1 GSM among other systems

Objectives

After this chapter the student will:

- be able to name and describe the most important mobile systems available
- be able to explain the difference between 1st, 2nd and 3rd generation mobile systems
- be familiar with the standardisation work and organisation of GSM
- be able to name and describe the most important services in a GSM network

1.1 Introduction

The first part of this chapter deals with the mobile systems that can be said to compete with - or possibly complement - GSM. The second part deals with the evolution of the GSM standard. What bodies decide the content of GSM, and what bodies specify the details dictating that content. The third part deals with the services provided in a GSM-system.

1.2 Competing and complementing systems

Cordless Telephones

- In the listing of competing and complementing technologies, the technology of Cordless telephones is a good starting point.

Cordless telephones are known to most of us as a cordless phone to be used around the house. It functions point-to-point, meaning that each handset has its own base station. Outside the coverage of the base station the handset has no service.

Another type of cordless telephony is often associated with the public service ”telepoint”, but can also be built as smaller business systems. Telepoint can be seen as a system with ”mobile phone boxes”. The base stations, called telepoints are placed in shopping malls, train stations and other public places, from which it is possible to place a call but not to receive a call.

To overcome the disadvantage of only one way calling, users may also carry a pager or use a terminal with a built-in pager. Available services include the ability to respond to the pager and make an automatic call-back to the caller. These cordless phones handle point-to-multipoint; meaning that each base station handles several handsets.

A third type of cordless telephony in Europe that includes roaming and handover functions is DECT (Digital Enhanced Cordless Telephony). It was published by ETSI in 1992 and had the first products available from 1993.

Initially, DECT was focused on two main application areas: the ”cordless PBX” and the conventional residential cordless telephones. A PBX (private branch exchange) is a telephone system within an enterprise that switches calls between enterprise users on local lines while allowing all users to share a certain number of external phone lines. The main purpose of a PBX is to save the cost of requiring a line for each user to the telephone company's central office.
More recently, other applications have appeared. These include radio in the local loop (RLL) and applications that combine DECT access equipment with digital cellular backbone networks such as GSM. RLL (Radio in the

Local Loop) system is an alternative or a complement to wired access to bring telephony and data services to residential and small business subscribers. One key element in this radio access system is the base station. The base station can be installed on a rooftop or mast, and supports the radio-connected subscribers. It is connected to the host local exchange.

In difference to earlier systems DECT offers mobile originated as well as mobile terminated traffic. Within the DECT standard, there are different applications (e.g. voice telephony, ISDN access and data communications). A number of profiles are being standardised by ETSI to support different DECT applications for the purpose of interoperability.

It is designed for high and dynamic capacity (25 to 500 kbit/s) and a large set of services. It is based on the seven layers of the OSI model, and is a truly ISDN-compatible mobile system.

PHS (Personal Handyphone System) is a Japanese system. It is also built on digital cordless technology and for a micro-cell architecture that enables high capacity. PHS uses dynamic channel assignment and the standardised network interface is based on an ISDN interface.

PHS is designed to transmit speech, data and facsimile signals

PACS (Personal Access Communications Systems), USA, is a standard adopted by ANSI for Personal Communications Systems (PCS). Equipment built to this standard provides users with convenient wireless access to voice and data services, and is typically interconnected with the public telephone network.

The frequency bands for DECT, PHS and PACS are just above GSM 1800.

First Generation Cellular systems

The breakthrough in mobile telephony came with cellular systems where in a geographical area several basestations are placed, each covering one cell. The first generation of cellular systems were launched during the early or mid-eighties. Among those are NMT 450 and NMT 900 (Nordic Mobile Telephone system), TACS (Total Access Communication System) and AMPS (Advanced Mobile Phone Service).

System	**NMT 450**	**NMT 900**	**TACS**	**AMPS**
Frequency band [MHz]	453-457.5, 463-467.5	890-915, 935-960	890-915, 935-960	825-845, 870-890
Duplex distance [MHz]	10	45	45	45
Number of carriers	180	1000 / 1999	1000	660 (832)
Carrier spacing [kHz]	25	25 / 12.5	25	30

First generation cellular systems

- *AMPS* (Advanced Mobile Phone Service): this can be described as one of the first operational mobile telecommunications system based on the cellular concept.
- *NMT450/900* (Nordic Mobile Telephone): introduced in 1981 to offer mobile communications to the Scandinavian market. This service is based on analogue speech transmission using FDMA.
- *TACS* (Total Access Communication System): primarily introduced in Great Britain in 1985. This service is also based on analogue speech transmission using FDMA.

Second Generation Cellular

The second generation of cellular systems were launched for commercial use in the beginning of the nineties. Among these were GSM (Global System for Mobile Communication), D-AMPS (Digital-Advanced Mobile Phone Service) and PDC (Personal Digital Cellular). A network conforming to any of these standards will offer almost identical network behaviour (feature transparency).

System	GSM 900	D-AMPS	PDC
Frequency band [MHz]	890-915, 935-960	825-845, 870-890	1429-1453, 1477-1501
Duplex distance [MHz]	45	45	48
Number of carriers	124	660	960
Time slots/carrier	8 / 16*	3	3
Carrier spacing [kHz]	200	30	24

Second generation cellular systems ** with a half rate coder*

- *GSM* (Global System for Mobile communications): came into commercial use in 1991. From its origin in Europe it has spread all over the world.
- D-AMPS (Advanced Mobile Phone System): designed to be a soft migration from AMPS into a digital system using the same infrastructure as AMPS systems
- *PDC* (Personal Digital Cellular): uses a TDMA structure with three time slots per carrier, with a bandwidth of 24 MHz.

Generation 2.5 (Moving towards a third Generation System)

In the short term most demands of a third generation system (handling of high traffic demand, using mobiles with low price and low power consumption) could be handled by enhanced second generation systems. A system like this is sometimes referred to as a generation 2.5 system. The terms PCN (Personal Communication Network) and PCS (Personal Communication System) are sometimes used collectively to describe these upgraded systems. PCN and PCS are more of names of ideas, more than actual technical standards.

In 1990 the specification of an 1800 MHz version of GSM was adapted to the scope of the standardisation group of GSM, with a frequency allocation of twice 75 MHz. GSM 1800 is aimed at reaching higher capacities in urban areas. GSM 1800 is one possible implementation of PCN.

PCS in the US is being implemented by a number of different operators using a number of systems. Some of the systems are already launched, some are a bit further down the road. These are the systems considered for PCS:

- GSM 1900 - Upbanded GSM (former name DCS 1800)
- CDMA at 1.9 GHz - Upbanded IS-95 (CDMA-AMPS)
- TDMA at 1.9 GHz - Upbanded IS-54 (TDMA-AMPS)
- CDMA/TDMA/FDMA (Omnipoint)
- PACS - Personal Access Communications Systems (low mobility)
- DCT - Modified DECT (low mobility)

SYSTEM	GSM 1800	GSM 1900
Frequency band [MHz]	1710 - 1785	1850 - 1910

	1805 - 1880	1930 - 1990
Duplex distance [MHz]	95	80
Number of carriers	374	**
Time slots/carrier	8/16*	**
Carrier spacing [kHz]	200	**

* *with a half rate coder.*

** *depends on the chosen standard.*

Third Generation Cellular

A third generation cellular system will need to handle very high traffic demand and data speeds considerably higher than those of the cellular systems of today. It would also need to introduce new services with great ease, use mobiles with low price and low power consumption, etc.

ITU (International Telecommunication Union, founded 1865) the oldest organisation in the United Nations is presently specifying IMT-2000 (International Mobile Telephony 2000) as the approach to design the framework for a third generation system. Within its domain it will then be possible to define different third generation systems.

In Europe, ETSI is specifying UMTS (Universal Mobile Telecommunications System). This standard is meant to be launched between 2000-2005. The concept is being formulated to fit the expected need of technologies around the turn of the century. The aim is to cover everything from voice and data to video.

UMTS will be a mobile communications system that can offer high-quality wireless multimedia services to a convergent network of fixed, cellular and satellite components.

Major milestones for UMTS came December 31st 1997 when regulatory framework for UMTS was defined, including spectrum licences for Phase 1. In the first quarter of 1998 operators were identified including drafting of licences. At the end of 1999 ETSI UMTS Phase 1 standard will be set and in the year 2002 commercial UMTS operation will be launched.

UMTS is in the process of being standardised in co-operation with the ITU.

	UMTS Phase 1: 2002	UMTS Phase 2: 2005
Services	-multimedia 144k, 2Mbit/s -service creation -service portability -roaming GSM/UMTS	-enhanced multimedia -roaming with other third generation networks

Terminals	-adaptive, download -dual mode/band GSM/UMTS	-enhanced multimedia capabilities
Access network	-new Base Station System 2Ghz -spectrum efficient	-extended ATM use -new band(s)
Core transport	-evolution of GSM -mobile/fixed convergence elements	-improved multimedia support by the use of ATM technology

UMTS schedule

When work on UMTS began, it was initially thought that it was possible to design an entirely new system, selecting new radio technologies and a new network platform on which the UMTS specifications could be based. Considering the large market penetration of GSM expected in the early 2000s and the huge investment already made by operators and manufacturers, it may well be more commercially justifiable to evolve the GSM standard to become part of the architecture for UMTS, rather than starting again from the beginning.

Satellite Systems

GMPCS (Global Mobile Personal Communications by Satellite) is a sometimes used term for a satellite system used for personal mobile communication. This is getting closer and closer to becoming a reality.

Inmarsat (International Maritime Satellite Organisation) began its services in 1982. Its remit was to provide communications for commercial, distress and safety applications for ships at sea. Inmarsat has an intergovernmental structure presently with 84 member countries. It has since then expanded into land, mobile and aeronautical communications. Typical users in addition to maritime include journalists and broadcasters, health teams and disaster relief workers, airlines and airline passengers.

Another satellite system is Iridium which placed 66 satellites into orbit and launched their service November 1, 1998. The Iridium network integrates land-based phone lines, local cellular coverage and satellites. Two other satellite systems are Globalstar and ICO. They will provide the users with speech, data and short message services. Globalstar was launched autumn 1999 and ICO plans to launch its service in August 2000.

	Globalstar	**Iridium**	**Inmarsat org.**	**ICO**
commercial launch	3Q 1999	1998	1982	2000
number of satellites	48	66	12	10
altitude from earth	1,410km	780km	35,786km	10.390km
mobile frequency (uplink) [MHz]	1610-1625.5	1610-1625.5	1626.5-1660.5	1985-2015
mobile frequency (downlink) [MHz]	2483.5-2500	1610-1625.5	3600.0-3629.0	2170-2200
subscriber links	CDMA	FDMA/TDMA		TDMA
channels per satellite	2800	3840		4500

1.3 The GSM Specification and GSM Association

In order to ensure the success of a digital based GSM network it was necessary to design a system, which would achieve conformity. This would enable price competition among suppliers, thus lowering the prices of the mobile equipment. This part will describe how this standardisation work has evolved - and continues to evolve, and also the types of services available in the GSM system.

One of the advantages with a digital network is that it enables us to introduce a great variety of services, e.g. transfer of data using hand held mobile equipment. These advances in telecommunication technology make mobile communication more attractive to a broader market.

The Creation of GSM

In the early 80´s, it became evident to several European countries that the evolving analogue systems were limited. This became very clear in Scandinavia with the experience of the NMT networks.

Firstly, it was becoming apparent that the potential demand for services was grossly under-estimated in the early 80´s, and was larger than the maximum capacity of the analogue networks.

Secondly, the different systems that were operating offered no compatibility for the mobile users, an example of this is the fact that, an NMT terminal cannot access a TACS network and vice versa. With this in mind, it was decided that while the frequency 900 MHz had been set aside (1979), for mobile communication, it would be prudent to initiate a pan-European mobile network that would be compatible.

This was the background when the Nordic countries in 1982 laid a proposal within CEPT to create one standard for mobile telephony in Europe. An important factor was the awareness of future extraordinary capacity demands.

CEPT organised a forum to handle the specification of this new system. It was called Groupe Spécial Mobile. It held its constituting meeting in Stockholm, December 1982, under the chairmanship of Thomas Haug from the Swedish PTT. 31 persons representing 11 countries participated.

By the end of the ´80´s it was again becoming apparent that a system with even higher capacity was required. At the request of the United Kingdom, the specification of a version of GSM adapted to 1800 MHz was added to the scope of the standardisation group, with a frequency allocation of two bands of 75 MHz. GSM 1800 it is aimed particularly at urban areas were

higher capacities are required, for example the type of mass-market approach known as PCN(Personal Communication Network).

GSM organisation

Specifying a complete system involves a lot of expertise, since not only the radio interface is dealt with but also all network-related questions. So, as the work submitted to the Groupe Spécial Mobile rapidly increased a split into a number of subgroups, Special Mobile Groups (SMG) was done. The number of subgroups are continously growing, the four first subgroups are as follows:

SMG1 was working with the definition of services to be offered by the system.

SMG2 concentrated on radio transmission including access method, carrier spacing and all the parameters for the air interface.

SMG3 was working with all other items of the systems, mainly network specifications. Open interfaces were thought to be essential, and for this reason the signalling protocols had to be very well specified. Here, ISDN (Integrated Service Digital Network), which at the time was near completion, had a great influence. Ideas from OSI (Open System Interconnection) can also be found in the definition of signalling protocols.

SMG4 was created later, to specify the implementation of Data services.

In 1989, the technical specification work with GSM was handed over to the newly created ETSI (European Telecommunication Standards Institute). ETSI was founded 1988 due to the deregulation in telecom. It had members not only from the PTT's but also from the suppliers that were to actually build the system. This new constitution of the specification body meant contribution of state of the art technology.

GSM specification

The intention of the work was to create a complete specification for a new mobile system. During the time of the work it became clear, though, that the specification could not be complete. There was too much to decide on and the continuous development in the telecommunication area was hard to foresee. This resulted in a division of the work into different phases:

<u>Phase 1</u>
This contains the basic services of the network

The phase 1 specification was frozen in 1990 opening up for a system start in 1991 with equipment built according to this standard. In the UK there were discussions about PCN (Personal Communication Network). This

resulted in that ETSI, on request from the UK, developed a standard for the 1800 MHz band called GSM 1800. This standard was based on GSM, with differences added as amendments and the specification was frozen in 1991.

Phase 2

The phase 2 specification brought a number of new functions and features which relate to improvements and extensions of the phase 1 features, such as:

- Introduction of half-rate channels
- Extension of the frequency band for GSM900 (50 additional channels)
- Provision for microcell environments
- General technical improvements (operation of MS, handover procedures, signalling)

Phase 2 which is the final standard was frozen in October 1995 and are progressively introduced in all networks.

Phase 2+

No mandatory time schedules have been laid down by the relevant groups for Phase 2+, but it is probably fair to say that some of the Phase 2+ items will more or less concede with the realisation of Phase 2 on the terminal side. On the network side, implementation of Phase 2+ features can basically take place at any time and rate, depending on the wishes of operators and the availability from manufacturers. As far as the standardisation work is concerned, the first approved Phase 2+ features was available in the first months of 1995 and there will be new ”batches” of approved modifications every year.

Some of the issues covered by Phase 2+ are:

- HSCSD (High Speed Circuit Switched Data)
- GPRS (General Packet Radio System)
- seamless roaming between a cellular and a satellite environment
- call completion to busy subscribers
- dual band and dual mode of operation

GSM Association

The GSM Memorandum of Understanding was originally signed in 1987 by 15 European signatories from 13 countries. This document gave the group of network operators and regulatory authorities who had committed themselves to the GSM standard the name of ”GSM MoU”. An amendment to the Memorandum was signed in 1991, allowing membership for countries outside CEPT that were also adopting the GSM standard and to authorising the participation, with a special status, of the GSM 1800 operators. Full membership was offered to GSM 1800 operators by a decision of MoU Group in 1994. In November 1998 the GSM MoU changed name to “GSM Association”.

The GSM Association relies on two basic principles of co-operation among its members :

- Mandatory implementation of international roaming service with every other member, upon becoming a member of the GSM Association.
- Definitions of a common position vis á vis the environment of the GSM operators : regulatory framework, ETSI/SMG and the suppliers of mobile stations and infrastructure systems.

The number and characteristics of GSM operators has changed drastically: the majority of operators are now located outside of Europe and their networks are highly variable in size and emphasis (e.g. operators from Channel Islands, Australia or China...). Consequently, the GSM Association has undertaken a reorganisation of its structure, regional interest groups have been formed in eight regions of the world to address and market specific member needs.

The work that is performed by the GSM Association encompasses a large variety of issues in the technical, commercial, regulatory and legal areas. The main areas of past and present activities can be summarised as follows:

- Harmonisation of the introduction of GSM networks and services
- Definition of billing and accounting principles for the international roaming service
- Definition of a standard roaming agreement between GSM operators
- Liaison with regulators and vendors on the type approval procedures and availability of mobile terminals
- Security and data protection aspects
- Strategies for the evolution of the GSM standard

- Promotion of the standard and exchange of GSM know-how
- Open standards and supplier choice with minimal proprietary interfaces
- Anti-fraud measures
- Regulatory liaison
- Funding of various activities (installation of the Permanent Secretariat, CEIR implementation, coverage information...)

A Permanent Secretariat is located in Dublin and the GSM Association has appointed a Technical Executive, who is in charge of the technical co-operation of the working groups, aiding in the promotion of the standard, and transfer of know-how.

1.4 Services

Traditionally the telecommunication services are divided into speech services and data services (fax, computer files, images etc). GSM provides both these types of communication services and in addition short-message services, which is like a paging service. To enable the subscriber to control and simplify the use of the different communication types a lot of supplementary services are specified.

Service provision to a certain subscriber depends on three items;
- the Subscription must include this service
- the mobile equipment must be able to handle the service
- the network must be able to offer the service.

Speech services

Telephony is the most important service in GSM, which allows calls to be set up between GSM subscribers and mobile or fixed telephone subscribers all over the world. To reach an emergency service a unified procedure has been agreed on, thus making emergency calls a distinct service in GSM. In Europe it can always be done by dialling 112.

Data services

GSM offers most of the data services provided by the PSTN and ISDN but with restricted transmission rates. The maximum bit rate allowed is 9.6 kbit/s, due to radio transmission limitations.

When in connection with PSTN users GSM offers services like fax and videotex. Since GSM is a fully digital system, the user will not need an audio modem - in fact GSM is not suited for standard modem signals. But for communication with users in the PSTN, users that need a modem for data transmission, the GSM operator must provide modems on the network side

When in connection with ISDN users, the GSM operator needs to provide rate adaptation due to GSM bit rate limitation. GSM has a maximum bit rate of 9.6 kbit/s. ISDN have a connection with 2*64 kbit/s traffic channels and 1*16 kbit/s signalling channel. To handle this, inter-working with GSM will, from the ISDN point of view, be considered as inter-working with PSTN, since the formats for adapting are developed already.

When in connection with PSPDN users (Packet Switched Public Data Network) the access can be made;

- when not in packet mode, through a PAD (Packet Assembly/ Disassembly). For this a modem with asynchronous located either in the PSTN or integrated in the GSM network will be used. This allows the GSM user to utilise an ordinary data terminal.
- when in packet mode, through the PSTN/ISDN or directly from the GSM network.
-

When in connection with CSPDN users (Circuit Switched Public Data Network) GSM can offer synchronous. CSPDN can be accessed directly from GSM.

Short-Message Services - SMS

GSM offers the function of sending and receiving short messages of alphanumeric characters. This function is similar to the paging, but with many improvements.

Point-to-point SMS enables a specific mobile station to send and receive a maximum of 160 alphanumeric characters. When successfully received, the network will be informed about the outcome. In case of transmission failure the message may be repeated. How to access the service, e.g. keying or by human operator, is decided by the GSM operator.

Cell broadcast SMS enables the operator to send a short message of maximum 93 alphanumeric characters to all idle mobile stations in a given geographical area on a cell basis. The operator can decide if this function is used for advertising or reserved for messages like traffic information and weather reports.

Supplementary services

The supplementary services will modify and simplify the use of the communication services. Most of these services are already existing in the fixed network and are merely adapted to mobility, if needed, in the GSM network. To activate or deactivate the different services the user must have a subscription for that specific service. Some of the services will be included in all subscriptions and some will require a special subscription. We will now look at some of the supplementary services and how they affect the calls to and from a mobile station.

Call forwarding, will forward an incoming call to another number, e.g. to an answering machine. Call forwarding could be used with the following conditions:
- unconditional
- on MS busy
- on no reply
- on MS not reachable

Barring of outgoing calls can be activated with the following conditions:
- all calls
- all international calls
- all international calls except those directed to the home PLMN (Public Land Mobile Network) country

Barring of incoming calls can be activated with the following conditions:
- all calls
- when roaming outside the home PLMN country

Call hold enables the user to interrupt an existing call and resume conversation afterwards.

Call waiting will warn the user, during a conversation, of an incoming call that may be rejected or accepted.

Calling line identification presentation/restriction will provide the called party with the number of the calling party. Restriction of the presentation can be ordered by the calling party, which in that case will override the presentation.

Connected line identification presentation/restriction will provide the calling party with the number of the called (connected) party. This could be useful if the called has diverted the call to another number or subscription. Restriction of the presentation can be ordered by the called party, which in that case will override the presentation.

Advice of charge gives the subscriber an indication of the call cost or used for real time charging like in a pay-phone application. The difficulty with this supplementary service occurs when the mobile roams abroad. For instance different currencies and different tariffs can make a difference between the call charge and the billed charge.

Multi-party service enables the subscriber to merge simultaneous conversations. This service applies only to speech communication.

Closed user group enables subscribers to form a group with restricted access to and from this specified group. This is done using a complex set of services, e.g. barring certain incoming and outgoing calls.