NEAR EAST UNIVERSITY

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Department of Electrical and Electronic Engineering

Wireless Networks

Graduation Project
EE – 400

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Nicosia - 2007

ACKNOWLEDGMENTS

First of all I prayed to Almighty ALLAH, for blessing me skills and keeping His mercy and sympathy through all my study.

I would like to pay my special regards to my project advisor "Dr.Ali Serener". Under his guidance, I successfully overcome many difficulties and learn a lot about communication especially about wireless networks. He never showed weary on my questions and replied patiently every time.

A bundle of thanks goes to my brother CH. MUHAMMAD SHAFIQ (C.E) for supporting and encouragement throughout my graduation. I can never forget to pay my special regards to my parents for their infinite favors at every critical moment of my life.

The best of acknowledge, I want to honor all of my friends, Syed Ali Hussnain, Munam Awais,Irfan Anjum and a lot of love for my brother Usman Sharif.

At the end I am again thankful to the doctors and professors encouraged me to complete my project

ABSTRACT

Wireless networks have emerged as one of the largest sectors of the telecommunications industry, evolving from a niche business in the last decade to one of the most promising areas for growth in the 21st century. It became possible to embed Low-Cost Low-Power radios in more types of electronic devices, like WiFi, WiMax, Zig Bee, Bluetooth and Ultra Wide band.

GSM was created within a traditional analysis environment for providing a single, digital, cellular system to replace a collection of incompatible analog systems within the European community.

This report explores some of the key technological advances and approaches that are now emerging as core components for wireless solutions of the future.

MATLAB simulations are performed to show how we can get a digital signal from an analog signal, an important method used by many wireless networks today.

INTRODUCTION

The 1990s were a period of tumultuous growth for the wireless communications industry, and few could have predicted the rapid rise of many of today's key players that chose "winning" approaches and technologies. Likewise, there were some amazing and startling failures in the wireless sector, despite the brilliant engineering and technological efforts that went into their formations. This report describes One of the most successful wireless communications technologies is GSM, and especially in the last decade low cost low power radios also. The pulse code modulation is described briefly, By using MATLAB simulation. The performance of pulse code modulation and the process of getting digital signal from analog signal are analyzed.

In chapter one we discussed briefly about the process of communication, from cable to the wireless communication with respect to the past, present and future events.

Chapter two describes the Group System Mobile (GSM), and the main characteristics of this system.

Chapter three gives an idea about the short distances and importance and benefits of these latest technologies in the wireless communication.

Chapter four describes the pulse code modulation.

Finally, chapter five includes the results obtained through simulation. The MATLAB code is included in the appendix section.

CHAPTER 1

OVERVIEW OF WIRELESS COMMUNICATIONS

1.1 Introduction

Wireless communications is, by any measure, the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public. Cellular systems have experienced exponential growth over the last decade and there are currently around two billion users worldwide. Indeed, cellular phones have become a critical business tool and part of everyday life in most developed countries, and are rapidly supplanting antiquated wireline systems in many developing countries. In addition, wireless local area networks currently supplement or replace wired networks in many homes, businesses, and campuses. Many new applications, including wireless sensor networks, automated highways and factories, smart homes and appliances, and remote telemedicine, are emerging from research ideas to concrete systems.

The explosive growth of wireless systems coupled with the proliferation of laptop and palmtop computers indicate a bright future for wireless networks, both as stand-alone systems and as part of the larger networking infrastructure. However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications. We will briefly review the history of wireless networks, from the smoke signals of the pre-industrial age to the cellular, satellite, and other wireless networks of today. We then discuss the wireless vision in more detail, including the technical challenges that must be overcome to make this vision a reality. We describe current wireless systems along with emerging systems and standards. The gap between current and emerging systems and the vision for future wireless applications indicates that much work remains to be done to make this vision a reality.

1.2 History of Wireless Communications

The first wireless networks were developed in the Pre-industrial age. These systems transmitted information over line-of-sight distances (later extended by telescopes) using smoke signals, torch signaling, flashing mirrors, signal flares, or semaphore flags. These early communication networks were replaced first by the telegraph network (invented by Samuel Morse in 1838) and later by the telephone. In 1895, a few decades after the telephone was invented, Marconi demonstrated the first radio transmission from the Isle of Wight to a tugboat 18 miles away, and radio communications was born. The first network based on packet radio, ALOHANET, was developed at the University of Hawaii in 1971. By far the most successful application of wireless networking has been the cellular telephone system. The roots of this system began in 1915, when wireless voice transmission between New York and San Francisco was first established. In 1946 public mobile telephone service was introduced in 25 cities across the United States. Thirty years after the introduction of mobile telephone service the New York system could only support 543 users. A solution to this capacity problem emerged during the 50's and 60's when researchers at AT&T Bell Laboratories developed the cellular concept.

The evolution of cellular systems from initial concept to implementation was glacial. In 1947 AT&T requested spectrum for cellular service from the FCC. The design was mostly completed by the end of the 1960's, the first field test was in 1978, and the FCC granted service authorization in 1982, by which time much of the original technology was out-of-date. The first analog cellular system deployed in Chicago in 1983 was already saturated by 1984, at which point the FCC increased the cellular spectral allocation from 40 MHz to 50 MHz. Throughout the late 1980's, as more and more cities became saturated with demand for cellular service, the development of digital cellular technology for increased capacity and better performance became essential.

The second generation of cellular systems, first deployed in the early 1990's, was based on digital communications. The shift from analog to digital was driven by its higher capacity and the improved cost, speed, and power efficiency of digital hardware. While second generation cellular systems initially provided mainly voice services, these systems gradually evolved to support data services such as email, Internet access, and short messaging. The second boost for the cellular industry came from the introduction of the second-generation (2G) digital technology standards, including Global System for Mobile Communications (GSM, previously known as Group Special Mobile), IS-136 (time-division multiple access, TDMA), IS-95 (code-division multiple access, CDMA), and Personal Digital Cellular (PDC). Digital technology has not only improved voice quality and services, but more important, significantly reduced the cost of handset and infrastructure systems, leading to further acceleration of the industry's growth since the mid-1990s.

Satellite systems are typically characterized by the height of the satellite orbit, low-earth orbit (LEOs at roughly 2000 Km. altitude), medium-earth orbit (MEOs at roughly 9000 Km. altitude), or geosynchronous orbit (GEOs at roughly 40,000 Km. altitude). The concept of using geosynchronous satellites for communications was first suggested by the science fiction writer Arthur C. Clarke in 1945. However, the first deployed satellites, the Soviet Union's Sputnik in 1957 and the NASA/Bell Laboratories' Echo-1 in 1960, were not geosynchronous due to the difficulty of lifting a satellite into such a high orbit. The first GEO satellite was launched by Hughes and NASA in 1963. GEOs then dominated both commercial and government satellite systems for several decades. The most compelling feature of these systems is their ubiquitous worldwide coverage, especially in remote areas or third-world countries with no landline or cellular system infrastructure. A natural area for satellite systems is broadcast entertainment. Direct broadcast satellites operate in the 12 GHz frequency band. These systems offer hundreds of TV channels and are major competitors to cable. Satellite delivered digital radio has also become popular. These systems, operating in both Europe and the US, offer digital audio broadcasts at near-CD quality.

1.3 Wireless Vision

The vision of wireless communications supporting information exchange between people or devices is the communications frontier of the next few decades, and much of it already exists in some form. This vision will allow multimedia communication from anywhere in the world using a small handheld device or laptop. Wireless networks will connect palmtop, laptop, and desktop computers anywhere within an office building or campus, as well as from the corner cafe. Wireless entertainment will permeate the home and any place that people congregate. Video teleconferencing will take place between buildings that are blocks or continents apart, and these conferences can include travelers as well, from the salesperson that missed his plane connection to the CEO off sailing in the Caribbean. Wireless video will enable remote classrooms, remote training facilities, and remote hospitals anywhere in the world. Wireless sensors have an enormous range of both commercial and military applications. Commercial applications include monitoring of fire hazards, hazardous waste sites, stress and strain in buildings and bridges, carbon dioxide movement and the spread of chemicals and gasses at a disaster site. These wireless sensors self-configure into a network to process and interpret sensor measurements and then convey this information to a centralized control location. Military applications include identification and tracking of enemy targets, detection of chemical and biological attacks, support of unmanned robotic vehicles, and counter-terrorism. Finally, wireless networks enable distributed control systems, with remote devices, sensors, and actuators linked together via wireless communication channels. Such networks enable automated highways, mobile robots, and easily-reconfigurable industrial automation.

The various applications described above are all components of the wireless vision. So what, exactly, is wireless communications? There are many different ways to segment this complex topic into different applications, systems, or coverage regions. Wireless applications include voice, Internet access, web browsing, paging and short messaging, subscriber information services, file transfer, video teleconferencing, entertainment, sensing, and distributed control. Systems include cellular telephone systems, wireless LANs, wide-area wireless data systems, satellite systems, and ad hoc wireless networks. Coverage regions include in-building, campus, city, regional, and global. The question of how best to characterize wireless communications along these various segments has resulted in considerable fragmentation in the industry, as evidenced by the many different wireless products, standards, and services being offered or proposed.

Moreover, there must be sufficient flexibility and creativity among both engineers and regulators to allow for accidental successes. It is clear, however, that the current and emerging wireless systems of today coupled with the vision of applications that wireless can enable insure a bright future for wireless technology.

1.4 Technical Issues

Many technical challenges must be addressed to enable the wireless applications of the future. These challenges extend across all aspects of the system design. As wireless terminals add more features, these small devices must incorporate multiple modes of operation to support the different applications and media. Wireless networking is also a significant challenge. The network must be able to locate a given user wherever it is among billions of globally-distributed mobile terminals. It must then route a call to that user as it moves at speeds of up to 100 km/hr. The finite resources of the network must be allocated in a fair and efficient manner relative to changing user demands and locations.

Perhaps the most significant technical challenge in wireless network design is an overhaul of the design process itself. Wired networks are mostly designed according to a layered approach, whereby protocols associated with different layers of the system operation are designed in isolation, with baseline mechanisms to interface between layers. As a signal propagates through a wireless channel, it experiences random fluctuations in time if the transmitter, receiver, or surrounding objects are moving, due to changing reflections and attenuation. Thus, the characteristics of the channel appear to change randomly with time, which makes it difficult to design reliable systems with guaranteed performance. Security is also more difficult to implement in wireless systems.

Design of wireless networks differs fundamentally from wired network design due to the nature of the wireless channel. This channel is an unpredictable and difficult communications medium.

1.5 Current Wireless Systems

The design details of these systems are constantly evolving, with new systems emerging and old ones going by the wayside.

1.5.1 Cellular Telephone Systems

Cellular telephone systems are extremely popular and lucrative worldwide. Cellular systems provide two-way voice and data communication with regional, national, or international coverage. Cellular systems were initially designed for mobile terminals inside vehicles with antennas mounted on the vehicle roof. Today these systems have evolved to support lightweight handheld mobile terminals operating inside and outside buildings at both pedestrian and vehicle speeds.

The basic premise behind cellular system design is frequency reuse, which exploits the fact that signal power falls off with distance to reuse the same frequency spectrum at spatially-separated locations (figure 1.1). Specifically, the coverage area of a cellular system is divided into non overlapping cells where some set of channels is assigned to each cell. This same channel set is used in another cell some distance away.

Operation within a cell is controlled by a centralized base station. The interference caused by users in different cells operating on the same channel set is called intercellular interference. The spatial separation of cells that reuse the same channel set, the reuse distance, should be as small as possible so that frequencies are reused as often as possible, thereby maximizing spectral efficiency. However, as the reuse distance decreases, intercell interference increases, due to the smaller propagation distance between interfering cells.

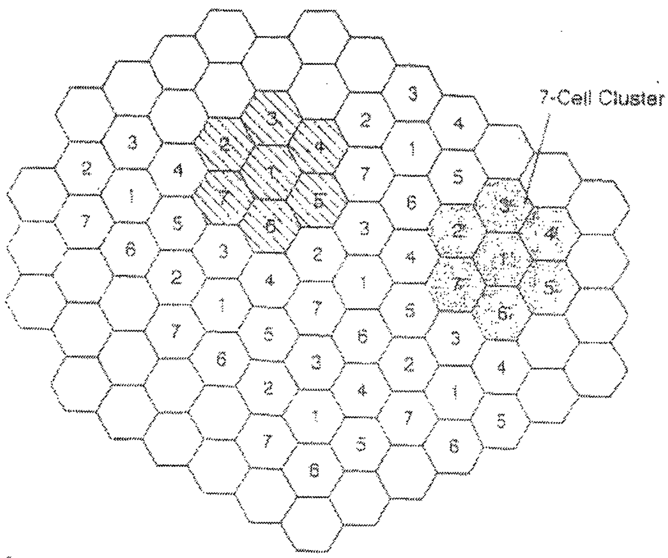

Figure 1.1 Cell arrangement with reuse factor N= 7

Since intercell interference must remain below a given threshold for acceptable system performance, reuse distance cannot be reduced below some minimum value. In order to determine the best reuse distance and base station placement, an accurate characterization of signal propagation within the cells is needed. Initial cellular system designs were mainly driven by the high cost of base stations, approximately one million dollars apiece. For this reason early cellular systems used a relatively small number of cells to cover an entire city or region.

Cellular systems in urban areas now mostly use smaller cells with base stations close to street level transmitting at much lower power. These smaller cells are called microcells or picocells, depending on their size. All base stations in a given geographical area are connected via a high-speed The MTSO acts as a central controller for the network, allocating channels within each cell, coordinating handoffs between cells when a mobile traverses a cell boundary, and routing calls to and from mobile users (figure 1.2).

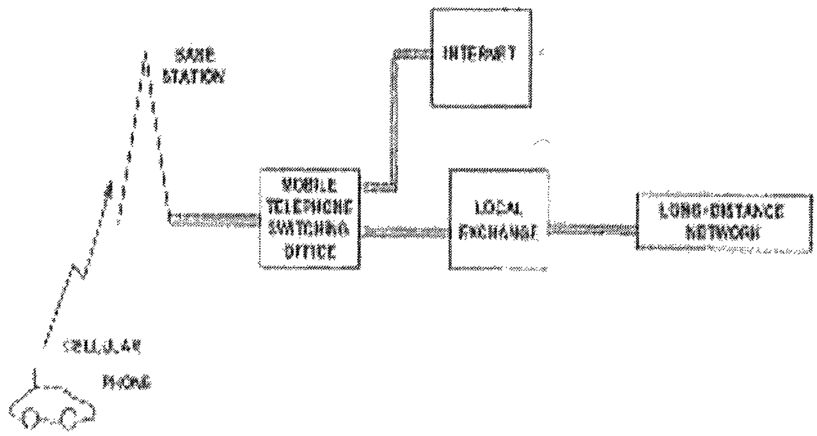

Figure 1.2 Current Cellular Network Architecture

The first generation (1G) cellular systems in the U.S., called the Advance Mobile Phone Service (AMPS), used FDMA with 30 KHz FM-modulated voice channels. The FCC initially allocated 40 MHz of spectrum to this system, which was increased to 50 MHz shortly after service introduction to support more users. This total bandwidth was divided into two 25 MHz bands, one for mobile-to-base station channels and the other for base station-to-mobile channels. The second boost for the cellular industry came from the introduction of the second-generation (2G) digital technology standards, including Global System for Mobile Communications (GSM, previously known as Group Special Mobile), IS-136 (time-division multiple access, TDMA), IS-95 (code-division multiple access, CDMA), and Personal Digital Cellular (PDC). Digital technology has not only improved voice quality and services, but more important, significantly reduced the cost of handset and infrastructure systems, leading to further acceleration of 100 billion dollars.

The third generation (3G) cellular systems are based on a wideband CDMA standard developed within the auspices of the International Telecommunications Union (ITU). The first 3G systems were deployed in Japan. One reason that 3G services came out first in Japan is the process of 3G spectrum allocation, which in Japan was awarded without much up-front cost. The 3G spectrum in both Europe and the U.S. is allocated based on auctioning, thereby requiring a huge initial investment for any company wishing to provide 3G service. European companies collectively paid over 100 billion dollars. However, the 2G spectrum in Europe is severely overcrowded, so users will either eventually migrate to 3G or regulations will change so that 3G bandwidth can be used for 2G services (which is not currently allowed in Europe).

1.5.2 Cordless Phones

Cordless telephones first appeared in the late 1970's and have experienced spectacular growth ever since. Many U.S. homes today have only cordless phones, which can be a safety risk since these phones don't work in a power outage, in contrast to their wired counterparts. Cordless phones were originally designed to provide a low-cost low-mobility wireless connection to the PSTN, i.e. a short wireless link to replace the cord connecting a telephone base unit and its handset. The first cordless systems allowed only one phone handset to connect to each base unit, and coverage was limited to a few rooms of a house or office. This is still the main premise behind cordless telephones in the U.S. today, although some base units now support multiple handsets and coverage has improved.

In Europe and Asia the second generation of digital cordless phones (CT-2, for cordless telephone, second generation) have an extended range of use beyond a single residence or office. Another evolution of the cordless telephone designed primarily for office buildings is the European DECT system. The main function of DECT is to provide local mobility support for users in an in-building private branch exchange (PBX). A more advanced cordless telephone system that emerged in Japan is the Personal Handyphone System (PHS). The PHS system is quite similar to a cellular system. The main difference between a PHS system and a cellular system is that PHS cannot support call handoff at vehicle speeds. However, it is clear from the recent history of cordless phone systems that to extend the range of these systems beyond the home requires either similar or better functionality than cellular systems or a significantly reduced cost.

1.5.3 Wireless LANs

Wireless LANs provide high-speed data within a small region, e.g. a campus or small building, as users move from place to place. Wireless devices that access these LANs are typically stationary or moving at pedestrian speeds. All wireless LAN standards in the U.S. operate in unlicensed frequency bands. The first generation wireless LANs were based on proprietary and incompatible protocols. Most operated within the 26 MHz spectrum of the 900 MHz ISM band using direct sequence spread spectrum, with data rates on the order of 1-2 Mbp. The second generation of wireless LANs in the U.S. operates with 80 MHz of spectrum in the 2.4 GHz ISM band. Both star and peer-to-peer architectures were used.

In Europe wireless LAN development revolves around the HIPERLAN (high performance radio LAN) standards. The first HIPERLAN standard, HIPERLAN Type 1, is similar to the IEEE 802.11a wireless LAN standard, with data rates of 20 Mbps at a range of 50 m. This system operates in a 5 GHz band similar to the U-NII band. Its network architecture is peer-to-peer. The next generation of HIPERLAN, HIPERLAN Type 2 is still under development, but the goal is to provide data rates on the order of 54 Mbps with a similar range, and also to support access to cellular, ATM, and IP networks. HIPERLAN Type 2 is also supposed to include support for Quality-of-Service (QoS), however it is not yet clear how and to what extent this will be done.

1.5.4 Wide Area Wireless Data Services

Wide area wireless data services provide wireless data to high-mobility users over a very large coverage area. In these systems a given geographical region is serviced by base stations mounted on towers, rooftops, or mountains. The cellular digital packet data (CDPD) system is a wide area wireless data service overlaid on the analog cellular telephone network. However, since newer generations of cellular systems also provide data services, CDPD is mostly being replaced by these newer services. Thus, wide area wireless data services have not been very successful, although emerging systems that offer broadband access may have more appeal.

1.5.5 Broadband Wireless Access

Broadband wireless access provides high-rate wireless communications between a fixed access point and multiple terminals. These systems were initially proposed to support interactive video service to the home, but the application emphasis then shifted to providing high speed data access (tens of Mbps) to the Internet, the WWW, and to high speed data networks for both homes and businesses. LMDS represents a quick means for new service providers to enter the already stiff competition among wireless and wireline broadband service providers. MMDS is a television and telecommunication delivery system with transmission ranges of 30-50 km. MMDS has the capability to deliver over one hundred digital video TV channels along with telephony and access to emerging interactive services such as the Internet. MMDS will mainly compete with existing cable and satellite systems. Europe is developing a standard similar to MMDS called Hiperaccess. WiMAX is an emerging broadband wireless technology based on the IEEE 802.16 standard.

1.5.6 Paging Systems

Paging systems broadcast a short paging message simultaneously from many tall base stations or satellites transmitting at very high power (hundreds of watts to kilowatts). Paging service also costs less than cellular service, both for the initial device and for the monthly usage charge, although this price advantage has declined considerably in recent years as cellular prices dropped. The low cost, small and lightweight handsets, long battery life, and ability of paging devices to work almost anywhere indoors or outdoors are the main reasons for their appeal. The system evolved to allow a short digital message, including a phone number and brief text, to be sent to the pagee as well. Some implemented "answer-back" capability, i.e. two-way communication. This required a major change in the pager design, since it needed to transmit signals in addition to receiving them, and the transmission distances to a satellite or distance base station is very large. Paging companies also teamed up with palmtop computer makers to incorporate paging functions into these devices. Despite these developments, the market for paging devices has shrunk considerably, although there is still a niche market among doctors and other professionals that must be reachable anywhere.

1.5.7 Satellite Networks

Commercial satellite systems are another major component of the wireless communications infrastructure. Geosynchronous systems include Inmarsat and OmniTRACS. The first generation Inmarsat-A system was designed for large (1m parabolic dish antenna) and rather expensive terminals. Newer generations of Inmarsats use digital techniques to enable smaller, less expensive terminals, around the size of a briefcase. Qualcomm's OmniTRACS provides two-way communications as well as location positioning. The most appealing use for satellite system is broadcasting of video and audio over large geographic regions. In the U.S. approximately 1 in 8 homes have direct broadcast satellite service, and satellite radio is emerging as a popular service as well. Similar audio and video satellite broadcasting services are widespread in Europe. Satellites are best tailored for broadcasting, since they cover a wide area and are not compromised by an initial propagation delay. Moreover, the cost of the system can be amortized over many years and many users, making the service quite competitive with terrestrial entertainment broadcasting systems.

1.6 The Wireless Spectrum

1.6.1 Methods for Spectrum Allocation

Most countries have government agencies responsible for allocating and controlling the use of the radio spectrum. In the U.S. spectrum is allocated by the Federal Communications Commission (FCC) for commercial use and by the Office of Spectral Management (OSM) for military use. Commercial spectral allocation is governed in Europe by the European Telecommunications Standards Institute (ETSI) and globally by the International Telecommunication Union (ITU) (figure 1.3). Governments decide how much spectrum to allocate between commercial and military use and this decision is dynamic depending on needs.

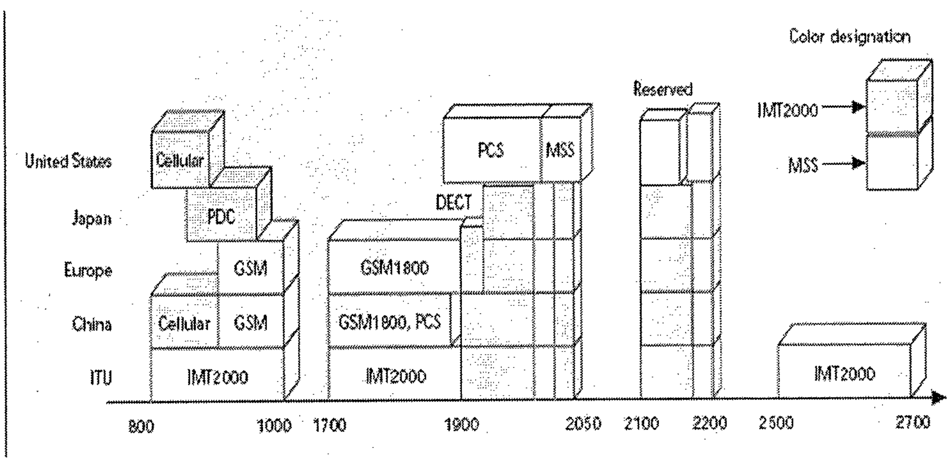

Figure 1.3 RF spectrum allocations in major region

The 3G spectral auctions in Europe, in which several companies ultimately defaulted, have provided fuel to the fire against spectral auctions. Satellite systems cover large areas spanning many countries and sometimes the globe. For wireless systems that span multiple countries, spectrum is allocated by the International Telecommunications Union Radio Communications group (ITU-R). The standards arm of this body, ITU-T, adopts telecommunication standards for global systems that must interoperate with each other across national boundaries.

There is some movement within regulatory bodies worldwide to change the way spectrum is allocated. Indeed, the basic mechanisms for spectral allocation have not changed much since the inception of the regulatory bodies in the early to mid 1900's, although spectral auctions and underlay systems are relatively new. The goal of changing. Spectrum allocation policy is to take advantage of the technological advances in radios to make spectrum allocation more efficient and flexible.

1.6.2 Spectrum Allocations for Existing Systems

Most wireless applications reside in the radio spectrum between 30 MHz and 30 GHz. These frequencies are natural for wireless systems since they are not affected by the earth's curvature, require only moderately sized antennas, and can penetrate the ionosphere.

Digital TV is slated for the same bands as broadcast TV, so all broadcasters must eventually switch from analog to digital transmission. Also, the 3G a broadband wireless spectrum is currently allocated to UHF TV stations 60-69, but is slated to be reallocated. Both 1G analog and 2G digital cellular services occupy the same cellular band at 800 MHz, and the cellular service providers decide how much of the band to allocate between digital and analog service. Unlicensed spectrum is allocated by the governing body within a given country. Often countries try to match their frequency allocation for unlicensed use so that technology developed for that spectrum is compatible worldwide.

1.7 Standards

Communication systems that interact with each other require standardization. Standards are typically decided on by national or international committees: in the U.S. the TIA plays this role. These committees adopt standards that are developed by other organizations. The IEEE is the major player for standards development in the United States, while ETSI plays this role in Europe. Both groups follow a lengthy process for standards development which entails input from companies and other interested parties, and a long and detailed review process. In general standards do not include all the details on all aspects of the system design. This allows companies to innovate and differentiate their products from other standardized systems. The main goal of standardization is for systems to interoperate with other systems following the same standard.

There are, of course, disadvantages to standardization. The standards process is not perfect, as company participants often have their own agenda which does not always coincide with the best technology or best interests of the consumers. In addition, the standards process must be completed at some point, after which time it becomes more difficult to add new innovations and improvements to an existing standard. Finally, the standards process can become much politicized. However, it would benefit everyone in the wireless technology industry if some of the problems in the standardization process could be mitigated.

CHAPTER 2

GLOBAL SYSTEM FOR MOBILE COMMUNICATION (GSM)

2.1 Introduction

In 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Group Special Mobile (GSM) to study and develop a pan-European public land mobile system. In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and phase I of the GSM specifications were published in 1990. Commercial service was started in mid-1991, and by 1993 there were 36 GSM networks in 22 countries. Although standardized in Europe, GSM is not only a European standard. Over 200 GSM networks (including DCS1800 and PCS1900) are operational in 110 countries around the world.

2.2 GSM Services

The services that GSM can provide include voice services, data services, messaging services, multicast services, and location services.

2.2.1 Voice Services

Voice service is a type of communication service where two or more people can transfer information in the voice frequency band (not necessarily voice signals) through a communication network. Voice service involves the setup of communication sessions between two (or more) users that allows for the real time (or near real time) transfer of voice type signals between users. The GSM system provides for various types of digital voice services. The voice service quality on the GSM system can vary based on a variety of factors.

The GSM system can dynamically change the voice quality because the GSM system can use several different types of speech compression. The service provider can select and control which speech compression process (voice coding) is used. The selection of voice coders that have higher levels of speech Compression (higher compression results in less digital bits transmitted) allows the service provider to increase the number of customers it can provide service to services. The GSM system is also capable of providing group voice services and broadcast voice services.

2.2.2 Full Rate Voice

Full rate communication is the dedication of the full capacity of a communication channel to a specific user or application. GSM full rate service allows 8 users to share each radio channel with a voice data rate of 13 kbps for each user.

2.2.3 Half Rate Voice

Half rate communication is a process where only half the normal channel data rate (the full rate) is assigned to a user operating on a radio communications channel. By reducing the data rate, the number of users that can share the radio communications channel can be increased. For the GSM time division multiple access (TDMA) systems, half the number of time slots is assigned during each frame of transmission.

This allows other radios to be assigned to the unused time slots. Half rate GSM voice service allows up to 16 users to share each radio channel with a voice data rate of approximately 6.5 kbps for each user.

2.2.4 Enhanced Full Rate Voice

Enhanced full rate (EFR) is an improved form of digital speech compression used in GSM networks. The EFR rate speech coder uses the same data transmission rate as the full rate speech coder. To improve the voice quality, new speech data compression processes (software programs) are used. To use the EFR speech coder, both the mobile station and the system must have EFR capability.

2.2.5 Voice privacy

Voice privacy is a process of modifying or encrypting a voice signal to prevent the listening of communications by unauthorized users. For digital systems (such as the GSM system) the digital transmission is modified (encrypted) when a secret key is shared, by both the sender and receiver of the information (voice or data signal). Only users with the secret key can receive and decode the information. The key that is used by the GSM system constantly changes so even if the key is compromised, it cannot be used again. Voice group call service (VGCS) is the process of transmitting a single voice conversation on a channel or group of channels so it can be simultaneously received by a predefined group of service subscribers .

2.2.6 Voice Group Call Service (Dispatch)

VGCS allows the simultaneous reception of speech conversation of a predefined group of mobile radios and/or a dispatch console. Each mobile radio that has group call capability is called a group call member. To help facility communication between multiple mobile devices and to integrate radio communication with other communication systems (such as a computer system) a dispatch console may be used. A dispatch console is a device or system that allows a person or group of people to access communication systems and services. The person who operates a dispatch console is a dispatcher. Dispatch consoles can be connected to a group call system wire (such as by an ISDN line) or via a radio base unit.

When connected by wire, a dispatch console can be located at any location within or outside a radio coverage area. Specific users (such as a dispatcher) can be assigned priorities to allow them to override the communication of other users. Group call service is also known as push to talk (PTT) service. PTT is a Process of initiating transmission through the use of a push-to-talk button. VGCS operates in half duplex (one-way at a time) communication mode. The push to talk process involves the talker pressing a talk button (usually part of a handheld microphone) that must be pushed before the user can transmit. If the system is available for PTT service (other users in the group not talking), the talker will be alerted (possibly with an acknowledgement tone) and the talker can transmit their voice by holding the talk button.

If the system is not available, the user will not be able to transmit/talk. Each group call member is uniquely identified by their own MSISDN and a group identification number (group ID). Each mobile radio or dispatcher can have access to more than one group code. Calls to a group may be limited to a specific geographic area (specific number of cell sites).

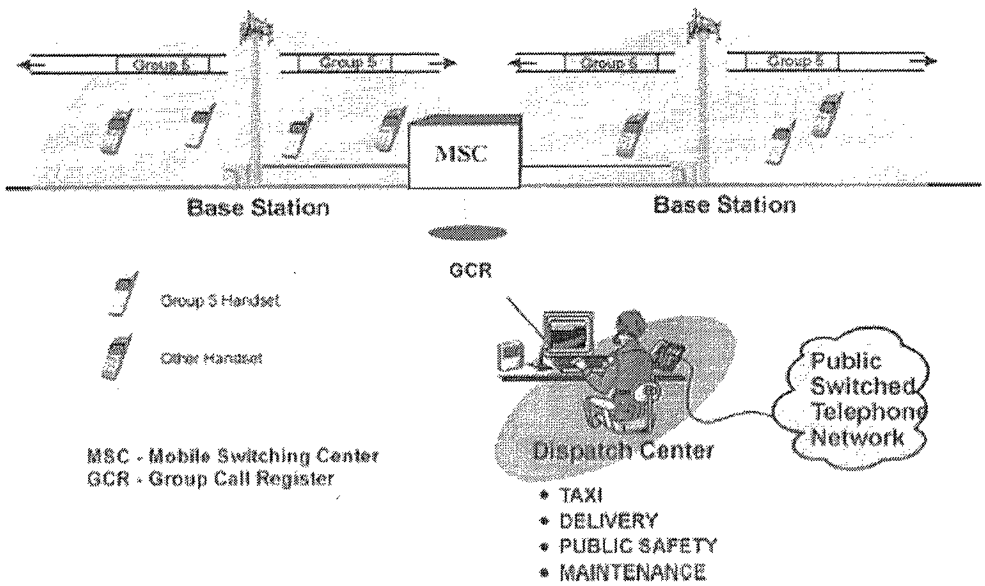

Figure 2.1 GSM Group Call (Dispatch) Service

The list of members in a dispatch group along with their identification, assigned priorities, and capabilities is stored in a group call register (GCR). (Figure 2.1) shows how voice group call service may operate in a GSM system.

In this diagram, a single voice message is transmitted on GSM radio channels in a pre-defined geographic area. Several mobile radios are operating with in the radio coverage limits (group 5 in this example) of the cells broadcasting the ground message. In this example, a user is communicating to a group. Each user in this group (including the dispatcher) listens and decodes the message for group 5. Other handsets in the area are not able to receive and decode the group 5 message.

2.2.7 Voice Broadcast Service (VBS)

Voice broadcast service (VBS) is the process of transferring a single voice conversation or message to be transmitted to a geographic coverage area. VBS subscribers or devices that are capable of identifying and receiving the voice communications then receive the conversation or message. (Figure 2.2) shows the basic operation of voice broadcast service. This example shows how an urgent news message (traffic alert) can be sent to all mobile devices that are operating within the same radio coverage area.

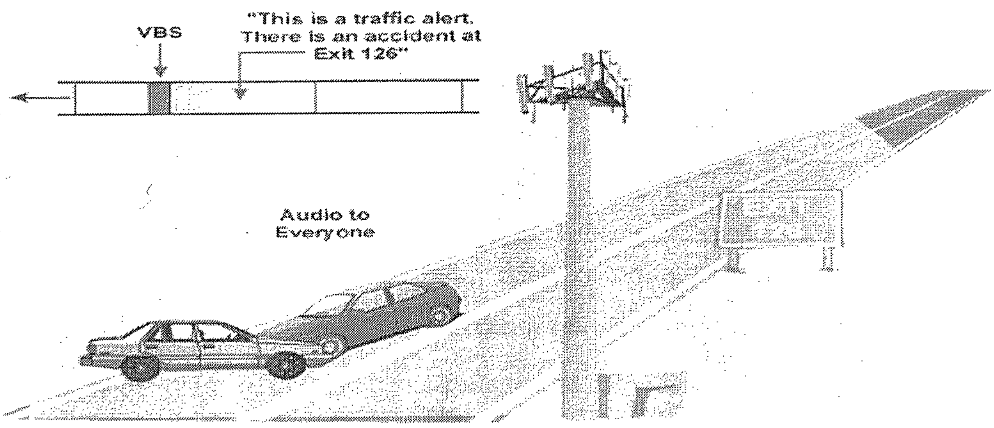

Figure 2.2 Voices Broadcast Service (VBS)

2.3 Data Services

Data Services are communication services that transfer information between two or more devices. Data services may be provided in or outside the audio frequency band through a communication network. Data service involves the establishment of physical and logical communication sessions between two (or more) users that allows the non-real time or near-real time transfer of data (binary) type signals between users.

When data signals are transmitted on a non-digital channel (such as an analog telephone line), a data modem must be used. The data modem converts the data signal (digital bits) into tones that can be transferred in the audio frequency band. Because the speech coder used in the GSM system only compresses voice signals and not data modem signals, analog modem data cannot be sent on a GSM traffic (voice) channel. When data signals are transmitted on a GSM radio channel, a data transfer adapter (DTA) is used. The DTA converts the data bits from a computing device into a format that is suitable for transmission on a communication channel that has a different data transmission format. DTAs are used to connect communication devices (such as a PDA or laptop) to a mobile device when it is operating on a GSM digital radio channel. The data services that the GSM system can provide include low-speed circuit switched data to medium speed packet data.

2.3.1 Circuit Switched Data

Circuit switched data is a data communication method that maintains a dedicated communications path between two communication devices regardless of the amount of data that is sent between the devices. This gives to communications equipment the exclusive use of the circuit that connects them, even when the circuit is momentarily idle. To establish a circuit-switched data connection, the address is sent first and a connection (possibly a virtual non-physical connection) path is established. After this path is setup, data is continually transferred using this path until the path is disconnected by request from the sender or receiver of data.

2.3.2 Packet Switched Data

Packet switched data is the transfer of information between two points through the division of the data into small packets. The packets are routed (switched) through the network and reconnected at the other end to recreate the original data. Each data packet contains the address of its destination. This allows each packet to take a different route through the network to reach its destination. To provide packet data service, the GSM system uses general packet radio service (GPRS). GPRS is a portion of the GSM specification that allows packet radio service on the GSM system. The GPRS system adds (defines) new packet control channels and gateways to the GSM system.

GPRS packet-switched data service is an "always-on" type of service. When the GSM device is initially turned on, it takes only a few seconds to obtain an IP address that is necessary to communicate with the network. Even when the GSM device is inactive and placed in the dormant state, reconnection is typically less than 1/2 a second.

2.3.3 Fax Services

Fax service is the transmission of facsimile (image) information between users. Facsimile signals have characteristics that are very different than audio signals. As a result, fax transmission involve the use of a communication channel that can send all audio frequencies or a data channel that is setup specifically for the transmission of fax information. Facsimile signals cannot be sent through the GSM speech coder. This requires the mobile telephone and GSM system to be setup for facsimile transmission. This may be automatically accomplished when a fax machine is connected to a GSM telephone or adapter or it may be manually accomplished through a keypad operation.

2.4 GSM NETWORK

GSM networks consist of cell site radio towers, communication links, switching center(s) and network databases and link to public telephone and data networks. The main switching system in the GSM wireless network is the mobile switching center (MSC). The MSC coordinates the overall allocation and routing of calls throughout the wireless system. Inter-system connections can link different wireless network systems to allow wireless telephones to move from cell site to cell site and system to system. The GSM system defines inter-system connections in detail to allow universal and uniform service availability GSM wireless devices.

(Figure 2.3) shows that the Base Station (BTS) contains a radio transceiver (radio and transmitter) that converts the radio signal into a data signal (data and digital voice) that can transfer through the network.

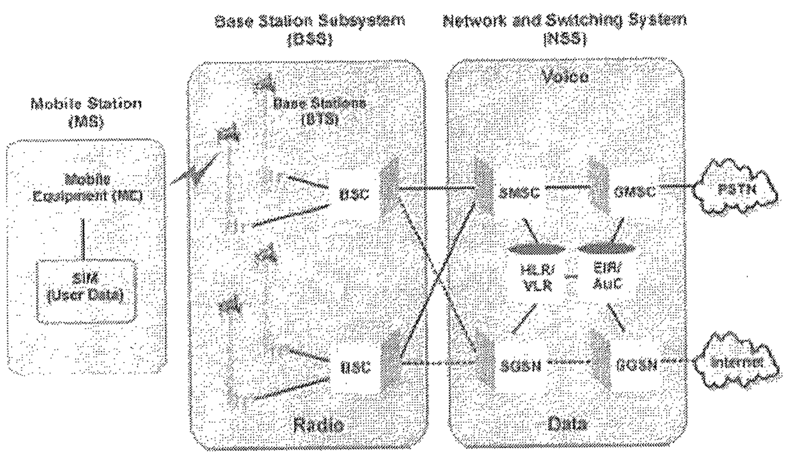

Figure 2.3 GSM Network Parts

2.4.1 Base Stations

Base stations may be stand alone transmission systems that are part of a cell site and is composed of an antenna system (typically a radio tower), building, and base station radio equipment. Base station radio equipment consists of RF equipment (transceivers and antenna interface equipment), controllers, and power supplies. Node B transceivers have many of the same functional elements as a wireless telephone. However, base station radios are coordinated by the GSM system's BSC and have many additional functions than a mobile telephone.

The radio transceiver section is divided into transmitter and receiver assemblies. The transmitter section converts a voice signal to RF for transmission to wireless telephones and the receiver section converts RF from the wireless telephone to voice signals routed to the MSC or packet switching network. The controller section commands insertion and extraction of signaling information. Unlike the wireless telephone, the transmit, receive, and control sections of a Node B base station are usually grouped into equipment racks. For example, a single equipment rack may contain all of the RF amplifiers or voice channel cards. Unlike analog or early-version digital cellular systems that dedicated one transceiver in each base station for a control channel, the UMTS system combines control channels and voice channels are mixed on a single physical radio channel. The components of a base station include transceiver assemblies, usually mounted in an equipment rack, each containing multiple assemblies or modules, one for each 5 MHz RF channel.

Base station components include the voice or data cards (sometimes called line cards), radio transmitters and receivers, power supplies, and antenna assemblies. Analog base stations are equipped with a radio channel scanning receiver (sometimes called a locating receiver) to measure wireless telephones' signal strength and channel quality during handover. The UMTS handover process has the advantage of using both base station receiver channel monitoring and radio channel quality information provided back to the system by the wireless telephones (radio signal strength and bit error rate) to assist in the handover process. This information greatly improves the RNCs hand-off decisions.

2.4.2 Radio Antenna Towers

Wireless base station antenna heights can vary from a few feet to more than three hundred feet. Radio towers raise the height of antennas to provide greater area coverage. There may be several different antenna systems mounted on the same radio tower. These other antennas may be used for paging systems, a point to point microwave communication link, or land mobile radio (LMR) dispatch systems. Shared use of towers by different types of radio systems in this way is very common, due to the economies realized by sharing the cost of the tower and shelter. However, great car must be taken in the installation and testing to avoid mutual radio interference between the various systems. A typical cell site antenna system has multiple antennas. One antenna is used for transmitting and two are used for reception for each radio coverage sector. In some cases, where space or other limitations prevent the use of three separate antennas, two antennas may be used, with one of the two serving as both a transmitter and a receiving antenna, and the other as a receiving antenna only.

Special radio frequency filters are used with the shared antenna to prevent the strong transmit signal from causing deleterious effects on the receiver. The basic antenna options are monopole mount, guy wire, free standing, or man made structures such as water towers, office buildings, and church steeples. Monopole heights range from 30-70 feet; free standing towers range from 20-100 feet; and guy wire towers can exceed 300 feet. Cell site radio antennas can also be disguised to fit in with the surroundings.

2.4.3 Radio Equipment

A radio transmitter in the base station contains audio processing, modulation, and RF power amplifier assemblies. An audio processing section converts digital audio signals from the communications link to channel coded and phase shift modulated signals. The transmitter audio section also inserts control information such as power control messages to the wireless telephone. A modulation section converts the audio signals into proportional phase shifts at the carrier frequency.

The RF power amplifier boosts the signal too much higher power levels. This is typically several Watts per RF communication channel compared to the low power of the wireless telephone (typically much less than 1 Watt). In the UMTS system, the transmitter power level for the control channel is usually fixed to define the cell boundaries (e.g. a control channel). The power level of dedicated (individual) channels may dynamically change to the lowest level possible that allows quality communication with the wireless telephone. This reduction in energy level reduces the overall interference to other wireless telephones that are operating in neighboring cells.

2.4.4 Communication Links

Communication links carry both data and voice information between the MSC, BSCs and the base stations. Options for the physical connections include wire, microwave, or fiber optic links. Alternate communication links are sometimes provided to prevent a single communication link failure from disabling communication . Some terrain conditions may prohibit the use of one type of communication link. For example, microwave systems are not usually used in extremely earthquake-prone areas because they require precise line-of-sight connection. Small shifts in the earth can miss-align microwave transceivers to break communications. Regardless of the physical type of communication link, the channel formats usually the same. Communication links are typically digital time-multiplexed to increase the efficiency of the communication line. The standard format for time-multiplexing communication channels between cell sites in North America is the 24 channel T1 line, or multiple T1 channels. The standard format outside of North America is the 32 channel (30 useable channels) E1 line.

2.5 GSM Products and Mobile Devices

GSM mobile devices (also called mobile stations) are voice and/or data input and output devices that are used to communicate with a radio tower (cell sites). GSM end user devices include removable subscriber identity modules (SIMs) that hold service subscription on information. The common types of available GSM devices include mobile telephones, PCMCIA cards, embedded radio modules, and external radio modems.

2.5.1 Subscriber Identity Module (SIM)

A subscriber identity module (SIM) is an "information" card that contains service subscription identity and personal information. The SIM card contains at least two numbers that identifies the customer, the international mobile subscriber identity (IMSI) and a secret authentication key number K.

The SIM contains a microprocessor, memory and software to hold and process information that includes a phone number, billing identification information and a small amount of user specific data (such as feature preferences and short messages). This information can be toted in the card rather than programming this information into the phone itself. A SIM card can be either credit card-sized (ISO format) or the size of a postage-stamp (Plug-In format).

SIM cards can be inserted into any SIM ready communication device. Access to a SIM card usually requires the use of a personal identity number (PIN) to restrict access to the SIM card to people who don't know the code. SIM cards may also be locked to the communication device by a SIM lock code (the service provider only knows the SIM lock code). The SIM lock code ensures that a communication device will only work with one or a group of subscriber identity module (SIM) cards.

The use of a SIM lock code by a service provider helps to ensure that a customer will only be able to use a communication device they provide at low cost with their SIM cards. If another SIM card is inserted to a communication device that is locked to a specific SIM card, the communication device will not operate.

2.5.2 Mobile Telephones

Mobile telephones are radio transceivers (combined transmitter and receives) that convert signals between users (typically people, but not always) and radio signals. Mobile telephones can vary from simple voice units to advance multimedia personal digital assistant ants (PADs). GSM mobile telephones may only include GSM capability (single mode) or it may include GSM and other types of wireless capability (dual mode). GSM mobile device may be only able to receive on one frequency band (single band) or two or more frequency bands (dual band or tri-band).

2.5.3 PCMCIA Air Cards

The PCMCIA card uses a standard physical and electrical interface that is used to connect memory and communication devices to computers, typically laptops. The physical card sizes are similar to the size of a credit card 2.126 inches (51.46 mm) by 3.37 inches 69.2 mm) long. There are 4 different card thickness dimensions: 3.3 (type 1), 5.0 (type 2), 10.5 (type 3), and 16 mm (type 4). GSM PCMCIA radio cards can be added to most laptop computers to avoid the need of integrating or attaching radio devices.

2.5.4 Embedded Radio Modules

Embedded radio modules are self contained electronic assemblies that may be inserted or attached to other electronic devices or systems. Embedded radio modules may be installed in computing devices such as personal digital assistants (PDAs), laptop computers, and other types of computing devices that can benefit from wireless data and/or voice connections.

2.5.5 External Radio Modems

External radio modems are self contained radios with data modems that allow the customer to simply plug the radio device into their USB or Ethernet data port on their desk-top or laptop computer. External modems are commonly connected to computers via standard connections such as universal serial bus (USB) or RJ-45 Ethernet connections.

(Figure 2.4) shows the common types of GSM products available to customers. This diagram shows that the product types available for GSM include single mode, dual mode and dual frequency mobile telephones, PCMCIA data cards, embedded radio modules, and external radio modems. GSM mobile telephones may be capable of operating on other systems (dual mode) or multiple frequencies. Small radio assemblies (modules) may be inserted (embedded) into other devices such as laptop computers or custom communication devices.

PCMCIA data cards may allow for both data and voice operations when inserted into portable communications devices such as laptops or personal digital assistants (PDAs). External modems may be used to provide data services to fixed users (such as desktop computers).

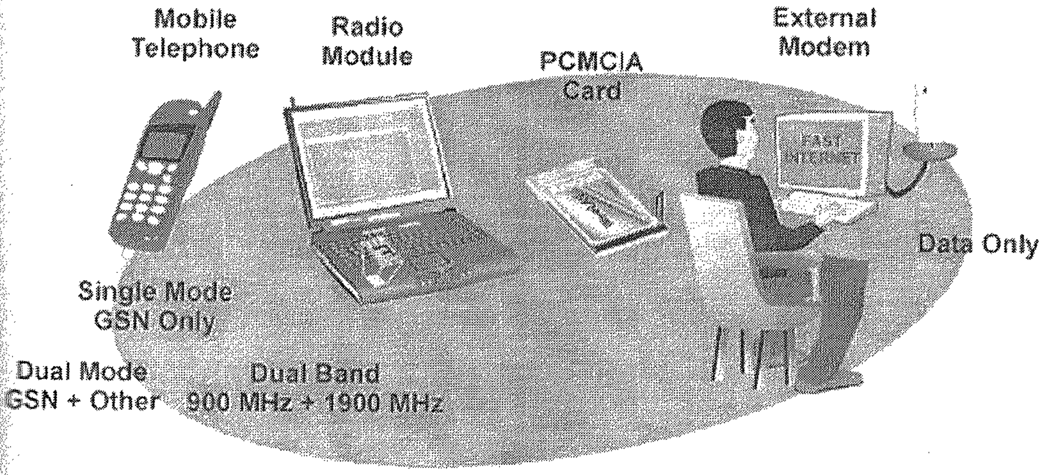

Figure 2.4 GSM Product Types

2.6 GSM Future Evolution

The evolution of GSM includes packet data transmission rates and high speed data wideband code division multiple access (WCDMA).

2.6.1 Enhanced Data for Global Evolution (EDGE)

Enhanced data for global evolution is an evolved version of the global system for mobile (GSM) radio channel that uses new phase modulation and packet transmission to provide for advanced high-speed data services. The EDGE system uses 8 level phase shift keying (8PSK) to allow one symbol change to represent 3 bits of information. This is 3 times the amount of information that is transferred by a standard 2 level GMSK signal used by the first generation of GSM system. This results in a radio channel data transmission rate of 604.8 kbps and a net maximum delivered data transmission rate of approximately 474 kbps.

The advanced packet transmission control system allows for constantly varying data transmission rates in either direction between mobile radios. (Figure 2.5) shows how a standard GSM radio channel is modified to use a new, more efficient modulation technology to create a high-speed packet data EDGE system. The EDGE system uses either 8 level quadrate phase shift keying (QPSK) modulation or the standard GMSK modulation (used by 2nd generation GSM systems.) This allows EDGE technology to be merged on to existing GSM systems as standard GSM mobile telephones will ignore the EDGE modulated time slots that they cannot demodulate and decode.

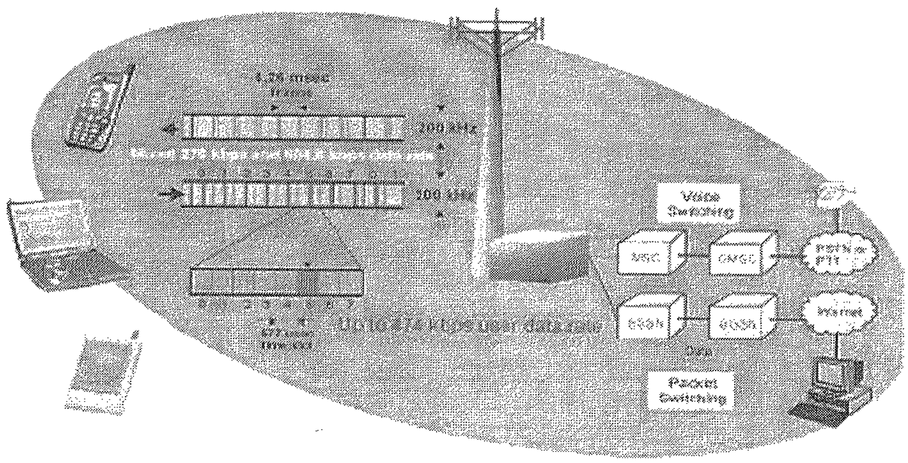

Figure 2.5 Edge System

2.6.2 Wideband Code Division Multiple Access (WCDMA)

Wideband code division multiple access is a 3rd generation mobile communication system that uses wideband code division multiple access (WCDMA) technology. The WCDMA infrastructure is compatible with GSM mobile radio communication system. WCDMA provides for high-speed data and voice communication services. Installing or upgrading to WCDMA technology allows mobile service providers to offer their customers wireless broadband (high-speed Internet) services and to operate their systems more efficiently (more customers per cell site radio tower). The WCDMA system is composed of mobile devices (wireless telephones and data communication devices called user equipment - UE), radio towers (cell sites called Node Bs), and an interconnection system (switches and data routers). The WCDMA system uses two types of radio channels; frequency division duplex (FDD) and time division duplex (TDD). The FDD radio channels are primarily used for wide area voice (audio) channels and data services. The TDD channels are typically used for systems that do not have the availability of dual frequency bands. Figure 2.6 shows a simplified diagram of a WCDMA system.

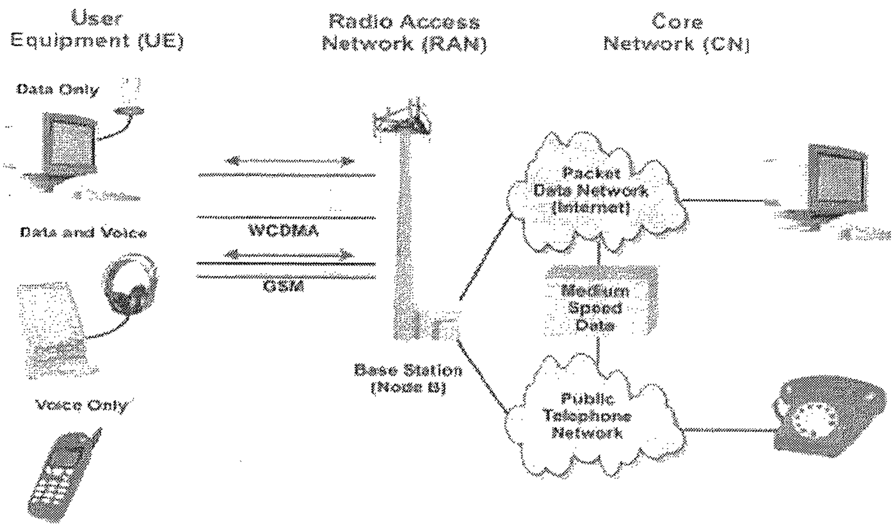

Figure 2.6 WCDMA System

(Figure 2.6) shows that the WCDMA system includes various types of mobile communication devices (called user equipment - UE) that communicate through base stations (node B) and a mobile switching center (MSC) or data routing networks to connect to other mobile telephones, public telephones, or to the Internet via a core network (CN). This diagram shows that the WCDMA system is compatible with both the 5 MHz wide WCDMA radio channel and the narrow 200 kHz GSM channels. This example also shows that the core network is essentially divided between voice systems (circuit switching) and packet data (packet switching).

CHAPTER 3

LOW-COST LOW-POWER RADIOS

As radios decrease their cost and power consumption, it becomes feasible to embed them in more types of electronic devices, which can be used to create smart homes, sensor networks, and other compelling applications.

3.1 Bluetooth

The Bluetooth standard is named after Harald I Bluetooth, the king of Denmark between 940 and 980 AD. Bluetooth is a standard for short range, low power, low cost wireless communication that uses radio technology. Although originally envisioned as a cable-replacement technology by Ericsson (a major cell phone manufacturer) in 1994, embedded Bluetooth capability is becoming widespread in numerous types of devices. They include intelligent devices (PDAs, cell phones, PCs), data peripherals (mice, keyboards, joysticks, cameras, digital pens, printers, LAN access points), audio peripherals (headsets, speakers, stereo receivers), and embedded applications (automobile power locks, grocery store updates, industrial systems, MIDI musical instruments).

Ericsson joined forces with Intel Corporation, International Business Machines Corporation (IBM), Nokia Corporation, and Toshiba Corporation to form the Bluetooth Special Interest Group (SIG) in early 1998. 3Com Corporation, Lucent/Agere Technologies Inc., Microsoft Corporation and Motorola Inc. joined the group in late 1999. Bluetooth technology is already supported by over 2100 companies around the world. The Wireless Personal Area Network (WPAN) technology, based on the Bluetooth Specification, is now an IEEE standard under the denomination of 802.15 WPANs.

3.1.1 Bluetooth specification

a. The piconet

The Bluetooth specification defines a piconet as an ad-hoc, spontaneous clustering of Bluetooth devices. In it, one device holds the role of master, while the rest of the devices are slaves. While there is no limit to the total number of slaves in a piconet, a maximum of seven slaves can be active in a piconet at any given point in time. If there are more than seven slaves, the rest of the slaves must be "parked." To reactivate a parked slave, the master must first place a currently active slave into a parked state. When two Bluetooth devices enter into communication range, they will attempt to communicate with each other. If no piconet is available at that time, a negotiation process will ensue. One device will become the master (usually the device which initiated the communication) and the other will become a slave.

b. Bluetooth device as a master and slave

A master and slave must exchange address and clock information in order for the slave to join the master's piconet (figure 3.1). Bluetooth devices each have a unique Global ID used to create a hopping pattern. The master radio shares its Global ID and clock offset with each slave in its piconet, providing the offset into the hopping pattern. A slave must be able to recreate the frequency-hopping sequence of the piconet it has joined, must know which frequency to use at which time, and must synchronize itself with the master's clock. The slave device does not actually adjust its own clock. Rather it tracks the amount of clock drift between its clock and the master's, and adjusts its transmission schedule accordingly.

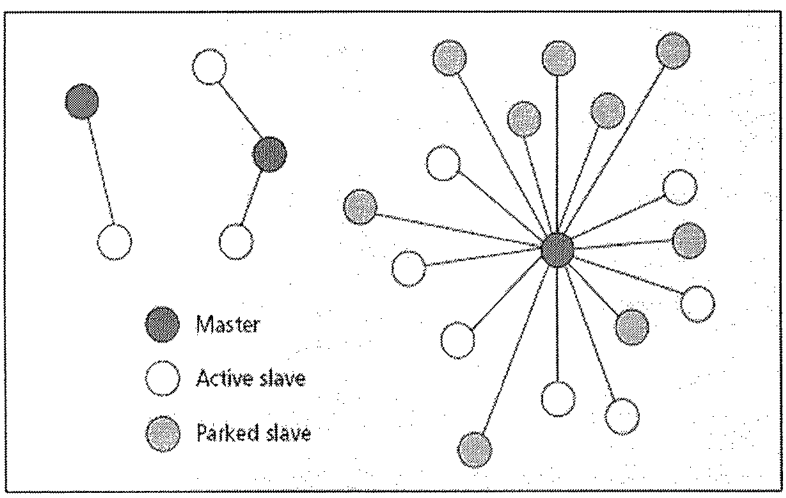

Figure 3.1 Piconet configurations.

c. Bluetooth Scatternet.

A bridge device may be a slave in all of the piconets to which it is connected, or it may be a master in one piconet and a slave in the others. The interconnection of two or more piconets via bridge devices results in the formation of a Bluetooth scatternet (figure3.2).

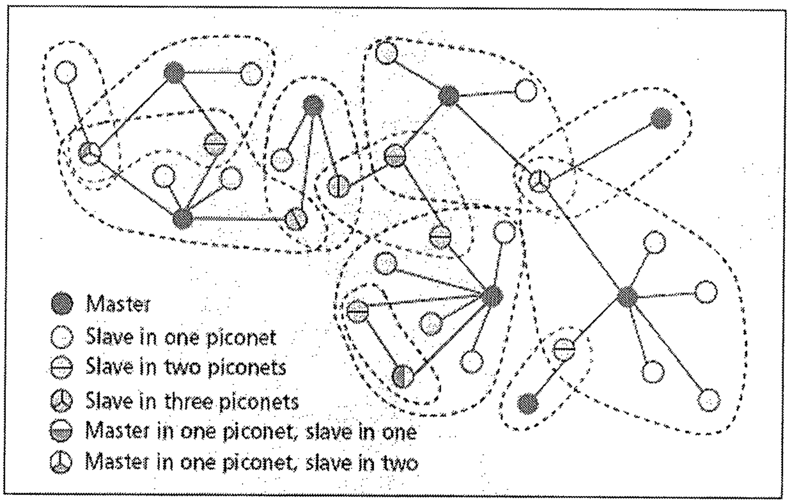

Figure 3.2 A complex scatternet configuration.

3.1.2 Power Management in Bluetooth

There are two main states are defined for Bluetooth devices:

In standby, no data are exchanged, only the clock is running.

Each device is connected with the master of the piconet. Four sub states are possible:
Active mode: The device is active in the piconet.
Sniff mode: This is a low-power-consumption state as the listening activity is working during sniff slots only.
Hold mode: The ACL traffic of a device is stopped for a certain period.
Park mode: The device is no longer a member of the piconet, but remains synchronized with the master of the piconet; this is the lowest power- consuming state.

3.1.3 Bluetooth Spectrum

Bluetooth devices use the 2.4 GHz band, which is unlicensed in most countries (in the United States it is known as the industrial, scientific, and medical, (ISM) band). In most European countries and the United States, 79 1-MHz-wide channels are allocated, while only 23 channels are allocated in France, Spain, and Japan.

3.2 WI MAX

WiMax, an acronym that stands for Worldwide Interoperability for Microwave Access and is based on point to point broadband wireless access and working on the group no. 16 of IEEE 802 i.e. IEEE 802.16. WiMax is known as one of the broadband fixed wireless access solutions for the "Last mile" and designed to address the MAN market.

3.2.1 Features of WiMax

Uses Microwaves for the Wireless Transfer of Data

- It stands for Wireless (WI) microwave access (MAX).
- It is used for high-speed, wireless networking at distances of a few kilometers.
- It Uses OFDM (which allows for non line-of sight communications and addresses multipath issues).
- It Includes TDD and FDD duplexing support.
- It has flexible channel sizes (3.5MHz, 5 MHz, 10 MHz).

3.2.2 WiMax Promises

- Up to thirty one (31) mile range without wires.
- Broadband speeds without cable or TI.
- Handles "last mile" access in remote areas.
- Licensing and equipment due in future.
- Affordable technology.

3.2.3 Standard based.

The Wi-MAX standard has fragmented into two variants: 802.16a, the original Wi-MAX standard, which can transfer at up to 70Mbps over distances of as much as 30 miles using the 10GHz and 66GHz spectrums. 802.16e. A more recent development which will operate in the 2GHz - 6GHz licensed bands, bringing the possibility of mobile devices using the technology.

3.2.4 Frequency under considerations

The WiMAX Forum expects that initial deployment will occupy frequency bands in the 5 GHz (license-exempt) and 2.5 GHz (licensed) bands.

- License-exempt 5 GHz. The frequency ranges of interest to WiMAX are bands between 5.25 and 5.28 GHz. This range is strategic for initial deployment especially in rural areas with a low population density.
- Licensed 3.5 GHz. Bands between 3.4 GHz and 3.6 GHz have been allocated for fixed wireless access in most countries (the US is an exception).
- Licensed 2.5 GHz. Bands between 2.5 GHz and 2.7 GHz have been allocated in the US, Mexico, Brazil, and some Southeast Asian countries.

3.2.5 WiMAX network architecture

WiMAX architecture is similar to the cellular telephony in that a service area is divided into cells WiMAX is able to operate in a Line Of Sight (LOS) and near or non LOS (NLOS) access approach. With its large range and high transmission rate, WiMAX can serve as a backbone for 802.11 hotspots for connecting to the Internet. Mobile devices connected directly to WiMAX base stations likely will achieve a range of 5 to 6 miles, because mobility makes links vulnerable (figure 3.3).

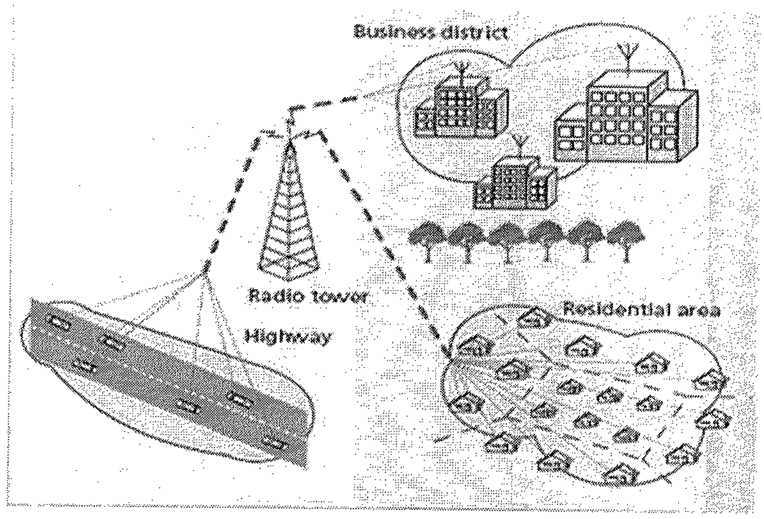

Figure 3.3 Wi MAX Network architecture

Currently, several companies offer proprietary solutions for wireless broadband access, many of which are expensive because they use chipsets from adjacent technologies, such as 802.11. Many companies that were offering proprietary solutions, however, have participated in the WiMAX Forum and now offer WiMAX based solutions.

3.2.6 WiMAX Development

Since the WiMAX Forum was established in 2001, several developments from the industry have jump-started the technology (figure3.4). Early developments came through the deployment of (precertification) WiMAX networks. In all, more than 150 commercial trials and WiMAX network deployments have taken place. One of the latest deals was between GlobeTel Wireless and Moscow-based Internafta in January 2006 to provide as many as 30 Russian cities with WiMAX-based wireless broadband. Since January 2006, the WiMAX Forum has been certifying products for fixed access based on 802.16-2004.

The products were tested at the WiMAX Forum's certification lab in Spain, and some 20 other manufacturers have reserved testing slots at the lab. Also in January 2006, Samsung revealed its WiMAX enabled M8000 handset, which connects directly to WiMAX base stations through 802.16e. The M8000 runs on a Windows Mobile operating system and provides entertainment and communication through a broadband connection.

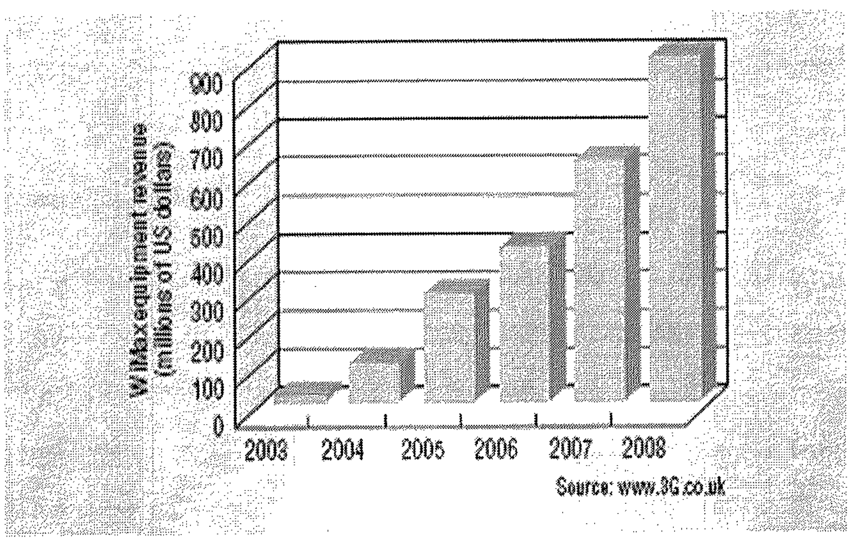

Figure 3.4 As WiMax technology becomes more popular, equipment sales are expected to grow significantly.

3.3 WiFi

WiFi stands for wireless fidelity and generally refer to any type of 802.11 networks, whether 802.1lb, 802.1la, 802.11g. WiFi is a wireless technology that uses radio frequency to transmit data through the air. WLAN access point or hub or transmitter sends out a wireless signal that allows Wireless devices to access within a circle of roughly 100 meters. Zone around the transmitter is known as hot spot. Computers connected to WiFi receivers near a hot spot can connect to Internet at high speeds without cable. WiFi refers to three types of wireless protocols that can work with each other: IEEE 802.1 lb ("Wireless B"), IEEE 802.1 la ("Wireless A"), and the newer IEEE 802.1lg ("Wireless G"). They can connect computers very fastly: 11 Mbps for Wireless B, 54Mbps for Wireless A, and 54Mbps for Wireless G.

3.3.1 Advantages of WiFi

- It Uses an unlicensed portion of the broadcast spectrum, and requires less regulatory controls in many countries.
- It frees network devices from cables, allows for a more dynamic network to be grown.
- Many reliable and bug-free WI-Fl products on the market.
- Competition amongst vendors has lowered prices considerably since their inception.

It is possible to move without breaking the network connection while connected on a WiFi network.

3.3.2 Disadvantages of WiFi

- The 802.11g and 802.11b standards of WiFi use the 2.4 GHz spectrum, which is crowded with other devices such as blue tooth, microwave ovens, and cordless phones. It may cause degradation in performance.
- Power consumption is fairly high compared to other standards, making battery life and heat a matter of concern. WiFi networks have limited range. A typical WiFi home router using 802.1 lb or 802.1 1g has a range of 150 ft (46 m) indoor and 300 ft (92 m) outdoors.

3.3.3 Architecture

a. WIFI building block

Block diagram shows mapping of the IEEE 802.11 requirements into a functional WiFi building block. The WiFi building blocks as shown in (figure3.5).

1. Antenna
2. Access Point (AP)
3. Router
4. Internet access

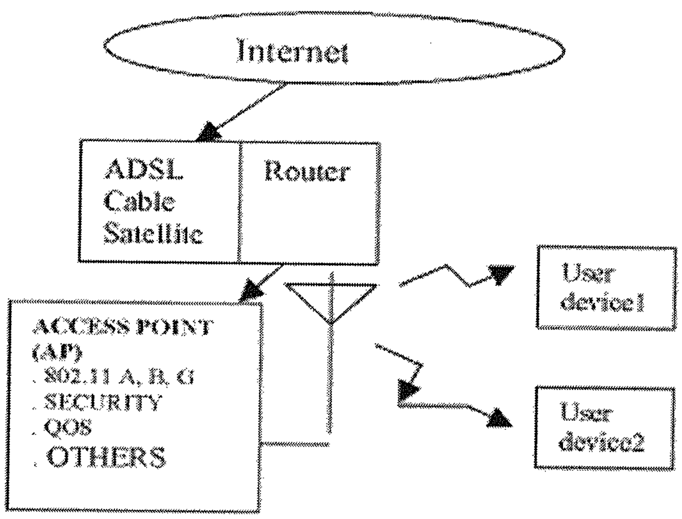

Figure 3.5 WiFi Sketch

b. WiFi Network Cell

WiFi network cell for 802.1 lb standard, this standard defines 11 channels (figure 3.6), the RF reach of each channel is about 160 ft in doors or about 300ft outdoors. There're three non-overlapping channels (channels, 1, 6, and 11). Channels 1, 6, and 11 are typically used to cover a large area.

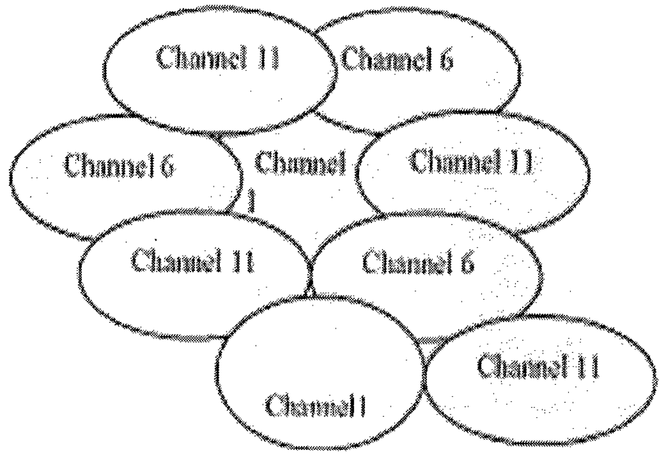

Figure 3.6 Channel allocation for WI FI

3.3.4 Network architecture

A network is established when a station(s) and APs have recognized each other and established a communication link. A network can be configured in two basic ways:

- Ad hoc (Peer-to-peer) network
- Infrastructure network

a. Ad hoc (Peer-to-peer) network

In this configuration, two or more stations can talk to each other without an AP. This arrangement is referred to as an Independent Basic Service Set (IBSS). Access to the wired network (Internet) is accomplished at the station that has the Internet access port.

b. Infrastructure network

This configuration consists of multiple stations connected to an AP. The AP acts as a bridge to the wired network. This arrangement is referred to as a Basic Service Set (BSS). WiFi supports various network types:

- Hub and spoke
- Mesh network.

3.4 Zig Bee

The whimsical name comes from the ZigBee principle, the zig-zag dance bees do to tell their colony mates the location, distance and direction of new food sources.

The ZigBee radio specification is designed for lower cost and power consumption than Bluetooth. The specification is based on the IEEE 802.15.4 standard. The radio operates in the same ISM band as Bluetooth, and is capable of connecting 256 devices per network. The goal of ZigBee is to provide radio operation for months or years without recharging, thereby targeting applications such as sensor networks and inventory tags.

3.4.1 History

ZigBee style networks began to be conceived near1998, when many engineers realize that both WiFi and Bluetooth were going to be unsuitable for many applications. Philips, Motorola, Honeywell, Invensys and Mitsubishi electric started promoting ZigBee when they formed the ZigBee alliance in October 2002. The ZigBee alliance's announced in October 2004 that its membership had more than doubled in the past year and had grown to more than 100 member companies, in 22 countries. By April 2005 membership had grown to more than 150 companies. The ZigBee specifications were ratified on 14 December 2004. The ZigBee alliance announces public availability of specification 1.0 on 13 June 2005.

3.4.2 Device Types

There are three different types of ZigBee devices: The most capable is a "ZigBee coordinator". It might bridge to other networks, and forms the root of network tree. It is able to store information about network. There is exactly one ZigBee coordinator in each network. A "full function device "(FFD) can act as an intermediate router, passing data from other devices. A "reduced function device"(RFD) is just smart enough to talk to the network; it control relay data from other devices.

3.4.3 Protocols

The ZigBee protocols support both beaconing and non-beaconing networks. In beaconing networks, the network node transmit beacons to confirm their presence to other network nodes, and to allow nodes to sleep between beacons, thereby lowering their duty cycle and extending their battery life. In non-beaconing, networks, most devices typically have their receivers continuously active, requiring a more robust power supply; however, this enables heterogeneous networks, in which some devices receive continuously while some remain asleep. In general the ZigBee protocols minimize the time the radio is on in order to reduce the power used by the radio.

3.4.4 ZigBee Spectrum

The ZigBee standard can operate in the 2.4 GHz band or the 868 MHz and 915 MHz ISM (industrial, scientific and medical) bands used in Europe and thus respectively. It sits below Bluetooth in terms of data rate: 250kbps at 2.4GHZ (Compared to Bluetooth's 1Mbps) and 20-40 kbps in the lower frequency bands. The operational range is 10-75m, compared to 10m for Bluetooth. ZigBee uses a basic master-slave configuration suited to static star networks of many infrequently used devices that talk via small data packets. This aspect suits ZigBee to building automation and control of multiple lights, security sensors and so on.

3.4.5 Uses

ZigBee is aimed at applications with low data rates and low power consumption. ZigBee current focus is to define a general-purpose, inexpensive self-organizing mesh network that can be shared by industrial controls, medical devices, smoke and intruder alarms, building automation and home-automation. The network is designed to use very small amounts of power, so that individual devices might run for a year or two with a single alkaline battery. ZigBee chips will open up the market for remote wireless control of light fitting, heating, ventilation and security systems in commercial and residential buildings.

3.5 Ultrawideband Radios

Ultrawideband (UWB) radios are extremely wideband radios with very high potential data rates. The concept of Ultrawideband communications actually originated with Marconi's spark gap transmitter, which occupied a very wide bandwidth. However, since only a single low-rate user could occupy the spectrum, wideband communications was abandoned in favor of more efficient communication techniques. The renewed interest in wideband communications was spurred by the FCC's decision in 2002 to allow operation of UWB devices as system underlayed beneath existing users over a 7

GHz range of frequencies. These systems can operate either at baseband or at a carrier frequency in the 3.6-10.1 GHz range. The underlay in theory interferers with all systems in that frequency range, including critical safety and military systems, unlicensed systems such as 802.11 wireless and Bluetooth, and cellular systems where operators paid billions of dollars for dedicated spectrum use. The FCC's ruling was quite controversial given the vested interest in interference-free spectrum of these users. To minimize the impact of UWB on primary band users, the FCC put in place severe transmit power restrictions. This requires UWB devices to be within close proximity of their intended receiver.

3.5.1 Ultrawideband Applications

UWB radios come with unique advantages that have long been appreciated by the radar and communications communities. Their wideband nature allows UWB signals to easily penetrate through obstacles and provides very precise ranging capabilities. Moreover, the available UWB bandwidth has the potential for very high data rates. Finally, the power restrictions dictate that the devices can be small with low power consumption. Short-range very high-speed broadband access to the Internet, covert communication links, localization at centimeter-level accuracy, high-resolution ground-penetrating radar, through-wall imaging, precision navigation and asset tracking, just to name a few.

Ultra-wide band is a developing communication technology that delivers very high speed wireless network data exchange rates (up to 80Mb/s) across relatively short distances (less than 10 m) with a low power source (UWB operates at low energy – reducing interference and power requirements. Although the connection speed decreases quickly as a function of distance, wireless UWB has the potential to replace the cables that currently connect devices. UWB can also use main wiring , co0 ax cable or twisted-pair cables to communicate with potential to deliver data faster than 1 gigabit per second. Recently, both Bluetooth and USB stakeholders have expressed an interest in using UWB at the core of their next generation standards.

3.5.2 Standard

There are a number of competing standards which makes universally compatible UWB products problematic in the short term. UWB signaling is being considered a potential candidate for the alternate physical layers protocol for the high data IEEE 802.15.3a standard as well as the low data rate IEEE 802.15.4a "ZIGBEE" wireless personal area network (WPAN). The IEEE 802.15.4a standard aims at providing a physical layer wireless communication protocol with ranging capabilities for low power applications such as sensor networks. The narrow duration of the UWB pulses unable is achieving stringent (<1m) ranging requirements.

CHAPTER 4

PULSE CODE MODULATION (PCM)

4.1 Quantization

Dealing with analog sources, a precise description of the source requires an infinite number of bits/source outputs, which is not an achievable goal. Therefore in transmission of analog sources some distortion is always present, and the goal is to minimize this distortion the rate distortion function which gives a fundamental limit on the tradeoff between the code rate and the distortion.

The fundamental limit promised by the rate-distortion function can only be approached asymptotically, that is by using very complex decoders and encoders .the encoder observes source outputs of length n, $x \in \chi^n$, and maps them into representation sequences of length n, $\hat{x}^n \in \hat{\chi}^n$. The number of the latter sequences is 2^{n^R} and therefore R bits/source output are required for their transmission. The larger the value of n, the closer to the rate distortion limit the system operates. This means that an effective quantization scheme should work on blocks of source outputs rather than single source outputs. Quantizers that operates on block of source output are called "vector quantizers," as opposed to" scalar quantizers," which quantize single source outputs.

The classification of quantizers into scalar and vector quantizers, one can classify quantizers on the bases of there general method for compressing data. As either waveform coders or analysis synthesis coders. in waveform coding for data compression, the output of the source, which is a waveform is compressed using one of several compression schemes, in analysis synthesis coders, the waveform is not directly compressed and transmitted, instead a model of production of the waveform is adopted and the main parameters of that model are compressed and transmitted. For example in speech coding the mechanism by which speech is produced can be modeled by time varying filter excited by either white noise or a sequence of impulses. In the analysis synthesis approach to speech coding. Parameters of the time varying filter and its inputs are quantized and transmitted. At the receiving end a filter that simulates the behavior of the vocal tract is generated and then excited by the appropriate input and thus a close replica of the waveform is generated .on the positive side. Model based quantization schemes achieve better compression ratios compared to waveform coders.

4.1.1 Scalar Quantization

In scalar quantization each single source output is quantized in to a number of levels and these levels are encoded in to a binary sequence. In general each source output is a real number, but transmission of real number requires an infinite number of bits. Therefore, it is required to map the set of real numbers in to a finite set and, at the same time, minimize the distortion introduced. In scalar quantization, the set of real numbers R is portioned into N disjoint subsets denoted by $\Re_k$, $1 \le k \le N$. Corresponding to each subset $\Re_k$, a representation point $\hat{x}_k$, which usually belongs to $\Re_k$, is chosen. If the source out put at time i, x_i, belongs to $\Re_k$. Then it is represented by $\hat{x}_k$, which is the quantized version of x. $\hat{x}_k$ is then represented by a binary sequence and transmitted. Since there are N possibilities for the quantized levels log N bits are enough to encode these levels into binary sequences (N is generally chosen to be a power of 2). Therefore the number of bits required to transmit each source output is R = log N bits.

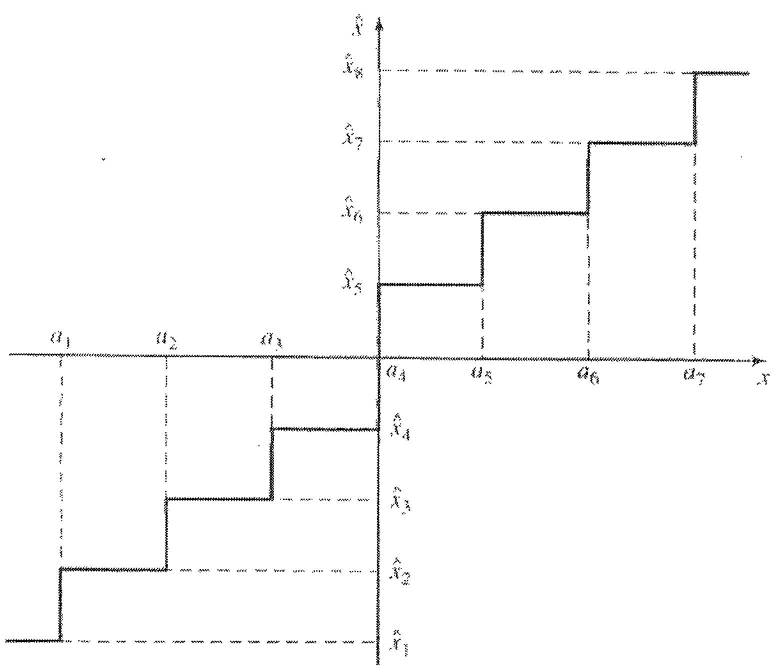

Figure 4 .1 Example of an 8-level quantization scheme

(Figure 4.1) shows an example of an eight-level quantization scheme. In this scheme, the eight regions are defined as $\Re_1 = (-\infty, a_1]$, $\Re_2 = (a_1, a_2]$ ... $\Re_8 = (a_7, +\infty]$ the representation point (or quantized value) in each region is denoted by $\hat{x}_i$ and shown in the figure. The quantization function Q is defined by

$$Q(x) = \hat{x}_i \qquad \text{for all } x \in \Re_i \tag{4.1}$$

This function is also shown in the figure, the quantization function is a non linear function that is non invertible. This is because all points in $\Re_i$ are mapped into a single point $\hat{x}_i$. Because the quantization function is noninvertible, some information is lost in the process of quantization and this lost information is not recoverable. If we are using the squared error distortion measure, then

$$d(x, \hat{x}) = (x - Q(x))^2 = \tilde{x}^2 \tag{4.2}$$

Where $\tilde{x} = x - \hat{x} = x - Q(x)$. Since X is a random variable, so are $\hat{X}$ and $\tilde{X}$, and therefore

$$D = E[d(X, \hat{X})] = E(X - Q(X))^2 \tag{4.3}$$

Definition

If the random variable X is quantized to Q(X), the signal to quantization noise ratio (SQNR) is defined by

$$\text{SQNR} = \frac{E(X^2)}{E(X - Q(X))^2} \tag{4.4}$$

When dealing with signals, the quantization noise power is

$$p_{\tilde{X}} = \lim_{T \to \infty} \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} E(X(t)) - Q(X(t))^2 dt \tag{4.5}$$

And the signal power is

$$p_X = \lim_{T\to\infty} \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} E(X^2(t)) \tag{4.6}$$

Hence the **SQNR** is

$$\text{SQNR} = \frac{P_X}{P_{\tilde{X}}}$$

4.1.2 Uniform Quantization

Uniform quantizers are the simplest examples of scalar quantizers. In a uniform quantizer the entire real line is portioned into n regions. All regions expect $\Re_1$ and $\Re_N$ are of equal length, which is denoted by Δ. This means that for all $1 \le i \le N-1$, we have $a_{i+1} - a_i = \Delta$. (Figure 4.1) is an example of an 8-level uniform quantizer. In a uniform quantizer, the distortion is given by

$$D = \int_{-\infty}^{a_1} (x-\hat{x}_1)^2 f_x(x)dx + \sum_{i=1}^{N-2} \int_{a_i+(i-1)\Delta}^{a_i+i\Delta} (x-\hat{x}_{i+1})^2 f_x(x)dx + \int_{a_1+(N-2)\Delta}^{\infty_1} (x-\hat{x}_N)^2 f_x(x)dx \tag{4.7}$$

it is seen from equation, that D is a function of N+2 design parameters, namely a_1, Δ, and $\{\hat{x}_i\}_{i=1}^{N}$, in order to design the optimal uniform quantizer, one has to differentiate D with respect to the above variables and find the values that minimize D. further assumption simplify the above relation to some extent. If we assume that $f_X(x)$ is an even function of x (symmetric density function), then the best quantizer will also have symmetry properties. This means that for even n, we will have $a_i = -a_{N-i} = -(\frac{N}{2} - i)\Delta$ for all $1 \le i \le \frac{N}{2}$ (which means $a_{\frac{N}{2}} = 0$), and

$\hat{x}_i = -\hat{x}_{N+1-i}$ for $1 \le i \le \frac{N}{2}$. In this case, we have

$$D = 2\int_{-\infty}^{(-\frac{N}{2}-1)\Delta}(x-\hat{x}_1)^2 f_x(x)dx + 2\sum_{i=1}^{\frac{N}{2}-1}\int_{(-\frac{N}{2}+i)\Delta}^{(-\frac{N}{2}+i+1)\Delta}(x-\hat{x}_{i+1})^2 f_x(x)dx \qquad (4.8)$$

When N is odd, we have a situation such as shown in figure 4.2. In this case $a_i = -a_{N-i} = -(\frac{N}{2} - i)\Delta$, for $1 \le i \le \frac{N+1}{2}$, which means $\hat{x}_{\frac{N+1}{2}}=0$. the distortion is given by

$$D = \int_{-\infty}^{(-\frac{N}{2}+1)\Delta}(x-\hat{x}_1)^2 f_x(x)dx$$

$$+2\sum_{i=1}^{\frac{N-3}{2}}\int_{(--\frac{N}{2}+i)\Delta}^{(-\frac{N}{2}+i+1)\Delta}(x-\hat{x}_1)^2 f_x(x)dx + \int_{\frac{-\Delta}{2}}^{\frac{\Delta}{2}} x^2 f_x(x)dx \qquad (4.9)$$

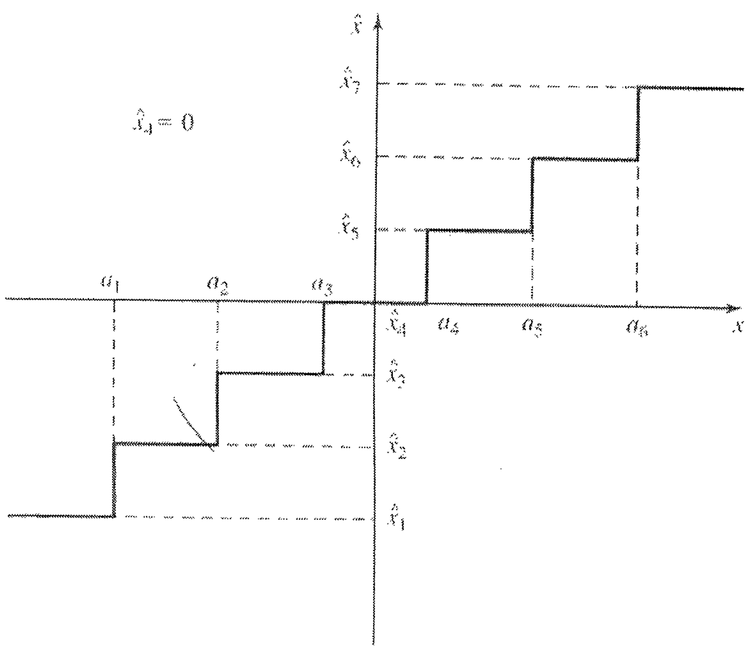

Figure 4. 2 7-level uniform quantizer

Minimization of distortion in these cases, although much simpler compared to the general case, is still a tedious task and is done mainly by numerical techniques.

4.2 Waveform coding

Waveform-coding schemes are designed to reproduce the waveform output of the source at the destination with as small a distortion as possible. In these techniques, no attention is paid to the mechanism that produces the waveform, and all attempts are directed at reproduction of the sores output at the destination with high fidelity. Because the structure of the source plays no role in the design of waveform coders and only properties of the waveform affect the design, waveform coders are robust and can be used with a variety of sources as long as the waveforms produced by the sources have certain similarities.

4.2.1 Pulse-Code Modulation (PCM)

Pulse-code modulation is the simplest and oldest waveform-coding scheme. A pulse-code modulator consists of three basic sections, a sampler, a quantizer, and an encoder. A functional block diagram of a PCM system is shown in (figure 4.3).

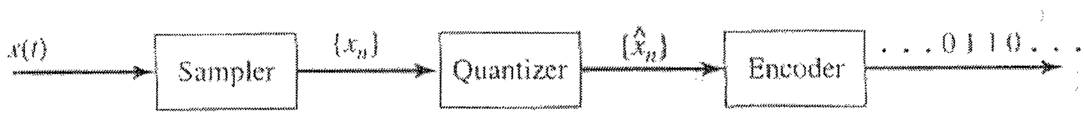

Figure 4.3 Block diagram of PCM system

The waveform entering the sampler is a band limited waveform with band width W. usually there exist a filter with bandwidth W to prevent any components beyond W from entering the sampler. This filter id called the presampling filter. The sampling is done at a rate higher than the Nyquist rate to allow for some guard-band. The sampled values than enter a scalar quantizer, the quantizer is either a uniform quantizer or non uniform quantizer. The choice of a quantizer is based on the characteristics of the source output. The output of quantizer is then encoded in to a binary sequence of length v where N = is the number of quantization levels.

4.2.2 Uniform PCM

In uniform PCM, it is assumed that the range of the input samples is [$-X_{\max}$, $+X_{\max}$] and the number of quantization levels N is a power of 2, $N = 2^{v}$. From this the length of each quantization region is given by

$$\Delta = \frac{2x_{\max}}{N} = \frac{x_{\max}}{2^{v-1}} \tag{4.10}$$

The quantized values in uniform PCM are chosen to be the midpoints of the quantization regions and, therefore, the error $\tilde{x}$ = x - Q(x) is a random variable taking values is the interval $(-\frac{\Delta}{2}, +\frac{\Delta}{2})$. In ordinary PCM applications, the number of levels (N) is usually high and the range of variations of the input signal (amplitude variations Xmax) is small. This means that the length of each quantization region (Δ) is small and under these assumptions, in each quantization region the error $\tilde{x}$ = x - Q(x) can be well approximated by a uniformly distributed random variable on $(-\frac{\Delta}{2}, +\frac{\Delta}{2})$. The distortion introduced by quantization (quantization noise) is, therefore,

$$E[\tilde{X}^2] = \int_{-\frac{\Delta}{2}}^{+\frac{\Delta}{2}} \frac{1}{\Delta} \tilde{x}^2 \, d\tilde{x} = \frac{\Delta^2}{12} = \frac{x_{\max}^2}{3N^2} = \frac{x_{\max}^2}{3 \times 4^{v}}$$

(4.11)

Where v is the number of bits/source sample. The SQNR ratio then becomes

$$\text{SQNR} = \frac{\overline{X^2}}{\overline{\tilde{X}^2}} = \frac{3 \times N^2 \overline{X^2}}{x_{\max}^2} = \frac{3 \times 4^{v} \overline{X^2}}{x_{\max}^2} \qquad (4.12)$$

If we denote the normalized X, that is ....

$$SQNR = 3 \times N^2 \overline{\breve{X}^2} = 3 \times 4^{v} \overline{\breve{X}^2} \qquad (4.13)$$

This means that SQNR in uniform PCM deteriorates as the dynamic range of the source increases because an increase in the dynamic range of source results in a decrease in $\overline{\breve{x}^2}$. The sensitivity to the source dynamic range can be improved by employing non uniform PCM.

If a signal has a band width of W, then the minimum number of samples for perfect reconstruction of the signal is given by the sampling theorem and is equal to 2W samples/sec is f_s, which is more than 2W, for each sample v bits are used, therefore a total of vf_s bits/sec are required for transmission of the PCM signal. In case of sampling at the Nyquist rate this is equal to 2_vW bits/sec. the minimum bandwidth requirement for transmission of R bits/secis R/2. Therefore the minimum bandwidth requirement of a PCM system is

$$BW = \frac{v f_s}{2} \tag{4.14}$$

This, in the case of sampling at the nyquist rate, gives the absolute minimum bandwidth requirement as

$$BW = v\,\mathrm{W} \tag{4.14}$$

This means that a PCM system expands the bandwidth of the original signal by a factor or at least v.

CHAPTER 5

PULSE CODE MODULATION RESULTS

In wireless communication, digital signals are modulated. First we use analog signal and then we convert analog signal to digital signal. In the process of conversion, first of all we take some sampled values with respect to time and then these values are quantized by different quantization methods. Now we will quantize the signal and convert it from a wave (cosine or sine) to the bits which are 0's and 1's. Matlab program is used for this purpose and the figure shows the different quantization levels.

5.1 Simulation of 16-level uniform pulse code modulation

(Figure 5.1) shows the 16-levels uniform pulse code modulation. We generate the quantized signals for 16 quantization levels. We choose the duration of the signal to be 10s, and the resulting SQNR is 25.13 dB.

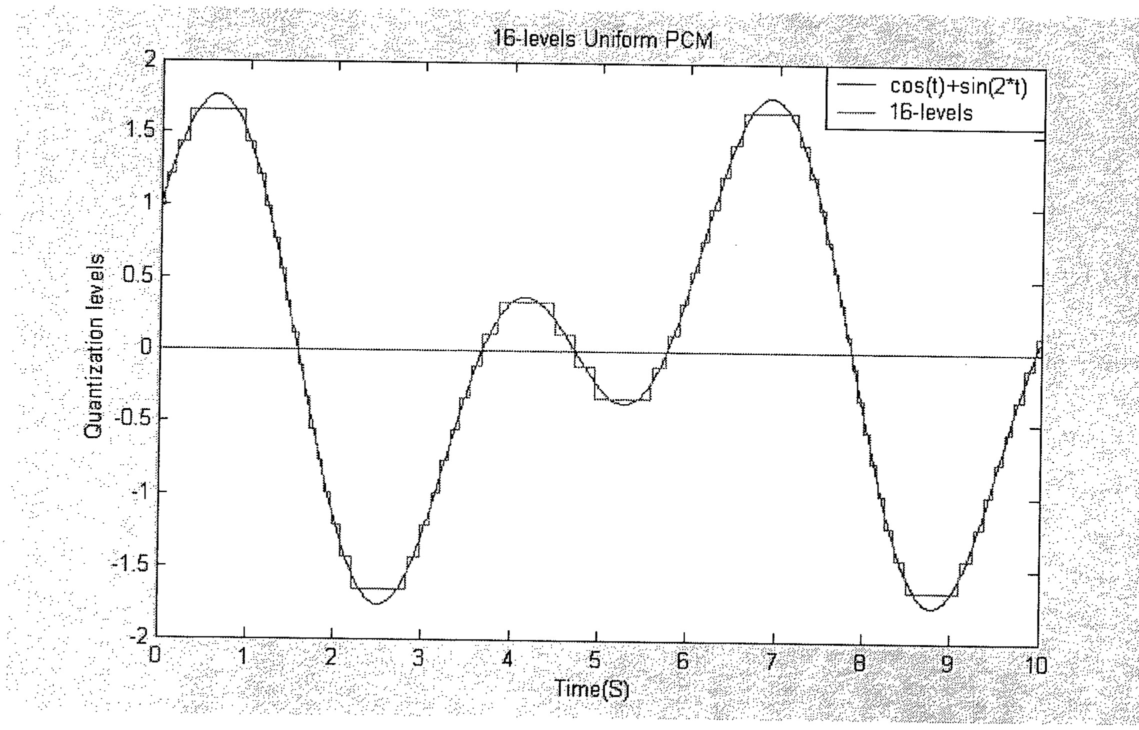

Figure 5.1 16-level uniform pulse code modulation

In this figure an analog signal is first sampled at a rate higher than the Nyquist rate, and then the samples are quantized. The analog signal is distributed on an interval denoted by [-2, 2] but with the increment of 0.5, so the intervals would be [-2, -1.5, -1, -0.5, 0, 0.5, 1.0, 1.5, 2.0].

It is seen from the figure that the interval of length $2_{x_{\max}}$ is divided into N equal subintervals, each of length $\Delta = \frac{2_{x_{\max}}}{N}$. If n is large enough, the density function of he input in each subinterval can be assumed to be uniform, resulting in a distortion of $D = \frac{\Delta^2}{10}$. If N is a power of 2, or $N = 2^V$, Then v bits are required for representation of each level. This means that if the bandwidth of the analog signal is W and if sampling is done at the Nyquist rate, the required bandwidth for transmission of the PCM signal is at least vW (in practice, 1.5 vW is closer to reality).

The distortion is given by,

$$D = \frac{\Delta^2}{10}$$

$$= \frac{x^2{}_{\max}}{3N^2}$$

$$= \frac{x^2{}_{\max}}{3 \times 4^v} \tag{5.1}$$

If the power of the analog signal is denoted by $\overline{X^2}$, the signal to quantization noise ratio (SQNR) is given by

$$\text{SQNR} = 3N^2 \frac{\overline{X^2}}{X_{\max}{}^2}$$

$$= 3 \times 4^v \frac{\overline{X^2}}{X_{\max}{}^2}$$

$$= 3 \times 4^v \overline{\breve{X}^2} \tag{5.2}$$

Where $\breve{X}$ denotes the normalized input by,

$$\breve{X} = \frac{X}{x_{\max}} \tag{5.3}$$

The SQNR in decibels is given by

$$SQNR_{1_{db}} \approx 4.8 + 6v + \overline{\breve{X}^2}_{1_{DB}} \tag{5.4}$$

5.2 64-level uniform pulse code modulation

In Figure 5.2 64 quantization levels pulse code modulation is shown, with the signal duration of 10s. The resulting SQNR is 31.66 db, with the intervals [-2, 2].

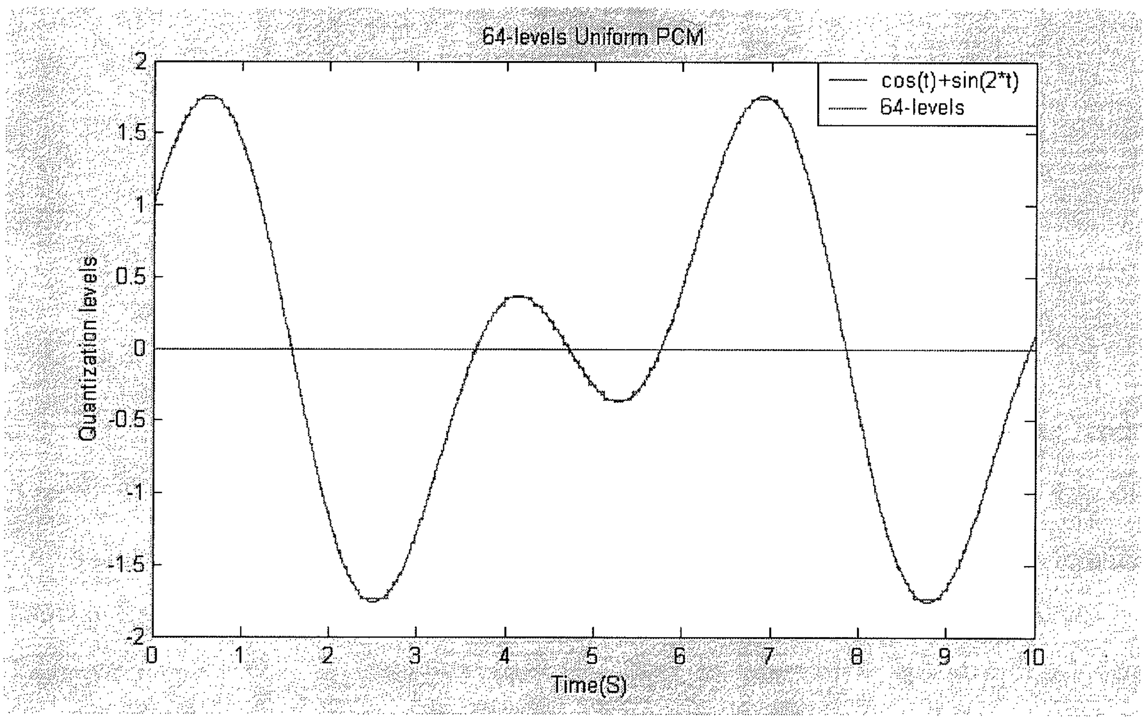

Figure 5.2 64-levels uniform pulse code modulation

64-quantization levels gives conclusion that as quantization levels increased, more accurate signal can be achieved. The values which rounded off the quantization levels can be rounded to more accurate number.

5.3 Comparison of 16 and 64 quantization levels

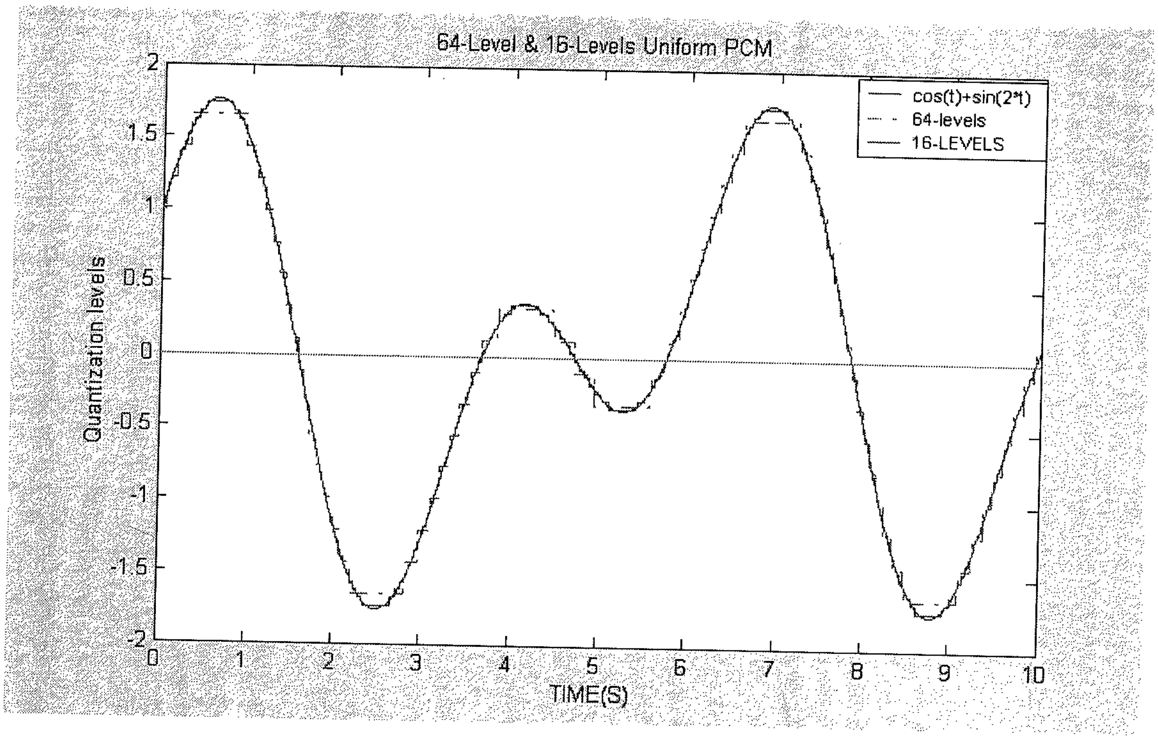

Figure 5.3 Comparisons of 16 and 64 quantization levels

(Figure 5.3) shows 16 and 64 quantization levels uniform pulse code modulation. The time duration for both is 10s and the number of intervals from [-2, 2].

In comparison it is seen that for 16-levele and 64-levels a big difference happened. Signals achieved by 64-levels are more accurate than the signals achieved by 16-levels quantization. Its mean to achieving more accurate signal quantization levels should be increase. After quantization, the quantization levels are encoded using v bits for each quantized level. The encoding scheme that is usually employed is natural binary coding (NBC), meaning that the lowest level is mapped into a sequence of all 0's and the highest level is mapped into a sequence of all 1's. All the other levels are mapped in increasing order of the quantized value.

5.4 Quantization of Gaussian random numbers

We generated a sequence of length 10,000 of sixteen mean, thirteen- variance Gaussian random numbers.

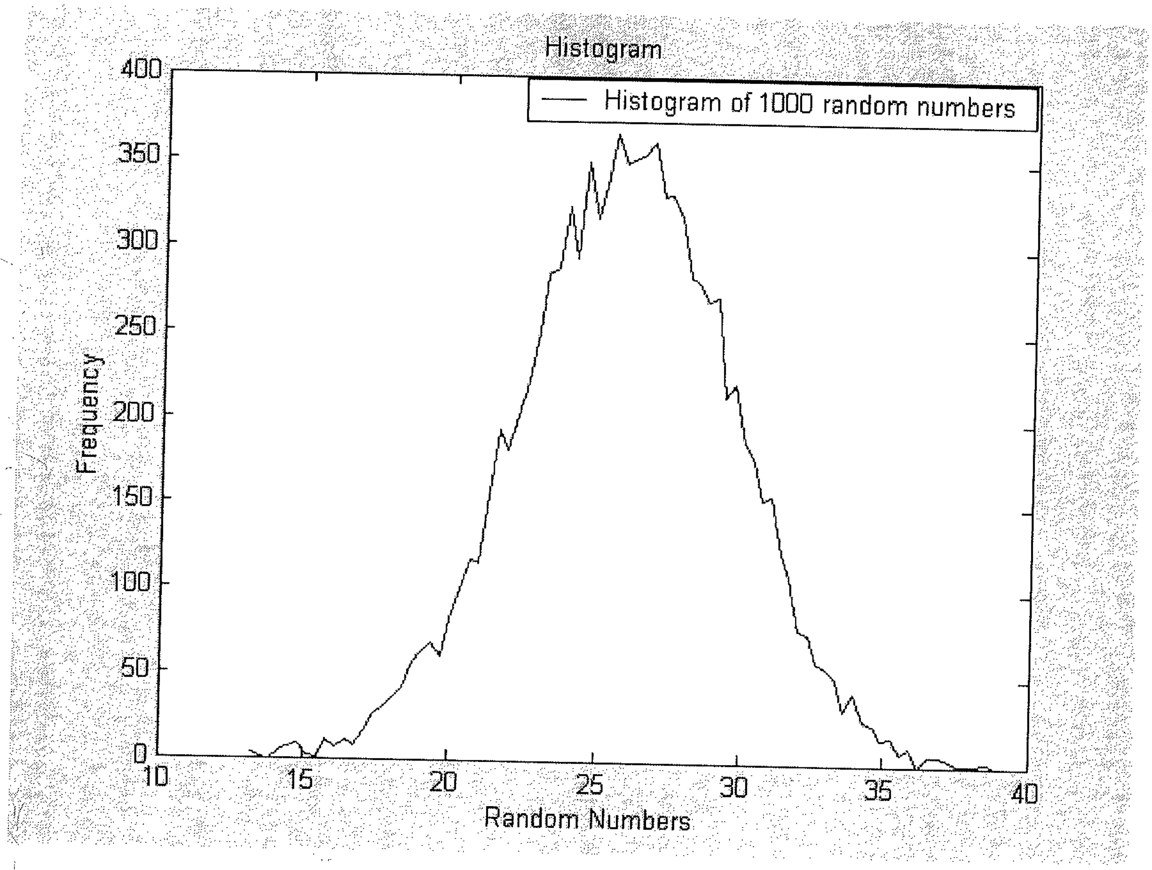

Figure 5.4 Histogram of 1000 random numbers

We found the SQNR when the number of quantization levels is 64, we also found the first five values of the sequence, the corresponding quantized values, and the corresponding codeword, by using the equation,

The results are

SQNR = 37.3253

Input = [30.6891 26.9704 25.4409 26.1233 29.5741]

Quantized values = [30.0912 26.4066 25.1784 26.4066 30.0912]

Codeword =

$$\begin{matrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 0 \end{matrix}$$

CONCLUSION

This report has attempted to describe some important new technologies and approaches to the wireless communications field that are likely to evolve in the coming decade. In the 1990s, cellular telephone service and the Internet grew from the incubator stage to global acceptance. In the next 10 years, we suspect the Internet and wireless communications will become intertwined in ways only imagined today.

In wireless communication, digital signals are modulated, after converting analog signal to digital signal, In the process of conversion, first of all we take some sampled values with respect to time and then these values are quantized by different quantization methods. Matlab program is used for this purpose and different quantization levels describe the accuracy of the quantization. First of all 16 levels and than 64 quantization levels pulse code modulation is done, and find the conclusion that as quantization levels are increasing more accurate signals can be achieved.

REFERENCES

[1] K. Pahlavan and P. Krishnamurthy, Principles of Wireless Networks A Unified Approach, New Jersey: Prentice Hall, 2002.

[2] W. Stallings, Wireless Communications and Networks, 2nd Ed., Prentice Hall, 2005.

[3] S.M. Cherry, "WiMax and Wi-Fi: Separate and Unequal," IEEE Spectrum, Vol. 41, pg. 16, March 2004.

[4] I. Poole, "What exactly is . . . ZigBee?," IEEE Commun. Eng., pp. 44-45, Aug.-Sept. 2004

[5] L. Yang and G.B. Giannakis, "Ultra-wideband communications: an idea whose time has come," IEEE Signl. Proc. Mag., Vol. 21, pp. 26 - 54, Nov. 2004

[6] Prokis, J.G, Salehi, M., Communication systems engineering, upper saddle river, New Jersy 07458, 2002.

APPENDIX A. MATLAB CODES DESCRIPTION

A.1 16-LEVEL SIGNAL TO QUANTIZATION NOISE RATIO

```
function [sqnr,a_quan,code] = u_pcm(a,n)
%       U_PCM  uniform PCM encoding of a sequence
%       [SQNR,A_QUAN,CODE] = U_PCM(A,N)
%       a = input sequence.
%       n = number of quantization levels (even).
%       sqnr = output SQNR (in dB).
%       a_quan = quantized output before encoding.
%       code = the encoded output.


amax=max(abs(a));
a_quan=a/amax;
b_quan=a_quan;
d=2/16;
q=d.*[0:16-1];
q=q-((16-1)/2)*d;
for i=1:16
a_quan(find((q(i)-d/2 <= a_quan) & (a_quan <= q(i)+d/2)))=...
q(i).*ones(1,length(find((q(i)-d/2 <= a_quan) & (a_quan <= q(i)+d/2))));
b_quan(find( a_quan==q(i) ))=(i-1).*ones(1,length(find( a_quan==q(i) )));
end
a_quan=a_quan*amax;
nu=ceil(log2(16));
code=zeros(length(a),nu);
for i=1:length(a)
for j=nu:-1:0
if ( fix(b_quan(i)/(2^j)) == 1)
code(i,(nu-j)) = 1;
b_quan(i) = b_quan(i) - 2^j;
end
```

```
 end
end
sqnr=20*log10(norm(a)/norm(a-a_quan))
end
```

A.2 64-LEVEL SIGNAL TO QUANTIZATION NOISE RATIO

```
amax=max(abs(a));
a_quan=a/amax;
b_quan=a_quan;
d=2/64;
q=d.*[0:64-1];
q=q-((64-1)/2)*d;
for i=1:64
a_quan(find((q(i)-d/2 <= a_quan) & (a_quan <= q(i)+d/2)))=...
q(i).*ones(1,length(find((q(i)-d/2 <= a_quan) & (a_quan <= q(i)+d/2))));
b_quan(find( a_quan==q(i) ))=(i-1).*ones(1,length(find( a_quan==q(i) )));
end
a_quan=a_quan*amax;
nu=ceil(log2(64));
code=zeros(length(a),nu);
for i=1:length(a)
for j=nu:-1:0
if ( fix(b_quan(i)/(2^j)) == 1)
code(i,(nu-j)) = 1;
b_quan(i) = b_quan(i) - 2^j;
end
end
end
sqnr=20*log10(norm(a)/norm(a-a_quan))
end
```

A.3 UNIFORM PULSE CODE MODULATION OF 64 AND 16 QUANTIZATION LEVELS

```
t=[0:0.01:10];
a=cos(t)+sin(2*t);
[sqnr64,aquan64,code64]=u_pcm(a,64);
sqnr64;
plot(t,a,t,aquan64,'-',t,zeros(1,length(t)))
xlabel('TIME(S)');
ylabel('Quantization levels');
title('64-level Uniform PCM');
legend('cos(t)+cos(2*t)','64-levels')
    end

t=[0:0.01:10];
a=cos(t)+sin(2*t);
[sqnr16,aquan16,code16]=u_pcm(a,16);
sqnr16;
plot(t,a,t,aquan16,'-',t,zeros(1,length(t)))
xlabel('TIME(S)');
ylabel('Quantization levels');
title('16-level Uniform PCM');
legend('cos(t)+cos(2*t)','16-levels')
   End

t=[0:0.01:10];
a=cos(t)+cos(2*t);
[sqnr16,aquan16,code16]=u_pcm(a,16);
[sqnr64,aquan64,code64]=u_pcm(a,64);
sqnr16;
sqnr64;
plot(t,a,'-',t,aquan16,'-.',t,aquan64,'-',t,zeros(1,length(t)))
title('64-Level & 16-Levels Uniform PCM')
```

```
xlabel('TIME(S)')
ylabel('Quantization levels')
legend('cos(t)+cos(2*t)','64-levels','16-LEVELS')
end
```

A.4 GENERATED 1000 LENGTH OF SEQUENCE

```
m=1+8+9+8;
v=m/2;
x=10:40;
z=1/(sqrt(2*pi*v)).*exp(-((x-m).^2)/(2*v));
plot(x,z)
hold on
y=(sqrt(13).*randn(1,10000))+26;
a=80;
[n,x]=hist(y,a);
n=hist(y,a);
n=(hist(y,a)/(400));
plot(x,n)
    end

m=1+8+9+8;
v=m/2;
a=(sqrt(13).*randn(1,10000))+26;
n=64;
[sqnr,a_quan,code]=u_pcm(a,64);
a_quan(1:5);
code(1:5,:);
    end
```