conservatively anticipated to rise by a factor of 10. Future mobile communications systems will have to utilize the frequency band as efficiently as possible, with the lowest possible transmit power. With experimental system, we have been able to demonstrate how powerful intelligent antennas can be in combination with OFDM. In doing so created a major module for future mobile communication systems [43].

Professionals term intelligent antenna systems “multiple-antenna systems” or Multiple Input, Multiple Output (MIMO) systems. According to this concept, multiple antennas concurrently transmit different flows of data over one and the same radio channel and frequency band. This is comparable to a room in which multiple clusters of people are at once conducting conversations both within each cluster and between clusters, yet without interfering with one another. In contrast to conventional individual antennas, which each transmit on a separate frequency, the MIMO method enables data rates to be multiplied by making significantly more efficient use of the costly frequency band resource [43].

Multiple-antenna systems are not typically used today is the very high computing power that is required at the receiving end because the information that is transmitted simultaneously by multiple antennas is received by multiple receiving antennas and has to be reconstructed in real-time for the receiving device. This exceeds the capabilities of the typical chips that are currently being employed in the mobile communication industry. The researchers at Siemens overcame this challenge by developing new and optimizing signal processing algorithms that can be efficiently implemented on the hardware modules that are available today [43].

The experimental system operates in the 5-GHz band and has a bandwidth of 100 MHz. The Orthogonal Frequency Division Multiplexing (OFDM) transmission method that it employs protects the signals against most types of interference, such as the echoes that are produced when the signals reflect off buildings. This method, which has long been known and is considered to be a highly promising transmission technology for future mobile communication, is already being employed today in Wireless LAN as well as in digital television (DVB) and radio (DAB). The global wireless industry is migrating to OFDM radio technology in the wireless LAN, fixed broadband wireless, and mobile phone segments, a transition that will take several years to complete [43] [61].

Hard Numbers and Experts Insights on migration to 4G wireless technology provides full information on how OFDM technology performs relative to CDMA, its effectiveness in the mobile environment and in what scenarios it will offer advantages over other technologies. The report also quantifies the spectral efficiency of a wide range of existing and forthcoming mobile wireless technologies in various configurations, illustrating the gains from techniques such as receive diversity, channel equalization and MIMO [44].

6.6 **4G Services and Applications**

The applications and service program that will lead the 4G market are not yet known, however, some trends are emerging from ongoing research [1]. Not presently but analytic list of service classes is as follows:

- *Tele-presence*: This class will support applications that use full stimulation of all senses to provide users with the illusion of actually being in a specific place. These will be real-time virtual reality services and will offer virtual meetings, an evolution of today’s teleconferencing applications. The conference attendants, although in different places, will have the illusion of participating in a conference in the very same room. Such applications, coupled with efficient compression techniques, will require capacities in the order of 100 Mbps.
- *Information access*: This class will call for the ability of instantaneous access to large volumes of data such as large video and audio files. Compared to tele-presence, such applications will be less delay sensitive, since real-time delivery of data is not needed here. As far as data rates are concerned, this class will demand the highest rates possible.

- *Inter-machine communication*: This service class will offer devices the ability to communicate with one another either for maintenance or for intelligence purposes. An example application of this type is car engine equipment that contains wireless interfaces enabling parts to contact the respective vendors when malfunctions occur.
- *Intelligent shopping*: This will present users access to information regarding prices and products offered by shops they visit, the user terminals will automatically tune to the shop's service providers and display information concerning the products sold.
- *Security*: Secure services will be an vital feature of the future generations of networks. Integrity of data is bound to be a crucial factor that will enable the proliferation of banking and electronic payment applications.
- *Location-based services*: It is visualization that 4G and future systems will have the ability to determine the location of users with a high level of accuracy. This cannot be made true with today's systems which can only report the cell servicing the user, thus being accurate to within a few city blocks at best. Emergency applications will greatly benefit from location-based services [1].

6.7 **4G Technology's Latest News**

Japan, China, Korea to Jointly Develop 4G Phones

China and Korea have agreed to jointly develop communications and other technologies for 4G cellular phones, which are expected to come into commercial use around 2010 [43].

VoIP Is the `Killer' Application to Drive Wireless Development from WiMAX to 4G

West estimates that, given a 4% global GDP growth rate, annual shipments for WiMAX chipsets will exceed $2.2 billion in 2008 [43].

Expect 4G telephony in 2012

Seven years from now, 4G phones will be in the shops, according to the vice-president of research at Telefonaktiebolaget LM Ericsson, Ulf Wahlberg [43].

Beijing 2008: The First 4G Wireless Olympic Games?

One other way to measure the success of the Games is the impact it has on the host city after the torch is extinguished. By deploying a 4G mobile broadband network for the Games, Beijing will ensure that its residents will enjoy profound and lasting benefits [43].

DoCoMo's (New Business Model)

The speed will be 100 times faster (than 3G). Our business will look completely different in 2010 [44].

Far East 4G Wireless Connection

Japan, China and South Korea plan to work together with developing new technologies like fourth generation mobile phones [43].

4G Mobile via Satellite

In addition to the Company's National Wireless Broadband Network, proposed telecommunications uses include cellular, 3G and 4G mobile [43].

4G Mobile PC Capabilities

3G and 4G Mobile operators have demanded products that will offer PC capabilities in a PDA form factor. Miniaturized or folding keyboards are not fully functional or portable [43].

6.8 **Summary of the Chapter**

In this chapter, I covered visualization of 4G and future wireless systems. Such systems target the market of 2010 and beyond, aiming to offer support to mobile applications demanding data rates of 50 Mbps and beyond. Due to the large time window to their deployment, both the telecommunications scene and the services offered by 4G and future systems are not known yet and as a result aims for these systems may change over time. However, as 3G systems move from the research to the implementation stage, 4G and future systems will take their place as an extremely interesting field of research on future generation wireless systems. This chapter has discussed number of issues:

- 4G and future systems aim to provide a common IP-based platform for the multiple mobile and wireless systems and possibly offer higher data rates. The desired properties of 4G systems are identified. OFDM, a promising technology for providing high data rates, is presented.
- In Pakistan, cellular networks future is very bright and millions of user availing the services of mobile, WLL, LDI companies. Cellular companies already operating in the country have significantly reduced their tariffs in view competitive environment. GSM

technology uses in Pakistan and from five out of four operators are providing cellular services with GSM technology.

- The applications and service classes that will dominate the 4G market are not yet known, research has identified some possibilities. Tele-presence, information access services, inter-machine communication and intelligent shopping will be enabled by 4G and future systems.
- The exact state of 4G and future systems cannot be reliably foreseen, due to the large time window until their deployment. Many issues of these systems are not so clear and are dependent on the evolution of the telecommunications market and society in general. Scenarios are tools for predicting future situations and setting research priorities. Three different scenarios for the future generations of wireless networks are presented, along with possible research issues for each scenario.

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