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CELL PLANNING

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ABSTRACT

GSM (Global System of Mobile Communication) has been well known as the world's most popular standard for new cellular radio and personal communication equipment throughout the world.

Global System for Mobile (GSM) is a second generation cellular system standard that was developed to solve the fragmentation problems of the first cellular systems in Europe.

GSM was first introduced into the European market in 1991. By the end of 1993, several non European countries in South America, Asia, and Australia had adopted GSM and the technically equivalent offshots, DCS 1800, which supports Personal Communication Services (PCS) in the 1.8 GHz to 2.0 GHz radio bands recently created by the governments throughout the world. GSM's success has exceeded the expectations of virtually everyone, and it is now the world's most popular standard for new cellular radio and Personal Communication Equipment throughout the world. It is predicted that by the year 2001, there would be 500 million GSM subscribers worldwide.

The GSM system architecture consists of three major interconnected subsystems that interact between themselves and with the users through certain network interfaces. The subsystems are the Base Station Subsystem (BSS), Network and Switching Subsystem (NSS), and The Operration Support Subsystem (OSS). The Mobile Station (MS) is also a subsystem, but is usually considered to be part of the BSS for architecture purposes. Equipment and Services are designed within GSM to support one or more of these specific subsystems.

The first subsystem named Base Station Subsystem (BSS), provides and manages radio transmission path between the mobile station and the mobile switching center. Second subsysten of GSM Architecture is Network and Switching Subsystem (NSS). This subsystem manages the switching functions of the system and allows the mobile switching centers to communicate with other networks. The last subsytem is known as Operation Support Subsystem (OSS). This subsystem's major functionality consists of supporting the operation and maintenance of GSM. It allows the system engineers to monitor, diagnose and troubleshoot all aspects of the GSM system. The above three basic subsystems built the GSM Architecture.

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LIST OF ABBREVIATIONS

AGCH	Access Grant Channel
AM	Amplitude Modulation
AMPS	Advanced Mobile Phone System
ARQ	Automatic Request for retransmission
AuC	Authentication Center
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
Bps	Bits per second
BS	Base Station
BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transceiver System
CC	Call Control
CCCH	Communication Control Channel
CCF	Call Control Function
CDMA	Code-Division Multiple Access
CEPT	Conference Europeenne des Postes et Telecommunications
CGI	Cell Global Identity Number
CM	Communication Management
dB	decibel
DCCH	Dedicated Control Channel
DECT	Digital Enhanced Cordless Telecommunication
DF	Data Frame
DRX	Discontinuous Receive
DTX	Discontinuous Transmission
EC	European Commission
EFR	Enhanced Full Rate
EIR	Equipment Identity Register
ETSI	European Telecommunications Standards Institute
FACCH	Fast Associated Control Channel
FCC	Federal Communications Commission
FCCH	Frequency Correction Channel

FDMA Frequency-Division Multiple Access

FM Frequency Modulation

GHz Gigahertz

GIWU GSM Interworking Unit

GMSC Gateway Mobile Services Switching Center

GMSK Gaussian Minimum Shift Keying

GP Guard Period

GPRS General Packet Radio Service

GSM Global System for Mobile communications

HLR Home Location Register

Hz Hertz

IEEE Institute of Electrical and Electronic Engineers

IMEI International Mobile Equipment Identity

IMSI International Mobile Station Identification

IMTS Improved Mobile Telephone Service

IN Intelligent Network

ISDN Integrated-Service Digital Network

ITA Interim Type Approval

ITU International Telecom Union

kbps kilo Bits Per Second

kHz kilohertz

LA Location Area

LAI Location Area Identity

LSF Line Supervision Frame

MHz Megahertz

MIC Mobile Internal Call

MM Mobility Management

MoU Memorandum of Understanding

MS Mobile Station

MSC Mobile Switching Center

MSISDN Mobile Subscriber ISDN

MSN	Mobile Service Node
MSRN	Mobile Station Roaming Number
MT	Mobile Termination
MTF	Maintenance Test Frame
MTSO	Mobile Phone Switching Office
MXE	Message Center
NMT	North Mobile Telephony
NSS	Network Switching Subsystem
OAM	Operation, Administration, Maintenance
OMC	Operation Maintenance Centers
OSS	Operational Subsystem
PCH	Paging Channel
PCM	Pulse Code Modulation
PCN	Personal Communications Networks
PCS	Personal Communications Services
PIN	Personal Identification Network
PLMN	Public Land Mobile Network
POTS	Plain Old Telephone Service
PS	Personal Station
PSTN	Public Switching Telephone Network
RACH	Random Access Channel
RCC	Radio Common Carrier
RF	radio frequency
RPE-LPC	Regular Pulse Excited-Linear Predicture Coder
RPE-LTP	Regular Pulse Excited-Long-Term Predictive
RR	Radio Resources Management
RS	Radio System
SACCH	Slow Associated Control Channel
SCH	Synchronization Channel
SDCCH	Stand-alone Dedicated Contol Channel

SIM	Subscriber Identity Module
SMS	Short Message Service
SS	Switching System
SS7	Signaling System Number 7
TACS	Total Access Communications System
TCH	Traffic Channel
TCH/F	Traffic Channel/Full rate
TCH/H	Traffic Channel/Half rate
TDMA	Time-Division Multiple Access
TM	Telemetry Site
UMTS	Universal Mobile Telecommunications System
VAD	Voice Activity Detection
VLR	Visitor Location Register
WAP	Wireless Application Process

INTRODUCTION

This project, Cell Planning, is intended to give the student an understanding of the radio network engineering processes and what elements they contain.

The project is broken down into chapters that explain the different elements of the process.

The first chapter, history of GSM. This chapter introduces first History of GSM, then continues with Services provided by GSM. Finally the Chronology of communication and wireless systems up to 1982 and the developments of GSM from 1982 until Todays are also given.

The second chapter, architecture of GSM network. This chapter is concerned to the GSM Architecture. I illustrate the process of GSM Architecture and the GSM Functions in details.

The third chapter , The architecture of the cellular mobile system. This chapter is start with What is a cellular phone system, and goes with Cellular covarage, Basic wireless principles and Alternative techniques. This chapter is the most important topic of my Graduation Project.

The fourth chapter is about Surveys. This chapter is overview of radio network survey of a cellular network as well as some radio measurements. Objectives of this chapter, explain briefly what a site survey is and what to consider during a survey and describe three different types of radio measurements.

1. INTRODUCTION TO GSM

1. 1. History of GSM

During the early 1980s, analogue cellular telephone systems were experiencing rapid growth in Europe, particularly in Scandinavia and the United Kingdom, but also in France and Germany. In the Nordic and Benelux countries the NMT 450 was developed, TACS in the UK and C-Netz in West Germany. The Radio com 2000 was in France and RTMI/RTMS in Italy. But each system was incompatible with everyone else's in equipment and operation and as business was becoming increasingly international, the cutting edge of the communications industry focused on exclusively local cellular solutions. These systems were fine if you wanted to call the office if you were in your own home, but not if you were with a client in another country. Also home market revenue simply wouldn't justify sustained programs of investment. As a solution in 1982 CEPT, the Conference des Administrations Europeans des Postes et Telecommunications comprised the telecom administrations of twenty-six European countries, established the Group Special Mobile (GSM). Its objective was to develop the specification for a pan-European mobile communications network capable of supporting the many millions of subscribers likely to turn to mobile communications in the years ahead. The home market revenue simply wouldn't justify sustained programs of investment so to further progress they lobbied for support from some political heavyweights. In 1985, the growing commitment to resolving the problem became evident when West Germany, France and Italy signed an agreement for the development of GSM. The United Kingdom added its name to the agreement the following year. By this time, CEPTs Group Special Mobile could argue persuasively that the standards they were developing held the key to a technically and economically viable solution as their standard was likely to employ digital rather than analogue technology and operate in the 900MHz frequency band. Digital technology offered an attractive combination of performance and spectral efficiency. In other words, it would provide high quality transmission and enable more callers simultaneously to use the limited radio band available. In addition, such a system would allow the development of advanced features like speech security and data communications. Handsets could be cheaper and smaller.

It would also make it possible to introduce the first hand-held terminals - even though in the early days in terms of size and weight these would be practically indistinguishable from a brick. Finally, the digital approach neatly complemented the Integrated Services Digital Network (ISDN), which was being developed by land-based telecommunications systems throughout the world. But the frequencies to be employed by the new standard were being snapped up by the analogue networks. Over-capacity crisis had started to sound alarm bells throughout the European Community. Demand was beginning to outstrip even the most optimistic projections. The Group Special Mobile's advocacy of digital cellular technology was on hand to offer light at the end of the tunnel. The Directive ensured that every Member State would reserve the 900MHz frequency blocks required for the rollout program. Although these were somewhat smaller than the amount advocated by the CEPT, the industry had finally achieved the political support it needed to advance its objectives. The logistical nightmare in the GSM, which followed soon left this achievement as a distant, dream so single, permanent organization at the helm. In 1986 the GSM Permanent Nucleus was formed and its head quarters established in Paris. It was all very well agreeing the technology and standards for this new product. But what about the creation of a market? It was essential to forge a commercial agreement between potential operators who would commit themselves to implementing the standard by a particular date. Without such an agreement there could be no network. Without the network there would be no terminals. Without network and terminals there would be no service. Stephen Temple of the UK's Department of Trade and Industry was charged with the task of drafting the first Memorandum of Understanding (MoU). In September 1987 network operators from thirteen countries signed a MoU in Copenhagen. One of the most important conclusions drawn from the early tests was that the new standard should employ Time Division Multiple Access (TDMA) technology. The strength of its technical performance ensured that narrowband TDMA had the support of major players like Nokia, Ericsson and Siemens. This promised the flexibility inherent in having access to a broad range of suppliers and the potential to get product faster into the marketplace. But as always as soon as one problem was solved other problems looming on the horizon. In 1989, the UK Department of Trade and Industry published a discussion document called "Phones on the Move". This advocated the introduction of mass-market mobile communications using new technology and operating in the 1800 MHz frequency band. The UK government licensed two operators to run what became known as Personal

Communications Networks (PCN). Operating at the higher frequency gave the PCN operators virtually unlimited capacity, where as 900MHz was limited. The next hurdle to over come was that of the deadline. If the 1 July 1991 launch date was not met there was a real danger that confidence in GSM technology would be fatally undermined but moral received a boost when in 1989 the responsibility for specification development passed from the GSM Permanent Nucleus to the newly created European Telecommunications Standards Institute (ETSI). In addition, the UK's PCN turned out to be more of an opportunity than a threat. The new operators decided to utilize the GSM specification - slightly modified because of the higher frequency - and the development of what became known as DCS 1800 was carried out by ETSI in parallel with GSM standardization. In fact, in 1997 DCS 1800 was renamed GSM 1800 (Global System for Mobile communication) to reflect the affinity between the two technologies. With so many manufacturers creating so many products in so many countries, it soon became apparent that it was critical that each type of terminal was subject to a rigorous approval regime. Rogue terminals could cause untold damage to the new networks. The solution was the introduction of Interim Type Approval (ITA). Essentially, this was a procedure in which only a subset of the approval parameters was tested to ensure that the terminal in question would not create any problems for the networks. In spite of considerable concern expressed by some operators, ITA terminals became widely available in the course of 1992. True hand held terminals hit the market at the end of that year and the GSM bandwagon had finally started to roll. From here the GSM became a success story. In 1987, the first of what was to become an annual event devoted to the worldwide promotion of GSM technology was staged by conference organizers IBC Technical Services. The Pan European Digital Cellular Conference. This year it celebrated its tenth anniversary in Cannes, attracting over 2,400 delegates. By the end of 1993, GSM had broken through the 1 million-subscriber barrier with the next million already on the horizon. By June 1995 Phase 2 of standardization came in to play and a demonstration of fax, video and data communication via GSM. When the GSM standard was being drawn up by the CEPT, six separate systems were all considered as the base. There were seven criteria deemed to be of importance when assessing which of the six would be used. Each country developed its own system, which was incompatible with everyone else's in equipment and operation. This was an undesirable situation, because not only was the mobile equipment limited to operation within national boundaries, which in a unified Europe were increasingly unimportant, but there was also a very limited market for each type of equipment, so economies of scale and the subsequent savings could not be realized.

The Europeans realized this early on, and in 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Group Special Mobile (GSM) to study and develop a pan-European public land mobile system. The proposed system had to meet certain criteria. In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and phase-I of the GSM specifications were published in 1990. Commercial service was started in mid-1991, and by 1993 there were 36 GSM networks in 22 countries with 25 additional countries having already selected or considering GSM. This is not only a European standard - South Africa, Australia, and many Middle and Far East countries have chosen GSM. Although standardized in Europe, GSM is not only a European standard. Over 200 GSM networks (including DCS1800 and PCS1900) are operational in 110 countries around the world. In the beginning of 1994, there were 1.3 million subscribers worldwide, which had grown to more than 55 million by October 1997. With North America making a delayed entry into the GSM field with a derivative of GSM called PCS1900, GSM systems exist on every continent, and the acronym GSM now aptly stands for Global System for Mobile communications. The developers of GSM chose an unproven (at the time) digital system, as opposed to the then-standard analogue cellular systems like AMPS in the United States and TACS in the United Kingdom. They had faith that advancements in compression algorithms and digital signal processors would allow the fulfilment of the original criteria and the continual improvement of the system in terms of quality and cost. The over 8000 pages of GSM recommendations try to allow flexibility and competitive innovation among suppliers, but provide enough standardization to guarantee proper inter-working between the components of the system. This is done by providing functional and interface descriptions for each of the functional entities defined in the system. The development of GSM started in 1982, when the Conference of European Posts and Telegraphs (CEPT) formed a study group called Group Special Mobile (the initial meaning of GSM). The group was to study and develop a pan-European public cellular system in the 900 MHz range, using spectrum that had been previously allocated. At that time, there were many incompatible analogue cellular systems in various European countries. Some of the basic criteria for their proposed system were:

- Good subjective speech quality.
- Low terminal and service cost.
- Support for international roaming.
- Ability to support handheld terminals.
- Support for range of new services and facilities.
- Spectral efficiency.
- ISDN compatibility.

In 1989, the responsibility for GSM was transferred to the European Telecommunication Standards Institute (ETSI), and the Phase I recommendations were published in 1990. At that time, the United Kingdom requested a specification based on GSM but for higher user densities with low-power mobile stations, and operating at 1.8 GHz. The specifications for this system, called Digital Cellular System (DCS1800) were published 1991. Commercial operation of GSM networks started in mid-1991 in European countries. By the beginning of 1995, there were 60 countries with operational or planned GSM networks in Europe, the Middle East, the Far East, Australia, Africa, and South America, with a total of over 5.4 million subscribers. As it turned out, none of the six candidates was actually used! The information collected during the tests did enable the GSM (Group Special Mobile) to design the specifications of the current GSM network. The total change to a digital network was one of the fundamental factors of the success of GSM. Digital transmission is easier to decode than analogue due to the limited number of possible input values (0,1), and as ISDN was becoming de facto at the time, it was logical to avail of digital technology. This also ensured that GSM could evolve properly in an increasingly digital world, for example with the introduction of an 8kps speech coder. It is much easier to change channel characteristics digitally than analogously. Finally, the transmission method decided on for the network was TDMA, as opposed to FDMA and CDMA. In 1989, responsibility for the specification was passed from CEPT to the newly formed and now famous European Telecommunications Standards Institute (ETSI). By 1990, the specifications and explanatory notes on the system were documented extensively, producing 138 documents in total, some reaching sizes of several hundred pages in length services.

1. 2. Overview

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 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.

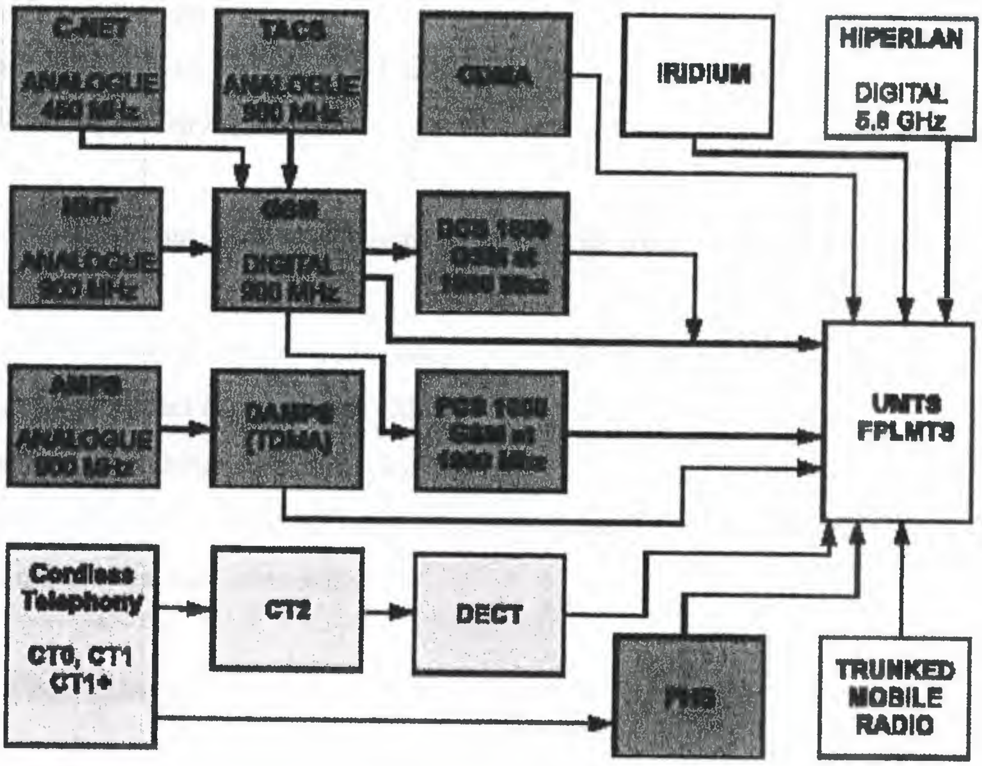


Figure 1.1 The Mobile Evolution

Before GSM networks there were public mobile radio networks (cellular). They normally used analogue technologies, which varied from country to country and from manufacturer to another. These analogue networks did not comply with any uniform standard. There was no way to use a single mobile phone from one country to another. The speech quality in most networks was not satisfactory.

GSM became popular very quickly because it provided improved speech quality and, through a uniform international standard, made it possible to use a single telephone number and mobile unit around the world. The European Telecommunications Standardization Institute (ETSI) adopted the GSM standard in 1991, and GSM is now used in 135 countries.

The benefits of GSM include:

- Support for international roaming
- Distinction between user and device identification
- Excellent speech quality

- Wide range of services
- Interworking (e.g. with ISDN, DECT)
- Extensive security features

GSM also stands out from other technologies with its wide range of services 1:

- Telephony
- Asynchronous and synchronous data services (2.4/4.8/9.6 kbit/s)
- Access to packet data network (X.25)
- Telematic services (SMS, fax, videotext, etc.)
- Many value-added features (call forwarding, caller ID, voice mailbox)
- E-mail and Internet connections

1. 3. Technology

1.3.1 Services Provided by GSM

From the beginning, the planners of GSM wanted ISDN compatibility in terms of the services offered and the control signalling used. However, radio transmission limitations, in terms of bandwidth and cost, do not allow the standard ISDN B-channel bit rate of 64 kbps to be practically achieved.

Using the ITU-T definitions, telecommunication services can be divided into bearer services, tele-services, and supplementary services. The digital nature of GSM allows data, both synchronous and asynchronous, to be transported as a bearer service to or from an ISDN terminal. Data can use either the transparent service, which has a fixed delay but no guarantee of data integrity, or a no transparent service, which guarantees data integrity through an Automatic Repeat Request (ARQ) mechanism, but with a variable delay. The data rates supported by GSM are 300 bps, 600 bps, 1200 bps, 2400 bps, and 9600 bps.

The most basic tele-service supported by GSM is telephony. As with all other communications, speech is digitally encoded and transmitted through the GSM network as a digital stream. There is also an emergency service, where the nearest emergency-service provider is notified by dialling three digits (similar to 911).

A variety of data services are offered. GSM users can send and receive data, at rates up to 9600 bps, to users on POTS (Plain Old Telephone Service), ISDN, Packet Switched Public Data Networks, and Circuit Switched Public Data Networks using a variety of access methods and protocols, such as X.25 or X.32. Since GSM is a digital network, a modem is not required between the user and GSM network, although an audio modem is required inside the GSM. Network to inter-work with POTS.

Other data services include Group 3 facsimile, as described in ITU-T recommendation T.30, which is supported by use of an appropriate fax adaptor. A unique feature of GSM, not found in older analogue systems, is the Short Message Service (SMS). SMS is a bi directional service for short alphanumeric (up to 160 bytes) messages. Messages are transported in a store-and-forward fashion. For point-to-point SMS, a message can be sent to another subscriber to the service, and an acknowledgement of receipt is provided to the sender. SMS can also be used in a cell-broadcast mode, for sending messages such as traffic updates or news updates. Messages can also be stored in the SIM card for later retrieval.

Supplementary services are provided on top of tele-services or bearer services. In the current (Phase I) specifications, they include several forms of call forward (such as call forwarding when the mobile subscriber is unreachable by the network), and call barring of outgoing or incoming calls, for example when roaming in another country. Many additional supplementary services will be provided in the Phase 2 specifications, such as caller identification, call waiting, multi-party conversations.

GSM Phase 1 features

- Call Forwarding
- All Calls
- No Answer
- Engaged
- Unreachable
- Call Barring

- Outgoing - Bar certain outgoing calls (e.g. ISD)
- Incoming - Bar certain incoming calls (Useful if in another country)
- Global roaming - Visit any other country with GSM and a roaming agreement and use your phone and existing number

GSM Phase 2 features

- SMS - Short Message Service - Allows you to send text messages too and from phones
- Multi Party Calling - Talk to five other parties as well as yourself at the same time
- Call Holding - Place a call on Hold
- Call Waiting - Notifies you of another call whilst on a call
- Mobile Data Services - Allows handsets to communicate with computers
- Mobile Fax Service - Allows handsets to send, retrieve and receive faxes
- Calling Line Identity Service - This facility allows you to see the telephone number of the incoming caller on our handset before answering
- Advice of Charge - Allows you to keep track of call costs
- Cell Broadcast - Allows you to subscribe to local news channels
- Mobile Terminating Fax - Another number you are issued with that receives faxes that you can then download to the nearest fax machine.

GSM Phase 2+ features

- (Available by 1998)
- Upgrade and improvements to existing services
- Majority of the upgrade concerns data transmission, including bearer services and packet switched data at 64 kbps and above
- DECT access to GSM
- PMR/Public Access Mobile Radio (PAMR)-like capabilities
- GSM in the local loop
- Virtual Private Networks
- Packet Radio
- SIM enhancements
- Premium rate services (e.g. Stock prices sent to your phone)

1.3.2 Third Generation (3G)

The mobile communications industry has evolved in three stages:

Figure 1.2 Mobile Communications Industry Evolution

Three generations of mobile phones have emerged so far, each successive generation more reliable and flexible than the last:

Analogue: You could only easily use analogue cellular to make voice calls, and typically only in any one country.

Digital mobile phone systems added fax, data and messaging capabilities as well as voice telephone service in many countries.

Multimedia services add high-speed data transfer to mobile devices, allowing new video, audio and other applications through mobile phones- allowing music and television and the Internet to be accessed through a mobile terminal.

With each new generation of technology, the services which can de deployed on them becomes more and more wide ranging and truly limited only by imagination. We are reaching that stage with 3G.

During the first and second generations different regions of the world pursued different mobile phone standards, but are converging to a common standard for mobile multimedia called Third Generation (3G) that is based on CDMA technology. Europe pursued NMT and TACS for analogue and GSM for digital, North America pursued AMPS for analogue and a mix of TDMA, CDMA and GSM for digital. 3G will bring these incompatible standards together, and the aim of this paper is to discuss the optimal migration path for mobile network operators to get from their existing 2G digital systems to the 3G world.

The Third Generation of mobile communications systems will soon by implemented. Following on the heals of analogue and digital technology, the Third Generation will be digital mobile multimedia offering broadband mobile communications with voice, video, graphics, audio and other information. This transition is shown in Table 1.1 below:

Table 1.1 Source Mobile Life streams

Generation	Type	Time	Description
First	Analogue	1980s	Voice centric, multiple standards (NMT, TACS etc.)
Second	Digital	1990s	Voice centric, multiple standards (GSM, CDMA, TDMA)
2.5	Higher Rate Data	Late 1990s	Introduction of new higher speed data services to bridge the gap between the second and Third Generation, including services such as General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE)
Third	Digital Multimedia	2010s	Voice and data centric, single standard with multiple modes

a) 3G Features

Packet Everywhere:

With Third Generation (3G), the information is split into separate but related "packets" before being transmitted and reassembled at the receiving end. Packet switching is similar to a jigsaw puzzle- the image that the puzzle represents is divided into pieces at the manufacturing factory and put into a plastic bag. During transportation of the now boxed jigsaw from the factory to the end user, the pieces get jumbled up. When the recipient empties the bag with all the pieces, they are reassembled to form the original image. All the pieces are all related and fit together, but the way they are transported and assembled varies.

Packet switched data formats are much more common than their circuit switched counterparts. Other examples of packet-based data standards include TCP/IP, X.25, Frame Relay and Asynchronous Transfer Mode (ATM). As such, whilst packet switching is new to the GSM world, it is well established elsewhere. In the mobile world, CDPD (Cellular Digital Packet Data), PDCP (Personal Digital Cellular Packet), General Packet Radio Service (GPRS) and wireless X.25 technologies have been in operation for several years. X.25 is the international public access packet radio data network standard.

Internet Everywhere:

The World Wide Web is becoming the primary communications interface- people access the Internet for entertainment and information collection, the intranet for accessing company information and connecting with colleagues and the extranet for accessing customers and suppliers. These are all derivatives of the World Wide Web aimed at connecting different communities of interest. There is a trend away from storing information locally in specific software packages on PCs to remotely on the Internet. When you want to check your schedule or contacts, instead of using a software package such as "Act!", you go onto the Internet site such as a portal. Hence, web browsing is a very important application for packet data.

High Speed:

Speeds of up to 2 Megabits per second (Mbps) are achievable with Third Generation (3G). The data transmission rates will depend upon the environment the call is being made in- it is only indoors and in stationary environments that these types of data rates will be available. For high mobility, data rates of 144 kbps are expected to be available- this is only about three times the speed of today's fixed telecoms modems.

New Applications, Better Applications:

Third Generation (3G) facilitates several new applications that have not previously been readily available over mobile networks due to the limitations in data transmission speeds. These applications range from Web Browsing to file transfer to Home Automation- the ability to remotely access and control in-house appliances and machines. Because of the bandwidth increase, these applications will be even more easily available with 3G than they were previously with interim technologies such as GPRS.

Service Access:

To use Third Generation (3G), users specifically need:

- A mobile phone or terminal that supports Third Generation (3G)
- A subscription to a mobile telephone network that supports Third Generation (3G)
- Use of Third Generation (3G) must be enabled for that user. Automatic access to the 3G may be allowed by some mobile network operators, others will charge a monthly subscription and require a specific opt-in to use the service as they do with other nonvoice mobile services
- Knowledge of how to send and/ or receive Third Generation (3G) information using their specific model of mobile phone, including software and hardware configuration (this creates a customer service requirement)
- A destination to send or receive information through Third Generation (3G). From day one, Third Generation (3G) users can access any web page or other Internet applications- providing an immediate critical mass of users.

These user requirements are not expected to change much for the meaningful use of 3G.

b) 3G Talking Points

The telecommunications world is changing as the trends of media convergence, industry consolidation, Internet and IP technologies and mobile communications collide into one. Significant change will be bought about by this rapid evolution in technology, with Third Generation mobile Internet technology a radical departure from that that came before in the first and even the second generations of mobile technology. Some of the changes include:

People will look at their mobile phone as much as they hold it to their ear. As such, 3G will be less safe than previous generations- because television and other multimedia services tend to attract attention to themselves- instead of hands-free kits, we will need eyes-free kits!

Data ("non-voice") uses of 3G will be as important as and very different from the traditional voice business.

Mobile communications will be similar in its capability to fixed communications, such that many people will only have a mobile phone. The mobile phone will be used as an integral part of the majority of people's lives- it will not be an added accessory but a core part of how they conduct their daily lives. The mobile phone will become akin to a remote control or magic wand that lets people do what they want when they want.

As with all new technology standards, there is uncertainty and the fear of displacement. Third Generation (3G) mobile is topical and contentious for several reasons:

Because the nature and form of mobile communications is so radically changed, many people don't understand how to make money in the nonvoice world, and do not understand their role in it.

3G licenses have started being awarded around the world, necessitating that existing mobile communications companies in the 2G world think about and justify their continued existence.

3G is based on a different technology platform- Code Division Multiple Access (CDMA)- that is unlike the Time Division Multiple Access (TDMA) technology that is widely used in the 2G world. GSM (Global System for Mobile Communications) was based on TDMA technology.

The US, Japanese and European mobile players all have different technology competences and are now unified in this single standard- the separate wireless evolution paths and European wireless leadership are thereby challenged.

Japanese network operators will be the first to implement 3G networks in the year 2001, and Japanese terminal manufacturers, who have not had much market share outside their home market, will be first with 3G terminals.

Many industry analysts and other pundits have questioned the return on an investment in 3G technology- questioning whether network operators will be able to earn an adequate return on the capital deployed in acquiring and rolling out a 3G network.

Many media and Internet companies have expressed an interest in bidding for and using 3G technology as a new channel to distribute their content, opening the opportunity for new entrants and new partnerships and value chains.

1. 4. The Different GSM-Based Networks

Different frequency bands are used for GSM 900, GSM1800 and GSM 1900 (Table 1.2). In some countries, an operator applies for the available frequencies. In other countries, e.g. United States, an operator purchases available frequency bands at auctions.

Table 1.2 Frequency bands for the different GSM-based networks

Network type	Frequency band UL / DL	Implementations
GSM 900	890-915 / 935-960 MHz	GSM 900
GSM1800	1710–1785 / 1805 -1880 MHz	GSM 1800
GSM1900	1850-1910 / 1930-1990 MHz	GSM1900

1.4.1 Where are the GSM Frequencies Used?

GSM networks presently operate in three different frequency ranges. These are:

a) GSM 900

(Also called GSM) operates in the 900 MHz frequency range and is the most common in Europe and the world.

b) GSM 1800

(Also called PCN (Personal Communication Network), and DCS 1800) - operates in the 1800 MHz frequency range and is found in a rapidly-increasing number of countries including France, Germany, Switzerland, the UK, and Russia. A European Commission mandate requires European Union members to license at least one DCS 1800 operator before 1998.

c) GSM 1900

(Also called PCS (Personal Communication Services), PCS 1900, and DCS 1900) The only frequency used in the United States and Canada for GSM. Note that the terms PCS is commonly used to refer to any digital cellular network operating in the1900 MHz frequency range, not just GSM.

1. 5. GSM System Architecture

The increasing demand for data services leads to the Internet growing and the World Wide Web has grown from 130 mostly educational sites in mid-1993 to 650,000 largely commercial sites at the beginning of 1997. There are now estimated to be well in excess of 50 million individual subscribers with Internet access. This development can be divided into two periods. First generation wireless networks evolve from specialized proprietary protocols or national standards. Wireless voice and data networks operate independently or, at best, are loosely coupled. Over the last decade a second-generation fully digital mobile communication network, now called the Global System for Mobil communications (GSM), with integrated voice and data capabilities has been created and deployed. GSM has three spectral variants: GSM 900, DCS1800 and PCS 1900 operating respectively in the 900MHz, 1.8 GHz and 1.9 GHz bands. GSM has matured to be adopted by around 200 operators in 100 countries. The success of GSM has produced a market led evolution. The GSM system was originally deployed in phase 1 as a basic voice and circuit data service and then additional supplementary services were added in the pre-planned phase 2. GSM is now in "phase 2+", which allows for the ongoing introduction of new services and which should eventually migrate to a third generation system known as the Universal Mobile Telecommunications System (UMTS). A rich collection of new data services is currently being defined under phase 2+. These services when combined with existing data services will provide greater choices and improved bandwidth.

The GSM system architecture consists of three major interconnected subsystems that interact between themselves and with the users through certain network interfaces. The subsystems are the Base Station Subsystem (BSS), Network and Switching Subsystem (NSS), and the Operation Support subsystem (OSS). The Mobile Station (MS) is also a subsystem, but is usually considered to be part of the BSS for architecture purposes. Equipment and services are designed within GSM to support one or more of these specific subsystems.

- The BSS provides and manages radio transmission paths between the mobile stations and the Mobile Switching Center (MSC). It also manages the radio interface. Each BSS consists of many Base Station Controllers (BSCs), which connect the MS to the NSS via the MSCs.
- The NSS manages the switching functions of the system and allows the MSCs to communicate with other networks such as the PSTN and ISDN.
- The OSS supports the operation and maintenance of GSM and allows system engineers to monitor, diagnose, and troubleshoot all aspects of the GSM system.

This subsystem interacts with the other GSM subsystems, and is provided solely for the staff of the GSM operating company, which provides service facilities for the network.

One goal of the GSM is to achieve separation between the NSS and BSS, so that other wireless technologies could be used, such as digital enhanced cordless telecommunications (DECT) and the satellite systems. The GSM air interface between the mobile stations and other subsystems of GSM combines both time division multiple access (TDMA) and frequency division multiple access (FDMA) with optional frequency hopping.

The following figure shows the block diagram of the GSM system architecture. The Mobile Stations (MS) communicate with the Base Station Subsystem (BSS) over the radio air interface. The BSS consists of many BSCs, which connect to a single MSC, and each BSC typically controls up to several hundred Base Transceiver Stations (BTSs).

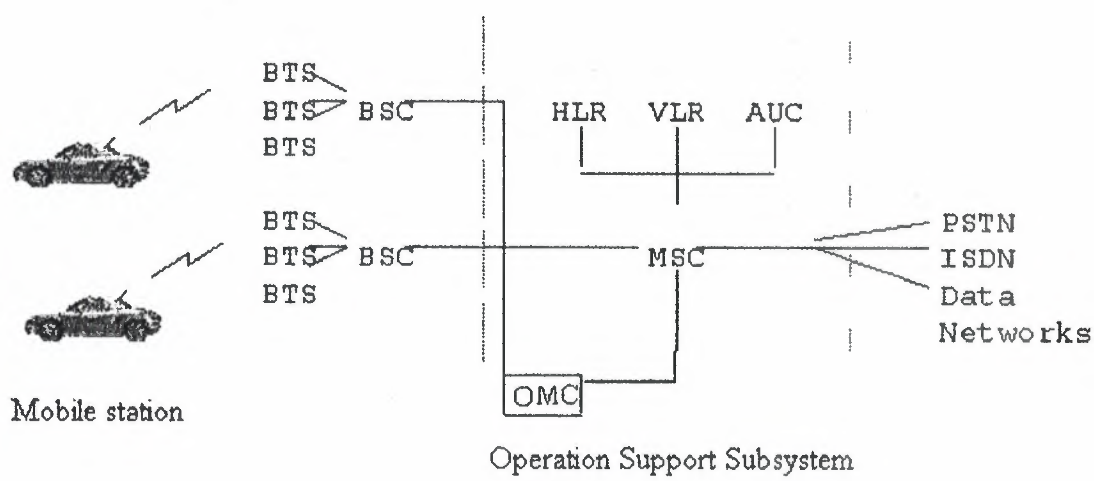


Figure 1.3 GSM System Architecture

The NSS handles the switching of GSM calls between external networks and the BSCs in the radio subsystem and is also responsible for managing and providing external access to several customer databases. The MSC is the central unit in the NSS and controls the traffic among all of the BSCs. In the NSS, there are three different databases called the Home Location Register (HLR), Visitor Location Register (VLR), and the Authentication Center (AUC). The HLR is a database, which contains subscriber information and location information for each user who resides in the same city as the MSC. Each subscriber in a particular GSM market is assigned a unique International Mobil Subscriber Identity (IMSI), and this number is used to identify each home user. The VLR is a database, which temporarily stores the IMSI and customer information for each roaming subscriber who is visiting the coverage area of a particular MSC. The Authentication Center is a strongly protected database, which handles the authentication and encryption keys for every single subscriber in the HLR and VLR. The OSS supports one or several Operation Maintenance Centers (OMC), which are used to monitor and maintain the performance of each MS, BS, BSC, and MSC within a GSM system.

2. ARCHITECTURE OF GSM NETWORK

2. 1. Overview

The GSM technical specifications define the different entities that form the GSM network by defining their functions and interface requirements. The GSM network can be divided into four main parts:

- The Mobile Station (MS).
- The Base Station Subsystem (BSS).
- The Network and Switching Subsystem (NSS).
- The Operation and Support Subsystem (OSS).

The architecture of the GSM network is presented in figure 2.1

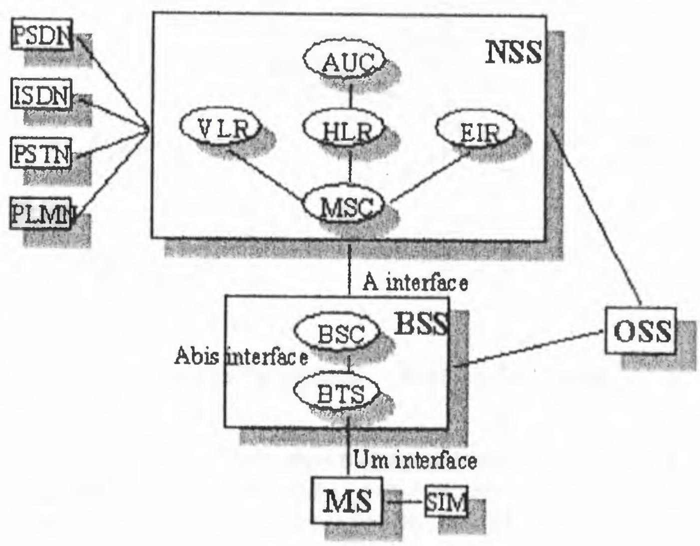


Figure 2.1 Architecture of the GSM network

A GSM network is composed of several functional entities, whose functions and interfaces are specified. Figure 2.1 shows the layout of a generic GSM network. The GSM network can be divided into three broad parts. The subscriber carries the Mobile Station. The Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile Services Switching

Center (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. The MSC also handles the mobility management operations. Not shown is the Operations and Maintenance Center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the U_m interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile Services Switching Center across the A interface. GSM provides recommendations, not requirements. The GSM specifications define the functions and interface requirements.
In detail but do not address the hardware. The reason for this is to limit the designers as little as possible but still to make it possible for the operators to buy equipment from different suppliers. The GSM network is divided into three major systems: the switching system (SS), the base station system (BSS), and the operation and support system (OSS). The basic GSM network elements are shown in Figure 2.2 and Figure 2.3.

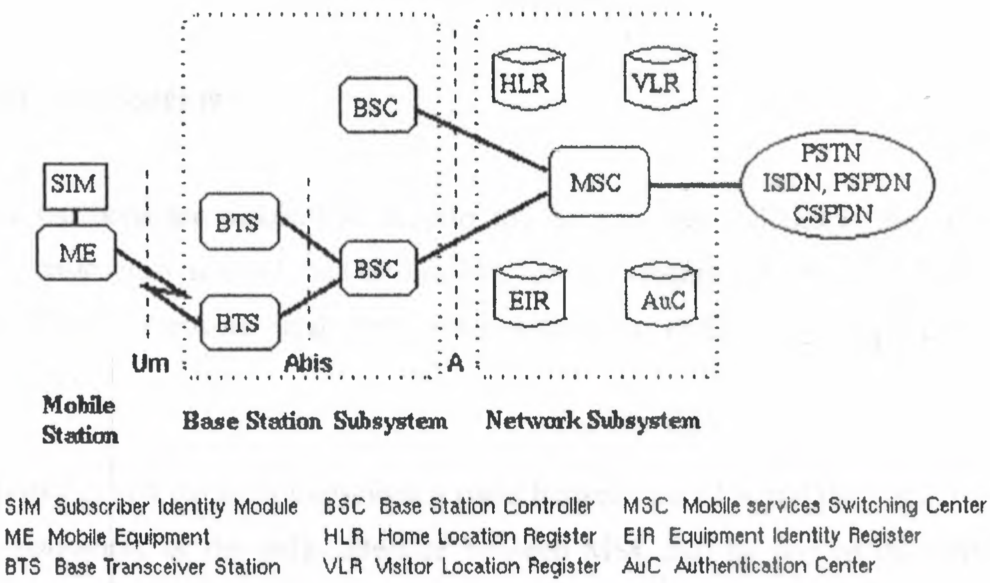


Figure 2.2 General architecture of a GSM network

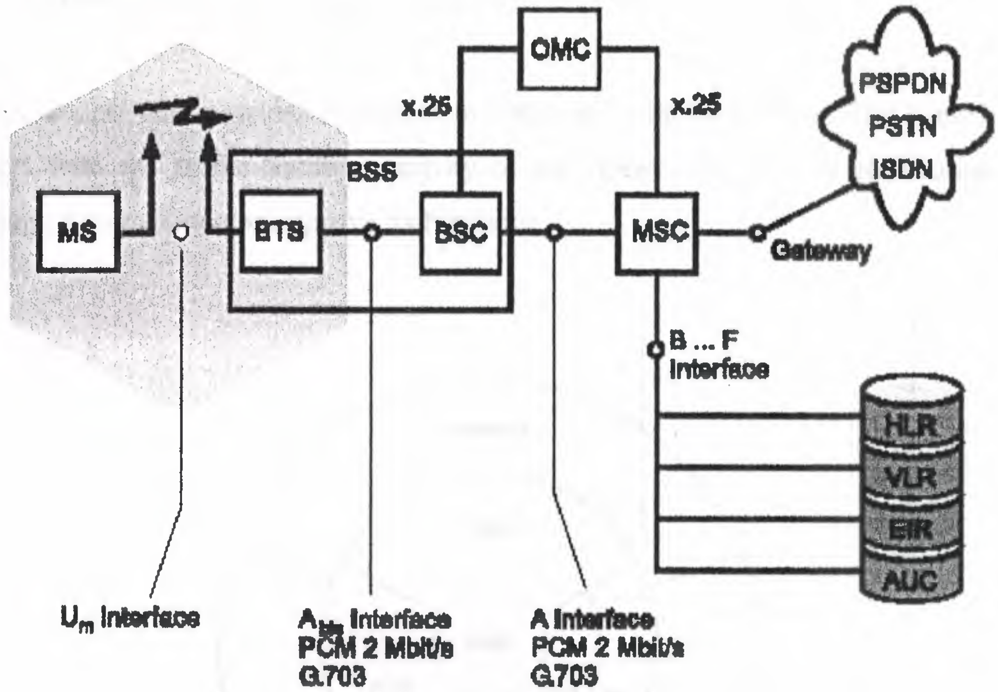


Figure 2.3 GSM network

2. 2. GSM Subsystems

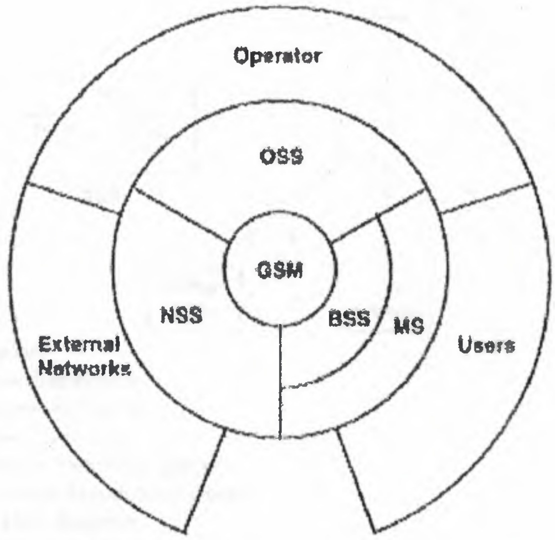
A series of functions are required to support the services and facilities in the GSM PLMN. The basic subsystems of the GSM architecture are (Figure 2.4) the Base Station Subsystem (BSS), Network and Switching Subsystem (NSS), and Operational Subsystem (OSS).

The BSS provides and manages transmission paths between the MSs and the NSS. This includes management of the radio interface between MSs and the rest of the GSM system. The NSS has the responsibility of managing communications and connecting MSs to the relevant networks or other MSs. The NSS is not in direct contact with the MSs. Neither is the BSS in direct contact with external networks. The MS, BSS, and NSS form the operational part of the GSM system. The OSS provides means for a service provider to control and manage the GSM system. In the GSM, interaction between the subsystems can be grouped in two main parts:

Operational: External networks to/from NSS to/from BSS to/from MS to/from subscriber

Control: OSS to/from service provider

The operational part provides transmission paths and establishes them. The control part interacts with the traffic-handling activity of the operational part by monitoring and modifying it to maintain or improve its functions.



BSS: Base Station Subsystem
NSS: Network and Switching Subsystem
OSS: Operational Subsystem
MS: Mobile Station

Figure 2.4 GSM Subsystems

2.2.1 Mobile Station

The MS consists of the physical equipment used by the subscriber to access a PLMN for offered telecommunication services. Functionally, the MS includes a Mobile Termination (MT) and, depending on the services it can support, various Terminal Equipment (TE), and combinations of TE and Terminal Adaptor (TA) functions (the TA acts as a gateway between the TE and the MT) (see Figure 2.6). Various types of MS, such as the vehicle-mounted station, portable station, or handheld station, are used.

The MSs come in five power classes which define the maximum RF power level that the unit can transmit. Tables 2.1 and 2.2 provide the details of maximum RF power for various classes in GSM and DCS-1800. Vehicular and portable units can be either class I or class II, whereas handheld units can be class III, IV, and V. The typical classes are II and V. Table 2.3 provides the details of maximum RF power for GSM and DCS-1800 micro-BSs.

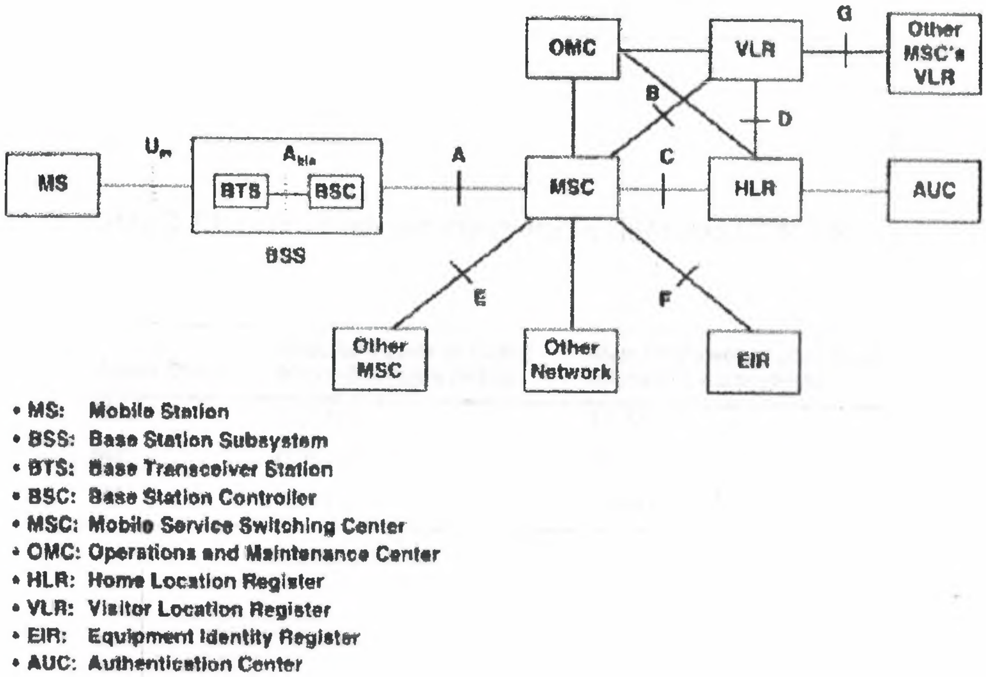


Figure 2.5 GSM Reference Model

Table 2.1 Maximum RF Power for MS in GSM

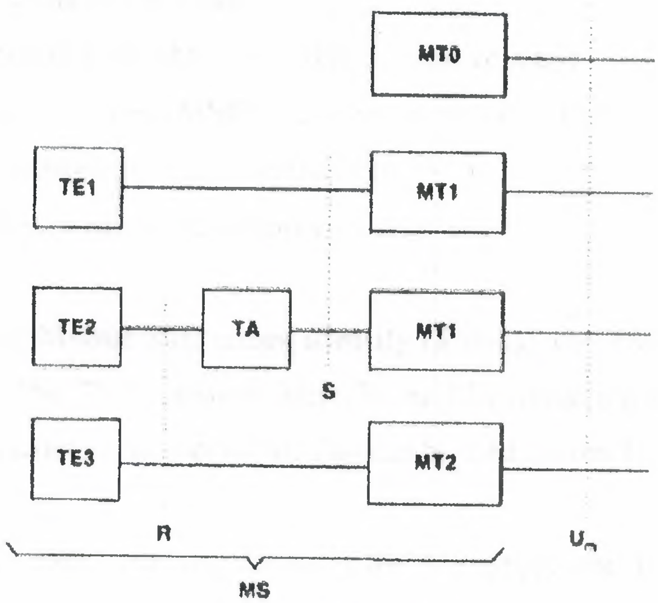
Class	MS Max. RF Power (watts)
I	20 (not currently implemented)
II	8
III	5
IV	2
V	0.8

Table 2.2 Power Level in DCS-1800

Power Class	Max. MS RF Power watts (dBm)	Max. BS RF Power watts (dBm)
1	1 (30)	20 (43)
2	0.25 (24)	10 (40)
3		5 (37)
4		2.5 (34)

Table 2.3 Power Levels for Micro-BS in GSM and DCS-1800

Power Class	Max. RF Power of GSM Micro-BS, watts (dBm)	Max. RF Power of DCS-1800 Micro-BS, watts (dBm)
M1	0.25 (24)	1.6 (32)
M2	0.08 (19)	0.5 (27)
M3	0.03 (14)	0.16 (22)



MT: Mobile Termination
TE: Terminal Equipment
TA: Terminal Adaptor

Figure 2.6 Types of MSs

Basically, an MS can be divided into two parts. The first part contains the hardware and software to support radio and human interface functions. The second part contains terminal/user-specific data in the form of a smart card, which can effectively be considered a sort of logical terminal. The SIM card plugs into the first part of the MS and remains in for the duration of use. Without the SIM card, the MS is not associated with any user and cannot make or receive calls (except possibly an emergency call if the network allows). The SIM card is issued by the mobile service provider after subscription, while the first part of the MS would be available at retail shops to buy or rent. This type of SIM card mobility is analogous to terminal mobility, but provides a personal-mobility-like service within the GSM mobile network.

An MS has a number of identities including the International Mobile Equipment Identity (IMEI), the International Mobile Subscriber Identity (IMSI), and the ISDN number. The IMSI is stored in the SIM. The SIM card contains all the subscriber-related information stored on the user's side of the radio interface.

IMSI: The IMSI is assigned to an MS at subscription time. It uniquely identifies a given MS. The IMSI will be transmitted over the radio interface only if necessary. The IMSI contains 15 digits and includes

- Mobile Country Code (MCC)—3 digits (home country)
- Mobile Network Code (MNC)—2 digits (home GSM PLMN)
- Mobile Subscriber Identification (MSIN)
- National Mobile Subscriber Identity (NMSI)

Temporary Mobile Subscriber Identity (TMSI): The TMSI is assigned to an MS by the VLR. The TMSI uniquely identifies an MS within the area controlled by a given VLR. The maximum number of bits that can be used for the TMSI is 32.

IMEI: The IMEI uniquely identifies the MS equipment. It is assigned by the equipment manufacturer. The IMEI contains 15 digits and carries

- The Type Approval Code (TAC)—6 digits
- The Final Assembly Code (FAC)—2 digits
- The serial number (SN)— 6 digits

- A Spare (SP)—1 digit

SIM: The SIM carries the following information:

- IMSI
- Authentication Key (K i)
- Subscriber information
- Access control class
- Cipher Key (K c) * (updated by the network)
- TMSI *
- Additional GSM services *
- Location Area Identity (LAI) *
- Forbidden PLMN

In some of the newer applications (data communications in particular), an MS can also be a terminal that acts as a GSM interface, e.g. for a laptop computer. In this new application the MS does not look like a normal GSM telephone. The seemingly low price of a mobile phone can give the (false) impression that the product is not of high quality. Besides providing a transceiver (TRX) for transmission and reception of voice and data, the mobile also performs a number of very demanding tasks such as authentication, handover, encoding and channel encoding.

The Authentification Center (AuC) is the network sub-system register which contains all the password numbers in the customer's SIM card, which is used for authentification and securuty over the network.

One of the main reasons why cell-phones can be so small and still have enough power to remain on standby for so long is that they use a receiving method known as Discontinuous Receive (DRX). This allows the mobile to only listen to paging signals when they are emitted by a known paging cycle of the network. The phones are not continuously checking for signals and use one tenth of the power requirements they would need therefore.

The mobile station is the formal name for what represents, for most people, their actual cell-phone and a smart card called the Subscriber Identity Module (SIM). Other examples of mobile stations are car-phones and transportable units. The SIM card can be regarded as separate from the actual terminal as a user can insert the card into another terminal, receive calls from there, and reap the full access of other subscribed services. The SIM card provides for greater security and renders theft futile as it may contain a user password or personal identity number. The terminal itself is uniquely identified by the International Mobile Equipment Identity (IMEI), which is similar in idea as the unique number a printer, say, has as a part of a computer network.

A Mobile Station consists of two main elements:

- The mobile equipment or terminal.
- The Subscriber Identity Module (SIM).

a) The Terminal

There are different types of terminals distinguished principally by their power and application: The `fixed' terminals are the ones installed in cars. Their maximum allowed output power is 20 W. The GSM portable terminals can also be installed in vehicles. Their maximum allowed output power is 8W.

The handheld terminals have experienced the biggest success thanks to their weight and volume, which are continuously decreasing. These terminals can emit up to 2 W. The evolution of technologies allows to decrease the maximum allowed power to 0.8 W.

b) The SIM

The SIM is a smart card that identifies the terminal. By inserting the SIM card into the terminal, the user can have access to all the subscribed services. Without the SIM card, the terminal is not operational. A four-digit Personal Identification Number (PIN) protects the SIM card. In order to identify the subscriber to the system, the SIM card contains some parameters of the user such as its International Mobile Subscriber

Identity (IMSI). Another advantage of the SIM card is the mobility of the users. In fact, the only element that personalizes a terminal is the SIM card. Therefore, the user can have access to its subscribed services in any terminal using its SIM card.

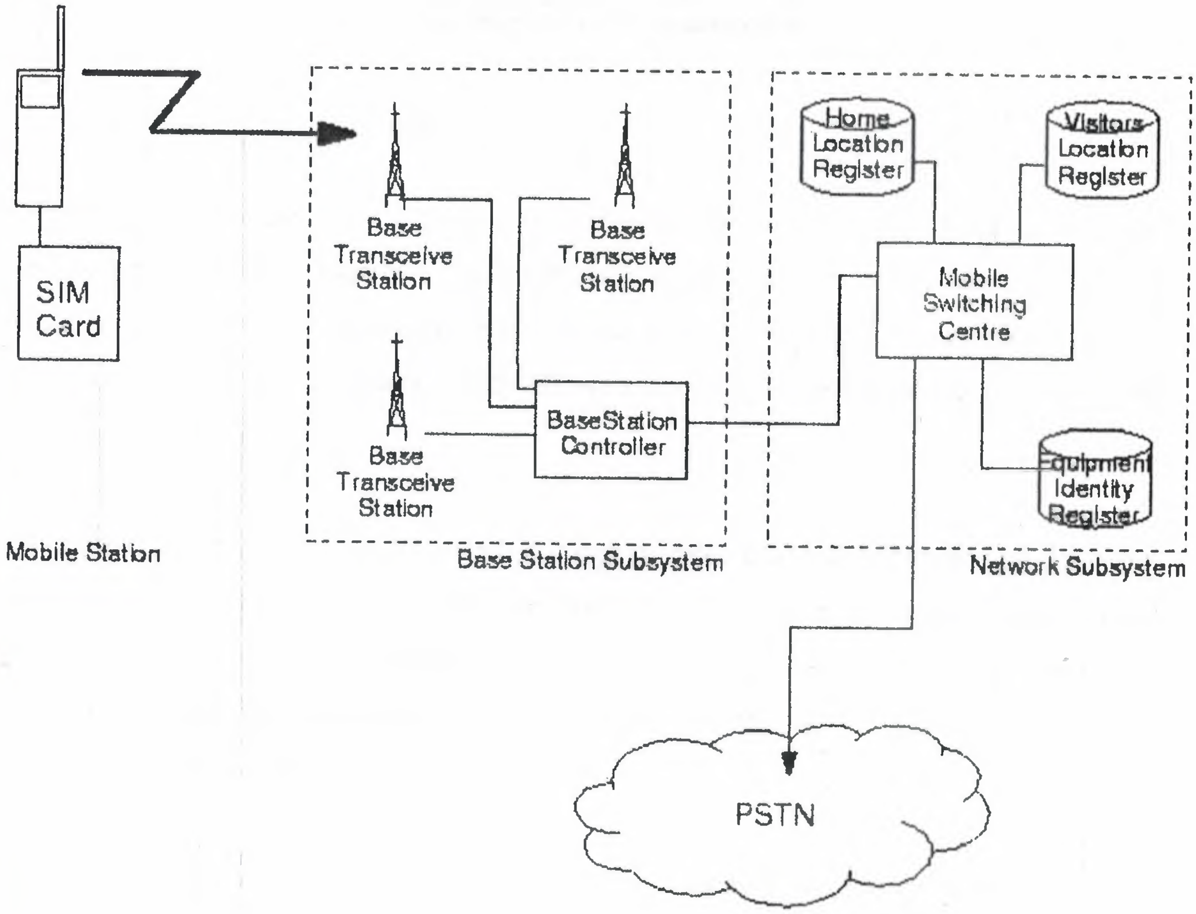


Figure 2.7 Overview of a GSM Mobile Network

2.2.2 Base Station Subsystem

All radio-related functions are performed in the BSS, which consists of base station controllers (BSCs) and the base transceiver stations (BTSs).

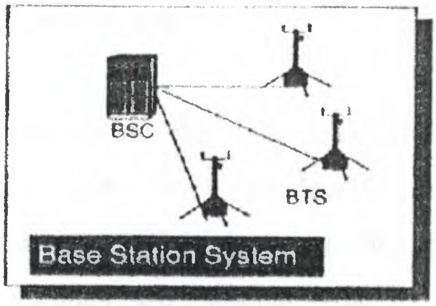


Figure 2.8 Base Station System

When a call is made from a mobile, the terminal searches for a local base station to connect to. A Base Station Sub-system is made up of two parts – the Base Transceiver Station (BTS) and the Base Station Controller (BSC). They both communicate across the standardized Abis interface, which allows a network to be composed of parts from different suppliers.

The Base-Transceiver Stations provide for one or more channels per radio cell. Its main job is to handle the radio-link protocols with the Mobile Station. It provides the two lowest layers of the radio interface, and so provides an error-corrected data path. At least one of the channels is used to carry control signals, which insure that the data arrives correctly at the destination.

The Base Station Controller manages the radio resources for one or more BTSs and operates within a particular region. Its main functions are to handle radio-channel setup, control frequency hopping, undertake handovers (except to cells outside its region) and provide radio performance measurements. The BSC is the connection between the mobile station and the Mobile Services Switching Center (MSC). Once the mobile has been successfully connected to a BTS, the BSC will set up a bi-directional signaling channel specifically for itself and it will connect it on to the MSC.

The BSS connects the Mobile Station and the NSS. It is in charge of the transmission and reception. The BSS can be divided into two parts:

- The Base Transceiver Station (BTS) or Base Station.
- The Base Station Controller (BSC).

The BSC also translates the 13 kbps voice channel used over the radio link to the standard 64 kbps channel used by the Public Switched Telephone Network or ISDN.

The BSC provides all the control functions and physical links between the MSC and BTS. It is a high-capacity switch that provides functions such as handover, cell configuration data, and control of radio frequency (RF) power levels in base transceiver stations. A number of BSCs are served by an MSC. Once the mobile has been successfully connected to a BTS, the BSC will set up a bi-directional signaling channel specifically for itself and it will connect it on to the MSC.

The BSC controls a group of BTS and manages their radio resources. A BSC is principally in charge of handovers, frequency hopping, exchange functions and control of the radio frequency power levels of the BTSs.

c) RBS200

The RBS 200 Base Station family was the first base station developed in the early 1990's. It exists only in the GSM 900/1800 product line. The RBS 200/204 is the GSM 900 BTS, and the RBS 205 is the BTS supporting GSM 1800.

d) RBS 2000

The RBS 2000 Base Station family is the second generation of base stations and can be used for GSM 900/1800 and GSM 1900.
There are six different models in the series:

- RBS 2101 with 2 Transceiver Units (TRUs)
- RBS 2102 and 2202 with 6 TRUs
- RBS 2103 (GSM 900 only) with 6 TRUs and smaller footprint
- RBS 2301 is the micro-base station
- RBS 2302 is the micro-base station supporting Maxite™
- RBS 2401 is the first dedicated indoor radio base station
- All models are outdoor versions except RBS 2202 and RBS 2401.

2.2.3 Network and Switching Subsystem

The NSS includes the main switching functions of GSM, data-bases required for the subscribers, and mobility management. Its main role is to manage the communications between GSM and other network users. Within the NSS, the switching functions are performed by the MSC. Subscriber information relevant to provisioning of services is kept in the HLR. The other database in the NSS is the VLR.

The MSC performs the necessary switching functions required for the MSs located in an associated geographical area, called an MSC area (see Figure 2.9).

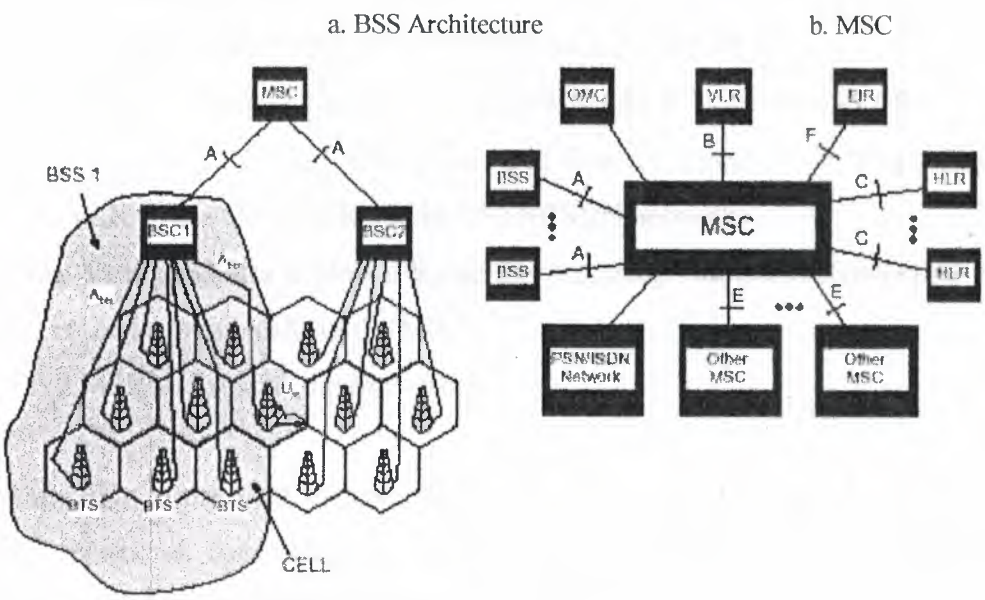


Figure 2.9 MSC Area in GSM

The MSC monitors the mobility of its subscribers and manages necessary resources required to handle and update the location registration procedures and to carry out the handover functions. The MSC is involved in the interworking functions to communicate with other networks such as PSTN and ISDN. The interworking functions of the MSC depend upon the type of the network to which it is connected and the type of service to be performed. The call routing and control and echo control functions are also performed by the MSC.

The HLR is the functional unit used for management of mobile subscribers. The number of HLRs in a PLMN varies with the characteristics of the PLMN. Two types of information are stored in the HLR: subscriber information and part of the mobile information to allow incoming calls to be routed to the MSC for the particular MS. Any administrative action by the service provider on subscriber data is performed in the HLR. The HLR stores IMSI, MS ISDN number, VLR address, and subscriber data (e.g., supplementary services).

The VLR is linked to one or more MSCs. The VLR is the functional unit that dynamically stores subscriber information when the subscriber is located in the area covered by the VLR. When a roaming MS enters an MSC area, the MSC informs the associated VLR about the MS; the MS goes through a registration procedure. The registration procedure for the MS includes these activities:

- The VLR recognizes that the MS is from another PLMN.
- If roaming is allowed, the VLR finds the MS's HLR in its home PLMN.
- The VLR constructs a Global Title (GT) from the IMSI to allow signaling from the VLR to the MS's HLR via the PSTN/ISDN networks.
- The VLR generates a Mobile Subscriber Roaming Number (MSRN) that is used to route incoming calls to the MS.
- The MSRN is sent to the MS's HLR.

The information in the VLR includes MSRN, TMSI, the location area in which the MS has been registered, data related to supplementary service, MS ISDN number, IMSI, HLR address or GT, and local MS identity, if used.

The NSS contains more than MSCs, HLRs, and VLRs. In order to deliver an incoming call to a GSM user, the call is first routed to a gateway switch, referred to as the Gateway Mobile Service Switching Center (GMSC). The GMSC is responsible for collecting the location information and routing the call to the MSC through which the subscriber can obtain service at that instant (i.e., the visited MSC). The GMSC first finds the right HLR from the directory number of the GSM subscriber and interrogates it. The GMSC has an interface with external networks for which it provides gateway function, as well as with the SS7 signaling network for interworking with other NSS entities.

The central component of the Network Subsystem is the Mobile services Switching Center (MSC). It acts like a normal switching node of the PSTN or ISDN, and additionally provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber. These services are provided in conjunction with several functional entities, which together form the Network Subsystem. The MSC provides the connection to the fixed networks (such as the PSTN or ISDN). Signaling between functional entities in the Network Subsystem uses Signaling System Number 7 (SS7), used for trunk signaling in ISDN and widely used in current public networks.

The Home Location Register (HLR) and Visitor Location Register (VLR), together with the MSC, provide the call-routing and roaming capabilities of GSM. The HLR contains all the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the mobile. The location of the mobile is typically in the form of the signaling address of the VLR associated with the mobile station. There is logically one HLR per GSM network, although it may be implemented as a distributed database.

The Visitor Location Register (VLR) contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. Although each functional entity can be implemented as an independent unit, all manufacturers of switching equipment to date implement the VLR together with the MSC, so that the geographical area controlled by the MSC corresponds to that controlled by the VLR, thus simplifying the signaling required. Note that; the MSC contains no information about particular mobile stations; this information is stored in the location registers.

The other two registers are used for authentication and security purposes. The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where its International Mobile Equipment Identity (IMEI) identifies each mobile station. An IMEI is marked as invalid if it has been reported stolen or is not type approved. The Authentication Center (AUC) is a protected database that stores a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and encryption over the radio channel.

The OSS supports one or several Operation Maintenance Centers (OMC), which are used to monitor and maintain the performance of each MS, BS, BSC, and MSC within a GSM system. The switching system (SS) is responsible for performing call processing and subscriber-related functions.

The Home Location Register (HLR) and the Visitor Location Register (VLR) handle call routing and roaming. 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 also includes data bases needed in order to store information about the subscribers and to manage their mobility. The different components of the NSS are described below.

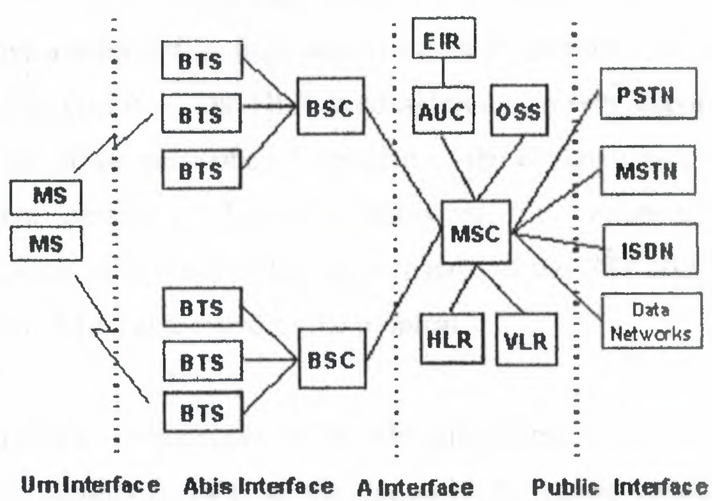


Figure 2.10 Components of the NSS

a) The Switching System

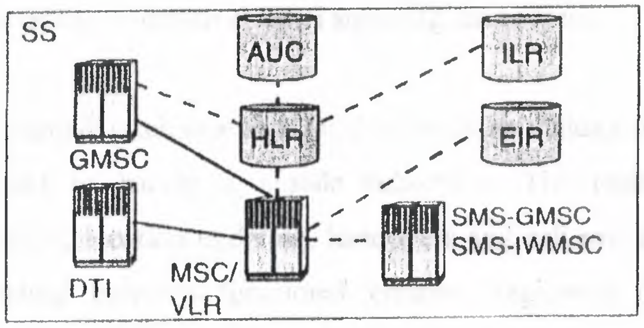


Figure 2.11 Switching System

- **Home Location Register (HLR):**

The HLR is a database used for storage and management of subscriptions. The HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status. When an individual buys a subscription from one of the PCS operators, he or she is registered in the HLR of that operator. The HLR is considered as a very important database that stores information of the subscribers belonging to the covering area of a MSC. It also stores the current location of these subscribers and the services to which they have access. The location of the subscriber corresponds to the SS7 address of the Visitor Location Register (VLR) associated to the terminal.

A database used for management of mobile subscribers. It stores the international mobile subscriber identity (IMSI), mobile station ISDN number (MSISDN) and current visitor location register (VLR) address. The main information stored there concerns the location of each mobile station in order to be able to route calls to the mobile subscribers managed by each HLR. The HLR also maintains the services associated with each MS. One HLR can serve several MSCs.

- **The Mobile services Switching Center (MSC):**

The MSC performs the telephony switching functions of the system. It controls calls to and from other telephone and data systems. It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others.

The MSC acts like a standard exchange in a fixed network and additionally provides all the functionality needed to handle a mobile subscriber. The main functions are registration, authentication, location updating, handovers and call routing to a roaming subscriber. The signaling between functional entities (registers) in the network subsystem uses Signaling System 7 (SS7). If the MSC also has a gateway function for communicating with other networks, it is called Gateway MSC (GMSC).

- **Visitor Location Register (VLR):**

Contains the current location of the MS and selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. A VLR is connected to one MSC and is normally integrated into the MSC's hardware.

The VLR contains information from a subscriber's HLR necessary in order to provide the subscribed services to visiting users. When a subscriber enters the covering area of a new MSC, the VLR associated to this MSC will request information about the new subscriber to its corresponding HLR. The VLR will then have enough information in order to assure the subscribed services without needing to ask the HLR each time a communication is established. The VLR is always implemented together with a MSC; so the area under control of the MSC is also the area under control of the VLR.

- **The Authentication Center (AUC):**

A unit called the AUC provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call. The AUC protects network operators from different types of fraud found in today's cellular world. The AUC register is used for security purposes.

The Authentication Center is the network subsystem register, which contains all the password numbers in the customer's SIM card, which is used for authentication and security over the network.

Authentication verifies a mobile customer with a complex challenge and reply routine. The network sends a randomly generated number to the mobile. The mobile then performs a calculation against it with a number it has stored in its SIM and sends the result back. Only if the switch gets the number it expects does the call proceed. The AC stores all data needed to authenticate a call and to then encrypt both voice traffic and signaling messages.

One of the main reasons why cell-phones can be so small and still have enough power to remain on standby for so long is that they use a receiving method known as Discontinuous Receive (DRX). This allows the mobile to only listen to paging signals when they are emitted by a known paging cycle of the network. The phones are not continuously checking for signals and use one tenth of the power requirements they would need therefore.

- **The Equipment Identity Register (EIR):**

The EIR is a database that contains information about the identity of mobile equipment that prevents calls from stolen, unauthorized, or defective mobile stations. The AUC and EIR are implemented as stand-alone nodes or as a combined AUC/EIR node.

The EIR is also used for security purposes. It is a register containing information about the mobile equipments. More particularly, it contains a list of all valid terminals. Its International Mobile Equipment Identity (IMEI) identifies a terminal. The EIR allows then to forbid calls from stolen or unauthorized terminals (e.g., a terminal which does not respect the specifications concerning the output RF power).

The EIR has three databases:

1-White list: for all known, good IMEIs

2-Black list: for bad or stolen handsets

3-Grey list: for handsets/IMEIs that are uncertain

- **Interworking Location Register (ILR):**

Around the world there are market demands for roaming capabilities with GSM. The ILR is the node that forwards roaming information between cellular networks using different operating standards. This currently exists only in the GSM 1900 network.

b) Additional Functional Elements

- **Message Center (MXE):**

The MXE is a node that provides integrated voice, fax, and data messaging. Specifically, the MXE handles short message service, cell broadcast, voice mail, fax mail, e-mail, and notification.

- **Mobile Service Node (MSN):**

The MSN is the node that handles the mobile intelligent network (IN) services.

- **The Gateway Mobile services Switching Center (GMSC):**

A gateway is a node interconnecting two networks. The GMSC is the interface between the mobile cellular network and the PSTN. It is in charge of routing calls from the fixed network towards a GSM user. The GMSC is often implemented in the same machines as the MSC.

- **Short Message Service - Gateway MSC (SMS-GMSC):**

A Short Message Service Gateway MSC (SMS-GMSC) is capable of receiving a short message from a Service Center (SC), interrogating an HLR for routing information and message waiting data, and delivering the short message to the MSC of the recipient MS. The SMS-GMSC functionality is normally integrated in an MSC/VLR node.

- **Short Message Service - InterWorking MSC (SMS-IWMSC):**

A Short Message Service InterWorking MSC (SMS-IWMSC) is capable of receiving a mobile originated short message from the MSC or an ALERT message from the HLR and submitting the message to the recipient SC. The SMS-IWMSC functionality is normally integrated in the MSC/VLR node.

- **Data Transmission Interface (DTI):**

DTI - consisting of both hardware and software - provides an interface to various networks for data communication. Through DTI, users can alternate between speech and data during the same call. Its main functions include a modem and fax adapter pool and the ability to perform rale adaptation. It was earlier implemented as the OSM InterWorking Unit (GIWU).

- **The GSM Interworking Unit (GIWU):**

The GIWU consists of both hardware and software that provides an interface to various networks for data communications. Through the GIWU, users can alternate between speech and data during the same call. The GIWU hardware equipment is physically located at the MSC/VLR.

The GIWU corresponds to an interface to various networks for data communications. During these communications, the transmission of speech and data can be alternated.

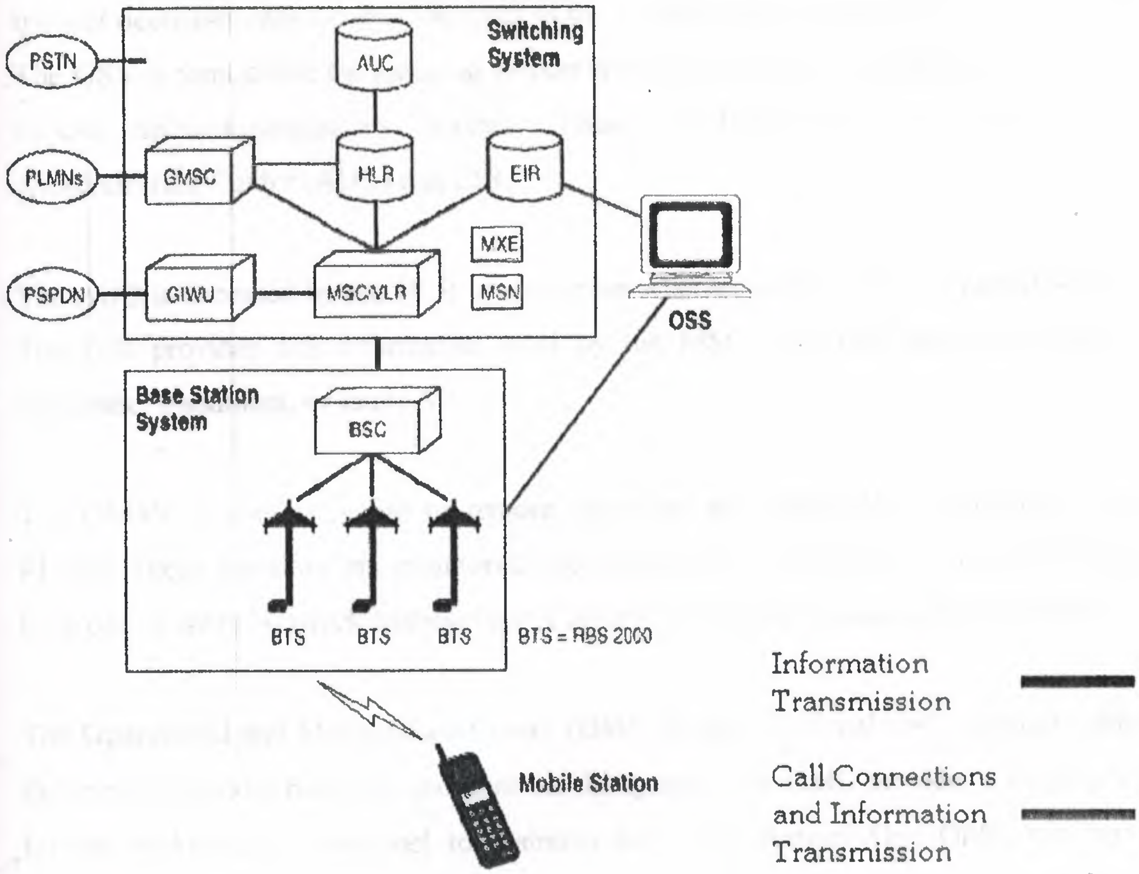


Figure 2.12 GSM Network Elements

2.2.4 Operation and Support Subsystem (OSS)

The operations and maintenance center (OMC) is connected to all equipment in the switching system and to the BSC. The implementation of OMC is called the operation and support system (OSS). The OSS is the functional entity from which the network operator monitors and controls the system. The purpose of OSS is to offer the customer cost-effective support for centralized, regional, and local operational and maintenance activities that are required for a GSM network. An important function of OSS is to provide a network overview and support the maintenance activities of different operation and maintenance organizations. The OSS is connected to the different components of the NSS and to the BSC, in order to control and monitor the GSM system. It is also in charge of controlling the traffic load of the BSS. However, the increasing number of base stations, due to the development of cellular radio networks,

has provoked that some of the maintenance tasks are transferred to the BTS. This transfer decreases considerably the costs of the maintenance of the system.
The OSS is responsible for handling system security based on validation of identities of various telecommunications entities. These functions are performed in the Authentication Center (AUC) and EIR.

The AUC is accessed by the HLR to determine whether an MS will be granted service. The EIR provides MS information used by the MSC. The EIR maintains a list of legitimate, fraudulent, or faulty MSs.

The OMSS is also in charge of remote operation and maintenance functions of the PLMN. These functions are monitored and controlled in the OMSS. The OMSS may have one or more Network Management Centers (NMCs) to centralize PLMN control.

The Operational and Maintenance Center (OMC) is the functional entity through which the service provider monitors and controls the system. The OMC provides a single point for the maintenance personnel to maintain the entire system. One OMC can serve multiple MSCs.

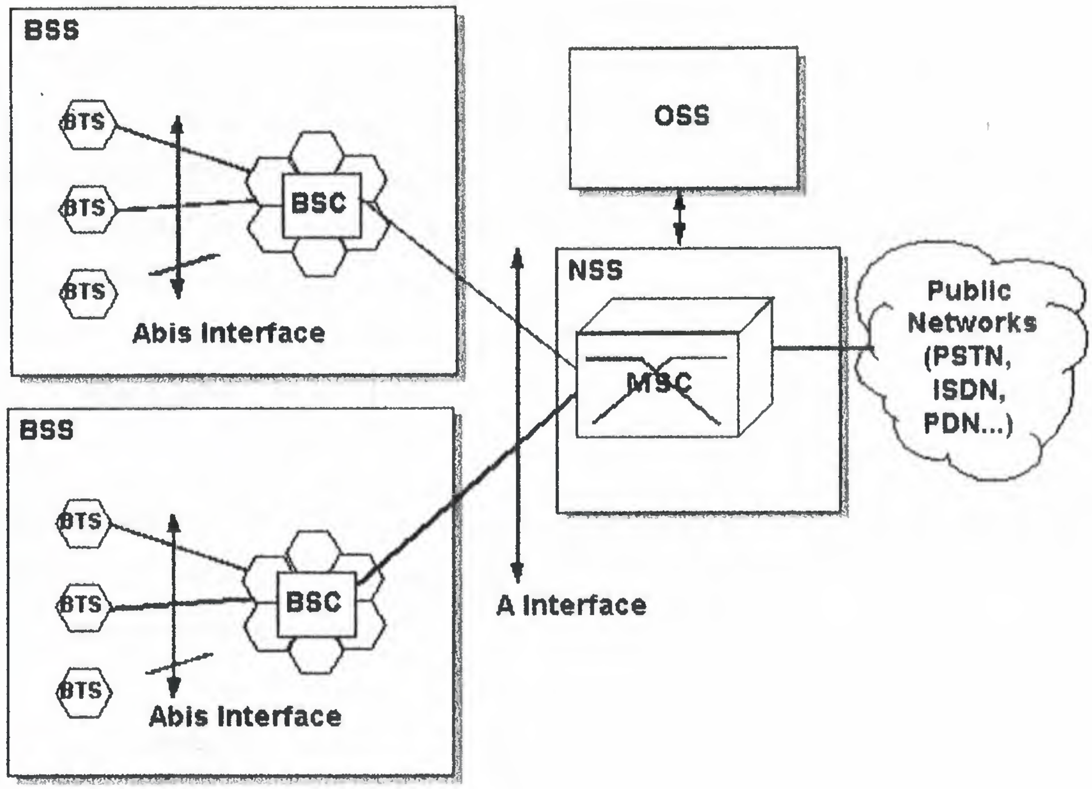


Figure 2.13 Major GSM Components

2. 3. The Geographical Areas of the GSM Network

The Figure 2.14 presents the different areas that form a GSM network.

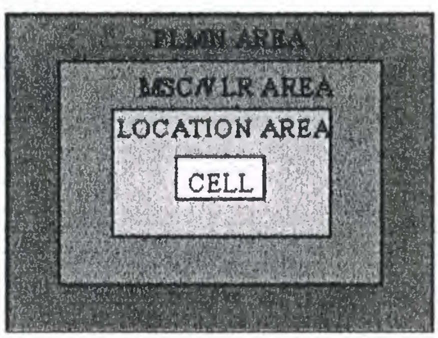


Figure 2.14 GSM Network Areas

As it has already been explained a cell, identified by its Cell Global Identity number (CGI), corresponds to the radio coverage of a base transceiver station. A Location Area (LA), identified by its Location Area Identity (LAI) number, is a group of cells served by a single MSC/VLR. A group of location areas under the control of the same MSC/VLR defines the MSC/VLR area. A Public Land Mobile Network (PLMN) is the area served by one network operator.

2. 4. The GSM Functions

In this paragraph, the description of the GSM network is focused on the different functions to fulfill by the network and not on its physical components. In GSM, four main functions can be defined:

- Transmission.
- Radio Resources management (RR).
- Mobility Management (MM).
- Communication Management (CM).

Ensuring the transmission of voice or data of a given quality over the radio link is only part of the function of a cellular mobile network. A GSM mobile can seamlessly roam nationally and internationally, which requires that registration, authentication, call routing and location updating functions exist and are standardized in GSM networks. In addition, the fact that the geographical area covered by the network is divided into cells necessitates the implementation of a handover mechanism. These functions are performed by the Network Subsystem, mainly using the Mobile Application Part (MAP) built on top of the Signalling System No. 7 (SS7) protocol.

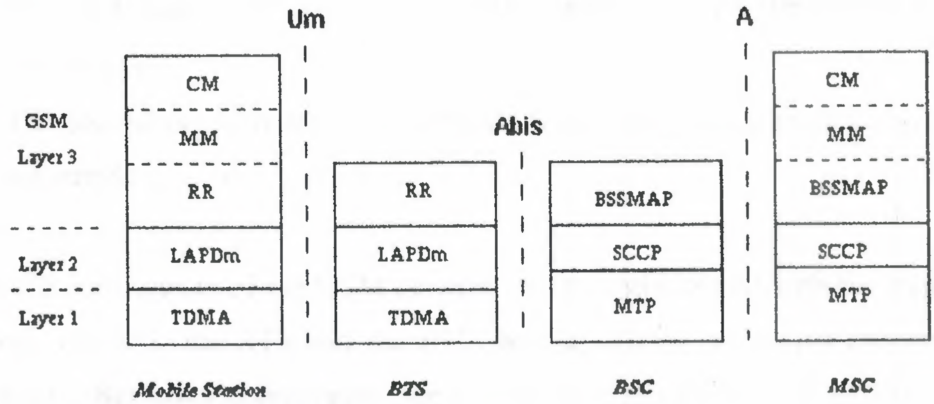


Figure 2.15 Signalling protocol structure in GSM

The signalling protocol in GSM is structured into three general layers, depending on the interface, as shown in Figure 2.16. Layer 1 is the physical layer, which uses the channel structures discussed above over the air interface. Layer 2 is the data link layer. Across the Um interface, the data link layer is a modified version of the LAPD protocol used in ISDN, called LAPDm. Across the A interface, the Message Transfer Part layer 2 of Signalling System Number 7 is used. Layer 3 of the GSM signalling protocol is itself divided into 3 sublayers.

- Radio Resources Management
- Mobility Management
- Communication Management

Signalling between the different entities in the fixed part of the network, such as between the HLR and VLR, is accomplished throught the Mobile Application Part (MAP). MAP is built on top of the Transaction Capabilities Application Part (TCAP, the top layer of Signalling System Number 7. The specification of the MAP is quite complex, and at over 500 pages, it is one of the longest documents in the GSM recommendations.

2.4.1 Transmission

The transmission function includes two sub-functions:

- The first one is related to the means needed for the transmission of user information.
- The second one is related to the means needed for the transmission of signaling information.

Not all the components of the GSM network are strongly related with the transmission functions. The MS, the BTS and the BSC, among others, are deeply concerned with transmission. But other components, such as the registers HLR, VLR or EIR, are only concerned with the transmission for their signaling needs with other components of the GSM network.

2.4.2 Radio Resources Management

The radio resources management (RR) layer oversees the establishment of a link, both radio and fixed, between the mobile station and the MSC. The main functional components involved are the mobile station, and the Base Station Subsystem, as well as the MSC. The RR layer is concerned with the management of an RR-session, which is the time that a mobile is in dedicated mode, as well as the configuration of radio channels including the allocation of dedicated channels.

An RR-session is always initiated by a mobile station through the access procedure, either for an outgoing call, or in response to a paging message. The details of the access and paging procedures, such as when a dedicated channel is actually assigned to the mobile, and the paging sub-channel structure, are handled in the RR layer. In addition, it handles the management of radio features such as power control, discontinuous transmission and reception, and timing advance.

2.4.3 Mobility Management

The Mobility Management layer (MM) is built on top of the RR layer, and handles the functions that arise from the mobility of the subscriber, as well as the authentication and security aspects. Location management is concerned with the procedures that enable the system to know the current location of a powered-on mobile station so that incoming call routing can be completed.

2.4.4 Communication Management

The Communication Management layer (CM) is responsible for Call Control (CC), supplementary service management, and short message service management. Each of these may be considered as a separate sublayer within the CM layer. Call control attempts to follow the ISDN procedures specified in Q.931, although routing to a roaming mobile subscriber is obviously unique to GSM. Other functions of the CC sublayer include call establishment, selection of the type of service (including alternating between services during a call), and call release.

2. 5. Wireless Application Protocol (WAP)

There are three major parts of any WAP-enabled system, namely the WAP Gateway, the HTTP Web Server, and the WAP Device itself, which is interacting with the WAP Gateway, as Figure 2.16 illustrates below. The WAP Gateway sends WML- formatted content to the WAP device, whilst the WAP gateway must communicate with the Web server using the Web's primary protocol, HTTP.

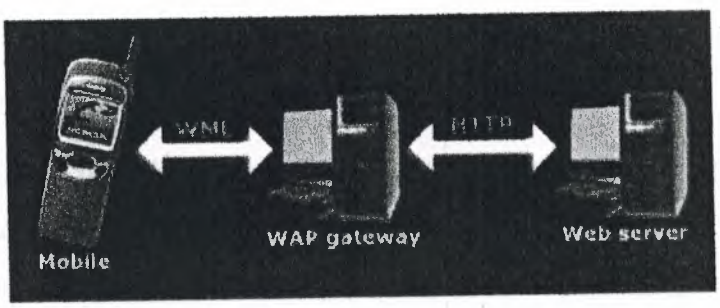


Figure 2.16 WAP-enabled System

All Web servers can communicate with a variety of information sources, using a number of different integration tools and protocols, for example a Web server can serve pages of information that are generated by tools such as Active Server Pages (ASP), ColdFusion, or PHP. Database integration is achieved using protocols such as CGI (the Common Gateway Interface) or, more likely,ODBC, as Figure 2.17 illustrates.

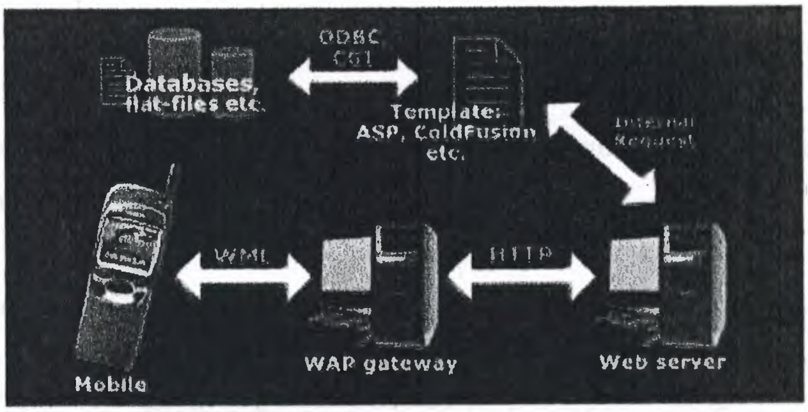


Figure 2.17 Database Integration

The Wireless Application Protocol (WAP) is a hot topic that has been widely hyped in the mobile industry and outside of it. WAP is simply a protocol- a standardized way that a mobile phone talks to a server installed in the mobile phone network. It is amazing how in just six months, it has become imperative for all Information Technology companies in Nordic countries and beyond to have a WAP division. Many many advertising agencies and "dot.coms" have announced WAP services.

WAP is hot for several reasons:

- It provides a standardized way of linking the Internet to mobile phones, thereby linking two of the hottest industries anywhere.
- Its founder members include the major wireless vendors of Nokia, Ericsson and Motorola, plus a newcomer Phone.com.
- By April 2000, the WAP Forum had over 350 member companies.
- Mobile information services, a key application for WAP, have not been as successful as many network operators expected. WAP is seen as a way to rectify this situation.

WAP also has its detractors and controversies:

- It is very difficult to configure WAP phones for new WAP services, with 20 or so different parameters needing to be entered to gain access to a WAP service.
- Compared with the installed base of Short Message Service (SMS) compliant phones, the relative number of handsets supporting WAP is tiny.
- WAP is a protocol that runs on top of an underlying bearer. None of the existing GSM bearers for WAP- the Short Message Service (SMS), Unstructured Supplementary Services Data (USSD) and Circuit Switched Data (CSD) are optimized for WAP.

The WAP standard is incomplete, with key elements such as Push (proactive sending of information to mobile devices) and wireless telephony (updating address reports and the like) included in the WAP 1.2, standardized in late 1999 and first expected to be implemented in the Spring of 2000.

There are many WAP Gateway vendors out there competing against each other with largely the same standardized product. This has led to consolidation such as the pending acquisition of APiON by Phone.com.

Other protocols such as SIM Application Toolkit and Mobile Station Application Execution Environment (MexE) are respectively already widely supported or designed to supercede WAP.

WAP services are expected to be expensive to use since the tendency is to be on-line for a long Circuit Switched Data (CSD) call as features such as interactivity and selection of more information are used by the end user. Without specific tariff initiatives, there are likely to be some surprised WAP users when they see their mobile phone bill for the first time after starting using WAP.

3. THE ARCHITECTURE OF THE CELLULAR MOBILE SYSTEM

3. 1. What is a Cellular Phone System?

No strict definition of a cellular phone system is generally accepted by industry professionals, but most experts would agree that it usually entails the following specific characteristics:

1. Division of heavily populated areas into small regions called cells. In this way, concentrated areas of population can have more transmitting stations;
2. Reducing coverage area yields to reduce the power of transmission and reuse the same frequencies in the different base stations;
3. Special design features that allow transmitters and receivers to operate in a controlled-interference environment;
4. Computer-controlled capabilities to set up automatic hand-offs from base station to base station when the signal-to-noise ratio or transmission distance can be improved to a more acceptable value.

3. 2. The Cellular Concept

Cellular mobile communication is based on the concept of frequency reuse. That is, the limited spectrum allocated to the service is partitioned into, for example, N non-overlapping channel sets, which are then assigned in a regular repeated pattern to a hexagonal cell grid. The hexagon is just a convenient idealization that approximates the shape of a circle (the constant signal level contour from an omnidirectional antenna placed at the center) but forms a grid with no gaps or overlaps. The choice of N is dependent on many trade-offs involving the local propagation environment, traffic distribution, and costs. The propagation environment determines the interference received from neighboring co-channel cells which in turn governs the reuse distance, that is, the distance allowed between co-channel cells (cells using the same set of frequency channels).

The cell size determination is usually based on the local traffic distribution and demand. The more the concentration of traffic demand in the area, the smaller the cell has to be sized in order to avail the frequency set to a smaller number of roaming subscribers and thus limit the call blocking probability within the cell. On the other hand, the smaller the cell is sized, the more equipment will be needed in the system as each cell requires the necessary transceiver and switching equipment, known as the base station subsystem (BSS), through which the mobile users access the network over radio links. The degree to which the allocated frequency spectrum is reused over the cellular service area, however, determines the spectrum efficiency in cellular systems. That means the smaller the cell size, and the smaller the number of cells in the reuse geometry, the higher will be the spectrum usage efficiency. Since digital modulation systems can operate with a smaller signal to noise (i.e., signal to interference) ratio for the same service quality, they, in one respect, would allow smaller reuse distance and thus provide higher spectrum efficiency. This is one advantage the digital cellular provides over the older analogue cellular radio communication systems.

It is worth mentioning that the digital systems have commonly used sectored cells with 120-degree or smaller directional antennas to further lower the effective reuse distance. This allows a smaller number of cells in the reuse pattern and makes a larger fraction of the total frequency spectrum available within each cell. Currently, research is being done on implementing other enhancements such as the use of dynamic channel assignment strategies for raising the spectrum efficiency in certain cases, such as high uneven traffic distribution over cells.

3. 3. Cellular Coverage

The major problems with radio distribution arise from electromagnetic wave propagation. As mentioned in the power of radio waves decreases with the inverse of the squared distance (d^{-2}); however, it must be remembered that this applies only in empty space. As a consequence, propagation at ground level in an urban environment with different obstacles is more difficult. A second problem is spectrum scarcity: the number of simultaneous radio communications supported by a base station is therefore limited. Cellular coverage allows a high traffic density in a wide area despite both problems at the expense of infrastructure cost and of complexity. Because of the limited transmission range of the terminals, cellular system is based on a large number of receptions and transmission devices on the infrastructure side (the base stations), which are scattered over the area to cover a small geographical zone called a cell.

3.3.1 Cluster

The cells are grouped into clusters. The number of cells in a cluster must be determined so that the cluster can be repeated continuously within the covering area of an operator. The typical clusters contain 4, 7, 12 or 21 cells. The number of cells in each cluster is very important. The smaller the number of cells per cluster is, the bigger the number of channels per cell will be. The capacity of each cell will be therefore increased. However a balance must be maintained in order to avoid the interference that could occur between neighbouring clusters. This interference is produced by the small size of the clusters (the size of the cluster is defined by the number of cells per cluster). The total number of channels per cell depends on the number of available channels and the type of cluster used. There are following types of cells: macrocells, microcells, selective cells, and umbrella cells.

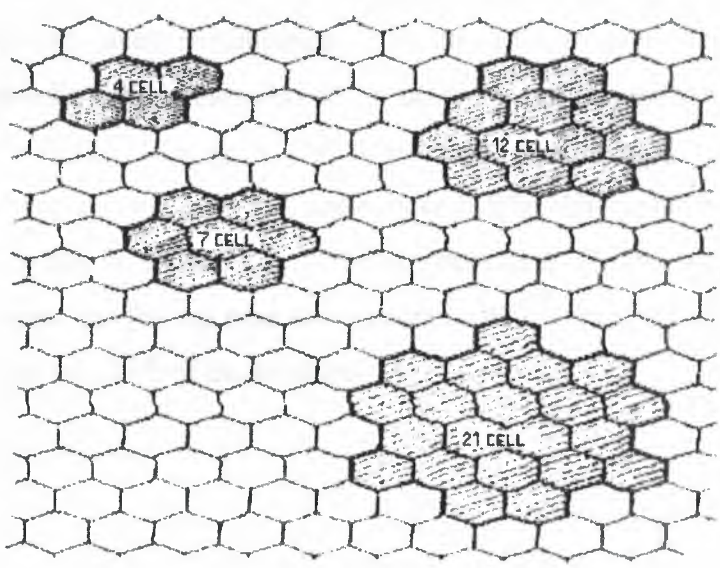


Figure 3.1 Typical clusters

- **Macrocells**

The macrocells are large cells for remote and sparsely populated areas.

- **Microcells**

These cells are used for densely populated areas. By splitting the existing areas into smaller cells, the number of channels available are increased as well as the capacity of the cells. The power level of the transmitters used in these cells is then decreased, reducing the possibility of interference between neighbouring cells.

- **Selective cells**

It is not always useful to define a cell with a full coverage of 360 degrees. In some cases, cells with a particular shape and coverage are needed. These cells are called selective cells. A typical example of selective cells is the cells that may be located at the entrances of tunnels where coverage of 360 degrees is not needed. In this case, a selective cell with coverage of 120 degrees is used.

- **Umbrella cells**

A freeway crossing of very small cells produces an important number of handovers among the different small neighbouring cells. In order to solve this problem, the concept of umbrella cells is introduced. An umbrella cell covers several microcells. The power level inside an umbrella cell is increased comparing to the power levels used in the microcells that form the umbrella cell. When the speed of the mobile is too high, the mobile is handed off to the umbrella cell. The mobile will then stay longer in the same cell (in this case the umbrella cells). This will reduce the number of handovers and the work of the network.

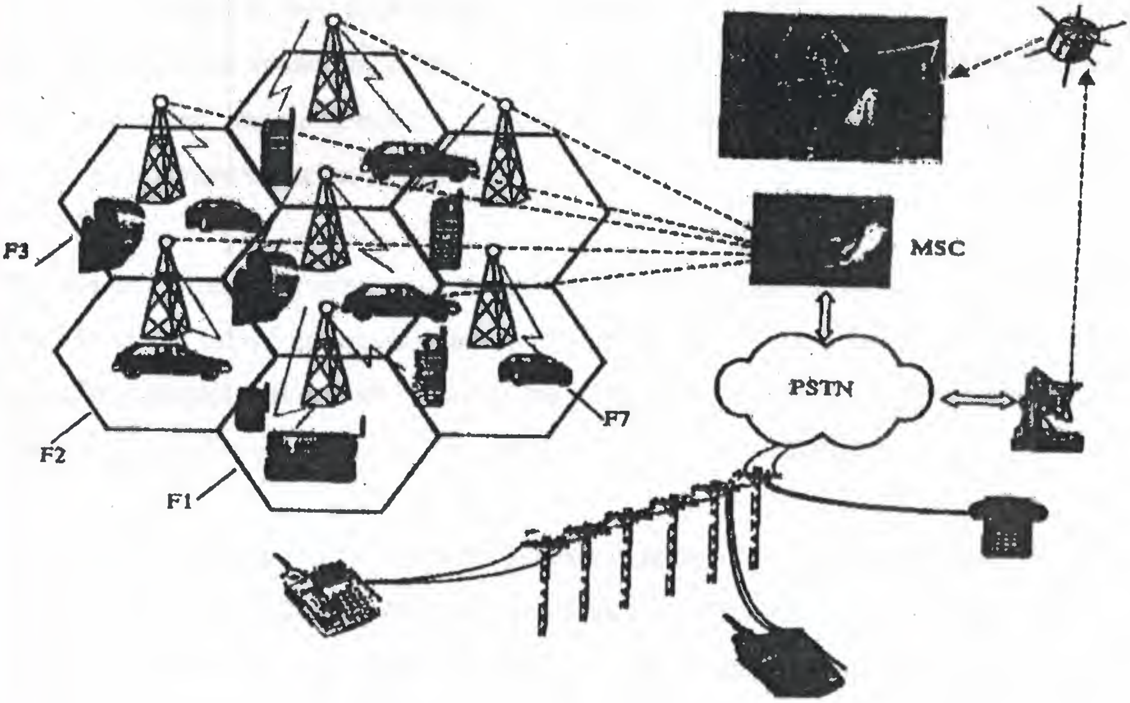


Figure 3.2 The cellular setup

The cells are often represented by hexagons, in order to model the system by paving the plane with a single geometrical figure. Hexagons nicely pave the plane without overlapping and are commonly used for calculating theoretical frequency reuse in cellular system.

At the centre of each hexagonal cell is a base station consisting primarily of a power source, computer-processing devices, and a base antenna. Each of the seven base stations in the Figure 3.2 operates on a different frequency, denoted by Fl, F2,…,F7. In the Global System for Mobile Communication (GSM), the design was aimed at the beginning at medium-sized cells, of a diameter expressed in kilometers or tens of kilometers. Yet, the lower boundary is difficult to determine: cells of more than one kilometer radius should be no problem. Whereas the system may not be fully suitable to cells with a radius below, say 300 meters. One source of limitation is more economics than due to physical laws. The efficiency of the system decreases when cell size is reduced and then the ratio between the expenditure and the traffic increases, and eventually reaches a point where economical considerations call for a halt. Another important point is the capacity of the system to move communication from one cell to another rapidly, and GSM requires longer a time to prepare such a transfer to cope with fast moving users in very small cells. The cell size upper bound is more obvious: The first, non-absolute, limitation in GSM is a range of 35 kilometers. Cells of bigger sizes are possible but require specially designed cell-site equipment and incur some loss in terms of maximum capacity.

The number of sites to cover a given area with a given high traffic density, and hence the cost of the infrastructure, is determined directly by the reuse factor and the number of traffic channels that can be extracted from the available spectrum. These two factors are compounded in what is called the spectral efficiency of system.

Seven cell configurations are used in industry, but so are 3 cell configurations, 4 cell configurations, 12 cell configurations, and even 21 cell configurations. Moreover even when a seven-cell configuration is employed, the signals from the individuals base stations do not span neat and clean hexagonal cells. Neat and clean coverage zones do not exist in the real world because, houses, buildings, and natural barriers together with unavoidable sources of RF interference create coverage regions that are shaped more like amoebas than circles or hexagonal cells. The cellular setup is shown in Figure 3.2.

The mobile units consist of a control unit, a transceiver, and appropriate antennas. The transceiver contains circuits that can tune to any of the 666 FM channels in the 800 MHz range assigned to the cellular system. Each cell site has at least one set up channel dedicated for signalling between the cell and its mobile units. The remaining channels are used for conversation. Each mobile unit is assigned a 10 digit number, identical inform to any other phone number. Callers to the mobile unit will dial the local or long distance number for desired mobile unit. The mobile user will dial 7 or 10 digits with a zero or a one prefix, where applicable, in case of calling from a fixed phone.

Whenever a mobile unit is turn on but not in use, the mobile control unit monitors the data being transmitted on a set up channel selected from among the several standards set up frequencies on the bases of signal strength. If signal strength becomes marginal as the mobile unit approaches a cell boundary, the mobile control finds a setup channel with a stronger signal.

3.3.2 Setting Up a Cellular Phone Call

When a phone call comes into the cellular system, from the conventional Public Switching Telephone Network (PSTN) or from another cellular phone, the computer-based Mobile Switching Centre (MSC) follows the three steps depicted in setting up the proper connection. In step one, an appropriate paging message is directed by MSC to all the Base Stations (BS) [Figure 3.3 (a)]. In the step two, appropriate cellular telephone acknowledges the page by sending digital pulse-train, back to the base station from which a signal came [Figure 3.3 (b)]. In step three, the base station automatically selects and activates a duplex voice channel to handle the call, then signals appropriate cellular phone for transmission and reception [Figure 3.3 (c)].

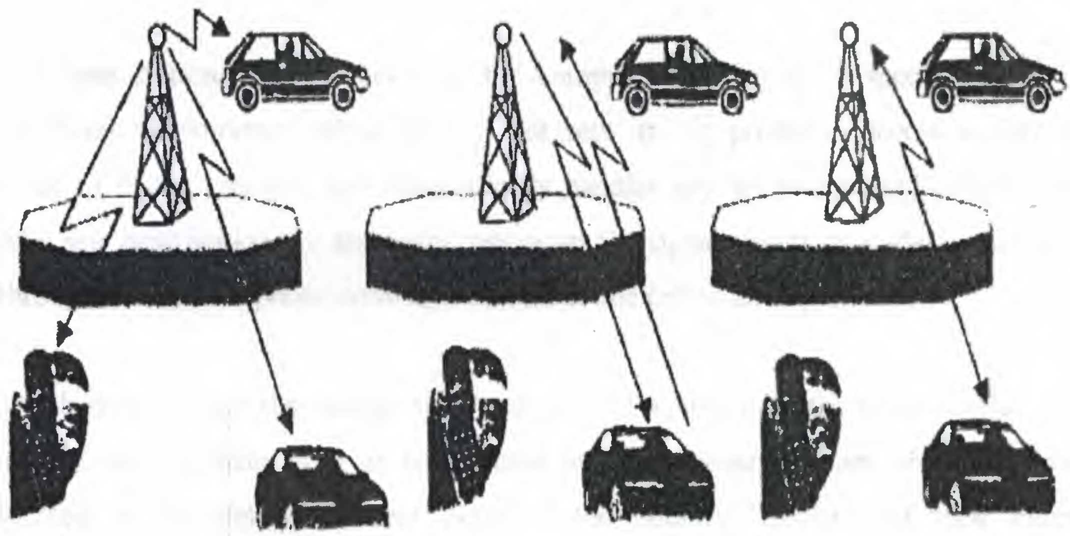


Figure 3.3 Setting up a cellular phone call

3.3.3 Roamers

The system is designed to make handling of roamers automatic. This is the principal goal of the cellular approach. Locating and hand-off are the concept that comes directly from the use of small cells. "Locating" in this sense is not the determination of precise geographic location-although that is obviously a factor. It is the process of determining whether a moving active user should continue to be served by his current channel and transmitter, or "handed off" to either another channel, cell, or both. The decision is made automatically by a computer, based on signal quality and potential interference, and involves sampling the signal from the mobile unit.

The Mobile Switching Centre (MSC) computer continuously analyses signal quality and makes the appropriate changes without any interruption in service.

With the cellular system, a subscriber could make a call from his car while driving in the countryside toward a city, continue through the city's downtown, and not hang up until well beyond the city on the other side. More importantly, the switching of transmitters and frequencies during the conversation would be entirely automatic, with no interruptions and no action required by the user or an operator.

The base stations are connected to the computer-based MSC a specifically designed computer telecommunications facility that sets up the proper connections, keeps the track of billing charges, and automatically handles any necessary hand-offs. Hand-offs to a new base station are attempted whenever the signal quality degrades as users travel through the cellular phone coverage area from one cell to another.

Trunk lines connect the cellular switch to the PSTN, and from the mobile cellular phone system can originate from or be directed toward ordinary phones or cellular phones located in completely different parts of the country. Because of their extensive frequency reuse in a small local area, cellular phone systems can handle a multitude of users. In most urban areas government regulators maintain the proper competitive environment by licensing two separate cellular phone companies, thus giving customers a choice between competitors.

Wherever there is a system to serve it, a roaming unit will be able to obtain a complete automatic service; however a call from a land phone to a mobile unit, which has roamed, to another metropolitan area presents additional problems. It would be technically possible for the system to determine automatically where the mobile unit is, and to connect it automatically to the land party. There are two reasons for not doing so. First, the caller will expect to pay only a local charge if a local number is dialed.

Second, the mobile user may not want to he identified to be at a particular location automatically by the system without an approval. Therefore the system will complete the connection only if the extra charge is agreed to, and when possible to do so without unauthorised disclosure of the service area to which the mobile unit has roamed.

3.3.4 Unique Features

There are two essential elements of the cellular concept, which are unique: frequency reuse and cell splitting.

Frequency reuse means using the same frequency or channel simultaneously for different phone conversations, in the same general geographic area. The idea of having more than one transmission on a given frequency is not new; it is done in virtually all radio services. What are unique to cellular systems-the closeness of the users; two users of the same frequency maybe only a few dozen miles apart, rather than hundreds of miles. This is achieved using relatively low-power transmitters on multiple sites, rather than single high-power transmitter that do this. Each transmitter covers only its own cell, and cells sufficiently far a part can also use the same frequency.

Cell splitting is based on the notion that cell sizes are not fixed and may vary in the same area or over time. The principle of the cell splitting, initially all the cells in an area may be relatively large. When the average number of users in some cells becomes too large to be handled with proper service quality, the overloaded cells are split into smaller cells by adding more transmitters. The same MSC can continue to serve all of the cell sites, but expansion of its computer and switching facilities probably will be required.

Multiple frequency reuse is possible because of the lower transmitter power radiated in each cell, and by not using the same frequency in adjacent cells. The cellular system can be expanded because cell splitting may occur as demand increases.

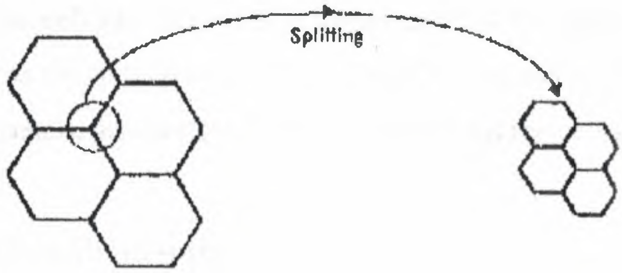


Figure 3.4 Splitting

The spectrum scarcity is circumvented by the reuse of radio resources. Frequencies used in a given cell are reused few cells away, at a distance sufficient enough so that the unavoidable interference created by the close use of the same spectrum which has fallen to an acceptable level. This depends in particular on the transmission method. This concept of frequency reuse is the key capacity. As an example, if the same frequency may be reused in very ninth cell, a spectrum allocation of N frequencies allows N/9 carriers to be used simultaneously in any given cell. The total system throughput can, therefore, be increased by reducing the cell size.

The world's most popular cellular phone system was Advanced Mobile Phone System (AMPS) developed in the United States, and Total Access Cellular System (TACS), developed to serve various European countries.

The American AMPS is an 800 MHz system with 30-kHz channel separations. Each cell handles 832 frequency modulation (FM) channels with digital frequency shift keying for the control-channel modulations. AMPS is presently being used in 37 different countries.

The TACS system operates at 900 MHz with 920 channels separated by 25 kHz. Like the AMPS system. TACS uses FM analog voice-channel modulations with digital frequency shift keying for the control channels.

3.3.5 Cell-site controller

Each cell contains one cell-site controller that operates under the direction of the switching centre. The cell-site controller manages each of the radio channels at the site, supervises calls, turns the radio transmitter and receiver on and off, injects data onto the control and user channels, and performs diagnostic tests on the cell-site equipment.

3. 4. Basic Wireless Principles

3.4.1 Cellular Defined

Four key components make up most cellular radio systems: the cellular layout itself, a carefully engineered network of radio base stations and antennas, base station controllers which manage several base stations at a time, and a mobile switch, which gathers traffic from dozens of cells and passes it on to the public switched telephone network.

All analog and digital mobiles use a network of base stations and antennas to cover a large area. The area a base station covers is called a cell, the spot where the base station and antennas are located is called a cell site. Viewed on a figure, the small territory covered by each base station appears like a cell in a honeycomb, hence the name cellular. Cell sizes range from sixth tenths of a mile to thirty miles in radius for cellular (1km to 50km). GSM and PCS use much smaller cells, no more than 6 miles (10km) across. A large carrier may use hundreds of cells.

Each cell site's radio base station uses a computerized 800 or 1900 megahertz transceiver with an antenna to provide coverage. Each base station uses carefully chosen frequencies to reduce interference with neighboring cells. Narrowly directed sites cover tunnels, subways and specific roadways. The area served depends on topography, population, and traffic. In some PCS and GSM systems, a base station hierarchy exists, with pico cells covering building interiors, microcells covering selected outdoor areas, and macrocells providing more extensive coverage to wider areas. See Figure 3.5 below.

The macro cell controls the cells overlaid beneath it. A macro cell often built first to provide coverage and smaller cells built to provide capacity.

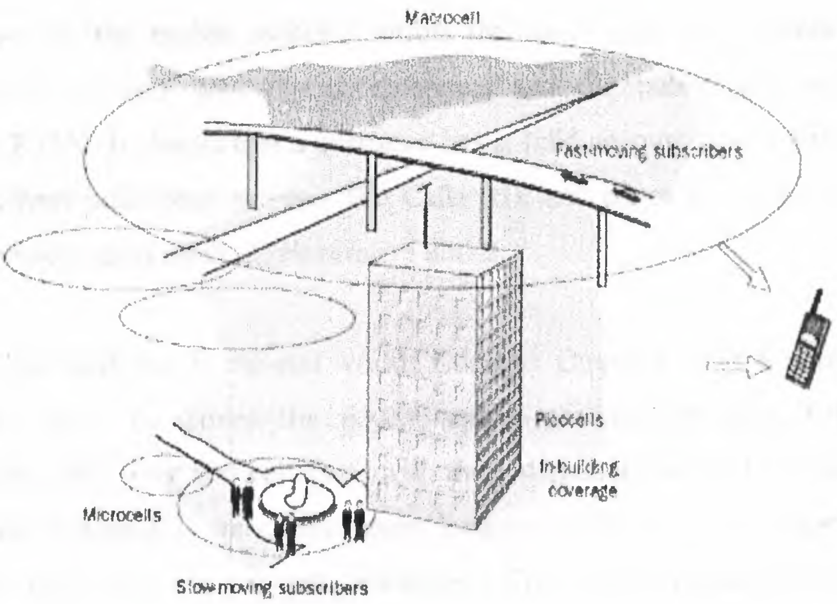


Figure 3.5 Pico cell, Microcell, Macrocell

Figure describes a business park or college campus as a typical situation. In those cases a macrocell provides overall coverage, especially to fast moving mobiles like those in cars. A microcell might provide coverage to slow moving people between large buildings and a piconet might cover an individual lobby or the floor of a convention center.

Typically microcells are employed along the sides of busy highways or on street corners.

Base station equipment by itself is nothing without a means to manage it. In GSM and PCS 1900 that's done by a base station controller or BSC. As Nokia puts it, a base station controller "is a high-capacity switch which provides total overview and control of radio functions, such as handover, management of radio network resources and handling of cell configuration data. It also controls radio frequency power levels in the RBSs, and in the mobile phones. Base station controllers also set transceiver configurations and frequencies for each cell." Depending on the complexity and capacity of a carrier's system, there may be several base station controllers.

These BSCs react and coordinate with a mobile telecommunication switching office or MTSO, sometimes called, too, a MSC or mobile switching center. With AMPS or D-

AMPs, however, the mobile switch controls the entire network. In either case, the mobile switch interacts with distant databases and the public switched telephone network or PSTN. It checks that a customer has a valid account before letting a call go through, delivers subscriber services like Caller ID, and pages the mobile when a call comes in. Among many other administrative duties.

How does this work out in the real world? Consider Omnipoint's PCS network for the greater city area. To cover the 63,000-square-mile service area, Ericsson says Omnipoint installed over 500 cell sites, with their attendant base stations and antennas, three mobile switching centers, one home location register, and one service control point. (The latter two are network resources.) The entire system cost $680 million dollars, although they didn't say if that included Omnipoint's discounted operating license. What makes up a cellular network, let's discuss the idea that makes that makes those networks possible: frequency reuse.

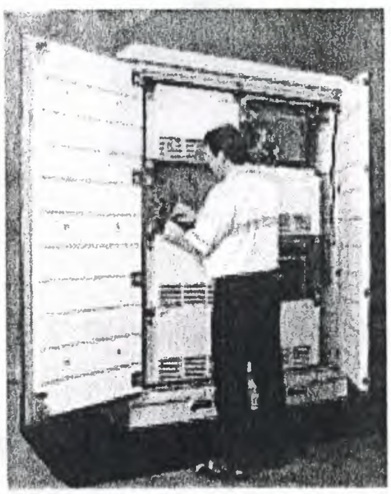


Figure 3.6 Dual band IS-136 Ericsson RBS 884 base station

3.4.2 Frequency reuse

The heart and soul, the inner core, the sine qua non of cellular radio is frequency reuse. The same frequency sets are used and reused systematically throughout a carrier's coverage area. If you have frequency reuse you have cellular. Frequency reuse distinguishes cellular from conventional mobile telephone service, where only a few frequencies are used over a large area, with many customer's competing to use the same channels. Much like a taxi dispatch operation, older style radio telephone service depended on a high powered, centrally located transmitter which paged or called mobiles on just a few frequencies.

Cellular instead relies on a distributed network of cells, each cell site with its own antenna and radio equipment, using low power to communicate with the mobile. In each cell the same frequency sets are used as in other cells. But the cells with those same frequencies are spaced many miles apart to reduce interference. Thus, in a 21 cell system a single frequency may be used several times. The lone, important exception to this are CDMA systems. In those, the same frequencies are used by every cell.

Each base station, in addition, controls a mobile's power output, keeping it low enough to complete a circuit while not high enough to skip over to another cell.

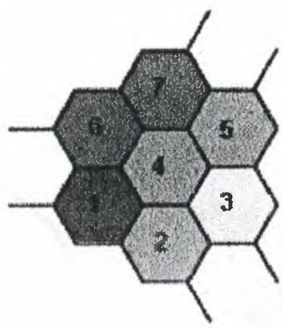


Figure 3.7 Cells with different set of channels

The frequency reuse concept. Each honeycomb represents a cell. Each number represents a different set of channels or paired frequencies. A cellular system separates each cell that shares the same channel set. This minimizes interference while letting the same frequencies be used in another part of the system. This is frequency reuse. Note, though, that CDMA based systems can use, in theory, all frequencies in all cells, substantially increasing capacity . For review, a channel is a pair of frequencies, one for transmitting on and one for receiving. Frequencies are described by their place in the radio spectrum, such as 900mHZ, whereas channels are described by numbers, such as channels 334 through 666.

3.4.3 Adding Cells and Cell Sectorizing

Adding cells and sectoring cells allows cellular expansion. Don't have enough circuits in a crowded cell? Too many customers? Then add to that cell by providing smaller cells like micro and pico cells, underneath and controlled by the existing and larger macro cell.By placing these short-range microcells along busy highways or at busy street corners, you effectively reduce the strain on the primary macrosites by a substantial margin.

Splitting a single cell does not mean that it is broken into smaller cells, like a dividing amoebae, but rather into sectors. A previously omnidirectional base station antenna, radiating equally in all directions, is replaced by several directional antennas on the same tower. This "sectorizing" thus divides the previously homogeneous cell into 3 or 6 distinct areas (120 and 60 degrees around the site respectively). Each sector gets its own frequencies to operate on.

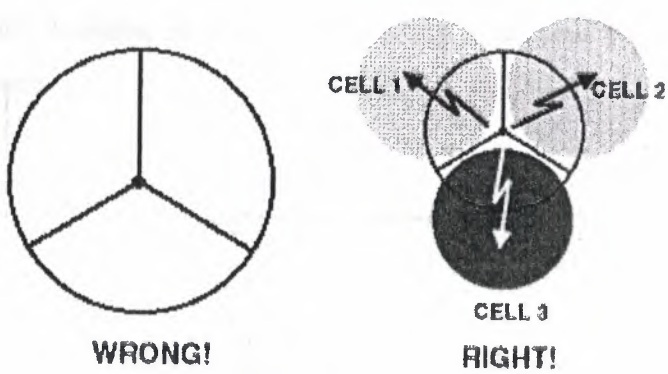


Figure 3.8 A cell site does not lie at the center of a cell, rather it lies at the edge of several cells. The pipe shared pieces represents sectors, cell areas covered by directional antennas at the cell site, using different frequencies than the other sectors and cells.

We sector cells to reduce interference between similar cells in adjacent clusters. Cell splitting is done to increase traffic capacity.

According to Telephony Magazine, AT&T began splitting their macrocell based New York City network in 1994. (They use IS-136 at both 800 and 1900 MHz.) Starting in Midtown Manhattan, the $30 million-plus project added 55 microcells to the three square mile area by 1997, with 10 more on the way. Lower Manhattan got a "few dozen." Microcells in lower Manhattan sought to increase signal quality, while Midtown improvements tried to increase system capacity. An AT&T engineer said "a macrocell costs $500,000 to $1 million to build, a microcell one-third as much and you don't have to build a room around it." AT&T used Ericsson base stations, with plans to use Ericsson 884 base stations as pictured above in the future. Camouflaged antennas got placed on buildings between 25 and 50 feet above street level.

3. 5. Cellular Phone

Cellular phone, or the advanced mobile phone service (AMPS), is a circuit-switched system. It is a means of providing mobile phone service using radio frequency transmission. In a traditional mobile phone system, a radio tower is placed at the centre of a city, and serves mobile vehicles within a radius of 25 to 75 miles. In most areas the number of channels available is around 40, making it possible to serve only a limited number of customers.

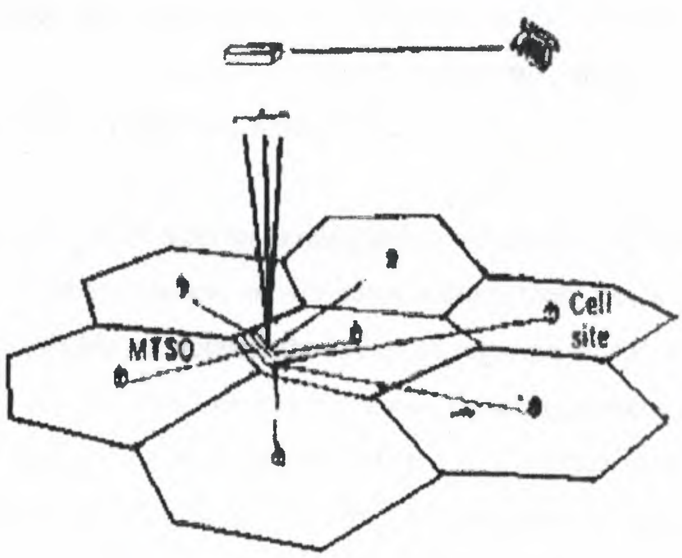


Figure 3.9 The AMPS system with cell sites located at the center each cell

Moreover, the strong signal emitted from the radio tower prevents the use of the same frequencies by radio towers in nearly cities from interference. In the cellular phone system, the total area covered by the system is divided into cells. Each cell has the shape of a hexagon, or a circle, and is served by a cell site. The cell site is an interface between the car phone and the terrestrial public phone network.

A large central controller called the mobile phone switching office (MTSO) controls all cell sites. All cell sites are wires connected to the MTSO.

Radio communications between the mobile vehicle and the cell site employs frequency modulation (FM). The capture effect of FM causes, when two separate transmissions on the same frequency arrive at a receiver, the receiver to suppress the weaker (that is the interfering) signal and detect the stronger signal without significant quality degradation. The AMPS utilises this FM capture effect to increase the efficiency in the use of the radio spectrum by repeating the use of channel frequencies in different cell sites. If two cell sites simultaneously transmit on the same radio channel, a FM receiver tuned to that channel will lock onto the transmitter with the stronger are quite different. However, in an AM system, changes in either the modulation or in the signal level affect the same parameter, amplitude. Therefore under conditions when the mobile receiver is subjected to signal components from more than one transmitter, modulation will be additive in the AM case whereas the situation with receivers is much more complex. Quasi-synchronous, W1 schemes have been found to operate most successfully when the frequency of sets between the transmitters are a few Hz.

The AGC system in an AM receiver is designed to compensate only for variations in the mean signal level and in practice, as will be seen later, these occur relatively slowly. It is considered undesirable to increase the speed of response of the AGC system, as this would have a detrimental effect on any sub-audio signalling systems such as those used for selective calling. Careful matching of the transmitter modulation indices is employed in quasi-synchronous schemes, but the accuracy of matching is not highly critical. Deterioration of performance occurs gradually with mismatch in AM schemes and this significantly eases the task of installatton. In addition, with AM schemes, it is relatively simple to employ “fill-in” base stations to improve coverage in areas where reception would otherwise be very poor. In an area where the receiver is subject to weak signals. The effect of quasi-synchronous operation is to pause a periodic increase in the background noise level at a rate equal to the offset frequency. This has only a minor detrimental effect on speech transmissions, but is potentially more serious when high-speed data is being transmitted over the link.

Quasi-synchronous FM (also known as Simulcast) schemes were initially set up with carrier frequency offsets of a few tens of Hz, which in the early days represented the performance limitation of quartz crystal oscillators. It was assumed that, due to the capture effect inherent in FM receivers.

The mobile would respond only to the strongest signal present and that period of apparently equal signal strength, when capture would not occur. Would be infrequent and would produce few problems. In practice, it was difficult to obtain good performance unless the modulation matching was very carefully undertaken with respect to both amplitude and phase. In addition, steps needed to be taken to avoid even approximately equal strength signals in areas where intelligible communication was required. The difficulties in establishing a successful quasi-synchronous FM scheme were considerable. It was marginally easier at UHF than at VHF, and the overall quality of reception was improved significantly if the frequency offsets were reduced from the few tens of Hz of the early schemes down to a few Hz as in the schemes most recently installed. The careful and accurate modulation matching that was necessary in FM schemes was much more easily achieved when the various transmitters were controlled by radio links rather than by land lines. Generally speaking, dedicated lines are not available, and it is relatively straightforward to match the modulation delay and modulation index over a radio link with adjustment needed only on rare occasions.

3. 6. Alternative Techniques

All base station transmitter use the same channel but are operated sequentially rather than simultaneously. However this apparently simple technique has several disadvantages, since the system operator will not be aware of the location of the mobiles, and a simple vehicle location scheme must therefore be incorporated into the system. This requires selective calling facilities which have been described earlier, and a return path receiver "voting system", to be incorporated. When the operator in a system if this type wishes to initiate a call, each base station in turn transmits the appropriate selective call sequence for the required mobile. On receipt of its call sequence the mobile automatically re-transmits its own sequence (identity) and alerts the driver to the fact that a call is imminent. Each base station receiver that is within range of that particular mobile will then inform the central control point of the system of the strength or quality of the signal that has been received from the mobile, so that the optimum base station site can be selected for that particular mobile phone the receivers "vote" as to which is the best base station site. For calls initiated by the mobile. The driver will normally transmit his selective call sign before initiating a message, and the system will select the optimum base station site in the same manner as before.

This technique which is in common use by message handling organisations that need a selective calling system anyway, provides satisfactory performance in almost all circumstances. In several terms, complexity is its major disadvantage, and its success relies very largely on the skill of the fixed-station operators.

Finally, in UHF (Upper High Frequency:300-3000 MHz, 10Mbps) schemes it is possible to extend the range of coverage, or to fill in areas within the overall coverage area where reception is poor, by the use of "on-frequency" repeaters. These are essentially high-gain amplifiers which receive the signal on one antenna and then retransmit it in a different direction on another antenna. Clearly there are problems. Since any feedback around the system caused by pick-up between one antenna and the other are likely to cause oscillation, and an isolation of about 90 dB is commonly required. This can he achieved at UHF but is not possible at lower frequencies. Generally speaking, on-frequency repeaters are not favoured where other tecniques can be used.

3. 7. Cellular Schemes

The most sophisticated technique in current use for area coverage a cellular scheme. At this point we will merely identify the principle of frequency re-use by which a large area is covered. If a fixed number of radio channels are available for use in a given radio phone system, they can be divided into a number of sets, each set being allocated for use in a given small area (a cell) served by a single base station. It is apparent that the greater the number or channels available in any cell, the more simultaneous phone calls that can he handled. But the smaller the total number of cells in a cluster that uses all the channels. For example, if the total number of channels is 56 than these can be split into 4 groups of 14 or 7 groups of 8, after which the frequencies have to be re-used. Some of the ways in which a fixed number of channels can be grouped to cover a given area are illustrated. Frequency re-use is a fundamental concept in cellular radio systems, but such systems need careful planning to avoid degradation by co-channel interference, i.e. interference with calls in one cell caused by a transmitter in another cell that uses the same set of frequencies.

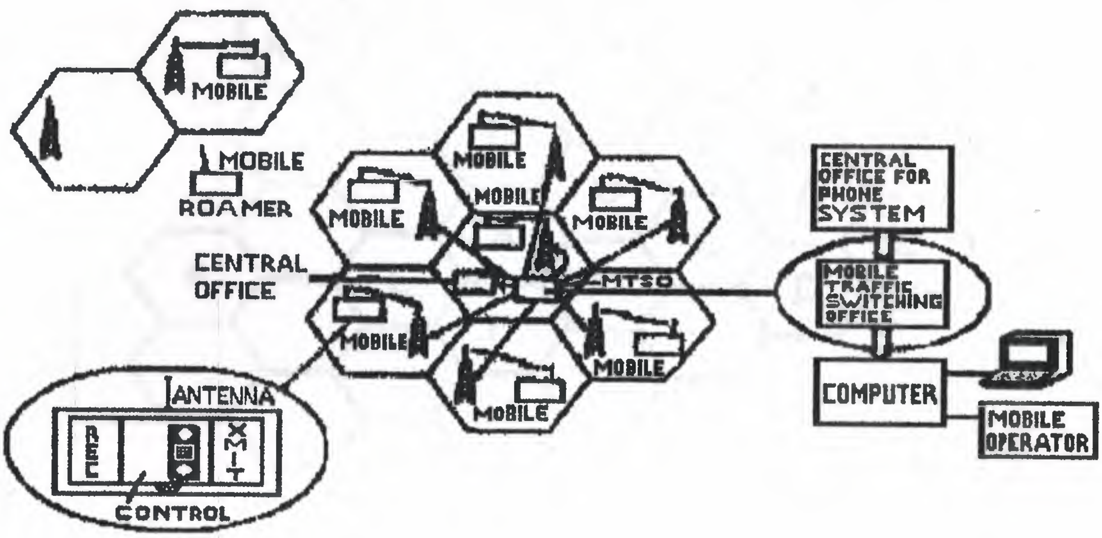


Figure 3.10 Typical cellular schemes

3. 8. Cellular Principles

The basic idea of the cellular concept is frequency reuse in which the same set of channels can be reused in different geographical locations sufficiently apart from each other so that channel interference be within tolerable limits. The set of channels available in the system is assigned to a group of cells constituting the cluster. Cells are assumed to have a regular hexagonal shape and the number of cells per cluster determines the repeat pattern. Because of the hexagonal geometry only certain repeat patterns can tessellate. The number N of cells per cluster is given by: where i and j are integers. We note that the clusters can accommodate only certain numbers of cells such as 1, 3, 4, 7, 9, 12, 13, 16, 9, 21, . . . , the most common being 4 and 7, The number of cells per cluster is intuitively related with system capacity as well as with transmission quality. The fewer cells per cluster, the larger the number of channels per cell (higher traffic carrying capacity) and the closer the cocells (potentially more cochannel interference). An important parameter of a cellular layout relating these entities is the D/R ratio, where D is the distance between cocells and R is the cell radius.

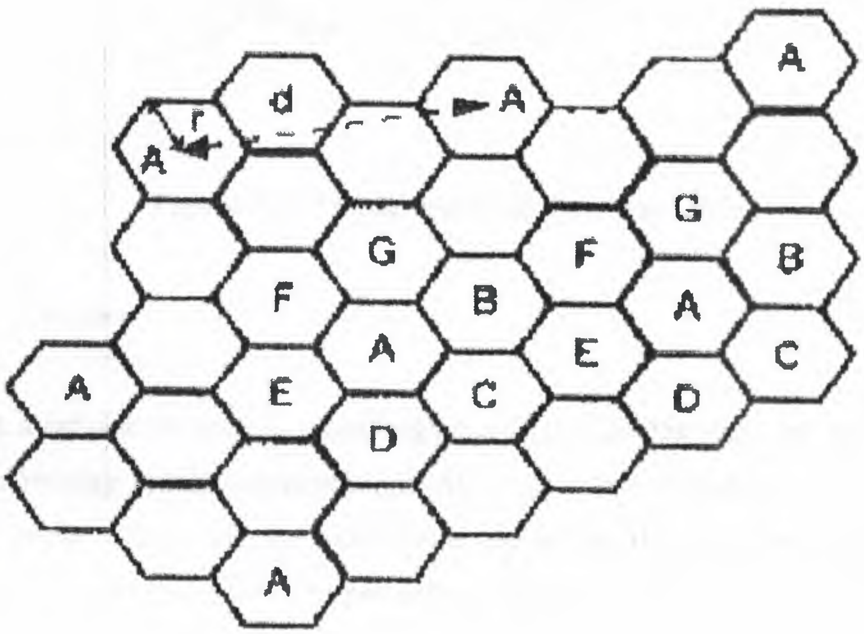


Figure 3.11 Frequency reuse pattern among cells

3.9 FDMA Cellular System

A frequency-division multiple access system can be used to provide high-quality mobile radiophone service. Known as AMPS (Advance Mobile Phone Service), the overall control of the system resides in a large central controller in each metropolitan service area.

This Mobile Telephone Switching Office (MTSO) in an electronic switching system programmed to provide call-processing and system fault detection and diagnostics.

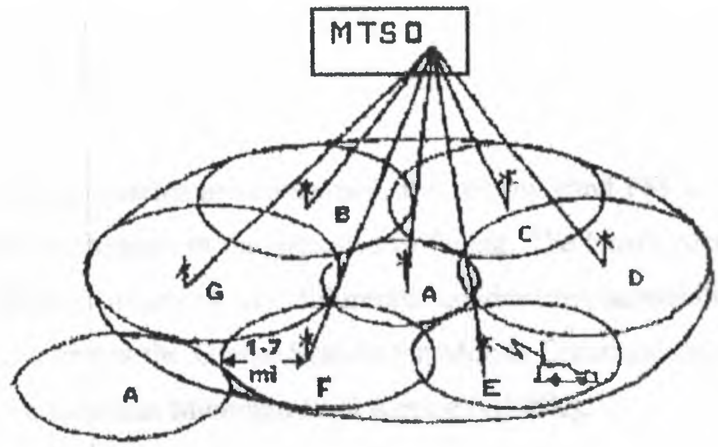


Figure 3.12 Mobile telephone switching office

3.9.1 Introduction

Designing a cellular network is a challenging task that invites engineers to exercise all of their knowledge in telecommunications. Although it may not be necessary to work as an expert in all of the fields, the interrelationship among the areas involved impels the designer to naturally search for a deeper understanding of the main phenomena.

In other words, the time for segregation, when radio engineers and traffic engineers would not talk to each other, at least through a common vocabulary, is probably gone. A great many aspects must be considered in a cellular network planning. The main ones include the following.

- Radio Propagation: Here the topography and the morphology of the terrain, the urbanisation factor and the clutter factor of the city, and some other aspects of the target geographical region under investigation will constitute the input data for the radio coverage design.

• Frequency Regulation and Planning: In most countries there is a centralist organisation, usually performed by a government entity, regulating the assignment and use of the radio spectrum. The frequency planning within the assigned spectrum should then be made so that interferences are minimised and the traffic demand is satisfied.

3.9.2 Modulation

As far as analog systems are concerned, the narrow band FM is widely used due to its remarkable performance in the presence of fading. The North American Digital Cellular Standard IS-54 proposes the n/4 differential quadrature phase-shift keying (n/4 DQPSK) modulation, whereas the Global System for Mobile Communications (GSM) establishes the use of the Gaussian Minimum-Shift Keying (GMSK).

3.9.3 Antenna Design

To cover targe areas and for low-traffic applications omnidirectional antennas are recommended. Some systems at their inception may have these characteristics, and the utilisation of omnidirectional antennas certainly keeps the initial investment low. As the traffic demand increases, the use of some sort of capacity enhancement technique to meet the demand, such as replacing the omnidirectional by directional antennas is mandatory.

3.9.4 Transmission Planning

The structure of the channels, both for signalling and voice, is one of the aspects to be considered in this topic. Other aspects include the performance of the transmission components (power capacity, noise, bandwidth, stability etc.) and the design or specification of transmitter and receivers.

3.9.5 Switching Exchange

In most cases this consists of adapting the existing switching network for mobile radio communication purposes.

3.9.6 Telegraphic

For a given grade of service and number of channels available, how many subscribers can be accommodated into the system? What is the proportion of voice and signalling channels?

3.9.7 Software Design

With the use of microprocessors throughout the system there are software applications in the mobile unit, in the base station, and in the switching exchange. Other aspects, such as human factors, economics, etc., will also in since the design. This chapter outlines the aspects involving the basic design steps in cellular network planning. Topics, such as traffic engineering, cell coverage, and interference will be covered, and application examples will be given throughout the section so as to illustrate the main ideas. We start by recalling the basic concepts including cellular principles, performance measures and system requirements, and system expansion techniques.

3. 10. The GSM system-narrow band TDMA

GSM of CEPT were clearly faced with a difficult choice, perceiving features of merit in all the systems offered. The advantages of TDMA as far as base station design is concerned are evident in permitting many channels to be supported by a single base station transceiver, but the number of channels per carrier, and consequently the bit rate, should not be too high to create difficulties for mobiles in having time to scan a number of base station transmissions to determine hand-off requirements. Additionally, the number of channels per carrier should not be too high if peak power output requirements from hand-portables are to be met and the equaliser complexity/ performance compromise within reach of short to medium term DSP.

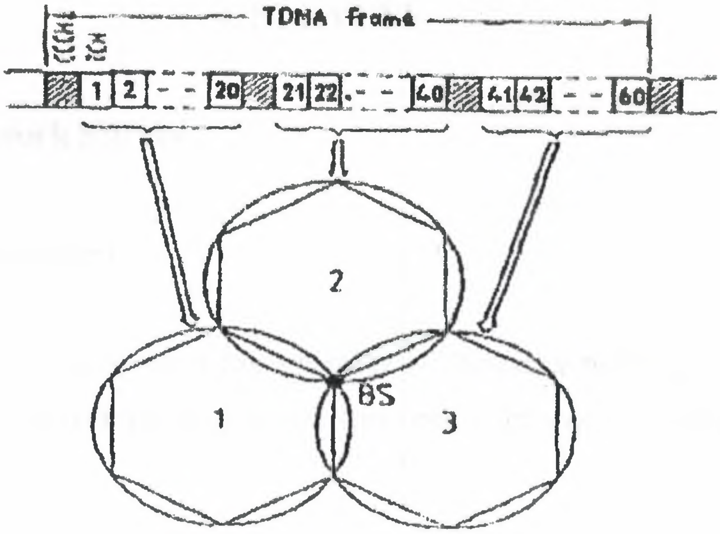


Figure 3.13 CD 100 frequency re-use strategy.

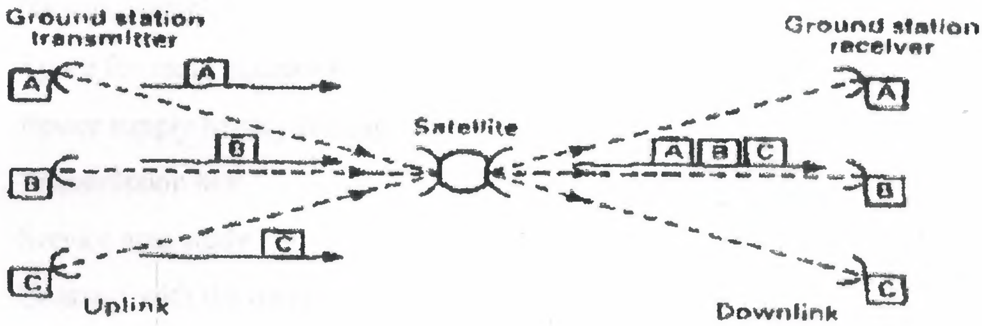


Figure 3.14 Basic TDMA operation.

4. SURVEYS

4. 1. Radio Network Survey

4.1.1 Basic Considerations

It is likely that the system operator has a number of alternative buildings which may be used in the cellular network planning phase. One reason for this is to reduce the initial cost.

The following aspects of site selection must be studied:

- Position relative to nominal grid
- Space for antennas
- Antenna separations
- Nearby obstacles
- Space for radio equipment
- Power supply/battery backup
- Transmission link
- Service area study
- Contract with the owner

4.1.2 Position Relative to Nominal Grid

The initial study for a cell system often results in a theoretical cell pattern with nominal positions for the site locations. The existing buildings must then be adapted in such a way that the real positions are established and replace the nominal positions. The visit to the site is to ensure the exact location (address/coordinates and ground level). It is also possible for more than one existing site to be used for a specific nominal position.

4.1.3 Space for Antennas

The radio propagation predictions provide an indication on what type of antennas can be used on the base station and in what direction the antennas should be oriented.

The predicted antenna height should be used as a guideline when the on-site study starts. If space can be found within a maximum deviation of 15% from the predicted height the original predictions can be used with sufficient accuracy.

If it is possible to install the antennas at a higher position than the predicted position, the operator must ensure that there is no risk force-channel interference. If the antennas are to be installed at a lower position than predicted, new predictions must be carried out based on this position.

It is not necessary that all antennas in one particular cell have the same height or direction. That is, it is possible to have cells on the same base station with different antenna heights. This can be the case if space is limited in some directions. There are also cell planning reasons for placing antennas at different heights. These include coverage, isolation, diversity, and/or interference.

4.1.4 Antenna Separations

There are two reasons for antennas to be separated from each other and from other antenna systems:

- To achieve space diversity
- To achieve isolation

The horizontal separation distance to obtain sufficient space diversity between antennas is 12-18 λ or 4-6 meter for GSM 900 and 2-3 m for GSM 1800/1900. Typical values of separation distances between antennas to obtain sufficient isolation (normally 30 dB) are 0.4 m (horizontal) and 0.2 m (vertical) for GSM 900.

4.1.5 Nearby Obstacles

One very important part in the Radio Network Survey is to classify the close surroundings with respect to influence on radio propagation. In traditional point-to-point communication networks, a line-of-sight path is required. A planning criterion is to have the first fresnel zone free from obstacles. (NOTE: The fresnel zone is the area in open space that must be practically free of obstructions for a microwave radio path to function property; some degree of fresnel consideration is required in the immediate vicinity of the microwave radio RF envelope/field.)

It is not possible to follow this guideline because the path between the base and the mobile subscriber is normally not line-of-sight. In city areas, one cell planning criterion is to provide margins for these types of obstacles.

If optimal coverage is required, it is necessary to have the antennas free for the nearest 50-100 m. The first fresnel zone is approximately five meters at this distance (for 900 MHz). This means the lower part of the antenna system has to be five meters above the surroundings.

4.1.6 Space for Radio Equipment

Radio equipment should be placed as close as possible to the antennas in order to reduce the feeder loss and the cost for feeders. However, if these disadvantages can be accepted, other locations for the equipment can be considered. In addition, sufficient space should be allotted for future expansions.

The radio network survey includes a brief study with respect to this matter. A more detailed analysis takes place when the location is chosen to be included in the cellular network.

4.1.7 Power Supply / Battery Backup

The equipment power supply must be estimated and the possibility of obtaining this power must be checked. Space for battery back-up may be required.

4.1.8 Transmission Link

The base station must be physically connected to the BSC. This can be carried out via radio link, fiber cable, or copper cable. Detailed transmission planning is not included in this project.

4.1.9 Service Area Study

During the network survey it is important to study the intended service areas from the actual and alternate base station lucations. Coverage predictions must be checked with respect to critical areas.

4.1.10 Contract With the Owner

The necessary legal documentation must exist between the land owner and the proposed site user, e.g., a contract for site leasing. Even though cost is a major consideration in the site acquisition process, cost is not discussed as a factor in this project.

4. 2. Radio Measurements

4.2.1 Path Loss Parameters

A radio survey involves installation of a transportable test transmitter somewhere in the area where the base station is to be installed. Using a specially equipped vehicle, signal strength can be measured. A locating unit, a measuring receiver with antenna, a control and processing unit, and a tape recorder are among the equipment contained in the unit. Signal level can be measured on a number of channel and, for each channel, samples are taken at an adjustable speed. Normally, samples are taken several times per wavelength traveled.

The data is pre-processed before it is stored on either the hard drive or a diskette and presented off-line after the survey. Results can be presented with respect to median value, standard deviation, and number of "measuring squares" along the test routes. The recorded files can be imported into EET and displayed on the map. The residual values (i.e., the difference between the prediction and the measurement) can also he displayed. If there is a difference, the path loss parameters in the prediction model can be adjusted according to the measurements.

4.2.2 Time Dispersion

Measurements must be performed to verify the time dispersion predictions. In addition, if there are quality problems, time dispersion measurements must be taken to verify that time dispersion is actually causing the poor quality.

The equipment used for time dispersion measurements consists of a transmitter and a receiver (Figure 4.1). The transmitter sends a short pulse, the signal is received, and the pulse response is evaluated in a controller(Figure 4.2). In this way, the time delay and the carrier to reflection ratio can be found.

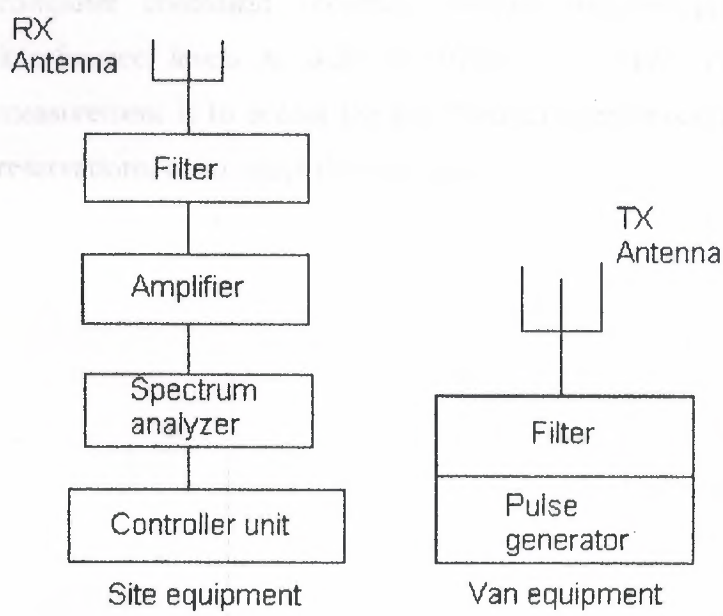


Figure 4.1 Time dispersion measurement equipment

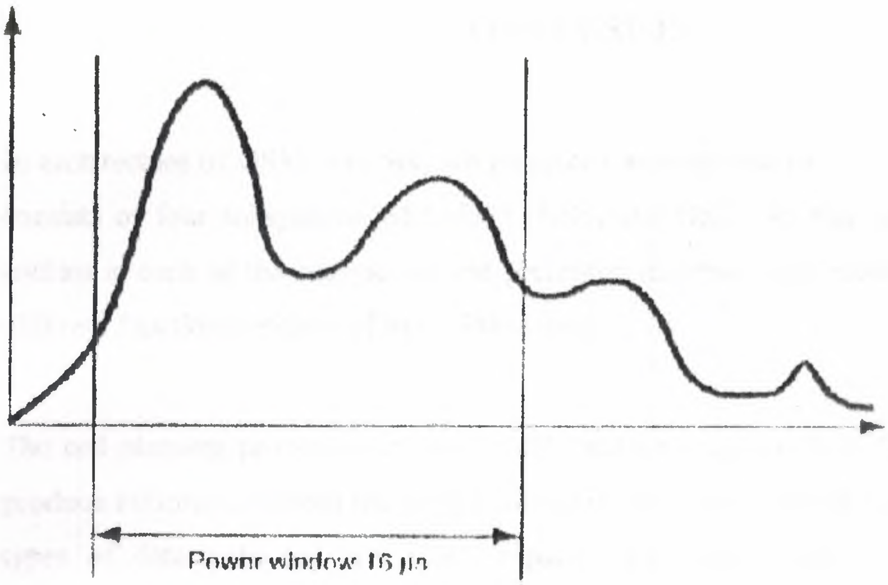


Figure 4.2 Impulse response

4.2.3 Interfering Transmitters

For sites where a number of other radio transmitters are co-located.These include a computer controlled spectrum analyzer and computer programs for calculating interference levels at different frequencies. The end result of a radio spectrum measurement is to accept the site from an interference point of view, to accept it with reservations, or to reject the site and find another one.

CONCLUSION

In architecture of GSM network, we presented an overview of the GSM system, which consists of four subsystems-MSS, BSS, NSS, and OSS. We also described functional entities in each of the subsystems and presented interfaces and protocols used between different functional entities of the GSM system.

The cell planning process starts with traffic and coverage analysis. The analysis should produce information about the geographical area and the expected need of capacity. The types of data collected are: Cost, capacity, coverage, grade of service, available frequencies, speech quality index and system growth capability.

Radio measurements are performed in order to verify the coverage and interference predictions. The sites where the radio equipment will be placed are visited. This is a critical step because it is necessary to assess the real environment to determine whether it is a suitable site location when planning a cellular network.

Once we have optimized and can trust the predictions generated by the planning tool, the dimensioning of the RBS equipment, BSC, and MSC is performed. The final cell plan is then produced. As the name implies, this plan is later used during system installation. In addition, a document called Cell Design Data (CDD) is filled out containing all cell parameters for each cell.

The system needs constant retuning because the traffic and number of subscribers increases continuously. Eventually, the system reaches a point where it must be expanded so that it can manage the increasing load and new traffic. At this point, a traffic and coverage analysis is performed and the cell planning process cycle begins again.

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