NEAR EAST UNIVERSITY

Faculty of Engineering

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Indoor Wireless Communication Systems

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ABSTRACT

Over the last ten years, the impact of wireless systems on the way we live and do business has been surpassed only by the impact of the Internet. Cell phones, pagers, and wireless Personal Digital Assistants (PDAs) have become so commonplace in our lives that it is easy to forget those ten years ago, they were a rarity. But wireless systems is still in its infancy, and the next stage of its development will be in supplementing or replacing the network infrastructure that was traditionally "wired" as well as enabling network infrastructures that previously could only be imagined. From local coffee shops to commercial Inventory control systems, within restaurants and throughout public airports, accessing central pools of information and communicating directly between users and among the devices themselves, wireless commerce is beginning to challenge the exchange system that our modem world currently embraces.

No longer are we restricted by the shortfalls of processing and Battery power, operating system efficiencies, or heat dissipation within the small footprint of the mobile device. Rather, we are limited only by the practical application of these technologies. How will we access information? How will we integrate multiple hardware and software technologies? Into intelligent and useable forın factors? Not all business Models necessarily imply the use of a single terminal to supply the user with voice, video, and data services. Ergonomic factors may dictate that Voice services are maintained privately while data exchange and video Information is easily viewable from a specified distance, perhaps on Complementary devices.

CONTENTS

INTRODUCTION

Over the last decade, development of wireless communications in north America Europe has been phenomenal, wireless systems technology has evolved along a logical path from simple first generation analog products designed or business use to econ generation digital wireless telecommunications systems or residential and business environments

As the industry plans and implements the second generation digital net-works in the mi 1990. Vision of next generation wireless information net emerging. complete persona communication we enable l the users all users to economically transfer any form information any desire locations the new network will be built on and interface with the separate first-generation and second-generation cordless and cellular services and will also encompass other means of wire line and wireless access such as local area Net-Work(LANs) and specialized mobile radio. For at least part of the 1990s, we will see systems that are cellular at new frequencies and some with new services . By the end of the decade, true third generation systems offering high bandwidth multi media applications may emerge.

The aim of this project is to investigate the general wireless systems. The project consists of introduction, six chapters and conclusion.

Chapter one, explains wireless communications as mobile telephones offer paging services, where paging systems offer two-way voice messaging, and mobile satellite systems can offer high-speed internet access.

Chapter two represents Telecommunications Applications and Services.

Chapter three describes Wireless Technology Basics, where Wireless communication involves the transfer of information signal through the air by the means of electromagnetic waves. To create electromagnetic waves, an electrical signal that continuously varies in power level and polarity, is applied to an antenna. As the level varies, the energy contained in the electrical signal is converted to electromagnetic waves that propagate away from the antenna.

Chapter four explains Mobile Radios (Cellular, PCs, and 3G).

Chapter five explains Bluetooth.

Chapter six mentions Paging Systems.

1. WIRELESS COMMUNICATIONS

1.1 Overview

Radio is the transmission of information between points through the use of electromagnetic (radio) waves. Wireless communication has changed dramatically over the past few years. Some companies have made money by exploiting these changes and some have lost their competitive advantages. The physical properties of radio have not changed over the years. However, the ability to exploit the transmission capacities of radio channels and the applications that rely on wireless transmission has dramatically changed. Because radio transmission has transitioned from unique analog systems to relatively standard digital systems, it is now possible for a single type of wireless system to offer several types of services. For example, mobile telephones offer paging services, paging systems offer two-way voice messaging, and mobile satellite systems can offer high-speed internet access.

1.2 Wireless Communications

The word radio is used to describe the transmission (radiating) of electromagnetic energy through air and other objects. Information can be transferred on electromagnetic waves by modifying or mixing the information with the radio waves (the carrier). Radio receivers capture electromagnetic waves of a certain frequency and decode the information that is on the radio signal. Because radio receivers will capture any electromagnetic wave of the appropriate frequency, radio signals that operate on the same frequency will interfere with each other. To reduce unwanted interference between users, the use of radio signals must be managed like any other natural resource. As a result, government regulatory agencies categorize the frequency bands and define the rules for the use of radio signals within their country.

Some users are given exclusive rights to use radio signals of a specific frequency range (licensed users) while others are given fair access (not guaranteed) through operational requirements that will minimize interference with each other (unlicensed users). The direction, pattern and energy loss that radio waves travel depend on the frequency and the type of transmission system that is used. In general, the lower frequency radio waves bend with the surface of the earth and around objects such as bridges and tunnels while higher frequency waves tend to travel in a direct path. Higher frequency signals loose more of their energy as they travel through objects such as raindrops. As a result, certain frequency ranges are better suited for specific communication applications.

Low frequency radio signals are good for radio broadcast applications such as car audio and land based television systems. Medium frequency signals are good for mobile communications. High frequency radio signals are commonly used for microwave point-to-point communications such as satellite television.

Figure 1.1 shows that there are many applications for wireless communication and that some of the applications are better suited for different frequency bands. This diagram can be viewed as a frequency dial on a radio receiver that can be tuned (frequency changed) to the relative frequency bands in which they operate. In the lower frequency band are AM radio stations, Citizen Band (CB) "walkie-talkie" radios and various types of unlicensed remote control devices (example: garage door openers). Next, there are some television channels, followed by FM radio stations. To the right,

You have ultra high frequency (UHF) broadcast television (TV) channels (channels 21 through 69). The military has some frequency bands between these public radio frequency bands. Cellular telephone frequencies come directly after the UHF television channel 69. The frequencies used for cellular telephone service were previously assigned to UHF television channels 70 through 83. Personal communications service (PCS) and 3rd Generation radio is approximately double the frequency of cellular. In the microwave bands, radio services include Wireless LAN, point-to-point communication,
And digital satellite services (DSS).

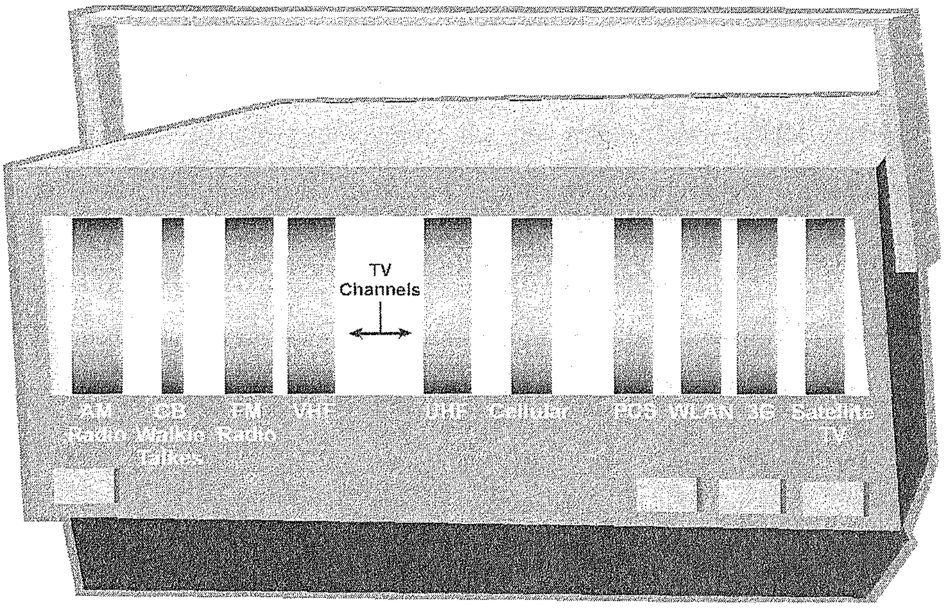

Figure 1.1 Radio Airwaves

German physicist Heinrich Hertz is recognized as the first person to create and measure radio waves (called Maxwell's waves) in 1888. As a result of his success, the measurement of frequency (cycles per second) is commonly called Hertz (Hz). Figure 1.2 shows how to measure a signal wave in cycles per second (Hertz). This diagram shows a signal wave that has three cycles that move past a point in/1 second. This equals a frequency of 3 Hertz. Radio waves typically have several million cycles per second that is called a Megahertz (MHz).

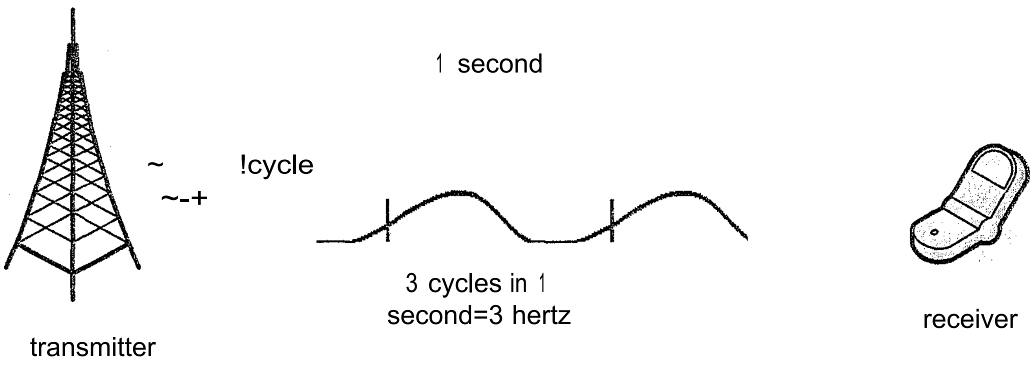

Figure 1.2 Measuring in Hertz (Hz)

Radio transmission devices transmit and receive on specific frequencies or within a band of frequencies with an assigned or controlled power level so they do not interfere with other radio transmitters operating on the same frequency. For example, television stations are assigned specific frequencies (television channels) and power levels that ensure the television signals will be limited to a- specific geographic area (such as a city). The signal level outside the geographic area is not enough to cause interference to other television Stations that are operating on the same frequency.

Television radio receivers (TVs) listen for specific frequencies (television channels) by allowing specific frequencies through a filter assembly. These band-pass-filters allow desired frequencies to pass through and block out unwanted frequencies (other channels).

To help to ensure radio communication applications can reliably share the same airspace, the radio spectrum has been divided into frequency ranges (frequency bands) and these bands are assigned (regulated) by government agencies.

1.3 Regulation of Wireless

Wireless must be regulated to help ensure users can benefit from wireless transmission without unwanted interference from other users. Globally, the United Nations International Telecommunication Union (ITU) recommends frequency bands for specific types of use (such as mobile telephones and satellite systems). The actual regulation of the use of wireless devices and airwaves is performed by agencies within each country.

The ITU is a specialized agency of the United Nations that was established to maintain and extend international cooperation for the maintenance, development, and efficient use of telecommunications. The union does this through standards and recommended regulations, and through technical and telecommunications studies. Based in Geneva, Switzerland, the ITLI is composed of two consultative committees: the International Radio Consultative Committee (CCIIR) and the Consultative Committee for International Telephony and Telegraphy (CCITT).

Within a country, there are agencies that develop and enforce regulations for wireless communications. Each country may have several regulatory\ authorities that may coordinate the licensing of users (authorization for use) and approval of products for use (approval of specific types of products). Examples of regulatory authorities include the Federal Communications Commission (FCC) for the USA, Office of Telecommunications (Oftel), Telecom Regulatory Authority for India (TRAI), and the Australian Communications Authority (ACA) One of the first regulatory efforts for wireless communication occurred in 1912 when the United States Congress passed the first airwave licensing law. Nearly a thousand licenses were issued and many of these went to colleges and universities. As a result of the great interest in for licenses to use wireless communication, the United States created the Federal Radio Commission (FRC) in 1927. In 1934, the United States transferred the responsibility for regulating radio from the FRC to a newly created Federal Communications Commission (FCC).

Regulatory authorities continually reallocate radio spectrum and the issuance of licenses. The exclusive right to offer specific types of services (licenses) may be given away or sold by govenunent agencies. Even if a govermnent agency has licensed a radio service provider, these licenses can be revoked for violations of their use such as when a service provider does not\ provide services in specific geographic areas within a specific amount of time.

1.4 Licensed Frequencies

Licensed frequency bands give the licensee (service provider or service user) the authority to use the radio spectrum within their licensed frequency band according to the requirements of the license. These requirements may include a type of service (such as paging or mobile telephone service), channel types (single or multiple channels), and power levels within a specific geographic area (amount of signal strength allowed). Initially, the purpose of licensing radio bands was to avoid collision in the airwaves between users. The role of licensing has changed to regulating the types of users to control (enable or reduce) competition and to obtain revenue from the issuance of licensees.

Initially, awardees of radio licenses were typically charged a minimal documentation fee by the regulatory authority. The awardees owned the right to use the frequency(s) for a specific amount of time. Awardees would build their system or sell services to customers. As the technology costs decreased and the systems developed such as cellular communications, some awardees were able to sell their systems and licenses and gain extraordinary profits.

As govermnents realized the significant value ofthese licenses, they began to create new frequency bands to sell at auctions so the government could gain the profits. In some countries where there were no available desirable frequency bands, the govermnents simply took away the license rights of some licensees and sold these rights to new licensees.

1.5 Unlicensed Frequencies

Unlicensed frequency bands are radio frequencies that can be used by any product or person provided the transmission conforms to transmission characteristics defined by the appropriate regulatory agency for unlicensed use.

While these unlicensed radio bands may allow users to operate in those frequency bands, all unlicensed devices that transmit radio signals are regulated by one or more government agencies within a country. The unlicensed frequency regulations typically specify the frequency, type of service, and method of access control. This helps to ensure that users of unlicensed devices (such as cordless telephones and radio controlled toys) do not regularly cause or receive unreasonable interference to or from other users. To ensure these devices are designed correctly to meet regulations, they are tested for conformance, This is called "type approval." A type approval from the regulatory agency (such as the FCC) identifies the equipment that is manufactured has passed tests certifying it meets the minimum requirements for that type of electronic or radio equipment. Most electronic devices must meet several regulatory specification requirements to receive type approval. When a device has received type approval, an identification tag is usually attached to the device that indicates the specific type of service the device is authorized to use.

The regulatory specification for unlicensed devices in the United States is FCC regulations, part 15. Part 15 of the FCC regulations describes the different types of unlicensed services that can be used in specific frequency bands and the radio access power levels and methods that must be conformed.

1.6 Categorist **Wireless Services**

Wireless services can be categorized into broadcast, two-way radio and point-to-point services. Broadcast services (such as radio and television) allow many receivers within a radio coverage signal to listen or watch the same information carried by a radio signal. Two-way services allow a defined group of receivers (such as taxis in a city) to send and receive voice communications or messages with independent operation. Point-to-point services allow controlled (private) communications between two fixed or portable locations (such as a microwave link).

1.7 Broadcast **Radio**

Broadcast radio is the transmission of an information signal to a specified geographic area or network. This allows the same information to be received by all customers in that geographic area that can successfully receive (demodulate) and decode the information. Because broadcasters typically do not know the recipient of information, the revenue for providing broadcast services is received by advertisers who insert advertisements for their goods or services on the radio or television channels. Radio and television programming has played a dominant role in information and entertainment delivery.

The broadcast industry has developed to allow existing broadcasters to offer new services including voice, data, and video services using conventional broadcast frequency allocations. These innovations include high-definition television (HDTV), digital audio broadcasting (DAB), and FM high-speed sub carrier (FM HSS) data services.

Figure 1.3 shows how a broadcast radio system can operate. In this diagram, one high power transmitter is located at a high point above the city. The transmitter may be broadcasting at over 50,000 watts to allow a radio signal to reach many homes and businesses within a 50-mile radius. Typically, any receiver that is capable of tuning into the broadcast signal can receive and listen to it. However, some systems (such as movie channels) are scrambled so only receivers with a signal decoding capability can listen or view the signal.

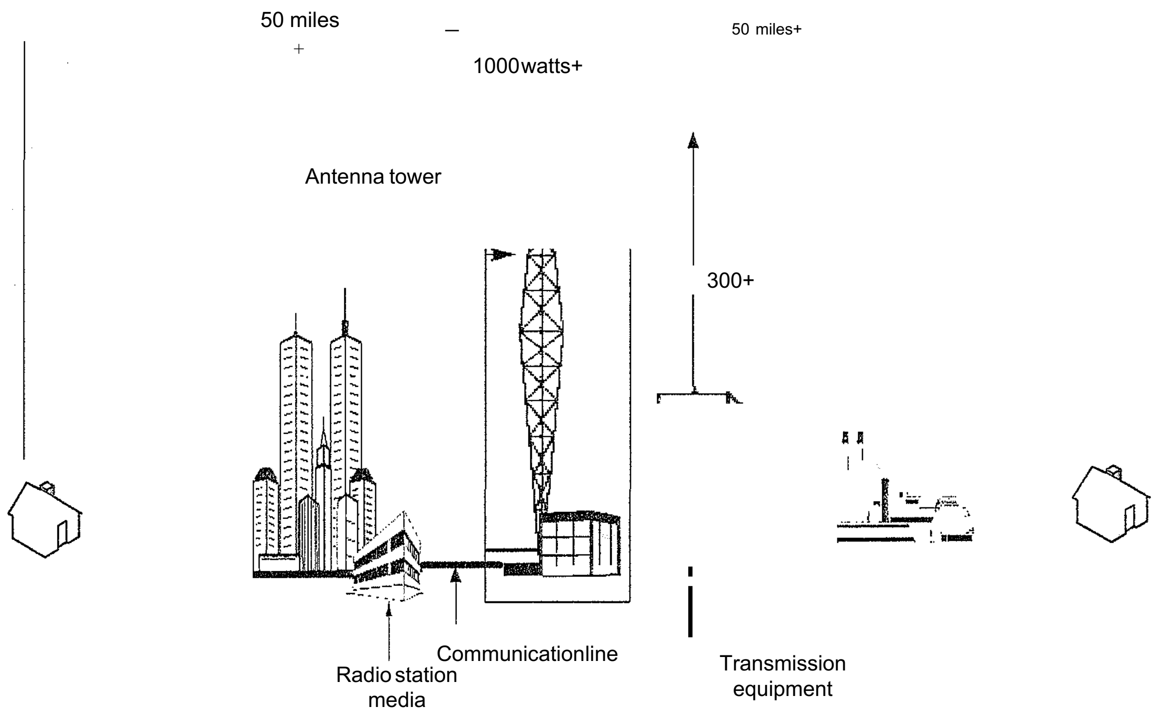

Figure 1.3 Radios Broadcast System

1.8 Two Way Radio **Communication.**

Two-way mobile radio systems allow communication on a dedicated radio chaımel between two or more mobile radios. Traditionally, two-way radio systems have served public safety and industrial applications. These systems typically only allow push-to-talk service (one-way at a time) to allow sharing of a single radio channels frequency. Two-way radio systems are available in a wide range of frequency band.

There are many types of two-way radio systems ranging from a simple pair of handheld citizen band (CB) "walkie-talkies" to elaborate wireless backbone radio [illegible] systems. Two-way radio communications also include non-terrestrial services such as: aeronautical mobile radio (communications with aircraft), maritime mobile (communications with ships at sea), and the new mobile satellite service (mobile communications via satellites). Two-way radio communications systems can be divided private and public systems. Network operators who provide communication services to relatively small groups of users own private two-way radio systems. Examples of the types of users for two-way systems include building maintenance workers or local delivery services. Companies that offer services to many types of users own public land mobile radio systems. These users may include salespeople, real estate brokers, and general consumers. Public wireless telephone system's in the United States that is licensed by the FCC, is ruled under the Commercial Mobile Radio Service (CMRS). These two-way mobile communication applications fill a general need for mobile and personal communications that has made a significant impact on business productivity, personal safety, and general social behaviors.

Figure 1.4 shows a typical private analog two-way radio system. In this diagram, a mobile radio has an FM transmitter and FM receiver bundled together. Because the mobile radio is used for "push-to-talk" service, the antenna does not need to be connected to both the transmitter and receiver at the same time. When the user presses the push to talk button, the antenna is connected to the transmitter. When the button is released, the antenna is connected to the receiver. A squelch circuit is connected to the receiver to allow the receiver audio to reach the speaker only when the receiver level or tone code is of sufficient level to ensure a good received signal. When the level is below that threshold (normally set by the user via a squelch knob), the speaker is discoımected and no sound (such as noise) can be heard. The mobile radio communicates with a radio tower that has a high power base station. The base station usually is connected to a control console that allows a dispatcher to communicate or to patch the audio channel to another location (such as a telephone line connection).

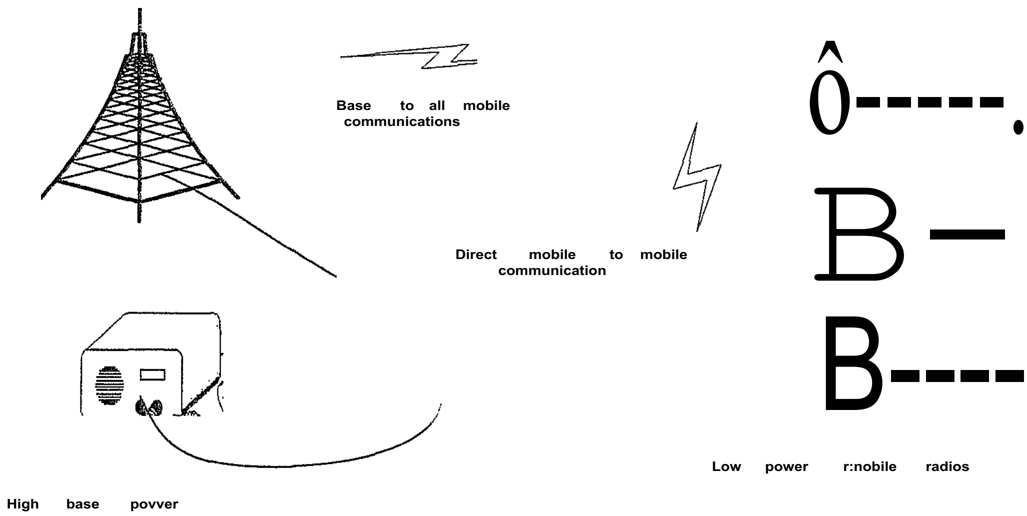

Figure 1.4 Private for Two Way Radio Operation

In public two-way cellular systems, many mobile telephones communicate through nearby radio base stations and their central switching system which then connects to other wired and wireless telephones. Mobile telephones can be portable (handheld), transportable (phones in a bag or case) or mobile (mounted in a vehicle). They can change frequency and power level and are usually controlled by messages received from the cellular system. Mobile telephones communicate through radio base stations that are located within a few miles. Each base station typically transmits and receives on several fixed frequencies. The base station converts and transfers the radio signals between the mobile telephone and switching system via dedicated wires or a microwave link. The switching system connects the calls to the public telephone network or to other mobile phones operating in the system.

Figure 1.5 shows the basic parts of a cellular mobile communication system. The mobile telephone has the ability to tune in to many different radio channel frequencies or codes. The base station commands the mobile telephone on which frequency to use in order to communicate with another base station that may be from two to fifteen miles away. The base station routes the radio signal to the MSC either by wire (e.g. a leased telephone line), microwave radio link, or fiber optic line. The MSC connects the call to the public switched telephone network (PSTN) and the PSTN then connects the call to its designation (e.g. office telephone).

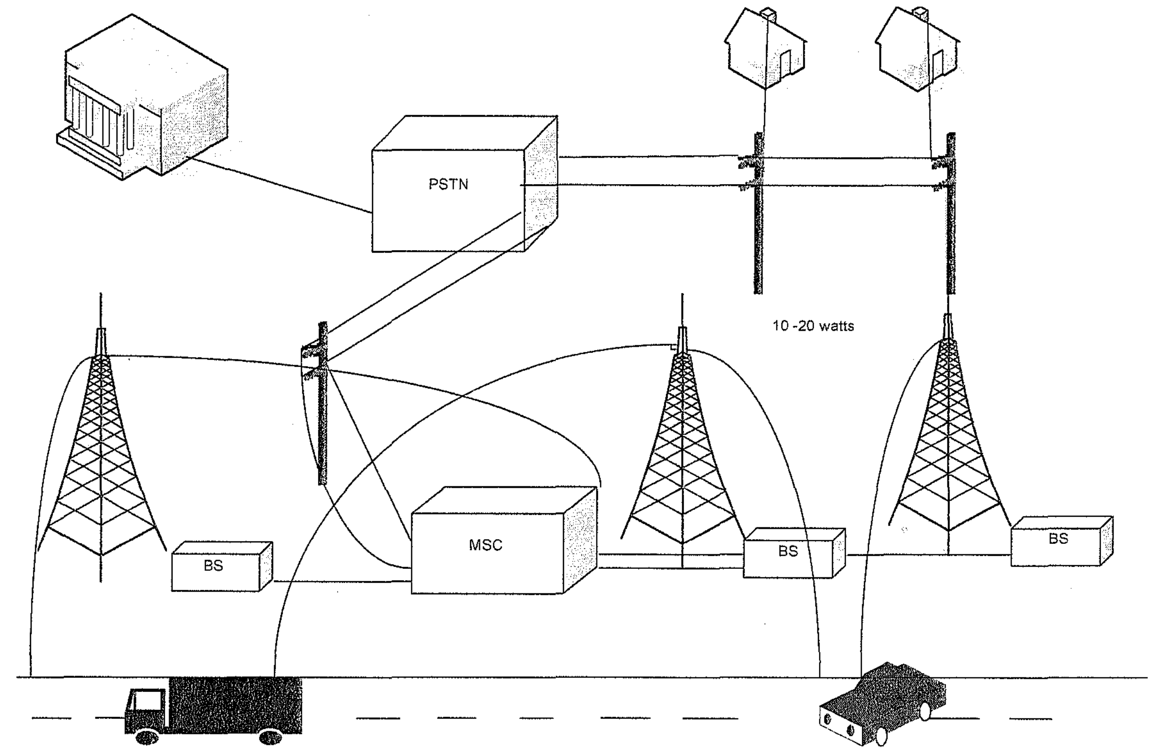

Figure 1.5 Public Cellular Radio Systems

1.9 Point-To-Point Services

Point-to-point communication systems involve the transmission of signals from one specific point to another. An example of point-to-point systems is Microwave radio relay links. The term "point-to-point" service is sometimes used to indicate end-to-end connectivity for sending information. This categorization is not technology specific, nor regulatory specific, it relates to applications where information is deliberate and routed between two specified destinations. Sometimes short message service (SMS) that is sent between specific users is called point-to-point messaging. Figure 1.6 shows how wireless can transfer multiple channels of information between points using a point-to-point microwave connection. In this example, a microwave radio signal is being used to transfer multiple communications channels (called logical channels) between two points. Several low speed communication channels are multiplexed (time shared) to produce a combined high-speed information signal. This combined signal modulates the transmitted microwave radio carrier signal. At the receiving point, the microwave signal is demodulated and separated (de-multiplexed) back into the original channel

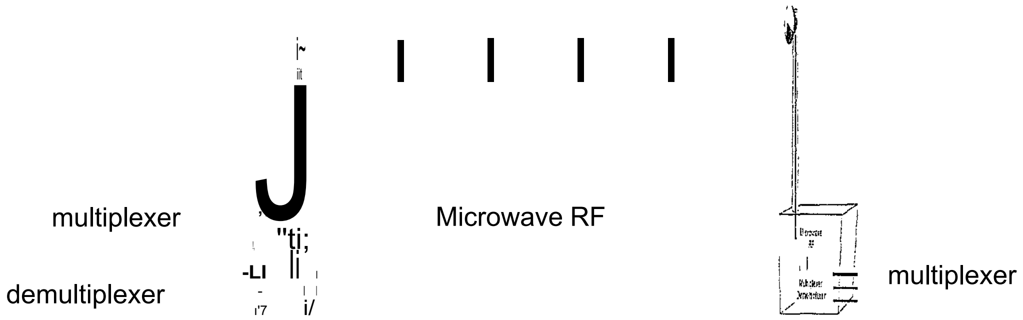

Figure 1.6 Point-To-Point Wireless Service

.1.10 Voice

Voice communication is the transmission and reception of audio and other signals that can be represented by the frequency band used for voice signal transmission. Wireless systems may transfer voice signals using analog and digital formats. Options for voice communications include different voice quality of service levels and voice privacy options.

Figure 1.7 shows a typical voice service application where a mobile radio is communicating with another mobile radio. As the user talks, their audio signal (sound pressure) is converted to electrical signals. These audio electrical signals (called the base band) transfer the information by modifying (modulating) the radio transmitter frequency (called the broadband) signal. This low-level radio signal is boosted by an RF amplifier in the transmitter section and converted to electromagnetic wave by the antenna. A nearby mobile radio receives the radio signal by using a frequency filter and compares the modified incoming radio signal to an unchanged frequency to extract the original audio electrical signal (called demodulation). A speaker converts the audio signal back to its original sound (acoustic signal).

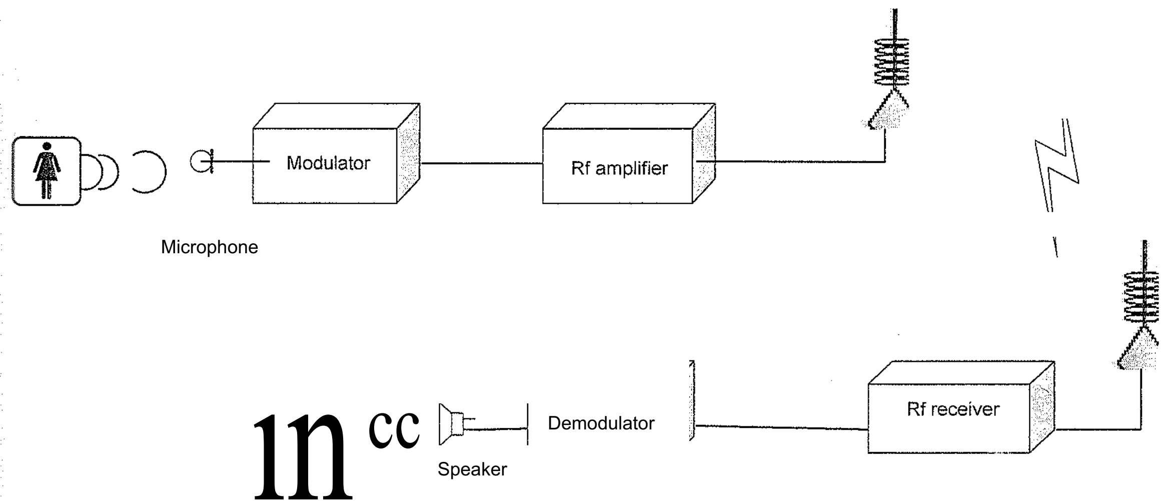

Figure 1.7 Voice Communications

Data

Data communication involves the transfer of digital information between a computer (and other digital devices) and one or more radio receivers. This transfer is performed through the use of a modulated radio signal. While it is necessary to have a wireless data transmitter and receiving communications device to operate at the same time to transfer the data, the user of data communications (the computers) typically do not require real time end to end connectivity. For example, if during a file transfer the computer is asked to wait for 5 to 10 seconds for new data, this may be acceptable for data transfer and unacceptable for voice communications.

This allows wireless data communications to use retransmit request messages to ensure messages were received correctly. Digital information typically has only 2 levels (on and off). On signals are typically called a 1 and off signals are usually called a 0.

The transfer of digital information by radio waves involves conversion from digital signals to analog radio waves. All radio waves can experience distortion. Unlike voice communications where the users can typically tolerate small amounts of distortion (noise) of the audio signal, digital information cannot typically tolerate distortion. Distortion could result in the misunderstanding of information or the incorrect reception of 1's and O's. To ensure digital information is correct and complete .Various error detection and error protection schemes are used. These error protection processes send additional data bits along with the actual data. These extra bits. (error protection bits) allow the systems to determine if the information is complete and correct. Unfortunately, these extra bits also use some of the available data transmission rate and therefore they reduce the maximum data transfer rate.

There are two basic ways to transfer digital information on a communication system; continuous data transmission (called "circuit switched") and burst transmission (called "packet switched.") For continuous data transmission (such as a large data file), the address is sent first and a continuous path is dedicated for data transmission. This path is maintained even if the source of data information is temporarily interrupted. For packet data transmission (such as a credit card validation request), the data information (the message) is divided up into small packets of digital information (such as 100 characters at a time) and each packet is given a sequence number and a destination address. These. packets migrate through an interconnected network independently and are reassembled into the original message when they reach their destination. Figure 1.8 shows a typical wireless data service. In this figure, a computer is sending a file. As the computer sends digital information (1's and O's), their base band electrical signal (high or low voltage) transfers the information by modifying (modulating) the radio transmitter frequency (broadband) signal. This low-level radio signal is boosted by an RF amplifier and converted to electromagnetic wave by the antenna. Another wireless data device receives the radio signal and many others from its antenna. Its receiver selects the correct radio signal by using a frequency filter and compares the modified incoming radio signal to an unchanged frequency remove the audio electrical signal (called demodulation). The audio electrical signal is converted to the original digital by a modem and routed to another data device.

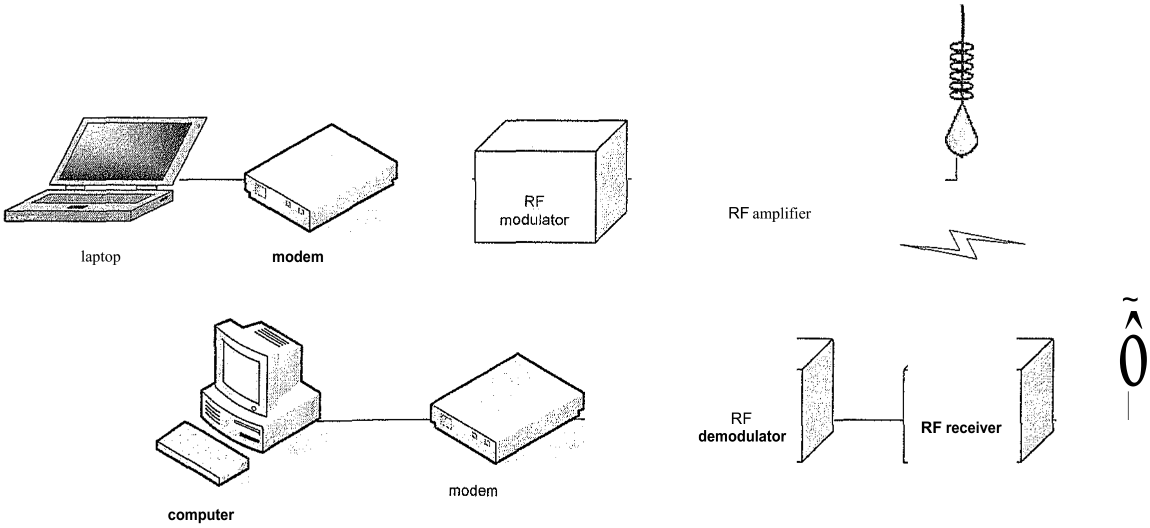

Figure 1.8 Wireless Data Communication

1.12 Video

Video communication is the transmission and reception of video (multiple images) and other signals that can be represented by the frequency band used for video signal transmission. Telecommunications systems can transfer video signals in analog or digital form. Video communication systems allow broadcasting companies to send a v2isual signal (typically combined visual and audio) to many radio receivers (typically televisions) by transmitting a high power radio signal that is modulated with visual information. Video communications typically are sent in one direction and consistent delays and some amount of signal distortion can be tolerated.

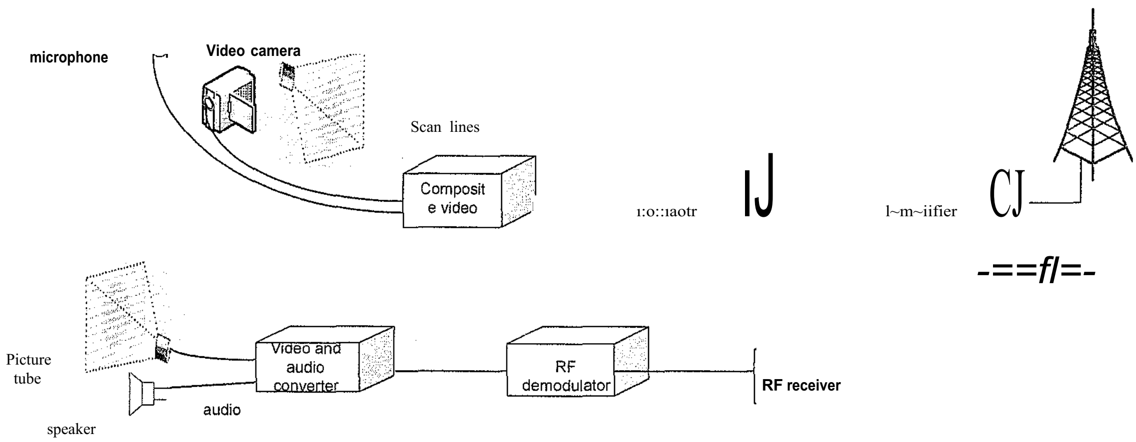

Figure 1.9 Video Communications

Video signals are very complex (rapidly changing). Because of this complex signal the required amount of frequency bandwidth is much larger than typical audio (cellular and radio). For example, 200 standard cellular radio channels (30,000 Hz wide) can fit into the radio bandwidth allocated to 1 television channel (6,000,000 Hz each).

Figure 1.9 shows the basic process used for video signal transmission. In this example, a television camera converts an image and audio sounds to electrical signals. The video signal is created by the use of a video camera that scans the viewing area line by line. At the beginning of each line scan, the video camera creates a synchronization pulse that is followed by the image signal (light level). A microphone creates the electrical audio signals from sound pressure waves. These video and audio signals are combined to fonu a composite video electrical signal. The composite video signal (base band) modulates the radio transmitter frequency (broadband) signal. This low-level radio signal is amplified to a very high power level for transmission. A video receiver (typically a television) receives the radio signal and many others from its antenna. Its receiver selects the correct radio signal by using a variable frequency filter (television channel selector) that demodulates the incoming radio signal to create the original. video and audio electrical signals. The video signal is connected to a display device (typically a picture tube) and the audio signal is connected to the speaker.

Summary

Wireless Communication. Provides an introduction to basic wireless Technology and industry terms. It covers who controls and regulates the Wireless industry. A basic definition of each of the major wireless technologies and services are provided. This chapter is an excellent basic introduction to wireless technology.

2. TELECOMMUNICATION APPLICATION AND SERVICES

2.1 **Overview**

Telephone applications are the processes or programs that provide specific features and benefits for the customer that involve the transfer of information through communication systems. Telecommunications services are the underlying communications processes that provide information for telecommunications applications. It is common to use the word services in place of applications, especially when the service is very similar to the application. Examples of communication applications include voice mail, email, and web browsing.

Telephone services include voice, data, and video transmission. Voice services can be categorized into quality of service and voice privacy. Data services use either circuit-switched (continuous connection) data or packet switched (dynamically routed) data. Video transmission is the transport of video (multiple images) that may be accompanied by other signals (such as audio or closed-caption text).Telecommunication services may be provided (distributed) to one or more users of information. Distribution öf services can be categorized into broadcast, multicast, and point-to-point delivery. Broadcast service delivers the same information to all users in a network. Multicast distribution service distributes information to specific users within a network. Point-to-point service transfers information between two specific users or devices within a network. The transfer of information between users can be unmodified or modified. Telecommunication services that only involve the transport of information are called bearer services. Services that require information processing (Such as store and forward) in the network are called teleservices. Services that combine bearer services and teleservices into new unique services are called supplemental services. System features and services are typically provided by call-processing software in the telephone network that interacts with end-user equipment. As a result, some telephone equipment may only be able to operate some system features (e.g., call forwarding) while some service features require device capabilities and software (e.g., calling number identification presentation). To help ensure the correct operation of services and device interaction, industry standards are created.

2.2 Voice Communications

Voice communication is the transmission and reception of audio and other signals that can be represented by the frequency band used for voice signal transmission. Telephone systems transfer voice signals in a variety of forms through by wire, radio, light, and other electronic or electromagnetic systems. These forms include analog and digital voice signals. Options for voice communications include different voice quality of service levels and voice privacy option

2.3 Voice Quality

Voice quality is a measurement of the level of audio quality, often expressed in mean opinion, score (MOS). The MOS is a number that is determined by a panel of listeners who subjectively rate the quality of audio on various Samples. The rating level varies from 1 (bad) to 5 (excellent). Good quality Telephone service (called toll quality) a MOS level of 4.0.

The first telephone systems used analog signals to represent the voice. To overcome the cumulative noise limitations of analog signal transmission, Digital transmission systems were created. These digital transmission signals Represented voice signals by discrete levels that can be recreated eliminating the noise. As a result, in the 1960's, many modern telephone systems Began to offer digital voice communications. The first digital voice services converted (digitized) the analog voice signal to a 64 kbps digital signal. This 64 kbps digital channel (called a DSO)provided "toll quality" voice with a MOS score of 4.0 or above. Generally, there is a tradeoff between system efficiency (bandwidth used) and the level of voice quality. To gain system efficiency (to add more customers per interconnection line), some telephone systems compress the voice using speech-coding (data compression) teclmology. The first compressed voice service uses adaptive pulse coded modulation (ADPCM) that further compresses the 64 DSO to 32 kbps ADPCM. Other voice compressed voice services have been developed that can use low bit-rate standard or proprietary speech compression algorithms. These can further compress the 64 kbps DSO to below 16 kbps or even 8 kbps.

2.4 Voice Privacy

Voice privacy is a process that is used to prevent the unauthorized listening of communications by other people. Voice privacy involves coding or encrypting of the voice signal with a key code so only authorized users with the correct key and decryption program can listen to the communication information. Digital systems are inherently more secure than analog systems because they can easily use an encrypted mode of operation. This encrypted mode of operation "scrambles" voice data before it is sent to other users in the network. The encryption uses a key (mask value) that is calculated from some form of secret data.

When the voice data is received, it must be decrypted using the same mask value that was used to encrypt it. Although an interceptor may be capable of receiving the data signals, they cannot learn the true data value unless the secret number that was added to it is also known. While the telephone system can offer an encryption mode that encrypts the signaling between the end-user's phone line and the telephone network, it is more common for the end-user to maintain their own voice encryption system. This does help to prevent unauthorized access to the telephone system. This also allows the end-user to have many different voice encryption algorithms. The voice encryption algorithms are typically stored on the end-user's telephone devices.

2.5 Data Communications

Data communication is the transmission and reception of binary data and other discrete level signals that can be represented by a carrier signal that can represent the discrete (usually on-off levels) for signal transmission. There are two basic types of data communications: circuit-switched data and Packet-switched data. Circuit-switched data provides for continuous data Signals while packet-switched data allows for rapid delivery of very short data messages.

2.6 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.

Figure 2.1 shows the basic operation of circuit-switched data. In this example, a laptop computer is sending a file to a company's computer that is connected to the public switched telephone network (PSTN). The laptop computer data communication software requests the destination phone number from the user to connect to the remote computer. This telephone number (the address) is used to connect a path through the PSTN switches until the call reaches the destination computer. The dialed number is first connected through local switch #1, port number 4236. This port number is assigned to a memory location in the switch that routes the data connection through a High speed line and time slot 6 to an IXC switch. The IXC switch then assigns a memory location in its switch to a high-speed line, time slot 3 that connects to local switch #2. Local switch #2 assigns a memory location in its switch to poıi number 1249. This port connects to the remote computer. Once this path through the network is setup, it remains constant throughout the data communications session regardless of how much data is transferred between the laptop computer and the company's computer.

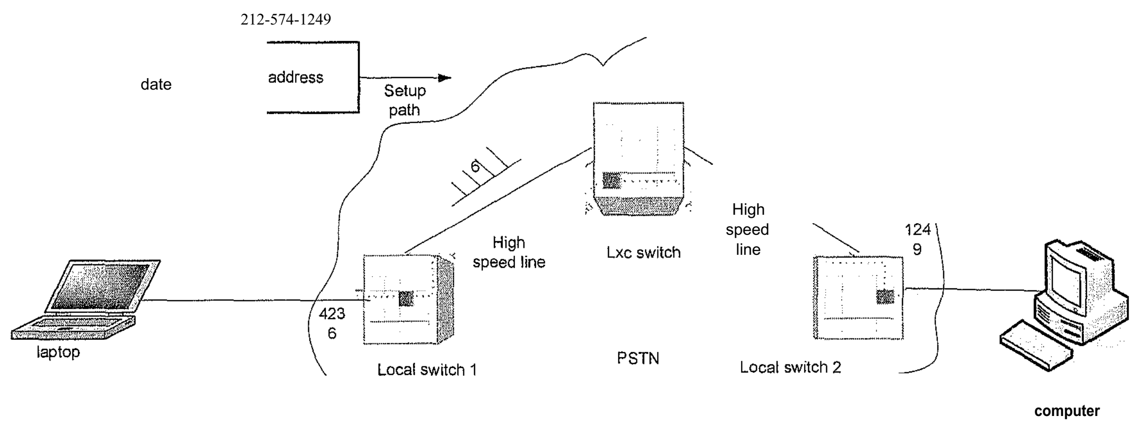

Figure 2.1 Circuit-switched Data

2.7 Packet -switehed Data

Packet data service provides data transfer in the form of short packets of Information. The public telephone network was designed primarily to offer Voice services. Shortly after the telephone network was introduced, circuit switched (Continuous) data services were offered. The operation requirements for circuit-switched and packet-switched data services are very different. Circuit switched data has substantial time and is inefficient for serving Sensing control and applications that require small amounts of information. Initially the standard telephone system had to be enhanced (functionally Divided) to offer packet data service. However, with the digitization of Communications systems, telephone systems operate more like packet data Systems.

Typical applications for packet data service include Internet browsing, wireless Email, train control system, route guidance, credit card processing and many other applications that benefit from the transmission of data in bursts when communicating, Packet data systems provide effective use of the resources. Packet data systems only use network equipment resources when there is information to Transfer. This provides the advantage of charging only for the amount of Information used and increased system efficiency. A packet is a group of digital bits that is transported and switched through a network of packet switches (often called routers) to their destination. The Structure of these packets (digital bit sequence) is arranged in a specific format to allow the determination of the destination address for each packet in Addition to the data that is being transported. Optionally, the packet structure may include other information such as the packet originator and error Protection bits. Transmitting data through a packet network involves dividing data files into small packets (typically under 100 bytes of information). A packet data System divides large quantities of data into small packets for transmission through a switching network that uses the addresses of the packets to dynamically route these packets through a switching network to their multi-mate destination. When a data block is divided, the packets are given sequence numbers so that a packet assembler/dissembler (PAD) device can recombine the packets to the original data block after they have been transmitted through the network

Figure 2.2 shows the basic operation that uses packet-switched data. In this example, a laptop computer is sending a file to a company's remote computer that is connected to a packet data network. The laptop computer data communication software requests the destination address for the packets for the user to connect to the remote computer (202.196.22.45). In this example, the source computer divides the data file into three parts and adds the packet address to each of the 3 data packets. The packets are sent through routers in the packet network that independently determine the best path at the time that will help the packet reach its destination (smart switches). This diagram shows the three packets take 3 different routes to reach their destination. When the 3 packets reach their destination, the remote computer reassembles the data packets into the original data file.

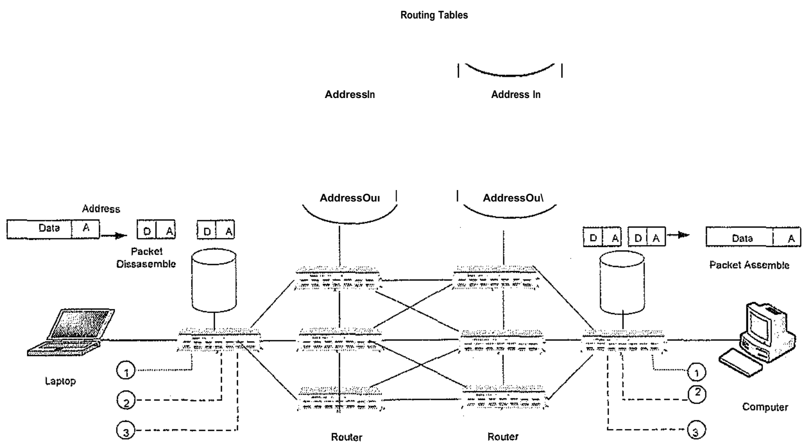

Figure 2.2 Packet-switched Data

2.8 Public Data Network (Internet)

Public data networks interconnect data communication devices (e.g. computers) with each other through a network that is accessible by many users (the pubic). To allow many different users to communicate with each other, standard communication messages and processes are used. The Internet is an example of a public data network (there are other public data networks) that use standard Internet protocol (IP) to allow anyone to transfer data from point to point by using data packets. Each transmitted packet in the Internet finds its way through the network switching through nodes (computers). Each node in the Internet forwards received packets to another location (another node) that is closer to its destination. Each node contains routing tables that provide packet-forwarding information. Each network in the Internet can have different transmission formats (e.g. different packet sizes, high-speed or low-speed data) but they all agree on how to receive and distribute IP packets. Internet service providers (ISPs) connect users (e.g. computers) to the Internet. ISPs are interconnected to each other through network service providers (NSP). NSPs are relatively large networks that may cross international boundaries. NSPs can connect to each other through network access points (NAPs). Because there are a limited number of NAPs, there are also private network access points (PNAPs). PNAPs are setup by the NSPs to relieve the congestion on the NAPs. Figure 2.3 shows the Internet. This diagram shows that the Internet is composed of users (end points), Internet service providers (ISPs), network service providers (NSPs), and network access points (NAPs). Computers are connected to the Internet via an ISP. The ISP receives data from the computer, reformats the data (if necessary), and forwards it to the destination computer in its network. If necessary, it may be routed to an NSP, which will route the data packets to their destination ISP to an NAP that will allow the packet to reach its destination. Eventually, packets reach their destination ISP that forwards the packets to the user.

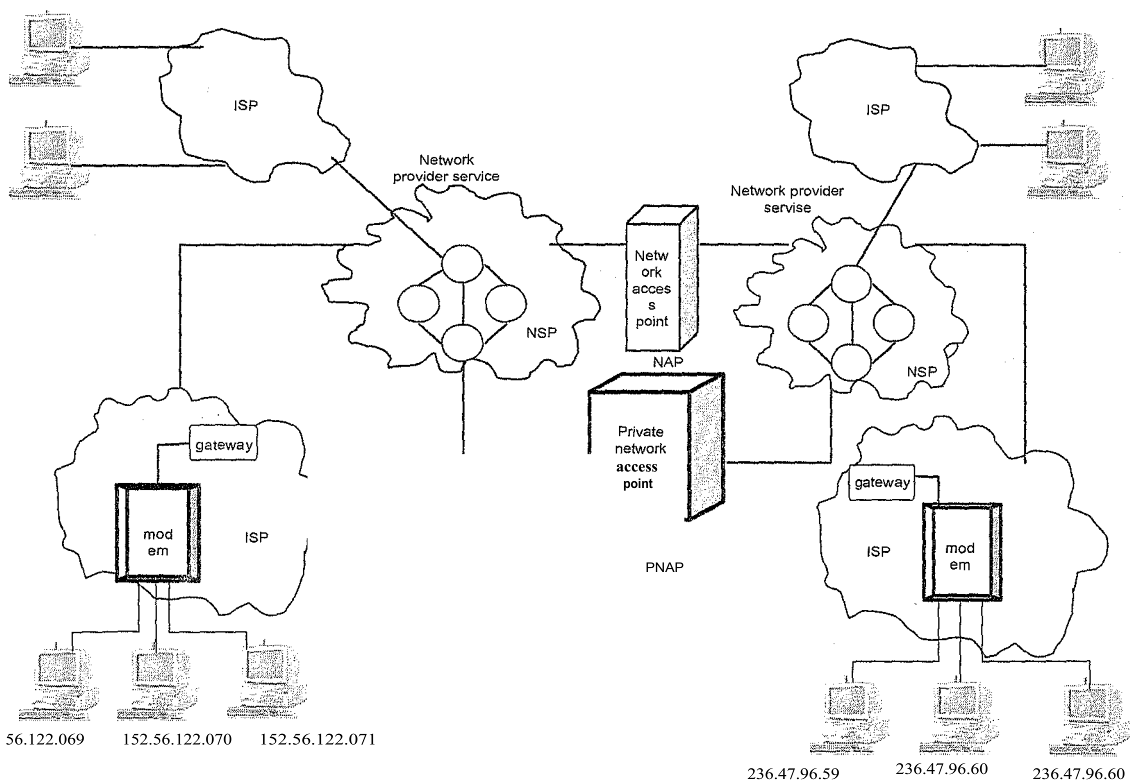

Figure 2.3 Internet

2.9 Video Communications

Video communication is the transmission and reception of video (multiple images) using electrical or optical transmission signals. Telecommunications systems can transfer video signals in analog or digital forın.

2.1 0 Analog Video

Analog video is the representation of a series of multiple images (video) through the use of rapidly changing signals (analog). This analog signal indicates the position, luminance, and color information within the video signal. Sending a video picture involves the creation and transfer of a sequence of individual still pictures called frames. Each frame is divided into horizontal and vertical lines. To create a single frame picture on a television set, the frame is drawn line by line. The process of drawing these lines on the screen is called scanning. The frames are drawn to the screen in two separate scans.

The first scan draws half of the picture and the second scan draws between the lines of the first scan. This scanning method is called interlacing. Each line is divided into pixels that are the smallest possible parts of the picture. The number of pixels that can be displayed determines the resolution (quality) of the video signal. The video signal television picture into three parts: the picture brightness (luminance), the color (chrominance), and the audio.

2.11 Digital Video

Digital video is a sequence of picture signals (frames) that are represented by binary data (bits) that describe a finite set of color and luminance levels. Sending a digital video picture involves the conversion of a scanned image to digital information that is transferred to a digital video receiver. The digital information contains characteristics of the video signal and the position of the image (bit location) that will be displayed.

2.12 Distribution Services

Distribution is the transfer of information throughout a geographic area or through a network. Distribution services include broadcast, multicast, and point-to-point communication.

2.13 Broadcast

Broadcast transmission is the distribution of an information signal to a specified geographic area or network system. Broadcasting allows the same information to be received by all customers in that geographic area that can successfully receive (demodulate) and decode the information.

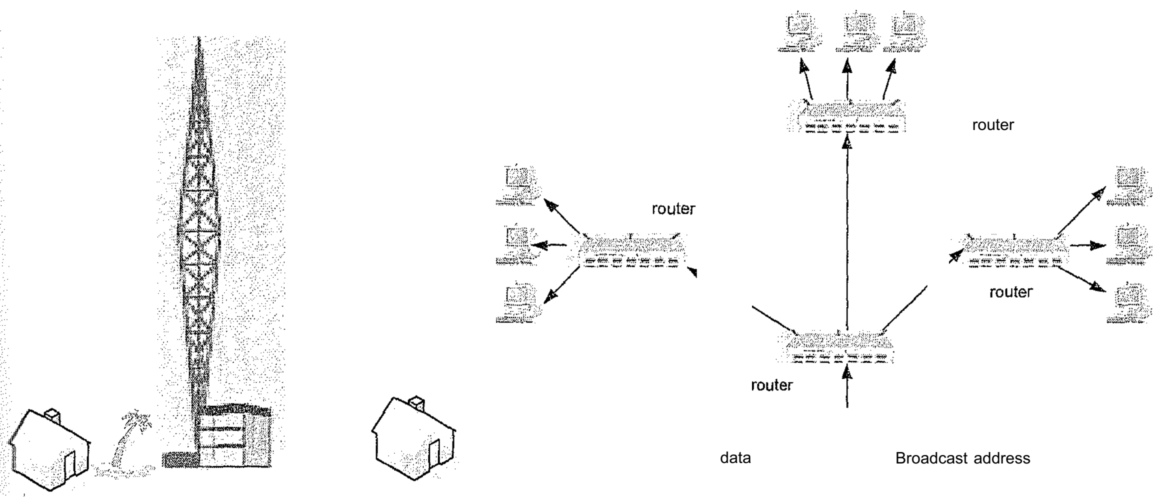

Figure 2.4 Broadcast Communication

2.14 Multicast

Multicast transmission is a communications service where a single message or information transmission contains an address (code) that is designated for several devices (nodes) in a network. Devices must contain the matching code to successfully forward or decode the message.

Figure 2.5 shows examples of how multicast services can be implemented. The first method uses encoded video broadcast transmission and encoded messaging to allow only a select group to view the received information. While all the television broadcast receivers all receive the same radio signal, only the receivers with the correct code will be able to descramble the television signal. The second method uses multicast routing in the Internet to store and forward data to an authorized group of recipients that are connected to its router. When a router in the Internet that is capable of multicast service receives a multicast message, it will store the message for forwarding. It then uses the multicast address to lookup a list of authorized recipients in its routing table. The stored message is then forwarded to the authorized receiving device or next router that is part of the multicast service.

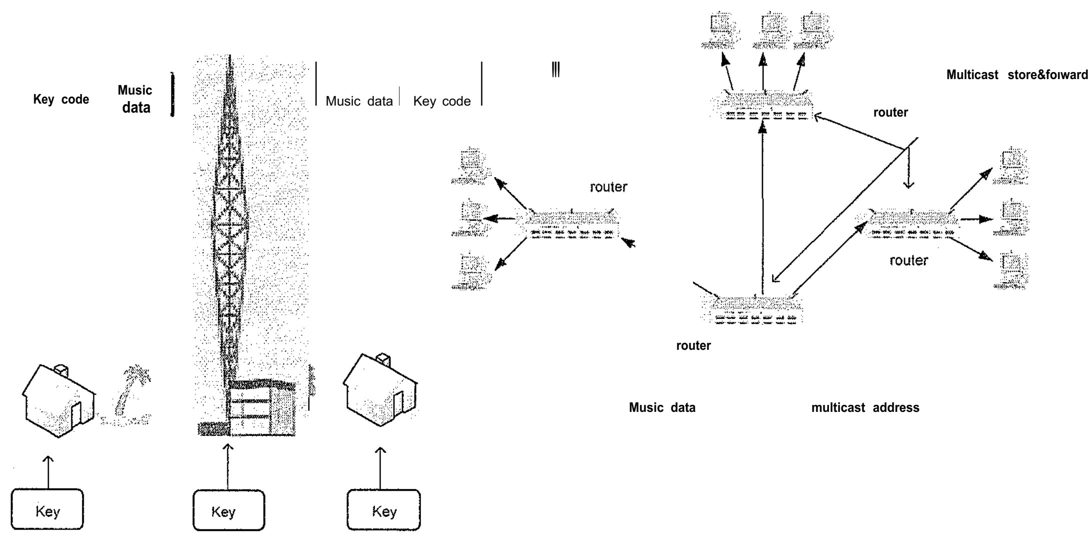

Figure 2.5 Multicast Communications

2.15 Point to Point

Point-to-point communication is the transmission of signals from one specific point to another. Point-to-point communication uses addressing to deliver information to a specific receiver of the information. It is possible to implement point-to-point communication through a broadcast network by using device addressing or through a network using network routing. Figure 2.6 shows examples of how point-to-point services can be implemented. The first method is a paging system that uses device addressing to uniquely identify a specific receiver of the information. While all the pager devices receive the same radio signal, only the receiver that has the correct paging code will be able to descramble the paging message. The second method uses network routing in the Internet to store and forward data to a specific recipient in the network. When a router in the Internet receives a point-to-point message, it will use the address to lookup the best forwarding path to transfer the information towards its destination. Using point-to-point communications by network routing only the designated recipient will receive the data.

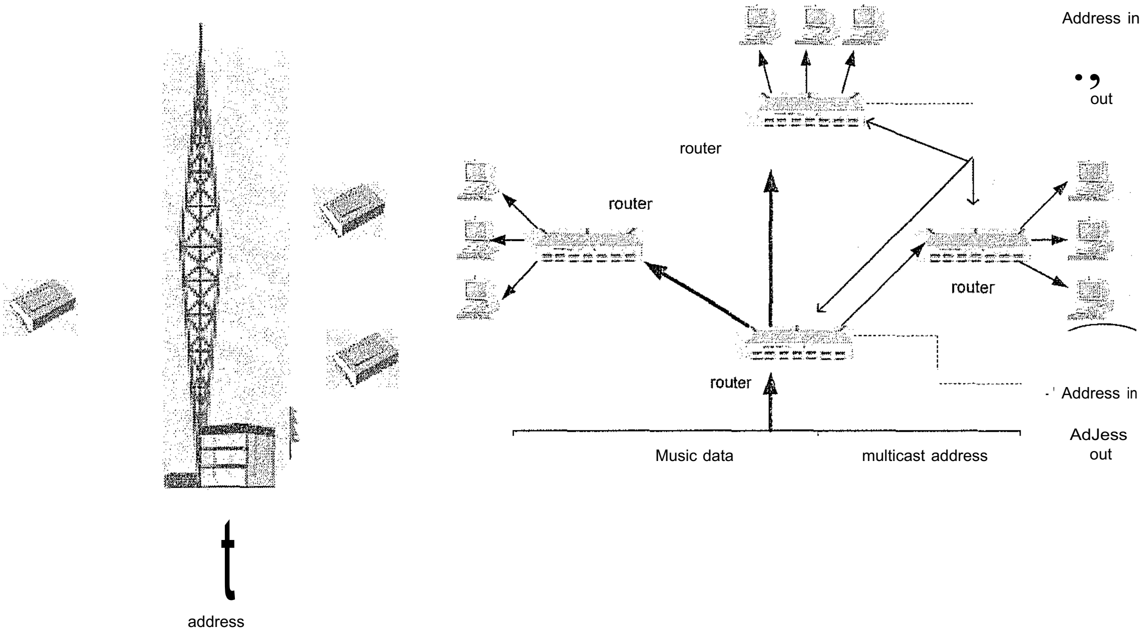

Figure 2.6 Point-to-Point Communications

2.16 Bearer Services

Bearer services are telecommunication services that are used to transfer user data and control signals between two pieces of equipment. Bearer services can range from the transfer of low speed messages (300 bps) to very high-speed data signals (10+ Gigabits). Bearer services are typically categorized by their information transfer characteristics, methods of accessing the service, Interworking requirements (to other networks), and other general attributes. Information characteristics include data transfer rate, direction(s) of data flow, type of data transfer (circuit or packet) and other physical characteristics. The access methods determine what parts of the system control could be affected by the bearer service. Some bearer services must cross different types of networks (e.g., wireless and wired) and the data and control information may need to be adjusted depending on the type of network. Other general attributes might specify a minimum quality level for the service or special conditional procedures such as automatic re-establishment of a bearer service after the service has been disconnected due to interference. Some categories of bearer services available via the telephone system include synchronous and asynchronous data, packet data, and alternate speech and data. Figure 2.7 shows a data transmission bearer service. In this diagram, a customer decides to send a data file to a computer that is connected to a public telephone network (at the office). In this example, the bearer service is 9.6 kbps circuit-switched data. The customer uses a modern to adapt their portable computer to the telephone network. The portable dials the office computer telephone number via the modern. The telephone system routes this call to a modern that connects the office computer to the telephone network. When the office computer modern accepts the call, the customer's modern begins to send data directly on the telephone line channel at 28.8 kbps. Because the telephone system bearer service only provides 9.6 kbps data communication, the end-to-end transmission will be adjusted to 9.6.

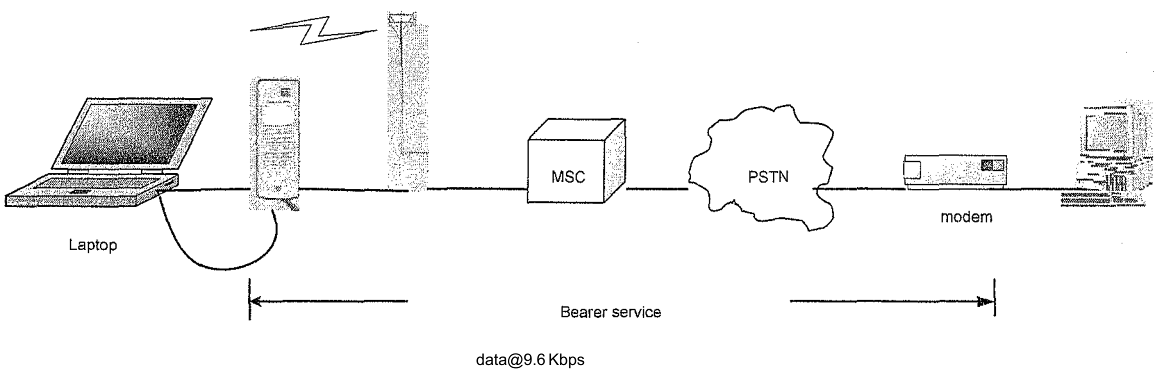

Figure 2.7 Bearer Service

2.17 Constant Bit Rate (CBR)

Constant bit-rate (CBR) service is a class of telecommunications service that provides an end-user with constant bit data transfer rate. CBR service is often used when real-time data transfer rate is required such as for voice.

2.18 Variable Bit Rate (VBR)

Variable bit-rate (VBR) is a category of teleconununications service that provides the users with a data transmission rate of service that can vary. Applications that use VBR services usually require some real-time interactivity with bursts of data transmission. An example of a VBR application is videoconferencing.

2.19 Available Bit Rate (ABR)

Available bit-rate (ABR) is a communications service category that provides the user with a data transmission rate that varies dependent on the availability of the network resources. ABR service may provide the user with feedback as to the changed data transfer rate and may have established minimum and maximum levels of data transmission rates.

2.20 Unspecified Bit Rate (UBR)

Unspecified bit-rate (UBR) is a category of telecommunications service that provides an unspecified data transmission rate of service to end-user applications. Applications that use UBR services do not require real-time interactivity nor do they require a minimum data transfer rate. UBR applications may not require the pre-establishment of connections. An example of a UBR application is Internet web browsing.

2.21 Committed. Information Rate

Committed information rate (CIR) is a guaranteed minimum data transmission rate of service that will be available to the user through a network. Applications that use CIR services include voice and real-time data applications. CIR can be measured in bits per second, burst size, and burst interval. Some service providers allow users to transmit data above the CIR level. However, when data is transmitted above the CIR level, some of the data may be selectively discarded if the network becomes congested.

2.22 Custom Calling Features

Custom local area signaling services (CLASS) are telephone service features available in a local access and transport area (LATA) that are primarily based on information that can be processed inside the telephone network. CLASS features include call forwarding, caller identification, and three-way calling.

2.23 Voice Mail (VM)

Voice mail (VM) is a service that provides a telephone customer with an electronic storage mailbox that can answer and store incoming voice messages. Voice mail systems use interactive voice response (IVR) technology to prompt callers and customers through the options available from voice mailbox systems. Voice mail systems offer advanced features not available from standard answering machines including message forwarding to other mailboxes, time of day recording and routing, special announcements, and other features.

2.24 Central Exchange (Centrex)

Centrex is a service offered by a local telephone service provider that allows the customer to have features that are typically associated with a private branch exchange (PBX). These features include 3 or 4 digit dialing, intercom features, and distinctive line ringing for inside and outside lines, voice mail waiting indication, and others. Centrex services are provided by the central office switching facilities that are located in the local telephone network.

2.25 Calling Centre

A call center is a place where calls are answered and originated, typically between a company and a customer. Call centers assist customers with requests for new service activation and help with product features and services. A call center usually has many stations for call center agents that communicate with customers. When call agents assist customers, they are typically called customer service representatives (CSRs).

Call centers use telephone systems that usually include sophisticated automatic call distribution (ACD) systems and computer telephone integration (CTI) systems. ACD systems route the incoming calls to the correct (qualified) customer service representative (CSR). CTI systems link the telephone calls to the accounting databases to allow the CSR to see the account history (usually producing a "screen-pop" of information).

2.26 Operator Services

Operator services are telecommunication services that use an operator to assist in the handling of a call or communication session. These special handling services include collect calling (billing to a called number), third party charging (billing to another phone or calling card), identification of a person who has called (call trace services), call information services (assistance with directory number location), rate information services (call charge rates), or any other service that requires an operator for special call processing services.

2.27 Supplementary Services

Supplementary services are services that enrich basic services. Often, the subscriber (user) can specify some of the operations of supplementary services (such as call forwarding). Supplementary services may be defined or installed in systems before complete testing or industry consensus can be reached.

Summary

Telecommunication Applications and Services. Describes the applications associated telecommunications. This chapter gives a broad overview of the different types of wireless services and how they operate. This includes voice, data, and remote control, point to point and broadcast services.

3. WIRELESS TECHNOLOGY BASICS

3.1 Overview

Wireless communication involves the transfer of information signal through the aır by the means of electromagnetic waves. To create electromagnetic waves, an electrical signal that continuously varies in power level and polarity, is applied to an antenna. As the level varies, the energy contained in the electrical signal is conveiied to electromagnetic waves that propagate away from the antenna. The electromagnetic waves are characterized by their energy (RF power) and frequency (cycles per second or Hz named after the German physicists Heinrich Rudolph Hertz). Commercial uses for these electromagnetic waves repeat their cycle in a frequency range of approximately 150,000 Hertz (150 kHz) to 300 billion (Giga) Hertz (300 GHz).

To allow information to be transferred using electromagnetic waves, an information signal (typically audio) slightly changes the wave shape of the electromagnetic signal. This is called a radio signal. Radio signals can co-exist with each other without interference if they are operating at different frequencies. Because an information signal slightly changes the electromagnetic signal (the carrier signal), this produces small changes in frequency.

3.2 Analog Signals

An analog signal is a signal that can vary continuously between a maximum and minimum value. An analog signal can assume an infinite number of values between the two extremes.

3.3 Digital Signals

Digital signals consist of a series of ones and zeros, most often represented in telecommunications signals by two different voltages. For example a +5 Volt level could represent a logical 1 (one) and 0 Volt level could represent a logical 0 (zero). The ones and zeros are called bits. Several bits (usually eight) are grouped into a byte and each byte is defined to have a specific meaning, such as a specific letter on a keyboard. Digital signals are used to represent specific levels on an analog signal.

While a digital signal cannot represent every point on an analog wave, they can come close enough to be almost indistinguishable. Digital signals are much easier to process by computer systems and they are able to resist the effects of noise better than analog signals. When the reference is made to bytes instead of bits, the b is capitalized. For example, 10 thousand (k) bytes (B) are represented by kb. Figure 3.4 shows a digital signal that is in the form of a series of bits and these bits are combined into groups of 8 bits to form Bytes (B). In this example, the bits 01011010 are transferred in 1 second. This results in a bit (transmission) rate of 8 bps. The earliest form of digital radio communication was Morse code. To send Morse code, the radio transmitter was simply turned on-and off to form dots and dashes. The receiver would sense (detect) the radio carrier to reproduce the dots and dashes. A codebook of dots and dashes was used to decode the message into symbols or letters. The on and off pulses or bits that comprise a modem digital signal are sent in a similar way.

3.4 Digitization of an Analog Signal

Digitization is the conversion of analog into digital form. The digitization process uses an analog-to-digital (pronounced A to D) converter that periodically senses (samples) the level of the analog signal and creates a binary number or series of digital pulses that represent the level of the signals The common conversion process is Pulse Code Modulation (PCM). For most PCM systems, the typical analog sampling rate occurs at 8000 times a second. Each sample produces 8 bits digital that results in a digital data rate (bit stream) of 64 thousand bits per second (kbps).

Digital bytes of information are converted to specific voltage levels based on the value (weighting) of the binary bit position. In the binary system, the value of the next sequential bit is 2 times larger. For PCM systems that are used for telephone audio signals, the weighting of bits within a byte of information (8 bits) is different than the binary system. The commanding process increases the dynamic range of a digital signal that represents an analog signal; smaller bits are given larger values than their binary equivalent. This skewing of weighing value gives better dynamic range.

This commanding process increases the dynamic range of a binary signal by assigning different weighted values to each bit of information than is defined by the binary system. Figure 3.1 shows how an analog signal is converted to a digital signal.

This diagram shows that an acoustic (sound) signal is converted to an audio electrical signal (continuously varying signal) by a microphone. This signal is sent through an audio band-pass filter that only allows frequency ranges within the desired audio band (removes unwanted noise and other non audio frequency components). The audio signal is then sampled every 125 microseconds (8,000 times per second) and converted into 8 digital bits. The digital bits represent the amplitude of the input analog signal.

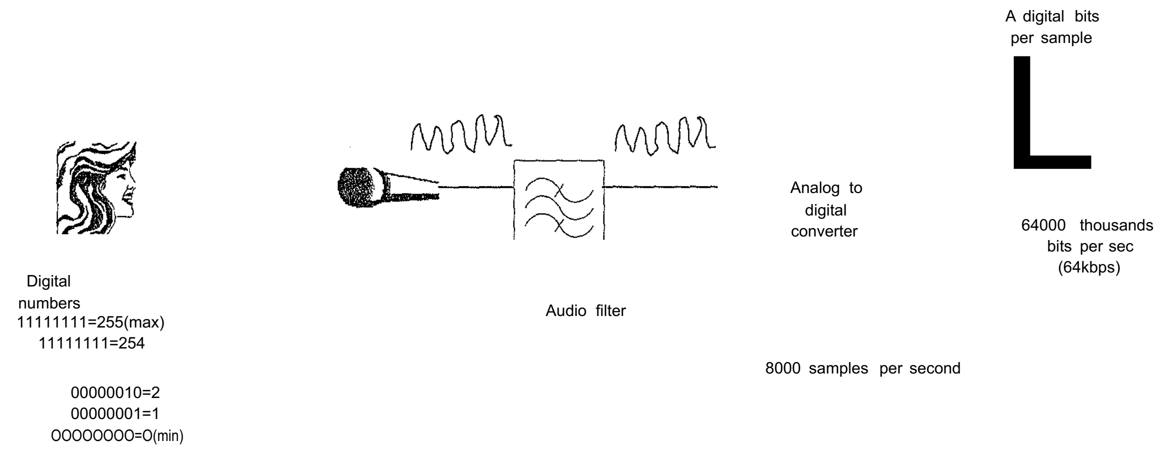

Figure 3.1 signal digitization

Digital signals are more reliable because of its resistance to added noise and the ability to easily add error detection and correction capability. Digital signals have two discrete levels (1 and 0). Small amounts of noise or interference do not affect these levels. By calculating a number for each block of data bits that are transmitted and adding a few extra data bits that represent this calculation, this allows a receiver to compare these extra bits to the original bits that are sent to determine if the bits were received correctly. In some cases, these extra bits can be used to help correct for bits that have been received in error.

3.5 Amplitude Modulation (AM)

Amplitude modulation is the transferring of information onto a radio wave by varying the amplitude (intensity) of the radio carrier signal. Figure 3.2 shows that amplitude modulation involves the transferring of information onto a carrier signal by varying the amplitude (intensity) of the carrier signal. This diagram shows an example of an AM modulated radio signal (on bottom) where the high of the radio carrier signal is changed by using the signal amplitude or voltage of the audio signal (on top).

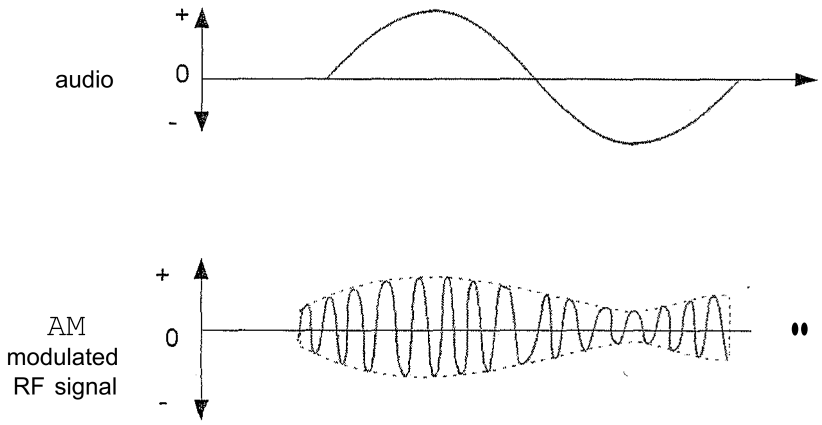

Figure 3.2 amplitude modulation

3.6 **Frequency Modulation** (FM)

Frequency modulation is the process of transferring an information signal onto a radio carrier wave by varying the instantaneous frequency of the radio carrier signal. In 1936, the inventor Armstrong demonstrated an FM transmission system that was much less susceptible to noise signals than AM modulation systems.

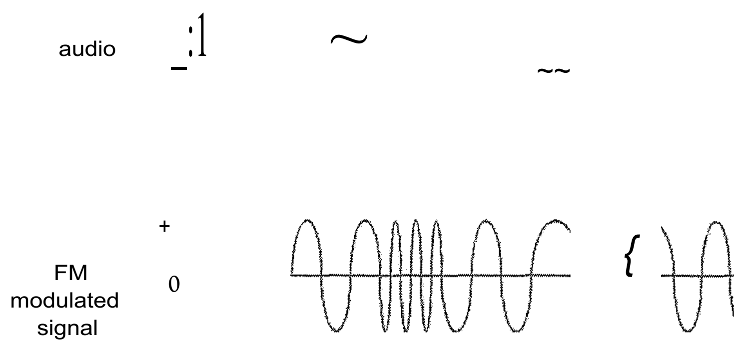

Figure 3.3 frequency modulation

Figure 3.3 shows how frequency modulation (FM) uses a modulation signal (audio wave) to change the frequency of the radio carrier signal as the voltage of the audio signal increases and decreases. One particular form of frequency modulation that is used to transmit digital information is called frequency shift keying (FSK). To represent a digital signal, the FSK modulator transmits on one frequency to signify a one (on) and a different frequency to signify a zero (off).

3.7 Phase Modulation (PM)

Phase modulation is a modulation process where the phase (relative time shift of the carrier sine wave relative to unshifted, "clock" sine wave of the same frequency) of the carrier signal is modified by the amplitude of the information (e.g., audio or data) signal.

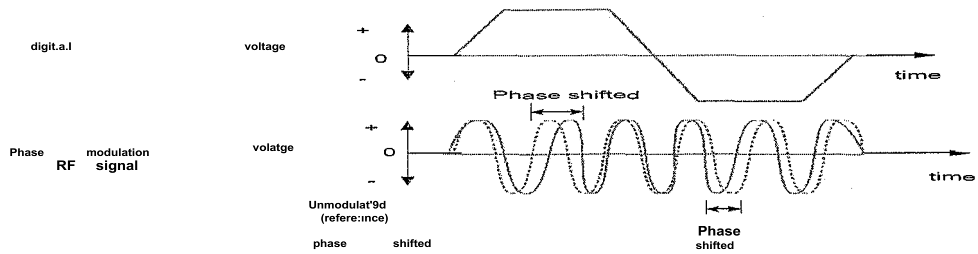

Figure 3.4 phase modulation

Figure 3.4 shows a sample of phase modulation (PM). In this diagram, a digital signal (on top) creates a phase modulated carrier signal (on bottom). As the digital signal voltage is increased, the frequency of the radio signal changes briefly so the phase (relative timing) of the transmitted signal advances compared to the unmodulated radio carrier signal. These results in a phase-shifted signal (solid line) compared to an unmodulated reference radio signal (dashed lines). When the voltage of the digital signal is decreased, the frequency changes again so the phase of the transmitted signals retards compared to the unmodulated radio carrier signal. Sophisticated modulation system can use all three variable parameters: frequency, amplitude or timing (phase) at the same time to transfer analog or digital information.

3.8 Frequency Division Multiple Access (FDMA)

Frequency division multiple access is a process of allowing mobile radios to share radio frequency allocation by dividing up that allocation into separate radio channels where each radio device can communicate on a single radio channel during communication. Frequency division multiple access (FDMA) is the first access technology used for two-way radios.

Figure 3.5 shows how a frequency band can be divided into several communication channels using frequency division multiplexing (FDM). When a device is communicating on a FDM system using a frequency carrier signal, its carrier channel is completely occupied by the transmission of the device. For some FDM systems, after it has stopped transmitting, other transceivers may be assigned to that carrier channel frequency. When this process of assigning chaımels is organized, it is called frequency division multiple access (FDMA). Transceivers in an FDM system typically have the ability to tune to several different carrier channel frequencies

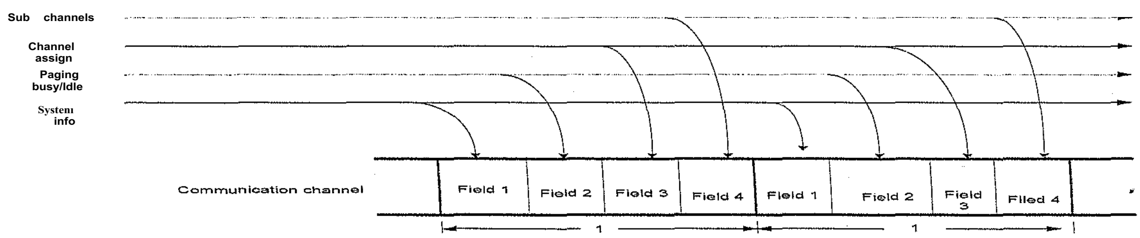

Figure 3.5 logical channel

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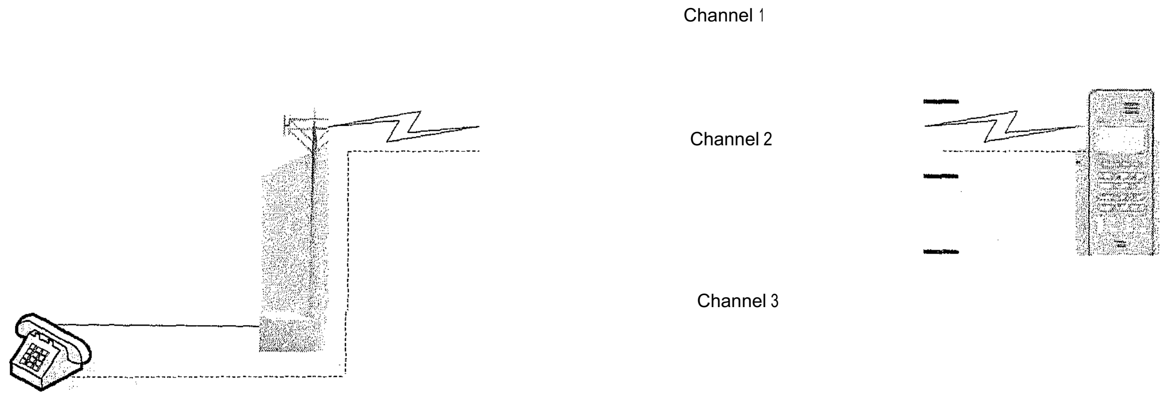

Figure 3.6 frequency divisions multiple accesses

3.10 Time Division Multiple Access (TDMA)

Time division multiple access (TDMA) is a process of sharing a single radio channel by dividing the channel into time slots that are shared between simultaneous users of the radio channel. When a mobile radio communicates with a TDMA system, is assigned a specific time position on the radio channel. By allowing several users to use different time positions (time slots) on a single radio channel, TDMA systems increase their ability to serve multiple users with a limited number ofradio channels.

3.11 Spread Spectrum (FHMA and CDMA)

Spread spectrum communications is a method of spreading information signals (typically digital signals) so the frequency bandwidth of the radio channel is much larger than the original information bandwidth. There are various forms of spread spectruın communications. The most popular forms of spread spectrum include frequency hopping multiple accesses (FHMA) and code division multiple access (CDMA).FHMA is an access teclmology where mobile radios may share radio chaı:mels by transmitting for brief periods of time on a single radio channel and then hoppiıigtô other radio channels to continue transmission. Each mobile radio is assigned a particular hopping pattern and collisions that occur are random and only cause a loss ofsmall amounts of data that may be fixed through error detection and correction methods, CDMA is a relatively new commercialized (verses militarized) modulation technique that is used in cellular and satellite systems. CDMA systems mix a relatively>lô:ı:ıg digital code with a small amount of communication data to produce a combined signal that is spread over a relatively wide frequency band. To receive the signal, the longcöcle is used to extract the original signal. Because the energy is spread over a wide bandwidth, multiple CDMA channels with different codes can co-exist with minimal interference. Figure 3.7 shows how a single direct sequence spread spectrum communication channel can have several channels. In this example, there are 3 different code patterns that are used for communication channels. When a receiver uses the reference code, a direct sequence.spread spectrum system can build a mask as shown in this figure for each conversation allowing only that 'information which falls within the mask to be transmitted or received.

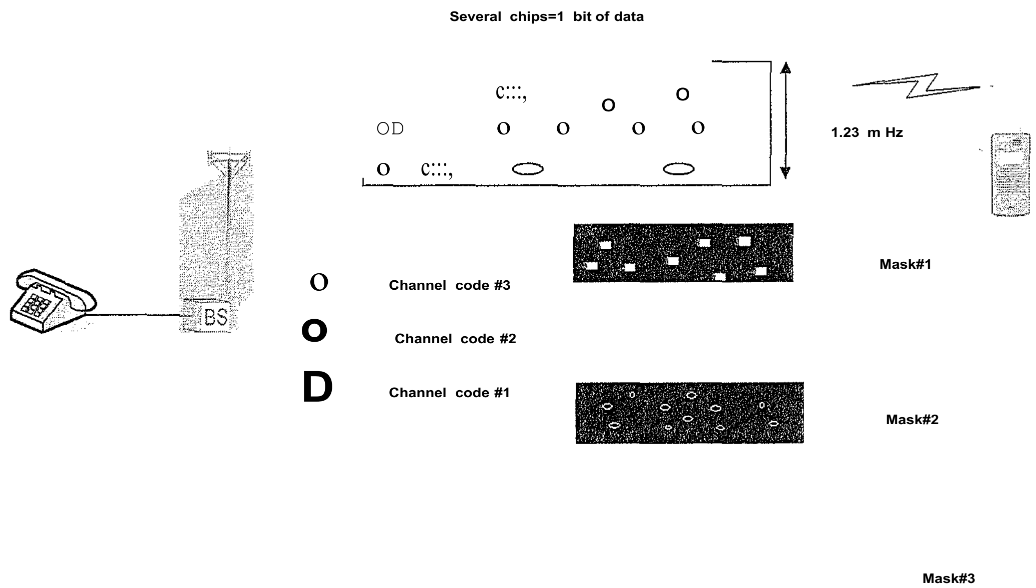

Figure 3.7 code divisions multiple accesses

3.12 Analog (Audio) Signal Processing

Analog signal processing is the conversion of analog signals into another form using analog (continuous) circuits or systems. Analog signal processing includes filters, shaping circuits, combiners, and amplifiers to change their shape and modify the content of analog signals. Audio signals contain a wide range of frequencies and it is usually not necessary to transmit all of these frequencies. These high and low frequencies can be removed by filtering. To remove these frequencies, audio signals may be processed by sha.ping circuits that add or remove emphasis to frequency (tone) or intensity (volume). When analog audio signals are used to modulate a radio wave, the high frequency components of the audio signal are emphasized (called pre-emphasis) to allow the modulator to be more effective Because the intensity of an audio signal can vary dramatically (some people talk loudly and others talk softly), an amplification of the audio signal may be reduced as the user talks louder (called commanding). When pre emphasis and commanding circuits are used to process an audio signal in a transmitter, the opposite functions (de-emphasis and expanding) are used in the receiver to restore the audio signal back to its original form. In some cases, additional signals may be combined with audio signals prior to transmission. These signals are used for control purposes. If control signals are added to an audio signal in a transmitter, they must be removed from the audio signal in the receiver by filtering. Audio amplifiers are used to adjust the volume of an audio signal.

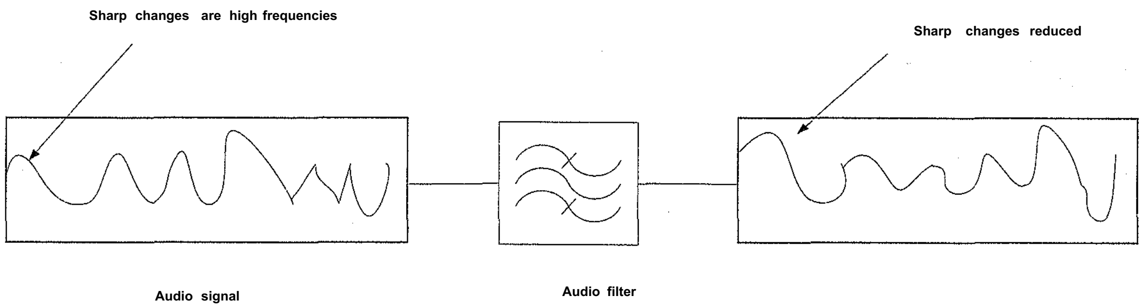

Figure 3.8 audio signal filtering

Figure 3.8 shows typical audio signal processing for a communications transmitter. In this example, the audio signal is processed through a filter to remove very high and very low frequency parts (audio band-pass filter). These unwanted frequency parts are possibly noise and other out of audio frequency signals that could distort the desired signal. The high frequencies can be seen as rapid changes in the audio signal. This diagram shows that the sharp edges of the audio signal (high frequency components) are removed after the audio band-pass filter has processed the audio signal.

3.13 Digital Signal Processing

Digital signal processing is the manipulation of digital signals into other forms using computing circuits or systems. Digital signal processors use software programs to allow them to perform complex signal processing operations such as filtering, modulation, data compression, and shaping of the information (such as digital audio signal) that are represented by digital signals. When analog signals are converted to digital format, the digital signals represent the original analog waveform. Just like analog signals that may be processed by filters, shaping circuits, combiners and amplifiers, digital signals can be processed to produce similar functions. To change a digital signal, a microprocessor is used to manipulate the incoming digital information via a program (stored instructions) that produces a new digital output. The program determines the functions that are performed in the digital signal. Because radio signals can experience signal distortion that can result in the incorrect determination of a digital signal (whether a zero or one had been sent), digital systems typically include error detection and correction processing. Error detection processing involves the creation of additional bits that are sent with the original data. The check bits are created by using a formula calculation on the digital signal prior to sending the data signals. After the digital signal is received, the formula can be used again to create check bits from the received digital signal. If the check bits match, the original digital signal was received correctly. If the check bits of the received data signal do not match the calculated results, this indicates that some or the entire digital signal was received in error. This process is called error detection. Some digital systems use sophisticated mathematical formulas to create the check bits so that the check bits can be used to make correciioiis (or predictions of the correct bits) to the received digital signal.

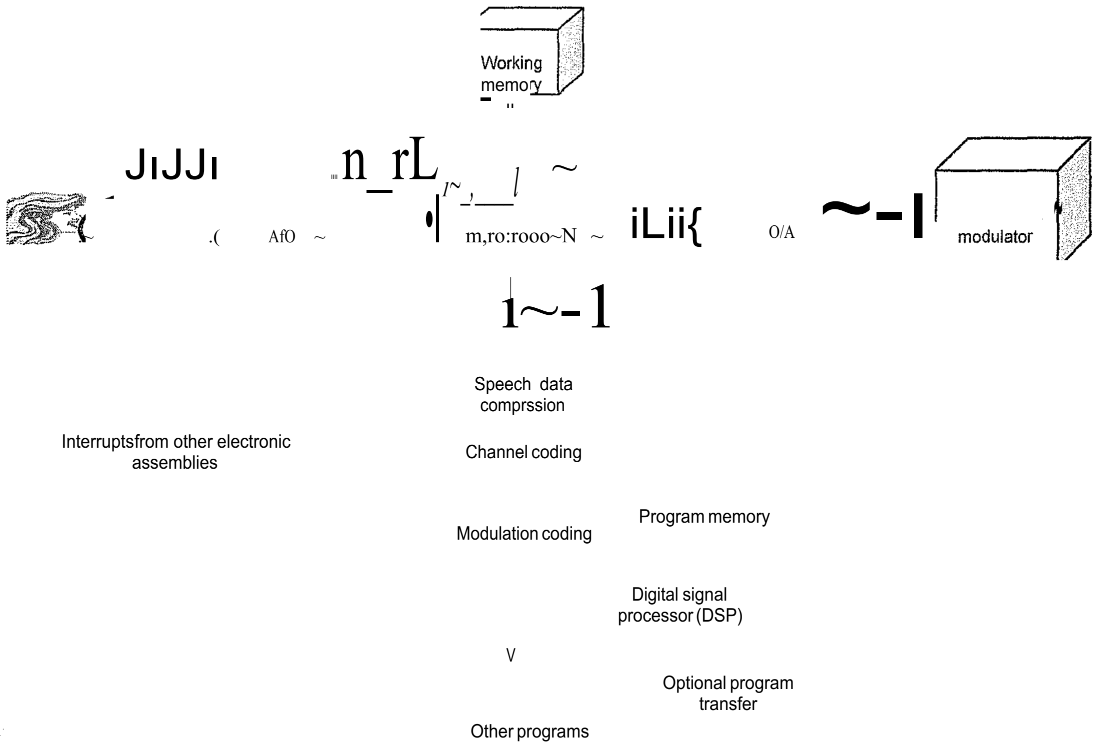

Figure 3.9 digital signal processing

Figure 3.9 shows typical digital signal processor that is used in a digital communication system. This diagram shows that this DSP has 3 software programs, digital signal compression, channel coding, and modulation coding. The digital signal compression software analyzes the digital audio signal and compresses the information to a lower data transmission rate. The channel coding adds control signals and error protection bits the modulation coding formats {shapes) the output signal so it can be directly applied to an RF modulator assembly. This diagram also shows that an optional interface is included to allow updating of the software programs that are stored in the DSP.

3.14 Radio Signal Processing

RF signal processing includes RF amplification and filtering. RF amplification is used to increase (amplify) a radio signal to a high level RF signal for transmission or to boost the low level of a received RF signal. RF filtering allows the passing of desired radio signals (such as the radio channel the receiver is listening to) while blocking unwanted signals (such as other radio channelsj.Figure 3.1 0 shows how the radio signal power level output of a mobile telephone is adjusted by commands received from the base station to reduce the average transmitted power from the mobile telephone.

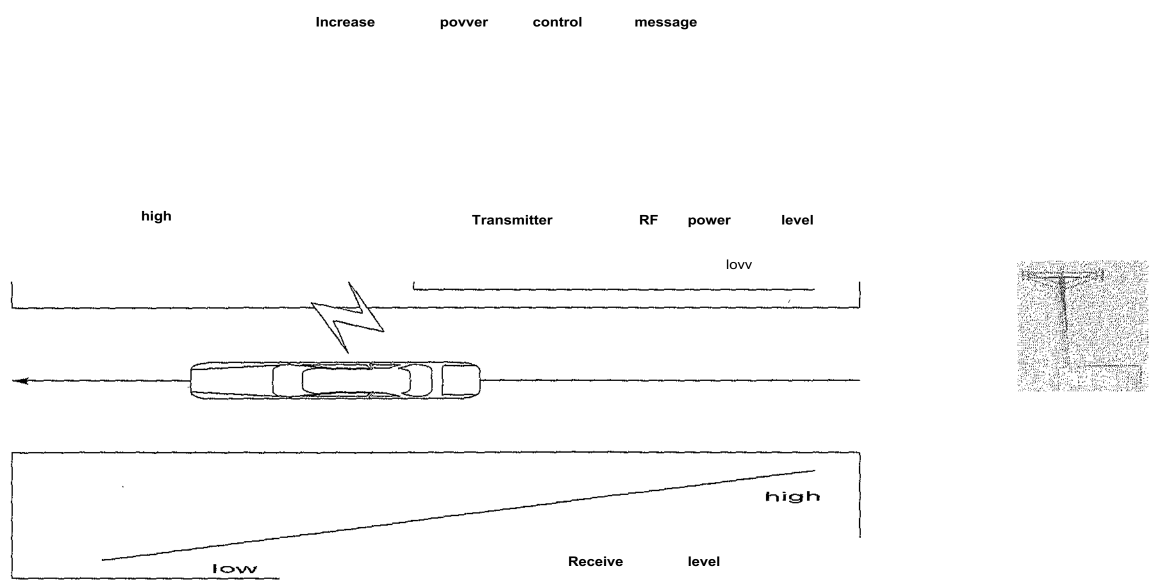

Figure 3.10 RF power control

This lower power reduces interference to nearby cell sites. As the mobile telephone moves closer to the cell site, less power is required from the mobile telephone and it is commanded to reduce its transmitter output power level. The base station transmitter power level can also be reduced although the base station RF output power is not typically reduced. While the maximum output power varies for different classes of mobile telephones, typically they have the.same minimum power level.

3.15 Radio Transmitters and Receivers

Radio transmitters convert information signals into electromagnetic waves and radio receivers convert the electromagnetic waves back into the original information signals. When a radio transmitter and receiver are combined into a single device. It is called a Radio transceiver (usually called a "radio.") Radios may be fixed in location (such as a television) or may be mobile (such as a cellular telephone). Figure 3.11 shows a block diagram of a mobile radio transceiver. In this diagram, sound is converted to an electrical signal by a microphone. The audio signal is processed (filtered and adjusted) and is sent to a modulator. The modulator creates a modulated RF signal using the audio signal. The modulated signal is supplied to an RF amplifier that increases the level of the RF signal and supplies it to the antenna for radio transmission. This mobile radio simultaneously receives another RF signal on a different frequency to allow the listening of the other person while talking. An amplifier in the receiver boosts (amplifies) the received RF signal to a level that is acceptable for the demodulator assembly. The demodulator extracts the audio signal and the audio signal is amplified so it can create sound from the speaker.

3.16 Radio Towers

Radio towers are poles, guided towers or free standing constructed grids that raise one or more antennas to a height that increases the range of a transmitted signal. Radio towers can vary in height from about 20 feet to more than 300 feet. A single radio tower may host several antenna systems that include paging, microwave or cellular systems. Radio towers are located strategically around the city to provide radio signal coverage to specific areas. At the base of the towers are electronic control rooms that contain the components to operate the radio portion of the communications system.

Base stations consist of one or more antennas, transmitters, receivers (for two-way systems), system controllers, and communication links and power supplies. Transmitters provide the high level RF power that is supplied to the antenna. For broadcast systems, the amount of transmitter power can exceed 50,000 Watts. Radio receivers boost and demodulate incoming RF signals from mobile radios. If a base station contains receivers, it is typical to use one or more different antennas for the receivers. Controllers coordinate the overall operation of the base station and coordinate the alarm monitoring of electronic assemblies. Communication links allow a command location (such as a television studio or a telephone switching center) to control and exchange information with the base station. Base station radio equipment requires power supplies. Most base stations contain primary and backup power supplies. A battery typically maintains operation when primary power is interrupted. A generator may also be included to allow operation during extended power outages. Figure 3.11 shows a base station functional diagram for a mobile radio system. This base station contains amplifiers, radio transceivers, RF combiners, control sections, communications links, a scanning receiver, backup power supplies, and an antenna assembly. The transceiver sections are similar to the mobile telephone transceiver as they convert audio to RF signals and RF to audio signals. The transmitter output side of these radio transceivers is supplied to a high power RF amplifier (typically 10 to 50 Watts). The RF combiner allows separate radio channels to be combined onto one or several antenna assemblies without interfering with each other. This combined RF signal is routed to the transmitter antenna on top of the radio tower via low energy-loss coaxial cable.

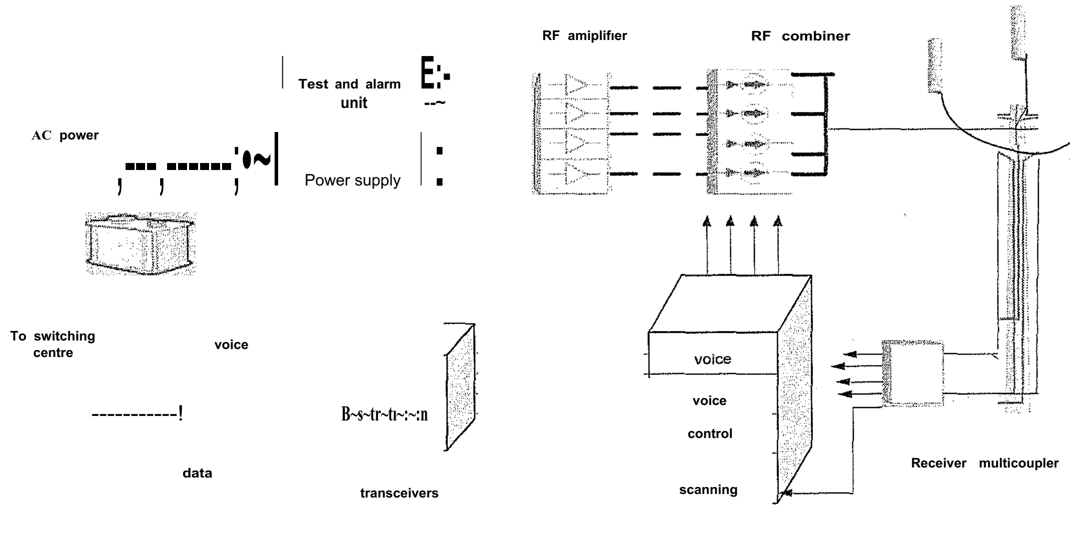

Figure 3.11 radio base station block diagram

3.17 Switching Facilities

Switching facilities are typically used in two-way mobile communication systems to allow the connection of mobile radios to other radios in the system or to the public telephone network. When used in a cellular system, the switching system is typically called a Mobile Switching Center (MSC). The MSC, just like a local telephone company, processes requests for service from mobile radios (subscribers) and routes the calls to other destinations. Figure 3 .12 shows a functional diagram of a switching center that is used for mobile telephone systems. This mobile switching center (MSC) consists of controllers, switching assembly, communications links, operator terminal, subscriber database, and backup energy sources. The controllers, each of which including powerful computers, are the brains of the entire cellular system, guiding the MSC through the creation and interpretation of commands to and from the base stations. In addition to the main controller, secondary controllers devoted specifically to control of the cell sites (base stations) and to handling of the signaling messages between the MSC and the PTSN are also provided.

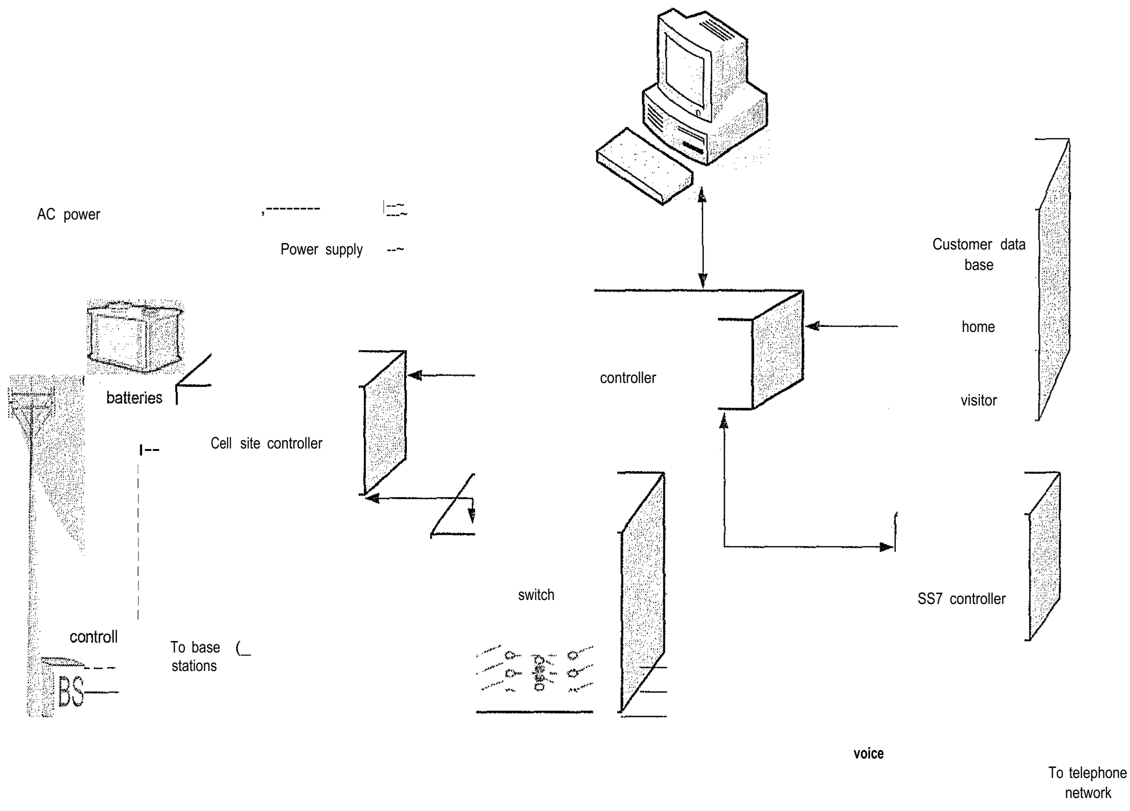

Figure 3.12 wireless switching system block diagram

A switching assembly routes voice connections from the cell sites to each other or to the public telephone network. Communications links between cell sites and the MSC may be copper wire, microwave, or fiber optic. An operator terminal allows operations, administration and maintenance of the system. A subscriber database contains features the customer has requested along with billing records. Backup energy sources provide power when primary power is interrupted. As with the base station, the MSC has many standby duplicate circuits and backup power sources to allow system operation to be maintained when a failure occurs.

3.18 Interconnection to Other Networks

Almost all wireless systems are connected to other networks. Broadcast systems may be connected to media sources (such as audio or video programs) via satellite links while cellular networks may be interconnected to the public telephone network. Interconnection involves the physical and software connection of network equipment or communications systems to the facilities of another network such as the public telephone network. Government agencies such as the Federal Communications Commission (FCC) or department of communications (DOC) regulate interconnection of wireless systems to the public telephone networks to ensure reliable operation.

3.19 Customer Databases

Customer databases are computer storage devices (typically a computer hard disk) that hold service authorization and feature preferences of customers. Each wireless subscriber has a real-time user profile in the database that is typically called the Home Location Register (HLR). The HLR identifies the current location of the mobile radio, the most likely place for the mobile to be, or the last location the subscriber was active. The MSC system controller uses this information to route calls to the appropriate radio tower for call completion. If the wireless user is not in a predetermined "home" range of the MSC, the mobile will register back through to the home signaling system to its Home Location Register (HLR) for profile information. This information will be temporarily stored in a Visitor Location Register (VLR). In some wireless networks, access to system services requires validation of the customer's identity.

Wireless phones transmit some of their identification information over the public airwaves when they attempt to access the system. Thieves may try and intercept this information and copy (clone) the identification information that would allow them to make phone calls that would be billed to the other telephone. To prevent this unauthorized duplication of identification information, an authentication process can be used that uses secret keys to validate access information. During the authentication process, code keys are created from secret codes that are stored in both the mobile radio and in the system. Along with basic identification information, these keys are exchanged during each system access attempt. The secret codes are not transmitted. Because the system and the mobile radio have the secret keys, both the mobile phone and the system can validate that the code information is correct. If the codes do not match, the system should not allow the call to be processed. New codes are created during each access attempt to prevent copying of the codes and immediately attempting access.

3.20 Internet

The Internet is a public data network that interconnects private and government computers together. The Internet transfers data from point to point by packets that use Internet protocol (IP). Each transmitted packet in the Internet finds its way through the network switching through nodes (computers). Each node in the Internet forwards received packets to another location (another node) that is closer to its destination. Each node contains routing tables that provide packet-forwarding information. Figure 3.13 shows the basic structure of the Internet. This diagram shows that the Internet is composed of users (end points), Internet service providers (ISPs), network service providers (NSPs), and network access points (NAPs). Computers are connected to the Internet via an ISP. The ISP receives data from the computer, reformats it (if necessary), and forwards it to the destination computer in its network.

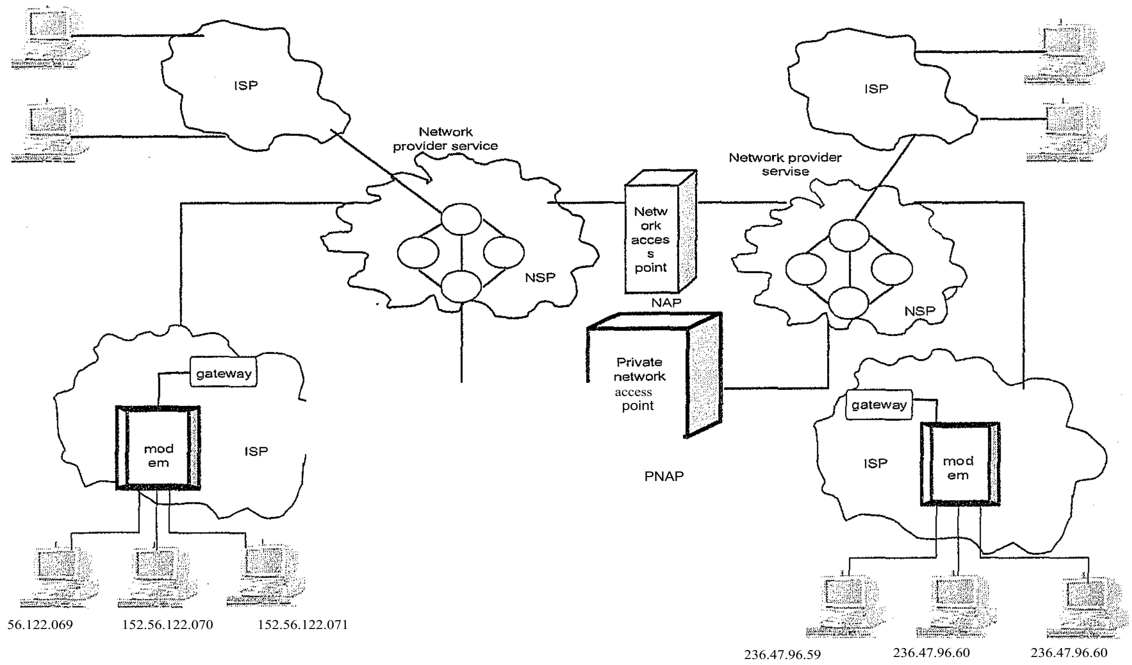

Figure 3.13 Public Internet

3.21 Public Switched Telephone Network (PSTN)

The Public Switched Telephone Network (PSTN) is the common wired telephone system used by the world to connect any telephone to any other telephone connected to the PSTN. Switches connect the network parts of the PSTN and switches have different hierarchical levels. Lower level switches are used to connect end users (telephones) directly to other end users in a specific geographic area. Higher-level switches are used to interconnect lower level switches. Switches send control messages to each other through a separate control signaling network called signaling system number 7 (SS7). The SS7 network is composed of signaling transfer points (STPs) and service control point (SCP) databases. A STP is used to route packets of control messages through the network. SCPs are databases that are used by the network to process or reroute calls through the network (such as 800 number toll free call routing).

3.22 Summary

Wireless Technology Basics explains the fundamentals of wireless technology and terminology. This includes how the radio frequency Spectrum is divided, the basics of radio frequency transmission and modulation, Radio networks.

4. MOBILE RADIOS (CELLULAR, PCS AND 3G)

4.1 Overview

Cellular personal communication service (PCS) and third generation 3G mobile radio systems are all cellular wireless communication networks that provide for voice and data communication throughout a wide geographic area. Cellular systems divide large geographic areas into small radio areas (cells) that are interconnected with each other. Each cell coverage area has one or several transmitters and receivers that communicate with mobile telephones within its area.

Figure 4.1 shows a basic cellular system. The cellular system connects mobile radios (called mobile stations) via radio channels to base stations. Some of the radio channels (or portions of a digital radio channel) are used for control purposes (setup and disconnection of calls) and some are used to transfer voice or customer data signals. Each base station contains transmitters and receivers that convert the radio signals to electrical signals that can be sent to and from the mobile switching center (MSC). The MSC contains communication controllers that adapt signals from base stations into a form that can be connected (switched) between other base stations or to lines that connect to the public telephone network. The switching system is connected to databases that contain active customers (customers active in its system).

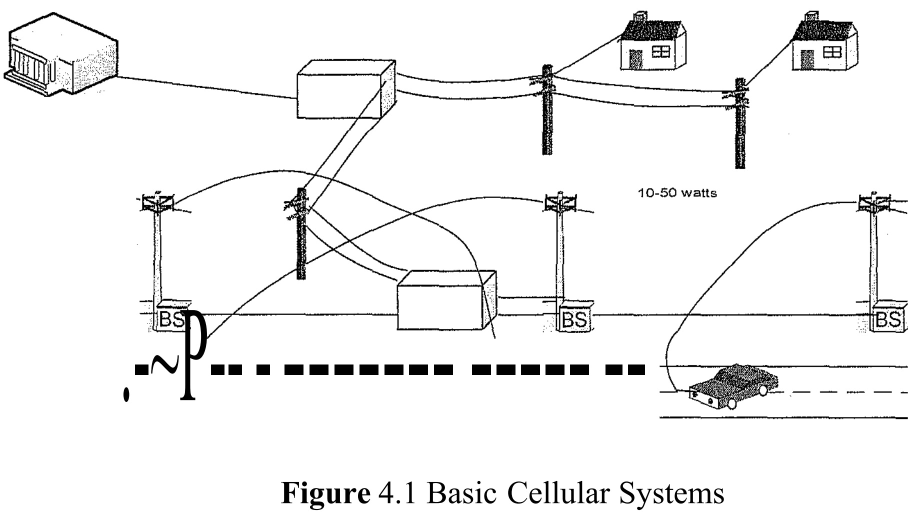

Figure 4.1 Basic Cellular Systems

When linked together to cover an entire metro area, the radio coverage areas (called cells) form a cellular structure resembling that of a honeycomb. Cellular systems are designed to overlap each cell border with adjacent cell borders to enable a "hand-off' from one cell to the next. As a customer (called a subscriber) moves through a cellular system, the mobile switching center (MSC) coordinates and transfers calls from one cell to another and maintains call continuity.

4.2 Analog Cellular

To allow for the conversion from analog systems to digital systems, some cellular technologies allow for the use of dual mode or multi-mode mobile telephones. These handsets are capable of operating on an analog or digital radio channel, depending on whichever is available. Most dual mode phones prefer to use digital radio channels, in the event both are available. This allows them to take advantage of the additional capacity and new features such as short messaging and digital voice quality, as well as offering greater capacity.

Cellular systems have several key differences that include the radio channel bandwidth, access technology type (FDMA, TDMA, and CDMA), data signaling rates of their control channel(s) and power levels. Analog cellular systems have very narrow radio channels that vary from 10 kHz to 30 kHz. Digital systems channel bandwidth ranges from 30 kHz to 1.25 MHz. Access technologies determine how mobile telephones obtain service and how they share each radio channel. The data signaling rates determine how fast messages can be sent on control channels. Channel from the base station to the mobile telephone is called the downlink. The uplink and downlink radio channels are normally separated by 45 MHz to 80 MHz. One of the key characteristics of cellular systems is their ability to handoff (also called handover) calls from one radio tower to another while a call is in process. Handoff is an automatic process that is a result of system monitoring and short control messages that are sent between the mobile phone and the system while the call is in progress. The control messages are so short that the customer usually cannot perceive that the handoff has occurred. Analog cellular systems are regularly characterized by their use of analog modulation (commonly FM modulation) to transfer voice information. Ironically, almost all analog cellular systems use separate radio channels for sending system control messages.

These are digital radio channels. In early mobile radio systems, a mobile telephone scanned the limited number of available channels until it found an unused one, which allowed it to initiate a call. Because the analog cellular systems in use today have hundreds of radio channels, a mobile telephone cannot scan them all in a reasonable amount of time. To quickly direct a mobile telephone to an available Channel, some of the available radio channels are dedicated as control channels. Most cellular systems use two types of radio channels, control channels and voice channels. Control channels carry only digital messages and signals, which allow the mobile telephone to retrieve system control information and compete for access. Control channels only carry control information such as paging (alert) and channel assignment messages. Voice channels are primarily used to transfer voice information. However, voice channels must also be capable of sending and receive some digital control messages to allow for necessary frequency and power changes during a call.

To receive calls, a mobile telephone is notified of an incoming call by a process called paging. A page is a control channel message that contains the telephone's Mobile Identification Number (MIN) or telephone number of the desired mobile phone. When the telephone determines it has been paged, it responds automatically with a system access message that indicates its access attempt is the result of a page message and the mobile telephone begins to ring to alert the customer of an incoming telephone call. When the customer answers the call (user presses "SEND" or "TALK"), the mobile telephone transmits a service request to the system to answer the call. It does this by sending the telephone number and an electronic serial number to provide the users identity. After a mobile telephone has been commanded to tune to a radio voice channel, it sends mostly voice or other customer information. Periodically, control messages may be sent between the base station and the mobile telephone. Control messages may command the mobile telephone to adjust its power level, change frequencies, or request a special service (such as three way calling).

To conserve battery life, a mobile phone may be permitted by the base station to only transmit when it senses the mobile telephone's user is talking. When there is silence, the mobile telephone may stop transmitting for brief periods of time (several seconds). When the mobile telephone user begins to talk again, the transmitter is turned on again. This is called discontinuous transmission.

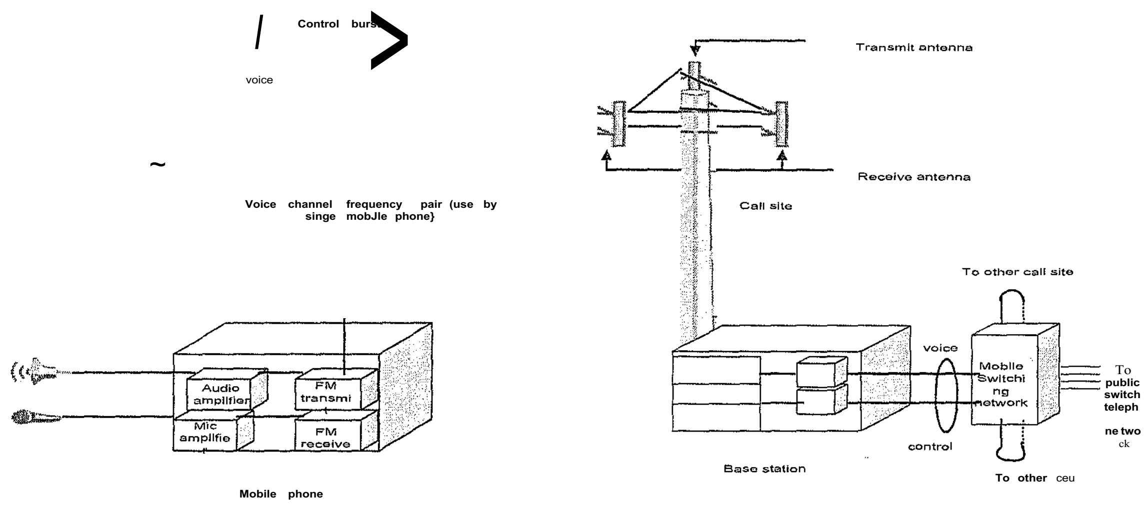

Figure 4.2 Analog Cellular Systems (I" Generation)

Figure 4.2 shows a basic analog cellular system. This diagram shows that there are two types of radio channels; control channels and voice channels. Control channels typically use frequency shift keying (FSK) to send control messages (data) between the mobile phone and the base station. Voice chaımels typically use FM modulation with brief bursts of digital information to allow control messages (such as handoff) during conversation. Base stations typically have two antennas for receiving and one for transmitting. Dual receiver antennas increases the ability to receive the radio signal from mobile telephones which typically have a much lower transmitter power level than the transmitters in the base station. Base stations are coımected to a mobile switching center (MSC) typically by a high speed telephone line or microwave radio system. This interconnection must allow both voice and control information to be exchanged between the switching system and the base station. The MSC is connected to the telephone network to allow mobile telephones to be connected to standard landline telephones.

4.3 Digital Mobile Radio

There are two basic types of systems; analog and digital. Analog systems commonly use FM modulation to transfer voice information and digital systems use some form of phase modulation to transfer digital voice and data information. Although analog systems are capable of providing many of the services that digital systems offer, digital systems offer added flexibility as digital cellular systems can ordinaı·ily serve several subscribers on a single radio channel at the same time. Depending on the type of system, this can range from 3 to over 20. To allow this, almost all digital cellular systems share the fundamental characteristics of digitizing and compressing voice information to accomplish this. This allows a single radio channel to be divided into several sub-channels (communication channels). Each communication channel can serve a single customer. Because each subscriber typically uses the cellular system for only a few minutes a day, several subscribers can share each one of these communication channels during the day. As a rule, 20 - 32 subscribers can share each communication channel; so if a digital radio channel has 8 communications channels (sub-channels), a cell site with 25 radio channels can support 4000 to 6400 subscribers.

Digital cellular systems use two key types of communication channels, control channels and voice channels. A control channel on a digital system is usually one of the sub-channels on the radio channel. This allows digital systems to combine a control channel and one or more voice channels on a single radio channel. The portion of the radio channel that is dedicated as a control channel carries only digital messages and signals that allow the mobile telephone to retrieve system control information and compete for access. The other sub-channels on the radio channel carry voice or data information. The basic operation of a digital cellular system involves initiation of the phone when it is powered on, listening for paging messages (idle), attempting access when required and conversation (or data) mode. When a digital mobile telephone is first powered on, it initializes itself by searching (scanning) a predetermined set of control channels and then tuning to the strongest one. During the initialization mode, it listens to messages on the control channel to retrieve system identification and setup information. Compared to analog systems, digital systems have more communication and control channels.

This can result in the mobile phone taking more time to search for control channels. To quickly direct a mobile telephone to an available control channel, digital systems use several processes to help a mobile telephone to find an available côntföl channel. These include having the phone memorize its last successful control chafü-ı.el location, a table of likely control channel locations and a mechanism for pointirrğjtd the location of a control channel on any of the operating channels. After a digital mobile telephone has initialized, it enters an idle mode where it waits to be paged fot<ru.l

incoming call or for the user to initiate a call. When a call begins to be received or initiated, the mobile telephone enters system access mode to try to access the system via a control channel. When it gains access, the control channel sends a digital traffic channel designation message indicating an open communications channel. This channel may be on a different time slot on the same frequency or to a time slot on a different frequency. The digital mobile telephone then tunes to the designated communications channel and enters the conversation mode. As the mobile telephone operates on a digital voice channel, the digital system commonly uses some form of phase modulation (PM) to send and receive digital information.

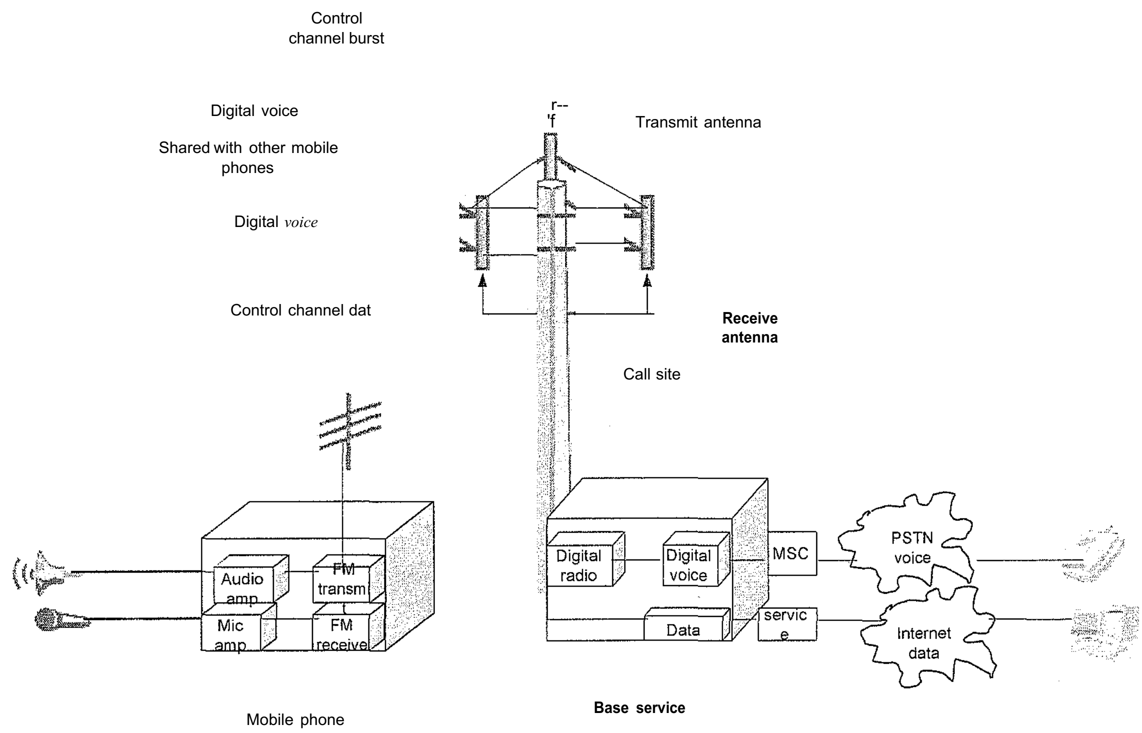

Figure 4.3 Digital Cellular Systems (2nd Generation)

A mobile telephone's attempt to obtain service from a cellular system is referred to as "access". Digital mobile telephones compete on the control channel to obtain access from a cellular system. Access is attempted when a command is received by the mobile telephone indicating the system needs to service that mobile telephone (such as a paging message indicating a call to be received) or as a result of a request from the user to place a call. Digital mobile telephones usually have the ability to validate their identities more securely during access than analog mobile telephones. This is made possible by a process called authentication. Authentication processes share secret data between the digital mobile phone and the cellular system. If the authentication is successful, the system sends out a channel assignment message commanding the mobile telephone to change to a new communication channel and conversation can begin. After a mobile telephone has been commanded to tune to a radio voice channel, it sends digitized voice or other customer data. Periodically, control messages may be sent between the base station and the mobile telephone. Control messages may command the mobile telephone to adjust its power level, change frequencies, or request a special service (such as three way calling).

4.4 Packet Based Digital Cellular (Generation 2.5)

Packet Based Cellular (commonly called - generation 2.5, or 2.5G) are 2nd Generation cellular technologies that have been enhanced to provide for advanced communication applications. Packet based digital cellular systems help the industry transition from one capability to a much more advanced capability. In cellular telecommunications, 2.5G systems used improved digital Radio technology to increase their data transmission rates and new packet based technology to increase the system efficiency for data users.

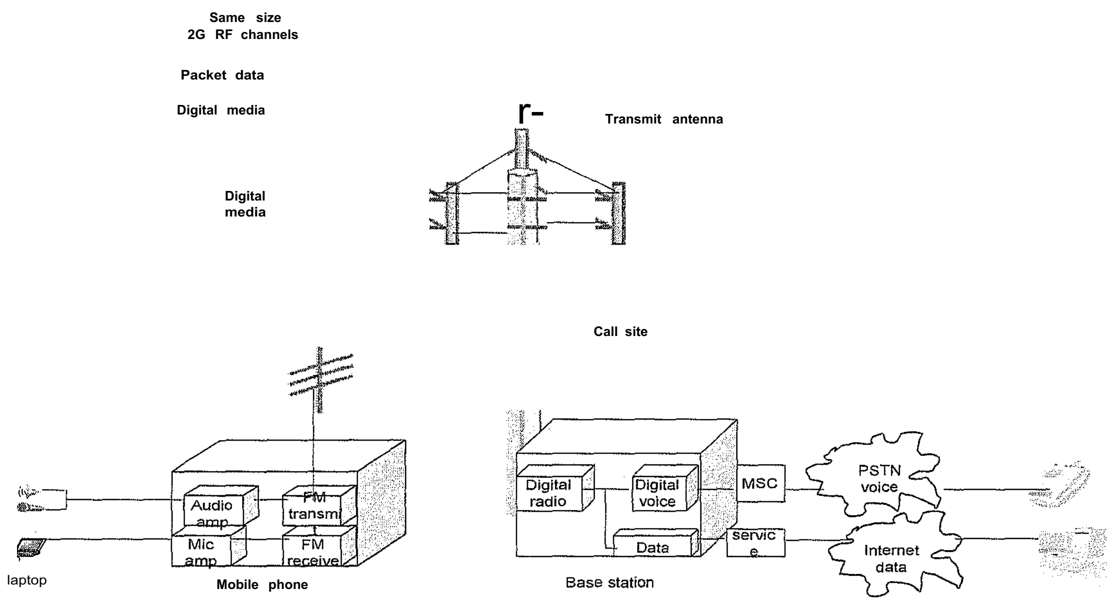

Figure 4.4 Upgraded Digital Cellular System (2, 1/2 Generation)

Figure 4.4 shows a 2nd generation digital cellular system that has been upgraded to offer similar features as 3rd generation systems. This diagram shows that the existing

2nd generation digital radio channel bandwidth is reused. In some cases, the modulation technology has been changed to allow for higher data transfer rates. In all cases, the digital traffic channel (DTC) is upgraded to allow for both circuit switched and packet data transmission capability. This is accomplished by dividing the digital radio channel into more control channels and digital communication channels (voice and data). This diagram shows that the digital radio channel can be connected to the existing mobile communication network for voice services or it can be connected (sometimes simultaneously) to a packet data network (such as the Internet) to allow for multimedia communication services.

4.5 Wideband Digital Cellular (3rd Generation)

Wideband Digital Cellular (commonly called 3rd generation) is cellular technology that uses wideband digital radio technology as compared to 2nd generation narrowband digital radio.

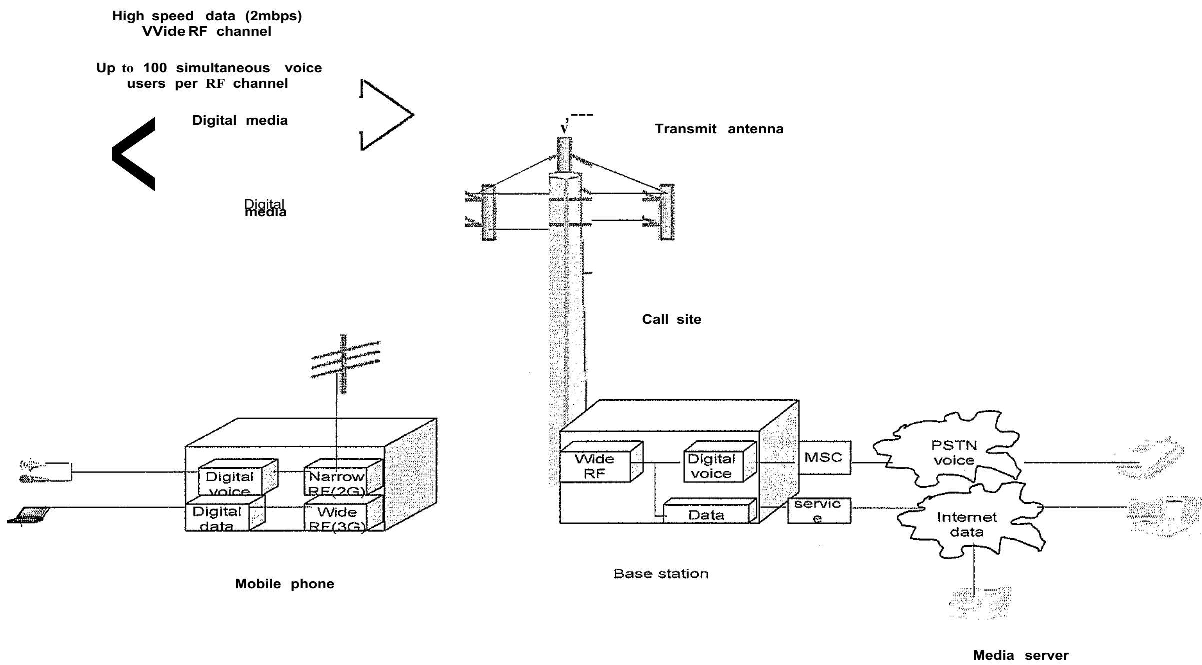

Figure 4.5 Wide Band Digital Cellular System (3rd Generation)

Figure 4.5 shows a wideband digital cellular system that permits very high speed data transmission rates through the use of relatively wide radio channels. In this system, the radio channels are much wider many tens of times wider than 2nd generation radio channels. This allows wideband digital cellular systems to send high-speed data to communication devices. This system also uses communication servers to help manage multimedia communication sessions. Aside from the use of wideband radio channels and enhanced packet data communication, this diagram shows that 3rd generation systems typically use the same voice network switching systems (such as the MSC) as 2nd generation mobile communications systems.

4.6 Analog Systems (Ist Generation)

There are many types of analog and digital cellular systems in use throughout the world. Analog systems include AMPS.

4.6.1 Advanced Mobile Phone Service (AMPS)

Advanced Mobile Phone Service (AMPS) was the original analog cellular system in the United States. It is still in widespread use and by1997; AMPS systems were operating in over 72 countries [5]. The AMPS system continues to evolve to allow advanced features such as increased standby time, narrowband radio channels, and anti-fraud authentication procedures. In 1974, 40 MHz of spectrum was allocated for cellular service [6] that provided only 666 channels. In 1986, an additional 10 MHz of spectrum was added to facilitate expansion [7] of the system to 832 channels. The frequency bands for the AMPS system are 824 MHz to 849 MHz (uplink) and 869 MHz to 894 MHz (downlink). Of the 832 channels, AMPS systems are divided into A and B bands to allow for 2 different service providers. There are two types of radio channels in an AMPS system; dedicated control channels and voice channels. On each system (A or B), mobile telephones scan and tune to one of21 dedicated control channels to listen for pages and compete for access to the system. The control channel continuously sends system identification information and access control information. Although the control channel data rate is 10 kbps, messages are repeated 5 times, which reduces the effective channel rate to below 2 kbps. This allows a control chaımel to send 10 to 20 pages per second. The AMPS cellular system is frequency duplex with its channels separated by 45 MHz. The control chaımel and voice channel signaling is transferred at 10 kbps. AMPS cellular phones have three classes of maximum output power.

4.6.2 Narrowband AMPS (NAMPS)

Narrowband Advanced Mobile Phone Service (NAMPS) is an analog cellular system that was commercially introduced by Motorola in late 1991 and was deployed worldwide. Like the existing AMPS technology, NAMPS uses analog FM radio for voice transmissions. The distinguishing feature of NAMPS is its use of a "narrow" 10 kHz bandwidth for radio channels, a third of the size of AMPS channels. Because more of these narrower radio channels can be installed in each cell site, NAMPS systems can serve more subscribers than AMPS systems without adding new cell sites. NAMPS also shifts some control commands to the sub-audible frequency range to facilitate simultaneous voice and data transmissions. In 1991, the first NAMPS standard, named IS-88, evolved from the US AMPS specification (EIA-553). The IS-88 standard identified parameters needed to begin designing NAMPS radios, such as radio channel bandwidth, type of modulation, and message format.

4.7 Digital Cellular Systems (2nd Generation)

The types of 2nd generation digital cellular systems include GSM, IS-136 TDMA and CDMA.

4.7.1 Global System for Mobile Communication (GSM)

The Global System for Mobile Communications (GSM) is a global digital radio system that uses Time Division Multiple Access (TDMA) technology. GSM is a digital cellular technology that was initially created to provide a single-standard pan-European cellular system. GSM began development in 1982, and the first commercial GSM digital cellular system was activated in 1991. GSM technology has evolved to be used in a variety of systems and frequencies (900 MHz, 1800 MHz and 1900 MHz) including Personal Communications Services (PCS) in North America and Personal Communications Network (PCN) systems throughout the world. By the middle of 2003, 510 networks in 200 countries offered GSM service.

The GSM system is a digital-only system and was not designed to be backward-compatible with the established analog systems. The GSM radio band is shared temporarily with analog cellular systems in some European nations. When communicating in a GSM system, users can operate on the same radio channel simultaneously by sharing time slots. The GSM cellular system allows 8 mobile telephones to share a single 200 kHz bandwidth radio carrier waveform for voice or data communications. To allow duplex operation, GSM voice communication is cöndücted on two 200 kHz wide carrier frequency waveforms.

The GSM system has several types of control channels that carry system and paging information, and coordinates access like the control channels on analog systems. The GSM digital control channels have many more capabilities than analog control channels such as broadcast message paging, extended sleep mode, and others. Because the GSM control channels use only a portion (one or more slots), they typically co-exist on a single radio channel with other time slots that are used for voice communication. A GSM carrier transmits at a bit rate of 270 kbps, but a single GSM digital radio channel or time slot is capable of transferring only I/8th of that, about 33 kbps of information (actually less than that, due to the use of some bit time for non-information purposes such as synchronization bits). Time intervals on full rate GSM channels are divided into frames with 8 time slots on two different radio frequencies. One frequency is for transmitting from the mobile telephone; the other is for receiving to the mobile telephone. During a voice conversation at the mobile set, one time slot period is dedicated for transmitting, one for receiving, and six remain idle. The mobile telephone uses some of the idle time slots to measure the signal strength of surrounding cell carrier frequencies in preparation for handover. On the 900 MHz band, GSM digital radio channels transmit on one frequency and receive on another frequency 45 MHz higher, but not at the same time. On the 1.9 GHz band, the difference between transmit and receive frequencies is 80 MHz. The mobile telephone receives a burst of data on one frequency, then transmits a burst on another frequency, and then Measures the signal strength of at least one adjacent cell, before repeating the process.

4.7.2 North American TDMA (IS-136 TDMA)

The North American TDMA system (IS-136) is a digital system that uses TDMA access technology. It evolved from the IS-54 specification that was developed in North America in the late 1980's to allow the gradual evolution of the AMPS system to digital service. The IS-136 system is sometimes referred to as Digital AMPS (DAMPS) or North American digital cellular

In 1988, the Cellular Telecommunications Industry Association created a development guideline for the next generation of cellular technology for North America. This guideline was called the User Performance Requirements (UPR) and the Telecommunications Industry Association (TIA) used this guideline to create a TDMA digital standard, called IS-54. This digital specification evolved from the original EIA-553 AMPS specification. The first revision of the IS-54 specification (Rev 0) identified the basic parameters (e.g. time slot structure, type of radio channel modulation, and message formats) needed to begin designing TDMA cellular equipment. There have been several enhancements to IS-54 since its introduction and in 1995; IS-54 was incorporated as part of the IS-136 specification. A primary feature of the IS-136 systems is their ease of adaptation to the existing AMPS system. Much of this adaptability is due to the fact that IS- 136 radio channels retain the same 30 kHz bandwidth as AMPS system Channels. Most base stations can therefore replace TDMA radio units in locations previously occupied by AMPS radio units. Another factor in favor öf adaptability is that new dual mode mobile telephones were developed to operate 611 either IS-136 digital traffic (voice and data) channels or the existing AMPS radiö channels as requested in the CTIA UPR document. This allows a single mobile telephone to operate on any AMPS system and use the IS-136 system whenever it is available.

The IS-136 specification concentrates on features that were not present in the earlier IS-54 TDMA system. These include longer standby time, short message service functions, and support for small private or residential systems that can coexist with the public systems. In addition, IS-136 defines a digital control channel to accompany the Digital Traffic Channel (DTC). The digital control channel allows a mobile telephone to operate in a single digital- only mode. Revision A of the IS-136 specification nöw supports operation in the 800 MHz range for the existing AMPS and DAMPS systems as well as the newly allocated 1900MHz bands for PCS systems. This permits dual band, dual mode phones (800 MHz and 1900 MHz for AMPS and DAMPS). The primary difference between the two bands is that mobile telephones cannot transmit using analog signals at 1900MHz.The IS-136 cellular system allows for mobile telephones to use either 30 kHz analog (AMPS) or 30 kHz digital (TDMA) radio channels. The IS-136 TDMA radio channel allows multiple mobile telephones to share the same radio frequency channel by time-sharing. All IS-136 TDMA digital radio channels are divided into frames with 6 time slots. The time slots used for the correspondingly numbered forward and reverse channels are time-related so that the mobile telephone does not simultaneously transmit and receive. The IS-136 system allows a standard time slot on a TDMA radio channel to be used as a digital control channel (DCC). The DCC carries the same system and paging information as the analog control channel (ACC). In addition to the control messages, the DCC has more capabilities than the ACC such as extended sleep mode, short message service (SMS), private and public Control channels, and others.

4.7.3 Code Division Multiple Access (IS-95 CDMA)

Code Division Multiple Access (CDMA) system (IS 95) is a digital cellular system that uses CDMA access technology. IS-95 technology was initially developed by Qualcomm in the late 1980's. CDMA cellular service began testing in the United States in San Diego, California during 1991. In 1995, IS-95 CDMA commercial service began in Hong Kong and now many CDMA systems are operating throughout the world, including a 1.9 GHz all-digital system in the USA that has been operating since November 1996. Spread spectrum radio technology has been used for many years in military applications. CDMA is a particular form of spread spectrum radio technology.

In 1989, CDMA spread spectrum technology was presented to the industry standards committee but it did not meet with immediate approval. The standards committee had just resolved a two-year debate between TDMA and FDMA and was not eager to consider another access technology. The IS-95 CDMA system allows for voice or data communications on either a 30 kHz AMPS radio channel (when used on the 800 MHz cellular band) or a new 1.25 MHz CDMA radio channel. The IS-95 CDMA radio channel allows multiple mobile telephones to communicate on the same frequency at the same time by special coding of their radio signals.CDMA radio channels carry control, voice, and data signals simultaneously by dividing a single traffic channel (TCH) into different sub-channels. Each of these channels is identified by a unique code. When operating on a CDMA Radio channel, each user is assigned to a code for transmission and reception. Some codes in the TCH transfer control channel information, and some transfer voice channel information. The control channel that is part of a digital traffic channel on a CDMA system has new advanced features. This digital control channel (DCC) carries system and paging information, and coordinates access similar to the analog control channel (ACC). The DCC has many more capabilities than the ACC such as a precision synchronization signal, extended sleep mode, and others. Because each CDMA radio channel has many codes, more than one control channel can exist on a single CDMA radio channel and the CDMA control channels co-exist with other coded channels that are used for voice. The IS-95 CDMA cellular system has several key attributes that are different from other cellular systems. The same CDMA radio carrier frequencies may be optionally used in adjacent cell sites, which eliminates the need for frequency planning, the wide-band radio channel provides less severe fading, which the inventors claim results in consistent quality voice transmission under varying radio signal conditions. The CDMA system is compatible with the established access technology, and it allows analog (EIA-553) and dual mode (IS-95) subscribers to use the saıne analog control channels. Some of the voice channels are replaced by CDMA digital transmissions, allowing several users to be multiplexed (shared) on a single RF channel. As With other digital technologies, CDMA produces capacity expansion by allowing multiple users to share a single digital RF chaımel.

The IS-95 CDMA radio chaımel divides the radio spectrum into wide 1.25 MHz digital radio channels. CDMA radio chaımels differ from those of other technologies in that CDMA multiplies (and therefore spreads the spectrum bandwidth of) each signal with a unique pseudo-random noise (PN) code that identifies each user within a radio channel. CDMA transmits digitized voice and control signals on the same frequency band. Each CDMA radio channel contains the signals of many ongoing calls (voice channels) together with pilot, synchronization, paging, and access (control) channels. Digital mobile telephones select the signal they are receiving by con-elating (matching) the received signal with the proper PN sequence. The correlation enhances the power level of the selected signal and leaves others untenanted. Each IS-95 CDMA radio channel is divided into 64 separate logical (PN coded) channels. A few of these channels are used for control, and the remainders carry voice information and data. Because CDMA transmits digital information combined with unique codes, each logical channel can transfer data at different rates (e.g. 4800 *bis,* 9600 b/s).

CDMA systems use a maximum of 64 coded (logical) traffic channels, but they cannot always use all of these. A CDMA radio channel of 64 traffic chaımels can transmit at a maximum information throughput rate of approximately 192 kbps [16], so the combined data throughput for all users caımot exceed 192 kbps. To obtain a maximum of 64 communication channels for each CDMA radio channel, the average data rate for each user should approximate 3 kbps.

If the average data rate is higher, less than 64 traffic channels can be used. CDMA systems can vary the data rate for each user dependent on voice activity (variable rate speech coding), thereby decreasing the average number of bits per user to about 3.8 kbps [17]). Varying the data rate according to user requirement allows more users to share the radio chaımel, but with slightly reduced voice quality. This is called soft capacity limit. In 1997 the CDMA Development Group (CDG) registered the trademark cdma as a label to identify second-generation digital systems based on the IS-95 standard and related technologies.

4.8 Japanese Personal Digital Cellular (PDC)

The PDC system is a TDMA technology with a radio interface that is very similar to IS-136, in that it has six timeslots and an almost identical data rate, and a core network architecture that is very similar to GSM. PDC operates in both the 900 MHz and 1,400 MHz regions·of the radio spectrum and a total of 60 million subscribers are served by this teclmology.

4.9 Upgraded. Digital Cellular System (Generation 2.5)

The types of upgraded 2nd generation digital cellular systems (generation 2.5) include GPRS, EDGE, and CDMA2000TM, lxRTT.

4.9.1 General Packet Radio Service (GPRS)

General Packet Radio Service (GPRS) is a portion of the GSM specification that allows packet radio service on the GSM system. The GPRS system adds (defines) new packet channels and switching nodes within the GSM system. The GPRS system provides for theoretical data transmission rates up to 172 kbps.

4.9.2 Wideband Digital Cellular Systems (3rd Generation)

The 3rd generation wireless requirements are defined in the International mobile Telecommunication, "IMT-2000" project developed by the international telecommunication union (ITU). The IMT - 2000 project that defined requirements for high speed data transmission, roaming and multimedia communication.

4.9.3 Wideband Code Division Multiple Access (WCDMA)

WCDMA is a 3rd generation digital cellular system that uses radio channels that have a wider bandwidth than 2nd generation digital cellular systems such as GSM or IS-95 CDMA. WCDMA is normally deployed in a 5 MHz channel plan. The Third Generation Partnership Project (3GPP) oversees the creation of industry standards for the 3rd generation of mobile wireless communication systems (WCDMA). The key members of the 3GPP include standards agencies from Japan, Europe, Korea, China and the United States. The 3GPP technology, also known as the Universal Mobile Telecommunications System (UMTS), is based on an evolved GSM core network that contains 2.5G elements, namely GPRS switching nodes. This concept allows a GSM network operator to migrate to WCDMA by adding the necessary 3G radio elements to their existing network, thus creating 'islands' of 3G coverage When the networks first launch. A large number of GSM operators have secured spectrum for WCDMA and many network launches are imminent, with live networks presently in Japan, the United Kingdom and Italy.

4.9.4 Code Division Multiple Access 2000 (CDMA2000)

CDMA2000 is a family of standards that represent an evolution from the IS- 95 code division multiple access (CDMA) system that offer enhanced packet transmission protocols to provide for advanced high-speed data services. The CDMA2000 technologies operate in the same 1.25 MHz radio channels as used by IS-95 and offer backward compatibility with IS-95. The CDMA2000 system is overseen by the Third· Generation Partnership Project 2 (3GPP2). The 3GPP2 is a standard setting project that is focused on developing global specifications for 3rd generation systems that use ANSI/TIA/EIA-41 Cellular Radio Intersystem Signaling..

4.10 Fourth Generation (4G) Networks

Even before 3G networks are fully launched and utilized, various study groups are considering the shape of the next generation of cellular technology, so called 4G.there is no single global vision or 4G as yet but the next generation of network is likely to be all IP-based, offer data rates up to 100 bps and support true global mobility. One route towards this vision is the convergence of technologies such as 3G cellular and Wireless LANs (WLANS)

4.11 Summary

Cellular, PCS and 3rd generation mobile explains the different types of analog and digital mobile telephone systems and their evolution. This chapter discusses the basic operations, attributes and services for analog cellular (1st generation), digital cellular (2nd generation), packet based cellular (2 Yz generation), and wideband cellular (3rd generation) communication systems. Covered are AMPS, TACS, GSM, CDMA, TDMA, GPRS, EDGE, EVDO, EVDV, WCDMA, CDMA2000, and more.

5. BLUETOOTH

5.1 **Overview**

Bluetooth is a standardized technology that is used to create temporary (ad-hoc) short-range wireless communication systems. These Bluetooth wireless personal area networks (WPAN) are used to coımect personal accessories such as headsets, keyboards, and portable devices to communications equipment and networks. Bluetooth was named after Harald Blatand, King of Denmark. King Blatand was head of Deıunark from 940 to 985 A.D and he is known for uniting the Danes and Norweigans. It seems appropriate to name the wireless technology that unifies communication between diverse sets of devices after King Blatant

Figure 5.1 shows the different types of devices that can be linked by wireless personal area network communication. This example shows that the computer can be located near the devices such as a keyboard, mouse, display, speakers, microphone, and a presentation projector. As these devices are brought within a few feet of each other, they automatically discover the Availability and capabilities of other devices. If these devices have been setup to allow communication with other devices, the user will be able to use these devices as if they were directly connected with each other. As the devices are removed from the area or turned off, the option to use these devices will be disabled from the user.

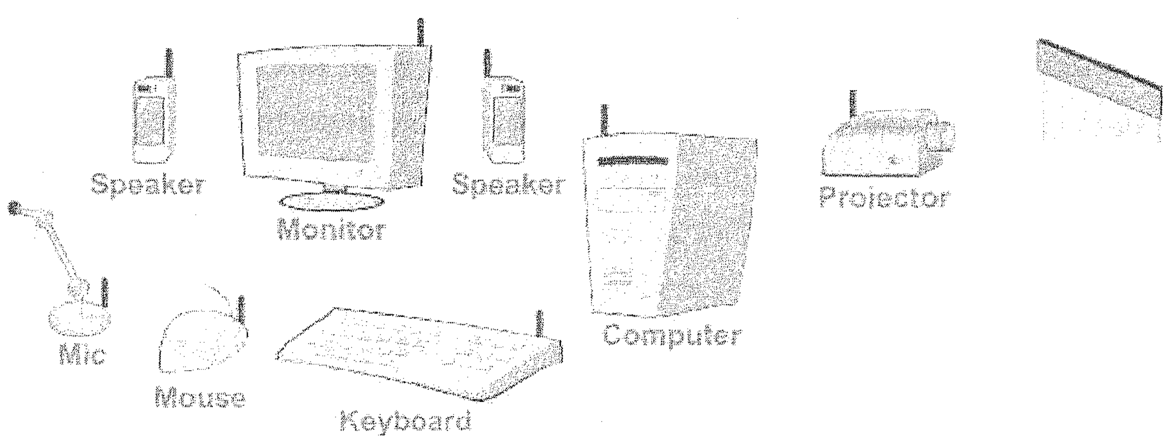

Figure 5.1 Wireless Personal Area Network Devices

The Bluetooth system operates in 2.4 GHz unlicensed (uncontrolled) frequency bands with very low radio transmission power of 1 mill watt to 100 mill watts. For unlicensed use, radio transmission is authorized for all users provided the radio equipment conforms to unlicensed requirements. Anyone can use the unlicensed frequency band but there is no guarantee they will perform at peak performance due to possible interference. Devices within the frequency bands are required to operate in such a way that they can co-exist in the same area with minimal interference with each other. While users are not required to obtain a license to use devices that operate in unlicensed frequency bands, the manufacturers of devices are required to conform to government regulations. These regulations also vary from country to country.

5.2 Development Timeline

Bluetooth evolved from simple replacement of wires to a dynamically changing wireless personal area network (WPAN). Bluetooth was first conceived in 1993 at Ericsson as a way to allow portable cellular telephones to get smaller while user devices such as PDAs and Laptops could interface with communication devices without the need for wires. In 1988, several companies setup agreements to form the special interest group (SIG) to develop and promote Bluetooth technology. In July 1999, version 1.0 of the Bluetooth specification was published. In December 1999, Additional promoter companies were added and a revised specification 1.0B was released. In 2001, Bluetooth specification 1.1 was released and in November 2003, Bluetooth specification 1.2 was released. Figure 5.2 shows how Bluetooth evolved from the time it was first conceived in 1993 to its status at the beginning of 2004. This diagram shows that the Bluetooth SIG was formed in 1998 and that version 1.0 Bluetooth specification was released in mid-1999. The first Bluetooth products were qualified in June 2000. There were 83 qualified Bluetooth products by the end of 2000. In February 2001, Bluetooth specification version 1.1 was released and there were 481 qualified products by the end of 2001. An additional 412 Bluetooth products were qualified in 2002 brining the total number of qualified Bluetooth products to 893 at the end of 2002. In November 2003, Bluetooth specification 1.2 was released and the total number of Bluetooth qualified products that were available at the end of 2003 was 1336.

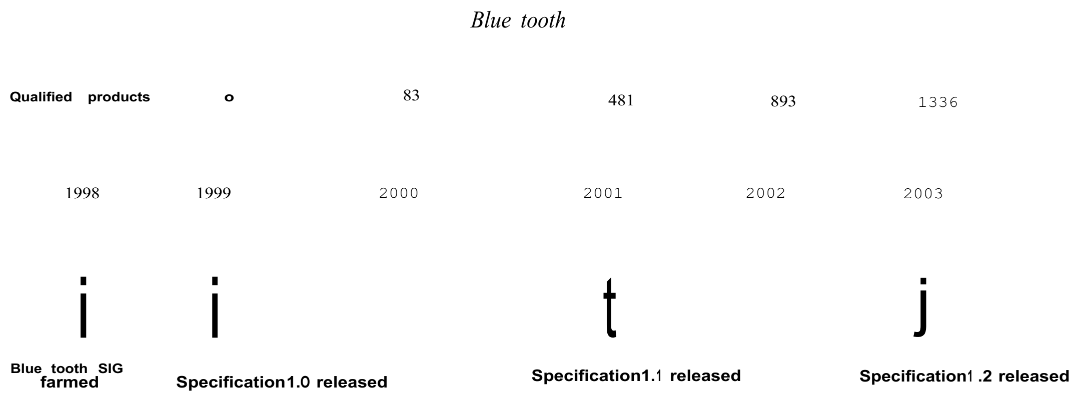

Figure 5.2 Bluetooth Timeline

5.3 Special Interest Group (SIG)

A special interest group works to help develop and promote information about a specific technology, product, or service. The Bluetooth SIG oversees the certification of Bluetooth assemblies and devices and promotes the use of Bluetooth technology. To allow the SIG to achieve its objectives, the SIG has setup or recognizes specific groups or facilities to be part of the development process. These include the Bluetooth qualification body (BQB), Bluetooth qualified test facility (BQTF), Bluetooth qualification review board (BQRB), and the Bluetooth qualification administrator (BQA).

The BQB is authorized by the Bluetooth qualification review board (BQRB) to be responsible for the checking of declarations and documents against requirements, reviewing product test reports, and listing conforming products in the official database of Bluetooth qualified products. BQTFs are test labs that are recognized and certified by the BQRB as being capable of testing and qualifying Bluetooth devices. The BQRB is responsible for managing, reviewing, and improving the Bluetooth qualification program through which vendor products are tested for conformance. The Bluetooth qualification administrator (BQA) is responsible for overseeing the administration of the qualification program.

The BQA ensures that qualified products can be listed on the Bluetooth website. In addition to the test programs, testing events ("UnplugFests") are made available to members to allow compatibility testing. UnplugFests (UPP) are testing events in which manufacturers or developers agree to test their products with other products in a secret closed environment. There are approximately 3 UnplugFests per year.

The participation in UnplugFests allows manufacturers and developers to find problems with their products or areas of correction or clarification that are needed in the Bluetooth specifications. Figure 5.3 shows the general product qualification process used by the Bluetooth special interest group (SIG) to ensure reliable operation and compatibility between Bluetooth devices. This example shows that the first step for product qualification is for the company to gather the program reference documents (PRDs), complete the product documentation, and submit the documents to the Bluetooth Qualification Board (BQB). The company then develops the prototype of the product and submits the product to a Bluetooth Qualification Test Facility (BQTF) for testing. The BQTF test report is then sent to the Bluetooth Qualification Board (BQB) for review. If the product documentation and test results are accepted by the BQB, the product will be added to the Bluetooth qualified product list.

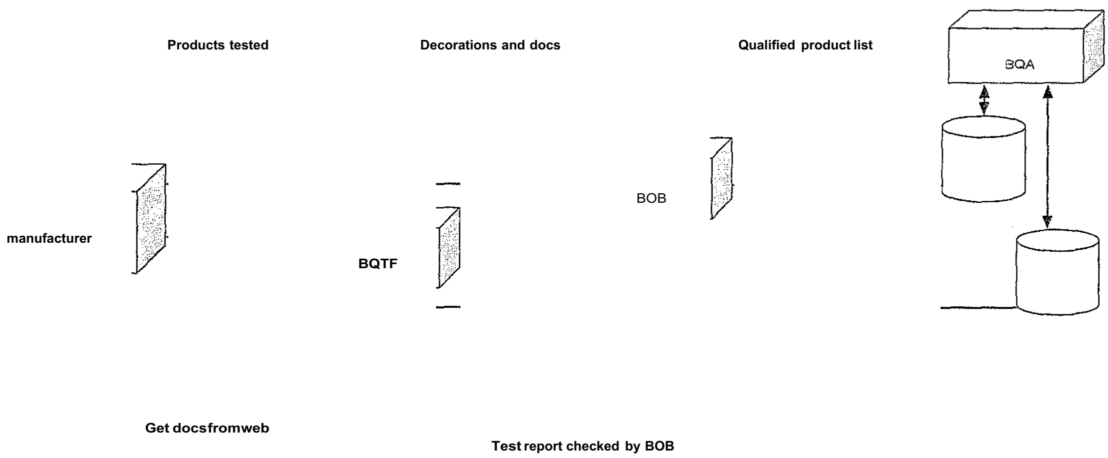

Figure 5.3 Bluetooth product qualification process

5.4 Bluetooth Basics

Bluetooth is a wireless personal area network (WPAN) communication system Standard that allows for wireless data connections to be dynamically added and removed between nearby devices. Each Bluetooth wireless network can contain up to 8 active devices and is called a Piconet. Piconets can be linked to each other (overlap) to form larger area Scatternets. The system control for Bluetooth requires one device to operate as the coordinating Device (a master) and all the other devices are slaves. This is very similar to the structure of a universal serial bus (USB) system that is commonly used in personal computers and devices such as digital cameras. However, unlike USB connections, most Bluetooth devices can operate as either a master (coordinator) or slave (follower) and Bluetooth devices can reverse their roles if necessary. The characteristics of Bluetooth include an unlicensed frequency band that ranges from 2.4 GHz to 2.483 GHz. This frequency band was chosen because it is available for use in most countries throughout the world. While the standard frequency band for Bluetooth is in the 2.400 GHz to 2.483 GHz (83 MHz) frequency band, the original Bluetooth specification had an optional smaller frequency band 23 MHz version for use in some countries. The use of a smaller frequency band does not change the data transmission rate, however, these devices will be more sensitive to interference (such as other Bluetooth device transmission) and this interference may cause a lower overall data transmission rate.

Every Bluetooth device has a unique 48-bit address BD_ADDR (pronounced "B-D-Adder"). In addition to identifying each Bluetooth device, this address is used to determine the frequency hopping pattern that is used by the Bluetooth device. Bluetooth devices may have different power classification levels. The 3 power versions for Bluetooth include; 1 mW (class 3), 2.5 mW (class 2) and 100 mWatts (class 1). Devices that have an extremely low power level of 1 mill watt have a very short range of approximately 1 meter. Bluetooth devices that have a power level of up to 100 mill watts can provide a transmission range of approximately 100 meters.

The high power version (class 1) is required to use adjustable (dynamic) power control that automatically is reduced when enough signal strength is available between Bluetooth devices. Because the objectives of Bluetooth are *low* power and low complexity, the simple modulation type of Gaussian frequency shift keying (GFSK) is used. This modulation technology represents a logical 1 or 0 with a shift of 115 kHz above or below the carrier signal. The data transmission rate of the RF channel is 1 Mbps.The smallest packet size in the Bluetooth system is the Bluetooth packet data unit (PDU). Bluetooth PDUs are transmitted between master and slave devices within a Bluetooth Piconet. Each PDU contains the address code of the Piconet, device identifier, and a payload of data. When the PDUs are used to carry logical channels, part of the data payload includes a header, which includes logical channel identifiers. The length of the PDU can vary to fit within 1, 3 or 5 time slot period (625 use per time slot). Control message PDUs (e.g. link control) always fit within 1 time slot system), device identifier (specific device within the piconet), logical channel identifiers (to identify ports), and a payload of data. If a specific protocol is used (such as a wireless RS-232 communication port - RFCOMM), an additional protocol service multiplexer (PSM) field is included at the beginning of the payload data. This diagram also shows that the PDU size can have a 1, 3 or 5 slot length.

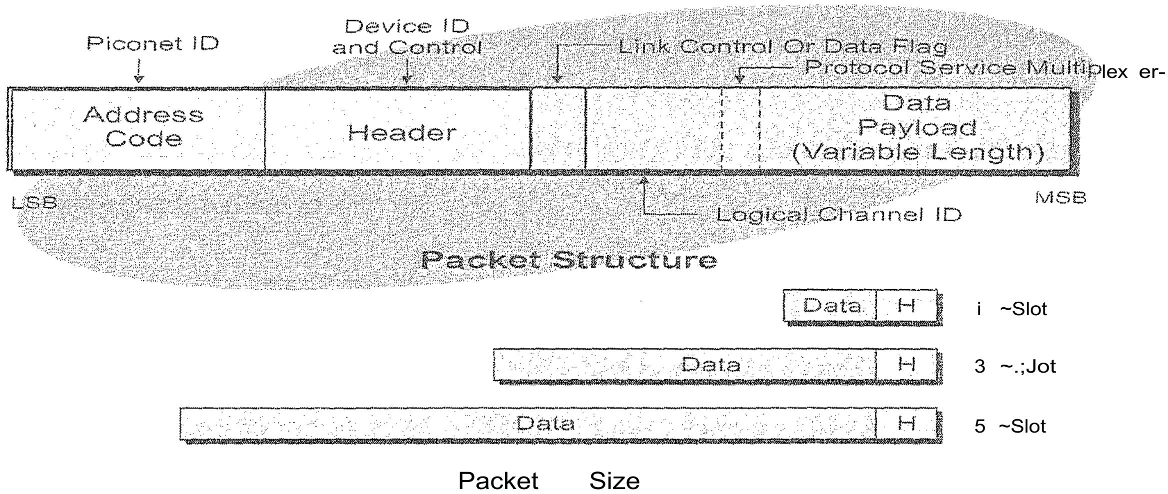

Figure 5.4 Bluetooth Packet Structure

The Bluetooth system uses time division duplex (TDD) operation. TDD operation permits devices to transmit in either direction, but not at the same time the basic radio transmission process used in the Bluetooth system. This diagram shows that the frequency range of the Bluetooth system ranges from 2.4 GHz to 2.483 GHz and that the basic radio transmission packet time slot is 625 usec. It also shows that one device in a Bluetooth piconet is the master (controller) and other devices are slaves to the master. Each radio packet contains a local area piconet ID, device ID, and logical channel identifier.

This diagram also shows that the hopping sequence is normally determined by the master's Bluetooth device address. However, when a device is not under control of the master, it does not know what hopping sequence to use, it listens for inquiries on a standard hopping sequence and then listens for pages using its own Bluetooth device address.

5.5 Temporary Small Networks (Piconets)

Bluetooth forms temporary small networks of Bluetooth communication devices of up to 8 active devices called Piconets. The Bluetooth system allows for wireless data connections within the Piconet to be dynamically added and removed between nearby devices. Because the Bluetooth system hops over 79 channels, the probability of interfering (overlapping) with another Bluetooth system is less than 1.5%. This allows several Bluetooth Piconets to operate in the same area at the same time with minimal interference. Bluetooth communication always designates one of the Bluetooth devices as a main controlling unit (called the master unit). This allows the Bluetooth system to be non-contention based.

This means that after a Bluetooth device has been added to the temporary network (the Piconet), each device is assigned a specific time period to transmit and they do not collide or overlap with other units operating within the same Piconet. Multiple Piconets can be linked to each other to form Scatternets. Scatternets allow the master in one Piconet to operate as a slave in another Piconet. While this allows Bluetooth devices in one Piconet to communicate with devices in another Piconet (cross-Piconet communication), the use of Scatternets require synchronization (and sharing of data transmission Bandwidth) making them inefficient.

5.6 Data Transmission Rates

The basic (gross) radio channel data transmission rate for a single Bluetooth radio channel is 1 Mbps with over 723.2 kbps available to a single user. The data rate available to each user is less than the radio channel data transmission rate because some of the data transmission is used for control and channel management purposes. The users in each Piconet split the remaining data transmission rate. Bluetooth Piconet that provides for headset operation, which uses 64 kbps channels in both directions, uses a total data transmission rate of 128 kbps. This is approximately 25% of the total available data transmission bandwidth. The Bluetooth system allows for different rates in different directions (asynchronous) or for equal data rate (symmetrical rate) transmission.

Figure 5.5 shows how the radio channel data transmission rate for Bluetooth devices is divided between transmission directions and between multiple devices. In example I, a PDA is transferring a large file to a laptop computer using asymmetrical transmission. During the transfer, it uses the 5-slot packet size to reach the maximum data transmission rate of 723.2 kbps from the PDA to the laptop. This only allows a data transmission rate of 57.6 kbps from the laptop to the PDA. Example 2 shows a symmetrical data transmission rate of 433.9 kbps between two video conferencing stations. How the data transmission rate from a laptop is shared between a wireless headset and a PDA. This example shows that the headset uses a symmetrical data transmission rate of 64 kbps from device I (the master coordinator) *to* device 2 and a 57.6 kbps asynchronous data transmission rate between the Laptop and the PDA.

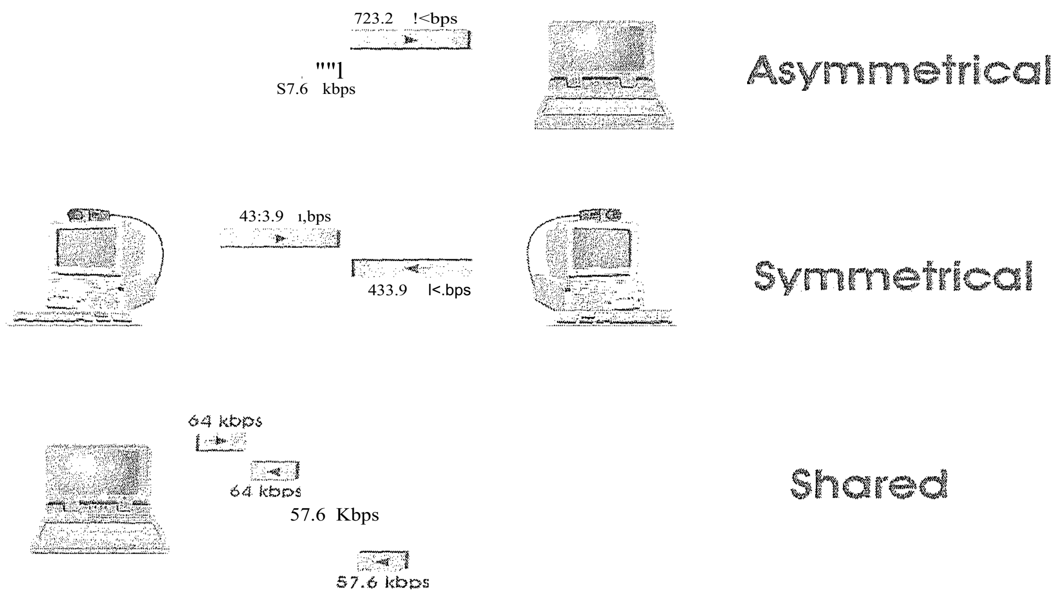

Figure 5.5 Bluetooth Data Transmission Rates

5.7 Frequency Hopping Spread Spectrum (FHSS)

Frequency hopping spread spectrum (FHSS) is a radio transmission process where a message or voice communication is sent on a radio channel that regularly changes frequency (hops) according to a predetermined code. The receiver of the message or voice information must also receive on the same frequencies using the same frequency hopping sequence. Frequency hopping was first used for military electronic countermeasures. Because radio communication occurs only for brief periods on a radio channel and the frequency hop channel numbers are only known to authorized receivers of the information, transmitted signals that use frequency hopping are difficult to Detect and monitor. Figure 5.6 shows a simplified diagram of how the Bluetooth system uses frequency hopping to transfer information (data) from a transmitter to a receiver using 79 communication channels. This diagram shows a transmitter that has a preprogrammed frequency tuning sequence and this frequency sequence occurs by hopping from channel frequency to channel frequency. To receive information from the transmitter, the receiver uses the exact same hopping sequence. When the transmitter and receiver frequency hopping sequences occur exactly at the same time, information can transfer from the transmitter to the receiver. This diagram shows that after the transmitter hops to a new frequency, it transmits a burst of information (packet of data). Because the receiver hops to the same frequency, it can receive the packet of data each time.

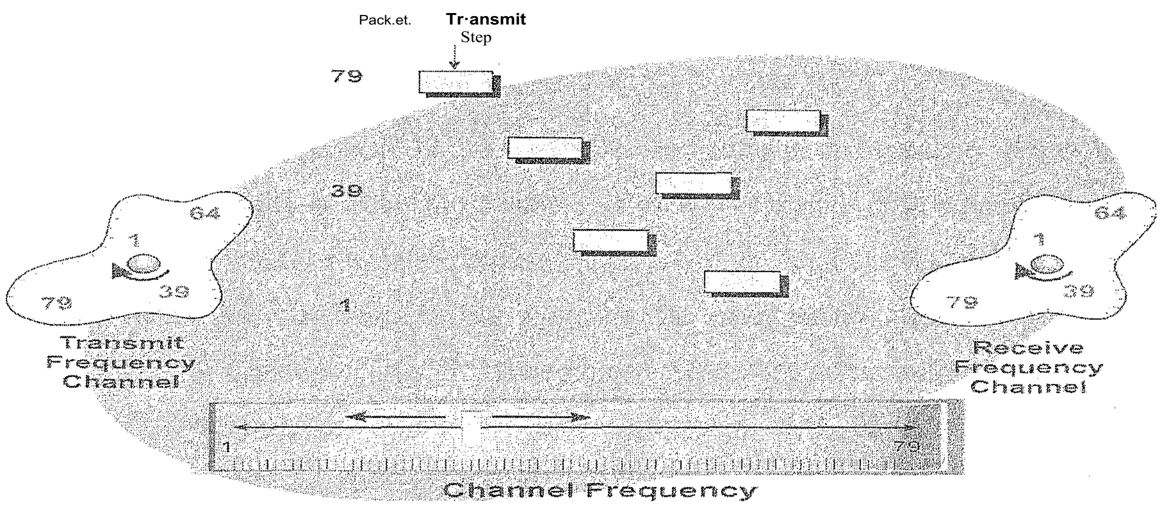

Figure 5.6 Bluetooth Frequency Hopping Operation

5.8 Service Discovery

Service discovery is the process of finding other devices that can communicate with your device and determining what capabilities they have that you may want to use. Service discovery protocol (SDP) is the communication messaging protocol used by a communication system (such as the Bluetooth system) to allow devices to discover the availability and capabilities of other nearby devices. The SDP process is similar to a registry in Windows as it dynamically creates a list of available resources. The discovery process begins with an inquiry message that a device sends that can be received by nearby devices. These devices are constantly looking for an inquiry message to respond to. When a device receives an inquiry message, it responds with an address that can be used to establish a connection with the device. If a device wants to discover the services of another device, it must use the device address and establish a temporary connection. The name and capabilities of the device can be discovered using service discovery protocol (SDP). The discovery process is optional. Devices can be programmed not to respond to inquiry messages.

5.9 Pairing with Other Bluetooth Devices

Bluetooth pairing is an initialization procedure whereby two devices communicating for the first time create an initial secret link key that will be used for subsequent authentication. For first-time connection, pairing requires the user to enter a Bluetooth security code or PIN. Since neither unit knows any secret keys of the other unit, a new secret key must be created. As a result, both devices request a PIN to be entered. Both users must enter the same PIN. This PIN is then used with other information to create a secret key in each unit

The Bluetooth pairing process allows devices to authenticate and create a secure link between two Bluetooth devices. For example, if user A desires to push a business card to user B, user A attempts to establish a connection with device B. If device B has been setup to reject the connection unless a device has been paired, device B requests authentication of device A. This PIN is combined with other information to produce a secret key.) Assuming the same PIN is entered by both users, the secret key that is created is the same for both users and this key can be used to help authenticate (validate) the identify of the other user.

5.10 Bonding with Other Bluetooth Devices

Bonding is the process of creating a very secure link key that is shared between Bluetooth devices. One way to create a very secure link key is to use the· initial secret link key that was created by the pairing process. The bonding process involves encoding (modifying) a unique unit key (created when the Bluetooth device is turned on) using the initial secret link key and sending the unit key to the other unit. This allows the Bluetooth devices to use each other's secret information to create a more secure link key. This secure link key can be used in future authentication validations.

5.11 Connecting with Other Bluetooth Devices

Connecting Bluetooth devices is the process of creating a communication session between devices. Communication sessions are the end-to-end transmission links between devices during operation of a software program or logical connection between two communications devices. In communications systems, the session involves the establishment of a physical channel, logical chaımel(s).The configuration of transmission parameters operation of higher-level applications and termination of the session as the application is complete. During a session, many processes or message transmissions may occur. Creating a connection between Bluetooth devices involves getting the attention of a device through paging and allowing the device to change it's frequency hopping sequence so that it can become part of the Piconet. If the Bluetooth device knows the address of the Bluetooth device it wants to connect to, the connection process usually takes less than 1-2 seconds. The ability of a device to allow "connections" is optional. Bluetooth devices can be programmed to not allow other devices to connect to them ("non-connectable. ")

The coımection process begins with the master unit changing its hopping sequence to the hopping sequence of the recipient device. The Bluetooth unit first sends many identification (ID) packets alerting the receiving device that someone wants to connect to them. When the receiving device (the slave) hears its ID address, it can immediately respond as no other units will be competing for its own access code. When the master hems that the recipient has responded, it sends a frequency hopping synchronization (FHS) packet that contains its Bluetooth Address. Both the master and slave then change their hopping sequence to the master's hopping sequence (the Piconet address). The master will then send a Poll message to the slave using the new hopping sequence and if the slave responds (usually with a null-no information response), the master knows it is connected to the recipient (slave) device. Figure 5.7 shows how a Bluetooth device can connect to other devices. This exaınple shows that the Bluetooth master unit first sends many ID packets using the hopping sequence of the recipient device. When the receiving device hems its ID address, it immediately responds. This allows the master to send a FHS packet that contains the masters Bluetooth Address. Now both the master and slave change their hopping sequence to the Piconet hopping sequence (determined by the master's Bluetooth Address).

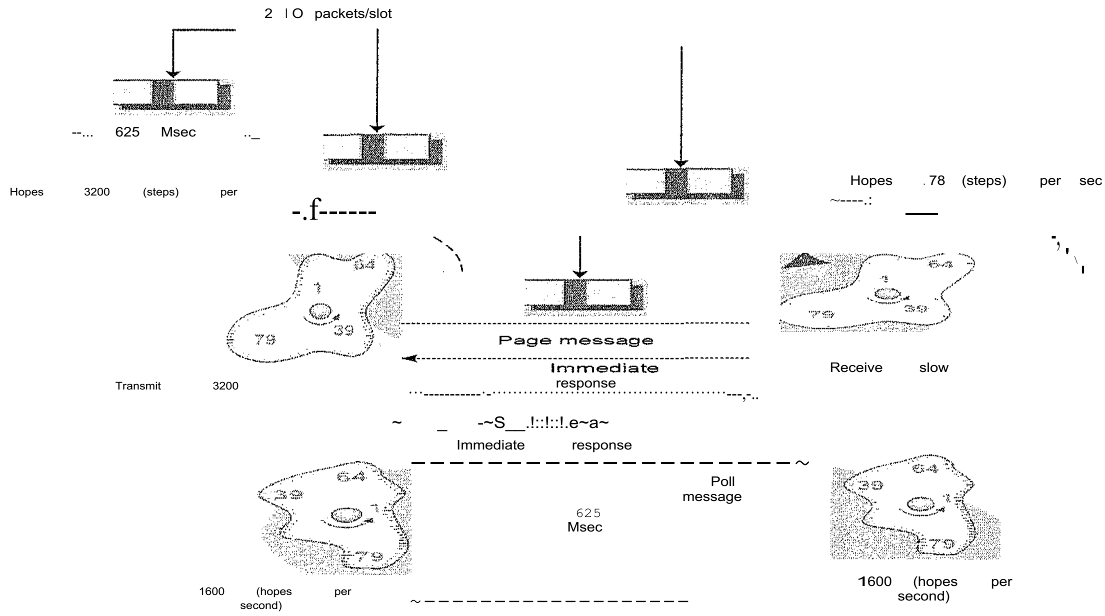

Figure 5.7 Bluetooth Connection Operations

5.12 Summary

Bluetooth covers the basics of short-range Bluetooth wireless networks used by accessories such as headsets, keyboards, cameras, and printers. This chapter includes operational descriptions of Bluetooth and home RF and how these technologies are evolving.

6. PAGING SYSTEMS

6.1 Overview

Paging is the process of delivering a voice or data message, via radio signal, to a person whose exact whereabouts are typically unknown by the message sender. Users usually carry a small paging receiver that presents a numeric or alphanumeric message displayed on an electronic readout; alternatively, messages could be sent and received as voice messages or in other data formats. The paging industry is transitioning from one-way numeric paging systems to two-way messaging and data gathering (telemetry) systems. The lifecycle of paging systems is likely to continue because paging systems generally have much better luck in building radio coverage, have smaller low cost devices (pagers), and the service cost is typically less than other systems such as cellular radio.

There are many types of paging systems that range from tone only to high speed two-way multimedia systems. Paging systems use different types of radio protocols to provide paging and message services. The early paging systems simply turned on or off a signal on a given frequency to alert the user of a specific page. Commercial paging systems often conform to industry Standards. The basic types of paging services include, tone, numeric, text (alpha) and voice. Two types of paging systems, one-way or two-way paging systems, can deliver these messages. One-way paging systems only permit the sending of messages from the paging system to the pager. Two-way paging systems allow the confirmation and response of a message from the pager to the system as well.

6.2 One-Way Paging

One-way paging is a process where paging messages (signals) are sent from a radio tower to a pager without a return verification signal. In its simplest farın, a one-way paging system can serve up to several hundred thousand numeric paging customers Figure 6.1 shows a one-way paging system. In this diagram, a high power transmitter broadcasts a paging message to a relatively large geographic area. All pagers that operate on this system listen to all the pages sent, paying close attention for their specific address message. Paging messages are received and processed by a paging center. The paging center receives pages from the local telephone company or it may receive messages from a satellite network. After it receives these messages, they are processed and sent to the high-power paging transmitter by an encoder. The encoder converts the pagers telephone number or identification code entered by the caller to the necessary tones or digital signal to be sent by the paging transmitter

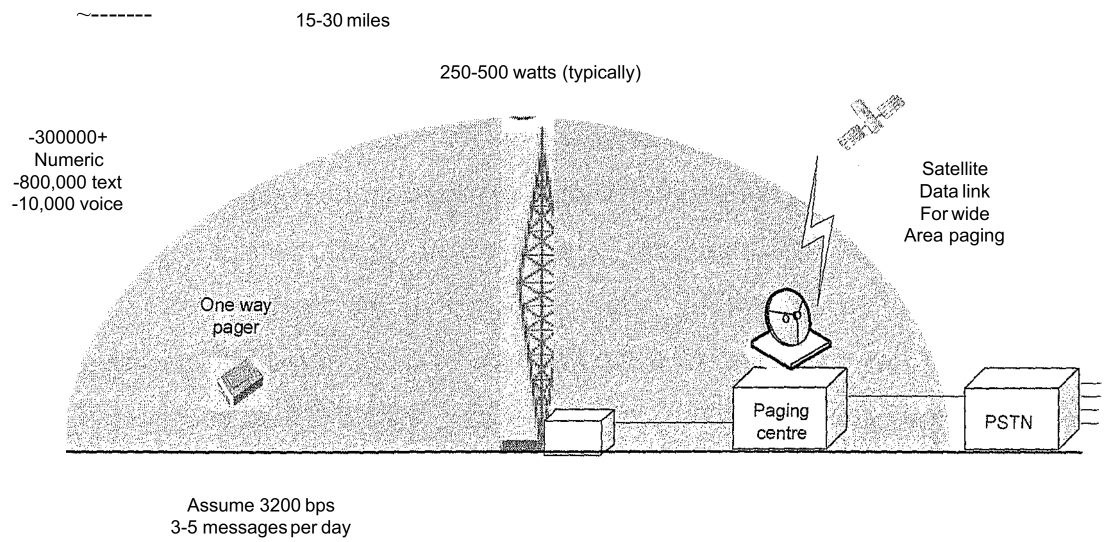

Figure 6.1 One-Way Paging Systems

6.3 Paging Frequencies

Paging frequencies are the band of frequencies authorized to provide paging services. Pagers typically operate on a specific frequency or group of frequencies (channels) near each other. Common frequency bands for frequency pagers are 130-150 MHz, 169 MHz, 400-500 MHz, and 900 MHz. Pagers can use different frequency bands and one or more paging protocols to operate. Even if they operate on the same frequency band, different pagers may use different communication protocols. This can result in a pager from one company not being capable of working on another company's network. Narrowband PCS for paging is 3 MHz of bandwidth in the 900 MHz frequency bands that is used for two-way messaging (paging) services in the United States. The FCC auctioned system operator licenses for the Narrowband PCS frequency channels for sale in 1995. Narrowband PCS is different from Broadband PCS that allows for two-way simultaneous voice as well as data communications.

6.4 Technologies

Some of the key technologies that are an important part of paging servıces include interactive voice response (IVR), localized paging, queuing, frequency synthesizers, s/ simulcast service, and paging protocols.

6.4.1 Interactive Voice Response (IVR)

Interactive voice response (IVR) is a process of automatically interacting with a caller through providing audio prompts to request information and store responses from the caller. The responses can be in the form of touchtone(TM) key presses or voice responses. Voice responses are converted to digital information by voice recognition signal processing. IVR systems are commonly used for automatic call distribution or service activation or changes. Early paging systems required the use of operators to key in the identification code of pagers to be notified of an incoming page. Paging systems have evolved to use IVR systems that guide a caller through the paging process. This reduces the operational cost (reduces staffing levels) and normally increases the reliability of the paging system to capture and send paging messages.

6.4.2 Localized Paging

Localized paging is the process of sending of messages only to transmitters that are located near where the pager may be located. The need for localized paging comes from the desire to use pagers throughout a large geographic area. Because one-way systems do not transmit back to the paging system, there is no way to know where the pager is located or if the message arrived successfully at the pager. This requires the same message to be transmitted to paging transmitters in all areas where the pager may be operating. This means that a one-way paging system that offers national paging service must transmit the page over the entire nation. For a nationwide system that operates on a particular frequency, the message is simultaneously sent to its nationwide network of antennas of 500 to 1,000 transmitters. To increase the capacity of one-way paging systems that cover large geographic regions, some systems with multi-city or national coverage require the user of a pocket pager to call in via telephone when they travel, and identify their location.

6.4.3 Queuing

Message queuing is a process of delaying or sequencing messages that are to be transmitted. Queuing involves receiving requests for service, prioritizing these requests, storing them in appropriate order and transferring the messages when the facilities (channels) are available to send them. Queuing systems may change the order of messages or services to be provided based on priority access. For example, communication requests from a public safety official may be given priority over a communication request from a consumer. One of the main advantages of paging compared to mobile voice service is its non-real time. messaging. Because paging messages can be delayed up to several minutes, this allows messages to be placed on a waiting list (queued) when the paging system becomes busy. This allows the system to operate more efficiently.

6.4.4 Pagers with Synthesizers

A frequency synthesizer is a device or electronic circuit that is capable of producing a range of frequencies based on the settings (programming) of the synthesizer. Frequency synthesizers are usually capable of producing very accurate frequencies by comparing the programmed frequency to a precise reference frequency (usually controlled by a low frequency crystal). The synthesizer Uses the programming (frequency setting) to control a dividing circuit (a counter) to sample the output frequency to the frequency of a reference crystal (the precise frequency of a crystal is controlled by its physical size). If the frequency changes above or below the reference frequency, it creates an adjustment signal (voltage) that is used to correct the output frequency. One of the key changes in the paging industry is the production of pagers that use frequency synthesizers instead of radio frequency (RF) crystals. The early designs ofpagers used RF crystals that allowed them to operate on a single frequency. If the customer wanted to change paging companies or if the paging system became busy on a specific frequency, pagers would need to be "re-crystallized." Pagers that use frequency synthesizers can be programmed by software to change frequencies. This eliminates the need for crystals. The only significant disadvantage is synthesizers cost more money than crystals.

6.4.5 Simulcast Transmission

Simulcast transmission is a process of transmitting a radio signal on the same frequency (or frequency that is very close) from multiple locations to allow the radio coverage area from adjacent radio transmitters to overlap. This overlap of radio coverage helps to ensure the radio signal more evenly covers a geographic area (preventing dead spots). Simulcast is extensively used in radio paging systems. To grow the system coverage and increase quality, paging operators added antennas and used a simulcast radio transmitting technique. Paging antennas are located every 10 to 50 miles, creating a huge coverage area. A simulcast transmission system uses multiple transmitters operating on the same frequencies to provide radio coverage throughout a larger geographic area. The primary benefits of simulcast transmission include better in-building penetration, better coverage, and lower cost pocket paging receivers. The disadvantage of simulcast transmission is that the same signal is sent on each of the radio towers. This does not increase the system serving capacity.

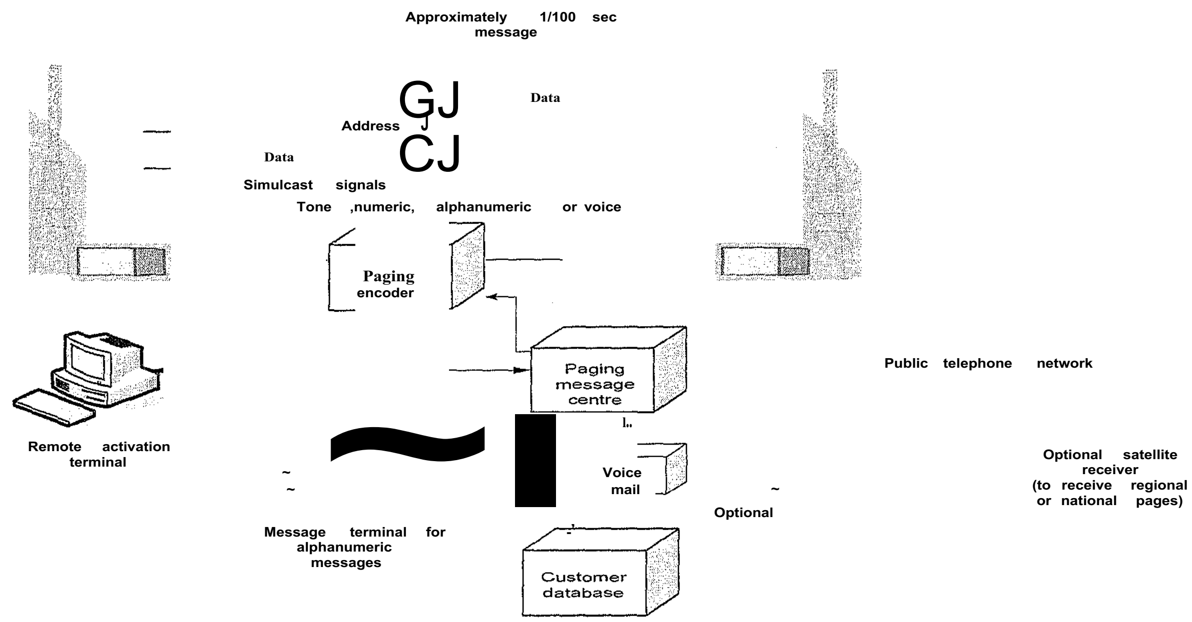

Figure 6.2 Simulcasts Paging

Figure 6.2 shows a paging system that uses simulcast transmission. The same paging message is sent to two paging transmitters. As can be seen in this example, the challenge with simulcast paging is as the pager is closer to one tower then the other, the transmit delay time can cause the signals to not directly overlap. Because radio signals travel so quickly, this delay is minor. However, it can result in some dead spots due to signal adding or subtracting. This diagram also shows that the ability to simulcast also depends on the distance and data rate of each of the transmitted signals to the radio (paging) receiver.

6.4.6 Paging Protocols

Paging protocols are the language used to communicate between the radio tower and the pager. Protocols define how pagers are addressed and how the messages are sent on the radio channel. Protocols differ in their data rates, maximum number of pages that can be addressed in a system, and types of services (tone, voice, text or numeric). The typical data rates transmitted on paging systems vary from approximately 1200 bps to 6400 bps. Some new paging systems can transfer data up to 112 kbps. There are several different protocols used for paging systems. Some paging protocols can be mixed on the same radio chaımel. For example, POCSAG protocols can be sent on the FLEX(T.M) system. The capacity of paging systems is primarily determined by the data transfer rate of the radio channel and the amount of data that is required for each message. For tone only pagers, only the address of the pager is required. Numeric paging messages usually include the pager's identification address, 7 to 10 digit telephone number, and error check bits (approximately 25 bytes of data). Instead of a numeric phone number, alphanumeric messages may contain up to 100 characters (approximately 100 bytes). Compressed voice messages (after the removal of the pauses) as a rule last for approximately 15 seconds at 4 kbps (7.5 Kbytes average). Early voice paging systems were usually performed by sending a tone alert message followed by FM modulated (non-digital) voice. Because the FM voice modulated duration is much longer than the address signaling portion, there is little difference for the Capacity of the system with tone/voice signaling.

6.5 Post Office Code Standard Advisory Group (POCSAG)

Post Office Code Standard Advisory Group (POCSAG) protocol is a pager addressing format that has been accepted throughout most parts of the world. The British Post Office developed the POCSAG standard in 1978.

The POCSAG signal format (also known as RPC Number 1) is composed of synchronization preamble (at least 576 bits) that is followed by batches of code words. Each batch contains a synchronizing code (SC) word that contains two code words. One of the code words is in the pager address and the other code word is in the message information. The sequence of batches in the POCSAG channel is preceded by a synchronization dotting sequence. The synchronization sequence is followed by a series of batches and each of these batches is preceded by its own synchronizing code. Each batch is divided into frames and each frame contains code words. One of the code words is the pager address and the other code word is the information of the paging message.

6.6 European Radio Messaging Systems (ERMES)

ERMES is an international paging technology that is primarily used in Europe, Asia and various other parts of the world. The ERMES is standardized by the European Telecommunications Standards Institute (ETSI) and operates using 25 kHz wide channels and transmits at 6250 bps. An ERMES system can provide for tone, numeric, voice paging, and alpha paging on the same radio channel. ERMES provide a high-speed paging service (when compared to POCSAG) by using advanced modulation (4-pAM). This four-frequency pulse amplitude modulation allows for the transfer of 4 bits of information for each symbol of information.

The ERMES radio channel is divided into sequences of 60 seconds and these sequences are divided into 60 cycles. The sequences are synchronized to coordinated universal time (UTC). Each cycle is further divided into subsequences of 12 seconds each. Each subsequence is divided into 16 batches (paging groups) and each batch contains a synchronization, system information, address, and text part.

6.7 Advanced Paging Operators Code (APOC)

Advanced Paging Operators Code (APOC) is a high-speed standard paging coded system that was announced in 1993. The use of APOC provides compatibility between pagers produced by all manufacturers and APOC is compatible with existing POCSAG networks. APOC features can be gradually added to existing POCSAG systems without a reduction in system capacity and it will not interfere with the operation of existing pagers. APOC was designed to increase the battery life of pagers by a ten-time increase over standard POCSAG pagers. The APOC system allows the operation of a system with multiple transmission rates up to high-speed paging transmission (6400 bps). The system also provides for data compression so the effective information transfer may be increased by over 50%. Other features of APOC include the use of identification codes that allow better roaming (operation on other systems), improved message grouping (for specific groups of users and applications), and delivery prioritization options (urgent or standard).

6.8 Reflex TM

Reflex *TM* is a two-way version of the FLEX paging technology. In addition to providing flexible paging data transmission rates, ReFLEX can provide a reverse data channel at 9,600 bps. The protocol is designed for the most recent Narrowband PCS frequencies for two-way messaging services. ReFLEX-25 has a bandwidth of 25 kHz and a forward data rate of 12,800 bps. ReFLEX-50 has a bandwidth of 50 kHz and a forward data rate of 25,600 bps. ReFLEX service has been available from several paging carriers since 1995. ReFLEX-25 can be set up as a simulcast system or a frequency re-uses system. When set up as a simulcast system, the capacity of the system is limited to the single channel that is re-broadcast by each tower. If the system approaches its maximum capacity, frequency re-use is possible to increase system capacity. ReFLEX first sends out a broadcast locating signal and the intended pager must respond or the page/message will not be sent. When the intended pager receives the page/message, ReFLEX requires an acknowledgment indication back from the pager.

6.9 Inflexion TM

Inflexion *TM* is a high-speed paging system that can transfer data at speeds of up to 112 kbps in the forward direction. These higher speeds support voice and computer applications. The voice messaging essentially downloads an electronic copy of a person's "voice mail" message to the pager. The user then "plays" back the message from the pager as if it was an answering machine e. InFLEXion is also like a cellular system, in that it knows exactly which antenna is serving the pager and does not broadcast the "voice mail" to the entire system.

6.10 Radio Broadcast Data System (RBDS)

Radio Broadcast Data System (RBDS) is a low bit rate data stream that is sent along with a high power FM radio broadcast signal. RBDS is sometimes used to offer paging services. RBDS is also used to identify the radio stations call letters, to provide information about program content and low bandwidth audio information. When sending the paging message along with a high power radio transmission signal, the typical data signaling rates for FM Sub-band paging is 1200 bps. There are plans for higher-speed radio broadcast data systems.

6.11 Tone Paging

Tone paging service notifies a paging customer that a message has been sent via a tone. This tone usually is designated to mean a callback to a single location is requested. This tone usually indicates the recipient should callback to a predetermined number (possibly a business office). The original "beep, beep" tone pagers that started it all have become very popular as entry-level private communications systems, including restaurants (beeping servers when orders are ready) and in other centralized locations where a tone page necessitates a choice in response to only one. In the early 2000s, the availability of tone pagers was relatively limited. However, tone pagers are sometimes used for dispatch operators or other industries that only need a response to a central office. When the user hears the tone, the user will go to a telephone and call a predetermined number Figure 6.3 shows basic operation of a tone paging system. This diagram shows how a tone paging system receives incoming calls and creates a message that can be sent to a tone pager to alert the tone pager user that a caller has called and left a message. In this example, a caller dials the tone pagers assigned telephone number. When the tone paging system receives the incoming call, it plays in interactive voice response message to the caller to leave a message. This message may be stored in a voice mailbox. The paging system then converts the telephone number to the pagers identifying address and sends the message to the paging transmitters. This diagram shows that the tone pager uses paging groups and this pager is assigned to paging group 4. When paging group 4 starts, the pager wakes up and looks for messages with its address. When it finds this message, it alerts the paging user with a tone ("beep-beepice mailbox number).

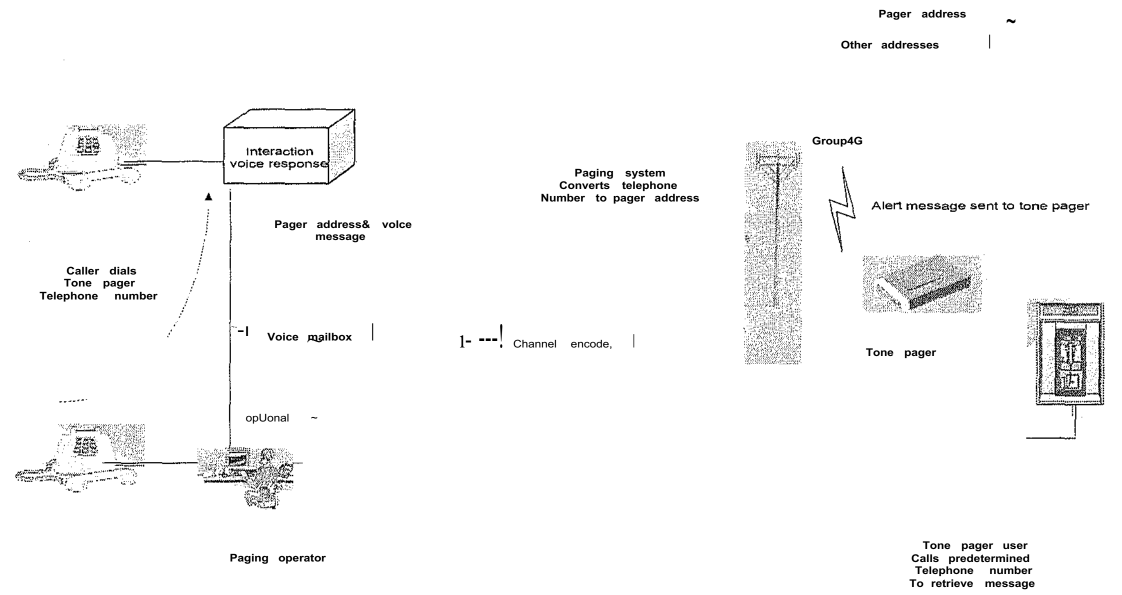

Figure 6.3 Tone Paging Systems

6.12 Numeric Paging

Numeric paging is the sending of paging messages (ordinarily telephone numbers) that are displayed on a small paging device. After the message is received, the user calls back the displayed telephone number to talk to the Sender. Numeric paging service normally involves signing up for local, regional or nationwide coverage with a monthly service charge. Both local and toll free/ free phone access (800 or 0800) numbers are typically offered. While some carriers offer pager users an unlimited number of paging messages, some paging service providers charge for additional pages beyond a predefined limit. When traveling (roaming) into other paging areas, paging customers usually must call into the paging system to inform them of their new area. This allows the paging system to send messages to the new area. Figure 6.4 shows the basic operation of a numeric paging system. This diagram shows how a numeric paging system receives incoming calls and creates a numeric message that can be sent to a numeric pager to alert the numeric pager of the telephone number that the caller wants the recipient to call. In this example, a caller dials the numeric pagers assigned telephone number. When the numeric paging system receives the incoming call, it plays an interactive voice response message to the caller to leave their number by entering the telephone number via the touch-tone buttons. That an operator may be used to receive the telephone number verbally as a phone with touch-tone may not be available. The paging system then converts the telephone number to the pagers identifying

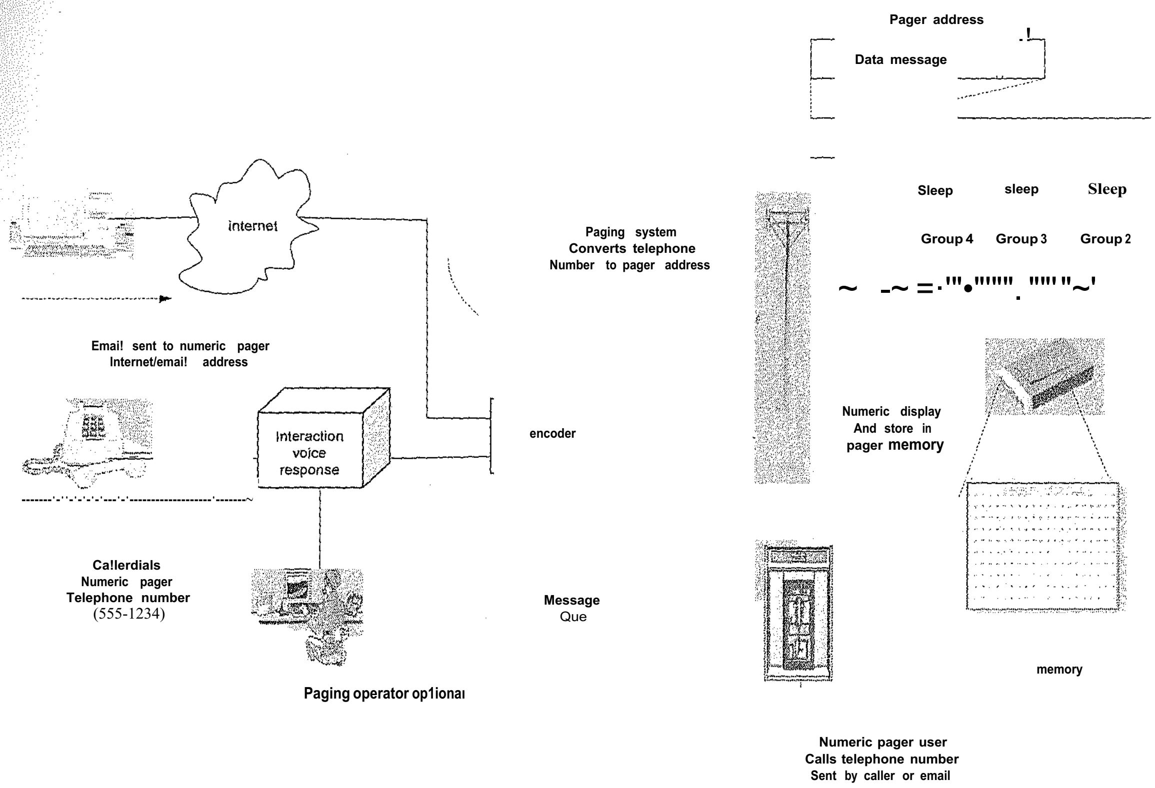

Figure 6.4 Numeric Paging Service

Address and sends the message to the paging transmitters. This diagram shows that the numeric pager uses paging groups and this pager is assigned to paging group 4. When paging group 4 starts, the pager wakes up and looks for messages with its address and the data that follows the message (usually the caller's telephone number). temporary memory. When the user sees the number, the user will go to a telephone and call the displayed number (usually the caller's telephone number).

6.13 Voice Paging

Voice paging is the process of transmitting voice messages to (and possibly from) paging devices. Voice messages may be transmitted in real time through a built-in speaker in the paging unit or they may be stored in the voice pager to allow replay of the message at a later time. Voice paging systems may be analog (usually FM transmission) or they may use digital transmission.

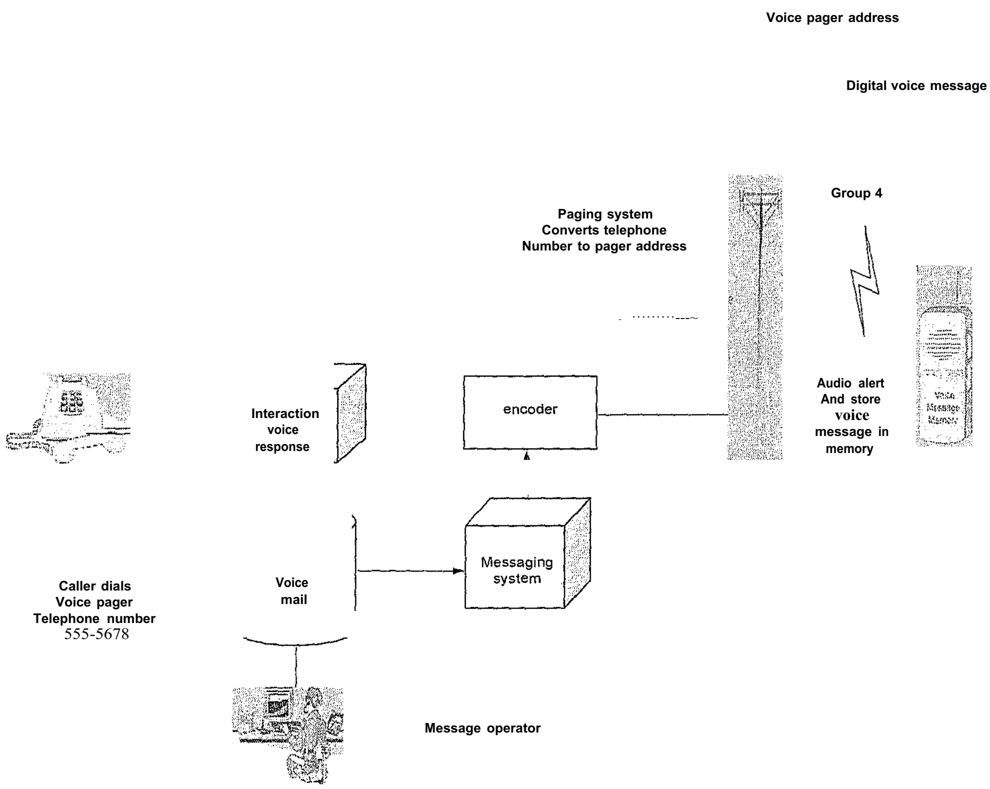

Figure 6.5 Voice Paging Systems

Figure 6.5 shows how a voice paging system receives voice messages from callers and forwards these messages on to a voice pager. In this example, a caller dials a paging access number. This number either connects the caller to an interactive voice response unit or an operator that can direct the caller to a voice mailbox associated with the voice pager. After the caller's message is stored in the voice mailbox, it will be placed in the queue for the voice mail system. When the message reaches the top of the queue (available time to send), it will be encoded (formatted) to a form suitable for transmission on Radio channel. In this example, the message is sent as part of group 4. Sending the messages in groups allows the pager to sleep during transmission of pages from other groups that are not intended to reach the voice pager. The voice message includes the voice pager address along with the voice message in digital form. During the reception of the message, it is stored into the voice message memory area so the voice pager can play the message one or many times after it is received.

6.14 Alpha or Text Messaging

Alpha or text messaging is the process of sending short strings of characters (text) to (and possibly from) a pager. The use of text messages results in easy to read messages as compared to numeric messaging. Because alpha messages are usually much longer than numeric pages, they require more transmission time. As a result, alpha messaging is usually more expensive than numeric paging. Alpha messaging service can take many forms, from manually converted verbatim text messages (converted by an operator) to automatic news and weather reports. Messages can be recorded into voice mail where operators type them up and send them out, or callers can dictate messages to live operators directly. Many alpha paging operators bundle free news, weather and sports feeds from other sources. While some carriers offer unlimited message transfer, many charge for additional pages (both numeric and text message) beyond a pre-defined limit. Some carriers charge so much per character while others simply charge by the message.

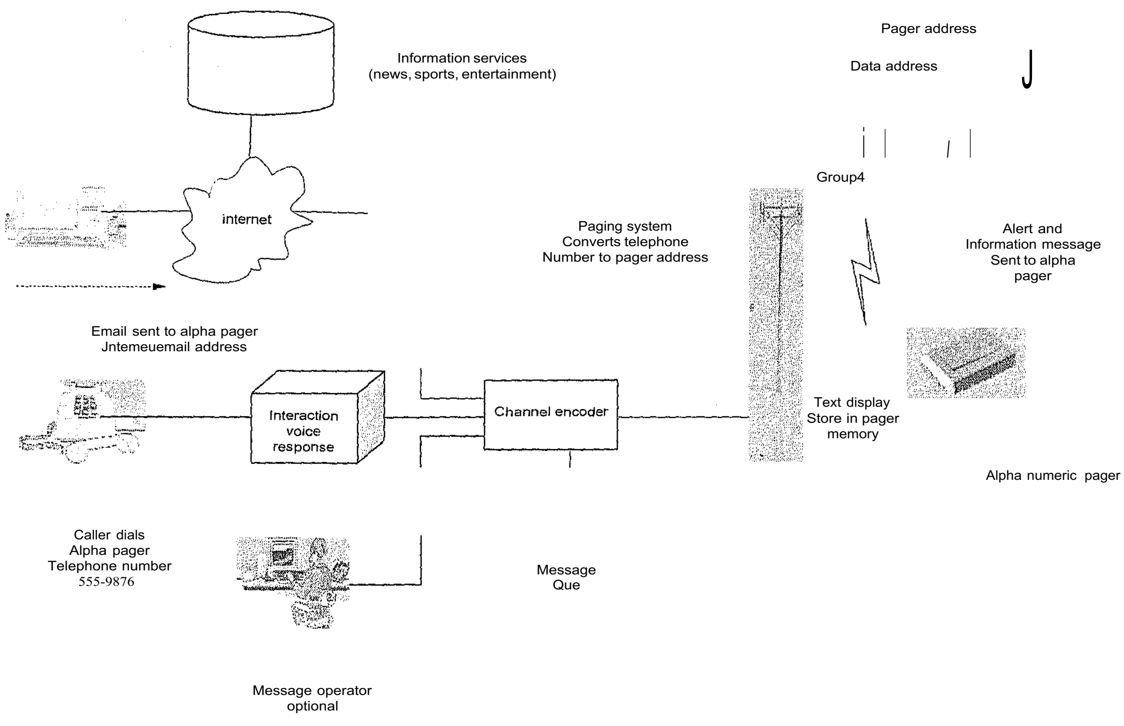

Figure 6.6 Alpha Paging Systems

Figure 6.6 shows how an alpha paging system receives voice, text, or data messages from callers and forwards these messages in text form to an alphanumeric . In this example, a sender can access the system by voice or by sending email messages via the Internet. When accessing the system by voice, a caller dials a paging access number and is either connected to an interactive voice response (IVR) unit or to an operator. When connected to an IVR, the user may be given options for specific messages (canned messages) or their voice may be converted to text messages. When connected to an operator, the operator converts (keys in) their messages to text form.

When messages are sent via the Internet, their format is changed to a form suitable for the alpha paging system. In any of these cases, the messages are placed in a message queue that holds the message until the system is available (no other messages waiting) before it. When the message reaches the top of the queue (available time to send), it will be encoded (formatted) to a form suitable for transmission on a radio channel. In this example, the message is sent as part of group 4. Sending the messages in groups allows the pager to sleep during transmission of pages from other groups that are not intended to reach the alphanumeric pager. The text message includes the pager address along with the text message in digital form. During the reception of the message, it is stored into the message paging memory area so the pager can display the message after it is received.

6.15 Summary

Paging Systems. Descriptions of one-way and two-way paging systems and how they are evolving from one-way delivery of simple numeric messages to two-way interactive information services.

CONCLUSION

Wireless Communication. Provides an introduction to basic wireless Technology and industry terms.

Wireless Technology Basics explains the fundamentals of wireless technology and terminology. This includes how the radio frequency Spectrum is divided, the basics of radio frequency transmission and modulation, Radio networks, discusses the basic operations, attributes and services for analog cellular (1st generation), digital cellular (2nd generation), packet based cellular (2 *Yi* generation), and wideband cellular (3rd generation) communication systems.

Bluetooth covers the basics of short-range Bluetooth wireless networks used by accessories such as headsets, keyboards, cameras, and printers. This chapter includes operational descriptions of Bluetooth and home RF and how these technologies are evolving.

Paging Systems are descriptions of one-way and two-way paging systems and how they are evolving from one-way delivery of simple numeric messages to two-way interactive information services.

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