NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

EVOLUTAION OF HUMAN COMMUNICATION OVER THE AGES

Graduation Project
EE- 400

Student: Alaa Insair (991241)

Supervisor: Professor. Dr. Fakhreddin Mamedov

Lefkoşa- 2003

NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

EVOLUTAION OF HUMAN COMMUNICATION OVER THE AGES

Graduation Project
EE- 400

Student: Alaa Insair (991241)

Supervisor: Professor. Dr. Fakhreddin Mamedov

Lefkoşa- 2003

ACKNOWLEDGMENT

First, I would like and foremost to thank my god whom its accomplishment would not have been possible.

Second, I would like also to deeply thank my supervisor Prof.Dr. Fakhreddin Mamedov for his available advice and belief in my work and my self over the course of this graduation project.

Third, thanks to faculty of engineering for having such a good computational enviroument.

Forth, I thank my family spicailly my parents ,with out their indless support and love for me ,without them i would never achieve my current position , i wish my mother lives happily ever after , and my father to be most proud in his son.

Last and not least i would also like to thank my friends in NEU : Suhail, Asad, Naseem, Aymen, Saleh, Ibrahim and all of my friends who where always available for my assistance thoughout this project.

ABSTRACT

This project include six chapters,deals with a core technology issue, and aims to compare two predominant wireless telecommunication technologies,Global System for Mobile Communication (GSM) and Code Division Multiple Access (CDMA) and the Evolution Towards of Universal Mobile Telecommunications Systems (UMTS),The Need for Third Generation Systems,UMTS and FPLMTS/IMT-2000 Standardization Plans and Summary of the chapter in the end , where This paper presents the current perspective on the European mobile and wireless telecommunication sector insofar as Third Generation advanced personal mobile communications are concerned.

TABEL OF CONTENTS

INTRODUCTION

The first human communication was truly a "wireless" communication. People communicated by direct speech and the range of communication were limited to the listening range of the human ear. The increasing requirement for information interchange over long distances saw the advent of innovative "technologies" like smoke signals, drums, et al. The advancement in technology has been rapid, and the turning point in the arena of long-distance communications was the invention of the telephone by Alexander Graham Bell. Phones were designed to communicate information across long distances using wires to transmit the voice "information". Then the need for mobility amongst the users of telephones saw the birth of wireless technologies, where users were no longer restricted to the termination point of the service at the consumer premises equipment

My project is include six chapters , The first one presents How Cellular Technology Works and it Introduction and it will have the Wireless Systems concept the first frequency band used for wireless products and Frequency Hopping (FH) – this technology.

About the second chapter presents why cellular technology is relevant to us, Digital Cellular System, What “multiplex" means? The two predominant ways to multiplex.

About the third chapter presents Global System for Mobile Communication (GSM), a small history about (GSM) and its standards in European digital communications and the Services of the Global System for Mobile Communication.

The forth chapter presents the Code Division Multiple Access (CDMA) and the technology is uses called direct sequence spread spectrum to provide more conversations for a given amount of bandwidth and digital service, Unique digital codes, rather than separate RF frequencies or channels, are used to differentiate subscribers.

About the fifth chapter it deals with the aims to compare two predominant wireless telecommunication technologies Global System for Mobile Communication (GSM) Code Division Multiple Access (CDMA).

The sixth chapter presents the Evolution Towards of Universal Mobile Telecommunications Systems (UMTS),The Need for Third Generation Systems, UMTS and FPLMTS/IMT-2000 Standardization Plans and Summary of the chapter where This paper presents the current perspective on the European mobile and wireless telecommunication sector insofar as Third Generation advanced personal mobile communications are concerned.

The unique aspect is that while one technology is relatively old, and time tested, the other one is a contemporary development that has caught wide popularity very quickly. There are a lot of debates, discussions and deliberations about which is the superior technology for respective applications.

1. HOW CELLULAR TECHNOLOGY WORKS

1.1. Introduction

The 20^{th} century has witnessed the development of a public wired network that allows affordable and reliable communication. However, this type of system is good for voice and low-rate data transmission and was not engineered to handle high-rate data transmission.

In the language of technology, wireless communication refers to any communication between two factors without the use of a direct cable line. Wireless phones send and receive signals over radio waves. There are two widespread wireless communication technologies, cellular radio, and cordless telephony. Cellular systems are currently limited to voice and low-speed data within areas covered by base stations. Cordless telephony basically refers to add-on of wireless capabilities to traditional telephones.

Cellular radio is the earliest form of wireless "personal communication". Bell Labs pioneered the cellular system design in the 1970's, and the initial technology was called Advanced Mobile Phone Service (AMPS). Similar technologies were soon deployed internationally, and together, these constituted the "first generation" cellular systems using analog frequency modulation (FM) for speech transmission and frequency shift key (FSK) for signaling. This way of sharing the spectrum is also called Frequency Division Multiple Access, or FDMA. The foundation of FDMA is Frequency Division Multiplexing, or FDM, which will be explained in section 4.2.

This paper focuses on cellular (radio) telephony, and not on cordless telephony. More specifically, it will concentrate on two enabling digital technologies, GSM and CDMA. The overall presentation is oriented towards broad coverage rather than technical depth. Please see the technical references for a more thorough treatment of the technical aspects of these technologies.

1.2. Wireless Systems concepts - Spread Spectrum and Frequency Options

The performance characteristics of a particular wireless unit are dependent on several factors. These include the type of spreading pattern (or if the signal is spread at all) and the frequency band used.

1.2.1. Spreading Technologies / Spread Spectrum

Frequency Hopping (FH) – this technology works by transmitting data on ever-changing frequencies in a pseudo-random pattern. Transmitter and receiver switch rapidly from frequency to frequency in a given range, never spending more than 0.5 seconds on any one channel. Use of this technology increases security, resistance to multipath effects (radio version of an echo), and permits large numbers of separate wireless LANs to operate within range of each other. Frequency Hopping also requires less power than Direct Sequence transmissions.

Direct Sequence (DS) – this technology divides each bit of information into smaller units called chips which are then broadcast simultaneously on a large number of channels. If one or more chips are lost during transmission, the remaining chips usually offer enough information to rebuild the signal. Direct Sequence is all about redundancy, with each bit of information being sent at least 11 times. This permits DS products to have twice the range at the same speed as FH, or twice the speed at the same range. The best bridges use DS technology. However, it requires more power to transmit, and only permits a few separate wireless LANs to operate in the same location.

Narrowband - this technology does not use any spreading pattern. Instead, it transmits and receives on a single channel, much like handheld radios, cordless telephones, and other radio devices. Security settings are encoded into the transmission, but this method is the least secure of the three (while still being as secure as standard wire). In addition, narrowband is more prone to interference, multipath effects, and cannot have significant numbers of separate wireless LANs operating in close proximity. Also, since the signal does not use any spreading patterns, range is reduced when compared to the other technologies. However, since the radios themselves need to be much less complex than those used by spread spectrum devices, the costs are significantly lower than other wireless systems.

1.2.2. Frequency Options

900Mhz - the first frequency band used for wireless products. 900Mhz equipment tends to be based on older technology, and is generally the least expensive spread spectrum hardware available. As a frequency, 900MHz penetrates well which translates into greater ranges than other frequencies. However, the 900MHz band is also used by cellular telephones, cordless telephones, and other commercial products that can lead to interference. The interference will not usually cause the wireless LAN to stop operating, but it can lead to slowdowns. 900MHz can be a good choice for smaller communities where range is more important than throughput. However, most manufacturers are phasing out 900MHz products and hardware.

2.4 GHz - this is the frequency band used most often in new wireless networking products. While 2.4 GHz radio waves do not penetrate as well as 900 MHz waves do, the range is still outstanding. More importantly, there is much less interference at this frequency which helps ensure wireless LANs and bridges using 2.4 GHz operate at their full rated speeds. The recent 802.11 standard uses the 2.4 GHz band for equipment, and virtually all wireless vendors offer a 2.4 GHz product, using either FH or DS. 2.4 GHz products are a good balance of speed and range and will work well in virtually any wireless LAN or bridging environment.

5.8 GHz - this is the newest frequency band to be used for wireless networks. 5.8 GHz permits very fast transmissions. In addition, very few sources of interference exist in this frequency range, ensuring very clean signal which virtually eliminates the need to retransmit any data. Also, since the 5.8 GHz band is much larger than the others listed here, equipment using this frequency may operate at much higher speeds. Perhaps the only drawback to the frequency is its tendency to reflect off dense obstacles rather than penetrate, thereby reducing the range.

2. WHY CELLULAR TECHNOLOGY IS RELEVANT TO US

2.1. Overview

The cord, which is always attached to the telephone unit or computer, limits a user's freedom and has no meaning except as a communication link. Cellular technology promises a future without wires, not just locally, but globally. Cordless, or wireless, is the way of the future. Instead of wires into the home or office, people will connect to the telephone network through a fixed radio terminal on the wall. These wireless connections are quicker to install and more cost-effective.

As can be seen from the following chart the World Cellular Subscriber base has grown tremendously since 1991. The red line depicts the number of subscribers in millionwhile the blue bars depict the number of countries where cellular technology is available.

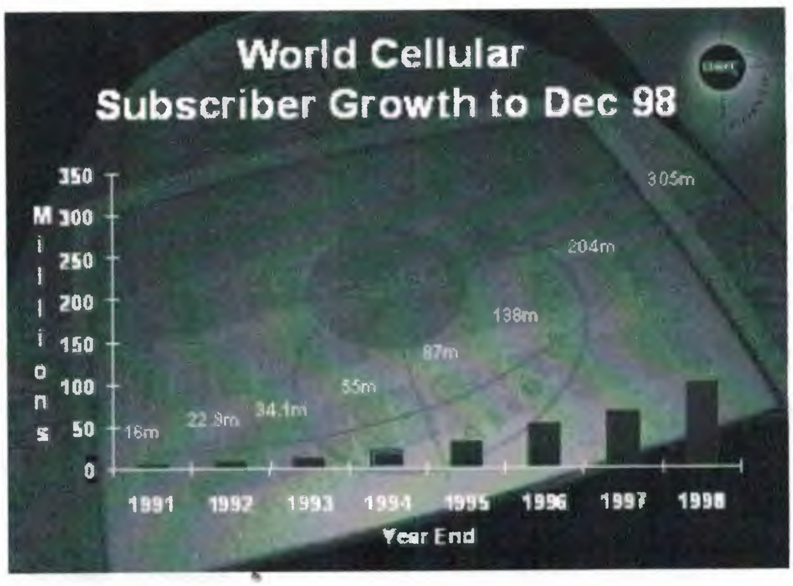

Figure 2.1 World Cellular Subscriber base has grown tremendously since 1991.

There is also an increasing trend by cellular users towards using wireless technologies for data transfer applications as well as voice telephony. The following chart shows estimates through the year 2007 for the percentage of cellular subscribers using wireless technologies for data transfer applications as well as voice telephony.

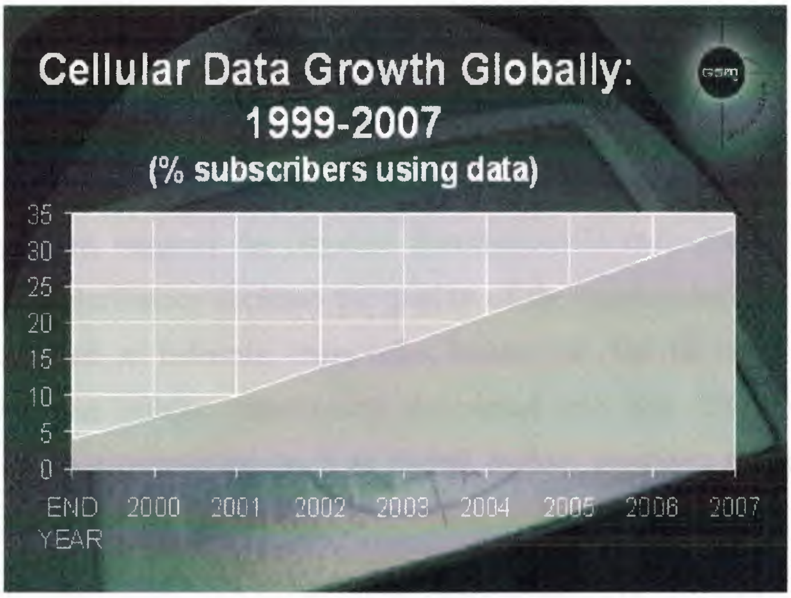

Figure 2.2 cellular data growth globally from 1999-2007

2.2. Transition from Analog to Digital Technology

In the 1980s most mobile cellular systems were based on analog systems. The first generation of phones were based on analog technology. Since the number of frequencies available for wireless is limited, digital phone technology was introduced.

2.2.1. Analog Cellular Systems

In the United States, a total of 50 Mhz in the bands 829-849 Mhz and 869-894 Mhz. is allocated to cellular mobile radio. In a given geographical licensing region, two carriers control 25 Mhz. The "A" and "B" bands are allocated to "non-wireline" and "wireline" carriers, respectively.

2.2.2 Digital Cellular Systems

The development of low-rate digital speech coding techniques coupled with the developments of integrated circuit technology; spawned the growth of digital systems. Analog systems were not able to cope with the increasing demand of traffic and utilization. In order to overcome this problem, new frequency bands and new technologies were proposed. But the possibility of using new frequency bands was rejected by many countries because of the restricted spectrum. The new analog technologies proposed were able to overcome the problem to a certain degree but the costs were large

Digitization allows the use of Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) as alternatives, or in addition, to FDMA (Early Analog System).

The quality of the service is vastly enhanced in a digital technology implementation. In fact, analog systems transmit the physical disturbances in radio transmission to the receiver. These disturbances decrease the quality of the communication because they produce effects such as fadeouts, cross talks, hisses, etc. On the other hand, digital systems avoid these effects transforming the signal into bits. This transformation combined with other techniques, such as digital coding, improves the quality of the transmission.

2.3 Multiple Access Technology

2.3.1 The Multiple Access Problem

The Multiple Access problem is that a common bandwidth has to be shared amongst N users simultaneously.

To "multiplex" means, "to combine multiple signals (analog or digital) for transmission over a single line or media. A common type of multiplexing combines several low-speed signals for transmission over a single high-speed connection".

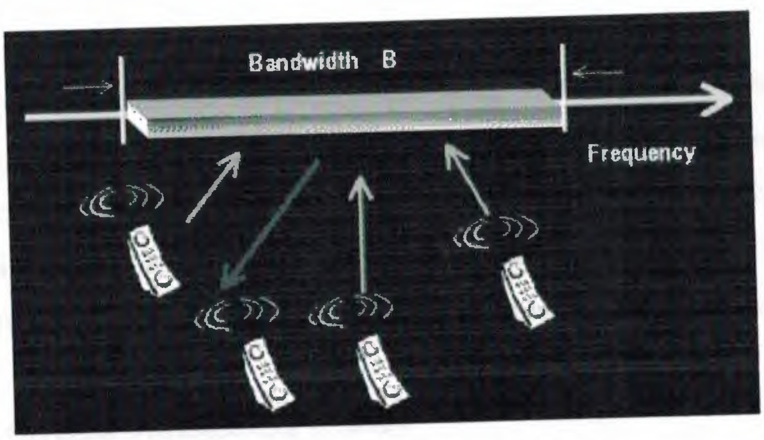

Figure 2.3 The Multiple Access Problem

Multiplexing is the process whereby multiple channels are combined for transmission over a common transmission path. There are two predominant ways to multiplex:

- Frequency Division Multiplexing
- Time Division Multiplexing

2.3.1.1. Frequency Division Multiplexing (FDM)

In FDM, the focus is on the frequency dimension. The channels are separated in the aggregate by their particular frequency ranges. The bandwidth is divided into evenly spaced narrowband frequency slices. This allows multiple users to communicate simultaneously using their respective narrowband frequency channels (Because the multiple channels are combined onto a single aggregate signal for transmission). Each user is pre-assigned to a narrowband frequency slice for the duration of their transmission. FDM, alone, is used primarily in analog transmission technologies.

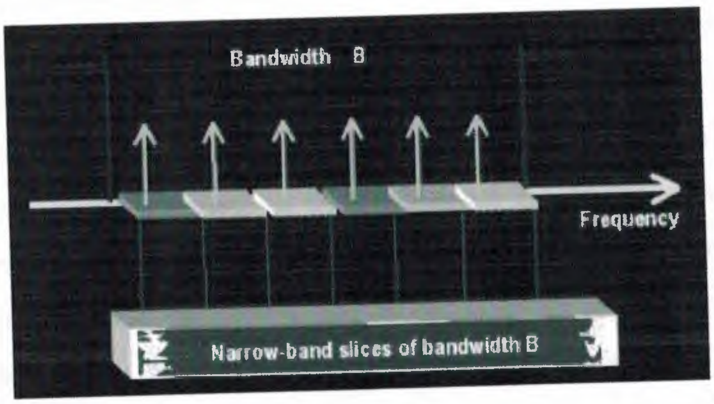

Figure 2.4 The bandwidth is divided into evenly spaced narrowband frequency slices. Examples of FDMA applications include AM Radio, FM Radio and Television Broadcasts (FDM was the first multiplexing scheme to enjoy widescale network deployment, and such systems are still in use today).

Overhead

There is always some unused frequency spaces between channels, known as guard bands. These guard bands reduce the effects of bleedover between adjacent channels, a condition more commonly referred to as crosstalk. This unfortunately reduces the actual bandwidth available for use. Also, since the total bandwidth is subdivided into only N frequency slices or channels, only N users may be supported simultaneously.

2.3.1.2. Time Division Multiplexing (TDM)

In TDM, in addition to frequency, a new dimension, time is added. Several users are allowed to "take turns" sharing a given narrowband frequency slice. The channels share the common aggregate based upon time. This allows several users to communicate simultaneously using a single narrowband frequency slice (The interval of time during which any single user can transmit is known as the TDM Frame). The assignment of time slices can either be dedicated (conventional) or dynamic (statistical).

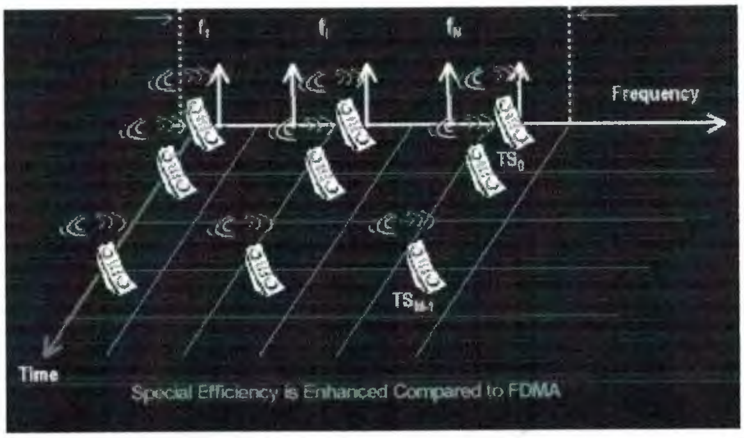

Figure 2.5 special efficiency is enhanced compared to FDMA

2.3.2. Conventional Time Division Multiplexing

Conventional TDM systems usually employ either Bit-Interleaved or Byte-Interleaved multiplexing schemes. In Bit-Interleaved multiplexing, a single data bit from an I/O port is output to the aggregate channel. This is followed by a data bit from another I/O port (channel), and so on, and so on, with the process repeating itself. A time slice is reserved on the aggregate channel for each individual I/O port. In Byte-Interleaved multiplexing, a series of bits comprising a byte from the I/O channels are placed sequentially, one after another, onto the high-speed aggregate channel. The drawback is that a time slot is reserved for use whether there is data to transmit or not. If there is no data to be transmitted inefficiencies can be observed.

2.3.3 Statistical Time Division Multiplexing

Here, the time slots are assigned to signals dynamically to make better use of bandwidth. Time slots are of variable length instead of static length and each signal must compete for a free time slot. A buffer is used during times of peak traffic to store data that cannot automatically receive a time slot. Additionally, since there is no set pattern to how a particular signal is transmitted within the narrowband slice each transmission holds a unique channel identifier to separate it from other transmissions.

Overhead

No channel is monitored continuously in a time-division multiplex system, so the sampling must be rapid enough in order to insure that the signal amplitude in a particular channel does not change too much between samples. Also, since a time-division multiplex system is based on precise timing, it is vitally important the demultiplexer be synchronized exactly with the information coming from the multiplexer.

3. GLOBAL SYSTEM FOR MOBILE COMMUNICATION (GSM)

3.1. Introduction

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard that would formulate specifications for a pan-European mobile cellular radio system operating at 900 MHz. It is estimated that many countries outside of Europe will join the GSM partnership.GSM (Global System for Mobile Communications) is a European digital communications standard which provides full duplex data traffic to any device fitted with GSM capability, such as a phone, fax, or pager, at a rate of 9600 bps using the TDMA communications scheme.

Since GSM is purely digital, it can easily interface with other digital communications systems, such as ISDN, and digital devices, such as Group 3 facsimile machines. Unlike any other service, GSM products such as cellular phones, require the use of a Subscriber Identity Module, or SIM card.

These small electronic devices are aproximatly the size of a credit card and record all of the user information it. This includes data such as programmed telephone numbers and network security features which identify the user. Without this module, the device will not function.

This allows for greater security and also greater ease of use as this card may be transported from one phone to another, while maintaining the same information available to the user. GSM is also present outside of Europe but known by different names. In North America it is known as PCS 1900 and elsewhere are DCS 1800 (also known as PCS). The only difference between these systems is the frequency at which operate. The number stands for the operating frequency in megahertz. While each system uses the GSM standard, they are not compatible with each other.

3.2. History

Originally the idea of cell-based systems for mobile communications was developed at Bell Laboratories over 25 years ago. However, the first commercially available mobile cellular systems were not introduced until the 1980's and the first commercially available digital mobile cellular system was not introduced until 1991.

The birth of digital mobile cellular systems began in Europe in the 1980's during which time analog mobile cellular systems were experiencing great popularity and growth. One of the misfortunes of this fledgling technology was that each European country was developing its own analog digital cellular system independently from the others. Two consequences from this were that a particular provider's service was only usable within the host country and therefore no particular provider could get a very large market share or reap the benefits from any kind of economies of scale.

In 1982 many European nations realized they needed a cohesive standardized technology. The responsibility for developing recommendations and standards for this new technology was given to the Conference of European Posts and Telegraphs (CEPT) who formed a think-tank called Groupe Spécial Mobile (GSM). From the beginning they had six requirements the standard had to fulfill:

- Low mobile and base station costs
- Good subjective voice (speech) quality
- Spectrum efficiency
- Compatibility with other technologies such as ISDN (Integrated Services Digital Network)
- Support for International roaming
- Ability to support a range of new services and facilities

In 1989 the responsibility for developing the standards and specifications for the new technology were transferred to the European Telecommunication Standards Institute (ETSI) where the name of the technology finally became Global System for Mobile Communications (GSM). They published phase 1 of the GSM specifications in 1990 and commercial services were started in mid-1991. GSM currently operates in three different frequency ranges, 900 Mhz, 1800 Mhz and 1900 Mhz,Since that time GSM subscribers have increased at a phenomenal rate. In 1993 there were 36 GSM networks in 22 countries. At the beginning of 1994 there were over 1.4 million subscribers worldwide. This number had reached 4.5 million just one year later, at the beginning of 1995, and 12.5 million by the end of 1995. By October 1997 there were over 65 million subscribers and at the end of 1998 there were GSM networks in more than 115 countries with over 130 millions subscribers. Currently, there are networks in over 130 countries servicing nearly 200 million subscribers.

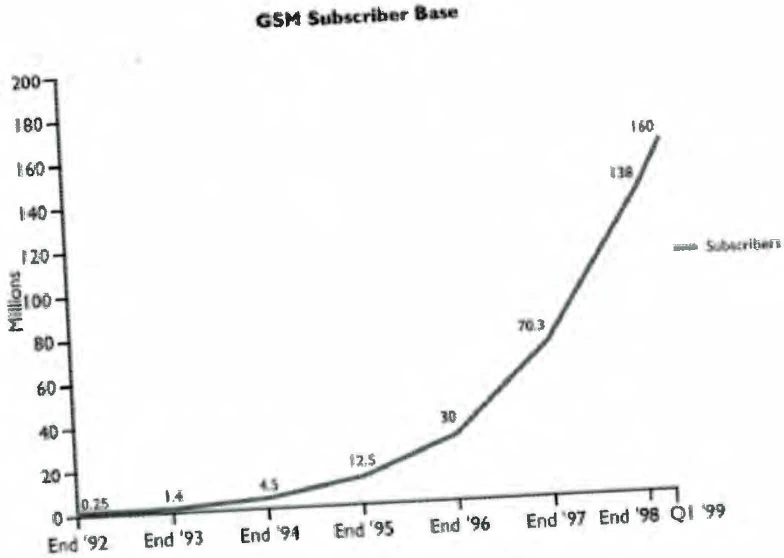

Figure 3.1 GSM Subscriber Base

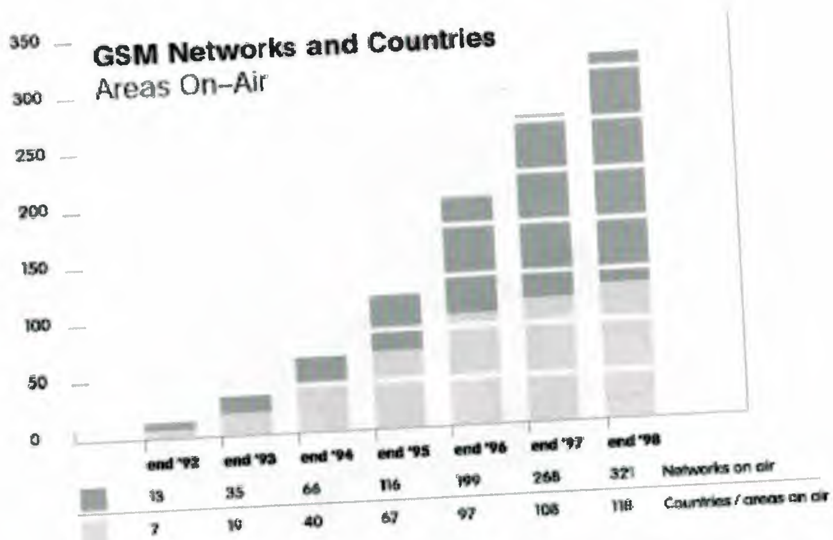

Figure 3.2 GSM networks and countries areas on-air

3.3. Overview

GSM phones do not use telephone lines to transmit a call. They utilize a certain frequency bandwidth to transmit the data. Calls are transmitted from the cellular phone via radio waves to cell sites, which relay the calls to the standard phone system. The cell site is the basic building block of a cellular system, which is actually its coverage area. Several cell sites aligned in a strategic configuration are known as a cellular system. GSM systems are arranged in such a way that the coverage area of one cell will overlap the coverage area of an adjacent cell. All the cell sites in a system are then connected to a Mobile Telephone Switching Office (MTSO), which connects the cellular system to the standard landline telephone system by way of a Central Office (CO). The most distinguishing feature of a cellular system, compared to the older mobile radio systems, is the use of these many base stations each having a relatively small coverage radius.

3.4. Cells

There are four main types of cells. They are macro cells , microcells, selective cells, and umbrella cells. Macrocells simply refer to cells whose geographic coverage is large due to the fact that the population density is small. Microcells are the opposite of macrocells. They refer to cells, whose geographic coverage is small because the population density is large. The reason that the cells differ in geographic coverage based on population density is to insure that the number of channels available for subscribers is sufficient. When microcells are used it is important that the transmitter power in these cells is reduced, otherwise the possibility of interference with neighboring cells increases.

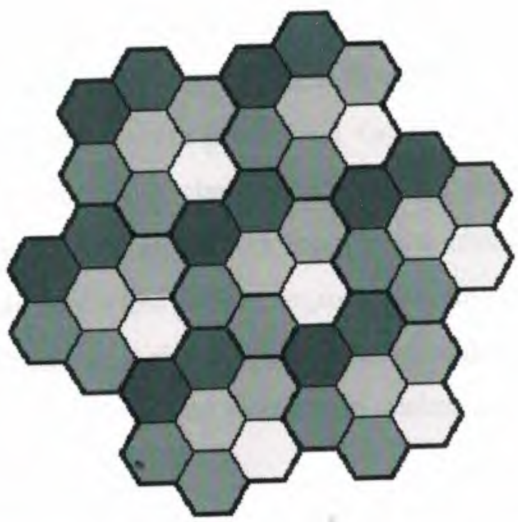

Figure 3.3 The graphic depicts the way in which frequency reuse within a network is done.

If one thinks of a particular frequency range as being a color it can be seen that no adjacent cells have the same frequency range. This ensures that frequencies from one tranmitter do not interfere with the frequencies from an adjacent cell's tranmitter.

Selective cells refer to a cell where it is not desirable or necessary to have full 360 mic coverage such as at the entrance to a tunnel. Umbrella cells refer to a macrocell, which hangs over several microcells. Umbrella cells are primarily used in very densely populated areas where many small cells converge. Its purpose is to be able to handle any overflow from the microcells that it covers.

Cells are further grouped into clusters. The network predetermines the number of cells in a cluster such that it can be repeated throughout that networks entire system. This number is very important. The smaller the number of cells in a cluster the larger the number of channels available. Conversely, the more cells in a cluster the fewer channels available. A compromise must be found between having a large number of channels available, and therefore a small number of cells in each cluster, and the interference that probabilistically increases as a result of having small cells packed together. Typical clusters have 4, 7, 12, or 21 cells.

Since the frequency range available is limited GSM works efficiently by reusing the available frequencies. Each frequency range is tied up for the physical area of the cell. If a cell's transmitter is very powerful the frequency range it uses can be tied up for hundreds of kilometers. GSM works most efficiently when the power of the transmitter is low.

As a subscriber drives through a cellular system making a call on a cellular phone, that call is transmitted to the nearest cell site on radio frequencies that are particular to that cell site. This radio link between the phone and the cell site is known as a cellular channel. One of the truly innovative characteristics of cellular technology is that these channels can be used again and again - as long as the channels are re-used at non-adjacent cell sites. In this way a low power, segmented transmitter/ receiver system can service a great many callers at a single time, without using a tremendous number of channels. It is this concept of channel re-use that makes cellular efficiency feasible.

3.5. Roaming

A caller traveling outside of the home cellular system to which he or she is a subscriber becomes a roamer. For a fee, the subscriber can continue to use the phone outside the home cellular system.

3.6. Hand-Offs / Handovers

When a caller nears the limit of a cell site's coverage area, the call will automatically and silently be transferred or handed-off to the next nearest cell site in the system. Unlike conventional mobile telephone systems, GSM service allows the caller to drive from one cellular coverage area to another while maintaining high quality reception. The cellular phone puts out a signal that is picked up by the closest tower in a particular cell site. The MTSO monitors signal strength at each cell and selects the appropriate site to process the call. As an automobile passes from one cell to another, the MTSO automatically hands-off the call to another transmitter in an adjoining cell. Signal hand-off occurs in a split second and is performed so smoothly that the procedure is transparent to the user. This hand-off is what allows one to drive through an entire coverage system without dropping a call.

There are four different types of handover:

- Handover of cells controlled by the same antenna
- Handover of cells controlled by the same base station
- Handover of cells belonging to the same switching office but controlled by different base stations
- Handover of cells controlled by different switching offices

When a mobile leaves a cell, the power of the signal received by the mobile phone starts to fade. When it reaches a specific level the mobile sends a message asking for a new cell assignment. If the user is still inside the antenna area the antenna will look to a nearby cell and assign the mobile to it. If the user is heading out of its controlling antenna's area it will ask the base station to assign the mobile to a new antenna. If the user is heading outside of its controlling base station area it will ask the switching office for an assignment to the next base station. If the user is leaving the switching office area, the switching office will make the assignment to the next switching office. At this point the user's call status becomes roaming.

3.7. Services

3.7.1. Security

One of the major concerns when individuals consider mobile technologies is the security of any calls or data transmissions. GSM has both user authentication and encryption on all data that is sent through the air. GSM authentication is taken care of by the use of a Subscriber Identification Module (SIM) card. Each subscriber is given a unique key that is stored with this SIM card (which is actually a microchip). It is also stored in the subscriber's home network Authentication Center (AuC). When a user wants to make a call or send data the AuC sends a random number to the mobile unit.

Both the AuC and the mobile unit use this random number and the user's unique key to generate a signed response (SRES) using a ciphering algorithm called A3. This SRES is sent back to the AuC and if it matches the SRES that theAuC calculated the user is authenticated.

.

Figure 3.4 (SIM Card in protective jacket), (SIM Card)

Besides the SIM cards installed into the back of a GSM cellular phone to prove to the AuC who the person using a cellular phone is, there are also security protections placed into the architecture of every GSM certified phone. Each GSM phone, or terminal, is given a unique International Mobile Equipment Identity (IMEI) number. A list of all of the IMEI's within a network is stored in the Equipment Identity Register (EIR) of the AuC. There are three possible statuses for a terminal:

- White-Listed – The terminal is allowed to connect to the network
- Grey-Listed – The terminal is slated for observation from the network for possible problems
- Black-Listed – The terminal has been reported stolen or its type has not been approved , The terminal is not allowed to connect to the network.

These statuses are dependent on the actual physical hardware of the GSM terminal and are independent of the SIM card installed.

Further security after a connection has been established uses encryption based upon the unique SIM key and TDMA frame number using the A5 encryption algorithm. This is for most intents and purposes overkill since the signal is already coded, interleaved, and transmitted using TDMA, which in and of itself provides protection from all but the most persistent eavesdroppers.

3.7.2. Noise Filtering

The obvious feature of a GSM network is for telephony communication. The largest concern within this area is the subjective quality of the speech transmission. Since GSM is a completely digital technology there are many areas that it can improve upon from its analog ancestors. Chiefly among these is in noise detection and suppression. In original analog systems whatever sound was offered the transmitter, was then heard by the receiver. However, by taking the analog signal and converting it to a digital one available technology is able to distinguish quite well between 'good' sound from a person talking and background noise and can suppress its relative volume. One of the drawbacks to this is that it is sometimes desirable for the person on the other end of the line to hear background noise. Consider two people discussing a song one has recently heard on the radio when it suddenly comes on the radio. The person describing this song would most simply like for the receiver to be able to hear the song in the background. This is the current dilemma in noise filtering.

An analog to noise filtering is discontinuous transmission (DTX). Since on average there is actual speaking less than 40% of time during a normal conversation there is a lot of silence. Using Voice Activity Detection (VAD) methods DTX turns off the transmitter during silence periods in a conversation. This results in less co-channel interference as well as saving power at the terminal. Normally the receiver would hear an annoying effect called clipping when this occurs, which sounds exactly like the line being dead. To assure users that the connection is still alive the system creates 'comfort noise' based on the characteristics of the background noise of the transmitter. This technology is constantly being updated to improve its efficiency.

3.7.3. Other Services

Most of the services offered by GSM can be broken down into three categories. The categories are labeled teleservices, bearer services, and supplementary services. Teleservices describe the most well known functions that can be handled by the normal Public Switched Telephone Network (PSTN). These include telephony, fax, emergency calls, teletex, short message service (SMS), and voice mail, compatibility with ISDN.

Bearer services include those services needed for the transportation of data. Some of these services are asynchronous and synchronous data transmission (315 – 9630 bps), Asynchronous PAD (packet-switched / packet assembler and disassembler) access (315 – 9630 bps), and synchronous dedicated packet data access (2400 – 9630 bps).

Supplementary services include a very large range of services. Some are familiar to current PSTN users and others are not. A short list of these include call forwarding, call barring, call hold, call waiting, and multiparty services

3.8. Architecture

The major elements in a typical GSM topology can be divided into four parts.

- The Mobile handset which is carried by the subscriber.
- Transfer antenna, deals directly with mobile phone.
- Base Station controls link between antenna and switching office.

Mobile Telephone Switching Office (MTSO) performs the switching of calls between the mobile and fixed network. The MTSO also handles the mobility management operations.

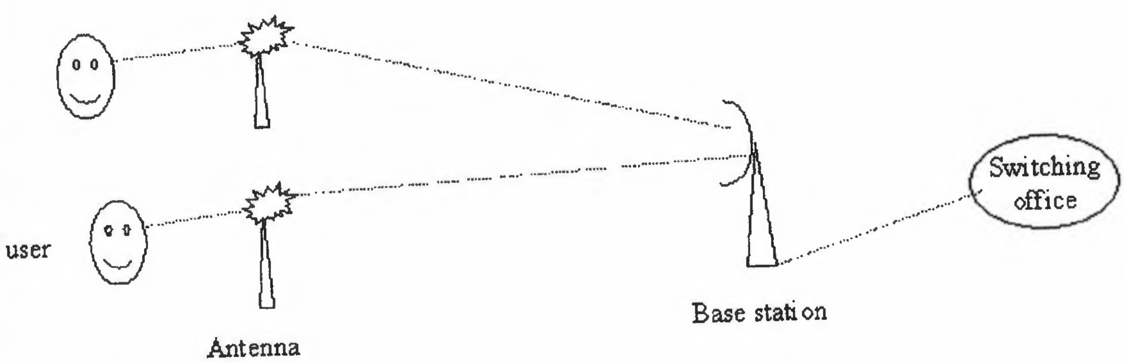

Figure 3.5 Architecture

3.8.1. Mobile Handset

The mobile handset consists of two main parts, a dumb terminal and a smart card (SIM). The SIM card is one of the most important features of GSM. The service provider issues a SIM card. It contains the phone number of the handset and vital personal information, including which network the subscriber belongs to, the unique secret key, and billing information. A user must insert the SIM card into the handset in order to be activate the handset. The only exception is for emergency services such as 911.

This enables users to switch GSM handsets by simply pulling out their SIM Card and inserting it into another device. As a result, users can keep the same number although they've switched handsets. Another feature that results from the use of SIM cards is that international travelers can simply carry their SIM card and rent a GSM compatible phone when they arrive. They must then just insert their card into the rented phone and calls made or received overseas will appear on their home account. A user could also remove their SIM card from the handset and lend it to another GSM user who could then insert their SIM card.

3.8.2. Transfer Antenna

In a GSM system, the coverage area is divided into cells. Every cell has an antenna, which is placed, in the center of the cell. Its job is to receive calls from users and to send these to the base station. The antennas also receive calls from the base station and send them to the particular mobile being called. There can be from one to sixteen antennas connected to one base station based on the density of the users in the cell.

3.8.3. Base Station (BS)

A BS controls one or more transfer antennas. It has more functionality than an antenna. Its job is to control handover of calls, power levels, and frequency assignment. A group of antennas and a base station connected together is often called a base station subsystem.

3.8.4. Switching Office

The mobile switching office is the heart of the GSM system. It provides the interface to the public wired network and billing collection. Its main role is to manage the communications between the mobile users and other users, such as mobile users, ISDN users, fixed telephony users, etc. It is supported by four databases that store information about the subscribers and manage their mobility. The functionality of each of the databases is described below.

Home location register database - Stores subscriber location information, both permanent and temporary. It tells the switching office to which location a subscriber belongs.

Visitor location register database - Maintains information about subscribers who are currently covered by switching service areas not within their permanent area. For example if a users account is in Pittsburgh and they travel to New York as soon as they turn their mobile on, it will start to send a signal to the nearest antenna. The antenna will send it to its base station, which will send it to switching office. The switching office will consult its home location database, which will confirm that this users home location is Pittsburgh. Then it will send a message to Pittsburgh to tell the Pittsburgh switching office that one of their subscribers is in the New York area. The Pittsburgh switching office will register this information in its database to send and receive calling information to the users temporary location in New York while maintaining that user billing information in Pittsburgh.

Authentication center database - Used for authentication activities of the system. It stores the encryption keys for all subscribers, which verifies a user's identity when a call is initiated

.Equipment identity register - Stores information on the type of equipment at the mobile station and plays a role in the physical security of a handset. It contains a list of all valid handsets. A handset is identified by its International Mobile Equipment Identity (IMEI). The EIR allows the blocking of calls from stolen or unauthorized terminals.

3.9. Multiple Access Scheme

Since the spectrum allotted to GSM transmissions is a limited resource shared by all users, a method is needed to divide up the bandwidth among as many users as possible. The method chosen by GSM is a combination of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). By this GSM takes advantages from both methods.

A mix of FDMA and TDMA increases the number of users that can be served in the same stretch of time. Using FDMA, a frequency is assigned to only one user. So the larger the number of users in a FDMA system, the larger the number of available frequencies must be available. The limited bandwidth allotment and the fact that a users assigned frequency will not be free until their transmission is complete explain why the capacity in a FDMA system can be quickly consumed. On the other hand, TDMA allows several multiple transmissions to occur at the same time within one channel. Each of the users, sharing the common channel, is assigned their own time slot within a group of time slots.

In GSM a 25 Mhz frequency band is allocated for each antenna. This band is divided, using an FDMA scheme, into 124 full duplex channels. Each channel data rate is 270.833 kbps, and operates on a 200 Khz frequency band. Normally a 25 Mhz frequency band can provide 125 (25,000,000 / 200,000 = 125) channels, but the first channel is used as control to prevent interception between subscriber's conversations. Each channel is then divided into time slots using a TDMA scheme. This scheme splits each channel into 8 time slots. Since each TDMA frame lasts 4.615 ms the time allotted to each user per frame is 0.577 ms (4.615 / 8). By performing a simple calculation one finds that each antenna can maintain up to 992 (124 X 8) conversations at the same time.

3.10. Frequency Reuse

In time, as more customers use the system, traffic will build up more and more so that there is the possibility that not enough frequencies are available to handle the conversations in a cell. There are two consequences that occur when this happens. Calls get blocked or dropped and the connection quality decreases. To solve this problem, new smaller cells can be installed within the old ones. Each one has its own antenna and set of frequencies. This modification can increase the capacity of the old cell and effectively create more channels for use by the subscribers. Generally, cells are created with diameters between 4 and 8 miles wide. To introduce smaller cells within larger ones, 60 to 120 degree directional antennas are installed inside the old cell.

It would seem this ability could theoretically continue forever. However, as cells get smaller and closer together two technical problems begin to emerge. First, the power level used must be reduced to keep the signal within the cell. The old cell antenna power must be reduced to prevent interference with the small cell frequencies. Second, As cells get smaller, handovers become much more frequent and more sophisticated management of handovers is required. Another interesting fact within GSM systems is that congested cells can borrow a frequency from adjacent cells not being used dynamically to meet its connection demands. By using this technique a thousands of simultaneous calls can be maintained in one system.

4. CODE DIVISION MULTIPLE ACCESS (CDMA)

4.1. Introduction

In the past few years, Code Division Multiple Access (CDMA) has become a popular concept in the wireless communications arena. CDMA is built on the spread-spectrum concept that has augmented digital communication for a number of years. Utilizing noise-like carrier waves to spread information over broader bandwidth than the original signal is the principle of spread spectrum technology. Currently CDMA enjoys capacity limits of approximately 8 – 10 times that of a regular AMPS network and approximately 4 – 6 times that of a GSM system.

CDMA uses a technology called direct sequence spread spectrum to provide more conversations for a given amount of bandwidth and digital service. Unique digital codes, rather than separate RF frequencies or channels, are used to differentiate subscribers. The codes are shared by both the mobile station (cellular phone) and the base station, and are called "Pseudo-Random Code Sequences." All users share the same range of radio spectrum.

CDMA is a digital multiple access technique specified by the Telecommunications Industry Association (TIA) as " IS-95." In March 1992, the TIA established the TR-45.5 subcommittee with the charter of developing a spread-spectrum digital cellular standard. In July of 1993, the TIA gave its approval of the CDMA IS-95 standard. IS-95 systems divide the radio spectrum into carriers which are 1,250 kHz (1.25 MHz) wide. CDMA is a digital wireless technology that was pioneered and commercially developed by QUALCOMM. CDMA is the most advanced digital media access wireless technique present today. In this scheme codes are used to separate different users without causing any interference. Consider a situation where there are four simultaneous users speaking at the same time in four different languages English, German, French and Spanish. There is a receiver in the audience who understands only English, so he will tune according to the English speaker and tune out the other three[105]. In the same way in a scheme like CDMA the channel is coded for each user and all the users use the same frequency band. The user then decodes the conversation according to his code for the channel. Since the frequency band is shared by different users CDMA is extremely efficient in bandwidth utilization.

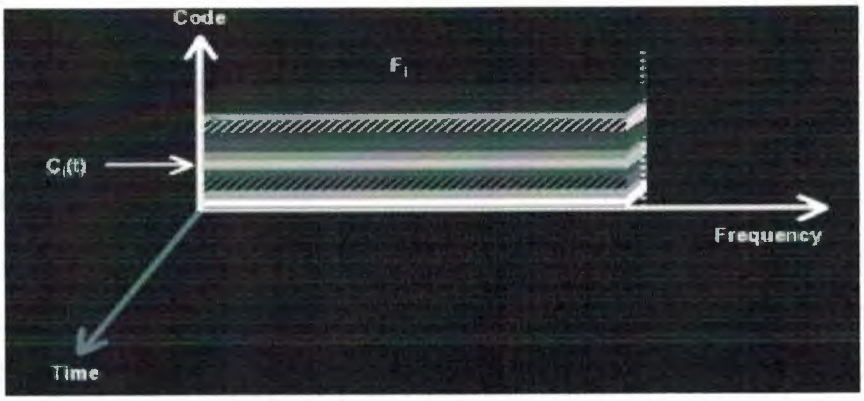

Figure 4.1 Code Division Multiple Access (CDMA)

4.2. History

CDMA's history can be traced back to the onset of the World War II era. It was first employed by the military as an anti-jamming technique to prevent enemy from jamming or interfering with their signals. In addition, CDMA could also conceal communication processes, therefore reducing the likelihood of transmission interception. Furthermore, it can be used to anticipate when signals will be received by measuring the distance of the transmission.

CDMA is relatively new to the commercial wireless industry when compared to GSM or AMPS. Even though it was first advocated in the late 1940's, non-military sectors did not really put it to use until the 1990's. There were two factors that facilitated general adoption of CDMA in the market. The first is that subscriber stations' size and cost can be greatly reduced with the advent of low cost and high-density digital ICs. Therefore, CDMA has received cellular radio system operators' worldwide acceptance as an upgrade that will dramatically increase both their system capacity and the service quality. The other factor is that stations need to set their transmitters to the lowest power levels possible to allow "multiple access" while still maintaining the overall communication quality.

4.3. Signal Clarity

CDMA is able to deliver very clear signals. According to Qualcomm, the pioneer of CDMA, CDMA's performance is about the same as wireline's because it filters out background noise, cross-talk or similar interference between cells. Moreover, CDMA's capacity is not as seriously affected by the multipath fading caused by propagation delay as the conventional analog transmission. Whereas subscribers using analog cellular phones might feel the fading effect when standing still, users using CDMA cellular phones might only feel that in moving vehicles.

4.4. Costs Savings

CDMA can cover more geographic area than GSM because of CDMA's outstanding air interface design. Thus, CDMA needs far fewer cell sites to operate. Fewer sites means more savings to service providers, as they can decrease their deployment time or expand more quickly if more sites are needed. This leads to lower costs in deployment, operation and maintenance.

In comparison to other cellular technologies, CDMA enables handsets to transmit with much lower power levels. Consequently, CDMA handsets will have longer battery life and it will give users increased talking time for their portable phones. Using smaller batteries, manufacturers can also produce smaller handsets that weigh less.

4.5. Hand-Offs / Handovers

As mobiles communicate with base stations before a handoff, CDMA allows the mobiles to detect which one has stronger signals and provide a soft handoff which acts in a "make-before-break" fashion. Thus, it can significantly reduce the chance of call disruptions or dropped calls resulted from handoff failures that occur very frequently in AMPS systems.

4.6. Services

4.6.1. Security

CDMA has long been used in military communication applications, CDMA can minimize eavesdropping because it is digitally encoded and transmitted over spread spectrum. Thus, enhanced user privacy and less security breach are made possible with CDMA.

4.6.2. Other Services

Prominent telecommunications manufacturers such as AT&T, Motorola, NEC Co. and Lucent Technologies have developed a variety of products based on CDMA. The economies of scale can allow the manufactures to bring down CDMA service providers' costs and allow them to offer wireless users more CDMA services or products. In addition to caller ID and short messaging services, CDMA also has other applications. As an example, Bell Mobility has recently began to offer its wireless customers the opportunity to try out options such as "wireless on-line banking, real-time e-mail and web browsing." Another example is a product called OmniTracs by Qualcomm. It is widely adopted by the trucking industry because it can keep track of trucks' locations and other maintenance information with the help of CDMA and satellites.

4.6.3. Architecture

CDMA uses direct-sequence (DS) technique to spread information encapsulated in a signal over the spectrum. The technique uses a pseudo-random binary sequence (also known as PN-code or pseudo noise code) to modulate the carrier frequency prior to transmitting the radio signal from the base station to the mobile.

The DS will repeat a particular digital sequence at a regular interval. For example, the sequence might be repeated for every 1023 bits. As this pseudo-random code is appended to the data and made available to the carrier, the transmission is spread over 1023 unique frequencies.

It should be noted that CDMA requires synchronization among base stations. Hence, the satellite-based radio navigation system, Global Positioning System, has been utilized to achieve a common time reference among base stations

To reduce the interference among different bands, it is important to select pseudo-random spreading codes with caution. Currently, (2^42-1) bits spreading code is being used for CDMA. Although this spreading code is applied to all users alike, each user has a "different place in the pattern" since manufactures will ensure that active users don't have the same position in the pattern. Moreover, making sure that all the users have equivalent transmission power is another way to reduce the interference.

An example can be drawn to elaborate the concept. First, a user will make a call with CDMA and the transmission rate will be at a standard rate of 9630 bps (9.6 kilobits per second). Then, this signal is spread to the rate of approximately 1.23 Megabits per second. Thereafter, these spread signals are transmitted along with the signals of all the other users within the cell where the user is located. Once the signal is received, the spreading codes are removed from the desired signal, separating the users and the call is restored to 9630 bps.

4.7. Multiple Access Scheme

Unlike GSM, CDMA does not employ frequency division multiplexing or time division multiplexing. CDMA only employs code division multiplexing. The way that it achieves this is by allocating the entire frequency band to all users based on a unique code given to each user when transmission is initiated. This allows for dynamic frequency allocation to users and provides the highest capacity of any current system.

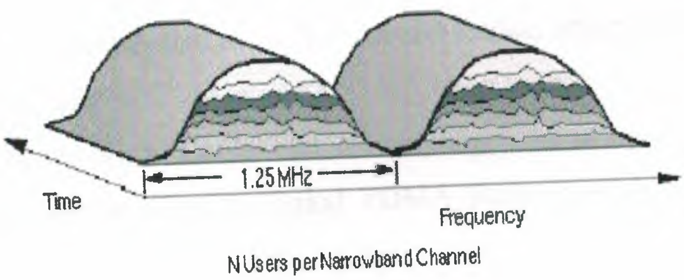

Figure 4.1 N Users Per Narrowband Channel

4.8. Issues

In short, as the wireless communication evolves from analog to digital cellular mode, the important issue to be considered by the industry is how to expand capacity, enhance user desired services, and lower costs while still offering quality services. In other words, coverage, quality and capacity will exert direct impact on the implementation of CDMA. On account of the close correlation among the three factors, we may be able to sacrifice some coverage and quality if we desire higher throughput and vice versa. The trade-off should be kept in mind to obtain the optimal performance of CDMA.

5. COMPARE BETWEEN GSM AND CDMA

5.1. Advantages of GSM

1. Increased radio spectrum efficiency to provide even greater network capacity (Which means it can support a high amount of subscribers!)
2. Provides highly sophisticated subscriber authentication, which reduces the possibility of fraud
3. Automatic location of mobile subscribers
4. Prevents the eavesdropping of conversations by employing sophisticated voice encryption techniques that are totally secure. Hence, ensures total confidentiality of voice and data
5. Provides better voice clarity and consistency, emanating interference due to digital transmission (Due to digital TDMA Techniques).It is comparable to a voiceline.
6. Simplifies the transmission of data, which allows the connection of laptop and palmtop computers to GSM cellular phones.
7. A single standard allowing International Roaming between the worlds GSM networks - (International Standards) Both national and international roaming is possible
8. Increased flexibility and utility using the Subscriber Identity Module (SIM) Card
9. Settle one bill in the subscribers local currencies at home
10. A host of personal services are available (Ex. Missed calls, voice mail notification, text messages)
11. Decreased size, price and weight of the telephone units
12. One phone - one number
13. Very large subscriber base estimated at over 150 million
14. National and International roaming supported
15. Increased flexibility and ease of transfer from different terminals by using the SIM cards
16. High service quality due to the digital TDMA technology
17. Automatic location of mobile subsribers
18. Confidentiality of voice and data due to the TDMA structure as well as extra authentication and encryption

19. Decreased size, price, and weight of mobile terminals
20. Very large list of base and optional services ranging from call waiting to voice-mail to SMS
21. Standard is flexible enough to allow for competition between manufacturers
22. Voice quality comparable to PSTN
23. Highest throughput of any mobile system at 115 Kbit/s packet switched

5.2. Disadvantages of GSM

1. The cost of equipment for either an AMPS or D-AMPS is less expensive than GSM implementation
2. Strict standards imposed by GSM regulations may inhibit creativity in advancing the technology
3. GSM is not compatible with AMPS technology
4. GSM may be outdated by an emerging wireless technology such as UMTS (Universal Mobile Telephone System)
5. Not currently supported in all areas of the US or worldwide

5.3. Advantages of CDMA

1. Improved Call Quality and Reduced Audible Effects of Multipath Fading
2. Swift Deployment and Greater Coverage for Lower Cost
3. Less Power Required for Transmission
4. Smaller Phones Fewer Dropped Calls
5. Improved Security and Privacy
6. Increased Data Throughput
7. Product Selection and Enhanced Services

5.4. Disadvantages of CDMA

With the proprietary nature of this emerging technology not many outside studies have been completed on this technology. Also, those companies who advocate CDMA do not wish to highlight the disadvantages, if any, of CDMA. The only disadvantage at this point to CDMA that has been brought to light is the fact that it is not in use as widely as GSM so roaming can be a problem, especially internationally.

5.5. Compatibility between GSM and CDMA

5.5.1. Dual-Mode Compatibility

At present, CDMA can co-exist with analog systems because more and more phones are manufactured to provide dual-mode operations. Dual-mode cellular phones can work on both digital and analog networks. For instance, a digital phone is configured to operate digitally by default if it is within the digital service area. However, it will switch to analog mode automatically if out of digital service area. Again, it will be switched back to digital mode once it is in the digital service region again. In general, there is a symbol on the handset display to show the users which mode is being used.

5.5.2. CDMA over GSM Trial

CDMA provides roaming convenience to the users by also offering the ability to inter-operate with digital GSM transmissions. The six-month experiment conducted by Andersen Consulting, Telemate Mobile Consultants of France and Detecon Consultants of Germany, together with several European operators, manufacturers and industry associations indicate that CDMA can be overlaid on top of GSM structure (GSM Mobile Switching Center) without much changes to either CDMA or GSM products. The extensive testing has been performed on "mobile-to-land, land-to-mobile and mobile-to-mobile" basis. The success of CDMA and GSM joint application development means that CDMA could be widely adopted in Europe soon because of the economic savings for implementations and the convenience to many wireless users.

5.6. The Battle between GSM and CDMA

The roots of the battle between GSM and CDMA run deep, and, many believe, are driven by national politics and corporate marketing rather than true technology issues. In FY97, Qualcomm, which patented the technology and aggressively markets its benefits received more than $150 million in royalties, or 7 percent of its total revenues.

Among major carriers, no. 1 carrier AT&T and SBC chose TDMA. US WEST, Bell Atlantic, Nynex, GTE, and, most recently, Sprint, went for CDMA. Bell South uses both TDMA and GSM, while Western Wireless, Omnipoint, PowerTell and Pac Bell opted for GSM

Some small companies bid for GSM licenses due to faster-time-to market issues,The technology is easily implemented because the infrastructure is already in place, and many OEM engineers have already done GSM work in Europe.and OEMs will hedge their bets on GSM equipment, and then devote resources to other technologies.

Since GSM giants Nokia and Ericsson squeezed others out of the U.S. market Motorola, Lucent and Nortel cast their votes for CDMA

Today, to meet the varied demands of service providers in the U.S., many OEMs are producing two or three standards. Nortel and Lucent now sit on both sides of the fence, while more minor European GSM players, including Siemens and Philips are tackling the CDMA market to "spread out the risk."

5.7. Company Contacts

5.7.1. The CDMA Development Group (CDG)

This Company fortunate to get valuable inputs from CDMA Group, which is the pioneering body for CDMA technology worldwide.

The CDMA Development Group (CDG) is a consortium of companies who have joined together to lead the adoption and evolution of CDMA wireless systems around the world. The CDG is comprised of the world's leading CDMA service providers and manufacturers. By working together, the members help ensure interoperability among systems, while expediting the availability of CDMA technology to consumers. CDG in cooperation with Lucent Technologies, digEvent corporation, Vodafone Airtouch, and Qualcomm held the first ever worldwide telecommunications on-line discussion. The focus of the discussion was CDMA and 3rd generation prospects for this technology. The on-line forum was held July 16th, 1999.

5.7.2. Aerial Communications Inc.

This company believed that they should interact with a company in the local community to get first hand inputs on various issues.

5.7.3. North American Companies

Table 5.1. GSM - North American Companies

Aerial Communications	NPI Wireless
Airadigm Communications, Inc	Omnipoint Communications, Inc.
American Personal Communications	Pacific Bell Mobile Services
BellSouth Mobility DCS	Powertel, Inc.
DIGIPH PCS	VoiceStream Wireless
Microcell Telecommunications	

Table 5.2. CDMA - North American Companies

Alltel Communications	Hansol PCS
Ameritech Cellular Services	Iridium LLC
BC TEL Mobility	IUSACELL Digital
Bell Atlantic Mobile	Leap Wireless International
Bell Mobility	Pegaso PCS, S.A. DE C.V.
Clearnet Communications, Inc.	Qualcomm
Frontier Cellular	Sprint PCS
Globalstar LP	US West
GTE Wireless	Vodafone AirTouch

5.8. Appendices

5.8.1. Table of GSM Historical Events

Table 5.3. Table of GSM Historical Events

Year	Event
1982	CEPT establishes the GSM group in order to develop the standard for a pan-European mobile cellular system
1985	Adoption of a list of recommendations generated by the GSM group for the standard
1986	Field tests performed to test the different radio techniques proposed for air propagation
1987	TDMA is chosen as the access method (FDMA will also be used); Initial Memorandum of Understanding (MoU) is signed by 12 countries
1989	The responsibility for the GSM specifications is passed to the ETSI
1990	Appearance of phase 1 of the GSM specifications
1991	Commercial launch of GSM service
1992	Enlargement of the number of countries endorsing the GSM-MoU
1994	GSM data transmission uses circuit switched technology at 9.6 Kbit/s rates
1995	Phase 2 of the GSM specifications appear
1998-1999	GSM data transmission still uses circuit switched technology, but increases rate to 38.6 Kbit/s
1999-2000	GSM data transmission goes to packet switched technology at a maximum of 115 Kbit/s rates

5.8.2. World Coverag

- **GSM World Coverage**

Figure 5.1. GSM World Coverage

- **CDMA World Coverage**

Figure 5.2. CDMA World Coverage

5.9. GSM Services

5.9.1. Teleservices

- Telephony
- Facsmile group 3
- Emergency calls – This service automatically dial the emergency phone number of the subscribers location (does not require a SIM card)
- Teletex
- Short Message Services (SMS) - Using these services, a message of a maximum of 160 alphanumeric characters can be sent to or from a mobile station. If the mobile is powered off, the message is stored. With the SMS Cell Broadcast (SMS-CB), a message of a maximum of 93 characters can be broadcast to all mobiles in a certain geographical area
- Fax mail - Thanks to this service, the subscriber can receive fax messages at any fax machine
- Voice mail - This service corresponds to an answering machine

- Data Services_Using your GSM phone to receive and send data is the essential building block leading to widespread mobile Internet access and mobile data transfer. GSM currently has a data transfer rate of 9.6k. New developments that will push up data transfer rates for GSM users are HSCSD (high speed circuit switched data) and GPRS (general packet radio service) are now available.

- Call forwarding and Calling line identity (CLI)_Use Call forwarding to divert incoming calls to another number.about the CLI its displays the number (name if stored on your phone) of the incoming call.

5.9.2. Bearer Services

A bearer service is used for transporting user data. A short list of bearer services are listed below:

- Asynchronous and synchronous data, 315-9630 bps
- Alternate speech and data, 315-9630 bps
- Asynchronous PAD (packet-switched, packet assembler/disassembler) access, 315-9630 bps
- Synchronous dedicated packet data access, 2400-9630 bps

5.9.3. Supplementary Services

1. Call Forwarding - The subscriber can forward incoming calls to another number if the called mobile is busy (CFB), unreachable (CFNRc) or if there is no reply (CFNRy). Call forwarding can also be applied unconditionally (CFU)
2. Call Barring. There are different types of "call barring" services:
3. Barring of All Outgoing Calls, BAOC
4. Barring of Outgoing International Calls, BOIC
5. Barring of Outgoing International Calls except those directed toward the Home PLMN Country, BOIC-exHC
6. Barring of All Incoming Calls, BAIC
7. Barring of incoming calls when roaming
8. Call hold - Puts an active call on hold
9. Call Waiting, CW - Informs the user, during a conversation, about another incoming call. The user can answer, reject or ignore this incoming call
10. Advice of Charge, AoC - Provides the user with an online charge information
11. Multiparty service - Possibility of establishing a multiparty conversation
12. Closed User Group, CUG - It corresponds to a group of users with limited possibilities of calling (only the people of the group and certain numbers)
13. Calling Line Identification Presentation, CLIP - It supplies the called user with the ISDN of the calling user.

14. Calling Line Identification Restriction, CLIR - It enables the calling user to restrict the presentation.
15. Connected Line identification Presentation, CoLP - It supplies the calling user with the directory number he gets if his call is forwarded.
16. Connected Line identification Restriction, CoLR - It enables the called user to restrict the presentation.
17. Operator determined barring - Restriction of different services and call types by the operator

6. EVOLUTION TOWARDS UNIVERSAL MOBILE TELECOMMUNICATIONS SYSTEMS (UMTS)

6.1. Overview

Tremendous importance is given in Europe to the development of Third Generation Mobile Telecommunications Systems. It is expected that mobile and personal communications will become a key driver for growth and innovation in the next millennium, as well as being a necessary building block of the Wireless Information Society.

Significant progress has been made since 1988 by a number of European Union (EU)-funded R&D projects working towards the development of the next generations of mobile communication concepts, systems and networks. The ACTS (Advanced Communications Technologies and Services) programme, launched in 1995 and extending until 1998, will provide greater opportunities to master and trial mobile and personal communications services and technologies, involving service providers, communications operators and equipment manufacturers.

From the user's perspective, the ACTS programme will strive to ensure that current mobile services are extended to include multimedia and broadband services, that access to services is possible without regard to the underlying networks, and that convenient, light weight, compact, and power efficient terminals adapt automatically to whatever air-interface parameters are appropriate to the user's location, mobility, and desired services.

The definition of the Third Generation of Mobile Systems, known as UMTS in Europe and FPLMTS/IMT-2000 elsewhere, is one of the most critical activities pursued in ACTS, given its broad impact and the urgency of the task.

6.2. Introduction

The unprecedented growth of world-wide mobile wireless markets, coupled with advances in communications technology and the accelerated development of services taking place in fixed networks, points to the urgent introduction of a flexible and cost effective Third Generation Mobile Communications System. In this context, UMTS (Universal Mobile Telecommunications System), as such systems are commonly referred to in Europe, have been the subject of extensive research carried out primarily in the context of the European Community Research Programmes such as RACE (Research and Technology Development in Advanced Communications Technologies in Europe) and ACTS (Advanced Communications Technologies and Services). Mobile telecommunications is recognised as a major driving force of socio-economic progress and is crucial for fostering the European industrial competitiveness and for its balanced and sustained economic, social and cultural development.

The success of mobile communication systems, as well as its consequences in terms of need of better, more efficient systems, and of additional spectrum, is analysed in Section 6.3. Japan, due to the recent explosive growth of mobile communications after the first steps in deregulation, in both cellular and cordless-based systems, leads the way by targeting 2000 for the deployment of Third Generation systems, with an eye already on a second phase to be deployed in 2005 with much higher data rates (10 Mbps versus 2 Mbps). Europe is targeting 2002 for basic UMTS service , and 2005 for full UMTS capabilities , a third phase is envisioned, conditioned upon market needs. In the US, however, the huge First Generation legacy, and the very recent, heavy investments in Second Generation systems, has led to a somewhat relaxed approach, targeting 2005 or even later. Enhancements to Second Generation systems are envisioned, to meet the market's needs.

Adding to the varying degrees of urgency to deploy Third Generation systems, different expectations, as well as different degrees of market liberalisation, lead to substantially distinct approaches to standardisation in Europe, Japan, and the US. In Section 6.4 we discuss the work ongoing at ETSI (European Telecommunications Standards Institute) and ITU (International Telecommunications Union).

A first result of standardisation, critical for the development of the new Third Generation systems, was the WARC '92 and WRC '95 recommendations of spectrum allocation for FPLMTS/IMT-2000 systems. Spectrum for UMTS has been identified in

Europe, coinciding with W(A)RC's recommendations. Section 6.5. presents the spectrum recommendations for Third Generation systems.

In the context of the ACTS programme, R&D in advanced mobile and personal communications services and networks, is called upon to play an essential role. The specific objectives that are addressed by the current ACTS projects include the development of Third Generation platforms for the cost effective transport of broadband services and applications, aiming at responding to the needs of seamless services provision across various radio environments and under different operational conditions. Since the scope of future mobile communications encompasses multimedia, far beyond the capabilities of current mobile wireless communication systems, the objective is to progressively extend mobile communications to include multimedia and high performance services, and enable their integration and inter-working with future wired networks. The European efforts towards the definition of UMTS, the European version of Third Generation systems, are analysed in detail in Section 6.6. A lot is expected from these efforts.

An important element of the ACTS programme has to do with result dissemination, cross-fertilisation, and consensus building. Ongoing activities in the Mobile project domain are discussed in Section 6.7., with emphasis on the annual Mobile Communications Summit, and the regular ACTS Concertation Meetings.

Section 6.8 presents the summary, emphasising the importance of R&D in Telecommunications given the pressure to expand the services and capabilities of mobile systems, and the consequent need for enhanced, more efficient systems, that preferably evolve from existing systems.

6.3. The Need for Third Generation Systems

6.3.1. The European Success Story

Europe has witnessed in recent years a massive growth of mobile communications, ranging from the more traditional analogue based systems to the current generation of digital systems such as GSM (Global System for Mobile Communications), DCS-1800 (Digital Communication System at 1800 MHz), ERMES (European Radio Messaging System), and to a lesser extent DECT (Digital European Cordless Telephone), and TETRA (Trans European Truncked Radio). The GSM family of products (GSM + DCS-1800), which represents the first large scale deployment of commercial digital cellular system ever, enjoys world wide success, having already been adopted by over 190 operators in more than 80 countries. As it can be seen in Figure 1, in a very short period of time, the percentage of European cellular subscribers using GSM or DCS-1800 has already exceeded 50%. In addition, the figure portrays the penetration rates of the combined analogue and digital cellular systems for the same time-frame. A snapshot of the situation for each of the EU countries, as well as the rest of Europe, in terms of number of subscribers and penetration of analogue/digital cellular for November 1996 is depicted in Figure 2. It is worth noticing that the biggest markets of Europe in terms of subscribers (i.e., UK, Italy and Germany) are not the markets with the largest penetration rates. In this respect, the largest penetration rates are found in the Nordic countries, close to or even exceeding 25% of the population.

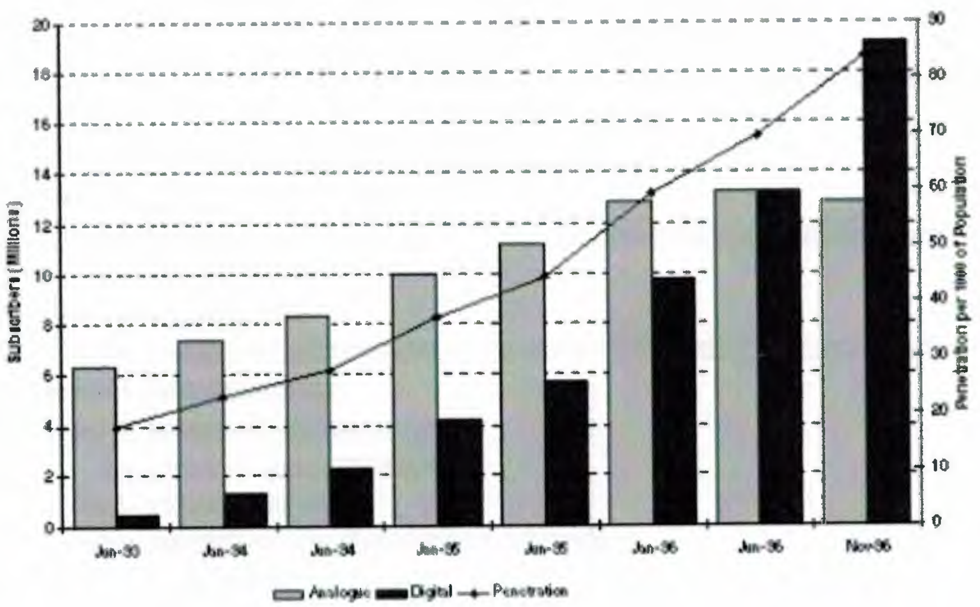

Figure 6.1. Mobile Cellular subscribers/penetration (European Union) up to November 1996

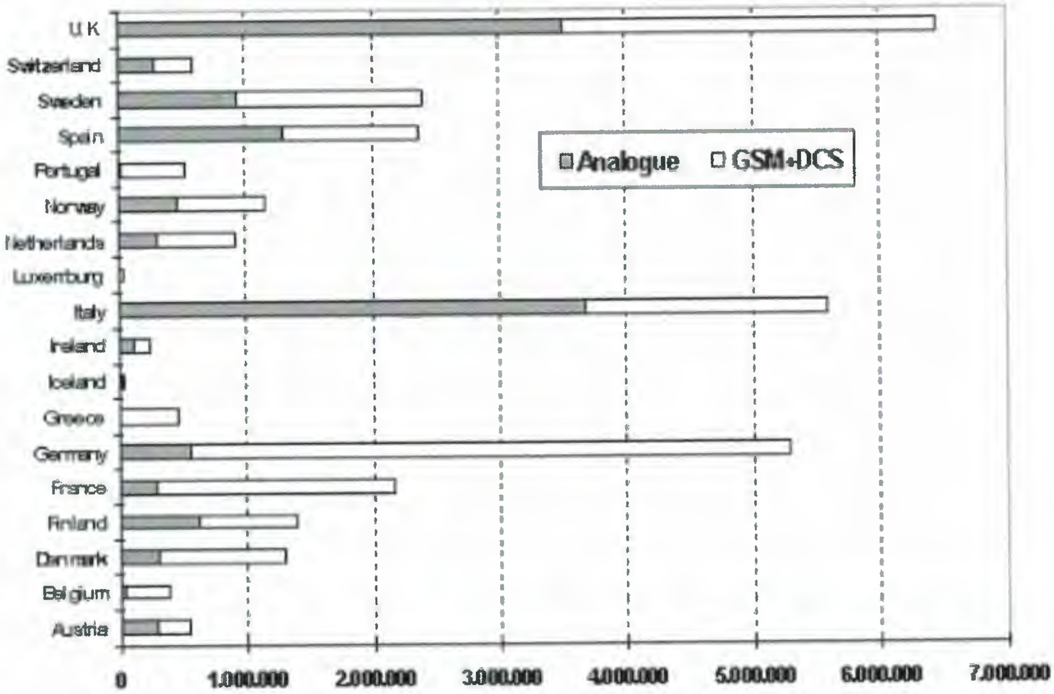

Figure 6.2. (a) Cellular Subscribers in the European Union in November 1996

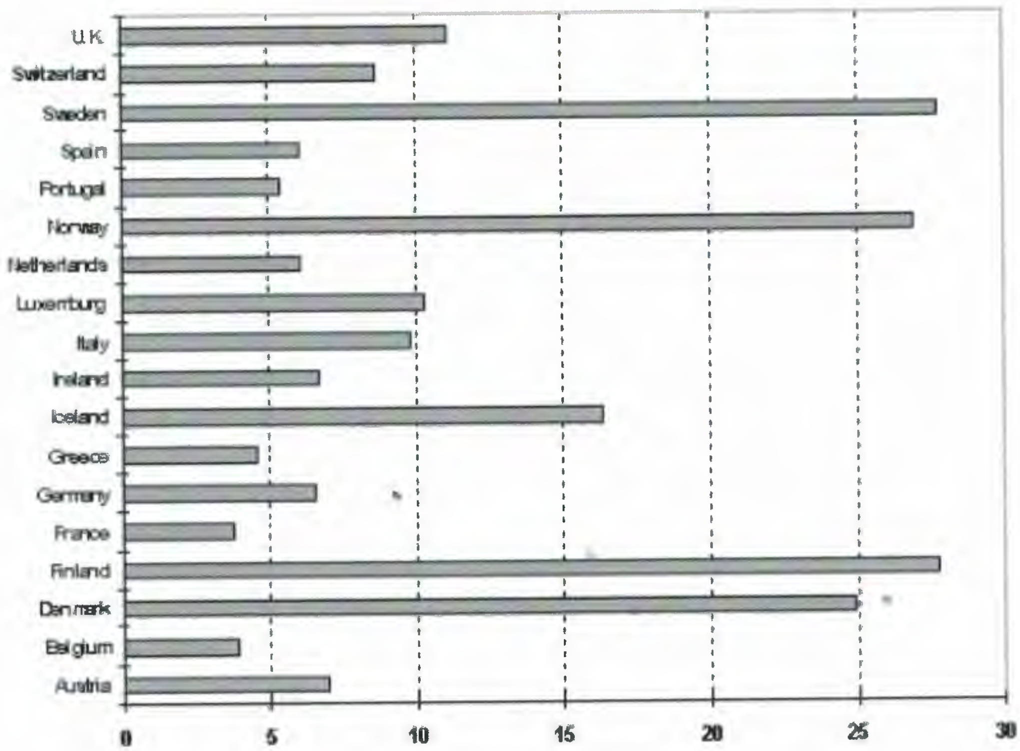

Figure 6.2. (b) Cellular Penetration in the European Union in November 1996

At current growth rates, it is envisaged that the total number of subscribers will reach some 200 million, in Europe alone, by the turn of the century. It should be noted that while the telephone density for fixed telephones is not expected to exceed the 50% mark (i.e., at most one phone for every two persons, or approximately two per family), while personal mobile communications, in all forms, promises to reach nearly 80% of Europe's population. Other systems, catering for more specialised applications or markets, such as wireless local loop, private mobile radio for police and safety systems and paging, are also called upon to contribute very strongly to the development of the market and the economic growth of Europe.

Third Generation systems and technologies are being actively researched world wide. In Europe, such systems are commonly referred under the name UMTS (Universal Mobile Telecommunications Systems) while internationally, and particularly in the ITU context, they are referred to as FPLMTS (Future Public Land Mobile Telecommunications Systems) or more recently IMT-2000 (International Mobile Telecommunications for the year 2000).

In this context, but also in a world-wide perspective, with many competing mobile and personal communication technologies and standards being proposed to fulfil the users' needs, the essential questions, to which no immediate, conclusive, firm answers can be given, are: “To what extent, and how fast, will the users' requirements evolve beyond the need for voice and low data rate communications?”, and “Which will be the technologies that will meet the requirements for mobile and personal communications services and applications beyond the year 2000?”.

The rapid advance of component technology; the pressure to integrate fixed and mobile networks; the developments in the domains of service engineering, network management and intelligent networks; the desire to have multi-application hand-held terminals; and above all the increasing scope and sophistication of the multimedia services expected by the customer; all demand performance advances beyond the capability of Second Generation technology. The very success of Second Generation systems in becoming more cost-effective and increasingly cost-attractive raises the prospect that it will reach an early capacity and service saturation in Europe's major conurbations. These pressures will lead to the emergence of Third Generation systems representing a major opportunity for expansion of the global mobile marketplace rather than a threat to current systems and products.

The ground work for UMTS started in 1990, and some early answers can already be provided regarding its requirements, characteristics and capabilities, with the initial standards development process already under way at ETSI (European Telecommunications Standards Institute). The basic premise upon which work is being carried out, is that by the turn of the century, the requirements of the mobile users will have evolved and be commensurate with those services and applications that will be available over conventional fixed or wireline networks. The citizen in the third millennium will wish to avail himself of the full range of broadband multimedia services provided by the global information highway, whether wired or wireless connected.

Various international fora have raised the issue of technology migration from Second to Third Generation via the use of spectrum in the FPLMTS/UMTS bands. This may result in the spectrum being allocated, in some parts of the world, in an inefficient piecemeal fashion to evolved Second Generation technologies and potentially many new narrow-application systems, thereby impeding the development of broadband mobile multimedia services.

Terminal, system and network technology as researched within the EU-funded ACTS projects, may alleviate to a large extent the complexity of the sharing of the spectrum between the Second and Third Generation systems. Finding the solution to the problem of evolution and migration path from Second (GSM, DCS-1800, DECT) to Third Generation systems (FPLMTS/UMTS), particularly from a service provision point of view (see Figure 6.3), is also the subject of intense research carried out in the context of ACTS projects. Some of the key questions that are addressed include a detail consideration of the feasibility, as well as the cost effectiveness and attractiveness of the candidate enhancements. In this context, the ACTS projects will develop a set of guidelines aiming at reducing the uncertainties and associated investment risks regarding the new wireless technologies, by providing the sector actors and the investment community with clear perspectives on the technological evolution and on the path to the timely availability to the user of advanced services and applications.

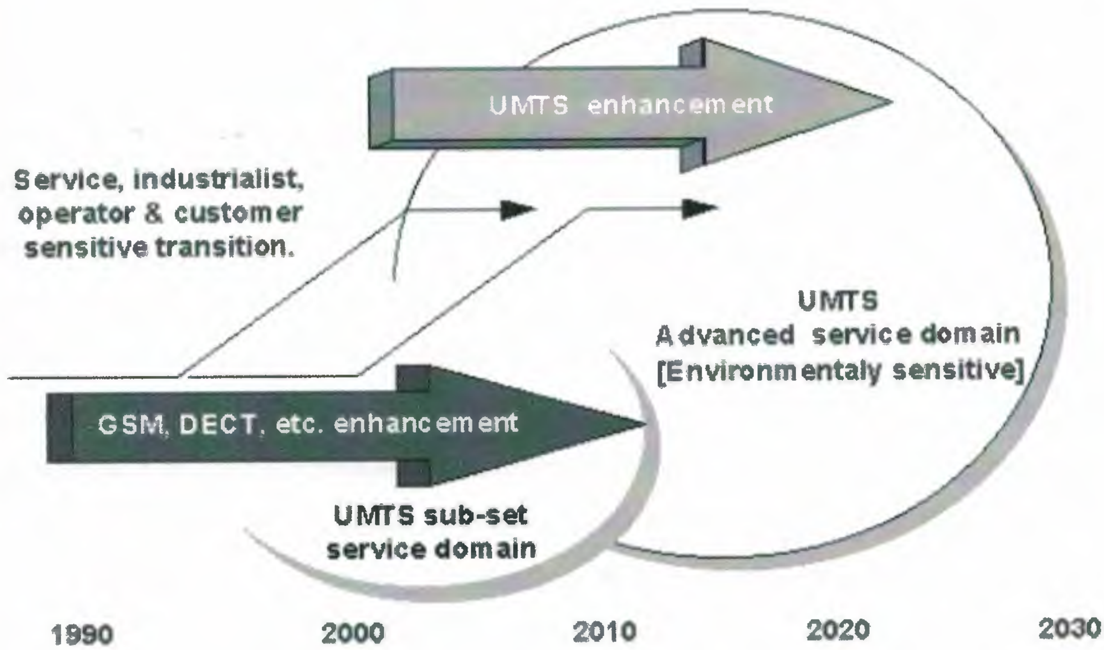

Figure 6.3. Evolution from Second to Third Generations

6.3.2. European regulatory dimension

In response to the imperatives of the internal European market, specific measures were taken, as early as 1987, to promote the Union-wide introduction of GSM, DECT, and ERMES. European Council Directives were adopted to set out common frequency bands to be allocated in each Member State to ensure pan-European operation, together with European Council Recommendations promoting the co-ordinated introduction of services based on these systems.

In 1994, the European Commission adopted a Green Paper on Mobile and Personal Communications with the aim of establishing the framework of the future policy in the field of mobile and personal communications. The Green Paper proposed to adapt, where necessary, the telecommunications policy of the European Union to foster a European-wide framework for the provision of mobile infrastructure, and to facilitate the emergence of trans-European mobile networks, services, and markets for mobile terminals and equipment.

Based on the Green Paper, the European Commission set out general positions on the future development of the mobile and personal sector, and defined an action plan which included actions to pursue the full application of competition rules; the development of a Code of Conduct for service providers; and the agreement on procedures for licensing of satellite-based personal communications. The action plan also advocated the possibility of allowing service offerings as a combination of fixed and mobile networks in order to facilitate the full-scale development of personal communications; the lifting of constraints on alternative telecommunications infrastructures and constraints on direct interconnection with other operators; the adoption and implementation of Decisions of the ERC (European Radiocommunications Committee) on frequency bands supporting DCS-1800 and TETRA; the opening up of an Europe-wide Numbering Space for pan-European services including personal communications services; and continuing support of work towards UMTS.

The combination of these regulatory changes will contribute to a substantial acceleration of the EU's mobile communications market and speed the progress towards Third Generation mobile/personal communications. It will however be necessary to encourage potential operators and manufacturers to invest in the required technology, by setting out a clear calendar for the adoption of the required new standards and the re-farming of the necessary spectrum. The applicable licensing regimes and rules for flexible sharing of the available spectrum need also to be adopted at an early stage so as to permit the identification of novel market opportunities commensurate with the broadband multimedia requirements of the Third Generation mobile telecommunications systems.

In light of the above, and in accordance with the political mandate given by the European Parliament and the European Council, the major actors in the mobile and personal communications sector have been brought together as a task force which has lead to the setting up of the UMTS Forum. The main objective of the Forum are to contribute to the elaboration of an European policy for mobile and personal communications based on an industry wide consensus view, and pave the way for ensuring that mobile communications will play a pivotal role in the Global Information Society.

The continued evolution of Second Generation systems has been recognised as an issue of great societal and economic importance for Europe and the European industry. To facilitate and crystallise such an ambition, and in accordance with the political mandate given by the European Parliament and the European Council, an ad-hoc group called the UMTS Task Force was convened by the European Commission and was charged with the task of identifying Europe's mobile communications strategy towards UMTS. The report of the UMTS Task Force and its recommendations have been largely endorsed by the European mobile industry, and as a result the UMTS Forum has now been created with the mandate to provide an on-going high level strategic steer to the further development of European mobile and personal communications technologies. High on the priorities of the UMTS Forum are the issues of technology, spectrum, marketing and regulatory regimes. Drawing participation beyond the European industry, the UMTS Forum is expected to play an important role in bringing into commercial reality the UMTS vision.

6.3.3. The Mobile Explosion in Japan after the First Steps at Deregulation

While in Europe the need for a full fledged Third Generation system is anticipated for 2005, the situation in Japan is such that the Japanese Ministry of Posts and Telecommunications (MPT) felt compelled to accelerate the standardisation process to have a new, high capacity system deployed by the year 2000.

Users of mobile communication systems, including cellular (analogue, TACS, and digital, PDC) and cordless (PHS, Personal Handyphone System) have increased dramatically in Japan, coinciding with the first, tentative steps at deregulation, at the rate of more than one million new users per month. At the end of September the numbers were already 19.26 million, out of which 3.95 million PHS users, and by the end of October they were, respectively, 20.471 million and 4.315 million.

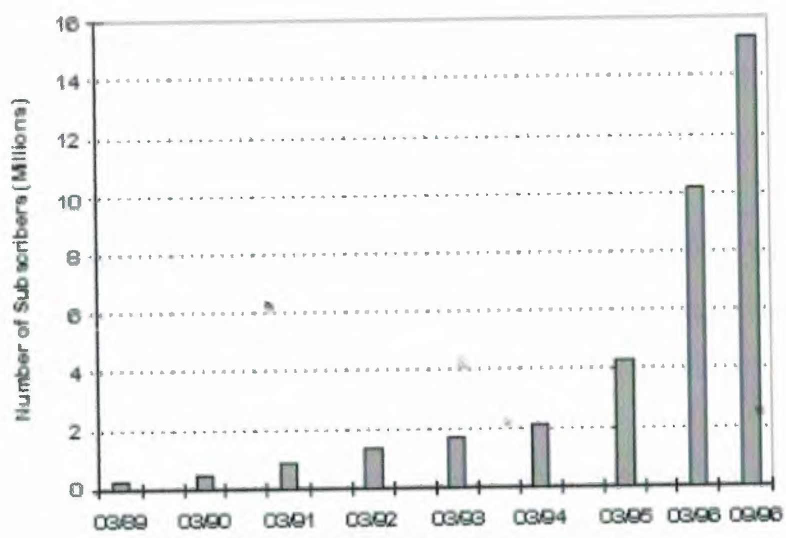

Figure 6.4. (a) Cellular Subscribers in Japan

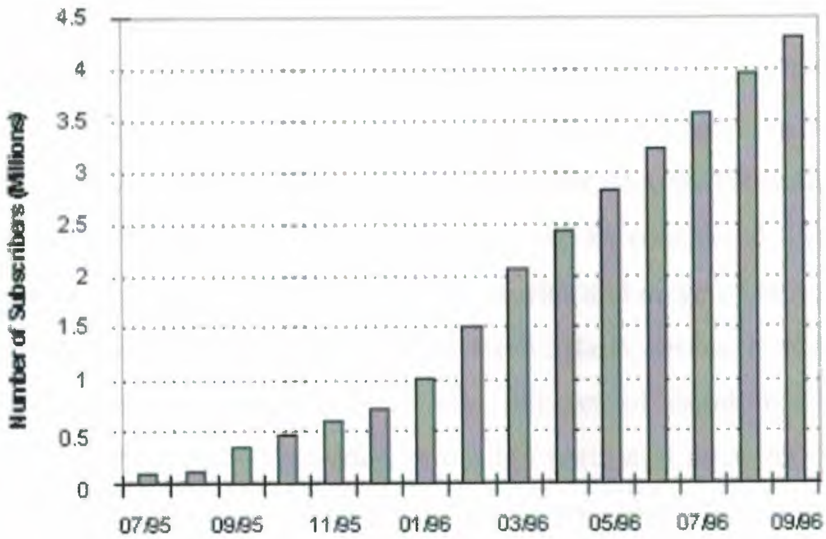

Figure 6.4. (b) PHS Subscribers in Japan

In an effort to meet the increasing demand for mobile communication systems, measures for promoting more efficient utilisation of frequencies are being studied and implemented, and a significant impetus has been given to the early introduction of Third Generation systems.

Recently, the MPT created the Study Group on the Next-Generation Mobile Communication Systems, and tasked it to prepare for April 1997 a concrete vision of next generation systems, and examine related technical issues including present status and trends, identification of the technological requirements, and measures to be taken towards implementation.

6.3.4 Developments in Korea

The development of FPLMTS in Korea has been recently launched by the Ministry of Information and Communications, under the supervision of ETRI (Electronics & Telecommunications Research Institute), with the aim of being complete by the year 2000 and deployed no later than 2001.

As for the air interface technology, it has already been decided it will be wideband-CDMA, a technology already extensively researched in Korea, starting as an adaptation of IS-95, and ending up as a full fledged wideband-CDMA system.

6.3.5. The US Situation

The most important factor to take into consideration in the US case is the significant AMPS (analogue, First Generation system) cellular base. On top of that, the recently deployed Second Generation systems represent huge investments that need to bring significant returns before replacement plans can be considered. Furthermore, as long as customers are satisfied with the grade of service and range of features offered by these systems, and sufficient capacity exists to service them, service providers will have little reason to consider anything else. The full set of capabilities expected in FPLMTS/IMT-2000 may not be needed in the US until well after 2005, while some subset may be needed earlier. The exact deployment time-frame will be dictated by the demands of the market. Timing is seen as a critical issue for the success of Third Generation systems.

It is also considered essential not to over-prescribe the Third Generation solution (market push, not technology pull). The approach is one of gradual availability of increasingly higher speed service offerings, as the market demands them, instead of leapfrogging into the final, high performance solution.

6.4. Standardisation

6.4.1. The Role of ETSI SMG

SMG (Special Mobile Group) within ETSI is a business and service oriented organisation responsible for two ETSI Projects:

GSM (including GSM and DCS-1800);

GSM-UMTS (including UMTS services concept and the UMTS evolution of the core network), a name still under consideration; and one horizontal task

UMTS GRAN (Generic Radio Access Network).

As per the recent meeting of the SMG Steering Group (11 October 96), the responsibilities of the SMG include, among others: definition of the services and features offered; selection and specification of the most efficient radio techniques, including the co-ordination of validation tasks; elaboration of specifications for network architecture, signalling protocols and conditions of inter-working with other networks; elaboration of roaming aspects with GSM and selected other systems, namely satellite systems; selection of the appropriate security procedures; elaboration of highly efficient, timely available tools for management of the network and of network evolution;

development of test specifications for the type approval of mobile terminals and other network elements; and maintenance of the specifications and controlled release of updated standards.

The specific objective of the GSM-UMTS project is "to develop UMTS as a world-wide competitive and versatile mobile multimedia communication standard with capabilities extending beyond a fully evolved GSM" by developing and maintaining the specifications of UMTS in the following areas: UMTS objectives and requirements; specification of UMTS service aspects; and specification of the evolution of the GSM core transport network to enable a GSM network operator to support UMTS GRAN.

Such an extended scope of activities led to the formation of subgroups which function as working groups of the ETSI GSM-UMTS project. We mention just a few: SMG5 deals with UMTS concept and co-ordination; SMG2 with Radio aspects; SMG1 with Services and Facilities; SMG3 with Network aspects; SMG4 with Data services; and SMG6 with Operation and Maintenance.

6.4.2. Standards Work in Japan

As early as August 94, MPT convened the Multimedia Mobile Communications Study Committee with the purpose of defining the concept, the market, the applications, and the milestones for the introduction of Mobile Multimedia Communication systems. The committee identified the following subjects as essential for implementing Mobile Multimedia Communications:

1) technological development, including radio technologies, hardware and software;
2) spectrum for Mobile Communications;
3) developments in the communications infrastructure;
4) market adjustment towards Mobile Multimedia Communications, including user-friendly interfaces, and quality content.

The milestones for Mobile Multimedia Communication systems were split in two phases: one around the year 2000, involving the implementation of FPLMTS as defined usually (data rates up to 2 Mbps), and a second phase, around the year 2010, for FPLMTS Phase 2, with data rates up to 10 Mbps. Standardisation work began in September 1994, with the establishment of ARIB (Association of Radio Industries and Businesses). The action plan involved the comparative study of CDMA and TDMA radio technologies, in two rounds, with down selection. The Japanese proposal(s) is(are) expected still in 1996. 1997 will be dedicated to the comparison with proposals from other countries/regions (if available).

6.4.3. Expediting Standards Work — an US experiment

6.4.3.1. Standardisation by the Market

The US wireless marketplace is an interesting topic for study in terms of competition and free market economics, with the government and regulatory authorities committed to allowing industry to compete in an open wireless market, from the licensing of spectrum through the choice of technologies deployed. The FCC (Federal Communications Commission), in particular, wants to ensure that only a minimum set of technical requirements be mandated such that new technologies and innovations are allowed to flourish based upon the demands of the market. As was seen in the recent PCS (Personal Communication Systems) auctions, the FCC tends to favour allowing market competition to determine what technologies will prevail, in contrast to mandated standards as is the case in other parts of the world. Therefore, from the US point of view, the challenge for global Third Generation standardisation is to be as open and flexible as possible in order to gain acceptance in the market.

6.4.3.2. The Role of Industry Organisations

Given the increased complexity, as well as the multiplicity of the standards for mobile communication systems, the telecommunications industry felt that the TIA (Telecommunications Industry Association) and the EIA (Electronic Industry Association) could no longer keep up with demand. As a result, many industry organisations have flourished with the single purpose of coming up with a standard proposal, as complete as considered appropriate, and to achieve this in a timely manner. That way, EIA/TIA is left with the job of articulating the proposal with existing standards, and finally of rubber-stamping the proposal. (We must note here that most US standards are not mandatory, but voluntary.)

As an illustration, mention can be made of the CDPD Forum, and the CDMA Development Group. The former managed to arrive at the specification for the digital packet data overlay on AMPS, and get to commercial operation in less than two years. The latter is actively defining, among other things, HSDS (High Speed Data Service) over IS-95, capable of providing, in phase 1, up to 64 kbps, both packet and circuit-switched.

6.4.4. UMTS and FPLMTS/IMT-2000 Standardisation Plans

At the global level, the work carried out within ITU, and particularly within TG 8/1, has been instrumental in the definition of FPLMTS/IMT-2000.

Due to the already existing differences in the use of FPLMTS bands by PCS in the US, PHS in Japan, and DECT in Europe, at least for the terrestrial component of FPLMTS there will most likely be different air interfaces as well as different channel assignments in different regions of the world. In any case, the goal in ITU-R TG 8/1 is still "to enable world-wide compatibility of operation and equipment, including international and intercontinental roaming."

The minimum performance capabilities for circuit and packet switched data that have recently (October 96) been agreed upon by TG 8/1 are:

- Vehicular Test Scenario: 144 kbps
- Pedestrian, and outdoor to indoor test scenario: 384 kbps
- Indoor office test scenario: 2048 kbps

The agreed upon time-plans of the different standardisation bodies in the different regions is put together below to show the difference in pace resulting from the anticipated need for an advanced Third generation system in each region. As expected, the US preparation is left far more open than the others, given the prevailing philosophy of letting the market decide when and how to act.

Table 6.1 UMTS and FPLMTS/IMT-2000 Standardisation Schedule

	ITU-R TG 8/1	**US**	**Europe**	**Japan**
Basic Technology selection			end 1997	1995
Candidate proposals	end 1997			1995
Evaluation of candidates	March 1998			1996
Key choices for the radio interface	March 1999			end 1996
Final Recommendation	end 1999		end 1999	3Q 1997
Deployment		2003-2005	Basic 2002 Full 2005	2000

6.5. Spectrum Issues

6.5.1. WARC '92 Spectrum Assignments for FPLMTS

The 1992 World Administration Radio Conference (WARC) of the International Telecommunications Union (ITU) targeted 230 MHz, in the 2 GHz band (1885-2025 MHz and 2110-2200 MHz), on a world-wide basis, for FPLMTS/IMT-2000, including both terrestrial and satellite components. The objective was identified as that of establishing, through the appropriate Global Standards and the co-ordinated assignment of spectrum by the various National and Regional Authorities, the future, truly ubiquitous personal mobile communications system, creating a seamless radio infrastructure capable of offering a wide range of services, in all radio environments, with the quality we have come to expect from the fixed networks.

The availability of the spectrum assigned to FPLMTS/IMT-2000 varies from region to region, the same happening with the strategies followed to insure its availability when time comes. Another aspect that is region specific, is how that spectrum can, or cannot, be shared with other systems. The whole 230 MHz of spectrum identified by WARC-92 was reserved in Europe to Third Generation, UMTS, technology. This even if part of the band allocated for DECT falls into the FPLMTS band.

Elsewhere, and especially in the US, the situation is far more complicated, and little hope exists of the ITU ever arriving at a common, Global Standard. In fact, regional solutions are already subsumed.

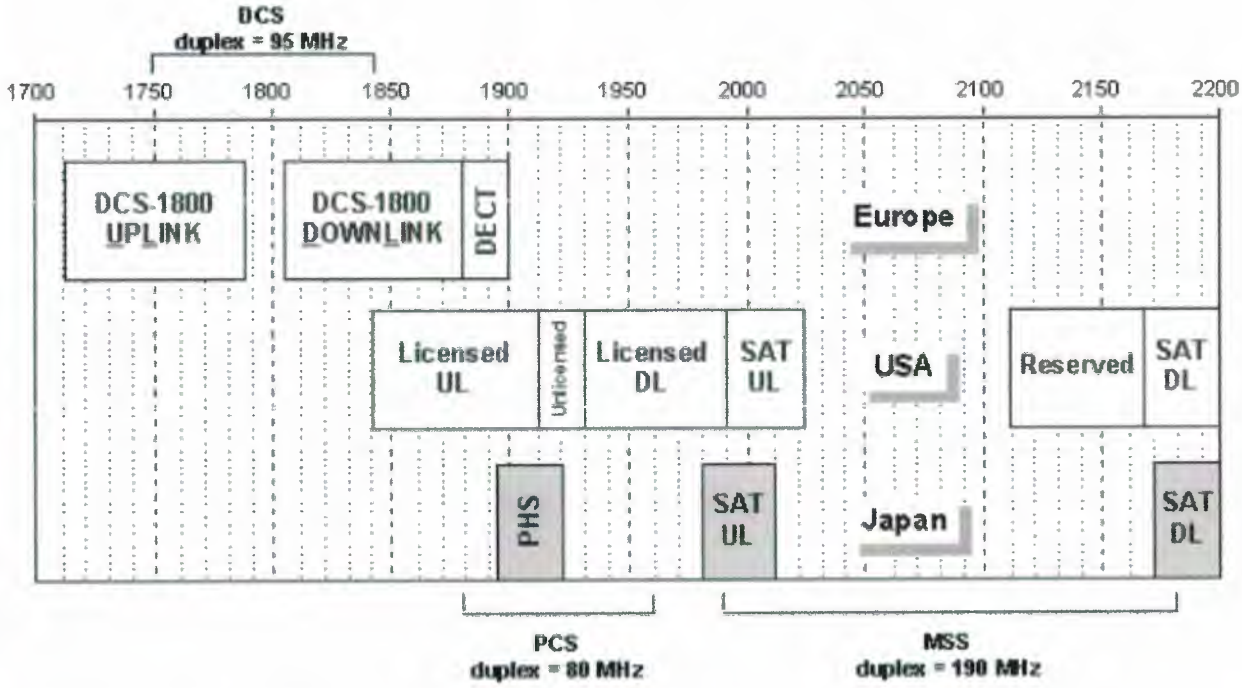

Figure 6.5. (a) Current Usage of Spectrum (Including the WARC '92 Spectrum)

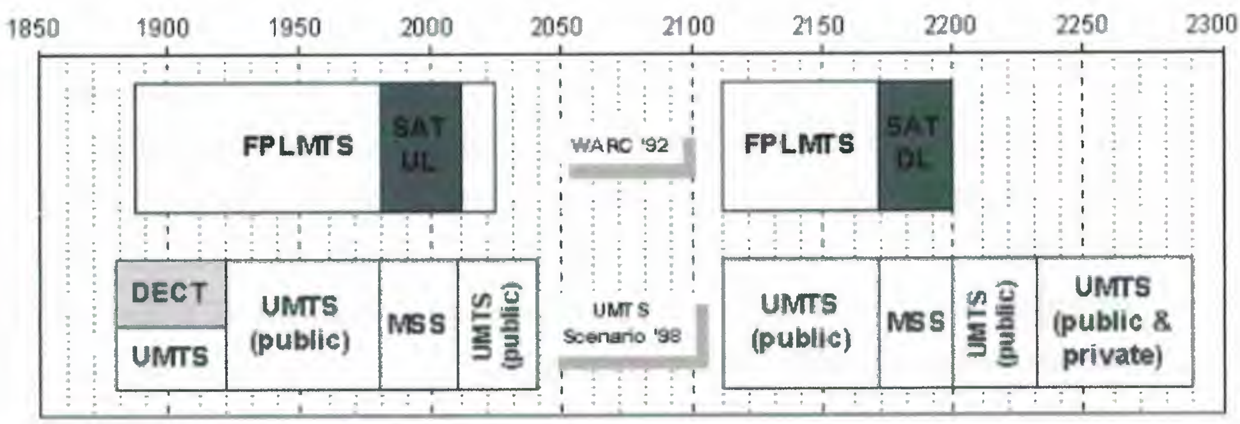

Figure 6.5. (b) Planned UMTS Bands in Europe

6.5.2. Spectrum for UMTS in Europe

The European Radiocommunications Office (ERO), recently convened a workshop on UMTS with the intention of presenting to the relevant sector actors in Europe the preliminary results of an ERO study on UMTS dealing with technology, spectrum requirements and frequency sharing, issues that are expected to affect the deployment of Third Generation mobile communications systems.

ERO's proposal advocates a two-phase approach, with phase 1 aiming to safeguard the spectrum already allocated to Third Generation mobile communicationssystems, and phase 2 being an effort for allocation of additional spectrum taking into account the ever

increasing market demand for multimedia mobile services being catered by mobile communications networks. Some preliminary indications of a possible way forward are:
The total amount of spectrum needed by Third Generation mobile communications systems is yet unclear. It is estimated that the requirements will be between 300 MHz and 500 MHz. These figures assume a multimedia service provision environment with competing operators. It is further noted that the minimum bandwidth required for one public operator is in the order of 2x20 MHz, and that each country will have to accommodate at least three public networks.
Further R&D is needed in technologies that will enable a more efficient use of spectrum (e.g., continuous dynamic channel selection, smart antennas, adaptive radio access and coding)
The possibility of using the Mobile Satellite Systems (MSS) frequency bands for terrestrial indoor use under a frequency sharing scenario needs to be further studied.
There is no immediate need (before year 2000) for additional spectrum, but additional spectrum will become a necessity for the second phase of the UMTS introduction.

6.6 The Road Ahead

In the context of the ACTS programme, R&D in advanced mobile and personal communications services and networks, is called upon to play an essential role. The specific objectives that are addressed by the current ACTS projects include the development of Third Generation platforms for the cost effective transport of broadband services and applications, aiming at responding to the needs of seamless services provision across various radio environments and under different operational conditions. Since the scope of future mobile communications encompasses multimedia, far beyond the capabilities of current mobile wireless communication systems, the objective is to progressively extend mobile communications to include multimedia and high performance services, and enable their integration and inter-working with future wired networks.
Third Generation mobile communication systems aiming also at integrating all the different services of Second Generation systems, provide a unique opportunity for competitive service provision to over 50% of the population, and cover a much wider range of broadband services (voice, data, video, multimedia) consistent and compatible with the technology developments taking place within the fixed telecommunications

networks. The progressive migration from Second to Third Generation systems, expected to start at the turn of the century, will therefore encourage new customers while ensuring that existing users will perceive a service evolution that is relatively seamless, beneficial, attractive and natural.

Figure 6.6 illustrates the range of service environments, from in-building to global, in which the Third Generation of personal mobile communication systems will be deployed, while Figure 6.7 portrays the technological capabilities of Third Generation systems, measured in terms of terminal mobility and required bit rates as compared to those of Second Generation platforms such as GSM.

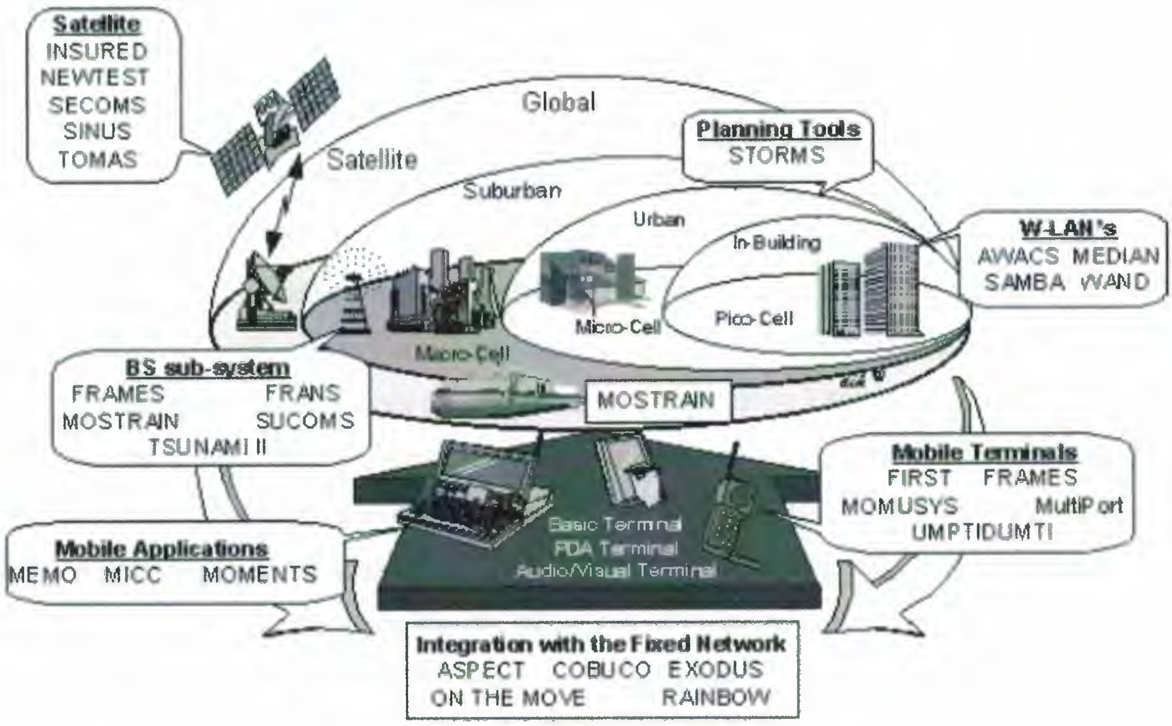

Figure 6.6. System environments

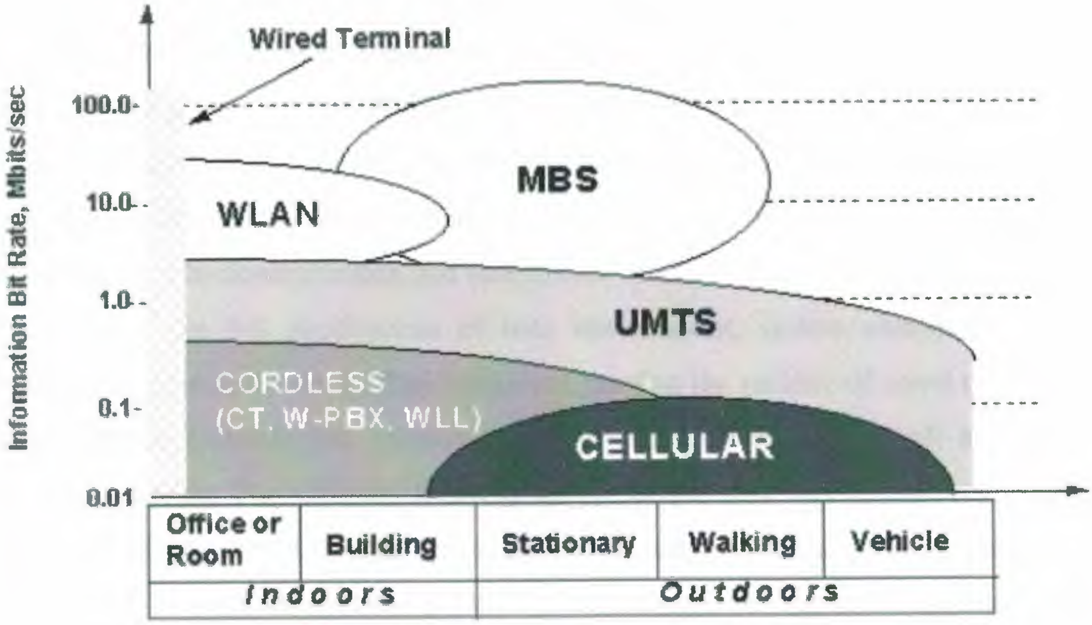

Figure 6.7. Mobility versus bit rates

In Europe, R&D on Third Generation technology, commonly referred to as UMTS, falls under the European Community RACE and ACTS Programmes. UMTS is conceived as a multi-function, multi-service, multi-application digital mobile system that will provide personal communications at rates ranging from 144 kbps up to 2 Mbps according to the specific environment, will support universal roaming, and will provide for broadband multimedia services. UMTS is designed to have a terrestrial and a satellite component with a suitable degree of commonality between them, including the radio interfaces. The R&D effort concentrates on the development of technical guidelines regarding, in particular, the level of UMTS support of ATM transmission technology of IBC networks, the compatibility of UMTS and fixed-network architecture, the allocation of intelligent functionality (UPT ? Universal Personal Telecommunications, and IN ? Intelligent Network), the level of integration of the satellite component of UMTS, and the multi-service convergence philosophy of the UMTS radio interface.

MBS (Mobile Broadband Systems), including their W-LAN (Wireless Local Area Network) dimension, are an extension to the wired B-ISDN, with the ability to provide radio coverage restricted to a small area (e.g., sports arenas, factories, television studios, etc.) allowing communication between MBS mobile terminals and terminals directly connected to the B-ISDN at rates up to 155 Mbps. Mobility and the proliferation of portable and laptop computers together with potential cost savings in the wiring and re-wiring of buildings are also driving forces in the introduction of broadband wireless customer premises networks in a picocell environment supporting the requirements for high-speed local data communication up to and exceeding 155 Mbps.

Some 24.000 person-months of effort will be devoted, until 1998, to R&D in personal mobile communication in the context of the EU-funded ACTS programme. The activities of the ACTS projects relate to services, network platforms, terminals, and technologies. The demonstration and assessment of novel services and applications take into account the full implications of user environment, system characteristics, and service provision and control. Projects aim at proving the validity of novel components or sub-system technologies, including multi-mode transceivers as well as tools for network planning. The common factor to all projects is that they contain a strong and clearly addressed thread of user involvement and innovative technology, and that the R&D effort is undertaken in the context of technology, service and application trials. Information on the current ACTS projects whose objectives relate to the field of mobile and personal communications can be found in the WWW pages linked to Figure 6. Regarding the now terminated RACE Programme, and in particular its mobile dimension, the reader is directed to the proceedings of the annual RACE conferences.

Given the global nature of the mobile communications markets, the EU-sponsored ACTS R&D programme has been open to international co-operation and to the participation of non-European companies in ACTS projects on a mutual benefit basis. Indeed different world regions need to co-operate, particularly in the area of standards development and frequency allocations to ensure not only the widespread availability of advanced and affordable wireless services and applications, but also global roaming and inter-operability. National and regional borders must be transcended, inter-connection of networks and inter-operability of services and applications must be encouraged, all with the objective of ensuring, through the convergence of telecommunications, computer and multimedia, the fulfilment of the potential of the upcoming wireless information age.

6.6.1. Universal Mobile Telecommunications Systems (UMTS)

The vision of UMTS, as it has emerged from work undertaken within RACE , calls for UMTS to support all those services, facilities and applications which customers presently enjoy, and to have the potential to accommodate, yet undefined, broadband multimedia services and applications with quality levels commensurate to those of the fixed IBC networks. In this context, projects will identify the cardinal services that

UMTS must support, the future-proofing UMTS bearer requirements in macro-, micro- and picocell environments, and the applications likely to be supported by UMTS. A considerable effort will be devoted to determining how best to ensure that UMTS will be designed so as to be perceived by the customers as a broadband service evolution of Second Generation technologies (evolution, not revolution), while ensuring a competitive service provision in a multi-operator environment.

UMTS represents a new generation of mobile communications systems in a world where personal services will be based on a combination of fixed and wireless/mobile services providing a seamless end-to-end service to the user. Bringing this about will require unified offering of services to the user in wireless and wired environments, mobile technology that supports a very broad mix of communication services and applications, flexible, on-demand, bandwidth allocation for a wide variety of applications, and standardisation that allows full roaming and inter-working capability, where needed, while remaining responsive to proprietary, innovative and niche markets. In particular, UMTS will support novel telematics applications such as dynamic route guidance, fleet management, freight control and travel/ tourism information, specifically for Road Transport Telematics (RTT) and high speed train communications. For applications where there is a very large degree of asymmetry in the down stream and upstream traffic channels, UMTS in combination with Digital Audio Broadcasting (DAB) techniques, can provide cost effective solutions.

With UMTS fully exploiting its capabilities as the integral mobile-access part of B-ISDN, telecommunications will make a major leap forward towards the provision of a technically integrated, comprehensive, consistent, and seamless personal communication system supported by both fixed and mobile terminals. As a result, mobile access networks will begin to offer services that have traditionally been provided by fixed networks, including wideband services up to 2 Mbps. UMTS will also function as a stand-alone network implementation.

Mobile satellite systems are a solution to the problem of economically covering large areas, and serving widely scattered or remote subscribers in rural areas in both developing and developed countries, as well as for ship and aircraft communications. It is intended that the satellite component of UMTS be integrated with its terrestrial component. To keep the inter-working between the two transparent to the end user, three levels of integration are identified as follows: network integration where the space and terrestrial networks can operate as separate entities; equipment integration that requires common service standards, consistent transmission parameters and common radio interface between satellite and terrestrial implementations; and system integration in which the satellite is an integral part of the terrestrial network and able to support handovers between terrestrial and satellite megacells. Clearly the satellite component of UMTS raises technical and economic issues that could impinge on the performance of the UMTS terrestrial service and, consequently, convergence must be carefully weighed.

At the time UMTS reaches service, ATM will be an established transmission technique; hence the UMTS environment must support ATM-cell transmission through to the user's terminal. This compatibility will enable service providers to offer a homogeneous network, where users can receive variable bit-rate services regardless of their access media (mobile or fixed, including wireless local loop). The flexibility of service provision across Europe, in multi-operator environment, also demands close attention to spectrum-sharing techniques, charging, billing and accounting, numbering, network security, privacy, etc., all of which may have regulatory implications. To these issues, one must add the degree of compatibility between UMTS and fixed network functionality, and the form of the multi-service capability at the radio interface.

UMTS will require a revolution in terms of radio air-interface design, and continued evolution of intelligent network (IN) principles. The arrival of a fully capable UMTS does not preclude the extension of such developments into those bands currently open to Second Generation technology. The resulting parallel process of UMTS design and Second Generation enhancement will call for careful market management and co-existence between UMTS and Second Generation service standards to ensure a smooth, customer sensitive transition. Indeed, multi-mode/multi-band transceiver technology may be used to provide multi-standard terminal equipment, particularly between UMTS, GSM/DCS-1800, and DECT.

6.6.2. Beyond UMTS ? Mobile Broadband Systems (MBS)

The strategic importance of mobile broadband communications systems catering for different mobility requirements ranging from stationary (for wireless local loops), through quasi-stationary (office and industrial environments), to fully mobile was recognised at an early stage in the context of RACE. The objectives of the work were namely to develop a quasi-mobile wireless system for bit-rates of up to 155 Mbps throughput (in the 40 or 60 GHz bands), and to create the industrial capacity to produce

the necessary system components (RF, IF and baseband systems, antennas, terminals).
In the context of MBS applications, the investigation and definition of system aspects, radio access schemes, network management issues, integration with IBC, etc., is critical. MBS systems will cater for novel multimedia and video mobile telecommunication applications, including those appropriate to W-LAN and WLL (wireless local loop) broadband systems.

As wireless terminal extensions to the B-ISDN, MBS systems concepts are being actively researched in the context of ACTS with emphasis on specific objectives including the demonstration of mobile broadband applications, video distribution, interactive video, audio and data communication service at bit-rates up to 155 Mbps on a mobile terminal connected to an IBC network; the demonstration of ATM compatibility between mobile and fixed terminals with implementation of the necessary mobility management-functions (especially for handover) and the required signalling, control and service-provision protocols; and finally the validation of quality-of-service parameters corresponding to the evaluated applications. As with UMTS, a satellite component of MBS will be investigated to determine the optimum frequency band (Ka - - 20-30 GHz, or 60 GHz bands).

The widespread availability of portable and laptop computers dictates the need for third-generation mobile systems to incorporate an integrated W-LAN capability to maintain its ?universality?. Application areas include mobile systems for offices, industrial automation, financial services, emergency and medical systems, education and training, with network connection for portable computers and personal digital assistants as well as ad hoc networking. The specific nature of each of the above related environments do, however, influence security, range, defined working area, transmission rate, re-using of frequencies, cost, maintenance, penetration potential, etc.

In creating a high-speed (up to 155 Mbps) local data communication link, significant research is required to identify a suitably reliable system and associated air interface. Important issues include frequency allocation and selection, choice of bandwidth, efficient coding schemes, specification of medium access procedures, definition of link control protocols, as well as connectivity aspects related to connection to other wired or wireless communications networks. In brief, ongoing W-LAN R&D activities seek solutions that recognise application, environment, cost, performance, networking and system architecture requirements.

ERO is already looking into spectrum allocation for MBS. The main tasks identified are:

- to review the currently designated frequency bands for MBS (terrestrial and satellite) and the applications which they may be able to support in terms of capacity, user bit rates, etc.;
- to examine the trends for further applications in different domains of public and private interest and their expected growth in terms of capacity, user bit rate, and bandwidth requirements, in order to provide advice on the appropriateness of the existing frequency allocations;
- to examine and identify the application sectors in different domains of public and private interest which are more likely to the demands for spectrum, taking into account the increasing use of mu6. Mobile Domain Result Dissemination and Concertation Activities

A key component of the work carried out in the EU-sponsored projects relates to the dissemination of research results. Still in the RACE Programme, after a series of annual conferences, a first Mobile Telecommunications Summit was held in Cascais, Portugal, in 1995.

This first Summit brought together not only the RACE Mobile projects, but also international experts in a variety of areas. An effort was also made to expose the RACE researchers to some timely subjects through a selection of Invited Papers with emphasis on UMTS and FPLMTS/IMT-2000 standardisation, not forgetting the US perspective, as well as on the future mobile terminals, with multimedia capabilities, in the context of mobile multimedia.

With the start of ACTS, it was decided to establish the ACTS Mobile Summit, open to international participation, to be organised on an annual basis. The First ACTS Mobile Communications Summit, was recently held in Granada, Spain (27-29 November, 1996). In spite of the fact that the ACTS projects are still in a preliminary stage, with little more than one year into their research, numerous contributions allowed for a lively conference, attended by more than 450 people, by far the largest European conference in the Mobile area. Many non-European participants, from the Far East, US and South America, as well as the active participation of representatives of many European national projects, contributed to an open, fruitful exchange of ideas. The emphasis of the Invited Papers section was on the Japanese experience and on the role of the UMTS Forum.

The Second ACTS Mobile Communications Summit will take place on 7-10 October, 1997, in Aalborg, Denmark. It will provide a major forum for the dissemination of the results of the European R&D initiatives towards Third Generation Mobile Communication Systems such as W-LANs, and UMTS (and also MBS) with their Satellite components, and enable the exchange of points of view at a technological as well as strategic level.

The ACTS Concertation Meetings, where the Mobile projects review the progress of the ongoing R&D initiatives, constitute additional opportunities for result dissemination and exchange of ideas. Effort will now be put in bringing in selected experts. The objective is to have interesting, even provocative presentations on timely issues in areas of interest to the Mobile community. As an example, some of the themes already selected are Software Radio, multi-Mbps WLL, content provision, and Intelligent Mobile Agents.

6.7. Mobile Domain Result Dissemination and Concertation Activities

A key component of the work carried out in the EU-sponsored projects relates to the dissemination of research results. Still in the RACE Programme, after a series of annual conferences, a first Mobile Telecommunications Summit was held in Cascais, Portugal, in 1995.

This first Summit brought together not only the RACE Mobile projects, but also international experts in a variety of areas. An effort was also made to expose the RACE researchers to some timely subjects through a selection of Invited Papers with emphasis on UMTS and FPLMTS/IMT-2000 standardisation, not forgetting the US perspective, as well as on the future mobile terminals, with multimedia capabilities, in the context of mobile multimedia.

With the start of ACTS, it was decided to establish the ACTS Mobile Summit, open to international participation, to be organised on an annual basis. The First ACTS Mobile Communications Summit, was recently held in Granada, Spain (27-29 November, 1996). In spite of the fact that the ACTS projects are still in a preliminary stage, with little more than one year into their research, numerous contributions allowed for a lively conference, attended by more than 450 people, by far the largest European conference in the Mobile area. Many non-European participants, from the Far East, US and South America, as well as the active participation of representatives of many European national projects, contributed to an open, fruitful exchange of ideas. The emphasis of the Invited Papers section was on the Japanese experience and on the role of the UMTS Forum.

The Second ACTS Mobile Communications Summit will take place on 7-10 October, 1997, in Aalborg, Denmark. It will provide a major forum for the dissemination of the results of the European R&D initiatives towards Third Generation Mobile Communication Systems such as W-LANs, and UMTS (and also MBS) with their Satellite components, and enable the exchange of points of view at a technological as well as strategic level.

The ACTS Concertation Meetings, where the Mobile projects review the progress of the ongoing R&D initiatives, constitute additional opportunities for result dissemination and exchange of ideas. Effort will now be put in bringing in selected experts. The objective is to have interesting, even provocative presentations on timely issues in areas of interest to the Mobile community. As an example, some of the themes already selected are Software Radio, multi-Mbps WLL, content provision, and Intelligent Mobile Agents.

6.8 Summary

This paper presents the current perspective on the European mobile and wireless telecommunication sector insofar as Third Generation advanced personal mobile communications are concerned. The case is made for the urgent need for enhanced, more efficient mobile communication systems, as well as for the spectrum required by the anticipated multimedia services that will be offered. The prevailing opinion that these Third Generation systems will have to evolve from existing Second Generation GSM/DCS-1800 systems is also substantiated.

Supported by telecommunications operators, equipment manufacturers, service providers, research institutes, universities and leading-edge users, a number of EU-funded R&D projects have proved to be instrumental in the development of Third Generation systems. The participation of representative users reflects the policy that R&D must be demand-driven to ensure that the developed technologies, services and applications are responsive to market requirements.

There is still much to be done to arrive at the definition and later at the specification of the future UMTS systems, but the structure is, we believe, in place to achieve that goal in a timely manner. The ACTS projects together with the organisations presently working on UMTS, namely the UMTS Forum, ETSI, and ERC, are recognised has having all that is needed to drive UMTS, each in its field. On one hand, the ACTS projects contribute to the definition of the UMTS concept, and to the standards work. On the other hand, the UMTS Forum is expected to contribute to the strategic perspective and guide the regulatory framework, while will ETSI prepare the necessary standards, and ERO will issue the required spectrum recommendations.

CONCLUSION

1. Wireless

Market research firm Dataquest predicts that revenue for wireless data services will grow from $460 million in 1999 to $3 billion in 2003. Cisco Systems and Motorola recently announced an alliance to develop global, Internet-based wireless networks. The two companies plan to invest $1 billion over the next four or five years to implement the project. 3Com recently acquired Smartcode Technologie, a French developer of wireless data communications and Internet-access software. 3Com expects to deliver wireless Web access in its upcoming 3Com Palm VII. Nextel Communications has joined with Motorola, Netscape, and Unwired Planet to form the Nextel Online family of wireless Internet services. Scheduled for launch in six cities later this year, a wireless Internet portal called Nextel Online will include stock quotes, weather, business headlines, and Nextel's Internet-based services. Microsoft is also jockeying for a position in the wireless business, through a new venture with British Telecom to develop a range of Internet, Intranet, and corporate data services for worldwide mobile customers. And a joint venture between General Magic and Wireless Knowledge (a new company partly owned by Microsoft and Qualcomm) will bring secure wireless access to Microsoft Exchange and mobile devices accessing the Internet.

2. GSM

Most people think of mobile communications as talking while on the move. But soon, we shall expect mobile communications to offer us a lot more. Increasing workforce mobility worldwide is fueling demand for more powerful and flexible communications products such as the ability to surf the Internet, on-line shopping, and videoconferencing. Expect to be able to access these services whether at work, at home or travelling. The mobile service of the future will connect to corporate LANs, enabling business people to share information among workgroup.

International standard:

Many telecommunication experts view the smart card (SIM) which is used in GSM system is the secret key for international communication. Right now the GSM user can establish his account in one country and travel to about 100 counties over the world and still use his same number. New GSM networks are being established every month, and it is predicted that the standard will be established in more than 130 countries with 315 operators by the end of the decade, and a combined subscriber base of 315 million by the year 2001.

Have laptop, Access Internet

Imaging that you are waiting in airport terminal and having nothing to do. How much it is wonderful to have your laptop connected to Internet and view your favorite sites. GSM promise to make this dream reality. GSM will be able to satisfy this expectation with a packet data capability now being designed, known as General Packet Radio Services (GPRS). GPRS will provide fast call set up times so that data users will not have to wait for the phone to dial, as they do with a circuit switched call. Instead, they will get through immediately.

3. CDMA

CDMA's versatility as a cellular, PCS, wireless local loop (WLL), and mobile satellite solution will overwhelm GSM in many countries, even including Europe where GSM has a large share of the market. As of Feb. 1998, Eastern Europe and countries such as China, India, Brazil, Russia have started to use CDMA as WLL solution. Moreover, operators in West European nations might also adopt CDMA for factors like capacity, coverage, and the roaming revenue from North American and Asian CDMA visitors who use CDMA for their wireless communications.

Besides being able to inter-operate with GSM, CDMA also has a Globalstar satellite network that will provide CDMA an even greater coverage area. For this reason, the major GSM manufacture Ericsson has planned to produce and sell CDMA handsets to take advantage of the wide Globalstar satellite footprint. Consequently, we can certainly be assured that there is plenty of room for CDMA technology to expand. On the other hand, the GSM shall still remain as the dominating wireless infrastructure over the next few years because CDMA will probably be laid over the existing GSM network.

4. Universal Mobile Telephone Service (UMTS)

Companies involved with both GSM and CDMA are working hard to develop 3rd generation technologies. One of these technologies is UMTS. It seeks to incorporate the best qualities inherent in GSM and CDMA in terms of spectral efficiency as well as trying to lower costs to the developer and the consumer. This technology is currently still under development, but should hit the market within the next 3 - 5 years.

REFERENCES

[1] Graduation Project EE400 Handbook Fakhreddin Mamedov,Özgür Cemal Özerdem

[2]"The European Path towards UMTS", Javier Gozalvez Sempere, February 1995

[3] Green Paper on "A Common Approach in the Field of Mobile and Personal Communications in the EU", Brussels, April 1994

[4] Mobile Broadband Systems (MBS) - Draft Final Report, ERO, November 1996

[5] ACTS Annual Report, European Commission, DG XIII-B, September 1995

[6] Proceedings of the RACE Mobile Telecommunications Summit, Cascais, November 1999

[7] European Commission, Cascais, Portugal, 22-24 November 1995

[8]Overview of the Global System for Mobile Communications' by John Scourias,1994

[9] RACE Vision of UMTS, Workshop on Third Generation Mobile Systems, Brussels, January 1995

[10] Mobile Broadband Systems (MBS) - Draft Final Report, ERO, November 1996

[11] Business Data Communication, Stallings W. and Slyke R. - , Third edition, Prentice Hall, Upper Saddle River, New Jersey, 1998.

[12] University of Bremen - CDMA Research

[13] www.gsm data knowledge site.com

[14] Ask Jeeves - Definitions

[15] www.acts mobile domain.com