GSM SYSTEM SURVEY

STUDENT TEXT
EN/LZT 123 3321
R2C

ERICSSON

DISCLAIMER

This book is a training document and contains simplifications. Therefore, it must not be considered as a specification of the system.

The contents of this document are subject to revision without notice due to ongoing progress in methodology, design and manufacturing.

Ericsson assumes no legal responsibility for any error or damage resulting from the usage of this document.

This document is not intended to replace the technical documentation that was shipped with your system. Always refer to that technical documentation during operation and maintenance.

- This document number, EN/LZT 123 3321, R2C supports course number LZU 108 852.

REVISION RECORD

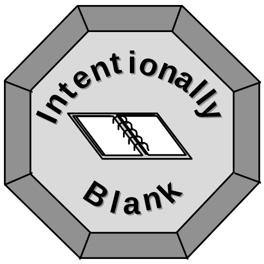
Date	Revision No.	Chapters Affected
96/09/02	R1A	All
97/07/04	R1B	All
97/09/09	R1C	All
98/05/27	R2A	All
98/11/30	R2B	All
99/08/30	R2C	1 - 7 and 9

Intentionally Blank

GSM System Survey

Table of Contents

Topic	Page


Intentionally
Blank

Introduction to Mobile Telecommunications and GSM

Chapter 1

This chapter is designed to provide the student with an introduction to mobile telecommunications and an overview of the GSM standard. It introduces the main system components, the network structure and basic terminology used.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the concept of a standard for mobile communications
- Describe the history of GSM development
- Describe the philosophy of GSM as a global common standard
- Describe the GSM network components
- Describe the GSM geographical network structure
- Describe the GSM frequency bands
- Describe the terminology used in GSM traffic cases

Intentionally Blank

1 Introduction to Mobile Telecommunications and GSM

Table of Contents

Topic	Page

Intentionally Blank

MOBILE TELEPHONY

Mobile telecommunications is one of the fastest growing and most demanding of all telecommunications technologies. Currently, it represents an increasingly high percentage of all new telephone subscriptions worldwide. In many cases, cellular solutions successfully compete with traditional wireline networks and cordless telephones. In the future, cellular systems employing digital technology will become the universal method of telecommunication.

HISTORY OF WIRELESS COMMUNICATION

The origins of mobile communications followed quickly behind the invention of radio in the late 1800s. The first applications of mobile radio were related to the navigation and safety of ships at sea. As radio concepts developed, so did it's use as a communications tool. The major milestones in the development of wireless communications are summarized in the following table:

Date	**Activity**
1906	Reginald Fesseden successfully transmits human voice over radio. Up until that time, radio communications consisted of transmissions of Morse Code.
1915	J. A. Fleming invents the vacuum tube making it possible to build mobile radios.
1921	The Detroit police department used a 2 MHz frequency in the department's first vehicular mobile radio. The system was only one way and police had to find a wireline phone to respond to radio messages.
1930s	Amplitude Modulation (AM) two-way mobile systems were in place in the U.S. that took advantage of newly developed mobile transmitters and utilized a "push-to-talk" or half-duplex transmission. By the end of the decade channel allocation grew from 11 to 40.
1935	Invention of Frequency Modulation (FM) improved audio quality. FM eliminated the need for large AM transmitters and resulted in radio equipment which required less power to operate. This made the use of transmitters in vehicles more practical.

1940s	The Federal Communications Commission (FCC) recognized a communication service it classified as Domestic Public Land Mobile (DPLM) radio service. The first DPLM system was established in St. Louis in 1946 and it utilized the 150 MHz band. The following year, a "highway" system was developed along the New York - Boston corridor using the 35-40 MHz band.
1947	D.H. Ring, working at Bell Laboratories, envisions the cellular concept.
1948	Shockley, Bardeen and Brittain, at Bell Laboratories, invent the transistor which enables electronic equipment, including the radio to be miniaturized.
1949	Radio Common Carriers (RCCs) were recognized.
1949, 1958	Bell Systems made broadband proposals.
1964	AT&T introduces Improved Mobile Telephone System (IMTS).
1968	The FCC began to address issue of new US spectrum requirements.
1969	Nordic countries of Denmark, Finland, Iceland, Norway and Sweden agree to form a group to study and recommend areas of cooperation in telecommunication. This led to the standardization of telecommunications for all members of the Nordic Mobile Telephone (NMT) group, the first comprehensive international standardization group.
1973	The NMT group specifies a feature allowing mobile telephones to be located within and across networks. This feature would become the basis for roaming.
1979	The FCC authorized the installation and testing of the first developmental cellular system in the US (Illinois Bell Telephone Company).
1981	Ericsson launches the world’s first cellular system in Saudi Arabia based on the analog NMT 450 standard.
1991	The first digital cellular standard (GSM) is launched.
1998	The number of mobile subscribers world-wide has grown to over 200 million.

Table 1-1 Milestones in development of wireless communications

☞ Did you know?

Ericsson predicts that in the year 2000, the number of mobile subscribers worldwide will be approximately 500 million.

MOBILE STANDARDS

Standards play a major role in telecommunications by:

- Allowing products from diverse suppliers to be interconnected
- Facilitating innovation by creating large markets for common products

The standards-making process is one of co-operation at many levels, both nationally and internationally and includes co-operation between:

- Industrial concerns within a country
- These industrial concerns and their governments
- National governments at an international level

The primary purpose of a standard for mobile communications is to specify how mobile phone calls are to be handled by a mobile network. For example, this includes specification of the following:

- The signals to be transmitted and received by the mobile phone
- The format of these signals
- The interaction of network nodes
- The basic network services which should be available to mobile subscribers
- The basic network structure (i.e. cells, etc.)

☞ Did you know?

The country with the highest per capita penetration of mobile subscribers is Finland, with over 40% of its population owning a mobile phone.

Since the development of NMT 450 in 1981, many standards for mobile communication have been developed throughout the world. Each mobile standard has been developed to meet the particular requirements of the country or interest groups involved in its specification. For this reason, although a standard may be suitable for one country, it may not be suitable for another. The main standards and the main markets in which they are used are summarized in the following table.

Year	Standard	Mobile Telephone System	Technology	Primary Markets
1981	NMT 450	Nordic Mobile Telephony	Analogue	Europe, Middle East
1983	AMPS	Advanced Mobile Phone System	Analogue	North and South America
1985	TACS	Total Access Communication System	Analogue	Europe and China
1986	NMT 900	Nordic Mobile Telephony	Analogue	Europe, Middle East
1991	GSM	Global System for Mobile communication	Digital	World-wide
1991	D-AMPS	Digital-AMPS	Digital	North and South America
1992	GSM 1800	Global System for Mobile communication	Digital	Europe
1994	PDC	Personal Digital Cellular	Digital	Japan
1995	PCS 1900	Personal Communication Services	Digital	North America

Table 1-2 The main cellular standards

ERICSSON IN MOBILE

Ericsson is one of the leading telecommunication companies in the world, with customers in more than 130 countries. Ericsson’s key product is the AXE digital exchange which is in service in the most sophisticated public networks in Europe, the Americas, Australia, Africa and Asia. One of the key reasons for the success of AXE is that it is modular in design which allows it to adapt easily to a wide variety of applications. The concept of open systems and standardized interfaces is fundamental to the development of all new telecommunication products within Ericsson.

Ericsson has been designing cellular radio systems since the 1970’s. It offers network products for all major standards, both analogue and digital. The largest Ericsson markets, measured in number of subscribers using an Ericsson system are North America and Europe.

Ericsson is the world's most successful supplier of mobile network infrastructure equipment and supplies 40% of the world's mobile telephony market. Ericsson supplies 50% of the world's digital telephony market. This means that half of all the world's digital mobile telephone calls are switched through Ericsson exchanges.

Mobile Standard	Ericsson Product
NMT 450	CMS 45
AMPS	CMS 8800
TACS	CMS 8810
NMT 900	CMS 89
GSM	CME 20
D-AMPS	CMS 8800-D
GSM 1800	CME 20
PDC	CMS 30
PCS 1900 (using GSM)	CMS 40
PCS 1900 (using DAMPS)	CMS 8800-D

Table 1-3 Ericsson’s cellular systems

GLOBAL SYSTEM FOR MOBILE COMMUNICATION (GSM)

HISTORY OF GSM

This history of GSM is outlined in the following table:

Date	Activity
1982-1985	• Conférence Européenne des Postes et Télécommunications (CEPT) began specifying a European digital telecommunications standard in the 900 MHz frequency band. This standard later became known as Global System for Mobile communication (GSM).
1986	• Field tests were held in Paris to select which digital transmission technology to use. The choice was Time Division Multiple Access (TDMA) or Frequency Division Multiple Access (FDMA).
1987	• A combination of TDMA and FDMA was selected as the transmission technology for GSM. • Operators from 12 countries signed a Memorandum of Understanding committing themselves to introducing GSM by 1991.
1988	• CEPT began producing GSM specifications for a phased implementation. • Another five countries signed the MoU.
1989	• European Telecommunication Standards Institute (ETSI) took over responsibility for GSM specification.
1990	• Phase 1 specifications were frozen to allow manufacturers to develop network equipment.
1991	• The GSM 1800 standard was released. • An addendum was added to the MoU allowing countries outside CEPT to sign.

1992	• Phase 1 specifications were completed. • First commercial Phase 1 GSM networks were launched. • The first international roaming agreement was established between Telecom Finland and Vodafone in UK.
1993	• Australia became the first non-European country to sign the MoU. • The MoU now had a total of 70 signatories. GSM networks were launched in Norway, Austria, Ireland, Hong Kong and Australia. • The number of GSM subscribers reached one million. • The first commercial DCS 1800 system was launched in the U.K.
1994	• The MoU now had over 100 signatories covering 60 countries. • More GSM networks were launched. • The total number of GSM subscribers exceeded 3 million.
1995	• The specification for the Personal Communications Services (PCS) was developed in the U.S.A. This version of GSM operates at 1900 MHz. • GSM growth trends continued steadily through 1995, with the number of GSM subscribers increasing at the rate of 10,000 per day and rising. • In April 1995, there were 188 members of the MoU from 69 countries.
1996	• The first GSM 1900 systems became available. These comply with the PCS 1900 standard.
1998	• At the beginning of 1998 the MoU has a total of 253 members in over 100 countries and there are over 70 million GSM subscribers world-wide. GSM subscribers account for 31% of the world’s mobile market.

Table 1-4 GSM Milestones

☞ Did you know?

The headquarters of the GSM MoU are in Dublin, Ireland.

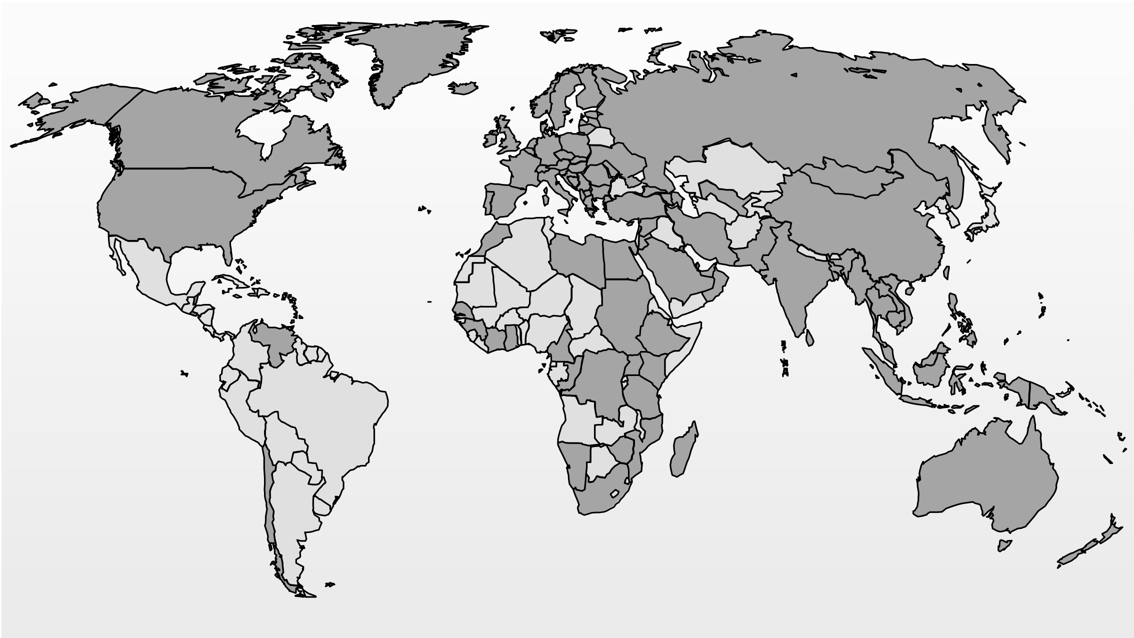


Figure 1-1 GSM worldwide (indicated by darker areas)

> ☞ Did you know?
>
> *The countries with the highest numbers of GSM subscribers are the United Kingdom and Italy.*

Because GSM provides a common standard, cellular subscribers can use their telephones over the entire GSM service area which includes all the countries around the world where the GSM system is used.

In addition, GSM provides user services such as high speed data communication, facsimile and a Short Message Service (SMS). The GSM technical specifications are also designed to work with other standards as it guarantees standard interfaces.

Finally, a key aspect of GSM is that the specifications are open-ended and can be built upon to meet future requirements.

GSM SPECIFICATIONS

GSM was designed to be platform-independent. The GSM specifications do not specify the actual hardware requirements, but instead specify the network functions and interfaces in detail. This allows hardware designers to be creative in how they provide the actual functionality, but at the same time makes it possible for operators to buy equipment from different suppliers.

The GSM recommendations consist of twelve series which are listed in the table below. These series were written by different working parties and a number of expert groups. A permanent nucleus was established in order to coordinate the working parties and to manage the editing of the recommendations. All these groups were organized by ETSI.

Series	Content
01	General
02	Service aspects
03	Network aspects
04	MS - BSS interface and protocol
05	Physical layer on the radio path
06	Speech coding specification
07	Terminal adaptor for MS
08	BSS - MSC interface
09	Network interworking
10	Service interworking
11	Equipment and type approval specifications
12	Operation and maintenance

Table 1-5 GSM Recommendations

The GSM 1800 section is written as a delta part within the GSM recommendations, describing only those differences between GSM 900 and GSM 1800. GSM 1900 is based on GSM 1800 and has been adapted to meet the American National Standards Institute (ANSI) standard.

GSM PHASES

In the late 1980s, the groups involved in developing the GSM standard realized that within the given time-frame they could not complete the specifications for the entire range of GSM services and features as originally planned. Because of this, it was decided that GSM would be released in phases with phase 1 consisting of a limited set of services and features. Each new phase builds on the services offered by existing phases.

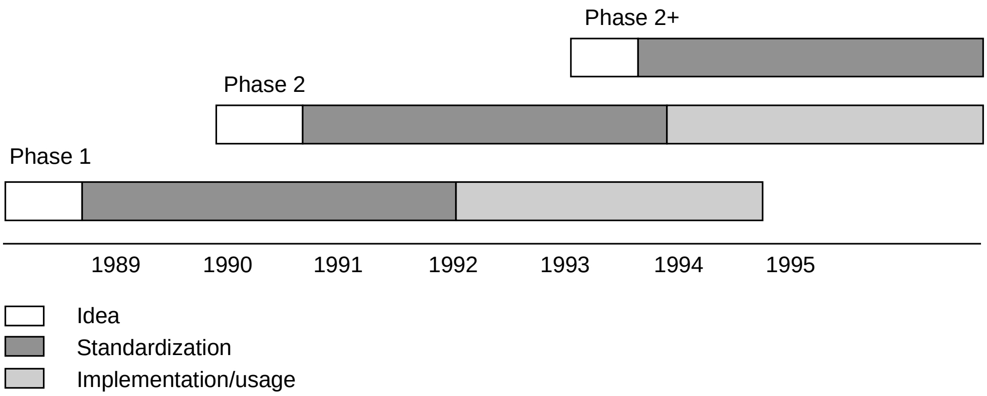


Figure 1-2 GSM phases

Phase 1

Phase 1 contains the most common services including:

- Voice telephony
- International roaming
- Basic fax/data services (up to 9.6 kbits/s)
- Call forwarding
- Call barring
- Short Message Service (SMS)

Phase 1 also incorporated features such as ciphering and Subscriber Identity Module (SIM) cards. Phase 1 specifications were then closed and cannot be modified.

Phase 2

Additional features were introduced in GSM phase 2 including:

- Advice of charge
- Calling line identification
- Call waiting
- Call hold
- Conference calling
- Closed user groups
- Additional data communications capabilities

Phase 2+

The standardization groups have already begun to define the next phase, 2+. The phase 2+ program will cover multiple subscriber numbers and a variety of business oriented features.

Some of the enhancements offered by Phase 2+ include:

- Multiple service profiles
- Private numbering plans
- Access to Centrex services
- Interworking with GSM 1800, GSM 1900 and the Digital Enhanced Cordless Telecommunications (DECT) standard

Priorities and time schedules for new features and functions depend primarily on the interest shown by operating companies and manufacturers and technical developments in related areas.

GSM NETWORK COMPONENTS

The GSM network is divided into two systems. Each of these systems are comprised of a number of functional units which are individual components of the mobile network. The two systems are:

- Switching System (SS)
- Base Station System (BSS)

In addition, as with all telecommunications networks, GSM networks are operated, maintained and managed from computerized centers.

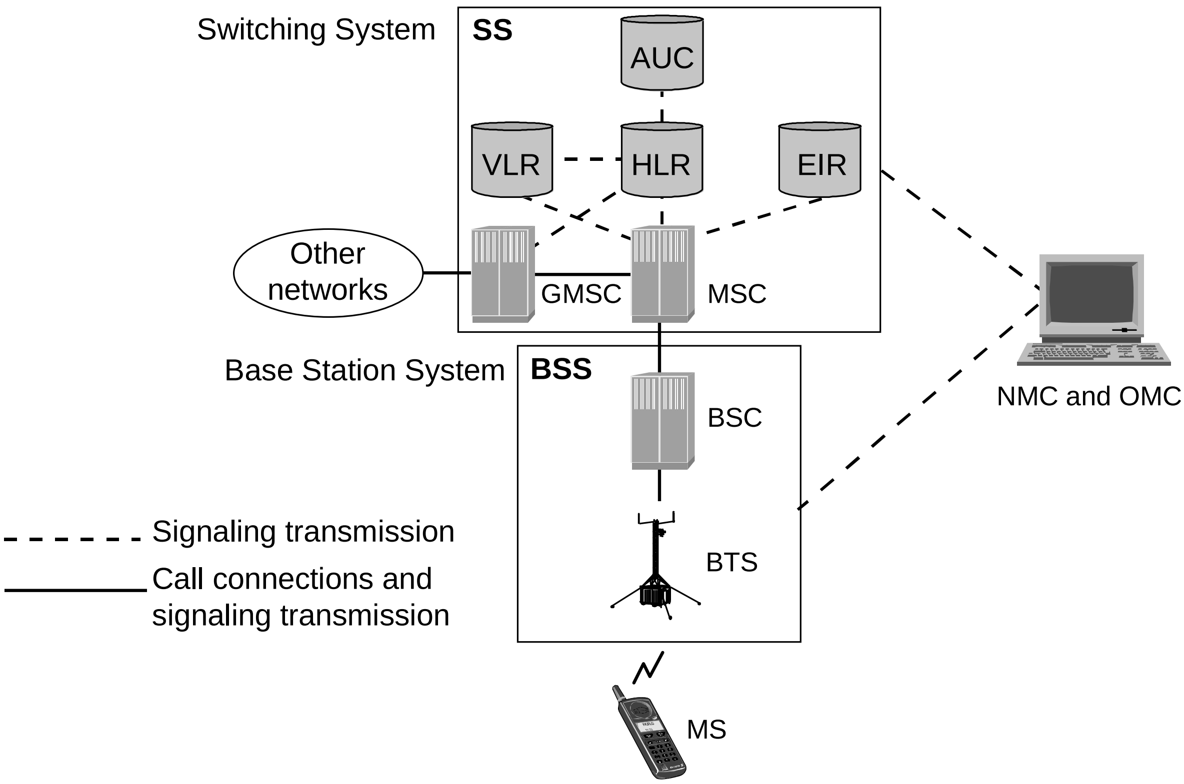


Figure 1-3 System model

Abbreviations:

AUC	AUthentication Center
BSC	Base Station Controller
BTS	Base Transceiver Station
EIR	Equipment Identity Register
HLR	Home Location Register
MS	Mobile Station
MSC	Mobile services Switching Center
NMC	Network Management Center
OMC	Operation and Maintenance Center
VLR	Visitor Location Register

The SS is responsible for performing call processing and subscriber related functions. It includes the following functional units:

- Mobile services Switching Center (MSC)
- Home Location Register (HLR)
- Visitor Location Register (VLR)
- AUthentication Center (AUC)
- Equipment Identity Register (EIR)

The BSS performs all the radio-related functions. The BSS is comprised of the following functional units:

- Base Station Controller (BSC)
- Base Transceiver Station (BTS)

The OMC performs all the operation and maintenance tasks for the network such as monitoring network traffic and network alarms. The OMC has access to both the SS and the BSS.

MSs do not belong to any of these systems.

SWITCHING SYSTEM (SS) COMPONENTS

Mobile services Switching Center (MSC)

The MSC performs the telephony switching functions for the mobile network. It controls calls to and from other telephony and data systems, such as the Public Switched Telephone Network (PSTN), Integrated Services Digital Network (ISDN), public data networks, private networks and other mobile networks.

Gateway Functionality

Gateway functionality enables an MSC to interrogate a network's HLR in order to route a call to a Mobile Station (MS). Such an MSC is called a Gateway MSC (GMSC). For example, if a person connected to the PSTN wants to make a call to a GSM mobile subscriber, then the PSTN exchange will access the GSM network by first connecting the call to a GMSC. The same is true of a call from an MS to another MS.

Any MSC in the mobile network can function as a gateway by integration of the appropriate software.

Home Location Register (HLR)

The HLR is a centralized network database that stores and manages all mobile subscriptions belonging to a specific operator. It acts as a permanent store for a person's subscription information until that subscription is canceled. The information stored includes:

- Subscriber identity
- Subscriber supplementary services
- Subscriber location information
- Subscriber authentication information

The HLR can be implemented in the same network node as the MSC or as a stand-alone database. If the capacity of a HLR is exceeded by the number of subscribers, additional HLRs may be added.

Visitor Location Register (VLR)

The VLR database contains information about all the mobile subscribers currently located in an MSC service area. Thus, there is one VLR for each MSC in a network. The VLR temporarily stores subscription information so that the MSC can service all the subscribers currently visiting that MSC service area. The VLR can be regarded as a distributed HLR as it holds a copy of the HLR information stored about the subscriber.

When a subscriber roams into a new MSC service area, the VLR connected to that MSC requests information about the subscriber from the subscriber's HLR. The HLR sends a copy of the information to the VLR and updates its own location information. When the subscriber makes a call, the VLR will already have the information required for call set-up.

AUthentication Center (AUC)

The main function of the AUC is to authenticate the subscribers attempting to use a network. In this way, it is used to protect network operators against fraud. The AUC is a database connected to the HLR which provides it with the authentication parameters and ciphering keys used to ensure network security.

Equipment Identity Register (EIR)

☞ Did you know?

Although useful, the EIR is actually an optional component of a GSM network, and is therefore, often not used.

The EIR is a database containing mobile equipment identity information which helps to block calls from stolen, unauthorized, or defective MSs. It should be noted that due to subscriber-equipment separation in GSM, the barring of MS equipment does not result in automatic barring of a subscriber.

BASE STATION SYSTEM (BSS) COMPONENTS

Base Station Controller (BSC)

The BSC manages all the radio-related functions of a GSM network. It is a high capacity switch that provides functions such as MS handover, radio channel assignment and the collection of cell configuration data. A number of BSCs may be controlled by each MSC.

Base Transceiver Station (BTS)

The BTS controls the radio interface to the MS. The BTS comprises the radio equipment such as transceivers and antennas which are needed to serve each cell in the network. A group of BTSs are controlled by a BSC.

NETWORK MONITORING CENTERS

Operation and Maintenance Center (OMC)

An OMC is a computerized monitoring center which is connected to other network components such as MSCs and BSCs via X.25 data network links. In the OMC, staff are presented with information about the status of the network and can monitor and control a variety of system parameters. There may be one or several OMCs within a network depending on the network size.

Network Management Center (NMC)

Centralized control of a network is done at a Network Management Center (NMC). Only one NMC is required for a network and this controls the subordinate OMCs. The advantage of this hierarchical approach is that staff at the NMC can concentrate on long term system-wide issues, whereas local personnel at each OMC can concentrate on short term, regional issues.

OMC and NMC functionality can be combined in the same physical network node or implemented at different locations.

MOBILE STATION (MS)

An MS is used by a mobile subscriber to communicate with the mobile network. Several types of MSs exist, each allowing the subscriber to make and receive calls. Manufacturers of MSs offer a variety of designs and features to meet the needs of different markets.

The range or coverage area of an MS depends on the output power of the MS. Different types of MSs have different output power capabilities and consequently different ranges. For example, hand-held MSs have a lower output power and shorter range than car-installed MSs with a roof mounted antenna.

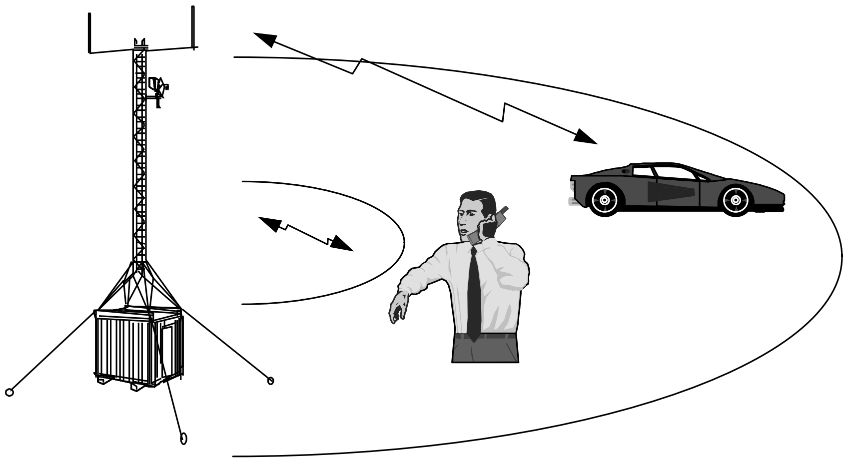


Figure 1-4 Ranges for different types of MSs

GSM MSs consist of:

- A mobile terminal
- A Subscriber Identity Module (SIM)

Unlike other standards, in GSM the subscriber is separated from the mobile terminal. Each subscriber's information is stored as a "smart card" SIM. The SIM can be plugged into any GSM mobile terminal. This brings the advantages of security and portability for subscribers. For example, subscriber A's mobile terminal may have been stolen. However, subscriber A's own SIM can be used in another person's mobile terminal and the calls will be charged to subscriber A.

GSM GEOGRAPHICAL NETWORK STRUCTURE

Every telephone network needs a specific structure to route incoming calls to the correct exchange and then on to the subscriber. In a mobile network, this structure is very important because the subscribers are mobile. As subscribers move through the network, these structures are used to monitor their location.

CELL

A cell is the basic unit of a cellular system and is defined as the area of radio coverage given by one BS antenna system. Each cell is assigned a unique number called Cell Global Identity (CGI). In a complete network covering an entire country, the number of cells can be quite high.

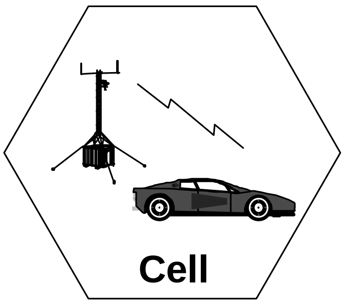


Figure 1-5 A cell

LOCATION AREA (LA)

A Location Area (LA) is defined as a group of cells. Within the network, a subscriber's location is known by the LA which they are in. The identity of the LA in which an MS is currently located is stored in the VLR.

When an MS crosses a boundary from a cell belonging to one LA into a cell belonging to another LA, it must report its new location to the network[1]. When an MS crosses a cell boundary within an LA, it does need to report its new location to the network. When there is call for an MS, a paging message is broadcast within all cells belonging to an LA.

[1] Note: This only occurs when the MS is idle. When the MS is on a call, it location is not updated, even if it changes LAs.

MSC SERVICE AREA

An MSC service area is made up of a number of LAs and represents the geographical part of the network controlled by one MSC. In order to be able to route a call to an MS, the subscriber's MSC service area is also recorded and monitored. The subscriber's MSC service area is stored in the HLR.

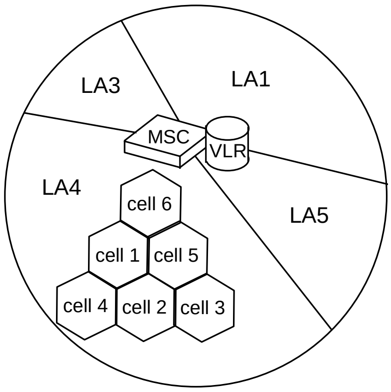


Figure 1-6 MSC service area

PLMN SERVICE AREA

A Public Land Mobile Network (PLMN) service area is the entire set of cells served by one network operator and is defined as the area in which an operator offers radio coverage and access to its network. In any one country there may be several PLMN service areas, one for each mobile operator's network.

GSM SERVICE AREA

The GSM service area is the entire geographical area in which a subscriber can gain access to a GSM network. The GSM service area increases as more operators sign contracts agreeing to work together. Currently, the GSM service area spans dozens of countries across the world from Ireland to Australia and South Africa.

International roaming is the term applied when an MS moves from one PLMN to another.

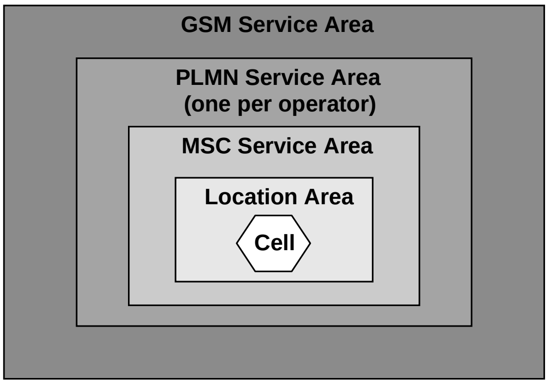


Figure 1-7 Relation between areas in GSM

The figures below show alternative views of the same network:

- The first figure shows the network nodes and their layout across the network. For simplicity, this may be referred to as the hardware view of the network.
- The second figure shows the geographical network configuration. For simplicity, this may be referred to as the software view of the network.

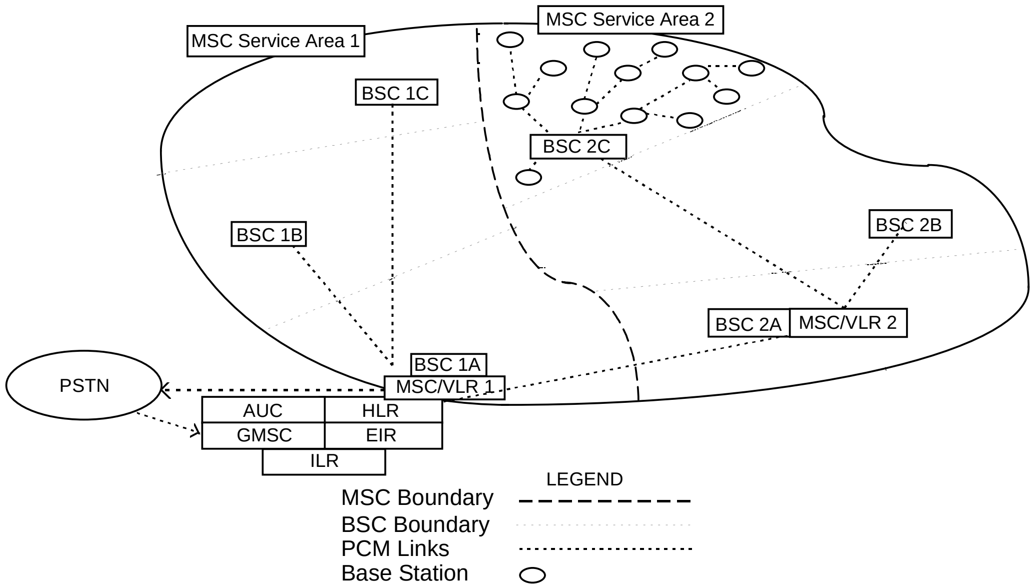


Figure 1-8 "Hardware" view of a sample network

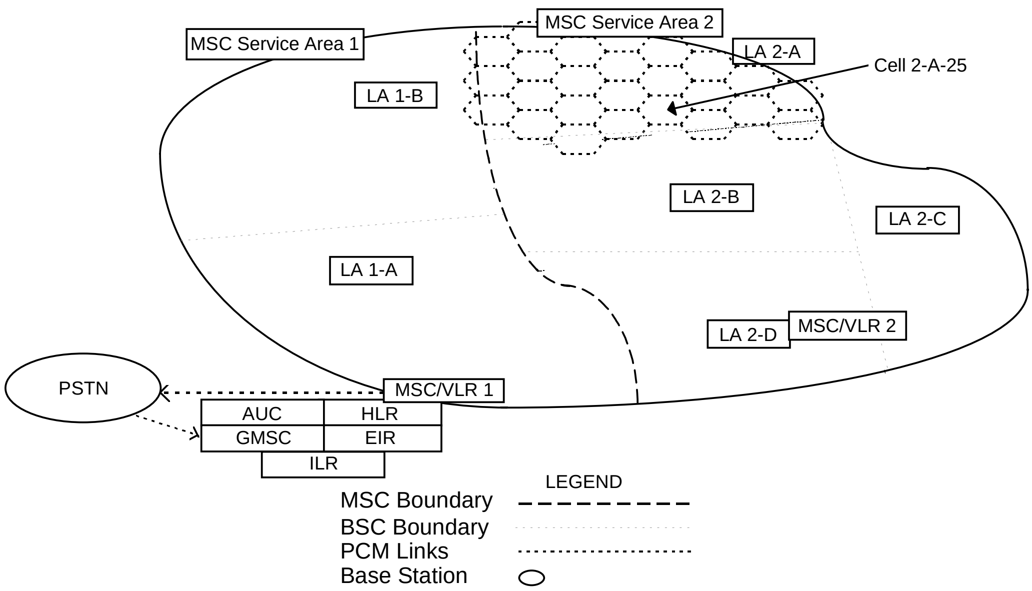


Figure 1-9 "Software" view of a sample network

GSM FREQUENCY BANDS

As GSM has grown worldwide, it has expanded to operate at three frequency bands: 900, 1800 and 1900.

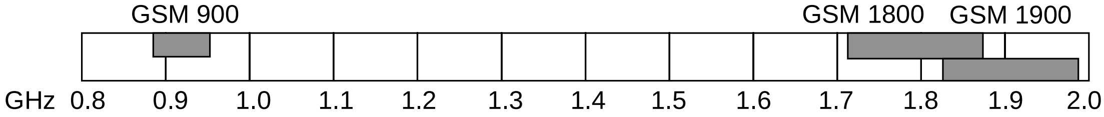


Figure 1-10 GSM frequency bands

GSM 900

The original frequency band specified for GSM was 900 MHz. Most GSM networks worldwide use this band. In some countries and extended version of GSM 900 can be used, which provides extra network capacity. This extended version of GSM is called E-GSM, while the primary version is called P-GSM.

GSM 1800

☞ Did you know?

This was originally named Digital Cellular System (DCS) 1800 MHz. In 1997 it was renamed GSM 1800.

In 1990, in order to increase competition between operators, the United Kingdom requested the start of a new version of GSM adapted to the 1800 MHz frequency band. Licenses have been issued in several countries and networks are in full operation.

By granting licenses for GSM 1800 in addition to GSM 900, a country can increase the number of operators. In this way, due to increased competition, the service to subscribers is improved.

GSM 1900

In 1995, the Personal Communications Services (PCS) concept was specified in the United States. The basic idea is to enable "person-to-person" communication rather than "station-to-station". PCS does not require that such services be implemented using cellular technology, but this has proven to be the most effective method. The frequencies available for PCS are around 1900 MHz. As GSM 900 could not be used in North America due to prior allocation of the 900 MHz frequencies, GSM 1900 MHz is seen as an opportunity to bridge this gap. The main differences between the American GSM 1900 standard and GSM 900 is that it supports ANSI signaling.

KEY TERMS

During the development of mobile systems, many terms arose which are used to describe the call cases and situations involving MSs. The primary terms used are described below.

An MS can have one of the following states:

- **Idle:** the MS is ON but a call is not in progress
- **Active:** the MS is ON and a call is in progress
- **Detached:** the MS is OFF

The following table defines the key terms used to describe GSM mobile traffic cases (there are no traffic cases in detached mode):

Mode	Term	Description
Idle	Registration	This is the process in which an MS informs a network that it is attached.
	Roaming	When an MS moves around a network in idle mode, it is referred to as roaming.
	International Roaming	When an MS moves into a network which is not its home network, it is referred to as international roaming. MSs can only roam into networks with which the home network has a roaming agreement.
	Location Updating	An MS roaming around the network must inform the network when it enters a new LA. This is called location updating.
	Paging	This is the process whereby a network attempts to contact a particular MS. This is achieved by broadcasting a paging message containing the identity of that MS.
Active	Handover	This is the process in which control of a call is passed from one cell to another while the MS moves between cells.

Table 1-6 Key terms

MS Registration and Roaming

When an MS is powered off it is detached from the network. When the subscriber switches power on, the MS scans the GSM frequencies for special channels called control channels. When it finds a control channel, the MS measures the signal strength it receives on that channel and records it. When all control channels have been measured, the MS tunes to the strongest one.

When the MS has just been powered on, the MS must register with the network which will then update the MS's status to idle. If the location of the MS is noticed to be different from the currently stored location then a location update will also take place.

As the MS moves through the network, it continues to scan the control channels to ensure that it is tuned to the strongest possible channel. If the MS finds one which is stronger, then the MS retunes to this new control channel[2]. If the new control channel belongs to a new LA, the MS will also inform the network of its new location.

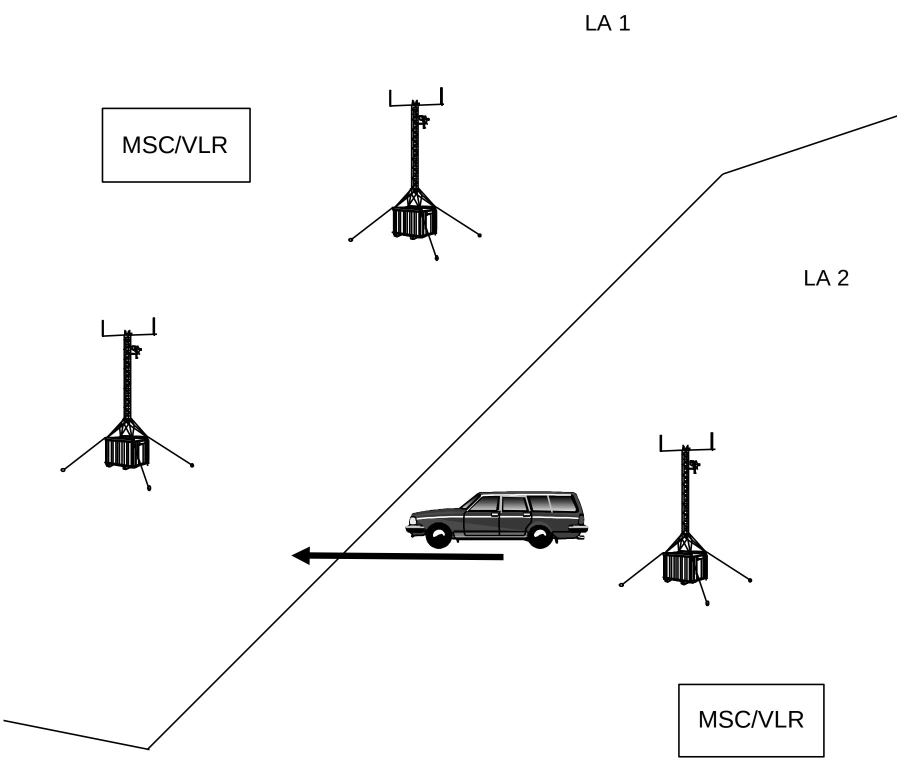


Figure 1-11 Roaming

[2] Note: In idle mode, it is the MS which decides which cell to move into. In active mode, the network makes this decision.

Overview of Ericsson’s GSM Systems

Chapter 2

This chapter is designed to provide the student with an overview of Ericsson’s GSM systems: CME 20 and CMS 40

OBJECTIVES:

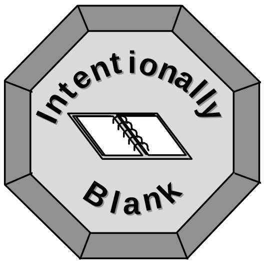
Upon completion of this chapter the student will be able to:

- Describe the CME 20/CMS 40 network elements and their main functionality

Intentionally Blank

2 Overview of Ericsson's GSM Systems

Table of Contents


Intentionally
Blank

ERICSSON IN GSM

Ericsson has been involved in GSM since its inception and took an active part in the GSM specification process.

☞ Did you know?
Germany was the location for the first Ericsson GSM network.

Ericsson is the largest supplier of GSM equipment in the world with a market share of approximately 50%. Over 100 GSM networks worldwide are supplied by Ericsson.

Ericsson is also one of the world's largest suppliers of GSM mobile phones and has an estimated 24% share of the world market.

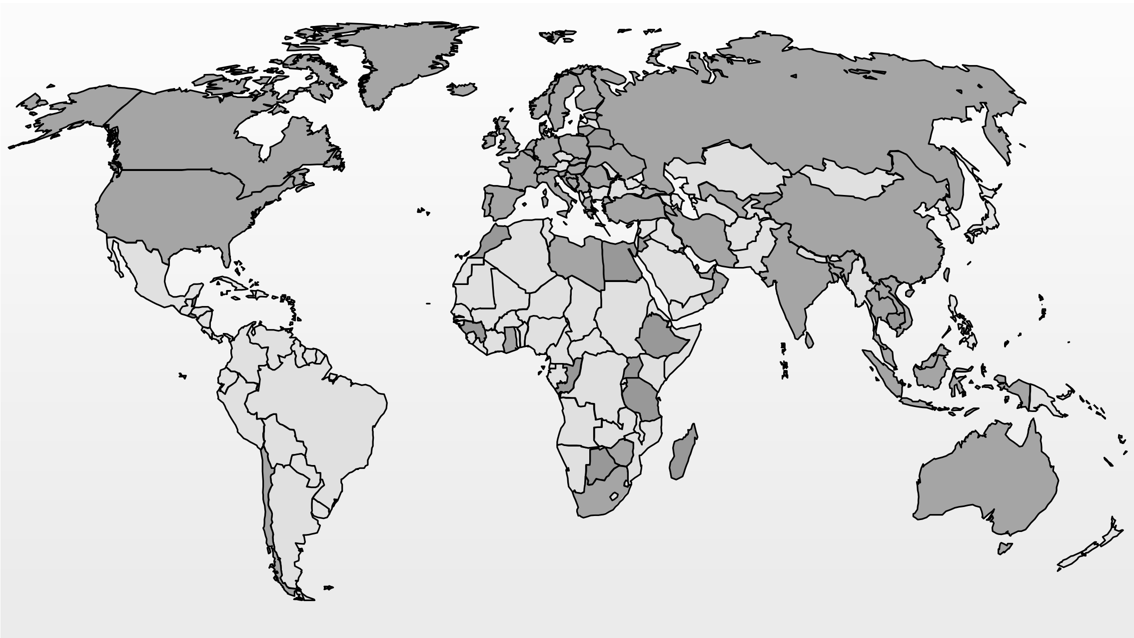


Figure 2-1 Ericsson GSM worldwide (indicated by darker areas)

ERICSSON'S GSM SYSTEM ARCHITECTURE

Ericsson provides two systems for GSM networks:

- Cellular Matra Ericsson (CME) 20: for GSM 900 and GSM 1800 networks
- Cellular Mobile System (CMS) 40: for GSM 1900 networks

> ☞ Did you know?
>
> *CME stands for Cellular Matra Ericsson, because the French company Matra was involved in the initial development of Ericsson's GSM system.*

Like the GSM system model itself, Ericsson's GSM systems are split into two primary systems: the Switching System (SS) and the Base Station System (BSS). However, depending on the requirements of a network operator, Ericsson's GSM systems can incorporate other functions and nodes, such as Mobile Intelligent Network (MIN) nodes and post processing systems.

Note: Ericsson's wide range of MSs are not considered to be part of either the CME 20 or CMS 40 product, due to the fact that an MS from any supplier can work with network equipment from any other supplier.

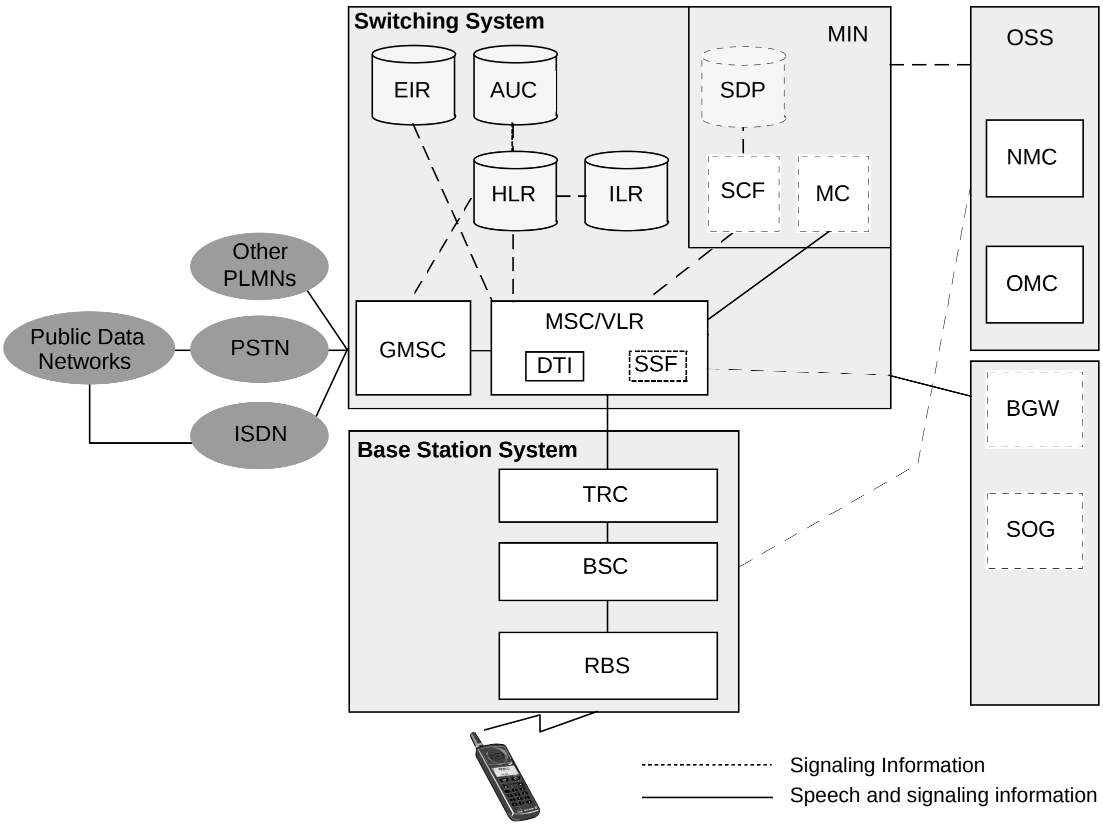


Figure 2-2 Ericsson GSM network system model

Basic or Additional	Abbrev.	System	Full component name	Platform
Basic	MSC/VLR	SS	Mobile services Switching Center/Visitor Location Register	AXE
Basic	GMSC	SS	Gateway MSC	AXE
Basic	HLR	SS	Home Location Register	AXE
Basic	ILR	SS	Interworking Location Register	AXE
Basic	AUC	SS	AUthentication Center	Unix/AXE
Basic	EIR	SS	Equipment Identity Register	Unix
Basic	DTI	SS	Data Transmission Interface	AXE
Basic	TRC	BSS	TRanscoder Controller	AXE
Basic	BSC	BSS	Base Station Controller	AXE
Basic	BTS	BSS	Base Transceiver Station	RBS
Basic	OMC	OSS	Operation and Maintenance Center	TMOS
Basic	NMC	OSS	Network Management Center	TMOS
Additional	MC	SS	Message Center	MXE
Additional	SSP	SS	Service Switching Point	AXE
Additional	SCP	SS	Service Control Point	AXE
Additional	SDP	SS	Service Data Point	Unix
Additional	SOG		Service Order Gateway	Unix
Additional	BGW		Billing GateWay	Unix

Table 2-1 Components of Ericsson network system

ERICSSON'S SS IMPLEMENTATION

Mobile services Switching Center/Visitor Location Register (MSC/VLR)

The MSCs in all Ericsson GSM networks are AXE exchanges. In all Ericsson GSM networks, the VLR is integrated into the MSC node. This means that signaling between the VLR and the MSC is done internally within the MSC/VLR network node and does not have to be carried over the rest of the network. This has the benefit of reducing the overall signaling load on the network.

Gateway Mobile services Switching Center (GMSC)

The GMSC is also implemented as an AXE exchange. In effect, it is an MSC with some additional software.

Home Location Register (HLR)

Ericsson's HLR is also based on AXE and can be implemented in the same node as the MSC/VLR or as a stand-alone node.

Interworking Location Register (ILR)

The Interworking Location Register (ILR) exists in CMS 40 networks only. An ILR makes inter-system roaming possible, meaning that a subscriber can roam from a GSM 1900 network to an AMPS network. The ILR consists of an AMPS HLR and a GSM 1900 VLR.

Authentication Center (AUC) and Equipment Identity Register (EIR)

The AUC and EIR are implemented either as stand-alone nodes or as a combined AUC/EIR node. The UNIX-based AUC and the EIR are developed by Sema Group. The AUC may alternatively reside on an AXE, possibly integrated with a HLR.

Data Transmission Interface (DTI)

The DTI is a hardware platform which implements the GSM-defined InterWorking Function (IWF). It performs data handling functions such as data rate conversion. DTI is implemented on an AXE platform and is integrated in the MSC/VLR. By being integrated into the AXE platform, the DTI does not need separate operation and maintenance facilities.

ERICSSON’S BSS IMPLEMENTATION

Ericsson’s BSS differs slightly from the GSM system model, in that a node called the Transcoder Controller (TRC) is added. However, this does not provide extra functionality - the functions of the TRC are part of the GSM model’s BSC.

Transcoder Controller (TRC)

The purpose of a TRC is to multiplex network traffic channels from multiple BSCs onto one 64 Kbits/s PCM channel which reduces network transmission costs. The TRC can be combined with the BSC or exist as a stand-alone node.

Base Station Controller (BSC)

The BSC in all Ericsson GSM networks is based on AXE technology. It can be implemented as a stand-alone node or integrated with either an MSC/VLR or a TRC.

Base Transceiver Station (BTS)

In Ericsson's GSM systems the BTS is included as part of a product called RBS. The RBS also contains extra functionality which enables the support of several GSM-defined BTSs.

Ericsson offers a wide range of RBSs for use in GSM networks:

- RBS 2101
- RBS 2102
- RBS 2103
- RBS 2202
- RBS 2301
- RBS 2302
- RBS 2302 MAXITE

ERICSSON'S OMC AND NMC IMPLEMENTATION

Operation and Support System (OSS) is Ericsson's product to support the activities performed in an OMC and/or NMC. The network operator monitors and controls the network through OSS which offers cost effective support for centralized, regional and local operations and maintenance activities. OSS is based on Ericsson's Telecommunications Management and Operations Support (TMOS) platform.

OSS is designed as a complete network management system which can be used to control all the main network elements such as MSC/VLRs, HLRs, ILRs, TRCs, BSCs, EIRs, AUCs and Mobile Intelligent Network (MIN) nodes. OSS can also control BTSs through the BSCs.

OSS uses a Graphical User Interface (GUI) enabling easier system use and network management.

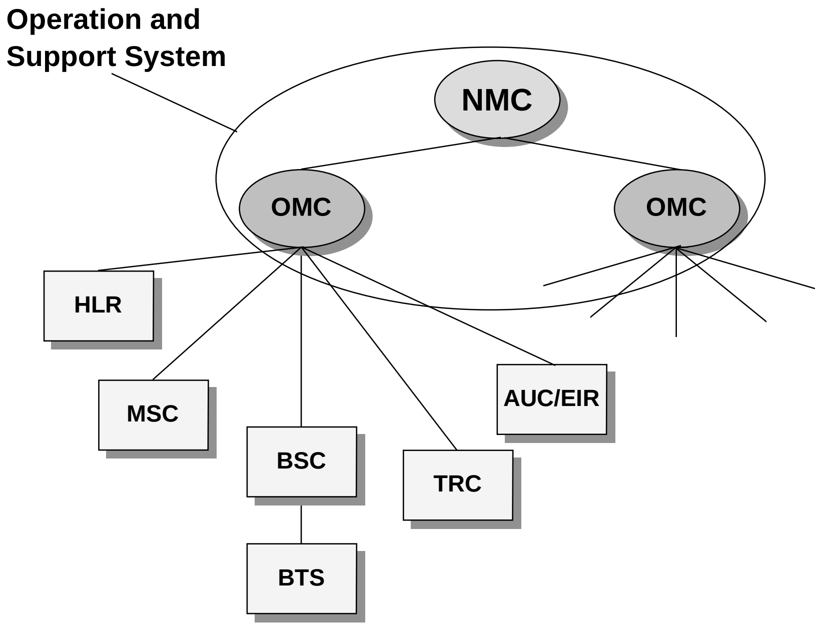


Figure 2-3 OSS provides central supervision of all network elements

Telecommunication Management Network (TMN)

OSS and TMOS are based on the international Telecommunication Management Network (TMN) standard. TMN is a model for the management of telecommunication networks. The most important areas of network management identified by TMN are:

- Configuration Management
- Fault Management
- Performance Management

Configuration Management

In OSS, the cellular network can be displayed on screen using a Graphical Cell Configuration (GCC). GCC gives a graphical view of the entire network and allows the operation and maintenance staff to zoom in on specific regions of the network to get a more detailed picture of particular cells.

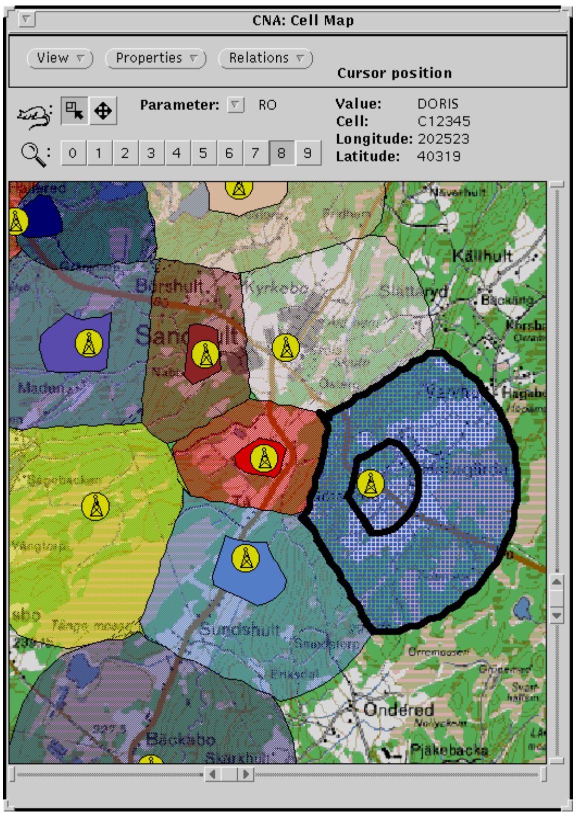


Figure 2-4 Graphical Cell Configuration

Fault Management

The operator can monitor the status of the network by using Network Alarm Status Presentation. If a failure occurs in the network, one or more alarms are activated and forwarded to the OMC. Different icons are depicted on screen to indicate the severity of the alarm. One icon is used to show critical situations while another icon is used to show warnings.

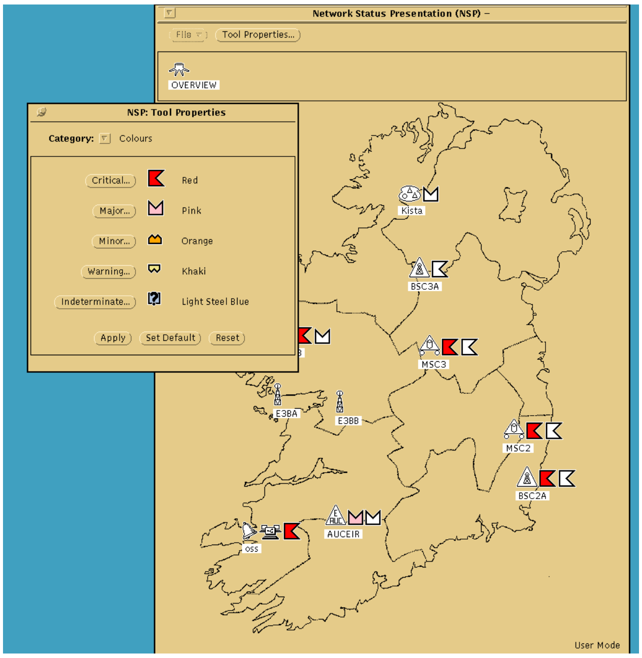


Figure 2-5 Network Alarm Status Presentation map showing icons for different types of alarms

Performance Management

In order to plan for future use of the cellular network, each operator must check the performance of the network. With performance management it is possible for an operator to collect and receive statistics based on both short-term and long-term measurements.

ADDITIONAL ERICSSON NETWORK COMPONENTS

A basic GSM network can be enhanced by the addition of some or all of the following functions.

Additional Nodes

Message Center (MC)

A Message Center (MC) may be added to a GSM network to provide voice/fax mail and handling of the Short Message Service (SMS) and SMS Cell Broadcast (SMSCB) text messages. These services can generate considerable revenue for a network operator, as they are becoming increasingly popular.

In the Ericsson GSM system the MC is implemented by Ericsson's MXE product. Like other network nodes, the MXE can also be controlled by OSS.

Mobile Intelligent Network (MIN) nodes

Mobile Intelligent Network (MIN) nodes can be added to a basic GSM network to provide value-added services to subscribers.

☞ Did you know?

Examples of MIN services include:
- *freephone*
- *premium rate*
- *personal number*
- *televoting*
- *cellular virtual private network*

Ericsson's MIN nodes include:

- **Service Switching Point (SSP):** an SSP acts as an interface between the call control functions of the mobile network and the service control functions of a Service Control Point (SCP). Ericsson's SSP is AXE-based and may be integrated within an MSC/VLR (recommended) or stand-alone.
- **Service Control Point (SCP):** an SCP contains the intelligence of a MIN service or services. This intelligence is realized in software programs and data. Ericsson's SCP is also AXE-based and the recommended configuration is as a stand-alone node, accessible by all MSC/SSPs.
- **Service Data Point (SDP):** an SDP manages the data which is used by an MIN service. Ericsson's SDP is a stand-alone node based on UNIX.

Post Processing Systems

Post processing systems are used by network operators to handle and analyze the large amounts of information which is generated by calls in the network.

Service Order Gateway (SOG)

A network operator requires administrative systems to analyze and manage network information such as customer subscriptions, billing information and for fraud detection. An operator’s administrative systems are normally called Customer Administration Systems (CAS). They are complex systems which are often inflexible and costly to adapt to the specific needs of individual network operators.

The Service Order Gateway (SOG) is an Ericsson product which enables CASs to exchange information with network elements which contain service information, such as the HLR.

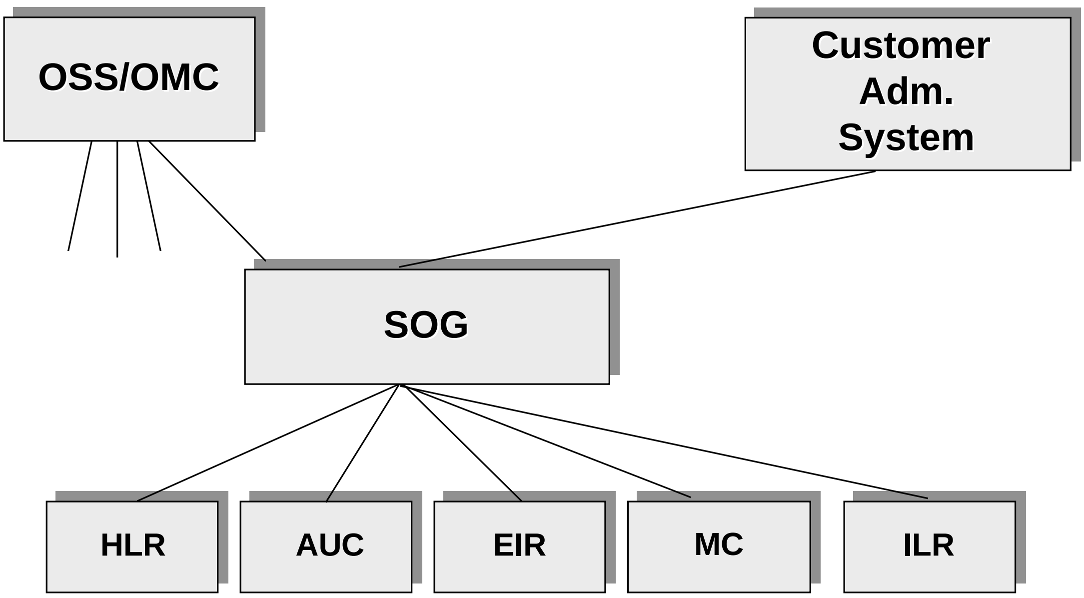


Figure 2-6 Service Order Gateway (SOG)

Billing GateWay (BGW)

A Billing GateWay (BGW) collects billing information or Call Data Record (CDR) files from network elements such as MSCs and forwards them to post-processing systems that use the files as input. A BGW acts as a billing interface to the network elements in an Ericsson network and its flexible interface supports adaptation to any new types of network elements. Any internal BGW alarms are forwarded to OSS at an OMC.

A BGW is usually connected to the customer administration and billing systems and is handled by the administrative organization.

The figure below shows some of the possible billing information required when analyzing a specific call.

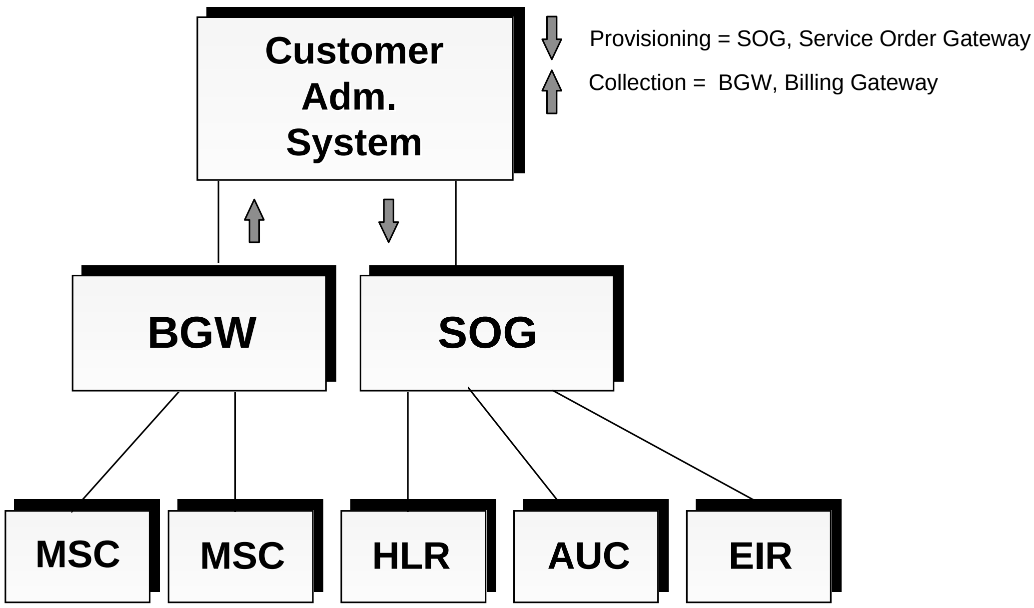


Figure 2-7 Billing information

Intentionally Blank

Wireless Concepts

Chapter 3

This chapter is designed to provide the student with an overview of basic concepts of wireless communications.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the concept of frequencies
- Describe the Time Division Multiple Access technique
- Describe the concepts of analog and digital signals
- Describe some transmission problems
- Describe the methods used to solve transmission problems
- Describe the GSM speech transmission process

Intentionally Blank

3 Wireless Concepts

Table of Contents

Topic	Page

FREQUENCY CONCEPTS

The following table summarizes the frequency-related specifications of each of the GSM systems. The terms used in the table are explained in the remainder of this section.

System	P-GSM 900	E-GSM 900	GSM 1800	GSM 1900
Frequencies: • Uplink • Downlink	 890-915 MHz 935-960 MHz	 880-915 MHz 925-960 MHz	 1710-1785 MHz 1805-1880 MHz	 1850-1910 MHz 1930-1990 MHz
Wavelength	~ 33 cm	~ 33 cm	~ 17 cm	~ 16 cm
Bandwidth	25 MHz	35 MHz	75 MHz	60 MHz
Duplex Distance	45 MHz	45 MHz	95 MHz	80 MHz
Carrier Separation	200 kHz	200 kHz	200 kHz	200 kHz
Radio Channels[1]	125	175	375	300
Transmission Rate	270 kbits/s	270 kbits/s	270 kbits/s	270 kbits/s

Table 3-1 Frequency-related specifications

[1] Note: Every GSM network uses one channel as a guard channel. This reduces the number of channels available for traffic by one. This is used to separate GSM frequencies from the frequencies of neighboring applications, e.g. 889 MHz. In this way extra protection (and quality) for GSM calls is ensured.

FREQUENCY

☞ Did you know?

Due to frequency, a BTS transmitting information at 1800 MHz with an output power of 10 Watts (W) will cover only half the area of a similar BTS transmitting at 900 MHz. To counteract this, BTSs using 1800 MHz may use a higher output power.

An MS communicates with a BTS by transmitting or receiving radio waves, which consist of electromagnetic energy. The frequency of a radio wave is the number of times that the wave oscillates per second. Frequency is measured in Hertz (Hz), where 1 Hz indicates one oscillation per second. Radio frequencies are used for many applications in the world today. Some common uses include:

- Television: 300 MHz approx.
- FM Radio: 100 MHz approx.
- Police radios: Country dependent
- Mobile networks: 300 - 2000 MHz approx.

The frequencies used by mobile networks varies according to the standard being used[2]. An operator applies for the available frequencies or, as in the United States, the operator bids for frequency bands at an auction. The following diagram displays the frequencies used by the major mobile standards:

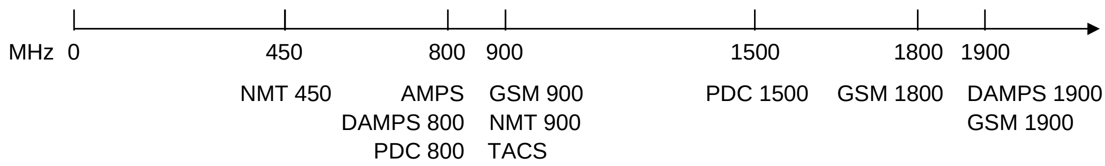


Figure 3-1 Frequencies for major mobile standards

[2] As these frequencies are used to carry information, they are often referred to as carrier frequencies.

Wavelength

There are many different types of electromagnetic waves. These electromagnetic waves can be described by a sinusoidal function which is characterised by wavelength. Wavelength (λ) is the length of one complete oscillation and is measured in metres (m). Frequency and wavelength are related via the speed of propagation, which for radio waves is the speed of light (3×10^8 m/s).

The wavelength of a frequency can be determined by using the following formula:

$$\text{Wavelength} = \frac{\text{Speed}}{\text{Frequency}}$$

Thus, for GSM 900 the wavelength is:

$$\text{Wavelength} = \frac{3 \times 10^8 \text{m/s}}{900 \text{ MHz}}$$

$$\text{Wavelength} = \frac{300{,}000{,}000 \text{ m/s}}{900{,}000{,}000}$$

Wavelength = 0.33 m (or 33 cm)

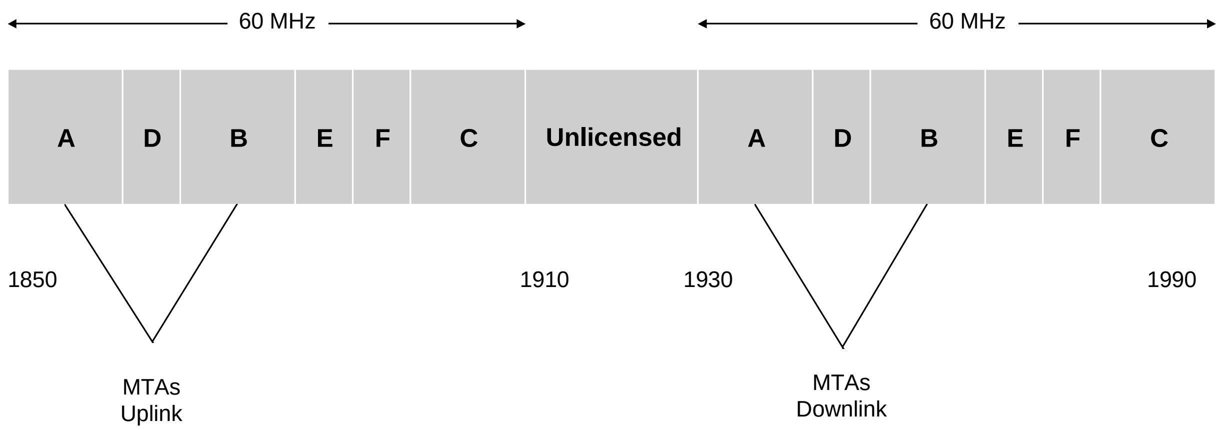
From this formula it can be determined that the higher the frequency, the shorter the wavelength. Lower frequencies, with longer wavelengths, are better suited to transmission over large distances, because they bounce on the surface of the earth and in the atmosphere. Television and FM radio are examples of applications which use lower frequencies.

Higher frequencies, with shorter wavelengths, are better suited to transmission over small distances, because they are sensitive to such problems as obstacles in the line of the transmission path. Higher frequencies are suited to small areas of coverage, where the receiver is relatively close to the transmitter.

The frequencies used by mobile systems compromise between the large-coverage advantages offered by lower frequencies and the closeness-to-the-receiver advantages offered by use of higher frequencies.

Example of Frequency Allocation - United States

In 1994, the Federal Communications Commission (FCC) in the United States (US) auctioned licenses to prospective mobile network operators. Each network operator owns the rights to the license for ten years. Further auctions will be held following that period for the same licenses. The FCC has specified six blocks within the frequency band: three duplex blocks A, B, and C (30 MHz each) and three other duplex blocks D, E, and F (10 MHz each).



A,B	2 x 15 MHz	MTA
C	2 x 15 MHz	BTA
D, E, F	2 x 5 MHz	BTA

Figure 3-2 Spectrum allocation for PCS 1900 in the United States

For telecommunications purposes, the US is divided into 51 regions or Major Trading Areas (MTA) and 493 Basic Trading Areas (BTA). One MTA can be as large in geographical area as a state, while a BTA can be about the size of a large city. The FCC issued two PCS 1900 licenses for each MTA and four licenses for each BTA[3]. Thus, a city such as Los Angeles will be served by 6 operators: 2 MTA companies operating in California and 4 BTA companies operating in Los Angeles.

[3] Note: The choice of technology to use with the 1900 MHz frequencies is made by the successful companies. Both D-AMPS 1900 and GSM 1900 have been popular choices

BANDWIDTH

Bandwidth is the term used to describe the amount of frequency range allocated to one application. The bandwidth given to an application depends on the amount of available frequency spectrum. The amount of bandwidth available is an important factor in determining the capacity of a mobile system, i.e. the number of calls which can be handled.

CHANNELS

Another important factor in determining the capacity of a mobile system is the channel. A channel is a frequency or set of frequencies which can be allocated for the transmission, and possibly the receipt, of information. Communication channels of any form can be one of the following types:

Type	Description	Examples
Simplex	One way only	FM radio, television
Half duplex	Two way, only one at a time	Police radio
Full duplex	Two way, both at the same time	Mobile systems

A simplex channel, such as an FM radio music station, uses a single frequency in a single direction only. A duplex channel, such as that used during a mobile call, uses two frequencies: one to the MS and one from the MS. The direction from the MS to the network is referred to as *uplink*. The direction from the network to the MS is referred to as *downlink*.

☞ Did you know?

Because it requires less power to transmit a lower frequency over a given distance, uplink frequencies in mobile systems are always the lower band of frequencies - this saves valuable battery power of the MSs.

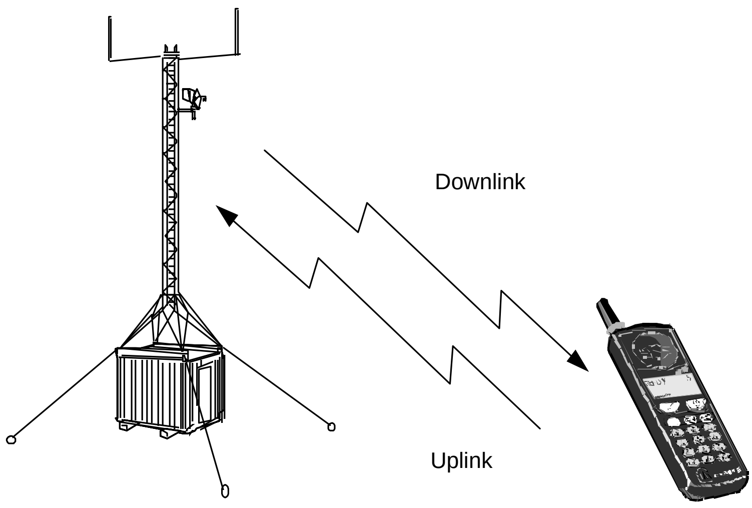


Figure 3-3 Uplink and downlink on a radio channel

Duplex Distance

The use of full duplex requires that the uplink and downlink transmissions must be separated in frequency by a minimum distance. This is the duplex distance. Without it, uplink and downlink frequencies would interfere with each other.

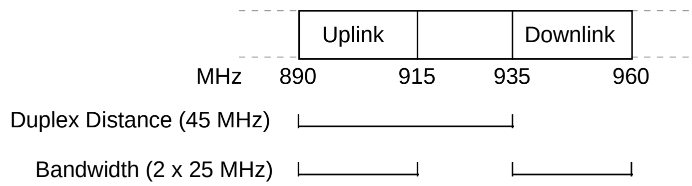


Figure 3-4 Duplex Distance

Carrier Separation

In addition to the duplex distance, every mobile system includes a carrier separation[4]. This is the distance on the frequency band between channels being transmitted in the same direction. This is required in order to avoid the overlapping of information in one channel into an adjacent channel.

The length of separation between two channels is dependent on the amount of information which is to be transmitted within the channel. The greater the amount of information to transmit, the greater the amount of separation required.

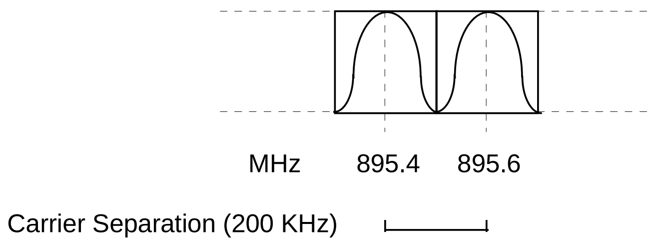


Figure 3-5 Carrier separation

From the figure above, it can be seen that the information to be sent is modulated around the carrier frequency of 895.4 MHz. The same is true of the information to be sent on 895.6 MHz. To avoid interference between the two sets of information, a separation distance of 200 kHz is required. If less separation were used, they would interfere and a caller on 895.4 MHz may experience crosstalk or noise from the caller on 895.6 MHz.

[4] Carrier separation is sometimes referred to as carrier bandwidth.

Capacity and Frequency Re-use

It is the number of frequencies in a cell which determines the cell's capacity. Each company with a license to operate a mobile network is allocated a limited number of frequencies. These are distributed throughout the cells in their network. Depending on the traffic load and the availability of frequencies, a cell may have one or more frequencies allocated to it.

It is important when allocating frequencies that interference is avoided. Interference can be caused by a variety of factors. A common factor is the use of similar frequencies close to each other. The higher the interference, the lower the call quality.

To cover an entire country, for example, frequencies must be re-used many times at different geographical locations in order to provide a network with sufficient capacity. The same frequencies can not be re-used in neighboring cells as they would interfere with each other so special patterns of frequency usage are determined during the planning of the network.

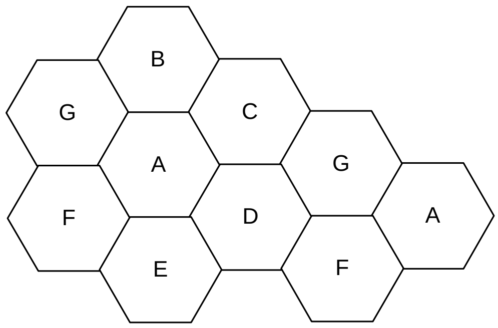


Figure 3-6 Neighboring cells cannot have the same frequency (simplified)

These frequency re-use patterns ensure that any frequencies being re-used are located at a sufficient distance apart to ensure that there is little interference between them. The term "frequency re-use distance" is used to describe the distance between two identical frequencies in a re-use pattern. The lower the frequency re-use distance, the more capacity available in the network.

TRANSMISSION RATE

The amount of information transmitted over a radio channel over a period of time is known as the transmission rate. Transmission rate is expressed in bits per second or bit/s. In GSM the net bit rate over the air interface is 270kbit/s

MODULATION METHOD

In GSM 900, the frequency that is used to transfer the information over the air interface is around 900 MHz. Since this is not the frequency at which the information is generated, modulation techniques are used to translate the information into the usable frequency band. Frequency translation is implemented by modulating the amplitude, frequency or phase of the so called carrier wave in accordance with the wave form of the input signal (e.g. speech). Any modulation scheme increases the carrier bandwidth and hence is a limit on the capacity of the frequency band available. In GSM, the carrier bandwidth is 200 kHz.

As a general rule, using simpler modulation techniques, 1 bit/s can be transmitted within 1 Hz. Using this method, only 200 kbits/s could be transmitted within 200 kHz. However, more advanced modulation techniques are available which can transmit more bits/s within 1 Hz. The modulation technique used in GSM is Gaussian Minimum Shift Keying (GMSK). GMSK enables the transmission of 270kbit/s within a 200kHz channel.

The channel capacity in GSM does not compare favorably with other digital mobile standards, which can fit more bits/s into a channel. In this way the capacity of other mobile standards is higher. However, GSM’s GMSK offers more tolerance of interference. This in turn enables the tighter re-use of frequencies, which leads to an overall gain in capacity which out-performs that of other systems.

ACCESS METHOD: TIME DIVISION MULTIPLE ACCESS (TDMA)

> ☞ Did you know?
>
> *TDMA is not the only possible access method for mobile systems. Analog systems use Frequency DMA (FDMA) while some systems use Code DMA (CDMA).*

Most digital cellular systems use the technique of Time Division Multiple Access (TDMA) to transmit and receive speech signals. With TDMA, one carrier is used to carry a number of calls, each call using that carrier at designated periods in time. These periods of time are referred to as time slots. Each MS on a call is assigned one time slot on the uplink frequency and one on the downlink frequency. The information sent during one time slot is called a burst.

In GSM, a TDMA frame consists of 8 time slots. This means that a GSM radio carrier can carry 8 calls.

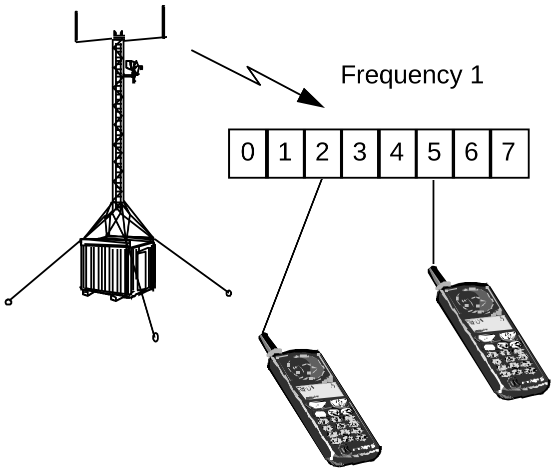


Figure 3-7 TDMA

<u>Note:</u> Only the downlink direction is shown. There is also a corresponding frame in the uplink direction.

ANALOG AND DIGITAL TRANSMISSION

INTRODUCTION TO ANALOG AND DIGITAL

Analog Information

Analog information is continuous and does not stop at discrete values. An example of analog information is time. It is continuous and does not stop at specific points. An analog watch may have a second-hand which does not jump from one second to the next, but continues around the watch face without stopping.

Analog Signals

An analog signal is a continuous waveform which changes in accordance with the properties of the information being represented.

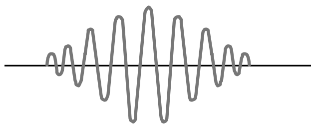


Figure 3-8 Analog Signal

Digital Information

Digital information is a set of discrete values. Time can also be represented digitally. However, digital time would be represented by a watch which jumps from one minute to the next without stopping at the seconds. In effect, such a digital watch is taking a sample of time at predefined intervals.

Digital Signals

For mobile systems, digital signals may be considered to be sets of discrete waveforms.

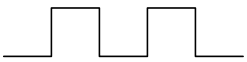


Figure 3-9 Digital Signal

ADVANTAGES OF USING DIGITAL

Human speech is a form of analog information. It is continuous and changes in both frequency (higher and lower pitches) and amplitude (whispering and shouting).

At first, analog signals may appear to be a better medium for carrying analog information such as speech. Analog information is continuous and if it were to be represented by discrete samples of the information (digital signal), then some information would be missing (like the seconds on the digital watch). An analog signal would not miss any values as it too is continuous.

All signals, analog and digital, become distorted over distances. In analog, the only solution to this is to amplify the signal. However, in doing so, the distortion is also amplified. In digital, the signal can be completely regenerated as new, without the distortion.

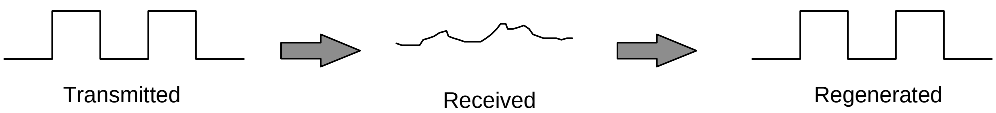


Figure 3-10 Regeneration of digital signal

The problem with using digital signals to transfer analog information is that some information will be missing due to the technique of taking samples. However, the more often the samples are taken, the closer the resulting digital values will be to a true representation of the analog information.

Overall, if samples are taken often enough, digital signals provide a better quality for transmission of analog information than analog signals.

TRANSMISSION PROBLEMS

Many problems may occur during the transmission of a radio signal. Some of the most common problems are described below.

PATH LOSS

Path loss occurs when the received signal becomes weaker and weaker due to increasing distance between MS and BTS, even if there are no obstacles between the transmitting (Tx) and receiving (Rx) antenna. The path loss problem seldom leads to a dropped call because before the problem becomes extreme, a new transmission path is established via another BTS.

SHADOWING

Shadowing occurs when there are physical obstacles including hills and buildings between the BTS and the MS. The obstacles create a shadowing effect which can decrease the received signal strength. When the MS moves, the signal strength fluctuates depending on the obstacles between the MS and BTS.

A signal influenced by fading varies in signal strength. Drops in strength are called fading dips.

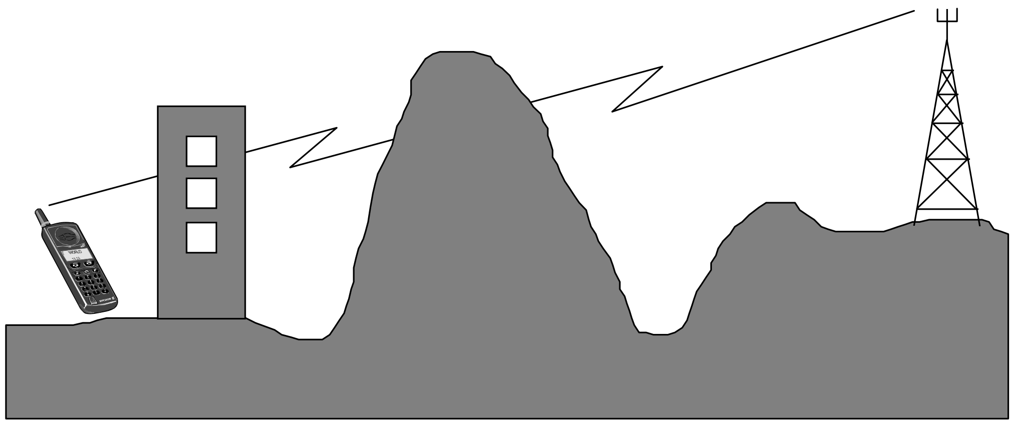


Figure 3-11 Shadowing

MULTIPATH FADING

Multipath fading occurs when there is more than one transmission path to the MS or BTS, and therefore more than one signal arriving at the receiver. This may be due to buildings or mountains, either close to or far from the receiving device.

Rayleigh fading and time dispersion are forms of multipath fading.

Rayleigh fading

This occurs when a signal takes more than one path between the MS and BTS antennas. In this case, the signal is not received on a line of sight path directly from the Tx antenna. Rather, it is reflected off buildings, for example, and is received from several different indirect paths. Rayleigh fading occurs when the obstacles are close to the receiving antenna.

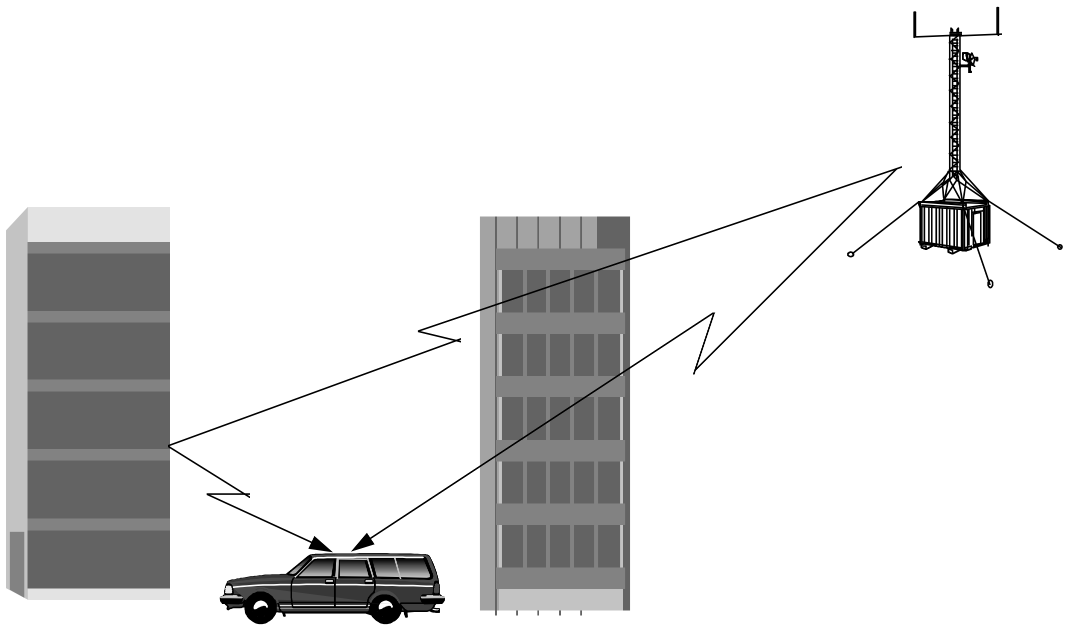


Figure 3-12 Rayleigh fading

The received signal is the sum of many identical signals which differ only in phase (and to some extent amplitude). A fading dip and the time that elapses between two fading dips depends on both the speed of the MS and the transmitting frequency. As an approximation, the distance between two dips caused by Rayleigh fading is about half a wavelength. Thus, for GSM 900 the distance between dips is about 17 cm.

Time Dispersion

Time dispersion is another problem relating to multiple paths to the Rx antenna of either an MS or BTS. However, in contrast to Rayleigh fading, the reflected signal comes from an object far away from the Rx antenna.

Time dispersion causes Inter-Symbol Interference (ISI) where consecutive symbols (bits) interfere with each other making it difficult for the receiver to determine which symbol is the correct one. An example of this is shown in the figure below where the sequence 1, 0 is sent from the BTS.

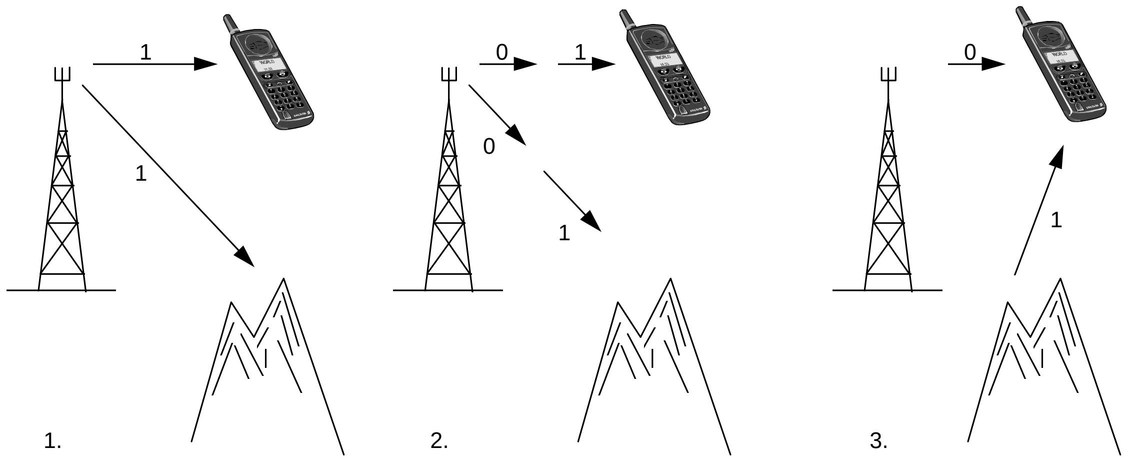


Figure 3-13 Time dispersion

☞ Did you know?
One bit is transmitted every 3.7 µs. Radio waves travel at $3x10^8$ m/s. Therefore, one bit travels approximately 1 km within one bit period. *Thus, if the direct path is 1km and the indirect path is 3 km long, the first bit transmitted will interfere with the 3rd bit transmitted.*

If the reflected signal arrives one bit time after the direct signal, then the receiver detects a 1 from the reflected wave at the same time it detects a 0 from the direct wave. The symbol 1 interferes with the symbol 0 and the MS does not know which one is correct.

TIME ALIGNMENT

Each MS on a call is allocated a time slot on a TDMA frame. This is an amount of time during which the MS transmits information to the BTS. The information must also arrive at the BTS within that time slot. The time alignment problem occurs when part of the information transmitted by an MS does not arrive within the allocated time slot. Instead, that part may arrive during the next time slot, and may interfere with information from another MS using that other time slot.

Time alignment is caused by a large distance between the MS and the BTS. Effectively, the signal cannot travel over the large distance within the given time.

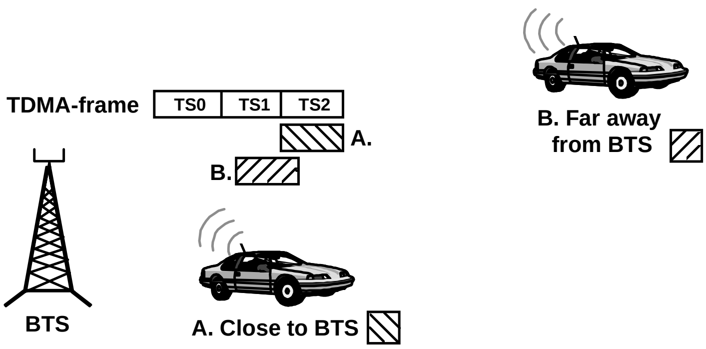


Figure 3-14 The time alignment problem

For example, an MS is close to a BTS and has been allocated time slot 3 (TS 3). During the call, the MS moves away from the BTS causing the information sent from the BTS to arrive at the MS later and later. The answer from the MS also arrives later at the BTS. If nothing is done, the delay becomes so long that the transmission from the MS in time slot 3 overlaps with the information which the BTS receives in time slot 4.

COMBINED SIGNAL LOSS

Each of the problems described above occur independently of each other. However, in most calls some of these problems may occur at the same time. An illustration of what the signal strength may look like at the MS Rx antenna when moving away from the BTS Tx antenna is shown in Figure 3-15. The problems of path loss, shadowing and Rayleigh fading are present for this transmission path.

The signal strength as a global mean value decreases with the distance (path loss) and finally results in a lost connection. Around this global mean, slow variations are present due to shadowing effects and fast variations are present due to Rayleigh fading.

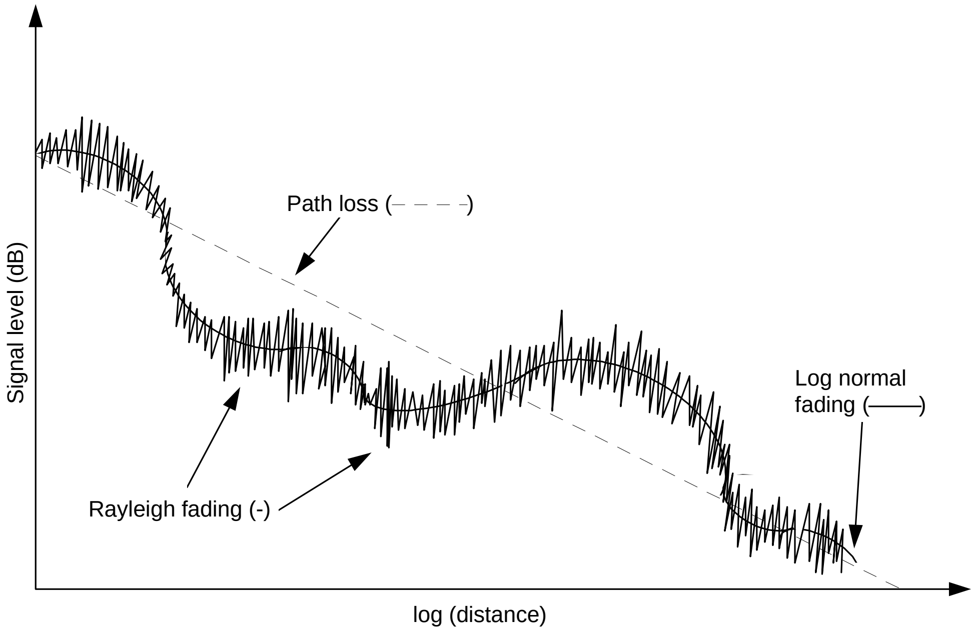


Figure 3-15 Rx signal strength versus distance

At any one point from the Tx antenna, the received signal can look like the signal in Figure 3-16 below.

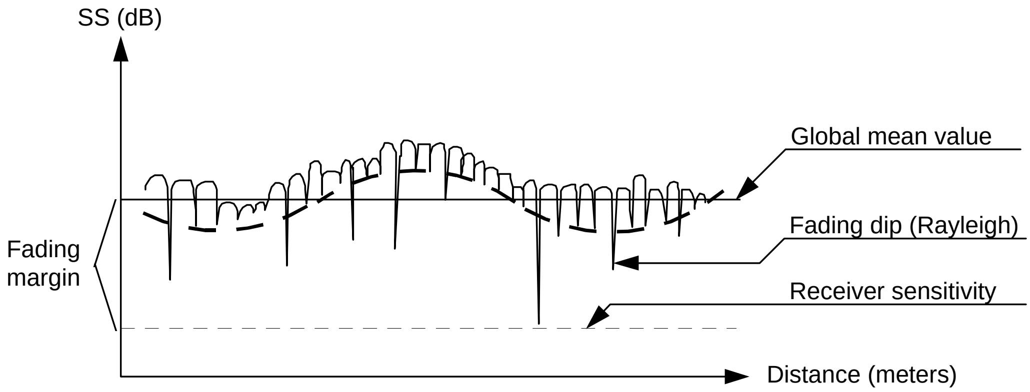


Figure 3-16 Rx signal strength

The lowest signal strength value required for a specified output is called receiver sensitivity level. To detect the information sent from Tx antenna, X watts must be received. If the signal falls below X, the information will be lost and the call may be dropped. To ensure that no information is lost, the global mean value must be as many dB above the receiver sensitivity level as the strongest (deepest) fading dip gives rise to. This fading margin is the difference between the global mean value and the receiver sensitivity.

SOLUTIONS TO TRANSMISSION PROBLEMS

This section describes some solutions to the problems described in previous sections. Although many of these do not entirely solve all problems on the radio transmission path, they do play an important part in maintaining call quality for as long as possible.

CHANNEL CODING

In digital transmission, the quality of the transmitted signal is often expressed in terms of *how many of the received bits are incorrect*. This is called Bit Error Rate (BER). BER defines the percentage of the total number of received bits which are incorrectly detected.

Transmitted bits	1	1	0	1	0	0	0	1	1	0	
Received bits	1	0	0	1	0	0	1	0	1	0	
Errors		↑					↑	↑			3/10 = 30% BER

This percentage should be as low as possible. It is not possible to reduce the percentage to zero because the transmission path is constantly changing. This means that there must be an allowance for a certain amount of errors and at the same time an ability to restore the information, or at least detect errors so the incorrect information bits are not interpreted as correct. This is especially important during transmission of data, as opposed to speech, for which a higher BER is acceptable.

Channel coding is used to detect and correct errors in a received bit stream. It adds bits to a message. These bits enable a channel decoder to determine whether the message has faulty bits, and to potentially correct the faulty bits.

INTERLEAVING

> ☞ Did you know?
>
> *Interleaving could be compared to sending a group of important people from A to B on different planes. By doing so, the likelihood of losing the entire group is minimised.*

In reality, bit errors often occur in sequence, as caused by long fading dips affecting several consecutive bits. Channel coding is most effective in detecting and correcting single errors and short error sequences. It is not suitable for handling longer sequences of bit errors.

For this reason, a process called interleaving is used to separate consecutive bits of a message so that these are transmitted in a non-consecutive way.

For example, a message block may consist of four bits (1234). If four message blocks must be transmitted, and one is lost in transmission, without interleaving there is a 25% BER overall, but a 100% BER for that lost message block. It is not possible to recover from this.

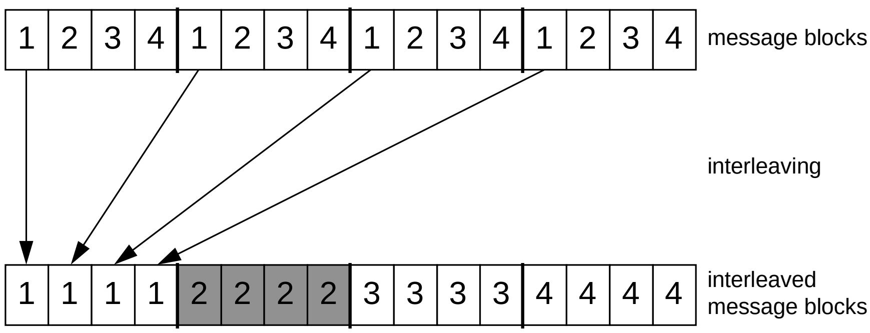


Figure 3-17 Interleaving

If interleaving is used, as shown in Figure 3-18, the bits of each block may be sent in a non-consecutive manner. If one block is lost in transmission, again there is a 25% BER overall. However, this time the 25% is spread over the entire set of message blocks, giving a 25% BER for each. This is more manageable and there is a greater possibility that the errors can be corrected by a channel decoder.

1	X	3	4	1	X	3	4	1	X	3	4	1	X	3	4

Figure 3-18 Received interleaved message blocks

ANTENNA DIVERSITY

Antenna diversity increases the received signal strength by taking advantage of the natural properties of radio waves. There are two primary diverstiy methods: space diversity and polarization diversity.

Space Diversity

An increased received signal strength at the BTS may be achieved by mounting two receiver antennae instead of one. If the two Rx antennae are physically separated, the probability that both of them are affected by a deep fading dip at the same time is low. At 900 MHz, it is possible to gain about 3 dB with a distance of five to six meters between the antennae. At 1800 MHz the distance can be shortened because of its decreased wavelength.

By choosing the best of each signal, the impact of fading can be reduced. Space diversity offers slightly better antenna gain than polarization diversity, but requires more space.

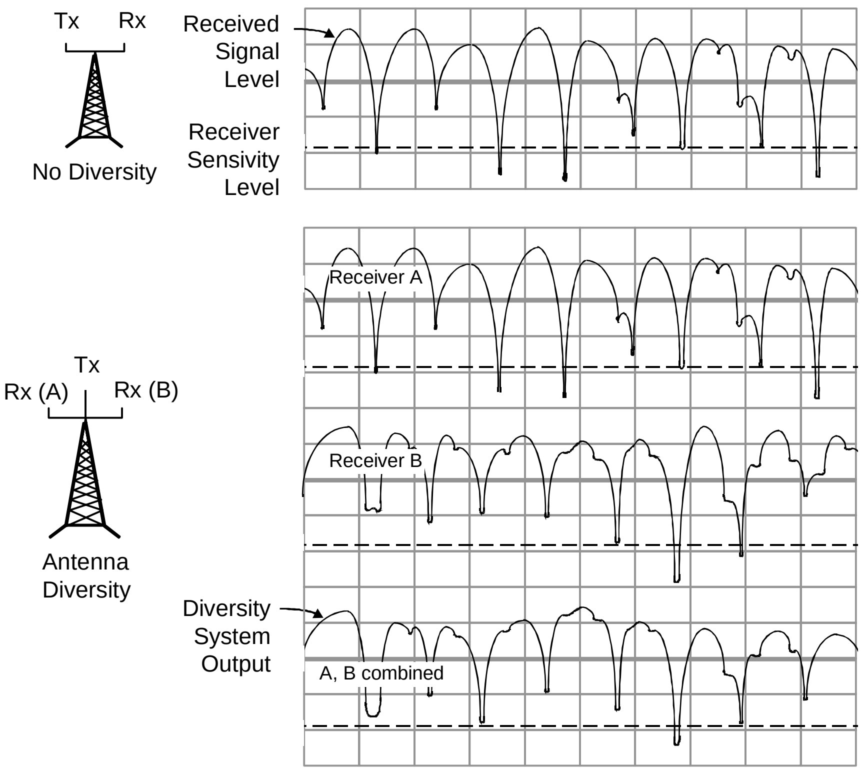


Figure 3-19 Space diversity

Polarization Diversity

With polarisation diversity the two space diversity antennae are replaced by one dual polarized antenna. This antenna has normal size but contains two differently polarized antenna arrays. The most common types are vertical/horizontal arrays and arrays in ±45 degree slant orientation. The two arrays are connected to the respective Rx branches in the BTS. The two arrays can also be used as combined Tx/Rx antennas. For most applications, the difference between the diversity gain for space diversity and polarization diversity is negligible, but polarization diversity reduces the space required for antennae.

ADAPTIVE EQUALIZATION

Adaptive equalization is a solution specifically designed to counteract the problem of time dispersion. It works as follows:

1. A set of predefined known bit patterns exist, known as training sequences. These are known to the BTS and the MS (programmed at manufacture). The BTS instructs the MS to include one of these in its transmissions to the BTS.

2. The MS includes the training sequence (shown in the figure as "S") in its transmissions to the BTS. However, due to the problems over the radio path, some bits may be distorted.

3. The BTS receives the transmission from the MS and examines the training sequence within it. The BTS compares the received training sequence with the training sequence which it had instructed the MS to use. If there are differences between the two, it can be assumed that the problems in the radio path affected these bits must have had a similar affect on the non-training sequence bits.

4. The BTS begins a process in which it uses its knowledge of what happened the training sequence to correct the other bits of the transmission.

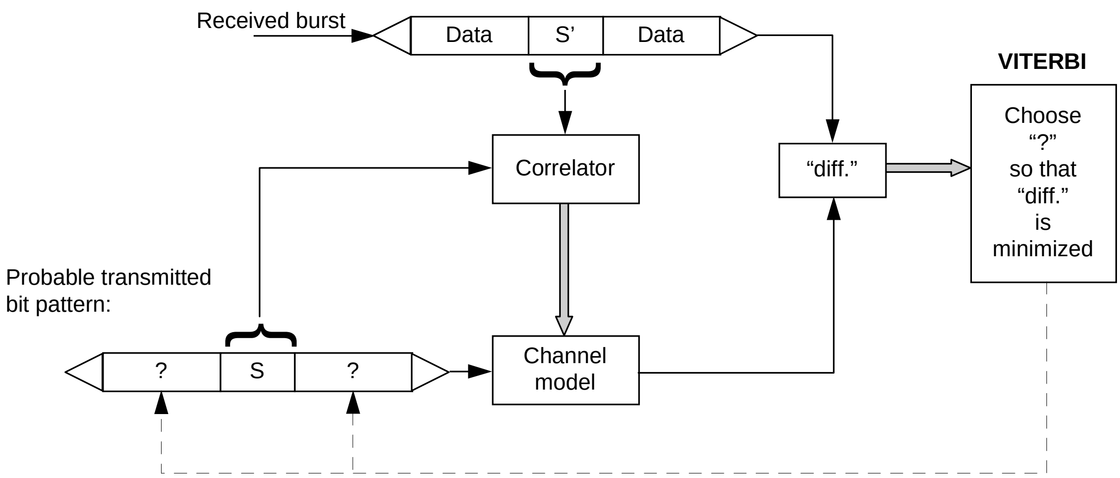


Figure 3-20 Adaptive equalization

Because some assumptions are made about the radio path, adaptive equalization may not result in a 100% perfect solution every time. However, a "good enough" result will be achieved. A viterbi equalizer is an example of an adaptive equalizer.

FREQUENCY HOPPING

As mentioned previously, Rayleigh fading is frequency dependent. This means that the fading dips occur at different places for different frequencies. To benefit from this fact, it is possible for the BTS and MS to hop from frequency to frequency during a call. The frequency hopping of the BTS and MS is synchronized.

In GSM there are 64 patterns of frequency hopping, one of which is a simple cyclic or sequential pattern. The remaining 63 are known as pseudo-random patterns which an operator can choose from.

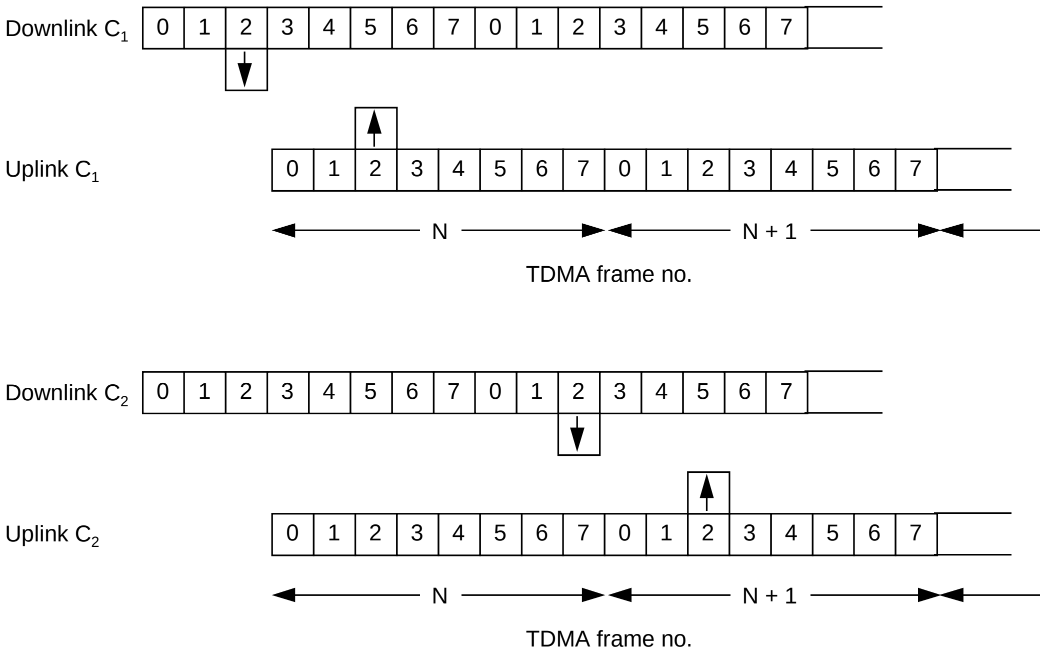


Figure 3-21 Frequency hopping

During TDMA frame N, C_1 is used and during TDMA frame N+1, C_2 is used. The call uses the same time slot but changes frequencies according to an identified pattern.

TIMING ADVANCE

Timing advance is a solution specifically designed to counteract the problem of time alignment. It works by instructing the mis-aligned MS to transmit its burst earlier than it normally would.

In GSM, the timing advance information relates to bit times. Thus, an MS may be instructed to advance its transmission by a certain number of bit times. The maximum in GSM is 63 bit times. This is one of the parameters that limits the GSM cell size to a maximum of 35 km radius.

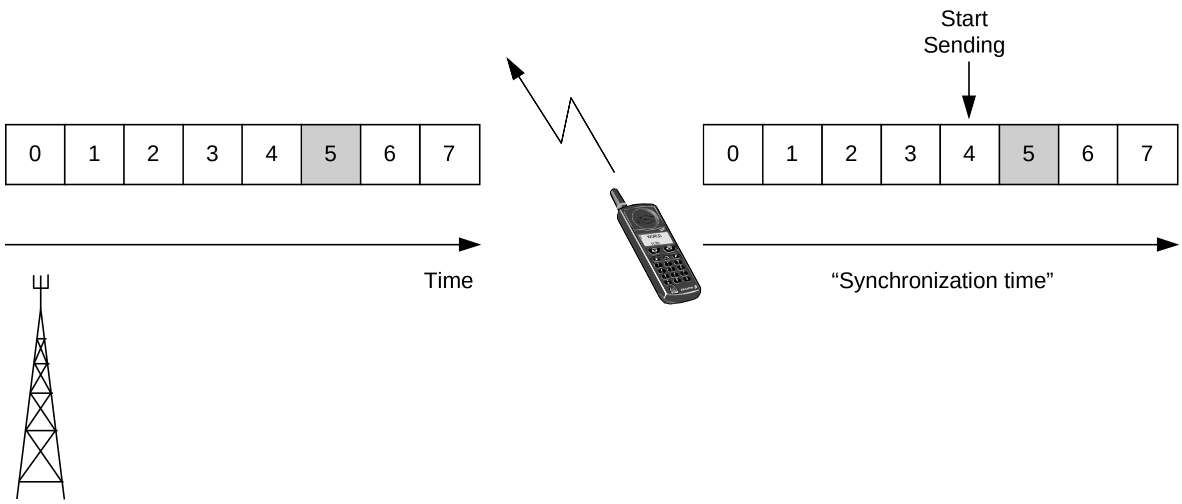


Figure 3-22 Timing advance

GSM TRANSMISSION PROCESS

STAGE 1: ANALOG TO DIGITAL (A/D) CONVERSION

One of the primary functions of an MS is to convert the analog speech information into digital form for transmission using a digital signal. The analog to digital (A/D) conversion process outputs a collection of bits: binary ones and zeros which represent the speech input.

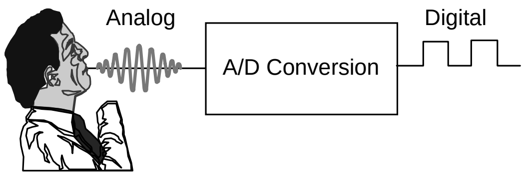


Figure 3-23 A/D conversion

The A/D conversion is performed by using a process called Pulse Code Modulation (PCM). PCM involves three main steps:

- Sampling
- Quantization
- Coding

Step 1: Sampling

Sampling involves measuring the analog signal at specific time intervals.

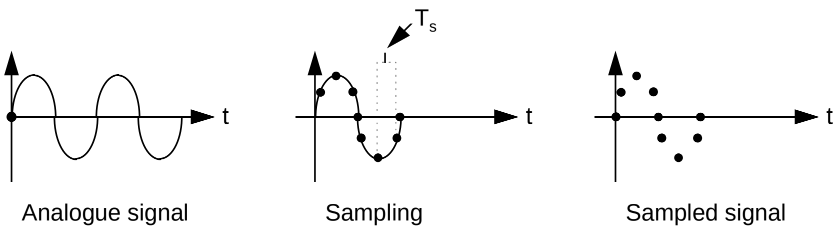


Figure 3-24 Analog signal sampling

The accuracy of describing the analog signal in digital terms depends on how often the analog signal is sampled, among other things. This is expressed as the sampling frequency. The sampling theory states that:

To reproduce an analog signal without distortion, the signal must be sampled with at least twice the frequency of the highest frequency component in the analog signal.

Normal speech mainly contains frequency components lower than 3400 Hz. Higher components have low energy and may be omitted without affecting the speech quality much. Applying the sampling theory to analog speech signals, the sampling frequency, should be at least 2 x 3.4 kHz = 6.8 kHz. Telecommunication systems use a sampling frequency of 8 kHz, which is acceptable based on the sampling theory.

Step 2: Quantization

The next step is to give each sample a value. For this reason, the amplitude of the signal at the time of sampling is measured and approximated to one of a finite set of values. The figure below shows the principle of quantization applied to an analog signal. It can be seen that a slight error is introduced in this process when the signal is quantized or approximated. The degree of accuracy depends on the number of quantization levels used. Within common telephony, 256 levels are used while in GSM 8,192 levels are used.

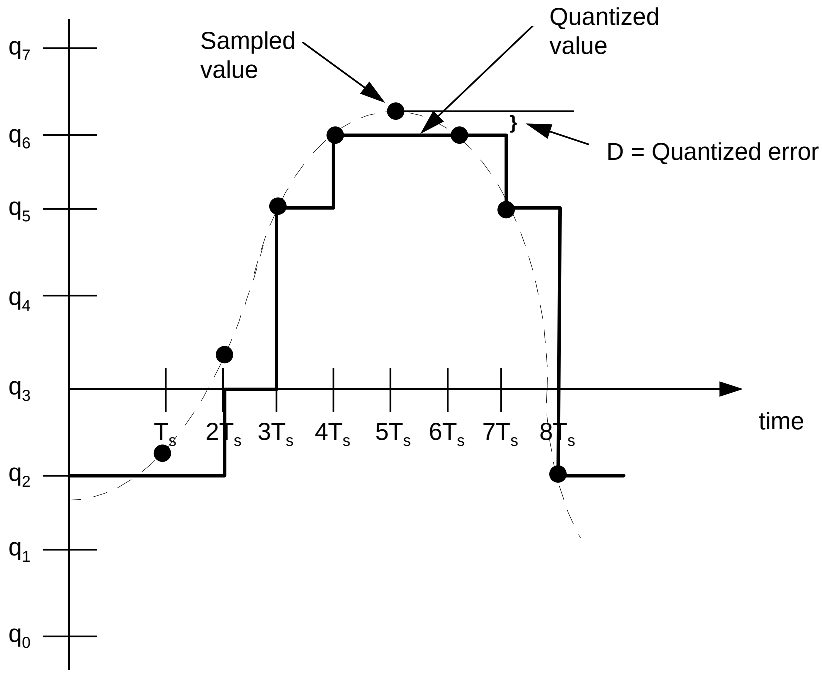


Figure 3-25 Quantization

Step 3: Coding

Coding involves converting the quantized values into binary. Every value is represented by a binary code of 13 bits (2^{13} = 8192). For example, a quantized value of 2,157 would have a bit pattern of 0100001101101:

Bit	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Total**
Set to	0	1	0	0	0	0	1	1	0	1	1	0	1	
Value	0	2048	0	0	0	0	64	32	0	8	4	0	1	**2157**

Table 3-2 Coding of quantised value 2157

Summary of A/D Conversion

The result from the process of A/D conversion is 8,000 samples per second of 13 bits each. This is a bit rate of 104 kbits/s.

When it is considered that 8 subscribers use one radio channel, the overall bit rate would be 8 x 104 kbits/s = 832 kbits/s. Recalling the general rule of 1 bit per Hertz, this bit rate would not fit into the 200 kHz available for all 8 subscribers. The bit rate must be reduced somehow - this is achieved using segmentation and speech coding.

STAGE 2: SEGMENTATION AND STAGE 3: SPEECH CODING

> ☞ Did you know?
>
> *In his childhood, Alexander Graham Bell constructed an artificial speaking machine. It was an anatomical model of the human voice tract, complete with teeth, throat, nasal passages and tongue.*
>
> *By carefully positioning these elements, while simultaneously introducing a sounds source in the throat, Bell was able to articulate simple English words.*

The key to reducing the bit rate is to send information about the speech instead of the speech itself. This can be explained with the following analogy:

> Person A wishes to listen to a certain piece of music and they know that person B has it on record. A rings B asking for the use of the record for some time. Unfortunately, the record is scratched and cannot be used. Instead, B sends A parameters of how the music is built up - the sheets of music - together with information about how fast it should be played - the frequency - and A reproduces the music.

In GSM, the speech coding process analyzes speech samples and outputs parameters of what the speech consists of: the tone, length of tone, pitch, etc. This is then transmitted through the network to another MS which generates the speech based on these parameters.

The process of segmentation and speech coding is explained in more detail as follows:

The human speech process starts in the vocal chords or speech organs, where a tone is generated. The mouth, tongue, teeth, etc., act as a filter, changing the nature of this tone. The aim of speech coding in GSM is to send only information about the original tone itself and about the filter.

Segmentation: Given that the speech organs are relatively slow in adapting to changes, the filter parameters representing the speech organs are approximately constant during 20 ms. For this reason, when coding speech in GSM, a block of 20 ms is coded into one set of bits. In effect, it is similar to sampling speech at a rate of 50 times per second instead of the 8,000 used by A/D conversion.

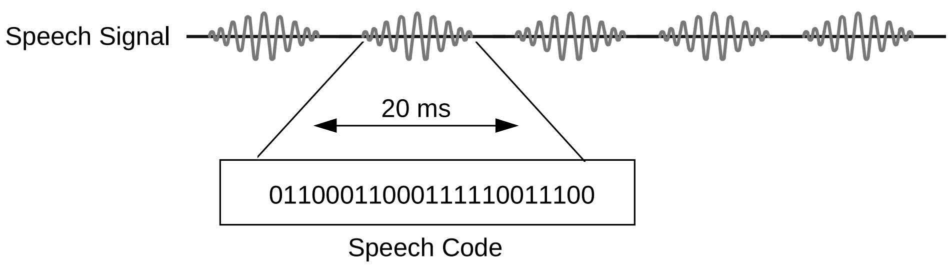


Figure 3-26 Segmentation and speech coding

Speech Coding[5]: Instead of using 13 bits per sample as in A/D conversion, GSM speech coding uses 260 bits. This calculates as 50 x 260 = 13 kbits/s. This provides a speech quality which is acceptable for mobile telephony and comparable with wireline PSTN phones.

Many types of speech coders are available. Some offer better speech quality, at the expense of a higher bit rate (waveform coders). Others use lower bit rates, at the expense of lower speech quality (vocoders). The hybrid coder which GSM uses provides good speech quality with a relatively low bit rate, at the expense of speech coder complexity.

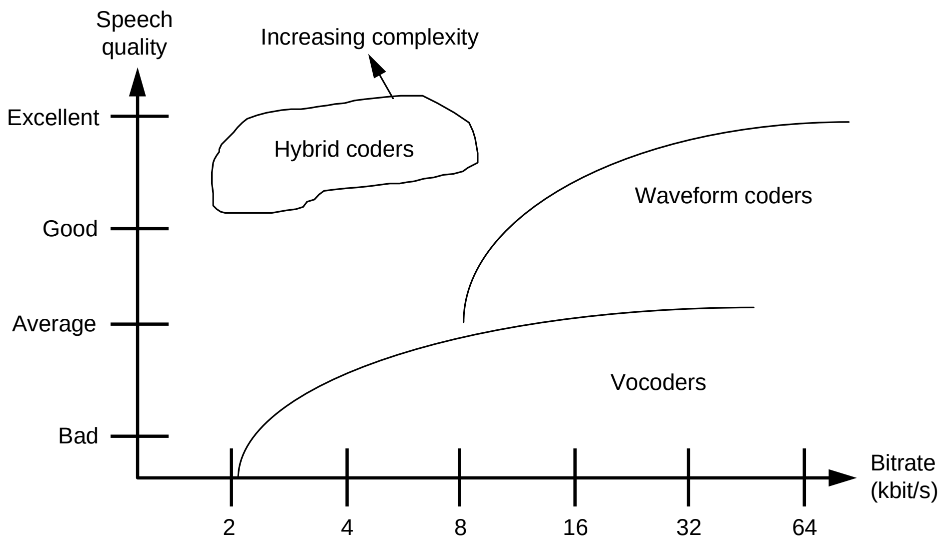


Figure 3-27 Speech quality vs. bit rate

Summary of Segmentation and Speech Coding

> ☞ Did you know?
>
> *The speech coding process described here is for full rate speech only. Alternatives are:*
>
> - *Half rate: 6.5 kbits/s*
> - *Enhanced Full Rate (EFR): 15.1 kbits/s*

The GSM speech coder produces a bit rate of 13 kbits/s per subscriber. When it is considered that 8 subscribers use one radio channel, the overall bit rate would be 8 x 13 kbits/s = 104 kbits/s. This compares favorably with the 832 kbits/s from A/D conversion.

However, speech coding does not consider the problems which may be encountered on the radio transmission path. The next stages in the transmission process, channel coding and interleaving, help to overcome these problems.

[5] The function of converting from PCM coded information to GSM speech coder information is called transcoding.

STAGE 4: CHANNEL CODING

Channel coding in GSM uses the 260 bits from speech coding as an input and outputs 456 encoded bits.

The 260 bits are split according to their relative importance:

- Block 1: 50 very important bits
- Block 2: 132 important bits and
- Block 3: 78 not so important bits

The first block of 50 bits is sent through a block coder, which adds three parity bits to result in 53 bits. It is these three bits which are used to detect errors in a received message.

These 53 bits, the 132 bits in the second block and 4 tail bits (total = 189) are sent to a 1:2 convolutional coder which outputs 378 bits. The bits added by the convolutional coder enable the correction of errors when the message is received.

The remaining bits of block 3 are not protected.

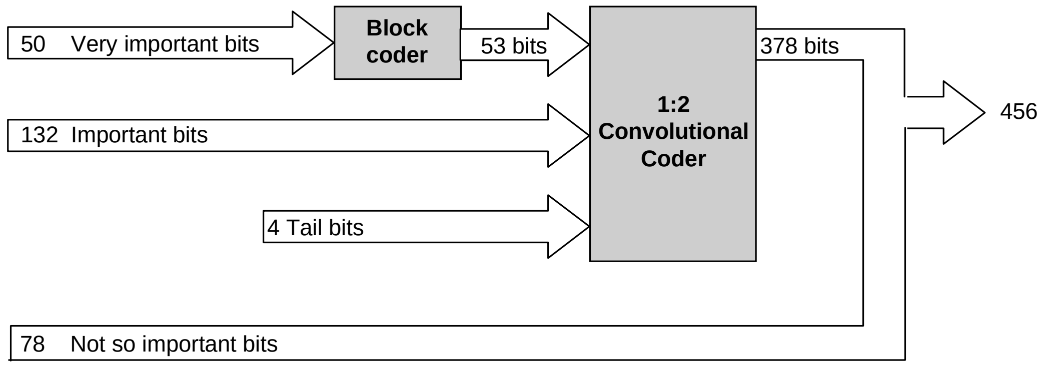


Figure 3-28 Channel coding

STAGE 5: INTERLEAVING

First level of interleaving

The channel coder provides 456 bits for every 20 ms of speech. These are interleaved, forming eight blocks of 57 bits each, as shown in the figure below.

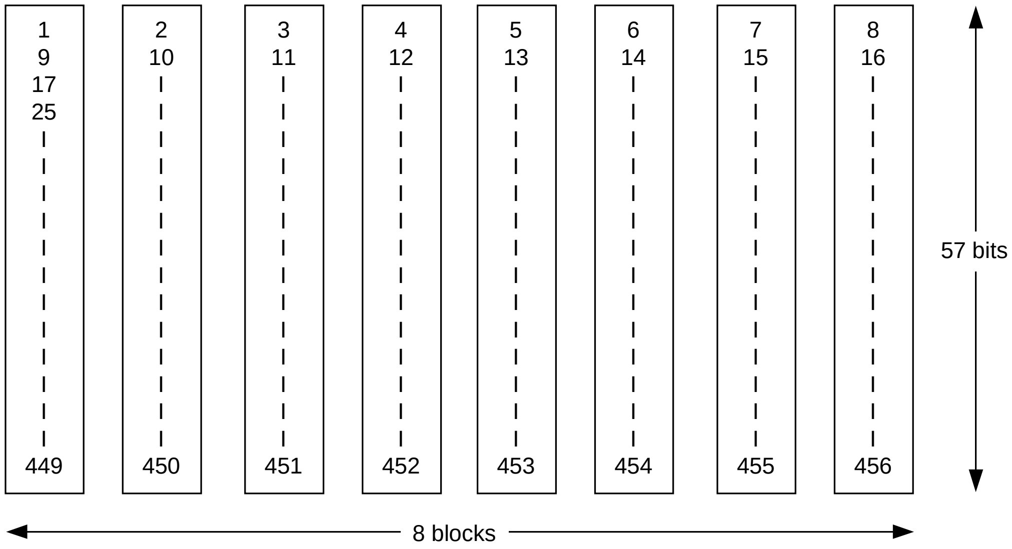


Figure 3-29 Interleaving of 20 ms of encoded speech

As can be seen in Figure 3-30, in any one burst, there is space for two of these blocks. (The remaining bits are explained later in this book.) Thus, if one burst transmission is lost, there is a 25% BER for the entire 20 ms of speech (2/8 = 25%).

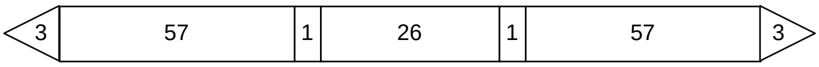


Figure 3-30 Normal burst

Second level of interleaving

If only one level of interleaving is used, a loss of this burst results in a total loss of 25%. This is too much for the channel decoder to correct. A second level of interleaving can be introduced to further reduce the possible BER to 12.5%.

Instead of sending two blocks of 57 bits from the same 20 ms of speech within one burst, a block from one 20 ms and a block from another 20 ms are sent together. This causes a delay in the system, because the MS must wait for the next 20 ms of speech. However, the system can now afford to loose a whole burst because the loss only affects 12.5% of the bits from each speech frame. This rate can be corrected by a channel decoder.

A	B	C	D
20 ms speech 456 bits = 8x57	**20 ms speech 456 bits = 8x57**	20 ms speech 456 bits = 8x57	20 ms speech 456 bits = 8x57

Figure 3-31 Speech frame

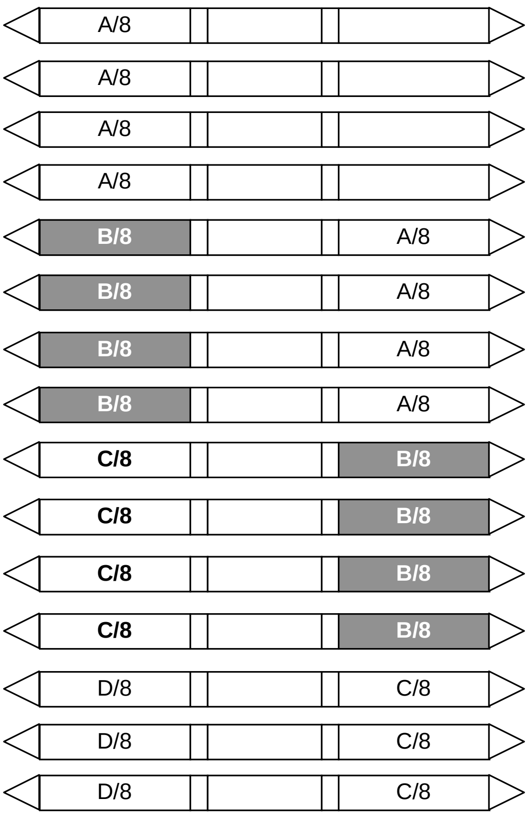


Figure 3-32 Second level of interleaving

STAGE 6: CIPHERING/ENCRYPTION

The purpose of ciphering is to encode the burst so that it cannot be interpreted by any device other than the intended receiver. The ciphering algorithm in GSM is called the A5 algorithm. It does not add bits to the burst, meaning that the input and output to the ciphering process is the same as the input: 456 bits per 20 ms.

STAGE 7: BURST FORMATTING

As previously explained, every transmission from an MS/BTS must include some extra information such as the training sequence. The process of burst formatting is to add these bits (along with some others such as tail bits) to the basic speech/data being sent. This increases the overall bit rate, but is necessary to counteract problems encountered on the radio path.

In GSM, the input to burst formatting is the 456 bits received from ciphering. Burst formatting adds a total of 136 bits per block of 20 ms, bringing the overall total to 592.

However, each time slot on a TDMA frame is 0.577 ms long. This provides enough time for 156.25 bits to be transmitted (each bit takes 3.7 μs), but a burst only contains 148 bits. The rest of the space, 8.25 bit times, is empty and is called the Guard Period (GP). This time is used to enable the MS/BTS “ramp up” and “ramp down”. To ramp up means to get power from the battery/power supply for transmission. Ramping down is performed after each transmission to ensure that the MS is not using battery power during time slots allocated to other MSs.

The output of burst formatting is a burst of 156.25 bits or 625 bits per 20 ms. When it is considered that there are 8 subscriber per TDMA frame, the overall bit rate for GSM can be calculated to be 270.9 kbits/s.

STAGE 8: MODULATION & TRANSMISSION

The 676 bits per 20 ms of speech must then be sent over the air using a carrier frequency. As previously explained, GSM uses the GMSK modulation technique. The bits are modulated onto a carrier frequency (e.g. 912.2 MHz) and transmitted.

The following figure summarizes the GSM transmission process.

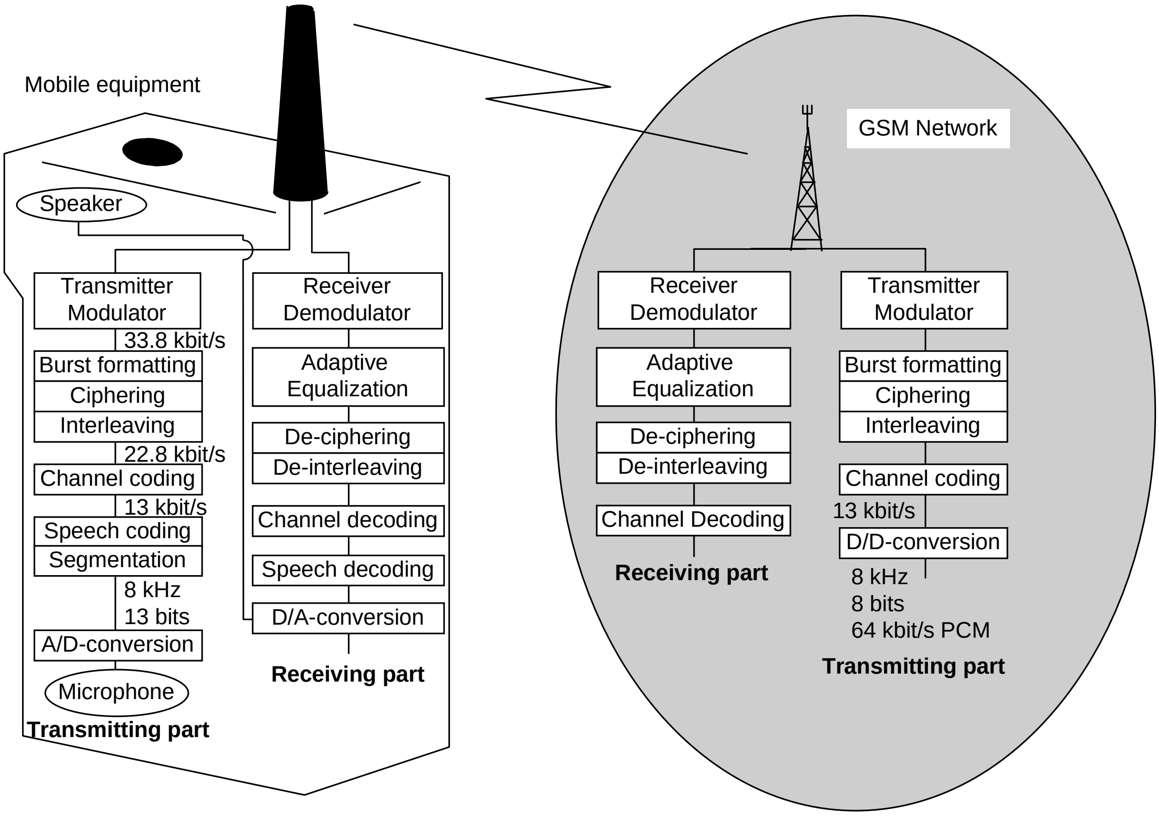


Figure 3-33 GSM transmission process

Channel Concepts

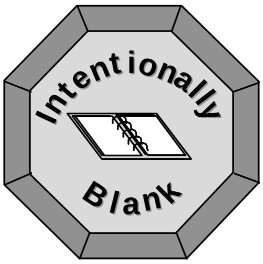
Chapter 4

This chapter is designed to provide the student with an overview of the air interface, including physical and logical channels. It addresses air interface components, their functions, features, and required specifications.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

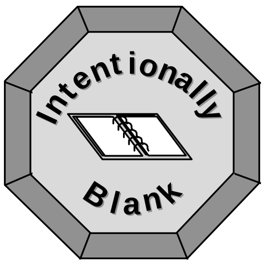
- Describe the difference between a logical and a physical radio channel
- Describe the content of the different logical channels that are used
- Describe the different burst formats which are used
- Describe how the logical channels are used in a sample traffic case


Intentionally
Blank

4 Channel Concepts

Table of Contents

Topic	Page


Intentionally
Blank

INTRODUCTION TO PHYSICAL AND LOGICAL CHANNELS

Each timeslot on a TDMA frame is called a physical channel. Therefore, there are 8 physical channels per carrier frequency in GSM.

Physical channels can be used to transmit speech, data or signaling information.

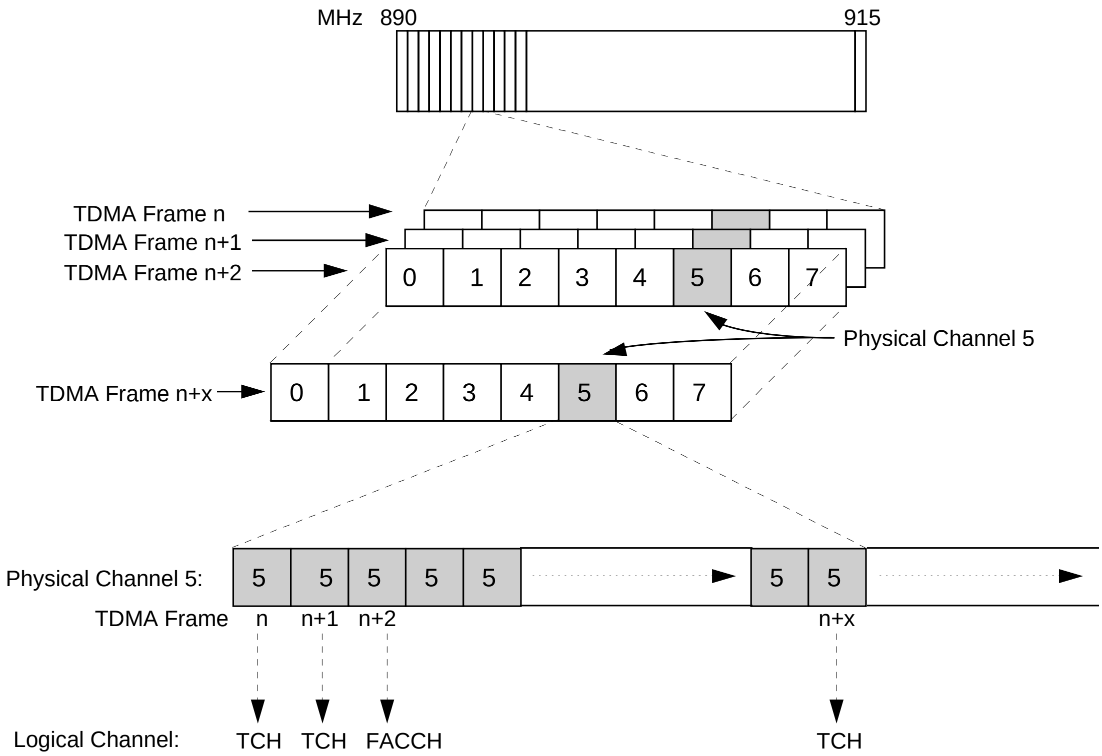


Figure 4-1 The TDMA channel concept

A physical channel may carry different messages, depending on the information which is to be sent. These messages are called logical channels. For example, on one of the physical channels used for traffic, the traffic itself is transmitted using a Traffic CHannel (TCH) message, while a handover instruction is transmitted using a Fast Associated Control Channel (FACCH) message.

LOGICAL CHANNELS

Many types of logical channels exist (see Figure 4-2), each designed to carry a different message to or from an MS.

All information to and from an MS must be formatted correctly, so that the receiving device can understand the meaning of different bits in the message. For example, as seen previously, in the burst used to carry traffic, some bits represent the speech or data itself, while others are used as a training sequence.

There are several types of burst. The relationship between bursts and logical channels is shown in the figure below.

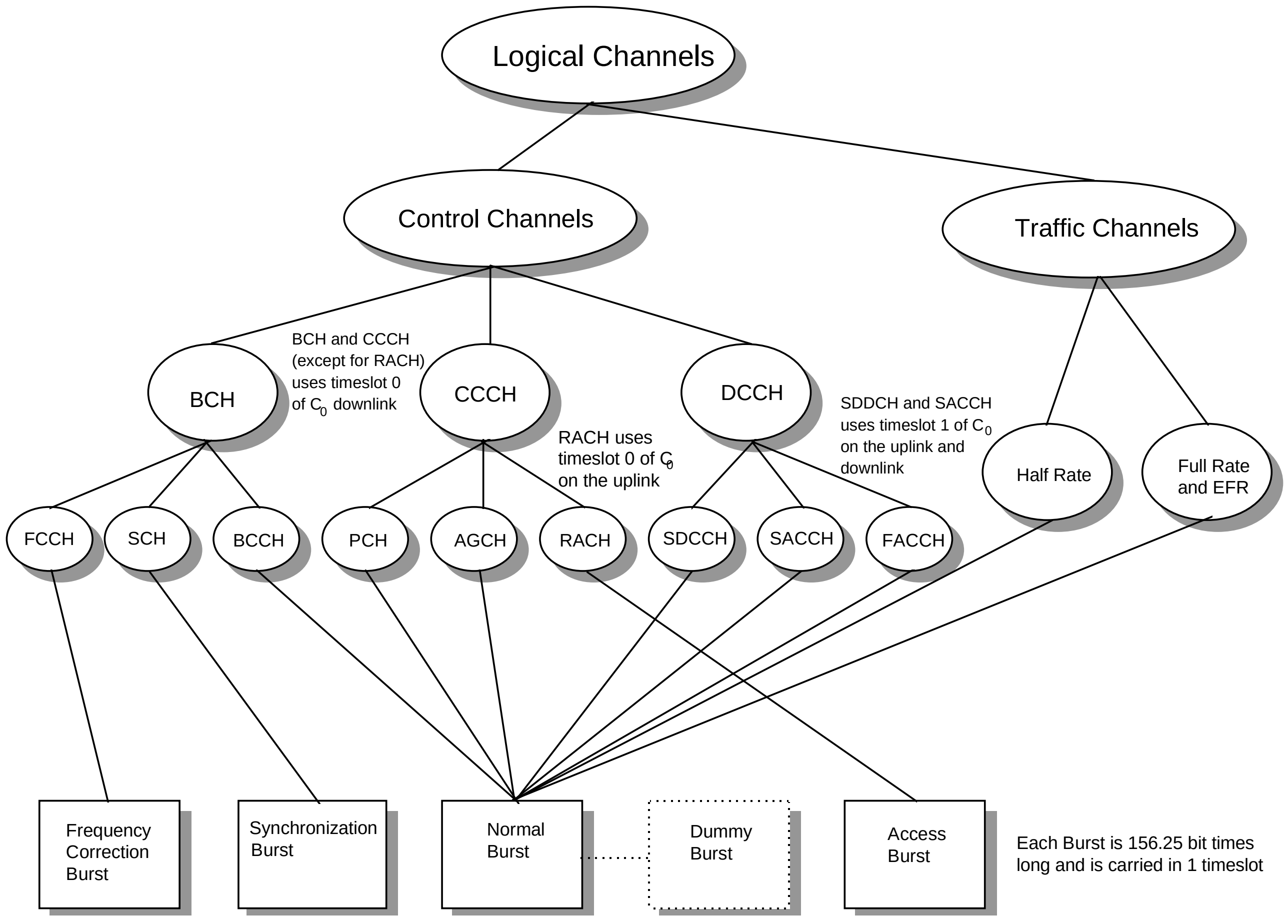


Figure 4-2 Logical channels and bursts

CONTROL CHANNELS

When an MS is switched on, it searches for a BTS to connect to. The MS scans the entire frequency band, or, optionally, uses a list containing the allocated carrier frequencies for this operator. When the MS finds the strongest carrier, it must then determine if it is a control channel. It does so by searching for a particular logical channel called Broadcast Control CHannel (BCCH).

A frequency carrying BCCH contains important information for an MS, including e.g. the current LA identity, synchronization information and network identity. Without such information, an MS cannot work with a network. This information is broadcast at regular intervals, leading to the term Broadcast CHannel (BCH) information.

Broadcast CHannels (BCHs)			
Logical Channel	*Direction*	*BTS*	*MS*
Frequency Correction CHannel (FCCH)	Downlink, point to multipoint	Transmits a carrier frequency.	Identifies BCCH carrier by the carrier frequency and synchronizes with the frequency.
Synchronization CHannel (SCH)	Downlink, point to multipoint	Transmits information about the TDMA frame structure in a cell (e.g. frame number) and the BTS identity (Base Station Identity Code (BSIC)).	Synchronizes with the frame structure within a particular cell, and ensures that the chosen BTS is a GSM BTS - BSIC can only be decoded by an MS if the BTS belongs to a GSM network.
Broadcast Control CHannel (BCCH)	Downlink, point to multipoint	Broadcasts some general cell information such as Location Area Identity (LAI), maximum output power allowed in the cell and the identity of BCCH carriers for neighboring cells.	Receives LAI and will signal to the network as part of the Location Updating procedure if the LAI is different to the one already stored on its SIM. MS sets its output power level based on the information received on the BCCH. Also, the MS stores a list of BCCH carriers on which it will perform measurements to assist in efficient handover.

Table 4-1 Broadcast channels

When the MS has finished analyzing the information on a BCH, it then has all the information required to work with a network. However, if the MS roams to another cell, it must repeat the process of reading FCCH, SCH and BCCH in the new cell.

If the mobile subscriber then wishes to make or receive a call, the Common Control CHannels (CCCH) must be used.

Common Control Channels (CCCH)			
Logical Channel	*Direction*	*BTS*	*MS*
Paging CHannel (PCH)	Downlink, point to point	Transmits a paging message to indicate an incoming call or short message. The paging message contains the identity number of the mobile subscriber that the network wishes to contact.	At certain time intervals the MS listens to the PCH. If it identifies its own mobile subscriber identity number on the PCH, it will respond.
Random Access CHannel (RACH)	Uplink, point to point	Receives request from MS for a signaling channel (to be used for call set-up).	Answers paging message on the RACH by requesting a signaling channel.
Access Grant CHannel (AGCH)	Downlink, point to point	Assigns a signaling channel (SDCCH) to the MS.	Receives signaling channel assignment (SDCCH).

Table 4-2 Common Control Channels

At this stage the MS and BSS are ready to begin call set-up procedures. For this the MS and BSS use Dedicated Control CHannels (DCCHs).

Dedicated Control Channels (DCCH)			
Logical Channel	*Direction*	*BTS*	*MS*
Stand alone Dedicated Control CHannel (SDCCH)	Uplink and downlink, point to point	The BTS switches to the assigned SDCCH. The call set-up procedure is performed in idle mode. The BSC assigns a TCH. (SDCCH is also used to transmit text messages).	The MS switches to the assigned SDCCH.Call set-up is performed. The MS receives a TCH assignment information (carrier and time slot).
Cell Broadcast CHannel (CBCH)	Downlink, point to multipoint	Uses this logical channel to transmit short message service cell broadcast.	MS receives cell broadcast messages.
Slow Associated Control CHannel (SACCH)	Uplink and downlink, point to point	Instructs the MS the transmitting power to use and gives instructions on timing advance.	Sends averaged measurements on its own BTS (signal strength and quality) and neighboring BTSs (signal strength). The MS continues to use SACCH for this purpose during a call.
Fast Associated Control CHannel (FACCH)	Uplink and downlink, point to point	Transmits handover information.	Transmits handover request.

Table 4-3 Dedicated Control Channels

TRAFFIC CHANNELS

☞ Did you know?

Enhanced Full Rate (EFR) speech coders improve the speech quality offered across one full rate TCH, but still use a full rate TCH logical channel.

Once call set-up procedures have been completed on the control physical channel, the MS tunes to a traffic physical channel. It uses the Traffic CHannel (TCH) logical channel. There are two types of TCH:

- Full rate (TCH): transmits full rate speech (13 kbits/s). A full rate TCH occupies one physical channel.
- Half rate (TCH/2): transmits half rate speech (6.5 kbits/s). Two half rate TCHs can share one physical channel, thus doubling the capacity of a cell.

BURSTS

BURST TYPES

There are five burst types. (See in Table 4-4 and Figure 4-3.)

Burst Type	Purpose	Used by	Contents
Normal	Used to carry information on traffic and control channels	BCCH, PCH, AGCH, SDCCH, CBCH, SACCH, FACCH, TCH	• Two blocks of 57 bits each for traffic • Training sequence (26 bits) • Steal flags (1 bit each) to indicate that FACCH has temporarily stolen 57 bits • Tail bits (always 000) • Guard period: 8.25 bit durations
Frequency Correction	Used for frequency synchronization of the mobile	FCCH	• 142 frequency correction bits • Tail bits • Guard period: 8.25 bit durations
Synchronization	Used for frame synchronization of the mobile	SCH	• Two blocks of 39 bits for TDMA frame structure information • 64 synchronization bits • Tail bits • Guard period: 8.25 bit durations
Access	Used for random and handover access	RACH	• 41 synchronization bits • 36 bits of access information • Tail bits • Guard period: 68.25 bit durations. A longer GP is used because it’s the first transmission from the mobile - no timing advance information is available
Dummy	Used when no other channel requires a burst to be sent and carries no information		• Pattern is identical to normal burst, but carries no information

Table 4-4 Burst types

THE RELATIONSHIP BETWEEN BURSTS AND FRAMES

The relationship between bursts and frames is shown in the figure below. There are two types of multiframe:

- **26 TDMA frame multiframe:** used to carry TCH, SACCH and FACCH
- **51 TDMA frame multiframe:** used to carry BCCH, CCCH, SDCCH and SACCH.

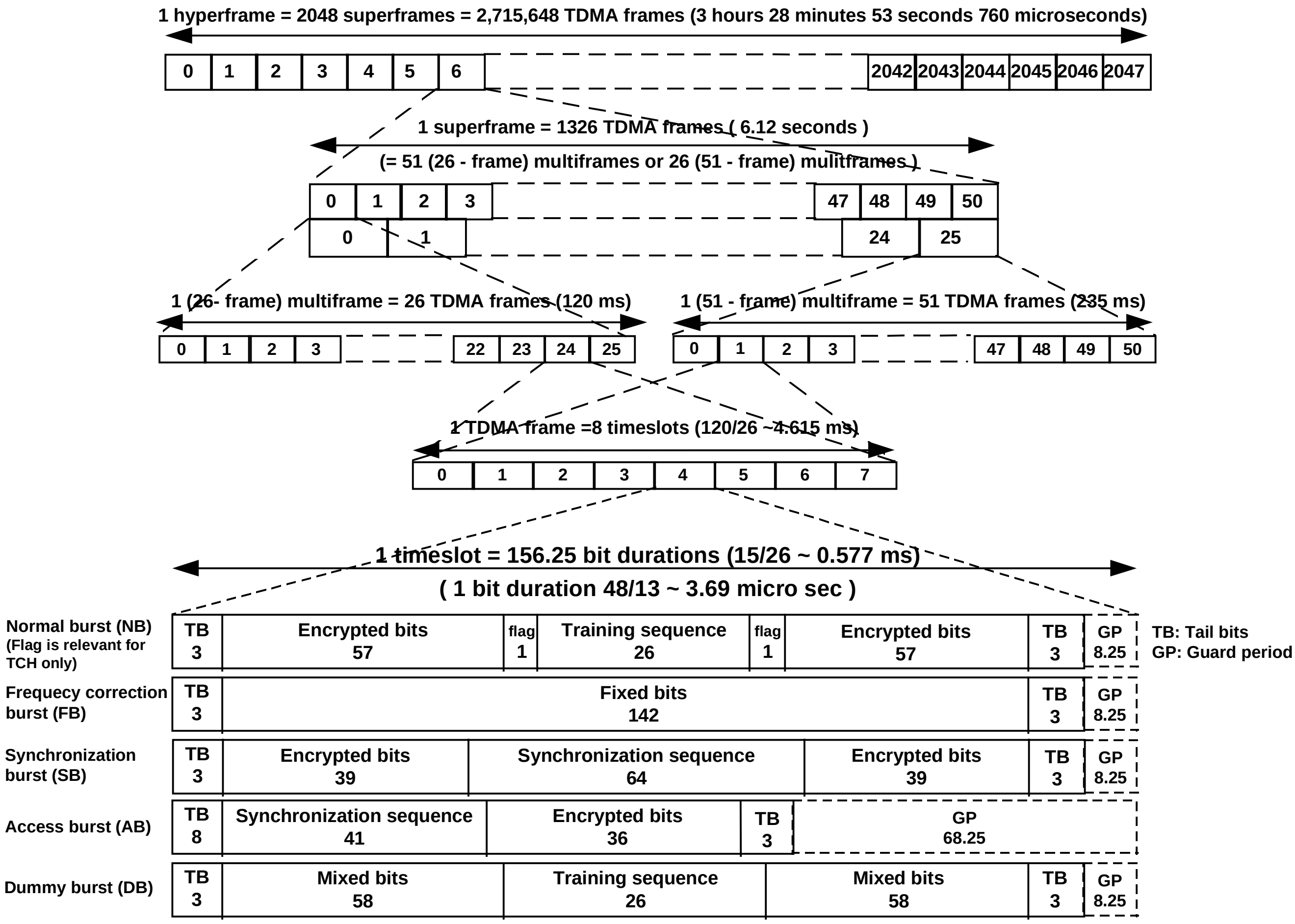


Figure 4-3 Bursts and frames

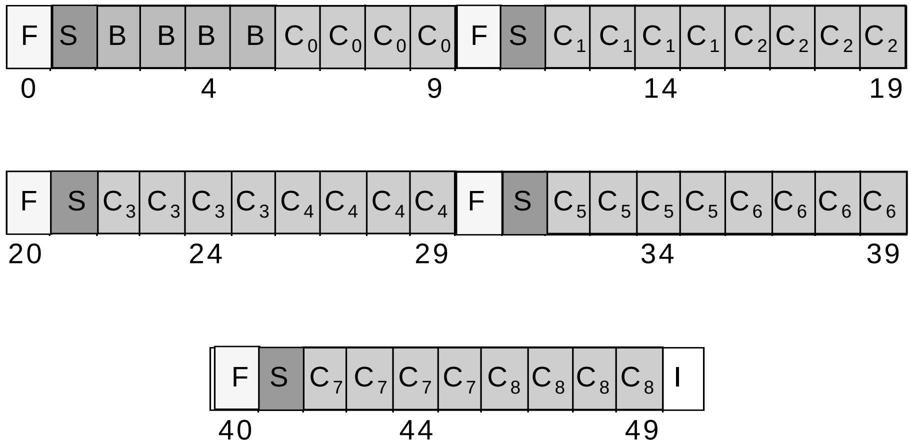


Figure 4-4 Multiplexing of BCHs and CCCHs on TS0

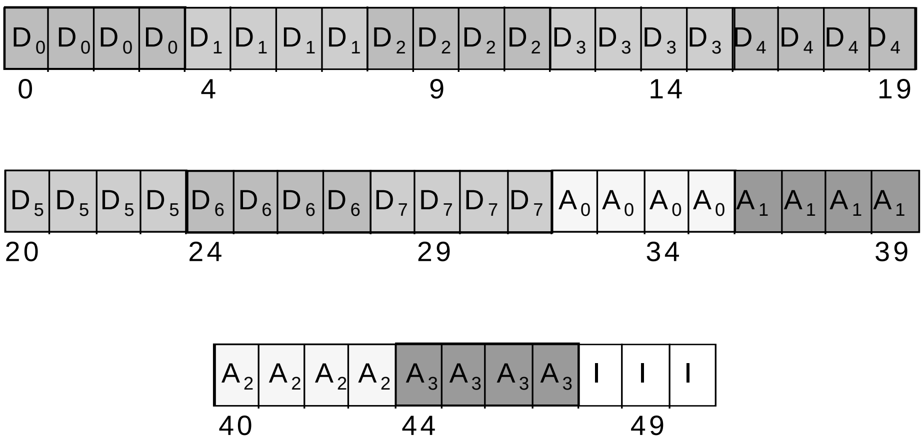


Figure 4-5 Multiplexing of SDCCHs and SACCHs on TS2

MAPPING OF LOGICAL CHANNELS ONTO PHYSICAL CHANNELS

Logical channels are transmitted on physical channels. The method of placing logical channels on physical channels is called **mapping.** While most logical channels take only one time slot to transmit, some take more. If so, the logical channel information is carried in the same physical channel time slot on consecutive TDMA frames.

Because logical channels are short, several logical channels can share the same physical channel, making the use of time slots more efficient.

The figure below shows the carrier frequencies for a sample cell, including an additional allocation of a time slot for DCCH information (due to a high call set-up load in the cell).

Carrier Frequency \ Time slot	0	1	2	3	4	5	6	7
0	B,C	T	D	T	T	T	T	T
1	T	T	D	T	T	T	T	T
2	T	T	T	T	T	T	T	T
3	T	T	T	T	T	T	T	T

Legend:
B: BCH
C: CCCH
D: DCCH
T: TCH

Figure 4-6 Mapping of control and traffic logical channels to physical channels

(**Note**: There are other ways to map the control channels than the one explained. Default mapping of DCCH in Ericsson GSM networks is TS2 of carrier 0.)

CARRIER 0, TIME SLOT 0

Time slot 0 of the first carrier frequency in a cell is always reserved for signaling purposes. In this way, when an MS is determining whether a carrier frequency is a BCCH carrier, it knows where to look.

On the downlink, BCH and CCCH information is transmitted. The only logical channel on the uplink is RACH. By having the uplink free for RACH only, a mobile subscriber can initiate a call at any time.

CARRIER 0, TIME SLOT 2

> ☞ Did you know?
>
> *SMS text messages are transmitted on channels assigned for DCCH. As the use of SMS increases, it is important for* operators *to dimension their control physical channels. Ericsson's systems enables the automatic reconfiguration of physical channels in the event of high text message traffic.*

Generally, time slot 2 of the first carrier frequency in a cell is also reserved for signaling purposes. The only exceptions to this are in cells with high or low traffic loads. As can be seen in Figure 4-6, if there is a high traffic load in a cell, it is possible to assign a second (or more) physical channel for the purpose of call set-up (using DCCH). This may be any physical channel other than 0 and 2 on carrier frequency 0.

Similarly, if there is a low traffic load in a cell, it is possible to use physical channel 0 on carrier frequency 0 for all signaling information: BCH, CCCH and DCCH. By doing so, physical channel 1 can be freed up for traffic.

Eight SDCCHs and 4 SACCHs can all share the same physical channel. This means that 8 calls can be set-up simultaneously on one physical channel.

CARRIER 0, TIME SLOT 1, 3-7 AND ALL TIME SLOTS ON OTHER CARRIERS IN THE SAME CELL

All time slots in a cell other than those assigned for signaling information are used for traffic, i.e. speech or data. Logical channel TCH is used.

In addition, at regular intervals during a call, an MS transmits to the BTS measurements it has made about signal strength and quality. Logical channel SACCH is used for this, replacing one TCH time slot at a time.

SAMPLE TRAFFIC CASE: CALL TO AN MS

The following traffic case describes a call to an MS and highlights the use of some logical channels during the call.

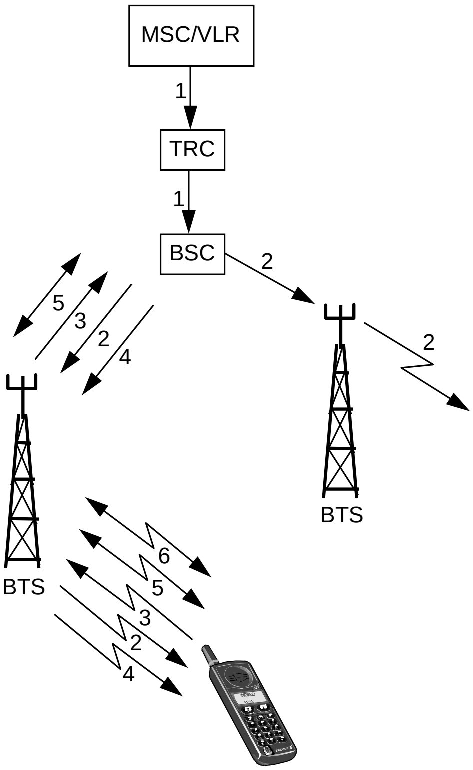
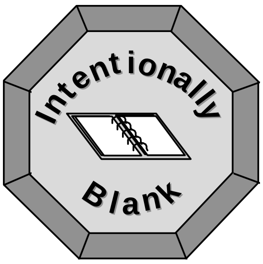


Figure 4-7 Call to an MS

1. The MSC/VLR knows which LA the MS is located in. A paging message is sent to the BSCs controlling the LA.
2. The BSCs distribute the paging message to the BTSs in the desired LA. The BTSs transmit the message over the air interface using **PCH**.
3. When the MS detects a PCH identifying itself, it sends a request for a signaling channel using **RACH**.
4. The BSC uses **AGCH** to inform the MS of the signaling channel (**SDCCH** and **SACCH**) to use.
5. **SDCCH** and **SACCH** are used for call set-up. A **TCH** is allocated and the **SDCCH** is released.
6. The MS and BTS switch to the identified **TCH** frequency and time slot. The MS rings. If the subscriber answers, the connection is established. During the call, the radio connection is maintained by information sent and received by the MS using **SACCH**.


Intentionally
Blank

Introduction to AXE

Chapter 5

This chapter is designed to provide the student with an overview of the AXE switching system. It describes basic AXE principles, lists its main components and outlines the main features of AXE.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

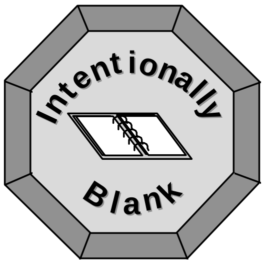
- Describe the architecture of Ericsson's AXE product
- Describe the AXE structure
- Describe the common telephony applications subsystems of AXE
- Describe the common control system subsystems of AXE

Intentionally Blank

5 Introduction to AXE

Table of Contents

Topic	Page


Intentionally
Blank

INTRODUCTION

☞ Did you know?

AXE was introduced to the market in 1975.

AXE is a multi-application, open-ended digital switching product for public telecommunications networks. It has real-time processing capacity and can handle high volumes of traffic. AXE is based on a model in which all functionality (switching, subscriber and network access, operation and maintenance, traffic control, charging control) is handled by each node in the network.

AXE AS A MULTI-APPLICATION PLATFORM

When AXE was introduced into the market it supported only the major telecommunications application, PSTN. Since then AXE has been continuously developed in response to the demands of modern telecommunications. AXE supports a wide range of applications in addition to PSTN:

- ISDN
- PLMN
- Business Communications

Overlaying these networks are Intelligent Networks (IN) and signaling networks, which AXE also supports. AXE provides functionality at different levels in these networks.

AXE in Ericsson's GSM Systems

Ericsson's GSM systems are based on AXE. This means that the features and services built into AXE can be provided as standard within CME 20/CMS 40. It also means that Ericsson's GSM systems will benefit from the future development of AXE. The AXE-based nodes in Ericsson's GSM systems are[1]:

- MSC/VLR
- GMSC
- HLR
- ILR
- SSP
- SCP
- TRC
- BSC

[1] Each of these is referred to as a Product Line.

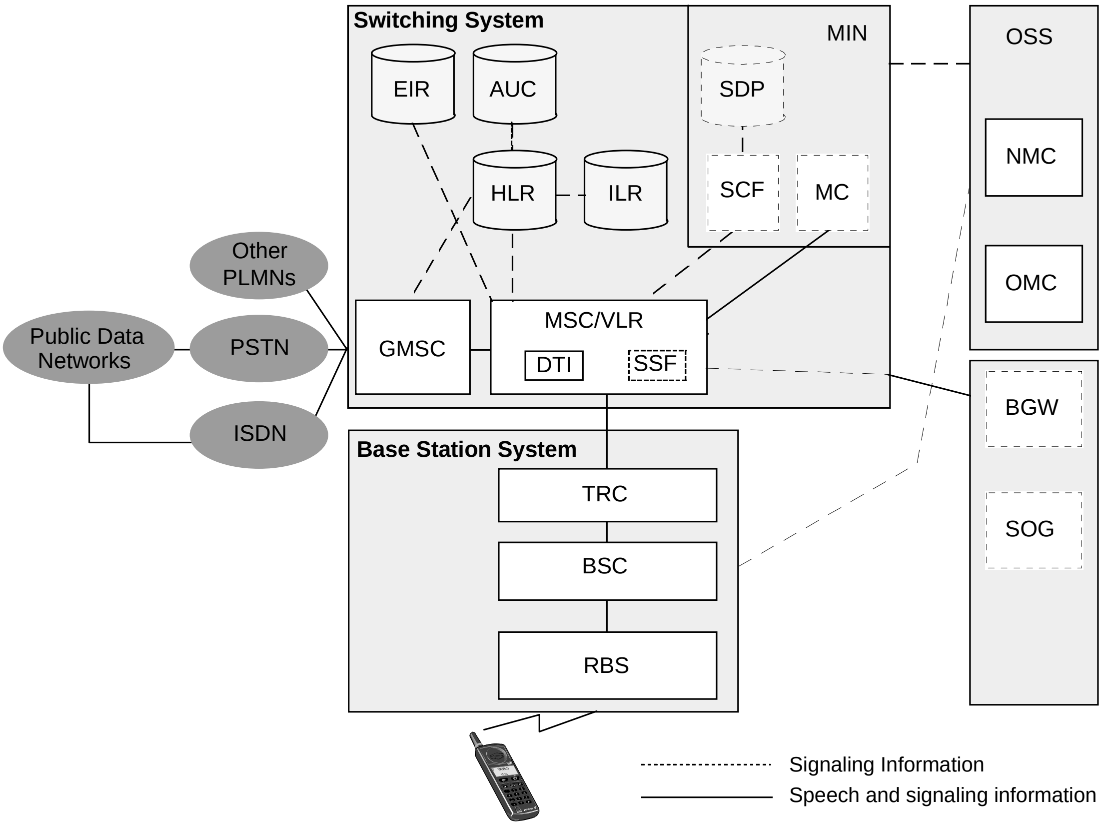


Figure 5-1 CME 20/CMS 40 network

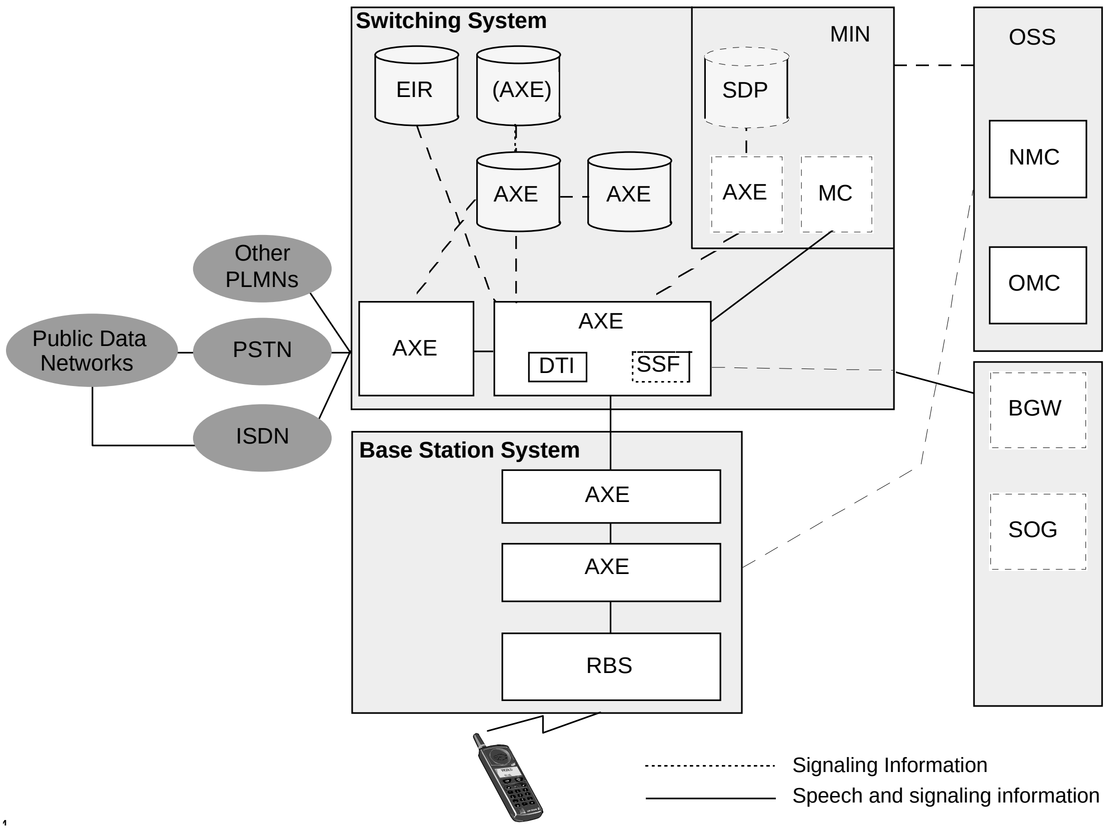


Figure 5-2 AXE Deployment in a CME 20/CMS 40 Network

AXE SYSTEM ARCHITECTURE

☞ Did you know?

The modularity of AXE is such that the following node configuration is possible (though not recommended): GMSC/VLR/HLR/AUC/DTI/BSC/TRC/SSP/SCP.

The key to the success of AXE is its unique flexibility and modularity. Modularity allows AXE to readily adapt to the changing requirements of networks and of end-users. This modularity means ease of handling which leads to reduced costs and the flexibility to adapt to the changing world of telecommunications.

Modularity is implemented in a number of ways in AXE. These are described below.

Functional Modularity

AXE is designed in such a way that nodes with different functions can be generated from the same system. For example, an AXE can act as an MSC/VLR or as a HLR. This can be achieved due to software and hardware modularity.

Software Modularity

AXE consists of a set of independent building blocks (known as function blocks), each performing a specific function and communicating with each other by means of defined signals and interfaces. Software modularity means that function blocks can be added, deleted or modified without requiring changes or redesign of other parts of the system.

Hardware Modularity

The physical packaging of AXE offers a high degree of flexibility and is based on industry-standard specifications. The packaging system contributes to ease of handling during design, manufacturing, installation and operation and maintenance. The basic building blocks of the packaging system are the plug-in units and the containers for these units, subracks. Plug-in units can be replaced or removed without disturbing other equipment.

Technological Modularity

AXE is an open-ended switching platform. This allows new technologies and functions to be added, enabling the continuous development of AXE. For example, AXE was not originally conceived for mobile applications, but when mobile was being developed, AXE proved to be the most suitable platform.

AXE STRUCTURE

There are currently two basic types of structure for AXE:

- Non-Application Modularity based AXE systems (AXE 105)
- Application modularity based AXE systems (AXE 106)

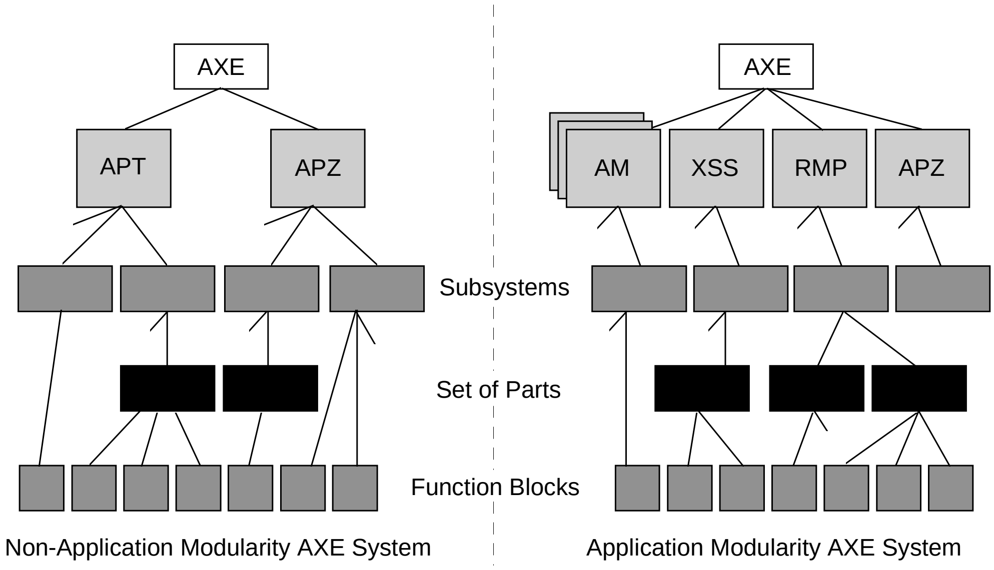


Figure 5-3 AXE system structures

Non-Application Modularity based AXE Systems

An example of an AXE node which is implemented without using Application Modularity is the BSC.

System Level 1

System Level 1 is the AXE 105 system itself and is a combination of System Level 2 systems.

System Level 2

At System Level 2, AXE 105 is divided into two:

- **APT:** this is the switching and telecommunications applications part of AXE
- **APZ:** this is the control or operating system part of AXE

Subsystem Level

Every AXE is a combination of APT and APZ subsystems. Similar functions (e.g. charging functions) are grouped together in one subsystem.

Set of Parts

If required, a set of parts can be used between the subsystem level and function block level. This groups a set of function blocks which perform tasks relating to a similar function.

Function Block Level

The tasks allocated to a certain subsystem are further divided into individual function blocks. Each function block constitutes a well defined unit with its own data and with standardized signal interworking.

Function Unit Level

Every function block consists of function units. There are 3 types of function units:

- A hardware unit
- A regional software unit which deals with routine work such as the scanning of hardware devices
- A central software unit which is responsible for the more complex analysis functions required, e.g. call set-up

A function block may consist of all three together or central software only.

Application Modularity based AXE Systems

Application modularity is a set of well-defined principles for building and implementing AXE software applications. An example of an AXE node which is implemented using Application Modularity is an MSC/VLR.

The Application Modularity structure is based on the principles used in telecommunications networks. For example, to provide services to end-users, network nodes must be capable of interworking with each other. This interworking is achieved by using common protocols and interfaces. Similarly, each Application Module (AM) is a self-contained product and is effectively decoupled from other AMs. For communication between AMs there are well-defined protocols and interfaces. AMs can be introduced, removed or upgraded without affecting other associated applications.

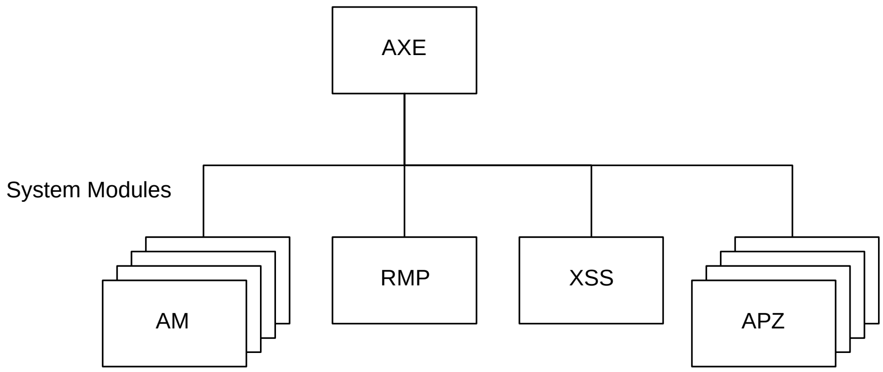


Figure 5-4 AXE 106 system structure

System Level 1

System Level 1 is the AXE 106 system itself and is a combination of System Modules.

System Moduels

AXE 106 contains the following System Modules:

- APZ
- eXisting Source System (XSS)
- Resource Module Platform (RMP)
- Application Modules (AMs)

APZ

APZ is the control or operating system of AXE. It is responsible for operating system functions, I/O functions, service functions, etc.

eXisting Source System (XSS)

The XSS is an APT adapted for use in an Application Modularity based AXE. The XSS is divided into two main parts:

- **Core APT (C/APT):** this contains the functionality which is common to all mobile systems offered by Ericsson (i.e. CME 20, CMS 40, CMS 30, CMS 8800).
- **1/APT:** this contains the functionality which is specific to Ericsson's GSM systems (CME 20 and CMS 40).

Resource Module Platform (RMP)

This co-ordinates the system for the application modules. All hardware required by AMs is provided to them by the RMP. This hardware may be located in either the RMP or in the XSS.

Application Modules (AMs)

An AM is used to model and implement application oriented functions. An example is the Service Control Function AM (SCFAM) which implements MIN functions. The AMs which are available in Ericsson's GSM systems are listed in the following table. An AM consists of subsystems and function blocks.

Title	Function Description
Home Location Register AM (HLRAM)	This AM is responsible for the storage and handling of subscription data in the HLR
Formatting and Output AM (FOAM)	FOAM is responsible for the formatting and output of charging information. The charging data is collected by the charging service in the RMP. FOAM retrieves this and formats it according to the network operators requirements. By separating the formatting and output of charging information from the generation of charging data, market-specific aspects of charging can be handled more effectively
Service Switching Function AM (SSFAM)	This AM provides MIN service switching functionality
Service Control Function AM (SCFAM)	This AM provides MIN service control functionality.
SYStem Operation and Maintenance AM (SYSOMAM)	This is responsible for system-wide operation and maintenance functions
Digital Access Services AM (DASAM)	This AM is responsible for providing both Primary Rate Access (PRA) and Basic rate Access (BA) in an MSC/VLR which includes such ISDN services
ISDN User Services AM (IUSAM)	IUSAM implements ISDN subscriber services
ISDN Operation and Maintenance AM (ISOMAM)	This AM implements operation and maintenance activities for the ISDN application within an MSC/VLR
Direct Access Gateway AM (DAGAM)	Provides direct access to Internet services in an MSC/VLR which includes such capabilities

Table 5-1 Available Application Modules

Application Platform Services Interface (APSI)

The Application Platform Services Interface (APSI) is a system interface which offers client-server type services to other applications (the clients). The services of the APSI are either implemented in the RMP or XSS. The services of APSI are needed to co-ordinate the use of common resources between the different AMs. One example of such a service is the central switching part of AXE called the Group Switch (GS).

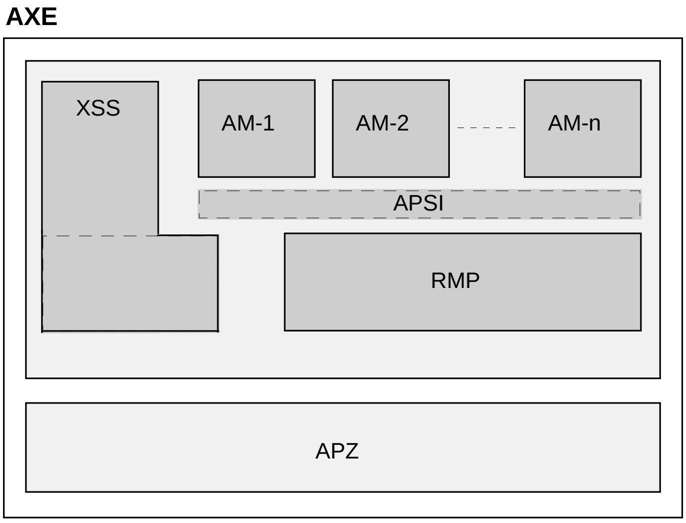


Figure 5-5 AXE system structure showing APSI

CONTROL SYSTEM ARCHITECTURE

Another important factor behind the flexibility of AXE is the control system architecture. AXE is a Stored Program Control (SPC) exchange. That is, software programs stored in the AXE computer control the operation of the AXE switching equipment. This is a two level system with both central and distributed control. This approach offers reliability and call handling efficiency.

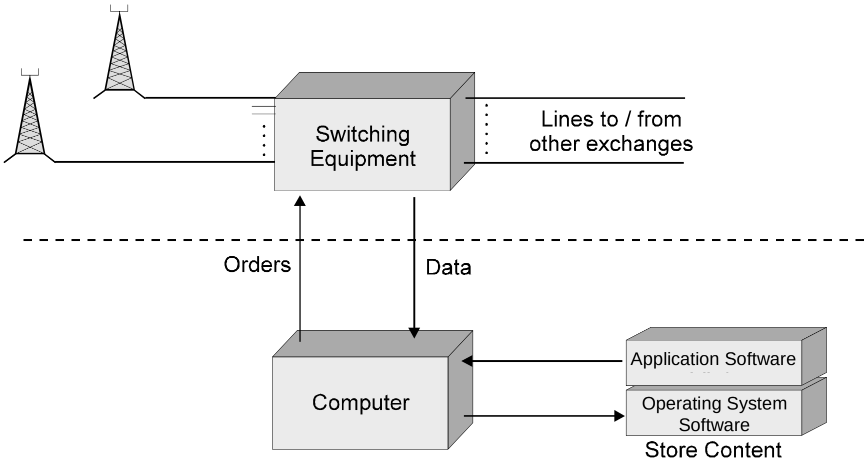


Figure 5-6 An SPC Exchange

The control system, APZ, is a two-level system with centralized and distributed logic. The central processing level consists of a duplicated Central Processor (CP) working in parallel synchronous mode. At the distributed level there are a number of Regional Processors (RP) working in pairs.

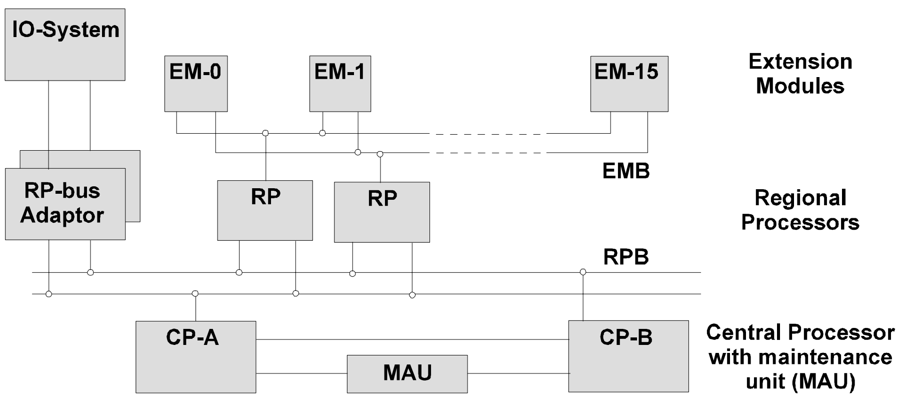


Figure 5-7 Hardware architecture, AXE

The RPs control hardware units called Extension Modules (EM). One RP-pair can control up to 16 EMs. The number of EMs connected to one RP-pair depends on the complexity of the tasks to be performed. The more RP capacity required, the fewer EMs can be connected. Two RPs in a pair share the work load of controlling the EMs.

The Input/Output (I/O) system provides connections with I/O devices such as terminals, printers, alarm displays, data links, flexible disks, hard disks and magnetic tapes. The I/O system performs all input/output functions and processes various maintenance, administrative, performance and call-related data.

TELECOMMUNICATIONS APPLICATIONS SUBSYSTEMS

The following table provides a brief overview of some basic telecommunications applications AXE subsystems. Some of these are described in more detail following the table.

Subsystem	Name	Function	Product Line
CCS	Common Channel signaling Subsystem	Handles SS7 signaling	All AXE nodes
CHS	CHarging Subsystem	Provides charging and accounting functions	MSC/VLR, GMSC
CHSS	CHarging Services Subsystem	Co-ordinates charging in an AXE 106 system.	MSC/VLR, GMSC
DTS	Data Transmission Subsystem	Provides packet mode services for ISDN basic access D-channel traffic	MSC/VLR, GMSC
ESS	Extended Switching Subsystem	Provides multiple connections and messages	MSC/VLR, GMSC
GSS	Group Switching Subsystem	Sets up, supervises and clears connections through the Group Switch. Provides synchronization	MSC/VLR, GMSC, TRC, BSC
HRS	Home location Register Subsystem	Stores mobile subscriber subscriptions	HLR
MDS	Mobile Data Subsystem	Administers VLR data	MSC/VLR, GMSC
MMS	Mobile Mobility and radio Subsystem	Handles the radio network and the connection towards the MSs	MSC/VLR, GMSC
MSS	Mobile Switching Subsystem	Handles traffic to and from mobile subscribers	MSC/VLR, GMSC
NMS	Network Management Subsystem	Assists management of the network by provision of statistics and controls traffic flow	MSC/VLR, GMSC
OMS	Operation & Maintenance Subsystem	Provides exchange maintenance and supervision	MSC/VLR, GMSC, HLR
RCS	Radio Control Subsystem	Controls the cell network including cell parameters	BSC, TRC
RMS	Remote Measurement Subsystem	Enables remote testing of trunks between exchanges	MSC/VLR
ROS	Radio Operation and maintenance Subsystem	Responsible for transmission interfaces to BTS/TRC	BSC
RTS	Radio Transmission and transport Subsystem	Controls transmission functions to/within the BSC	BSC, TRC
SHS	Short message Handling Subsystem	Handles all aspects of the SMS	MSC/VLR
SOMS	System-wide Operation and Maintenance Subsystem	Provides maintenance and supervision functions in an AXE 106 system	MSC/VLR, GMSC, HLR
SSS	Subscriber Switching Subsystem	Provides subscriber access switching functions	MSC/VLR
STS	Statistics and Traffic measurement Subsystem	Provides data collection and processing for all types of traffic handling	MSC/VLR, GMSC, HLR
TAS	Transceiver Administration Subsystem	Responsible for BTS operation and maintenance	BSC, TRC
TCS	Traffic Control Subsystem	Responsible for call set-up, supervision and clearing	MSC/VLR, GMSC
TSS	Trunk and Signaling Subsystem	Provides trunk links to other exchanges and signaling resources	MSC/VLR, GMSC

Table 5-2 Application Subsystems

TRAFFIC CONTROL SUBSYSTEM (TCS)

The Traffic Control Subsystem (TCS) consists of several function blocks and is comprised of software only. Its basic functions are:

- Set-up, supervision and clearing of calls
- Analysis of incoming digits
- Selection of outgoing routes

REgister function (RE): This block stores the incoming digits and co-ordinates the call set-up procedure.

CaLl supervision & Co-ordination Of Functions (CLCOF): This block takes over from RE when the call has been set up. It supervises and clears the call.

Digit Analysis (DA): This block contains tables for digit analysis. The action of analyzing digits in DA is called B-number analysis.

Route Analysis (RA): This block contains tables for selecting outgoing routes (including alternative routes).

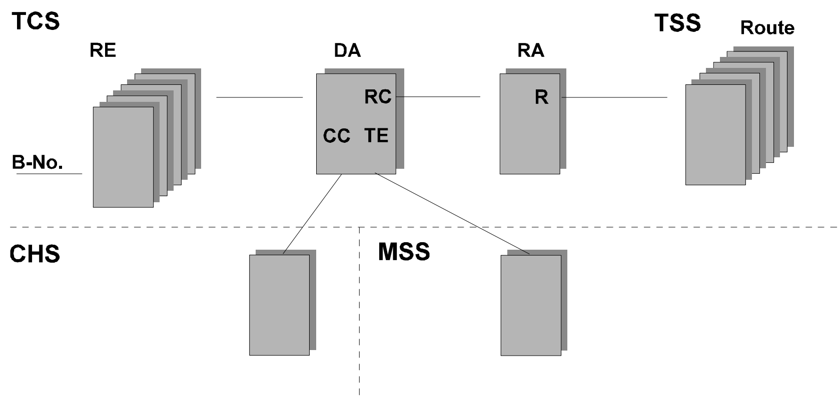


Figure 5-8 TCS, example of operation

An Example OF Interworking Involving Different Blocks in TCS

1. The received B-subscriber number will be stored in RE.
2. The digits will be sent to DA, one by one, for analysis. DA will ask for digits until the results below are obtained.
3. A Charging Case (CC) which will be sent to Charging Analysis (CA) in the charging subsystem.
4. Routing information, which will be one of the following:

- **An outgoing call:** The result will be a Routing Case (RC) which will point out an outgoing route in TSS.
- **An internal call:** The result will be a Terminated Call (TE) which will give a reference to MSS for a call to a mobile subscriber.

TRUNK AND SIGNALING SUBSYSTEM (TSS)

The Trunk and Signaling Subsystem (TSS) comprises both software and hardware. It handles signaling and the supervision of connections to other exchanges.

Trunk interfaces

Trunk lines to other network nodes are handled by Exchange Terminal Circuits (ETCs), which provide hardware interfaces to the group switch. Data rates on trunk lines can be either 2.048Mbits/s or 1.544Mbits/s, each using different ETC types.

Transmission interface towards the Radio Base Stations

The transmission towards the base station uses either a 2.048 Mbits/s or 1.544 Mbits/s digital interface. The connection between the MSC/VLR and the BS is described in later chapters.

Echo Canceller in POOL (ECPOOL)

In all telephony networks there are different sources of echo. In fixed networks, echo may be noticed if satellite links are used to transfer speech (due to the length of the transmission path to/from the satellite). In digital cellular systems delay is introduced in the speech/channel coding mechanisms. Echo cancellers are used to minimize echo. The echo canceller used by Ericsson is called ECPOOL and is placed in the MSC/VLR.

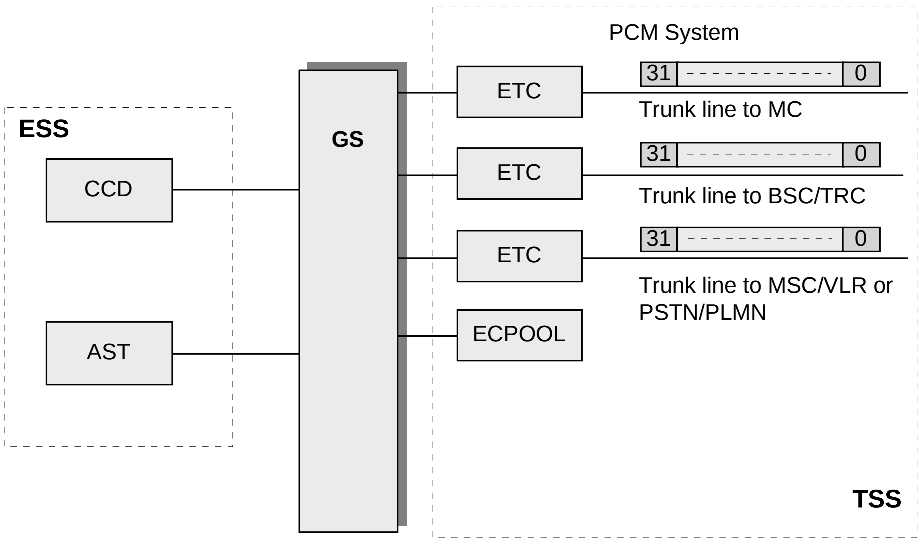


Figure 5-9 TSS hardware

COMMON CHANNEL SIGNALING SUBSYSTEM (CCS)

The Common Channel Signaling subsystem (CCS) consists of both software and hardware. It contains functions for signaling, routing, supervision and correction of messages sent in accordance with Signaling System No. 7 (SS7).

Signaling terminals in CCS

Signaling terminals (C7ST) for signaling according to SS7 are connected directly to the signaling network link. The signaling terminal is implemented on one circuit board and each magazine holds two boards.

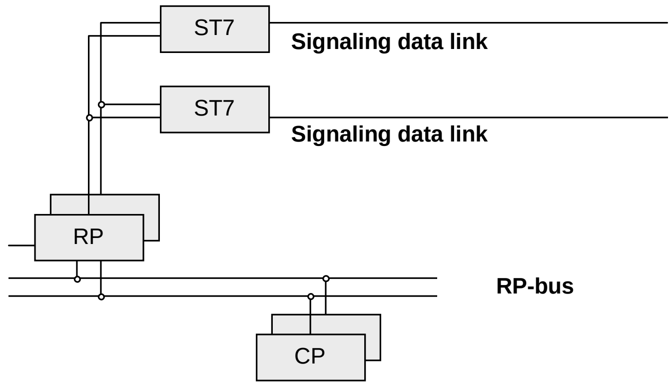


Figure 5-10 Signaling terminals

GROUP SWITCHING SUBSYSTEM (GSS)

The Group Switching Subsystem (GSS) consists of a switching and network synchronization functions. GSS is mainly responsible for selection, connection and disconnection of speech or signal paths through the Group Switch (GS).

Switching

The digital group switch is a Time-Space-Time (T-S-T) switch. The Time Switch Module (TSM) consists of buffer memories and the Space Switch Module (SPM) of digital cross-point matrices. For reliability reasons, the switching network as a whole is duplicated in two separate planes working synchronously.

Up to 16 Pulse Code Modulation (PCM) links, each one containing 32 time slots, can be connected to one TSM. A TSM is built up of 512 multiple positions (16x32=512).

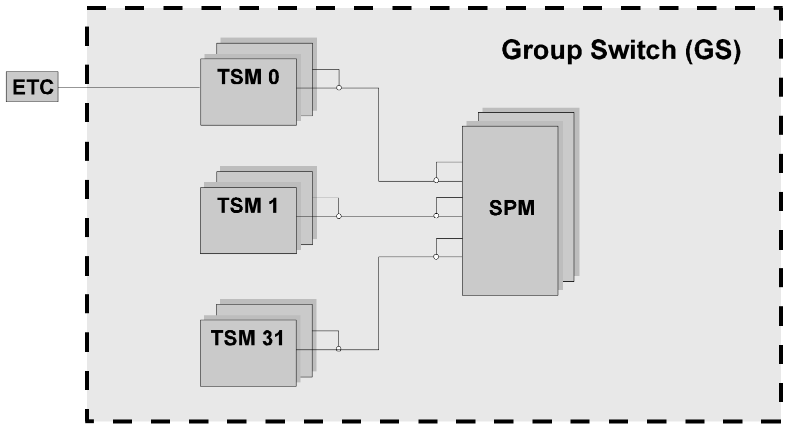


Figure 5-11 Group switch hardware

If 24-channel PCM systems are used, special ETCs adapt the rate from 1544 kbits/s to 2048 kbits/s.

One PCM time slot is always connected to the same memory position (multiple point) in TSM. The incoming digital information, that is, PCM time slot (8 bits), is written into the TSM. It is then read out from the TSM, switched in the SPM, written into another (or to the same) TSM and sent out on the PCM time slot to the destination.

This procedure is repeated 8000 times/second for each time slot in each direction. The internal clocking rate in TSM/SPM is higher than that because there are 16 PCM systems to take care of in the same time. This clocking rate amounts to 4.096 MHz (8 kHz X 16 PCM systems x 32 time slots = 4.096 MHz).

The size of the group switch can be extended as necessary. Several SPMs can be interconnected to form a large matrix. This gives a maximum switch capacity of 64 K multiple positions - the 64 K Group Switch.

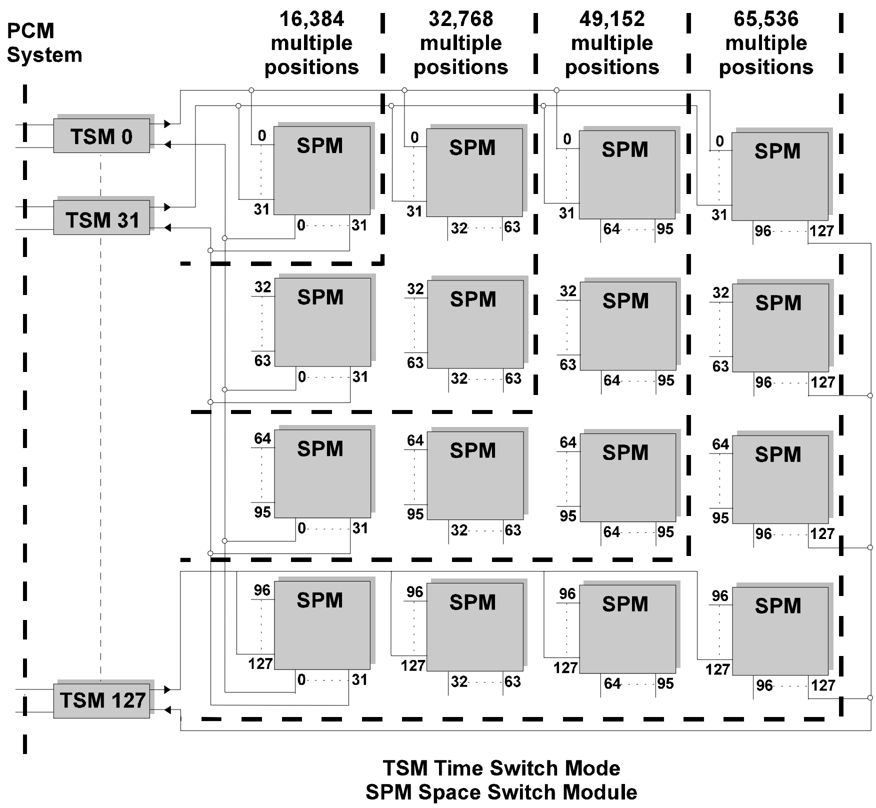


Figure 5-12 A fully equipped group switch

Network Synchronization (NS)

The Group Switch requires clocking. The clock rate determines the rate at which samples are read from or written into the speech stores in the TSMs. Network synchronization contains Clock Modules (CLM), triplicated for reliability, and reference clocks (not shown in the figure below).

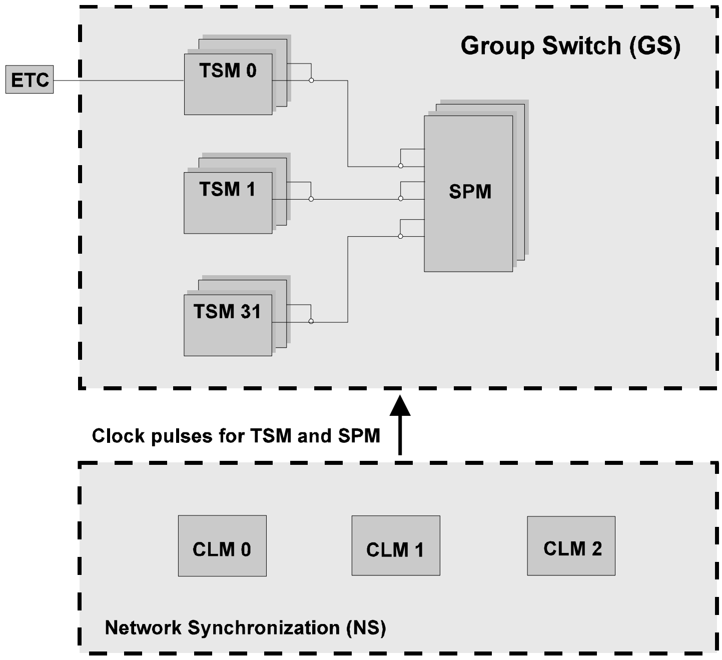


Figure 5-13 Clock modules to synchronize the group switch

CHARGING SUBSYSTEM (CHS)

The CHarging Subsystem (CHS), which consists of software only, is used for charging of the mobile subscribers. The charging function makes it possible to collect and output data concerning calls, supplementary services and invocation of such services.

The calls are charged by means of Charging Data Recording (CDR). This means that data about each call, such as calling party number, called party number, date, time, call duration, etc., is recorded and stored on magnetic disk or tape.

The collection and output of data can be performed in the originating MSC/VLR, the GMSC or the terminating MSC/VLR depending on the result of the charging analysis.

The data is stored in records known as Call Data Records (CDRs) which are stored on the hard disk of the AXE. When the data is needed at the billing center it is output through X.25 data links.

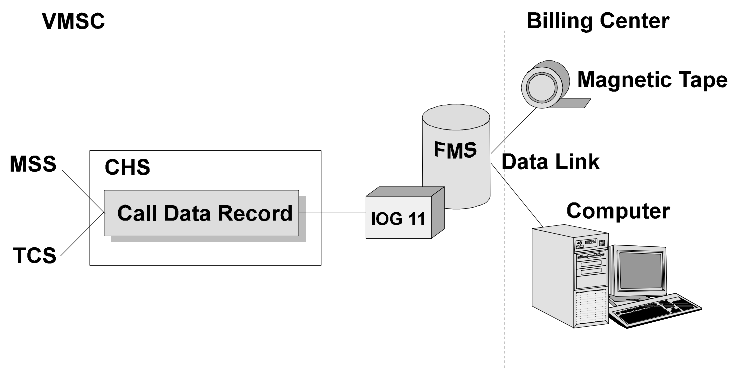


Figure 5-14 Charging in AXE

OPERATION AND MAINTENANCE SUBSYSTEM (OMS)

Operation and maintenance functions common to various subsystems in the switching system, APT, have been collected to form the Operation and Maintenance Subsystem (OMS).

An example of an OMS function is maintenance of trunk circuits, involving supervision functions such as:

- Blocking supervision
- Seizure supervision
- Disturbance supervision

Among other functions, OMS is responsible for making sure that the processor is not overloaded.

Operation and maintenance functions related to a specific subsystem, e.g. GSS or MSS, are implemented in the respective subsystem. A version of OMS adapted for use in the RMP is called the OMS-R.

NETWORK MANAGEMENT SUBSYSTEM (NMS)

The Network Management Subsystem (NMS) consists of software only. The subsystem contains functions for supervising the traffic flow through the exchange, and for introducing temporary changes in that flow. This may occur for example, if there was an overload of traffic on a particular route.

STATISTIC AND TRAFFIC MEASUREMENT SUBSYSTEM (STS)

The Statistic and Traffic measurement Subsystem (STS) is a general system for collecting, storing, processing and presenting statistical data for all types of traffic handling and maintenance applications in Ericsson’s GSM systems. STS consists of software only.

CONTROL SYSTEMS SUBSYSTEMS

APZ is composed of the subsystems in the following table. Some of these subsystems are now discussed in further detail following the table.

Subsystem	Name	Function	Product Line
CPS	Central Processor Subsystem	Includes the duplicated processor and performs the high level processing functions and data handling	All
DBS	DataBase management Subsystem	Provides a semi-relational database system with extensions to support real-time system requirements	All
DCS	Data Communications Subsystem	Provides physical interfaces and data communication protocols for communication with AXE	All applications requiring I/O functions
FMS	File Management Subsystem	Manages the AXE mass storage devices. The FMS stores files of magnetic tape, flexible disks, hard disks and optical disks	All applications requiring I/O functions
MAS	MAintenance Subsystem	Supervises the operation of the CP and takes appropriate action if a fault occurs	All
MCS	Man-machine Communication Subsystem	Provides functions for the communication between the staff and the AXE by means of alphanumeric terminals and alarm panels	All applications requiring I/O functions
OCS	Open Communications Subsystem	Provides standard data communications between applications in AXE and external computer systems	All
RPS	Regional Processor Subsystem	Includes the Regional processors which perform the basic routine tasks for the CP or act as an interface to the hardware	All
SPS	Support Processor Subsystem	Includes the Support Processors for I/O communication. SPS provides the operating system with alarms and interfaces, internal communication and supervisory functions for SP	All applications requiring I/O functions

Table 5-3 APZ Subsystems

CENTRAL PROCESSOR SUBSYSTEM (CPS)

The Central Processor Subsystem (CPS) contains both software and hardware and performs functions such as job administration, store handling, loading and changing of programs. For reliability, CPS contains 2 Central Processors (CPs) which operate in an executive/stand-by relationship. In the event of failure of the executive CP, the stand-by CP will take control without loss of service.

MAINTENANCE SUBSYSTEM (MAS)

MAintenance Subsystem (MAS) contains both software and hardware. MAS's function is to locate hardware faults and software errors, and to minimize the effects of such faults/errors.

REGIONAL PROCESSOR SUBSYSTEM (RPS)

The Regional Processor Subsystem (RPS) contains both software and hardware. The hardware is in the form of regional processors (RPs), while the software consists of administrative programs located in the RPs. RPs are controlled by the CP.

SUPPORT PROCESSOR SUBSYSTEM (SPS)

The Support Processor Subsystem (SPS) includes a Support Processor (SP) for communication with all Input/Output (I/O) devices. SPS has functions for blocking, deblocking and supervising of I/O devices. The SP is controlled by the CP.

FILE MANAGEMENT SUBSYSTEM (FMS)

The File Management Subsystem (FMS) handles all types of files used in AXE. The term "file" denotes all data stored on tape, floppy disks and magnetic disks. The data blocks of the AXE must always consult FMS before information is stored in external storage media (output of charging data, etc.).

MAN-MACHINE COMMUNICATION SUBSYSTEM (MCS)

The Man-Machine Communication Subsystem (MCS) handles communication between the I/O devices and the rest of the system. The I/O devices can be in the form of display units, printers, alarm panels, or the OSS system.

DATA COMMUNICATION SUBSYSTEM (DCS)

The Data Communication Subsystem (DCS) handles communication between blocks in the CP and the SP. The subsystem structure is in accordance with international standards for I/O systems: Open Systems Interconnection (OSI). DCS also handles communication over data links according to standardized data protocols X.25, X.75 and X.28. For example, charging data records are sent over a data link from DCS to a billing center.

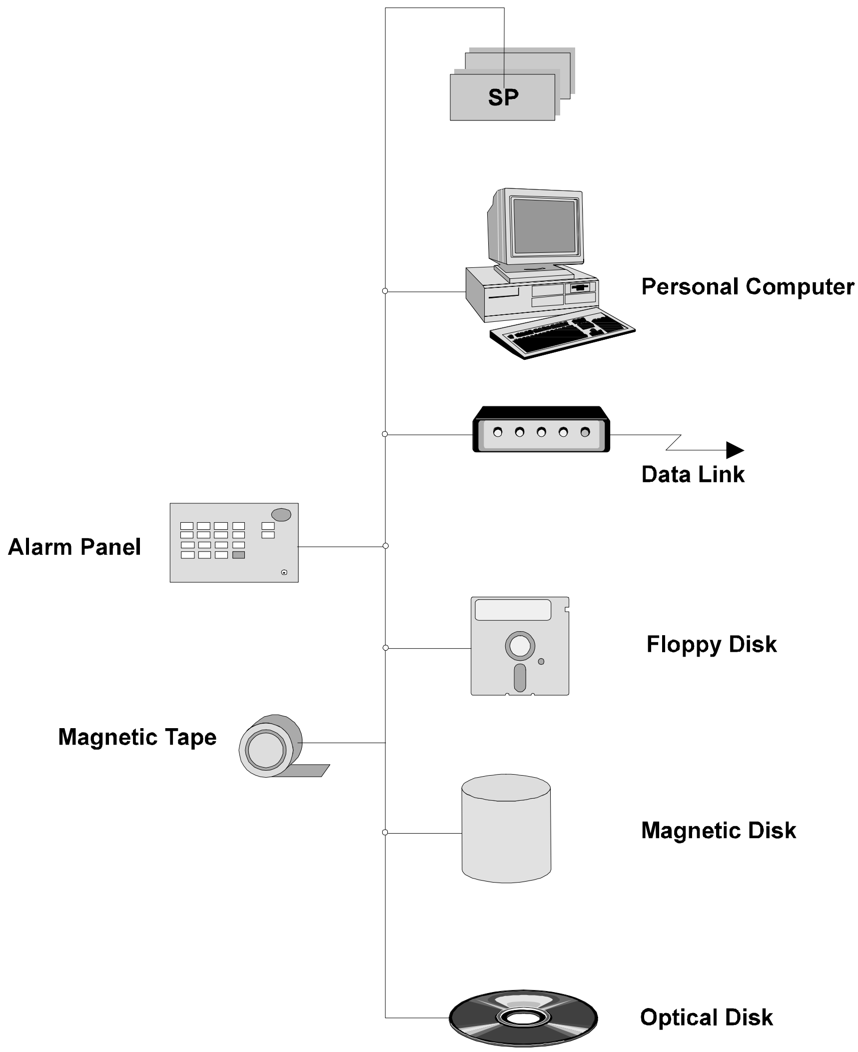


Figure 5-15 I/O System hardware

SUBSYSTEMS IN ERICSSON'S GSM PRODUCT LINES

The figures below summarizes the subsystems particular to each product line in Ericsson's GSM systems.

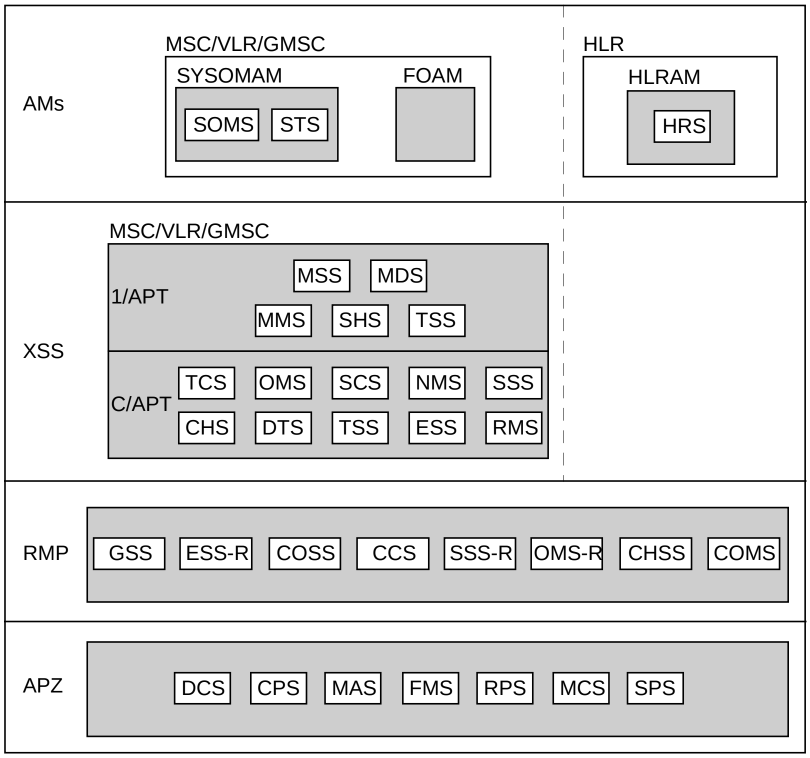


Figure 5-16 CME 20/CMS 40 Product Lines: Application Modularity based Products (possible additional AMs are not shown here)

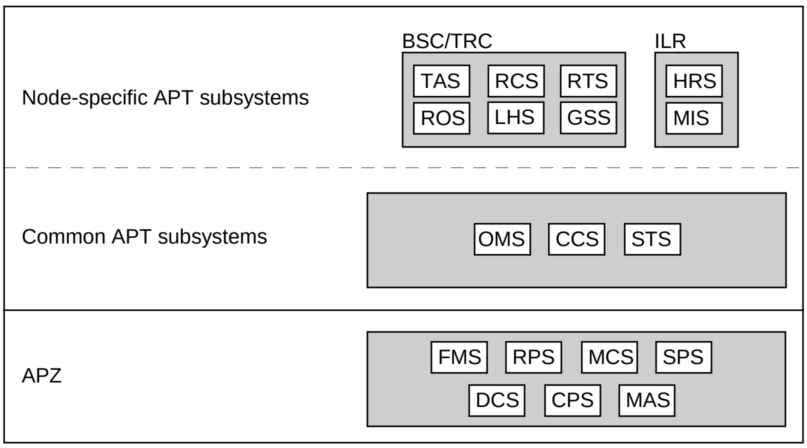


Figure 5-17 CME 20/CMS 40 Product Lines: Non-Application Modularity based Products

AXE HARDWARE

From its inception, the AXE system was designed to accommodate continuous change. Through the years, new applications have been introduced, its array of functions has grown, and its hardware has been steadily updated.

The latest advances in hardware technology have been brought into the system, thereby dramatically improving such characteristics as floor space, power consumption, system handling, and cost of ownership.

Ericsson has decided to make an overall modernization of AXE. The tool to do this is the AXE HardWare Modernization (HWM) program which is an umbrella project that shall initiate and co-ordinate all modernization projects which will be executed in parallel.

Ericsson's new cabinet based equipment practice is called BYB 501. BYB 501 complies with the metric standards for IEC (International Electrotechnical Commission) and ETSI (European Telecommunications Standards Institute) standards and has excellent EMC (Electromagnetic Compatibility), offering important advantages compared with other equipment practices. For example, the BYB 501 easily accommodates other standardized products. BYB 501 subrack can accommodate a mix of full size and half size plug-in units.

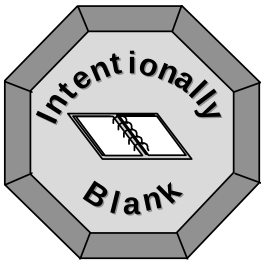
The Regional Processor (RP2) has decreased to only three boards (RP3) and will further reduce to one (RP4) when the Serial RP-Bus (RPB-S) is realized. Since the EM is a single board, there is no need to have a separate magazine for RP. These ideas have resulted in a new Generic EM Magazine referred to as GEMM.

GEMM comes in two generations: GEMM1 is for BYB 202 (the older AXE hardware structure) and GDM for BYB 501. GDM is the target for HWM, it will be in two version GDM-H half height and GDM-F full height.

A new regional processor called RP4 will be introduced, and will accommodate the new Serial Regional Processor bus (RPB-S).

BYB 202 will contain non modernized products in either wide 1200mm or narrow version 720mm. A compact version of APT 212 20 will use a narrow BYB 202 cabinet.

The old Group Switch (GS) will be replaced by a new GS. The newly enhanced Group Switch subsystem requires only half as many plug-in unit types as its predecessor, its footprint is between 80% and 95% smaller in large configurations, and power has been reduced by similar amounts. This has been achieved by such advances as combining all TSM functions on one plug-in unit.


Intentionally
Blank

Switching System

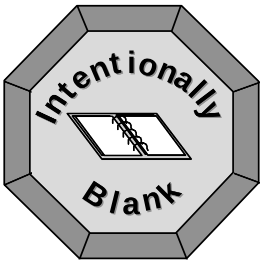
Chapter 6

This chapter is designed to provide the student with an overview of the switching system, including its nodes and their functionality.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the basic switching system structure
- Describe the basic switching system functionality
- Describe the functions and implementation of each switching system node


Intentionally
Blank

6 Switching System

Table of Contents

Topic	Page

INTRODUCTION

The Switching System in Ericsson's GSM systems contains the following components:

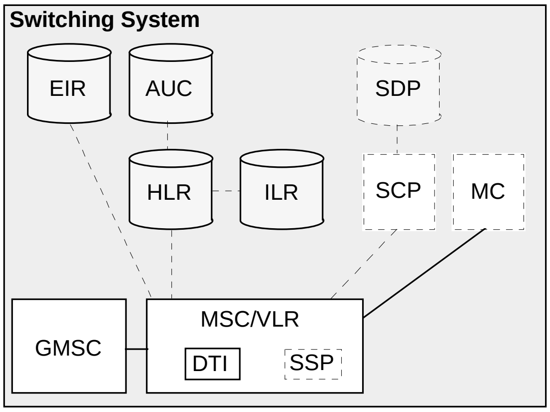


Figure 6-1 Switching System

Type	Abbrev.	Full component name	Platform
Basic	MSC/VLR	Mobile services Switching Center/Visitor Location Register	AXE
	GMSC	Gateway MSC	AXE
	HLR	Home Location Register	AXE
	ILR	Interworking Location Register	AXE
	AUC	AUthentication Center	Unix/AXE
	EIR	Equipment Identity Register	Unix
	DTI	Data Transmission Interface	AXE
Additional	MC	Message Center	MXE
	SSP	Service Switching Point	AXE
	SCP	Service Control Point	AXE
	SDP	Service Data Point	Unix

Table 6-1 Switching System components

Each network component is described in the remainder of this chapter.

MOBILE SERVICES SWITCHING CENTER/VISITOR LOCATION REGISTER (MSC/VLR)

MSC FUNCTIONS

The primary node in a GSM network is the MSC. It is the node which controls calls both to MSs and from MSs. The primary functions of an MSC include the following:

- **Switching and call routing:** an MSC controls call set-up, supervision and release and may interact with other nodes to successfully establish a call. This includes routing of calls from MSs to other networks such as a PSTN.
- **Charging:** an MSC contains functions for charging mobile calls and information about the particular charge rates to apply to a call at any given time or for a given destination. During a call it records this information and stores it after the call, e.g. for output to a billing center.
- **Service provisioning:** supplementary services are provided and managed by an MSC. In addition, the SMS service is handled by MSCs.
- **Communication with HLRs:** the primary occassion on which an MSC and HLR communicate is during the set-up of a call to an MS, when the HLR requests some routing information from the MSC[1].
- **Communication with the VLR:** associated with each MSC is a VLR, with which it communicates for subscription information, especially during call set-up and release.
- **Communication with other MSCs:** it may be necessary for two MSCs to communicate with each other during call set-up or handovers between cells belonging to different MSCs.
- **Control of connected BSCs:** as the BSS acts as the interface between the MSs and the SS, the MSC has the function of controlling the primary BSS node: the BSC. Each MSC may control many BSCs, depending on the volume of traffic in a particular MSC service area. An MSC may communicate with its BSCs during, for example, call set-up and handovers between two BSCs.

[1] An MSC may include gateway functionality, in which case there is more communication with HLRs.

- **Direct access to Internet services:** traditionally, an MSC accessed the Internet nodes of an Internet Service Provider (ISP) via existing networks such as the PSTN. However, this function enables an MSC to communicate directly with Internet nodes, thus reducing call set-up time. Direct access can be provided by using an access server called Tigris (from Advanced Computer Communications). This may be integrated in an MSC or stand-alone connected to an MSC.

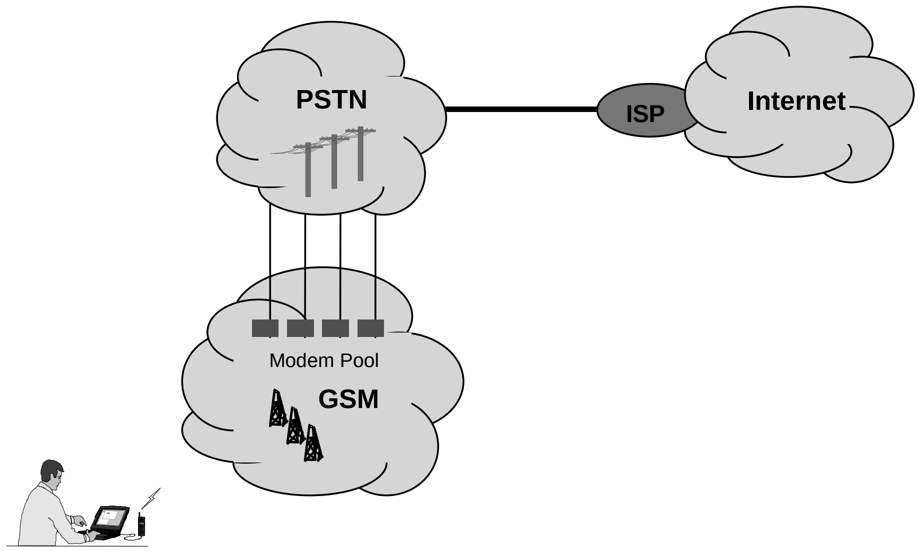


Figure 6-2 Internet access via GSM/PSTN (traditional method)

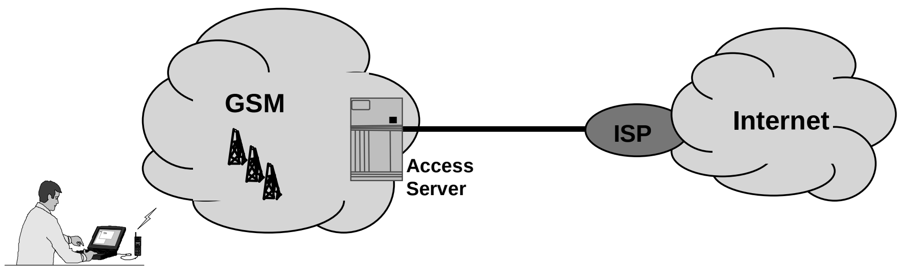


Figure 6-3 Direct access to Internet

- **ISDN Primary Rate Access (PRA):** this function enables an MSC to provide PRA services to subscribers. For example, this could be used by a network operator to offer PABX connection services through the PLMN. In this way the operator can compete directly with PSTN operators for ISDN business subscribers.

VLR FUNCTIONS

The role of a VLR in a GSM network is to act as a temporary storage location for subscription information for MSs which are within a particular MSC service area. Thus, there is one VLR for each MSC service area. This means that the MSC does not have to contact the HLR (which may be located in another country) every time the subscriber uses a service or changes its status.

The following occurs when MSs move into a new service area:

1. The VLR checks its database to determine whether or not it has a record for the MS (based on the subscriber's IMSI)

2. When the VLR finds no record for the MS, it sends a request to the subscriber's HLR for a copy of the MS's subscription

3. The HLR passes the information to the VLR and updates its location information for the subscriber. The HLR instructs the old VLR to delete the information it has on the MS

4. The VLR stores its subscription information for the MS, including the latest location and status (idle)

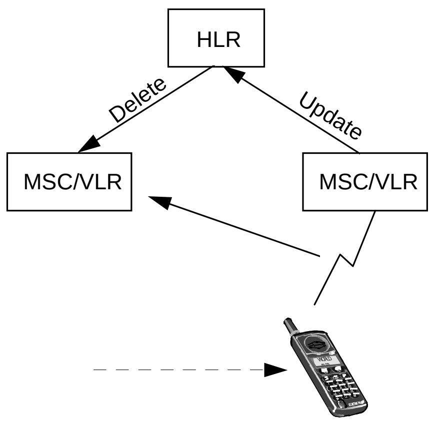


Figure 6-4 VLR-HLR interaction

For the duration which the MS is within in its MSC service area, a VLR contains a complete copy of the necessary subscription details, including the following information for each MS:

- Identity numbers for the subscriber
- Supplementary service information (e.g. whether the subscriber has call forwarding on busy activated or not)
- Activitiy of MS (e.g. idle)
- Current LA of MS

MSC/VLR IMPLEMENTATION

In Ericsson's GSM systems, the MSC and VLR are integrated in the same AXE-based node. The reason for this is that there is an extensive amount of information exchange between the two nodes for every call, particularly during call set-up. The MSC-VLR interface is completely internal within the AXE, but each is treated as a distinct and separate function.

An MSC/VLR contains the common APZ and APT subsystems described previously, along with the subsystems in the following table, each of which is implemented in software only.

Subsystem	**Functions**
Mobile Data Subsystem (MDS)	• VLR functions
Mobile Mobility and radio Subsystem (MMS)	• Control of BSCs • Control of handovers involving the MSC
Mobile Switching Subsystem (MSS)	• Switching and call routing • Communication with HLRs • Communication with other MSCs
Short message Handling Subsystem (SHS)	• Handling of SMS messages

Table 6-2 MSC/VLR Subsystems

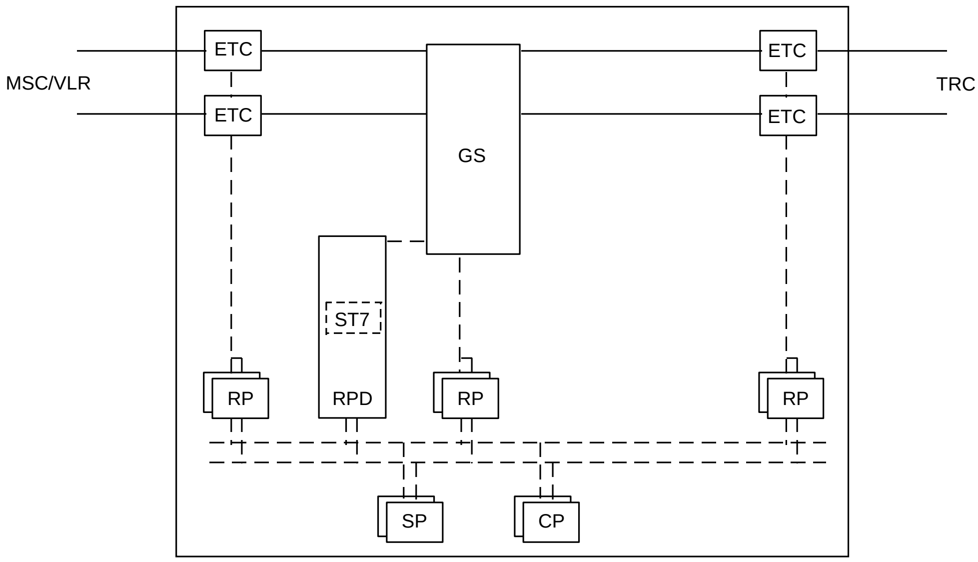


Figure 6-5 MSC/VLR hardware

GATEWAY MSC (GMSC)

GMSC FUNCTIONS

Gateway functionality enables an MSC to interrogate a HLR in order to route a mobile terminating call. It is not used in calls from MSs to any terminal other than another MS.

For example, if a person connected to the PSTN wants to make a call to a GSM mobile subscriber, then the PSTN exchange will access the GSM network by first connecting the call to a GMSC. The GMSC requests call routing information from the HLR which provides information about which MSC/VLR to route the call to. The same is true of a call from an MS to another MS.

GMSC IMPLEMENTATION

Any MSC in the mobile network can function as a gateway by integration of the appropriate software and definition of HLR interrogation information. In effect it then becomes a GMSC/VLR.

In Ericsson's GSM systems, gateway functions are provided within the subsystem MSS. The only additional hardware required is hardware to interface to the signaling link to the HLR.

Gateway Function:

1. Find and interrogate HLR for roaming number.
2. Route the call according to the interrogation.

HOME LOCATION REGISTER (HLR)

HLR FUNCTIONS

The HLR is a centralized network database that stores and manages all mobile subscriptions belonging to a specific operator. It acts as a permanent store for a person's subscription information until that subscription is cancelled. The information stored includes:

- Subscriber identity (i.e. IMSI, MSISDN)
- Subscriber supplementary services
- Subscriber location information (i.e. MSC service area)
- Subscriber authentication information

The primary functions of the HLR include:

- **Subscription database management:** as a database, the HLR must be able to process data quickly in response to data retrieval and update requests from other network nodes. For this reason it acts as a database management system. Each subscriber record contains a substantial amount of parameters.
- **Communication with MSCs:** when setting up calls to an MS, it is necessary for the HLR to contact the MSC serving the MS for routing information. By analyzing the MSISDN, MSC knows which HLR to contact worldwide for that MS's subscription.
- **Communication with GMSCs:** during call set-up to an MS, the GMSC requests MS location information from the HLR, which then provides this in the form of routing information. Also, if the subscriber is detached the HLR will inform the GMSC that there is no need to perform further routing of the call.
- **Communication with AUCs:** before any activity involving change or use of susbcription information takes place, the HLR must retrieve new authentication parameters from an AUC.
- **Communication with VLRs/ILRs:** when an MS moves into a new MSC service area the VLR for that area requests information about the MS from the HLR of the subscriber. The HLR provides a copy of the subscription details, updates its MS location information and instructs the old VLR to delete the information it has about that MS. As the ILR acts as a VLR for AMPS subscribers, the HLR communicates with it in a similar way.

HLR IMPLEMENTATION

The HLR can be implemented in the same network node as the MSC/VLR (i.e. MSC/VLR/HLR) or as a stand-alone database. An MSC/VLR/HLR node is a suitable solution for a small start-up GSM network as it saves hardware and signaling load on the links between MSC/VLR and HLR.

A stand-alone HLR is a suitable solution for large networks. It has the following advantages:

- There are no traffic disturbances creating better reliability
- When the HLR is separate from the MSC/VLR, there is more capacity available for call handling in the MSC/VLR

If the capacity of a HLR is exceeded by the number of subscribers, additional HLRs may be added.

HLR Redundancy

In order to provide additional network reliability, an additional “mated” HLR is used to mirror the data in a HLR and can automatically take over if required.

System Structure

In Ericsson’s GSM systems the HLR is an AXE-based AM called HLRAM. Along with the standard APZ and APT subsystems the HLR includes the APT subsystem Home location Register Subsystem (HRS) which performs the necessary subscription management.

INTERWORKING LOCATION REGISTER (ILR)

ILR FUNCTIONS

Ericsson's ILR offers roaming capabilities between mobile telephony systems complying with different standards. The ILR is specific to the CMS 40 product portfolio and enables AMPS network subscribers to roam to a GSM 1900 network. The ILR consists of an AMPS HLR, a GSM 1900 VLR and interfacing functions.

For AMPS subscribers who wish to avail of this roaming functionality, their AMPS network subscriptions are copied into the HLR side of the ILR. When they roam into the GSM 1900 network, the HLR copies this information into the VLR side of the ILR, as occurs for normal GSM roaming subscribers.

From the subscriber's point of view however, there is only one subscription.

ILR IMPLEMENTATION

In Ericsson's GSM systems the ILR is AXE-based. It includes the common APZ and APT subsystems outlined previously and the following additional subsystems:

Subsystem	Functions
Home location Register Subsystem (HRS)	• AMPS Subscriber database management
Mobile Intersystem roaming Subsystem (MIS)	• Mapping and translation of services and protocols • Communication with other nodes

Table 6-3 ILR subsystems

ILR hardware is similar to HLR hardware.

AUTHENTICATION CENTER (AUC) AND EQUIPMENT IDENTITY REGISTER (EIR)

PLMNs need a higher level of protection than traditional telecommunication networks. Therefore, to protect GSM systems, the following security functions have been defined:

- **Subscriber authentication:** by performing authentication, the network ensures that no unauthorized users can access the network, including those which are attempting to impersonate others.
- **Radio information ciphering:** the information sent between the network and an MS is ciphered. An MS can only decipher information intended for itself.
- **Mobile equipment identification:** because the subscriber and equipment are separate in GSM, it is necessary to have a separate authentication process for the MS equipment. This ensures, e.g. that a mobile terminal which has been stolen is not able to access the network.
- **Subscriber identity confidentiality:** during communication with an MS over a radio link, it is desireable that the real identity (IMSI) of the MS is not always transmitted. Instead a temporary identity (TMSI) can be used. This helps to avoid subscription fraud.

The AUC and EIR are involved in the first three of the above features, while the last is handled by MSC/VLRs (and is described in the “Traffic Cases” chapter).

AUC FUNCTIONS

The primary function of an AUC is to provide information which is then used by an MSC/VLR to perform subscriber authentication and to establish ciphering procedures on the radio link between the network and MSs.

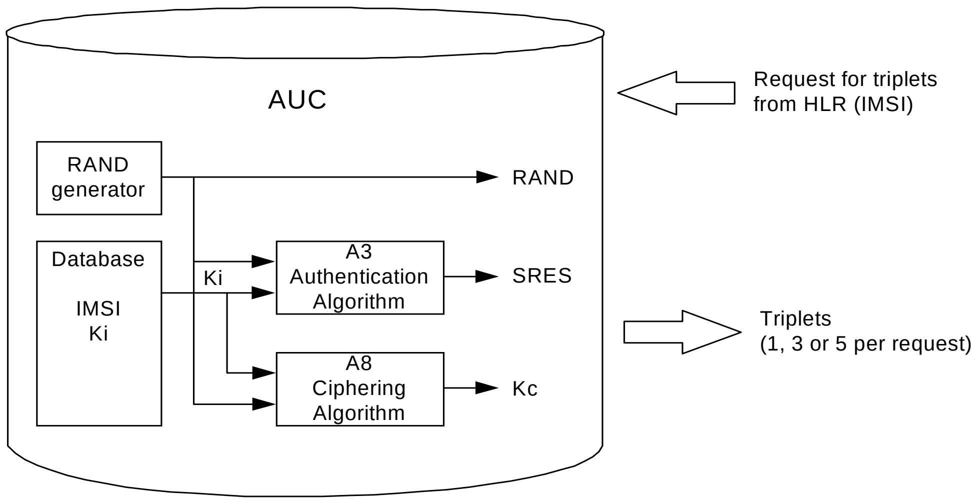
The information provided is called a triplet and consists of:

1. A non predictable RANDom number (RAND)
2. A Signed RESponse (SRES)
3. A ciphering Key (Kc)

Provision of Triplets

At subscription time, each subscriber is assigned a subscriber authentication Key (Ki). Ki is stored in the AUC along with the subscriber's IMSI. Both are used in the process of providing a triplet. The same Ki and IMSI are also stored in the SIM. In an AUC the following steps are carried out to produce one triplet:

1. A non-predictable random number, RAND, is generated
2. RAND and Ki are used to calculate SRES and Kc, using two different algorithms, A3 and A8 respectively
3. RAND, SRES and Kc are delivered together to the HLR as a triplet



RAND	Random number
SRES	Signed Response
Kc	Ciphering key
Ki	Subscriber authentication key
IMSI	International Mobile Subscriber Identity

Figure 6-6 Provision of triplets

Authentication Procedure

1. The MSC/VLR transmits the RAND to the MS.
2. The MS computes the signature SRES using RAND, the subscriber authentication key (K_i) and the A3 algorithm.
3. The signature SRES is sent back to MSC/VLR which performs authentication, by checking whether the SRES from the MS and the SRES from the AUC match. If so, the subscriber is permitted to use the network. If not, the subscriber is barred from network access.

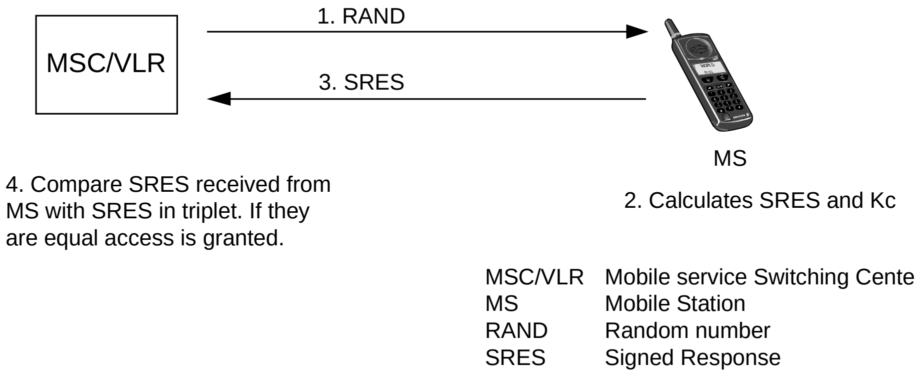


Figure 6-7 Authentication procedure

Authentication can be performed during:

- Each registration
- Each call setup attempt
- Location updating
- Before supplementary service activation and deactivation

There can be exceptions for subscribers belonging to other PLMNs.

Ciphering Procedure

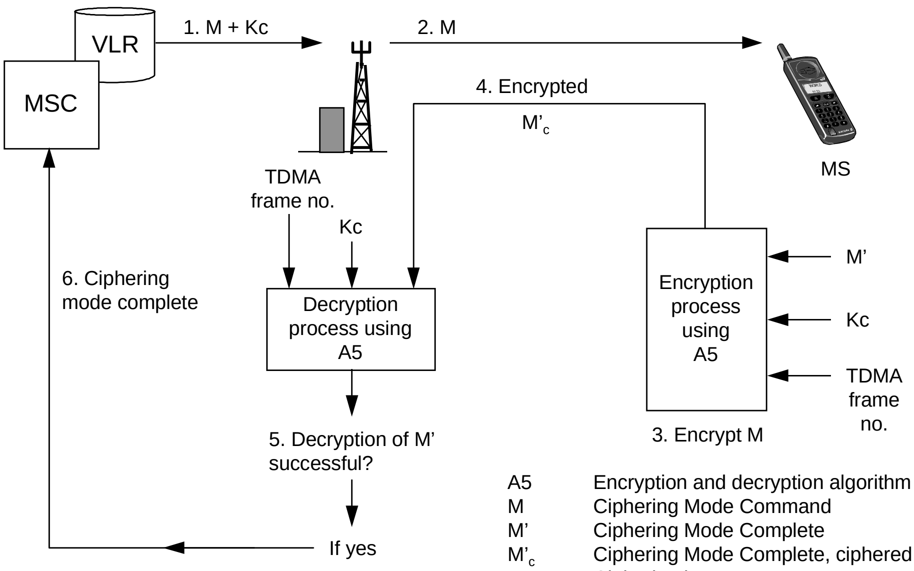
> ☞ Did you know?
>
> *There are actually 2 A5 algorithms. The A51 algorithm was of military grade and could only be used in NATO countries. This has been replaced by a non-military grade general GSM algorithm called A52.*

Confidentiality means that user information and signaling exchanged between BTSs and MSs is not disclosed to unauthorized individuals, entities or processes.

A ciphering sequence is produced using Kc and the TDMA frame number as inputs in the encryption algorithm A5. The purpose of this is to ensure privacy concerning user information (speech and data) as well as user related signaling elements.

In order to test the ciphering procedure some sample of information must be used. For this purpose the actual ciphering mode command (M) is used.

1. M and Kc are sent from the MSC/VLR to the BTS.
2. M is forwarded to the MS.
3. M is encrypted using Kc (calculated earlier with SRES in the authentication procedure) and the TDMA frame number which are fed through the encryption algorithm, A5.
4. The encrypted message is sent to the BTS.
5. Encrypted M is decrypted in the BTS using Kc, the TDMA frame number and the decryption algorithm, A5.
6. If the decryption of M was successful, the ciphering mode completed message is sent to the MSC. All information over the air interface is ciphered from this point on.



A5	Encryption and decryption algorithm
M	Ciphering Mode Command
M'	Ciphering Mode Complete
M'_c	Ciphering Mode Complete, ciphered
Kc	Ciphering key
MSC	Mobile services Switching Center
VLR	Visitor Location Register

Figure 6-8 Ciphering procedure

EIR FUNCTIONS

Equipment Identification Procedure

☞ Did you know?

Up to recently, many networks did not use an EIR. However, a Centralised EIR (CEIR) has been set-up in Europe (located in Ireland) which is used by many European network operators.

The equipment identification procedure uses the identity of the equipment itself (IMEI) to ensure that the MS terminal equipment is valid.

1. The MSC/VLR requests the IMEI from the MS.
2. MS sends IMEI to MSC.
3. MSC/VLR sends IMEI to EIR.
4. On reception of IMEI, the EIR examines three lists:
   - A **white list** containing all number series of all equipment identities that have been allocated in the different participating GSM countries.
   - A **black list** containing all equipment identities that have been barred.
   - A **gray list** (on operator level) containing faulty or non approved mobile equipment.
5. The result is sent to MSC/VLR, which then decides whether or not to allow network access for the terminal equipment.

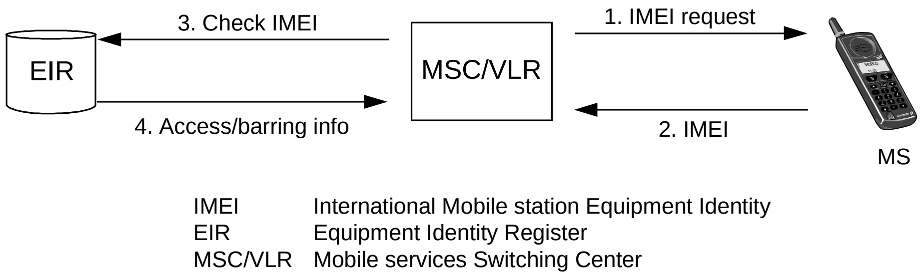


Figure 6-9 Equipment identification

The decision to identify equipment remains with individual operators. GSM specifications recommend identification for each attempted call set-up.

AUC AND EIR IMPLEMENTATION

In a GSM network the AUC is connected directly to a HLR. The EIR is connected to an MSC/VLR.

In Ericsson's GSM systems the AUC may be implemented on either AXE or Unix (from Sema Group). The EIR is implemented on a Unix platform from Sema Group.

If implemented on AXE, the most common configuration for an AUC is integrated with a HLR as an AUC/HLR node. This reduces the signal processing requirements of both. The AUC is implemented using the AUC Application Module (AUCAM).

The most common implementation is a Unix-based AUC/EIR node, which provides the following benefits to the operator:

- AUC and EIR processing is physically separated from the switching function in the MSC. This provides better network planning flexibility when the network needs to be expanded.
- The common platform is based on standard industry computer hardware (HW) and software (SW).

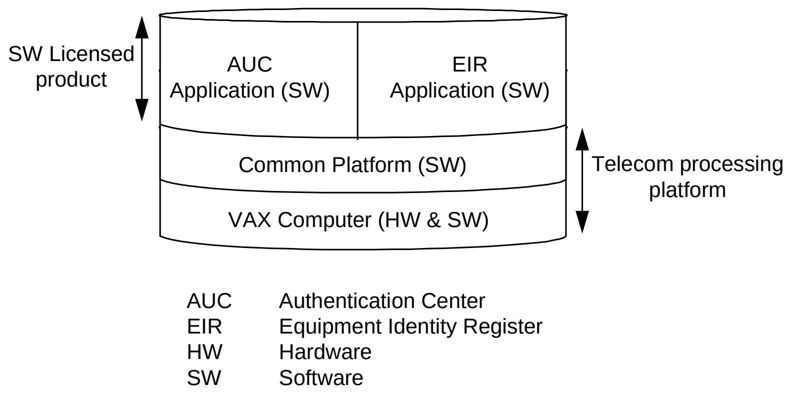


Figure 6-10 AUC/EIR product structure

DATA TRANSMISSION INTERFACE (DTI)

This section gives a brief introduction to the data handling capabilites of Ericsson's GSM systems. For a more detailed survey of such functions, please refer to the appendix titled "Data Services".

DTI FUNCTIONS

> ☞ Did you know?
>
> *In previous versions of CME20/CMS 40 the functions of the DTI were implemented using a GSM Inter-Working Unit (GIWU), separate from the MSC/VLR.*

The DTI implements the GSM Inter-Working Function (IWF). It performs data handling functions such as data rate conversion and provides the functions necessary for data interworking between GSM networks and other networks, including:

- **Data Traffic to/from PSTN:** this involves modem and fax calls. For connections to the PSTN a modem is selected by the DTI to perform the necessary rate and format conversions.
- **Data Traffic to/from ISDN:** the whole set of data communications towards ISDN is available, since the MSC/DTI is capable of signaling and mapping basic service information between the ISDN and the GSM network.
- **Data Traffic to/from PDNs:** the DTI handles data traffic to and from Public Data Networks (PDNs) such as the Packet Switched PDN (PSPDN) and Circuit Switched PDN (CSPDN).
- **Data Traffic between mobiles:** the data traffic inside the PLMN must pass through the DTI to handle the protocol used for rate adaptation in the radio path.
- **HSCSD:** this version of High Speed Circuit Switched Data (HSCSD) allows the connection of 2, 3, or 4 time slots on one radio channel each carrying 9.6 kbits/s. The DTI handles rate conversion to PSTN or ISDN as appropriate.

DTI IMPLEMENTATION

The DTI is integrated within an MSC/VLR. The DTI is managed by the Data Transmission Subsystem (DTS).

The DTI sub-rack contains eight plug-in units, each one supporting four data channels. Therefore, a total of 32 simultaneous data calls can be supported by each DTI sub-rack.

MESSAGE CENTER (MC)

MC FUNCTIONS

An MC may be added to a GSM network to provide one or more of the following messaging services:

- Voice mail
- Fax mail
- Short Message Service (SMS) text messages
- SMS Cell Broadcast (SMSCB) text messages

These services can generate considerable revenue for a network operator, as they are becoming increasingly popular.

Voice Mail

Voice mail ensures that all calls to a person can be completed, even when a person does not answer calls. A calling party can record a voice message for the subscriber they are calling.

A subscriber can use their MS to select diversion to voice mail based on a particular event or status (e.g. busy, unreachable).

The subscriber is informed that they have voice messages in their mailbox by means of either a short text message or phone call from the network at regular intervals. If their MS is detached, this indication is sent when the subscriber next attaches to the network.

The subscriber can then retrieve their voice mail messages at a later stage. Functions for storing voice messages over a long period also exist.

Fax Mail

Fax mail operates similarly to voice mail. For MSs which support fax, a subscriber can set diversion for all or some fax calls to a fax mailbox. When the MS is next attached to the network, the network will deliver the fax message to a fax machine identified by the MS.

SMS

A short text message consists of up 160 alphanumeric characters, entered at a Short Message Entity (SME) such as an MS (using the keypad) or computer terminal.

A short message always originates or terminates in a GSM network, meaning that a short message can not be sent between two SMEs residing outside a GSM network.

The short message originator knows if the message delivery is successful or unsuccessful via notification. When a message is submitted, the deferred delivery option can be requested. This option makes it possible to specify the time the message is to be delivered.

An MC which handles SMS messages is often referred to as an SMS Center (SMS-C). When a message is to be forwarded to an MS, the system must first determine where the MS is situated. As in ordinary voice traffic, a gateway requests the routing information. The gateway is called the SMS GMSC.

Each short message is time stamped by the SMS-Center when it is submitted. A message is deleted once the delivery is successful or once the time specified in deferred delivery expires.

When a message is buffered, the SMS-C regularly attempts to deliver the message, at intervals defined by the operator.

SMSCB

The SMSCB service enables a message of up to 93 alphanumeric characters to be delivered to all attached MSs in one cell. This may be useful for identifying key phone numbers in the cell’s area such as that of a hospital or police station. Alternatively, it may be used for advertising services within the cell (e.g. “Superfood Restaurant in this area at the junction of M8 and I33”).

MC IMPLEMENTATION

One MC node may handle one or more messaging service. For example, depending on the amount of SMS traffic, it may be more efficient to have one MC acting as an SMS-C only, with other messaging services handled by another separate MC.

It is also possible to integrate SMS-C functions on an MSC, leading to the term SMS InterWorking MSC (SMS-IWMSC). Additionally, the SMS GMSC functions may reside in the same node as the GMSC functions used for voice calls.

In Ericsson's GSM systems the MC is implemented by Ericsson's MXE product. The most important component of MXE is the message kernel. The message kernel is the central message store and forward nucleus responsible for safe storage of messages, routing and retry attempts.

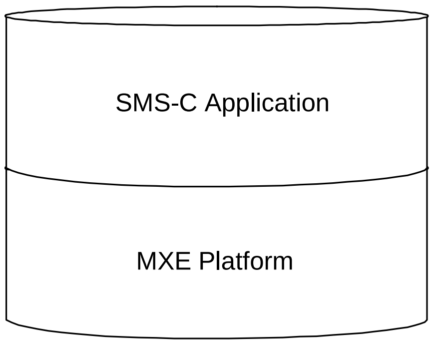


Figure 6-11 SMS-C on an MXE

SERVICE SWITCHING POINT (SSP), SERVICE CONTROL POINT (SCP) AND SERVICE DATA POINT (SDP)

This section gives a brief introduction to the Mobile Intelligent Network (MIN) handling capabilites of Ericsson's GSM systems. For a more detailed survey of such functions, please refer to the appendix titled "Mobile Intelligent Network Services".

Mobile Intelligent Network (MIN) nodes can be added to a basic GSM network to provide value-added services such as Freephone and Personal Number to subscribers.

Ericsson's MIN nodes include:

- **Service Switching Point (SSP):** an SSP acts as an interface between the call control functions of the mobile network and the service control functions of a Service Control Point (SCP). Ericsson's SSP is an AXE-based AM (SSFAM) and may be integrated within an MSC/VLR (recommended) or stand-alone.

- **Service Control Point (SCP):** an SCP contains the intelligence of a MIN service or services. This intelligence is realized in software programs and data. Ericsson's SCP is also an AXE-based AM (SCFAM) and the recommended configuration is as a stand-alone node, accessible by all MSC/SSPs.

- **Service Data Point (SDP):** an SDP manages the data which is used by an MIN service. Ericsson's SDP is a stand-alone node based on Unix.

Base Station System

Chapter 7

This chapter is designed to provide the student with an overview of the base station system. It addresses base station system components, their functions, features, and required specifications.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the basic base station system structure
- Describe the functions of the Transcoder Controller
- Describe the implementation of the Transcoder Controller
- Describe the functions of the Base Station Controller
- Describe the implementation of the Base Station Controller
- Describe the functions of the Radio Base Station
- Describe the implementation of the Radio Base Station

Intentionally Blank

7 Base Station System

Table of Contents

Topic	Page

Intentionally Blank

INTRODUCTION

The Base Station System (BSS) is responsible for all the radio-related functions in the system, such as:

- Radio communication with the mobile units
- Handover of calls in progress between cells
- Management of all radio network resources and cell configuration data.

Ericsson's BSS consists of three components:

- **Base Station Controller (BSC):** the BSC is the central node within a BSS and co-ordinates the actions of TRCs and RBSs.
- **Transcoder Controller (TRC):** the TRC provides the BSS with rate adaptation capabilities. This is necessary because the rate used over the air interface and that used by MSC/VLRs are different - 33.8 kbits/s and 64 kbits/s respectively. A device which performs rate adaptation is called a transcoder.
- **Radio Base Station (RBS):** an RBS acts as the interface between MSs and the network, by providing radio coverage functions from their antennae.

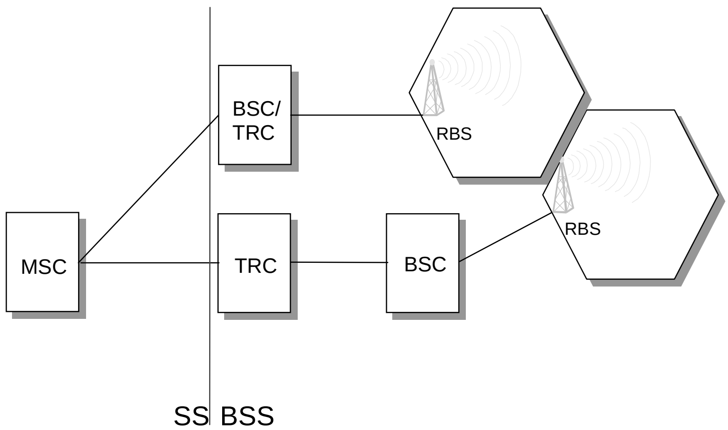


Figure 7-1 BSS in Ericsson's GSM systems

BASE STATION CONTROLLER AND TRANSCODER CONTROLLER

There two main options available for implementing the TRC and BSC in Ericsson's BSS:

- **BSC/TRC:** a combined BSC and TRC on the same AXE. This is suitable for medium and high capacity applications, e.g. urban and suburban area networks. The node can handle up to 1,020 transceivers (TRXs). 15 remote BSCs can be supported from one BSC/TRC.
- **Stand-alone BSC and stand-alone TRC:** the stand-alone BSC (without transcoders) is optimized for low and medium capacity applications and is a complement to the BSC/TRC, especially in rural and suburban areas. It caters for up to 300 TRXs. The stand-alone TRC is located at the MSC/VLR to increase transmission efficiency. A stand-alone TRC can support 16 remote BSCs.

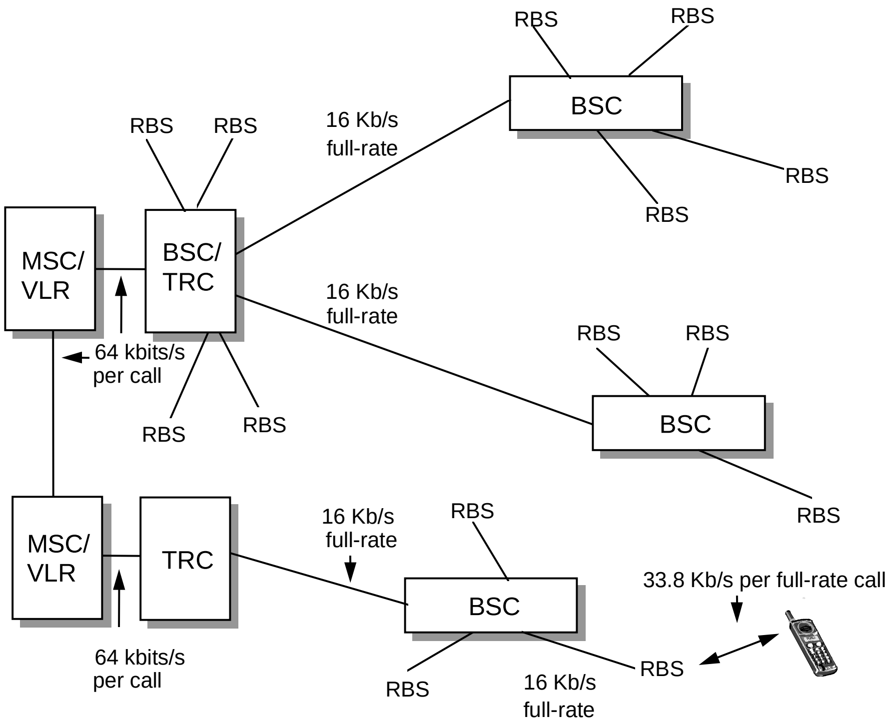


Figure 7-2 TRC utilization and transmission rates in BSS

RADIO BASE STATIONS

Ericsson's Radio Base Station (RBS) 2000 series of base stations implements the GSM-defined BTS. This includes the following RBSs:

- RBS 2101
- RBS 2102
- RBS 2103
- RBS 2202
- RBS 2301
- RBS 2302
- RBS 2302 MAXITE

OTHER ACCESS NETWORK EQUIPMENT

☞ Did you know?

In Sweden, all three of the mobile network operators is working with the national rail company to ensure coverage for travellers. This involves placing an antenna on top of the train and a leaky cable running within the length of the train.

Many mobile networks include additional equipment to provide improved coverage. Examples of such equipment includes:

- **Repeaters:** these are placed in locations throughout the access network to repeat the digital signal from the MS and BTS. This helps to reduce the BER and thus provide better quality calls to subscribers. A typical location for a repeater may be on top of a building

- **Leaky cable:** this is simply a cable carrying the electromagnetic energy which has "holes" in it to leak out this radio signal at regular intervals. This may be suitable in areas which are difficult to cover using traditional base station equipment. For example, a leaky cable could be used to provide coverage within an underground train system

TRANSCODER CONTROLLER (TRC)

TRC FUNCTIONS

The primary functions of a TRC are to perform transcoding and to perform rate adaptation.

Transcoding

As previously explained, the function of converting from the PCM coder information (following A/D conversion) to the GSM speech coder information is called transcoding. This function is present in both the MS and the BSS.

Rate Adaptation

Rate adaptation involves the conversion of information arriving from the MSC/VLR at a rate of 64 kbits/s to a rate of 16 kbits/s for transmission to a BSC (for a full rate call). This 16 kbits/s contains 13 kbits/s of traffic and 3 kbits/s of inband signaling information.

This is an important function. Without rate adaptation the links to BSCs would require four times the data rate capabilities. Such transmission capabilities form an expensive part of the network. By reducing the rate to 16 kbits/s, it is possible to use one quarter of the transmission links and equipment.

In Ericsson’s GSM systems, the TRC contains units which perform transcoding and rate adaptation. These hardware units are called Transcoder and Rate Adaptation Units (TRAUs).

All TRAUs are pooled, meaning that any BSC connected to the TRC can request the use of one of the TRAUs for a particular call.

The TRC also supports discontinuous transmission. If pauses in speech are detected, comfort noise is generated by the TRAU in the direction of the MSC/VLR.

TRC IMPLEMENTATION

> ☞ Did you know?
>
> *In previous versions of Ericsson's GSM systems the TRC did not exist. Its functions were included as part of the BSC. This has been changed to reduce the data rate between the MSC and BSC sites, thus reducing transmission network costs.*

The TRC is implemented on the AXE platform consisting of standard APZ and APT subsystems and the following APT subsystems:

Subsystem	Functions
ROS: Radio Operation and maintenance Subsystem	Transmission network management
RTS: Radio Transmission and transport Subsystem	TRAU Handling

Table 7-1 BSC Subsystems

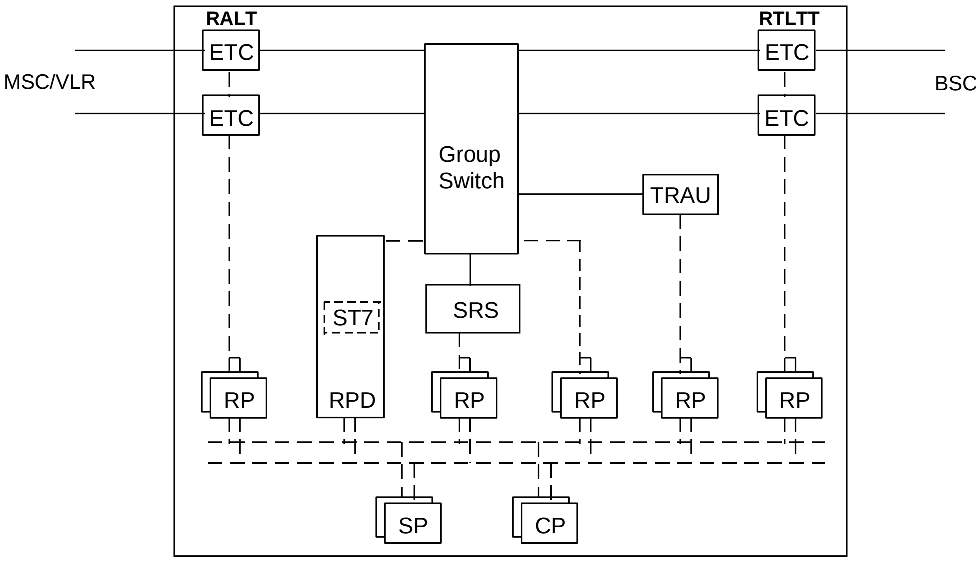


Figure 7-3 TRC hardware configuration

The hardware which is specific to the TRC is:

- Transcoder and Rate Adapter Unit (TRAU)

BASE STATION CONTROLLER (BSC)

BSC FUNCTIONS

☞ Did you know?

During the initial specification of GSM, the radio-related functions were intended to be included in the MSC. However, the increasing complexity of the GSM radio system led to the requirement for more dedicated radio intelligence.

The BSC controls a major part of the radio network. Its most important task is to ensure the highest possible utilization of the radio resources. The main functional areas of the BSC are:

- Radio Network Management
- RBS Management
- TRC Handling
- Transmission Network Management
- Internal BSC Operation and Maintenance
- Handling of MS connections

Radio Network Management

Radio network management includes the following tasks:

- **Administration of radio network data** including:
  - Cell Description Data (e.g. cell identity, BCCH channel number, maximum and minimum output powers in the cell, RBS type, etc.)
  - System information data (e.g. information about whether or not the cell is barred from access, maximum output power allowed in the cell, BCCH channel identities in neighboring cells)
  - Locating data (e.g. cell rank used in HCS and high traffic load situations)
  - Cell load sharing data, i.e. parameters for forcing early handovers from congested cells
- **Traffic and event measurements:** (e.g. number of call attempts, congestion, traffic levels for a cell, traffic levels for an MS, number of handovers, number of dropped connections, etc.).
- **Idle channel measurement:** the RBS collects statistics from the MSs about signal strength and quality. These statistics are then used during the channel allocation process, so that a channel with low interference is allocated for a call.

RBS Management

Ericsson’s RBS implementation is transceiver-orientated, ensuring good redundancy features. This means that as little as possible of the equipment is common to several transceivers.

This philosophy inevitably leads to a master slave relationship between the BSC and the transceivers in the RBS. A logical model of the RBS is built up within the BSC and RBS equipment can be logically defined, connected and disconnected.

The main tasks of RBS management are:

- **RBS configuration:** this involves the allocation of frequencies to channel combinations and power levels for each cell according to available equipment. If equipment becomes faulty causing the loss of important channels, reconfiguration of the remaining equipment is activated, sacrificing less important channels.
- **RBS software handling:** this involves the control of program loads.
- **RBS equipment maintenance:** RBS faults and disturbances are recorded and logged continuously.

TRC Handling

Although TRAUs are located in a TRC, the BSC, as controller of the radio resources of a GSM network, actually co-ordinates the sourcing of a TRAU for a call.

During call set-up, the BSC instructs the TRC to allocate a TRA device to the call. If one is available, the TRC confirms the allocation of a TRA device. The TRA device is considered to be under the control of the BSC for the duration of the call.

Transmission Network Management

The transmission network for a BSC includes the links to and from MSC/VLRs and RBSs. This involves the following tasks:

- **Transmission interface handling:** this provides functions for administration, supervision, test and fault localization of the links to RBSs. The BSC configures, allocates and supervises the 64 kbits/s circuits of the PCM links to the RBS. It also directly controls a remote switch in the RBS which enables efficient utilization of the 64 kbits/s circuits.

Internal BSC Operation and Maintenance

Operation and maintenance tasks can be performed locally in the BSC or remotely from the OSS. Internal BSC operation and maintenance involves the following features:

- **TRH maintenance:** administration, supervision and test of the TRansceiver Handler (TRH) is carried out in the BSC. The TRH consists of both hardware and software. A TRH is located on a Regional Processor for the Group switch (RPG). One RPG thus serves several transceivers. There can be several RPGs in the BSC.

- **Processor load control in the BSC:** this function ensures that during processor overload situations, a large number of calls can still be handled by the BSC. If too many calls are accepted, real time requirements such as call set-up times can not be fulfilled. To prevent this, some calls need to be rejected in situations of high load. Calls already accepted by the system are given full service and are not affected by the overload situation.

Handling of MS Connections

Call Set Up

Call set up involves the following processes:

- **Paging:** the BSC sends paging messages to the RBSs defined within the desired LA. The load situation in the BSC is checked before the paging command is sent to the RBS.
- **Signaling set-up:** during call set-up, the MS connection is transferred to an SDCCH allocated by the BSC. If the MS initiated the connection, the BSC checks its processor load before the request is further processed.
- **Assignment of traffic channel:** after SDCCH assignment, the call set-up procedure continues with the assignment of a TCH by the BSC. As this takes place, the radio channel supervision functions in the BSC are informed that the MS has been ordered to change channels. If all TCHs in the cell are occupied an attempt can be made to utilize a TCH in a neighboring cell.

During a Call

The main BSC functions during a call are:

- **Dynamic power control in MS and RBS:** the BSC calculates adequate MS and BTS output power based on the received measurements of the uplink and downlink. This is sent to the BTS and the MS every 480 ms to maintain good connection quality.
- **Locating:** the locating function continuously evaluates the radio connection to the MS, and, if necessary, suggests a handover to another cell. This suggestion includes a list of handover candidate cells. The decision is based on measurement results from the MS and BTS. The locating process is being executed in the TRC.
- **Handover:** if the locating function proposes that a handover take place, the BSC then decides which cell to handover to and begins the handover process.

  If the cell belongs to another BSC, the MSC/VLR must be involved in the handover. However, in a handover, the MSC/VLR is controlled by the BSC. No decision making is performed in the MSC because it has no real time information about the connection.
- **Frequency Hopping:** two types of hopping are supported by the BSC:
  - Baseband hopping: this involves hopping between frequencies on different transceivers in a cell
  - Synthesizer hopping: this involves hopping from frequency to frequency on the same transceiver in a cell

BSC IMPLEMENTATION

The BSC is implemented on a non-AM-based AXE platform consisting of standard APZ and APT subsystems and the following APT subsystems:

Subsystem	Functions
RCS: Radio Control Subsystem	• Radio network management • Handling of MS connections
ROS: Radio Operation and maintenance Subsystem	• Transmission network management • Internal BSC operation and maintenance
RTS: Radio Transmission and transport Subsystem	• TRC Handling
TAS: Transceiver Administration Subsystem	• RBS Management
LHS: Link Handling Subsystem	• Transmission network management

Table 7-2 BSC Subsystems

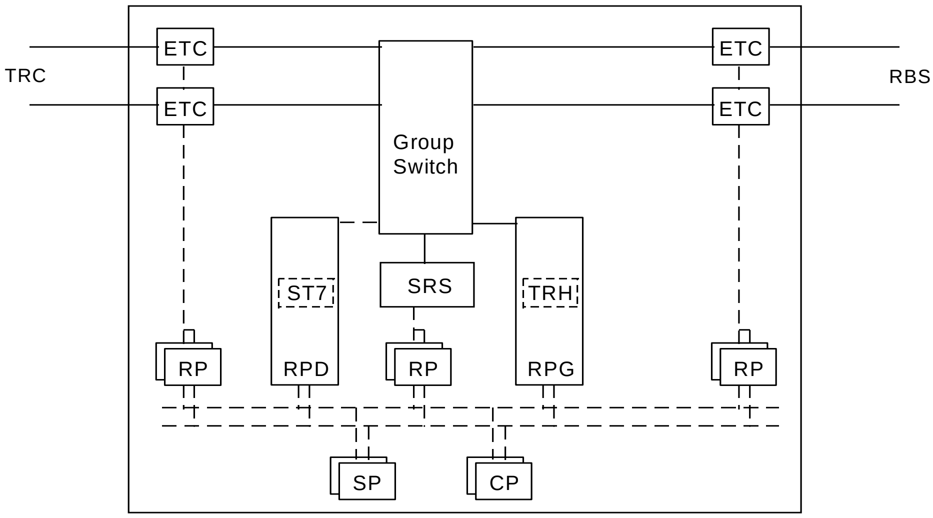


Figure 7-4 BSC hardware configuration

The hardware which is specific to the BSC is:

- Regional Processor for the Group switch (RPG)/TRansceiver Handler (TRH)

BSC/TRC

It is possible to combine the functions of the TRC and BSC in one AXE-based node.

The subsystems in a BSC/TRC are the same as those used in a stand-alone BSC.

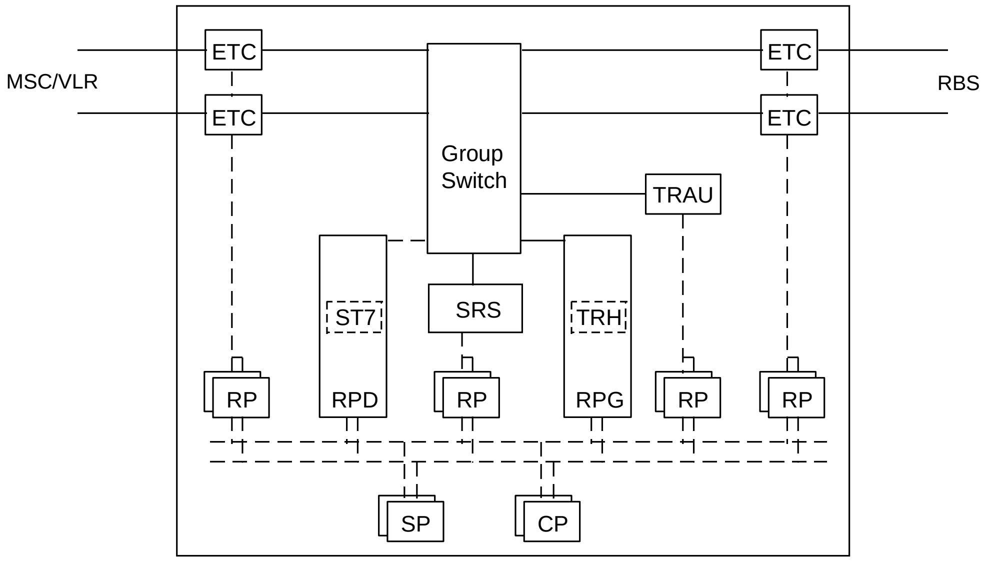


Figure 7-5 BSC/TRC hardware configuration

The hardware which is specific to the BSC/TRC is:

- RPG/TRH
- TRAU

RADIO BASE STATION (RBS)

RBS INTRODUCTION

An RBS includes all radio and transmission interface equipment needed on site to provide radio transmission for one or several cells.

The RBS 2000 family is Ericsson's second generation of RBS offering products with a low total lifetime cost[1]. This is achieved by functions including long Mean Time Between Failure (MTBF) performance and short Mean Time To Repair (MTTR). In addition, this product line is quick and easy to install thus giving the possibility to achieve a rapid network roll out.

RBS 2000 provides products for both indoor and outdoor installations and is available for GSM 900, GSM 1800 and GSM 1900.

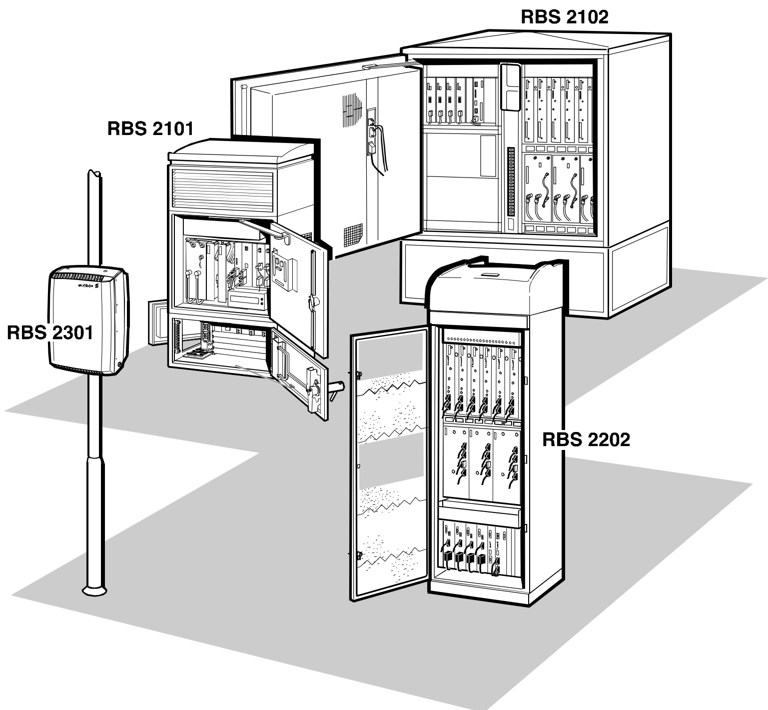


Figure 7-6 Examples of the RBS 2000 series

[1] Ericsson's first generation of RBS for GSM was called the RBS 200 series

RBS FUNCTIONS

RBS functionality can be divided into the following areas:

- Radio resources
- Signal processing
- Signaling link management
- Synchronization
- Local maintenance handling
- Functional supervision and testing

Radio Resources

An RBS's main function is to provide connection with the MSs over the air interface. This includes the following tasks:

- **Configuration and system start:** site configuration involves loading of software from the BSC and setting parameters prior to system startup, including:
  - Transmitter and receiver frequencies
  - Maximum output power
  - Base Station Identity Code (BSIC)
- **Radio transmission:** to transmit several frequencies using the same antenna, a combiner or a set of combiners are needed. Transmission power is controlled from the BSC.
- **Radio reception:** in addition to reception of traffic on the physical channels, a primary RBS function the detection of channel requests from MSs (e.g. when a call is being made).

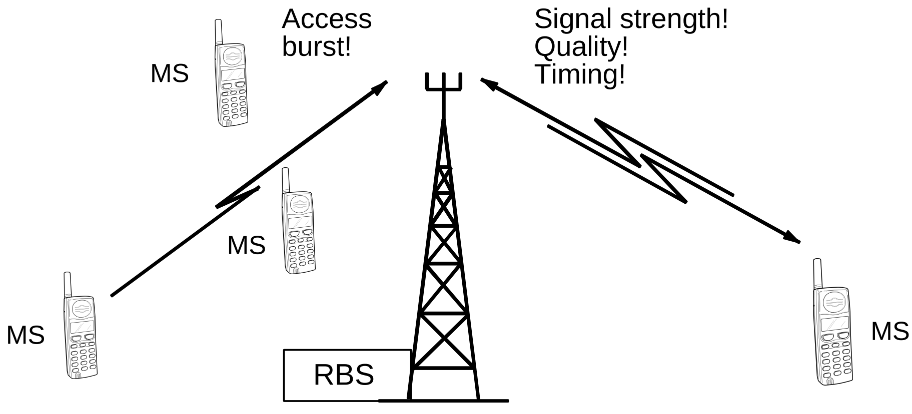


Figure 7-7 The RBS listening for channel requests and measuring the uplink on an established connection

Signal Processing

An RBS is responsible for the processing of signals before transmission and after reception. This includes:

- Ciphering using the ciphering key
- Channel coding and interleaving
- Adaptive equalization
- Realization of diversity
- Demodulation

Signaling Link Management

An RBS manages the signaling link between the BSC and MS, applying the appropriate protocols to the information being sent.

Synchronization

Timing information is extracted from the PCM-links from the BSC and is sent to a timing module within the RBS. This enables the RBS to synchronize with the correct frequency reference and TDMA frame number.

Local Maintenance Handling

An RBS enables operation and maintenance functions to be carried out locally at the RBS site, without BSC connection. In this way, field technicians can maintain RBS equipment and software on site.

Functional Supervision and Testing

Supervision and testing of RBS functions is supported, using either built-in tests during normal operation or tests executed by command.

RBS 2000 IMPLEMENTATION

All types of RBS within the RBS 2000 series have the following characteristics:

- Support for user flexibility by providing modular hardware and software designs.
- Transceiver oriented design, which stresses using as little common equipment as possible ensuring dependable performance.
- Design and use are aimed at keeping system life cycle costs low.

The RBS 2000 series is based on standardized hardware units called Replaceable Units (RU). The major RUs are:

- Distribution switch Unit (DXU)
- TRansceiver Unit (TRU)
- Combining and Distribution Unit (CDU)
- Power Supply Unit (PSU)
- Energy Control Unit (ECU)

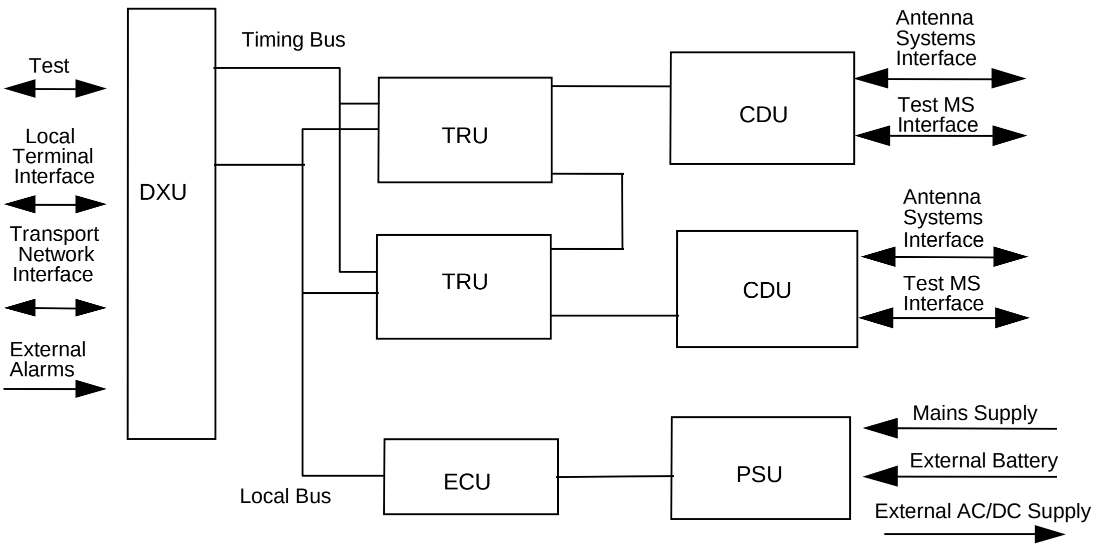


Figure 7-8 Replaceable units in RBS 2000

Distribution switch Unit (DXU)

The DXU performs the following tasks:

- Provides an interface to the BSC
- Manages the link resources and connects the traffic time slots from the BSC link to the TRUs
- Controls signaling to the BSC and performs concentration
- Extracts synchronization information from the link and generates a timing reference for the RBS

In addition, the DXU has a database which stores information about installed hardware.

TRansceiver Unit (TRU)

One TRU includes all functionality needed for handling one radio carrier (i.e. the 8 time slots in one TDMA frame). It is responsible for radio transmitting, radio receiving, power amplification and signal processing.

The TRU contains a radio frequency test loop between the transmitter and the receiver. This facilitates TRU testing by generating signals and looping them back.

TRUs are connected by a bus to enable frequency hopping. Some RBS products can contain up to 6 TRUs.

Combining and Distribution Unit (CDU)

The CDU is the interface between the TRUs and the 2-way antenna system. The task of the CDU is to combine signals to be transmitted from various transceivers and to distribute received signals to the receivers. All signals are filtered before transmission and after reception using bandpass filters.

A range of CDU types have been developed to support different configurations within the RBS 2000 family. They consist of different types of CDUs, including:

- Without combiners
- With hybrid combiners
- With filter combiners to support large configurations

CDUs with duplex filters make it possible to transmit and receive using the same antenna.

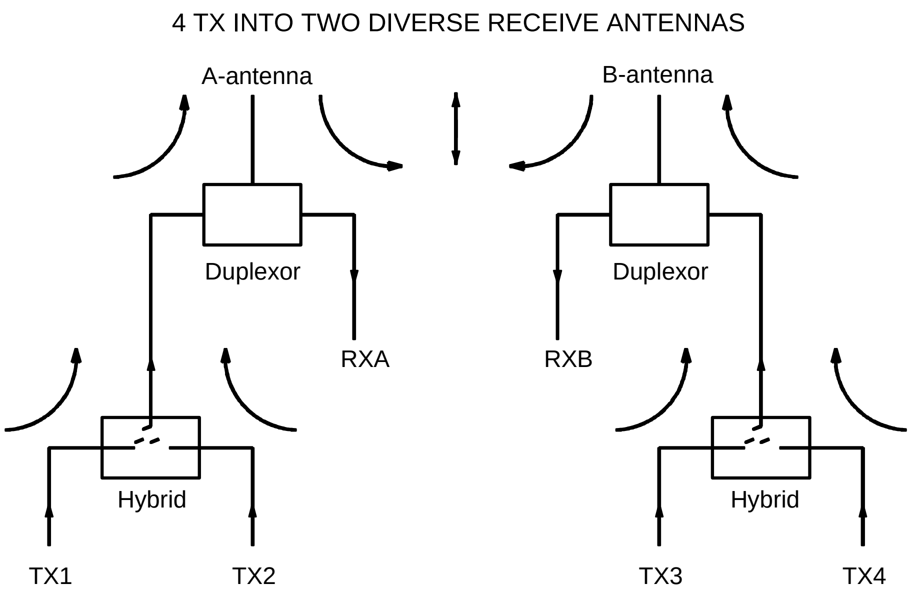


Figure 7-9 Example of a CDU type C

Power Supply Unit (PSU)

The PSU rectifies the power supply voltage to the +24 VDC necessary for RBS operation.

Energy Control Unit (ECU)

The ECU controls and supervises the power equipment and regulates the environmental conditions inside the cabinet.

The RBS 2000 is pre-assembled at the factory including program load and parameter settings making a quick startup possible.

Assembly can also be carried out on site. The RBS software is downloaded from the BSC and stored in a non-volatile (flash memory) program store. In a working RBS, this flash memory keeps cell down time low because traffic does not need to be interrupted. Power failure recovery can also be done quickly.

RBS 2000 IN A NETWORK

The Transmisison Drop and Insert (TDI) function makes it possible to connect RBSs together. This is an important cost saving feature of Ericsson's RBSs, as an RBS need not be connected to the BSC directly via a dedicated link. Instead it may be more economic to connect that RBS to another RBS in the region, thus saving on expensive transmission costs. The following network topologies are supported:

- Star: this is the traditional architecture, where each RBS is connected directly to a BSC
- Cascade: a cascade architecture includes RBSs connected to each other without a loop, thus using transmission resources efficiently
- Loop: this architecture includes RBSs connected to each other with a loop, ensuring that even if one link fails, another path is available

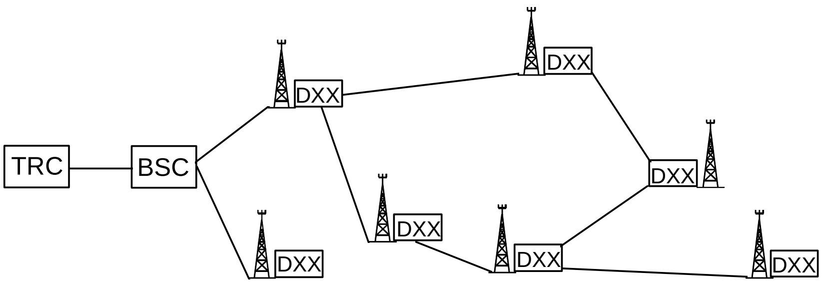


Figure 7-10 Ericsson's RBS 2000 Network Configurations

RBS 2000 SERIES DESCRIPTIONS

RBS Type	Location	Max. TRUs	Cells	Coverage Type	Dimensions (h-w-d) (mm)	Temperature Range (°C)
RBS 2101	Outdoor	2	1	Macro	1285-705-450	-33...+55
RBS 2102	Outdoor	6	1-3	Macro	1605-1300-760	-33...+45
RBS 2103	Outdoor (GSM 900 only)	6	1-3	Macro	2300-900-795	-33...+35
RBS 2202	Indoor	6	1-3	Macro	1775-600-400	+5...+40
RBS 2301	Indoor/Outdoor	2	1	Micro	535-408-160	-33...+45
RBS 2302	Indoor/Outdoor	2	1	Micro	535-408-170	-33...+45
Maxite	Indoor/Outdoor	2	1	Macro	535-408-160	-33...+45

Table 7-3 RBS 2000 Series

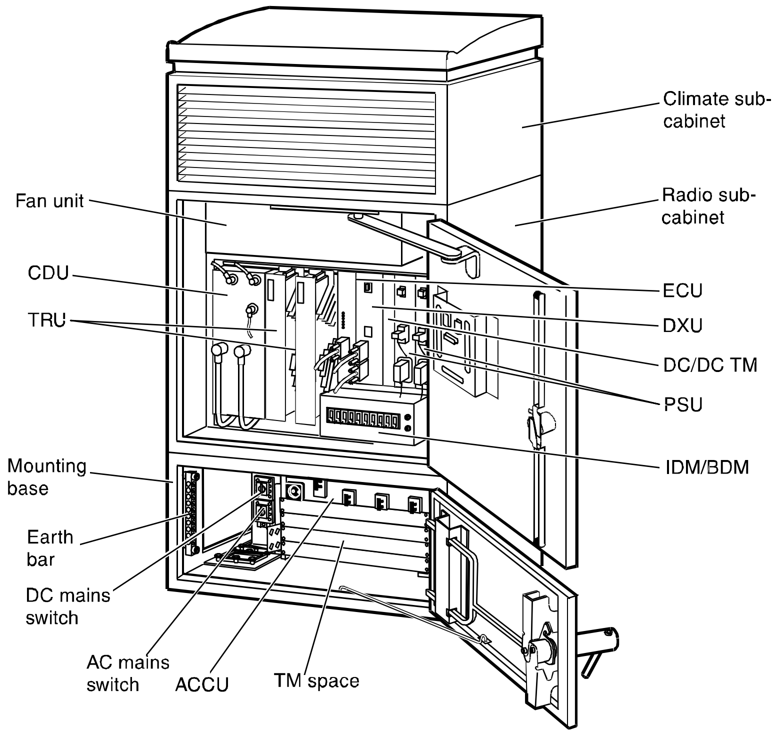


Figure 7-11 RBS 2101

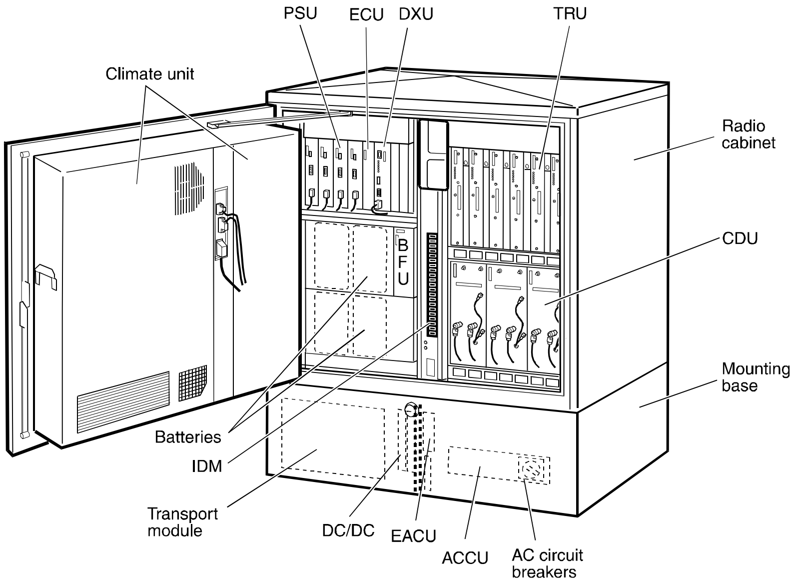


Figure 7-12 RBS 2102

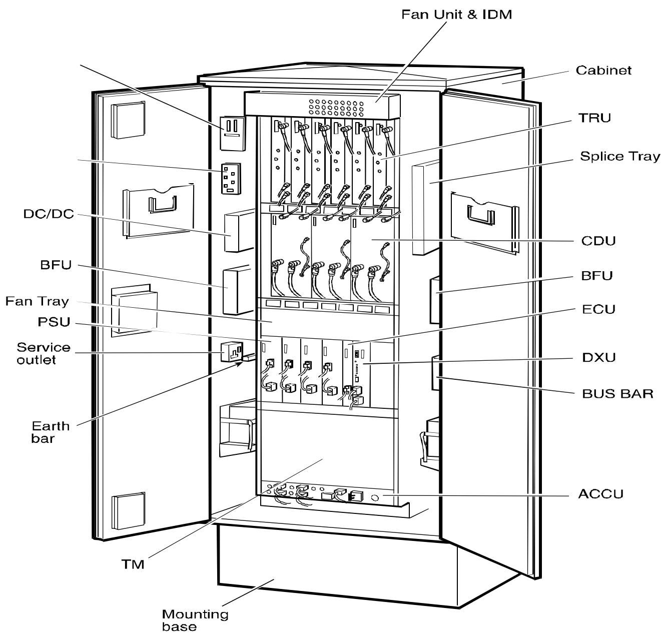


Figure 7-13 RBS 2103

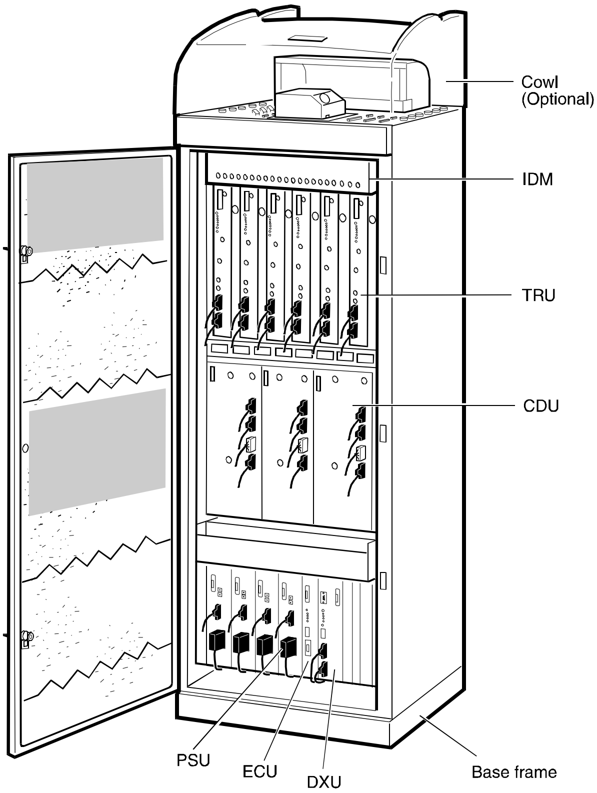


Figure 7-14 RBS 2202

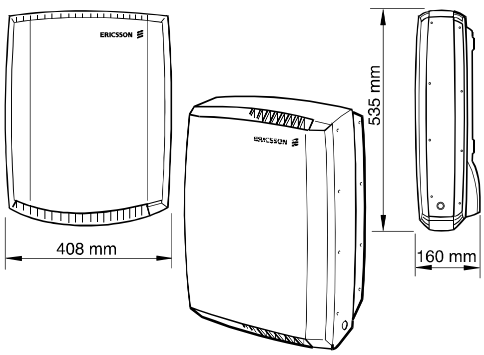


Figure 7-15 RBS 2301. RBS 2302 is almost identical

Mobile Stations

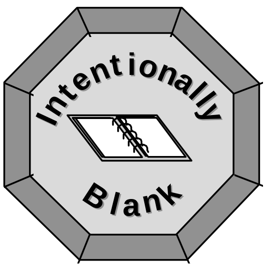
Chapter 8

This chapter is designed to provide the student with an overview of the mobile station. It addresses mobile station components, their functions, features, and required specifications.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the functions of a mobile station
- Describe the reason for separated subscription and telephony equipment
- Describe the different mobile station classes
- Describe the objectives of the Subscriber Identity Module
- Describe the mobile station features
- Identify the mobile stations provided by Ericsson for GSM systems


Intentionally
Blank

8 Mobile Stations

Table of Contents

Topic	Page

INTRODUCTION

☞ Did you know?

In addition to being the largest supplier of mobile network infrastructure, Ericsson is one of the largest suppliers of mobile phones.

The MS is the equipment used to access the network. The MS consists of two independent parts:

- Subscriber Identity Module (SIM) card
- Mobile Equipment (ME)

A SIM card is an electronic smart card which stores information about the subscription. The ME is the actual telephone terminal.

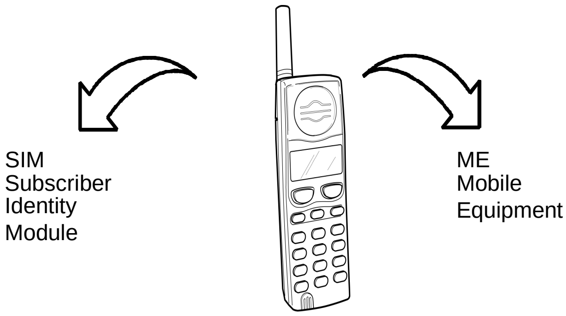


Figure 8-1 Mobile station

MOBILE STATION FUNCTIONS

TRANSMISSION AND RECEIPT

As described previously, the transmission and receipt process in an MS includes the steps shown in Figure 8-2.

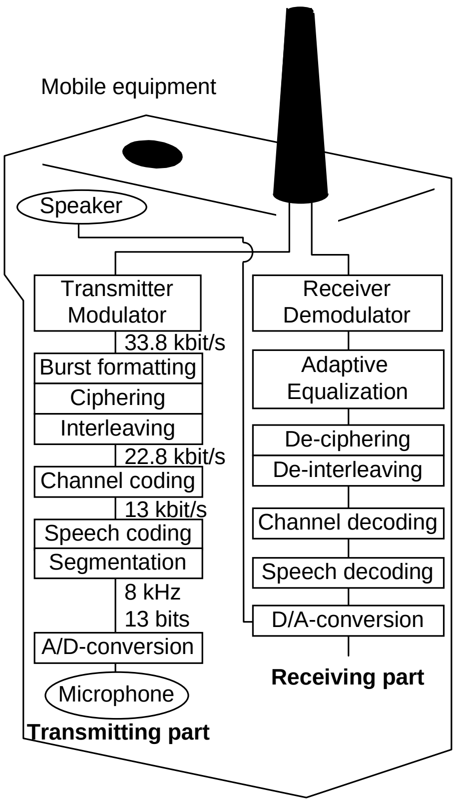


Figure 8-2 Transmission and receipt in an MS

MEASUREMENTS MADE BY THE MOBILE STATION

The measurements made by an MS are used in making decisions about signal strength and handovers. Measurements are taken in both idle and active mode.

Idle Mode

Cell selection is made at “power on” of the mobile:

1. The mobile scans all radio frequency channels in the GSM system and calculates average levels for each. The mobile tunes to the strongest carrier and determines if it is a BCCH carrier. If so, the mobile reads the BCCH information to find out if the cell is locked (e.g. chosen PLMN, barred cell, etc.). Otherwise the mobile tunes to the second strongest carrier, and so on until a valid BCCH carrier is found.
2. The mobile may optionally include a BCCH carrier memory of valid BCCH carriers in the home PLMN. In this case it only needs to search these carriers. If this ends unsuccessfully, the mobile performs as in 1.
3. If no valid BCCH carrier is found, but a BCCH carrier belonging to another GSM network operator is found, the mobile will display the message “Emergency calls only”. Every emergency call is permitted onto a GSM network, even if the subscriber has not subscribed to the network the MS chooses.

   Alternatively, if no valid BCCH carrier is found, and no other network can be found, the MS will display the message “No network”. In this case no calls (including emergency calls) can be made.

Once it has tuned to a valid BCCH carrier, the mobile is informed which BCCH carriers it is to monitor for cell re–selection purposes. These are the BCCH carriers in neighboring cells. A list of the strongest carriers is updated regularly by the MS as a result of the measurements.

Active Mode

During a call, the mobile continuously reports (via SACCH) to the system how strong the received signal strength is from BTSs. Both signal strength and quality are measured on the MS's "own" BTS. These measurements are used by the BSC to make fast decisions about target cells when a handover is required.

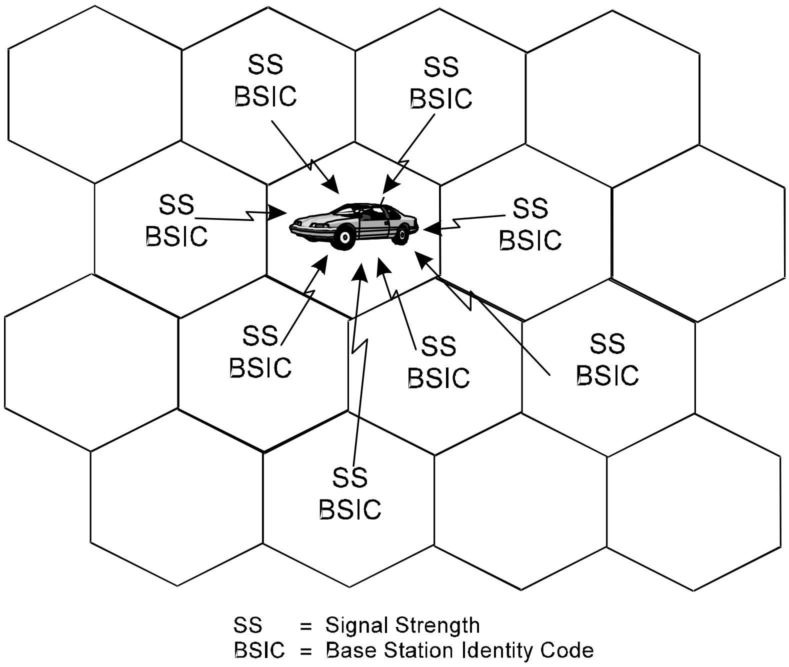


Figure 8-3 Monitoring BCCH carriers

Measurements on neighboring cells during a call takes place when the mobile is idle, i.e. when it is not transmitting or receiving.

POWER SAVING FUNCTIONS

Discontinuous Transmission (DTX)

Discontinuous Transmission (DTX) is a method of saving battery power for the MS. An MS with the DTX function detects the input "voice" and turns the transmitter ON only while "voice" is present. When there is no voice input, the transmitter is turned OFF.

When the MS detects that speech is absent during the conversation, it sends out a signal called “Post” to report a transmission output state OFF for the TCH. Conversely, when the MS detects that speech is present again, it sends out a signal called “Pre” to report the transmission output state ON for the TCH.

The Post signal incorporates background noise information from the MS, which enables the BTS to generate background noise. This ensures that the other subscriber on the call hears something and does not think that the mobile subscriber has ended the call.

The MS transmits the Post signal periodically during a speech pause, to enable the BTS to update the background noise.

Discontinuous Reception (DRX)

Another method used to conserve power at the MS is Discontinuous Reception (DRX). The paging channel, used by the BTS to signal an incoming call, is structured into sub-channels. Each MS is assigned one of these sub-channels and needs to listen only to its own sub-channel. In the time between successive paging sub-channels, the mobile can go into “sleep mode”, when almost no power is used.

TYPES OF MOBILE STATION

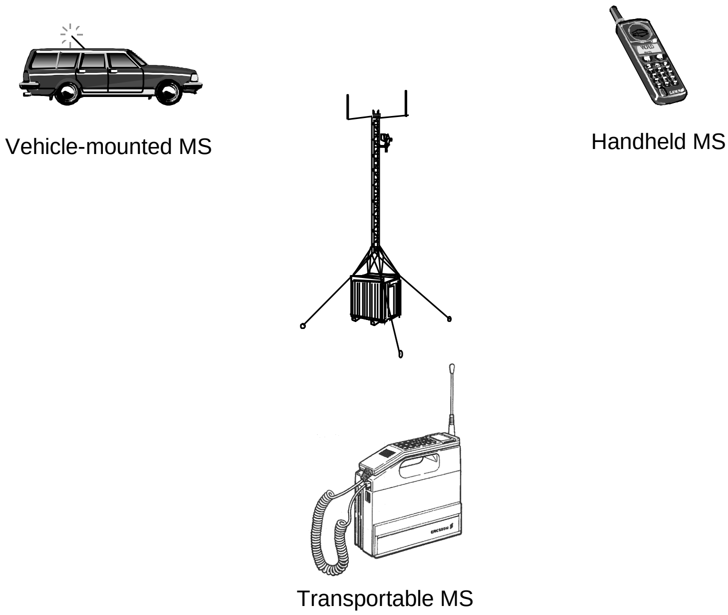


Figure 8-4 Types of mobile station

VEHICLE-MOUNTED MOBILE STATIONS

Vehicle-mounted MSs are physically mounted to the dashboard of a vehicle. The antenna unit is separately mounted on the outside of the vehicle. These MSs are more powerful than hand-held or transportable, therefore offering a greater range and signal quality.

TRANSPORTABLE MOBILE STATIONS

In a transportable MS the antenna is not attached to the hand-set. These MSs support all power levels required in the system and can either be vehicle-mounted or hand-carried. They usually consist of a portable plug-in unit and a vehicle-mounted adapter.

HAND-HELD MOBILE STATIONS

The hand-held MS is hand-carried, with the antenna attached to the hand-set. Hand-held MSs are portable and are usually pocket-sized.

Hand-held MSs can also be vehicle-mounted by plugging the MS into an interface inside the vehicle. The vehicle provides battery charging facilities and has an externally mounted antenna connection.

Figure 8-5 Ericsson hand-held mobile equipment

MOBILE STATION CLASSES

Different types of MSs have different output power capabilities and therefore different ranges. Hand-held phones generally have a lower output power and consequently a shorter range than a vehicle-mounted phone. The output power varies according to the distance from the BTS. The further away from the source, the weaker the signal will be.

According to GSM specifications, MSs are categorized into five classes according to MS output power. These classes are listed in the following table:

Class	Type	Maximum output power		
		GSM 900	GSM 1800	GSM 1900
1	Vehicle & transportable	Undefined	1 Watt	1 Watt
2	Vehicle & transportable	8 Watts	0.25 Watts	0.25 Watts
3	Hand-held	5 Watts	Undefined	Undefined
4	Hand-held	2 Watts	Undefined	Undefined
5	Hand-held	0.8 Watts	Undefined	Undefined

Table 8-1 MS Power Classes

The location of the MS also affects the received power of the transmitted signal. An MS located at the top of a high building has a greater range than one that is located at or below ground level.

ERICSSON MOBILE PHONES

Ericsson offers a wide range of mobile phones for major cellular standards. For GSM alone, Ericsson has over twenty models.

GSM 900	GSM 1800	GSM 1900
GF 788	PF 768	CF 788
GF 768	PH 388	CH 388
GH 688	PH 337	CF 388
GA 628	S 868	CA 318
GS 18	SH 888	CH 337
GH 398		CF 337
GH 388		CF 688
GF 388		
GA 318		
GO 118		
GH 337		
GF 337		
GH 218		
TH 337		
S 868		
SH 888		

Table 8-2 Ericsson's range of GSM phones

☞ Did you know?

In the film "Tomorrow Never Dies", James Bond used various Ericsson phones, including a specially developed concept phone: JB 988

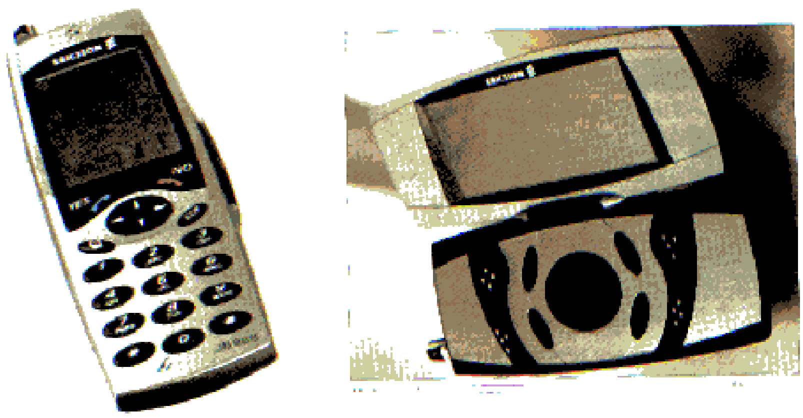


Figure 8-6 James Bond's mobile phone, designed by Ericsson

EXAMPLE OF ERICSSON'S GSM PHONES

GF 788

The GF 788 is Ericsson's smallest and one of its most sophisticated mobile phones. The phone is palm-sized and flips open when in use. Its dimensions are 105x49x24 mm and it weighs only 135 g. The battery provides 180 minutes of talktime and 60 hours of standby time. It has a range of system menus which can be customized for personal use. It has an internal phone book, clock, alarm and has data/fax capability.

Figure 8-7 Ericsson's GF 788

SUBSCRIBER IDENTITY MODULE (SIM)

A key feature of the GSM standard is the Subscriber Identity Module (SIM) card. A SIM card contains information about the subscriber and must be plugged into the ME to enable the subscriber to use the network. With the exception of emergency calls, MSs can only be operated if a valid SIM is present.

The SIM stores three types of subscriber related information:

- Fixed data stored before the subscription is sold: e.g. IMSI, authentication key and security algorithms
- Temporary network data: e.g. the location area of the subscriber and forbidden PLMNs
- Service data: e.g. language preference, advice of charge

GSM phase 1 SIMs contain all necessary network control information, while phase 2 SIMs include a large number of extra features such as a language identifier and a preferred language option.

TYPES OF SIM CARD

Two physical types of SIMs are specified. These are the ”ID-1 SIM” and the ”Plug-in SIM”. The logical and electrical interfaces are identical for both types of SIM.

ID-1 SIM

The format and layout of the ID-1 SIM comply with ISO standards for Integrated Circuit (IC) cards (i.e. credit card size).

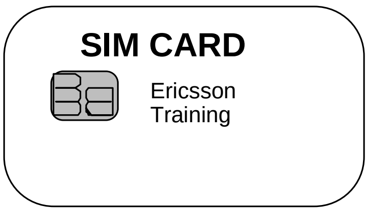


Figure 8-8 ID-1 SIM card

Plug-in SIM

The plug-in SIM is smaller than the ID-1 SIM. It is intended for semi-permanent installation in the ME.

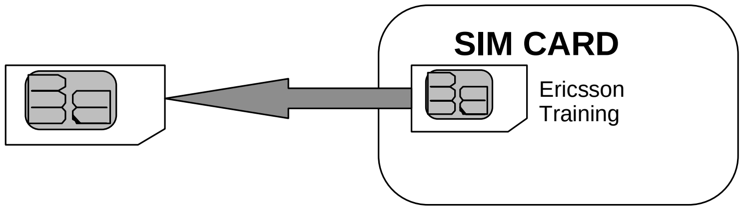


Figure 8-9 Plug-in SIM card

SECURITY FEATURES

GSM defines a number of security features to be supported by SIMs. These are:

- Authentication algorithm, A3
- Subscriber authentication key, Ki
- Ciphering key generation algorithm, A8
- Ciphering key, Kc
- Control of access to data stored and functions performed in SIM

SIM INFORMATION STORAGE REQUIREMENTS

A SIM contains information for GSM network operations. This information can be related to the mobile subscriber, GSM services or PLMN.

The data storage requirements of a SIM are divided into two categories: mandatory and optional.

Mandatory storage

A SIM must provide storage capability for the following:

- Administrative information: describes the SIM’s mode of operation, e.g. normal or type approval
- IC card identification: unique information identifying the SIM and the card issuer
- SIM service table: indicates which optional services are provided by the SIM (e.g. last numbers dialled, call length indication, PLMN selection, etc.)
- International Mobile Subscriber Identity (IMSI): an identity-number used by the network to identify the subscription
- Location information: comprising LAI, current value of periodic location updating timer and location update status
- Ciphering key (Kc) and ciphering key sequence number
- List of carrier frequencies to be used for cell selection
- Forbidden PLMNs
- Language preference: subscriber's preferred languages

The location information, Kc and the Kc sequence number may be updated at each call termination.

In addition the SIM must be able to manage and provide storage in accordance with the security requirements:

- Personal Identification Number (PIN)
- PIN enabled / disabled indicator
- PIN error counter
- PIN Unlock Key (PUK)
- PUK error counter
- Subscriber authentication key (Ki)

SUBSCRIBER DATA STORED IN THE MOBILE EQUIPMENT

All subscriber related information transferred to the ME during operation must be deleted after the removal of the SIM or deactivation of the MS. Examples of such information are the PIN and the PUK codes.

PIN MANAGEMENT

A SIM is required to have a PIN function even if it is deactivated by a user. The PIN consists of 4 to 8 digits.

An initial PIN is loaded by the network operator at subscription time. Afterwards the PIN, including the length, can be changed by the user. In addition, the user can decide whether to use the PIN function or not by activating an appropriate SIM-ME function called the PIN disabling function. The PIN is disabled until the user changes the status of the function. This PIN disabling function can be blocked at subscription time by a person authorized to do so.

If an incorrect PIN is entered, the user is informed. After three consecutive incorrect entries the SIM is blocked, even if between attempts the SIM has been removed or the MS has been switched off.

BLOCKING/UNBLOCKING OF SIM

When a SIM is blocked GSM network operations are forbidden. To unblock the SIM, the user must enter the PIN Unblocking Key, PUK.

The PUK is an 8 digit numerical code. If the PUK is entered incorrectly the user is informed. The user can make 10 attempts to enter the PUK before the system blocks entry, in which case the subscriber must contact their network operator.

MOBILE STATION FEATURES

An MS feature is defined as a piece of equipment or a function which relates directly to the operation of the MS.

TYPES OF MS FEATURES

MS features are defined as mandatory or optional. Mandatory features must be implemented as long as they pertain to the MS type. The choice of implementing optional features is left up to the manufacturers. Manufacturers are responsible for ensuring that the MS features neither conflict with the air interface nor interfere with the network, any other MS, or the MS itself.

Standardization of a minimum set of features is desirable to make a simple and uniform set of MS features independent of the MS manufacturer and type. This minimum set includes all the mandatory features.

There are three categories of MS features:

- **Basic:** Basic MS features are directly related to the operation of basic telecommunication services. Each feature is classed as being mandatory or optional.

- **Supplementary:** A supplementary MS feature is directly related to the operation of the supplementary service (e.g. display of calling line number). All supplementary MS features are optional.

- **Additional:** Additional features are neither basic nor supplementary. All additional MS features are optional.

BASIC MOBILE STATION FEATURES

Mandatory

Display of called number: This feature enables the caller to check that the selected number is correct before call set-up.

Dual Tone Multi Frequency function (DTMF): The MS must be able to send DTMF tones.

Indication of call progress signals: Indications are given such as tones, recorded messages or a visual display based on signaling information returned from the PLMN. On data calls, this information may be signaled to the Data Terminating Equipment (DTE).

Country/PLMN indication: The country/PLMN indicator shows in which GSM/PLMN the MS is currently registered. This indicator is necessary so that the user knows when roaming is taking place and that the choice of PLMN is correct. Both the country and PLMN are indicated. When more than one GSM/PLMN is available in a given area this information is indicated.

Country/PLMN selection: If more than one GSM/PLMN is available, the user must have the ability to select their preferred choice.

Service indicator: The user is informed that there is adequate signal strength (as far as can be judged from the received signal) to allow a call to be made and that the MS has successfully registered on the selected PLMN. This can be combined with the Country/PLMN Selection.

Subscription identity management: The IMSI is part of the SIM card and is physically secured and standardized in the GSM system. If the user can remove the SIM, its removal detaches the MS from the network causing a call in progress to be terminated, and preventing the initiation of further calls (except emergency calls).

International Mobile station Equipment Identity (IMEI): Each MS must have a unique identity and must transmit this if requested by the PLMN. The IMEI is incorporated into a module which is built into the MS and is physically secured. The implementation of each individual module is to be carried out by the manufacturer.

Support of A5/1 and A5/2: Provisions are made for support of up to seven algorithms as well as the support of ‘no encryption’. It is mandatory for A5/1 and A5/2 and non encrypted mode to be implemented, but other algorithms are optional.

Short message indication and acknowledgment: This feature allows delivery of short messages to a MS from a service center. Such messages are submitted to the service center by a telecommunications network user who can also request information on the message status from the service center. The service center then transmits the message to the active MS user.

The MS must therefore provide an indication to the user that a message has been received from the service center and must also send an acknowledgment signal to the PLMN, to show that this indication has been activated. The PLMN then returns this acknowledgment to the service center.

Short message overflow indication: An MS user using the short message service will be informed when an incoming message cannot be received due to insufficient memory.

Emergency call capabilities: It must be possible to make an emergency call even without a valid SIM.

Optional

On/Off switch: The MS can be equipped with the means of switching its power supply on and off. Switch-off is generally “soft”, so that the MS completes housekeeping functions, such as deregistration, before actually switching off.

Keypad: A physical means of entering numbers, generally in accordance with the layout below:

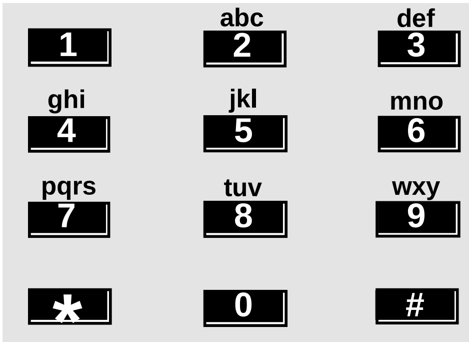


Figure 8-10 Keypad

DTE/DCE interface: This is a standard connector for attaching Data Terminating Equipment (DTE)/Data Communication Equipment (DCE) to an MS and is used with data services.

ISDN ’S’ terminal interface: A standard connector for attaching equipment to ISDN.

International access function (‘+’ key): This enables a direct, standard method of gaining international access. For this purpose, the MS may have a key whose primary or secondary function is marked “+”. This has the effect of generating the International Access Code (IAC) in the network. This is useful because the IAC varies from country to country and may be unknown by a subscriber who is roaming internationally (e.g. the IAC in Sweden is 009, while it is 00 in Ireland).

Short Message Service Cell Broadcast (SMSCB) screening: This feature enables the user of the MS to receive only those broadcast messages that are of interest to the user and in this way save on consumption of battery power. This may be useful in the future to ignore advertisements sent as short messages.

SUPPLEMENTARY MOBILE STATION FEATURES

Charge indication: This feature enables the display of charging information provided by the PLMN on a per call basis.

Control of Supplementary Services: It is mandatory that Supplementary Services can be controlled from the MS.

ADDITIONAL MOBILE STATION FEATURES

Abbreviated dialing: The feature stores a full directory number or part of a directory number in the MS with the abbreviated address. After retrieval, the directory number may appear on the display. An incomplete directory number must be supplemented by means of the keypad function or a second stored number. The full directory number is then transmitted on the radio path.

Fixed number dialing: Using this feature in conjunction with an electronic lock makes it possible to place a bar on calling any numbers other than those pre-programmed into the MS. There are two sub-categories to this service:

- All calls are made to only one predetermined number.
- Calls can be made to several predetermined numbers. The required number is selected by means of an abbreviated address code.

Sub-addresses may be added to the predetermined number.

In both cases, the actual directory number is transmitted on the radio path.

Barring of outgoing calls: This feature allows outgoing calls to be blocked with the exception of emergency calls. The barring condition may be activated/deactivated by using a key word.

The barring may be selective, that is, applied to individual services, individual call types (e.g. long distance, international calls) or supplementary services. No network signaling is involved.

DTMF control digits separator: This enables subscribers to enter DTMF digits with a telephone number. When the called party answers, the ME automatically sends the DTMF digits to the network after a delay of three seconds. This may be useful for accessing a voice mailbox, when the subscriber knows the actions which they wish to perform. For example, the sequence

087 5551234#31 may dial the mailbox (087 5551234) access menu 3 and delete message 1.

Call charge units meter: The MS may incorporate a call charge units indicator. This call charge indicator gives information about the actual call charge units consumed during the last conversation or information about accumulated call charge units for each PLMN.

Selection of directory number in short messages: The short message (point-to-point mobile-terminated or mobile-originated, or cell broadcast) can be used to convey a directory number which the receiver wishes to call. This can be indicated by enclosing the directory number in a pair of inverted commas (“ “).

If the displayed message contains these characters enclosing a directory number then a call can be set up. The message can contain more than one directory number, in which case the receiver selects the desired one. This service is useful for giving someone a telephone number via SMS.

Last numbers dialed (LND): The MS can store the last ‘N’ numbers dialed in the SIM and/or the ME. ‘N’ can take the value up to 10 in the SIM but there is a greater number storage capacity in the ME.

FIXED CELLULAR APPLICATION (FCA)

INTRODUCTION

Over the last few years the potential market for building fixed telephony systems using cellular access technology has grown rapidly. Using wireless technologies instead of traditional copper wire offers many benefits to an operator, including:

- **Cost:** Investment in the local loop (the final connection from the local exchange to the subscriber's premises) represents a large percentage of an operator's costs. Maintenance of the access network is costly and time-consuming. However, Radio in the Local Loop (RLL) systems can be installed and maintained with less expense than wire-based systems.
- **Time:** Wireless systems can be rapidly deployed in far less time than is required to install the underground or overground cables required for wire-based systems.
- **Flexibility:** Wireless systems are highly flexible and can be easily adapted to different situations.

To meet the needs of the growing fixed-cellular telephony market, Ericsson provides Fixed Cellular Application (FCA). FCA provides a fixed telephony network using standard cellular systems. FCA is based on GSM and offers a range of functions that support service and price differentiation for the end user.

SYSTEM ASPECTS

FCA uses, as much as possible, existing technology and services to create new applications.

In a fixed cellular application the demand for indoor coverage is crucial. To gain indoor coverage everywhere in a macro cell network would require a very high signal strength margin, resulting in a very expensive network. A possible solution for indoor signal gain is to use repeaters which are devices for boosting signals. This is suitable for situations where indoor coverage is required in a certain building and capacity demands are not too high.

Another solution is to use outdoor (or window-mounted) antennae for indoor terminals. The length of the antenna cable will, however, be limited to a maximum of a few meters. It must also be remembered that by applying these solutions, the subscribers will use the macro cell frequencies and thereby steal capacity from outdoor users.

A more advanced technique is to apply specific indoor micro or pico cells. The problem will then occur that frequencies used in these cells cannot be re-used in adjacent macro cells or in nearby buildings. Consequently, many channels are needed.

The mobility of fixed cellular subscribers is low. In some cases it may even be a requirement that there will be no mobility at all in the network. By applying local or regional subscriptions, or using a parameter-setting to block handovers, the mobility in the network can be restricted.

FIXED CELLULAR TERMINALS (FCT)

The subscriber equipment is called a Fixed Cellular Terminal (FCT). There are two main types depending on end-user requirements:

- A terminal with the functionality of an ordinary MS, but built into housing more adapted to the fixed telephone environment.
- A terminal based on MS radio parts integrated to a line-interface simulating a PSTN connection to which ordinary DTMF or dial pulse telephones can be attached (integrated adapters for fax and data can be added optionally).

All models of FCTs are applicable for Ericsson digital systems. The FCTs look the same regardless of whether they will be used within a GSM 900, GSM 1800 or GSM 1900-system. The only hardware difference is the frequency band used.

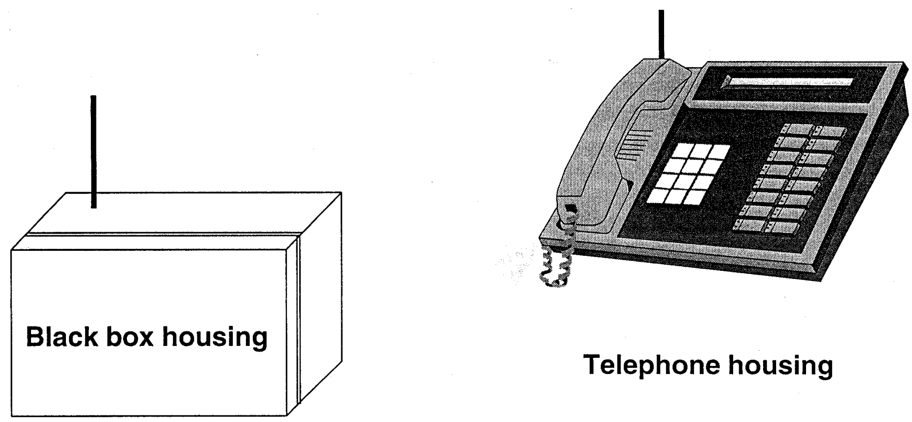


Figure 8-11 Fixed cellular terminals

Ericsson has defined and developed three different FCT models:

- FCT Residential
- FCT Basic
- FCT Office

Residential

A residential appears as a “black-box” without a display or a keypad and is wall-mounted. This terminal is able to handle voice, fax and data calls. However, fax and data communication require an external adaptor.

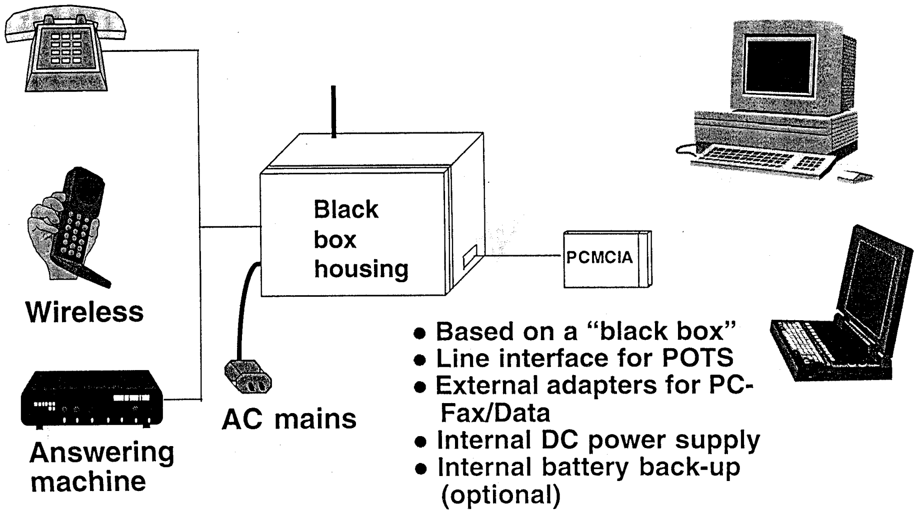


Figure 8-12 Residential model

Basic

The basic terminal looks like a wireline telephone with display and keypad and can be either desk-top or wall-mounted. It can handle voice calls and Short Message Service (SMS).

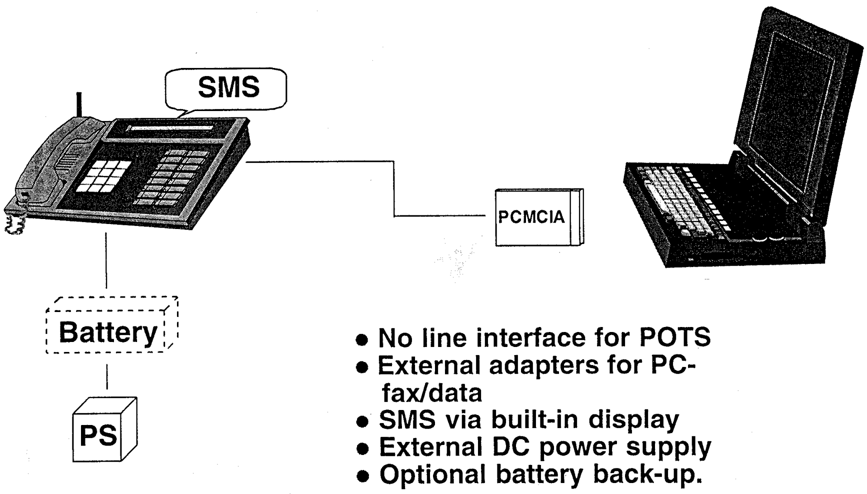


Figure 8-13 Basic model

Office

The office terminal also looks like a wireline telephone with a display and a keypad and can be either desk-top or wall-mounted. It is able to handle voice, fax and data calls and SMS. Fax and data capability have been integrated and can be offered from this terminal.

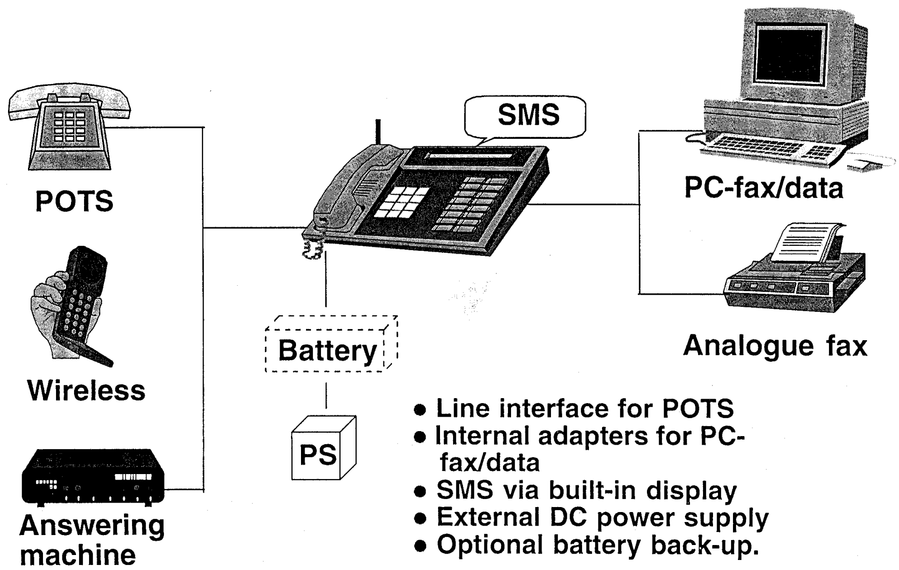


Figure 8-14 Office model

Intentionally Blank

Traffic Cases

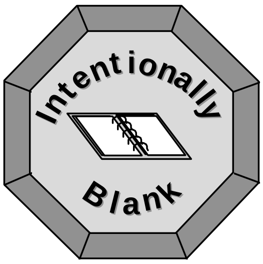
Chapter 9

This chapter is designed to provide the student with an overview of traffic cases. It describes the interaction between network elements in different traffic cases.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the structure and use of GSM identity numbers
- Describe the interaction of network nodes in various traffic cases which attach the mobile station to the network
- Describe the interaction of network nodes in various traffic cases when the mobile station is roaming in the network
- Describe the interaction of network nodes in various traffic cases which detach the mobile station from the network
- Describe the interaction of network nodes in various traffic cases when the mobile station is involved in a call
- Describe the interaction of network nodes in various traffic cases when the mobile station is involved in the Short Message Service


Intentionally
Blank

9 Traffic Cases

Table of Contents

Topic	Page

Intentionally Blank

GSM NETWORK IDENTITIES

Network identities are numbers which a GSM network uses to locate a mobile subscriber when it is establishing a call to that subscriber. As the network relies on these identities to route calls to subscribers, it is important that each identity is unique and correct.

Numbering plans are used to identify different networks as specified by the International Telecommunications Union - Telecommunications (ITU-T). For a telephone number in the PSTN/ISDN network, ITU-T’s numbering plan E.164 is used.

SUBSCRIBER-RELATED IDENTITIES

Mobile Station ISDN number (MSISDN)

The Mobile Station ISDN number (MSISDN) uniquely identifies a mobile telephone subscription in the PSTN numbering plan. This is the number dialed when calling a mobile subscriber. As the MSISDN is the actual telephone number of the mobile subscriber, it is the only network identity that subscribers are aware of. All other network identities discussed in this chapter are for internal network use and subscribers do not need to be aware of them.

CME 20 MSISDN

In CME 20, the MSISDN consists of the following:

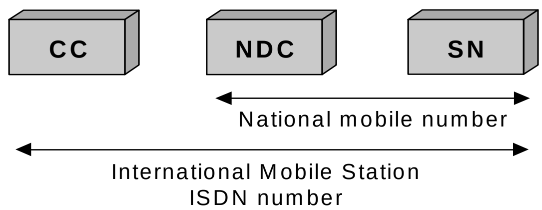


Figure 9-1 CME 20 MSISDN

CC	Country Code
NDC	National Destination Code
SN	Subscriber Number

An NDC is allocated to each PLMN. For example, in Ireland the NDCs 086 and 087 indicate the PLMNs of two different network operators. In some countries, more than one NDC may be required for each PLMN. The international MSISDN number may be of variable length. The maximum length is 15 digits, prefixes not included. A German subscriber calling an Irish GSM subscriber would dial the following number:

International prefix in Germany	CC	NDC	SN
00	353	87	1234567

Table 9-1 CME 20 MSISDN

CMS 40 MSISDN

In CMS 40, the MSISDN consists of the following:

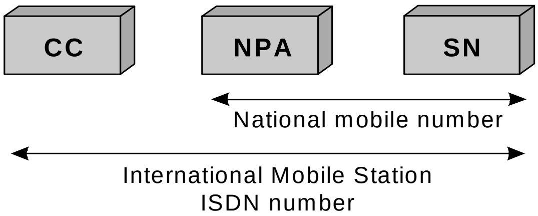


Figure 9-2 CMS 40 MSISDN

CC	Country Code
NPA	Number Planning Area
SN	Subscriber Number

The NPA is allocated to each GSM 1900 PLMN. The length of MSISDN is determined by the structure and operating plan for each operator. The maximum length is 15 digits, prefixes not included. A Swedish subscriber calling a Canadian GSM 1900 subscriber would dial the following number:

International prefix in Sweden	CC	NDC	SN
009	1	514	555 1234

Table 9-2 CMS 40 MSISDN

International Mobile Subscriber Identity (IMSI)

The International Mobile Subscriber Identity (IMSI) is a unique identity allocated to each subscriber which facilitates correct subscriber identification over the radio path and through the network. It is used for all signaling in the PLMN. All network related subscriber information is connected to an IMSI. The IMSI is stored in the SIM, the HLR and in the serving VLR.

The IMSI consists of three different parts:

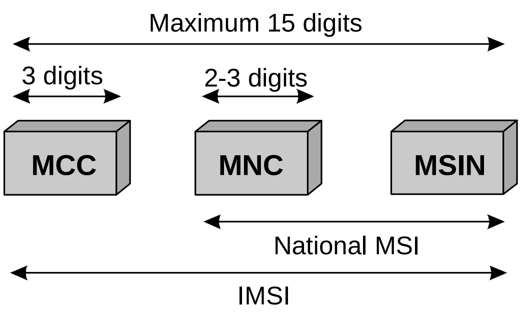


Figure 9-3 IMSI

MCC	Mobile Country Code
MNC	Mobile Network Code
MSIN	Mobile Station Identification Number

According to the GSM specifications, the IMSI has a maximum length of 15 digits.

Temporary Mobile Subscriber Identity (TMSI)

The Temporary Mobile Subscriber Identity (TMSI) is a temporary IMSI number made known to an MS at registration. It is used to protect the subscriber's identity on the air interface. The TMSI has local significance only (that is, within the MSC/VLR area) and is changed at time intervals or when certain events occur such as location updating. The TMSI structure can be determined by each operator but should not consist of more than 8 digits.

EQUIPMENT-RELATED IDENTITIES

International Mobile Equipment Identity (IMEI)

The International Mobile Equipment Identity (IMEI) is used to uniquely identify MS equipment to the network. The IMEI is used for security procedures such as identifying stolen equipment and preventing unauthorized access to the network. According to the GSM specifications, IMEI has a total length of 15 digits, and consists of the following:

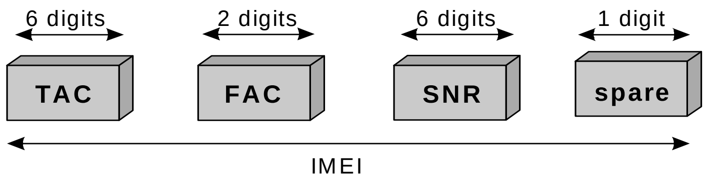


Figure 9-4 IMEI

TAC	Type Approval Code, determined by a central GSM body
FAC	Final Assembly Code, identifies the manufacturer
SNR	Serial Number, an individual serial number of six digits uniquely identifies all equipment within each TAC and FAC
spare	A spare digit for future use. When transmitted by the MS this digit should always be zero

International Mobile Equipment Identity and Software Version number (IMEISV)

The International Mobile Equipment Identity and Software Version number (IMEISV) provides a unique identity for every MS and also refers to the version of software which is installed in the MS. The version of software is important as it may affect the services offered by the MS or its speech coding capabilities.

For example, mobile networks need to know the MS speech coding capabilities when a call is being made (i.e. half rate/full rate, etc). This will be indicated by the IMEISV.

The IMEISV consists of the following:

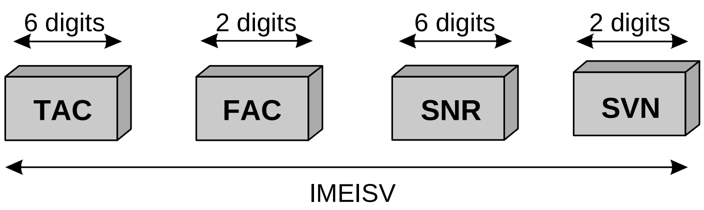


Figure 9-5 IMEISV

SVN	Software Version Number, allows the mobile equipment manufacturer to identify different software versions of a given type approved mobile. SVN value 99 is reserved for future use

LOCATION-RELATED IDENTITIES

Mobile Station Roaming Number (MSRN)

The Mobile Station Roaming Number (MSRN) is a temporary network identity which is assigned during the establishment of a call to a roaming subscriber. More information about the use of MSRN can be found in the "Traffic Cases" section later in the book. The MSRN consists of three parts:

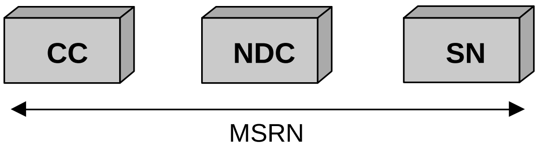


Figure 9-6 MSRN

Note: In this case, SN is the address to the serving MSC/VLR.

Location Area Identity (LAI)

The Location Area Identity (LAI) is a temporary network identity which is also required for routing. The two main purposes of the LAI are:

1. Paging, which is used to inform the MSC of the LA in which the MS is currently situated
2. Location updating of mobile subscribers

The LAI contains the following:

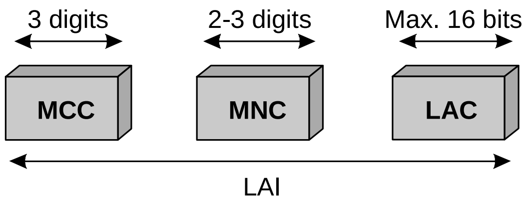


Figure 9-7 LAI

LAC	Location Area Code, the maximum length of LAC is 16 bits, enabling 65,536 different location areas to be defined in one PLMN

Cell Global Identity (CGI)

☞ Did you know?

The maximum number of cell identities in one operator's network is approximately 4.3 billion (65,536 x 65,536)

The Cell Global Identity (CGI) is used for identifying individual cells within an LA. Cell identification is achieved by adding a Cell Identity (CI) to the LAI components. The CI has a maximum length of 16 bits.

The CGI consists of:

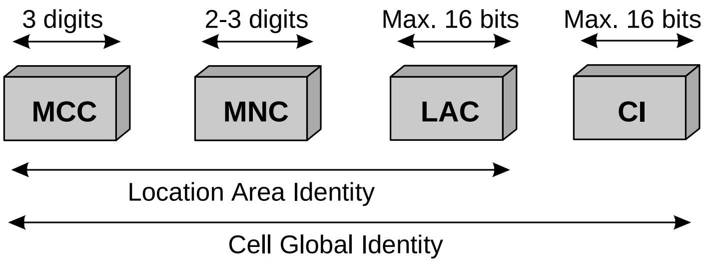


Figure 9-8 CGI

Base Station Identity Code (BSIC)

The Base Station Identity Code (BSIC) enables MSs to distinguish between different neighboring base stations.

The BSIC consists of:

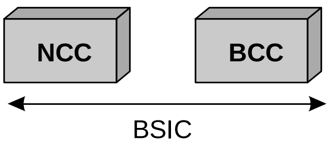


Figure 9-9 BSIC

NCC	Network Color Code (3 bits) identifies the PLMN. Note that it does not uniquely identify the operator. NCC is primarily used to distinguish between operators on each side of a border
BCC	Base Station Color Code (3 bits) identifies the Base Station to help distinguish between RBS using the same control frequencies

Location Number (LN)

The Location Number (LN) is a number related to a certain geographical area, which the network operator specifies by “tying” the location numbers to cells, location areas, or MSC/VLR service areas.

The LN is used to implement features like regional/local subscription and geographical differentiated charging.

The LN consists of the following:

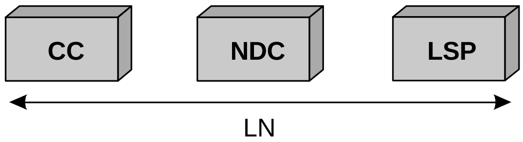


Figure 9-10 LN

LSP	Locally Significant Part

Regional Subscription Zone Identity (RSZI)

For each regional subscription, zones/regions need to be defined. This is achieved by using the Regional Subscription Zone Identity (RSZI).

The RSZI consist of the following:

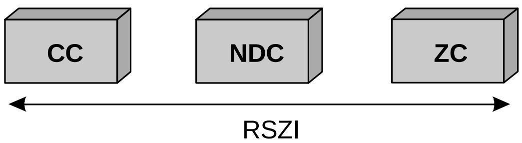


Figure 9-11 RSZI

ZC	The length of the Zone Code, is two octets

SUBSCRIBER IDENTITY CONFIDENTIALITY

Subscriber identity confidentiality means that the IMSI is not disclosed to unauthorized individuals, entities or processes.

This function protects a subscriber’s identity when the subscriber is using PLMN resources. It also prevents tracing the mobile subscriber’s location by listening to the signaling exchanges on the radio path.

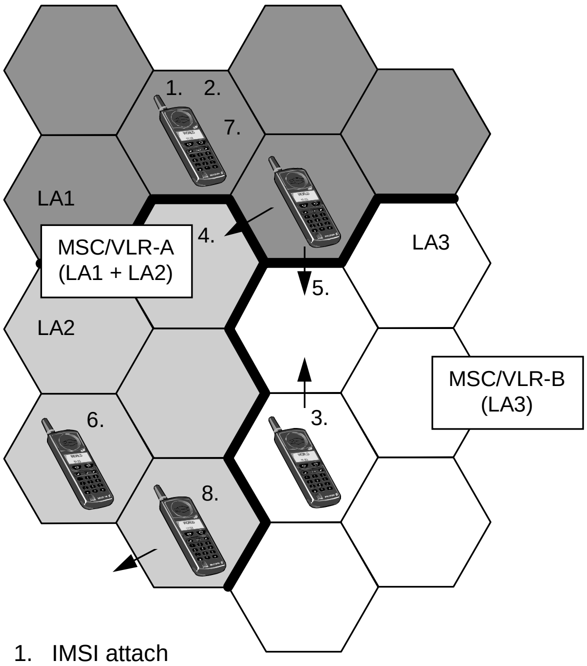
Subscriber Identity Confidentiality Procedure

Each time a mobile station requests a system procedure (e.g. location updating, call attempt or service activation), the MSC/VLR can allocate a new TMSI to an IMSI. The MSC/VLR transmits the TMSI to MS which stores it on the SIM card. Signaling between MSC/VLR and MS utilizes only the TMSI from this point on. Thus, the real subscriber identity, IMSI, is not transmitted over the radio path again.

TMSI is half the length of IMSI, thus allowing twice as many MSs to be paged in the same paging message.

IMSI is only used in cases when location updating fails or when the MS has no allocated TMSI.

TRAFFIC CASES: MS IN IDLE MODE



1. IMSI attach
2. Location updating, type IMSI attach
3. Changing cells within an LA
4. Location updating, same MSC/VLR
5. Location updating, new MSC/VLR
6. Location updating type periodic registration
7. IMSI detach
8. Implicit detach

Figure 9-12 Traffic cases when MS is in idle mode

ATTACHING TO THE NETWORK

IMSI attach

When an MS is switched on, the IMSI attach procedure is executed. This involves the following steps:

1. The MS sends an IMSI attach message to the network indicating that it has changed state to idle.
2. The VLR determines whether there is a record for the subscriber already present. If not, the VLR contacts the subscriber's HLR for a copy of the subscription information.
3. The VLR updates the MS status to idle.
4. Acknowledgement is sent to the MS.

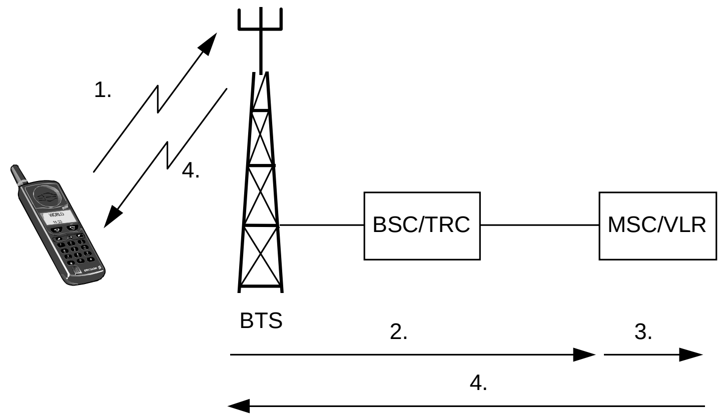


Figure 9-13 IMSI attach

Location Updating, type IMSI Attach

If the MS has changed LA while powered off, the IMSI attach procedure may lead to an update to the location of the MS.

During IMSI attach, the VLR may determine that the current LAI of the MS is different from the LAI stored in the MS's subscription information. If so, the VLR updates the LAI of the MS.

ROAMING IN THE NETWORK

Changing Cells within an LA

MSs are constantly moving around in the cellular network. The MS location information stored in the VLR is the LA. If an MS changes cells within an LA, the network is not updated.

The MS knows that the new cell belongs to the same LA by listening to the BCCH in the new cell. The BCCH broadcasts the cell's LAI. The MS compares the last LAI received with the new LAI. If they are the same, it means that the MS has not changed LAs and does not need to inform the network.

Location Updating, Same MSC/VLR

If an MS detects a change in LAI on the BCCH, it informs the network. When the MS sends the Location Updating message, the MSC/VLR determines whether it is an MS which is already registered, or if it is an MS visiting from another MSC/VLR.

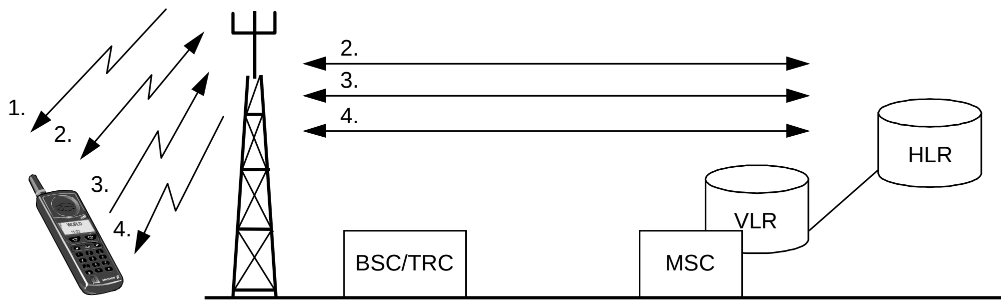


Figure 9-14 Location updating, same MSC/VLR

1. The MS listens to BCCH in the new cell to determine the LAI. The new LAI is compared to the old one. If they differ, a location update is necessary.
2. The MS establishes a connection with the network via SDCCH. Authentication is performed.
3. If authentication is successful, the MS sends a Location Updating Request to the system.
4. The system acknowledges Location Updating and requests RBS and MS to release the signaling channel.

Location Updating, New MSC/VLR

When an MS roams into a new LA, location updating is performed. However, unknown to the MS, the LA may belong to a new MSC/VLR. When the Location Update Request is received by the new VLR, it executes the procedure below.

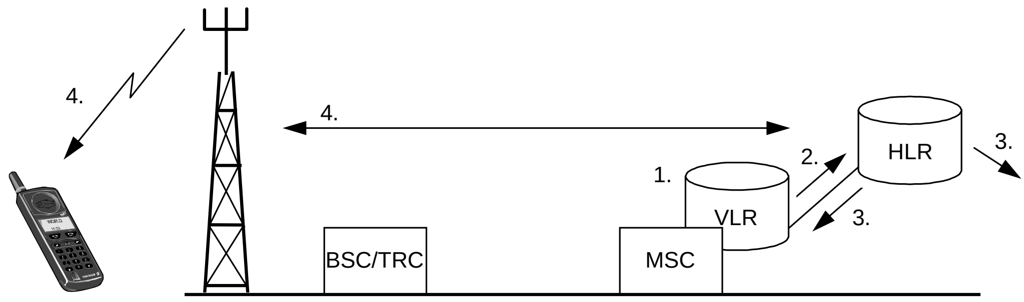


Figure 9-15 Location updating, new MSC/VLR

1. Authentication is performed. If authentication is successful, the VLR checks its database to determine whether or not it has a record for this MS.

2. When the VLR finds no record for the MS, it sends a request to the subscriber's HLR for a copy of the MS's subscription.

3. The HLR passes the information to the VLR and updates its location information for the subscriber. The HLR instructs the old VLR to delete the information it has on the MS.

4. The VLR stores its subscription information for the MS, including the latest location and status (idle). The VLR sends acknowledgement to the MS.

Location Updating, type Periodic Registration

Periodic registration is a feature which forces MSs to send a registration message to the network at predefined intervals. If an MS should miss such a registration, the network will mark the MS as detached. This may occur if an MS is out of the area of coverage and ensures that needless paging is not performed.

If the network uses periodic registration, the MS will be informed, on the BCCH of how often periodic registration must be performed. Periodic registration has an acknowledgment message. The MS tries to register until it receives this message.

DETACHING FROM THE NETWORK

IMSI Detach

IMSI detach enables the MS to indicate to the network that it is switched off. At power off, the MS sends an IMSI detach message to the network. On reception, the VLR marks the corresponding IMSI as detached. The HLR is not informed. No acknowledgement is sent to the MS.

Implicit Detach

If the MS sends an IMSI detach message to the system and the radio link quality is poor, the system might not be able to decode the information. Because no acknowledgment is sent to the MS, no further attempt is made. In this case, the system still regards the MS as attached. If periodic registration is in use, the system will soon determine that the MS is detached. The VLR then performs an implicit detach, marking the MS as detached.

MS Purging

MS purging is used to inform the HLR that the VLR is about to remove a subscriber record from the VLR. The HLR then sets the MS purged flag and treats the subscriber as unreachable. This saves unnecessary network signaling and database lookup.

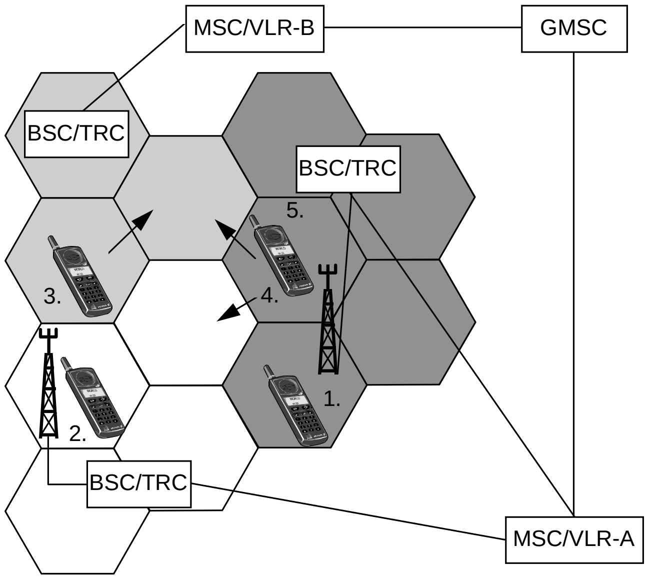
For example, a UK MS travels to Australia and performs a location update in an MSC/VLR in Australia. Later, the subscriber travels back to the UK, which takes some time. During this period, the subscriber is not active.

If MS purging is not used, when a caller makes a call to the MS, the HLR identifies the MS as registered in the Australian MSC/VLR and routes the call to it. The MSC/VLR then informs the HLR that the subscriber is unreachable.

If MS purging is used, the UK subscriber’s record will have been purged from the Australian MSC/VLR. When a call is made to the subscriber, the HLR identifies the MS as unreachable and does not contact the Australian MSC/VLR.

TRAFFIC CASES: MS IN ACTIVE MODE

An MS is in active mode when there is a call (speech, fax or data), or a call set up procedure taking place.



1. Call from MS (speech, fax, data, short message)
2. Call to MS (speech, fax, data, short message, cell broadcast)
3. Handover - intra - BSC
4. Handover - inter - BSC, intra - MSC
5. Handover - inter - MSC

Figure 9-16 Cases which activate an MS and cases when MS is in active mode

CALL FROM AN MS

This section describes what happens when a mobile subscriber wants to set up a voice call to a subscriber in the PSTN. Data and text message calls are described separately.

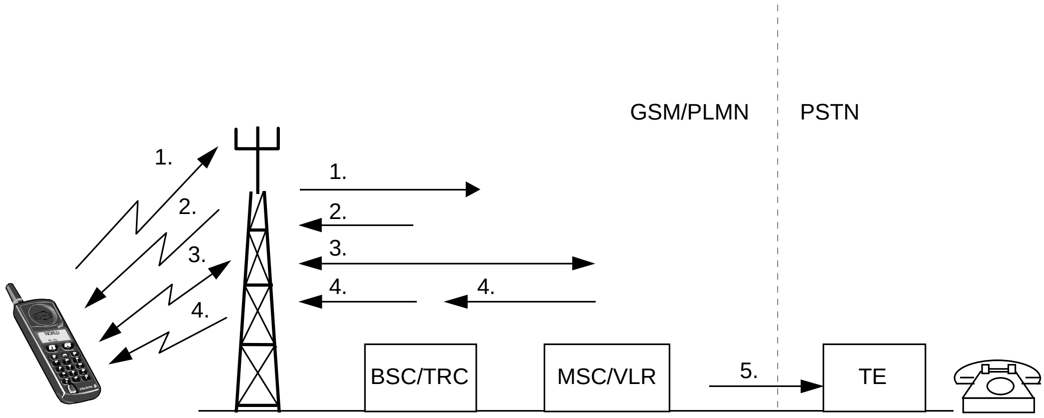


Figure 9-17 Call set-up MS to PSTN

1. The MS uses RACH to ask for a signaling channel.
2. The BSC/TRC allocates a signaling channel, using AGCH.
3. The MS sends a call set-up request via SDCCH to the MSC/VLR. Over SDCCH all signaling preceding a call takes place. This includes:
   - Marking the MS as “active” in the VLR
   - The authentication procedure
   - Start ciphering
   - Equipment identification
   - Sending the B-subscriber’s number to the network
   - Checking if the subscriber has the service “Barring of outgoing calls” activated
4. The MSC/VLR instructs the BSC/TRC to allocate an idle TCH. The RBS and MS are told to tune to the TCH.
5. The MSC/VLR forwards the B–number to an exchange in the PSTN, which establishes a connection to the subscriber.
6. If the B-subscriber answers, the connection is established.

CALL TO AN MS

The major difference between a call to an MS and a call from an MS is that in a call to an MS the exact location of the mobile subscriber is unknown. Therefore, the MS must be located using paging before a connection can be established.

Below is the description of the call set-up procedure for a call from a PSTN subscriber to a mobile subscriber. A call from an MS to a mobile subscriber operates according to the same process, the only difference being that the GMSC is contacted by another MSC/VLR instead of by a PSTN node.

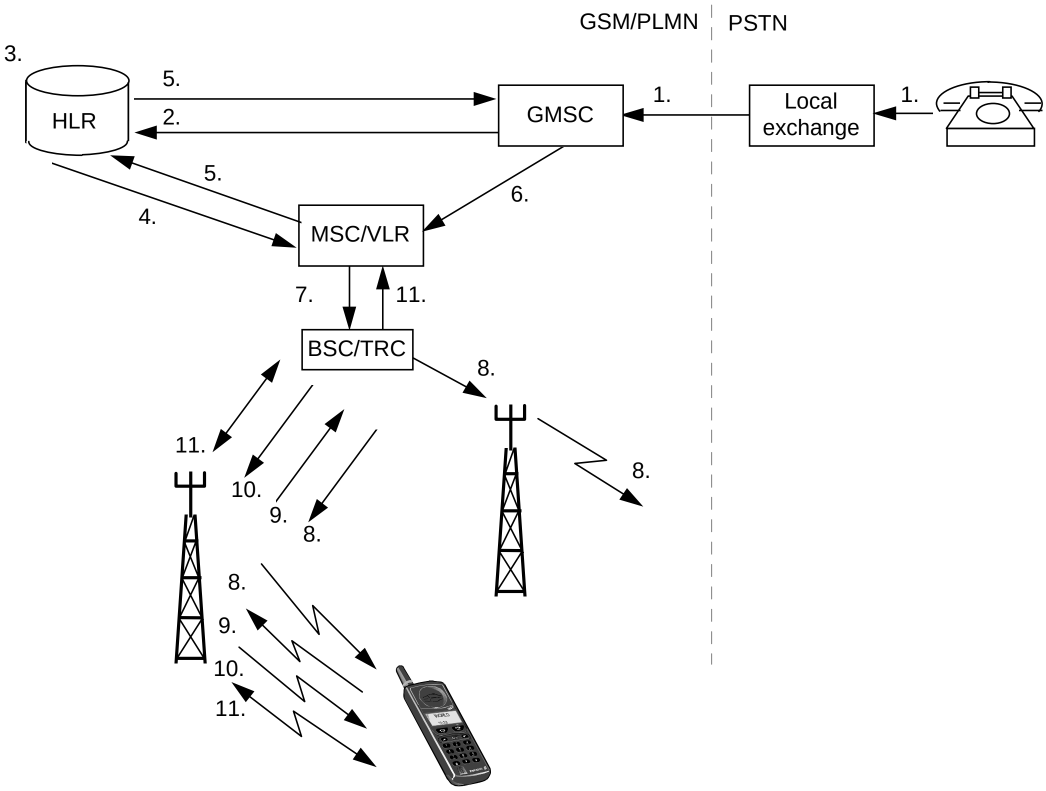


Figure 9-18 Call to MS from PSTN

1. The PSTN subscriber keys in the MS’s telephone number (MSISDN). The MSISDN is analyzed in the PSTN which identifies that this is a call to a mobile network subscriber. A connection is established to the MS’s home GMSC.
2. The GMSC analyzes the MSISDN to find out which HLR the MS is registered in, and queries the HLR for information about how to route the call to the serving MSC/VLR.
3. The HLR translates MSISDN into IMSI, and determines which MSC/VLR is currently serving the MS. The HLR also checks the service, “Call forwarding to C–number”. If the service is activated, the call is rerouted by the GMSC to that number.
4. The HLR requests an MSRN from the serving MSC/VLR.
5. The MSC/VLR returns an MSRN via HLR to the GMSC.
6. The GMSC analyses the MSRN and routes the call to the MSC/VLR.
7. The MSC/VLR knows which LA the MS is located in. A paging message is sent to the BSCs controlling the LA.
8. The BSCs distribute the paging message to the RBSs in the desired LA. The RBSs transmit the message over the air interface using PCH. To page the MS, the network uses an IMSI or TMSI valid only in the current MSC/VLR service area.
9. When the MS detects the paging message, it sends a request on RACH for a SDCCH.
10. The BSC provides a SDCCH, using AGCH.
11. SDCCH is used for the call set-up procedures. Over SDCCH all signaling preceding a call takes place. This includes:
    - Marking the MS as “active” in the VLR
    - The authentication procedure
    - Start ciphering
    - Equipment identification

    The MSC/VLR instructs the BSC/TRC to allocate an idle TCH. The RBS and MS are told to tune to the TCH.
12. The mobile phone rings. If the subscriber answers, the connection is established.

HANDOVER

The process of changing cells during a call is called handover in GSM terminology. To choose the best target cell, measurements are performed by the MS and the RBS. Because the MS contributes to the handover decision, this type of handover is often called Mobile Assisted HandOver (MAHO).

Locating

An MS continuously measures signal strength and quality on it’s own cell and signal strength on the BCCH carriers of the neighboring cells. The measurements are carried out on the downlink while MS is in active mode. The measurement results are sent to the RBS on SACCH at regular intervals.

The serving RBS measures signal strength and quality on the uplink.

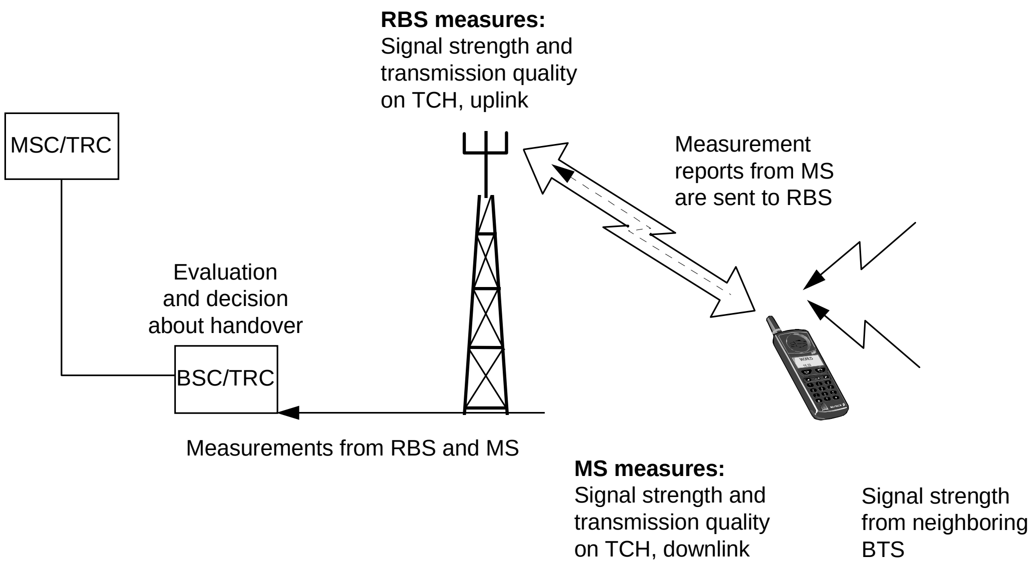


Figure 9-19 Measurements sent to BSC

The measurements from the RBS and MS are sent to the BSC in the form of measurements reports. Based on these reports, the BSC decides if a handover is necessary and to which cell. This is called locating.

As soon as a neighboring cell is considered to be better than the serving cell, a handover is attempted.

Another reason for attempting a handover, apart from signal strength and quality, is when the Timing Advance (TA) used by MS exceeds a threshold value set by the operator. This usually happens when the MS is moving over the cell border to another cell.

When the MS has changed cells, the new RBS informs the MS about the new neighboring BCCH carriers so measurements can be taken again. If the MS has also switched to a new LA, a location updating type normal takes place after the call has finished.

Handover can be used for load balancing between cells. During a call setup in a congested cell, the MS can be transferred to a cell with less traffic if an acceptable connection quality is likely to be obtained. Another area where forced handover is a useful tool is maintenance. Channels can be released from traffic if necessary, e.g. for RBS maintenance reasons.

There are several types of handover, including:

- Intra-cell handover
- Handover between cells controlled by the same BSC
- Handover between cells controlled by different BSCs, but the same MSC/VLR
- Handover between cells controlled by different MSC/VLRs

Each of these traffic cases is described in greater detail below. In each case, the decision to perform a handover has already been made and a target cell has been identified.

Intra-Cell Handover

A special type of handover is the intra-cell handover. It is performed when the BSC considers the quality of the connection too low, but receives no indication from the measurements that another cell would be better. In that case the BSC identifies another channel[1] in the same cell which may offer a better quality, and the MS is ordered to retune to it.

[1] Note: the BSC will attempt to handover first to a channel on another frequency. If none are available, it will perform a handover

Handover between Cells Controlled by the Same BSC

When performing a handover between two cells controlled by the same BSC, the MSC/VLR is not involved. However, the MSC/VLR will be informed when a handover has taken place. If the handover involves different LAs, location updating is performed once the call is finished.

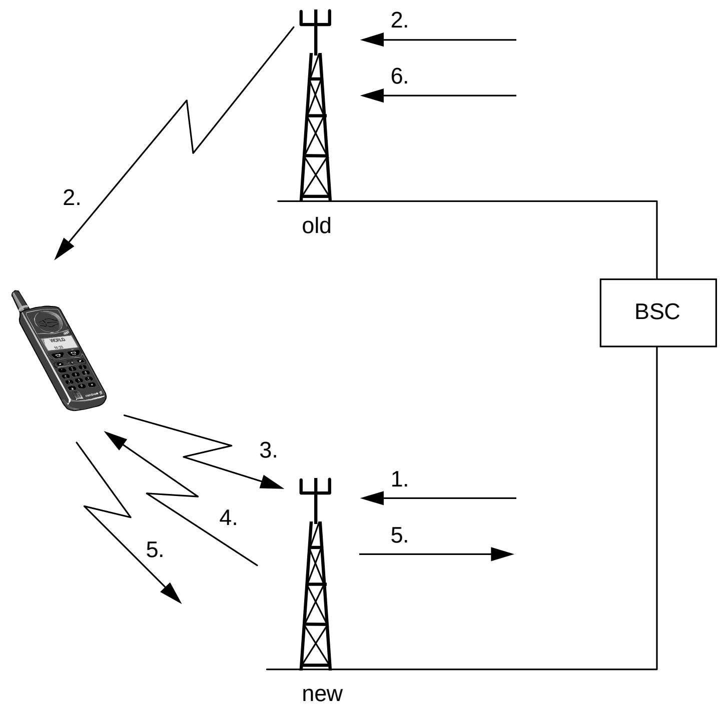


Figure 9-20 Handover: cells controlled by the same BSC

1. The BSC orders the new RBS to activate a TCH.
2. The BSC sends a message to the MS, via the old RBS, containing information about the frequency and time slot to change to and also the output power to use. This information is sent to the MS using FACCH.
3. The MS tunes to the new frequency, and transmits handover access bursts in the correct time slot. Since the MS has no information yet on TA, the handover bursts are very short (only 8 bits of information).
4. When the new RBS detects the handover bursts, it sends information about TA. This is also sent via FACCH.
5. The MS sends a Handover Complete message to the BSC via the new RBS.
6. The BSC tells the old RBS to release the old TCH.

Handover between Cells Controlled by Different BSCs but the Same MSC/VLR

When another BSC is involved in a handover, the MSC/VLR must also be involved to establish the connection between the two BSCs.

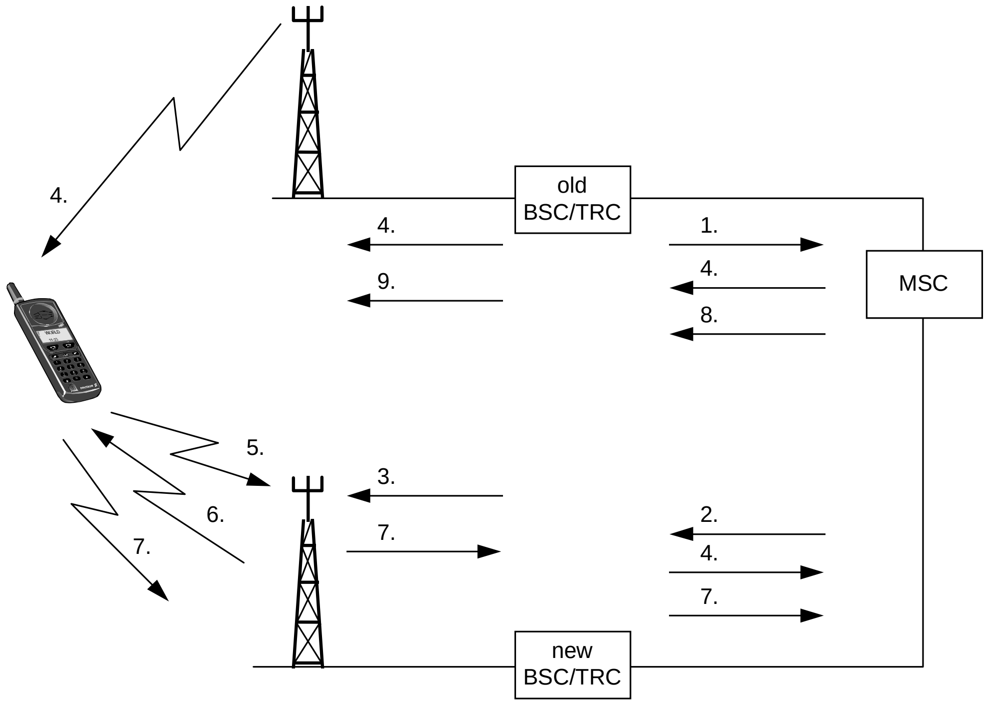


Figure 9-21 Handover: different BSCs but the same MSC/VLR

1. The serving (old) BSC sends a Handover Required message to the MSC containing the identity of the target cell.
2. The MSC knows which BSC controls this cell and sends a Handover Request to this BSC.
3. The new BSC orders the target RBS to activate a TCH.
4. The new BSC sends a message to the MS via the MSC and the old RBS.
5. MS tunes to the new frequency and transmits handover access bursts in the correct time slot.
6. When the new RBS sends information about TA.
7. MS sends a Handover Complete message to MSC via the new BSC.
8. MSC sends the old BSC an order to release the old TCH.
9. The old BSC tells the old RBS to release the TCH.

Handover between Cells Controlled by Different MSC/VLRs

Handover between cells controlled by different MSC/VLRs can only be performed within one PLMN and not between two PLMNs. Cells controlled by different MSC/VLRs also means that they are controlled by different BSCs.

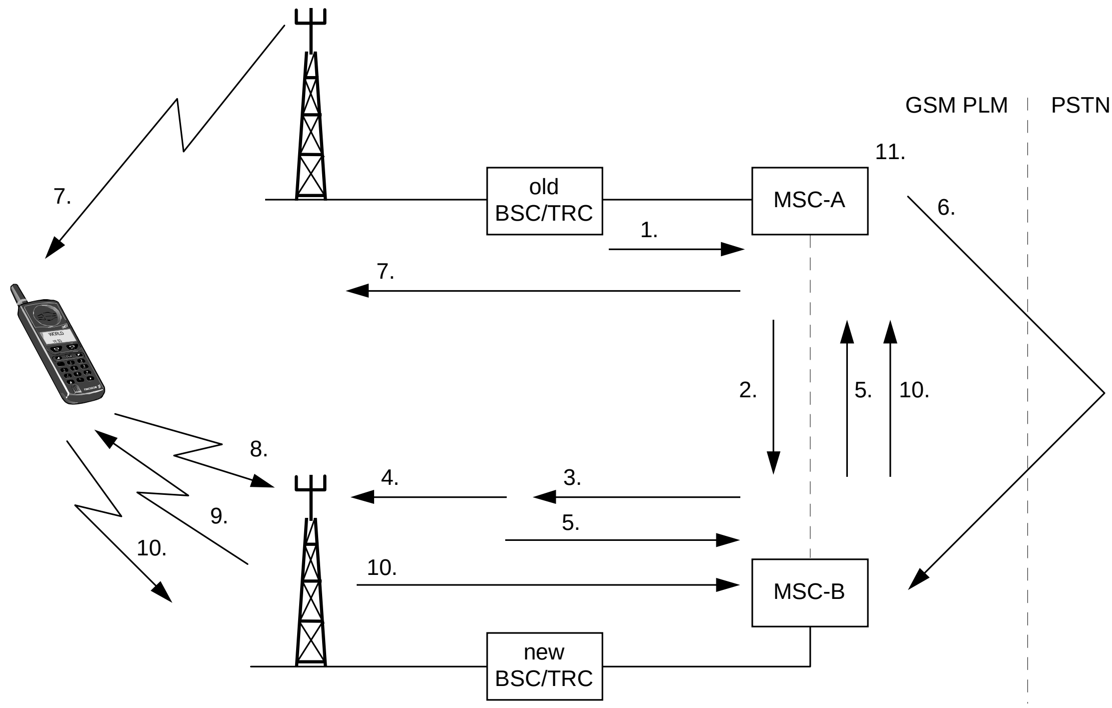


Figure 9-22 Handover: cells controlled by different MSCs

1. The serving (old) BSC sends a Handover Required message to the serving MSC (MSC–A), with the identity of the target cell.
2. MSC–A identifies that this cell belongs to another MSC, (MSC–B), and requests help.
3. MSC–B allocates a handover number to reroute the call. A Handover Request is then sent to the new BSC.
4. The new BSC orders the target RBS to activate a TCH.
5. MSC–B receives the information, and passes it on to MSC–A together with the handover number.
6. A link is set up to MSC–B, possibly via PSTN.
7. MSC–A sends a handover command to the MS, via the old BSC.
8. The MS tunes to the new frequency and transmits handover access bursts in the correct time slot.

9. When the new RBS detects the handover bursts it sends information about TA.
10. The MS sends Handover Complete message to the old MSC via the new BSC and the new MSC/VLR.
11. A new path in the group switch in MSC–A is established, and the call is switched through.
12. The old TCH is deactivated by the old BSC (not shown in the picture).

The old MSC, MSC–A, retains main control of the call until the call is cleared. This is because it contains the information about the subscriber and call details such as charging.

After call release, the MS must perform location updating because an LA never belongs to more than one MSC/VLR service area. The HLR is updated by the VLR–B, and will in turn tell VLR–A to delete all information about the mobile subscriber.

INTERNATIONAL TRAFFIC CASES

One of the primary features of GSM is the ability to perform international roaming and to handle international call cases. In order for a mobile subscriber to be able to make calls while roaming in a different GSM network, there must be an agreement between the subscriber’s home network operator and the visited network operator. This also applies to international roaming.

Although there are less significant affects on other traffic cases, the two traffic cases which are affected most are outlined here.

IMSI ATTACH

When an MS is roaming internationally, the following occurs:

1. The MS is switched on and scans all GSM frequencies within one frequency band (e.g. GSM 900). It is searching for a BCCH carrier. The MS tunes to the BCCH carrier which has the strongest signal strength and reads its system information. This includes the identity of the network operator.

2. The MS compares this network identity with the list of forbidden PLMNs in the SIM memory. This list contains all network identities which the subscriber’s home operator does not have an international roaming agreement with. If the network which the MS has tuned to is a forbidden network, the MS continues to scan for a permitted network.

3. If the MS does not find a permitted network, but has identified a forbidden network, it displays the message “Emergency Calls Only”. If the MS finds a permitted network, it tunes to it and sends an IMSI attach message.

4. The remainder of this traffic case is identical to that of the normal IMSI attach case, with the only difference being that the subscriber’s HLR is located in another country.

CALL TO AN MS

When an MS is roaming internationally and a call is made to it, the procedure used is identical to when the MS is in their home network. The only major difference is that the GMSC and HLR used are in the home network, while the MSC/VLR is in a network in another country.

DROPBACK FUNCTIONALITY

The following traffic case demonstrates the advantages of using dropback functionality. It involves two subscribers:

- Subscriber A is from France and is located in France under the control of the MSC/VLR-A.
- Subscriber B is from Sweden but is currently roaming internationally in France under the control of the same MSC/VLR-A.

1. Subscriber A calls subscriber B. The call is routed internationally from France to Sweden.
2. The Swedish network then identifies that B is in under the control of MSC/VLR-A in France and routes the call back to France. The subscribers are connected to each other and continue their call.

- **Without dropback:** the speech on the call goes through the GMSC in Sweden.
- **With dropback:** the speech on the call is switched within MSC/VLR-A, thus saving on processing and transmission costs.

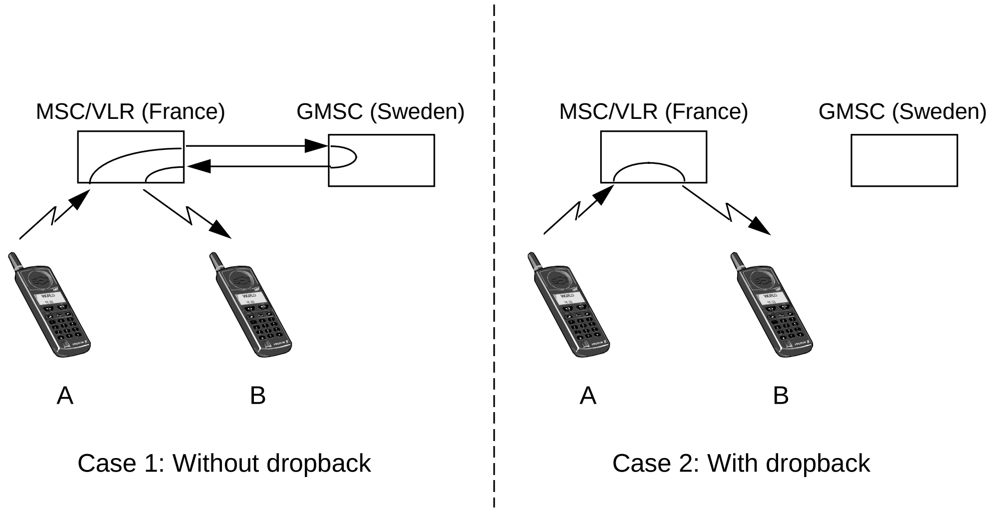


Figure 9-23 Traffic case showing the advantage of using dropback

SHORT MESSAGE SERVICE TRAFFIC CASES

The Short Message Service (SMS) provides a means of sending text messages containing up to 160 alpha-numerical characters to and from MSs. SMS makes use of a SMS Center (SMS-C), which acts as a store and forward center for short messages.

SMS consists of two basic services:

- Mobile terminated SMS: from an SMS–C to an MS
- Mobile originated SMS: from an MS to an SMS–C

In the two cases described below, the MS is in idle mode. If the MS is in active mode, short message is transmitted on the SACCH. No paging, call set-up, authentication, etc. needs to be performed in that case.

MOBILE ORIGINATED SMS

Mobile originated SMS transfers a short message submitted by the MS to an SMS-C. It also provides information about the delivery of the short message, either by a delivery report or failure report.

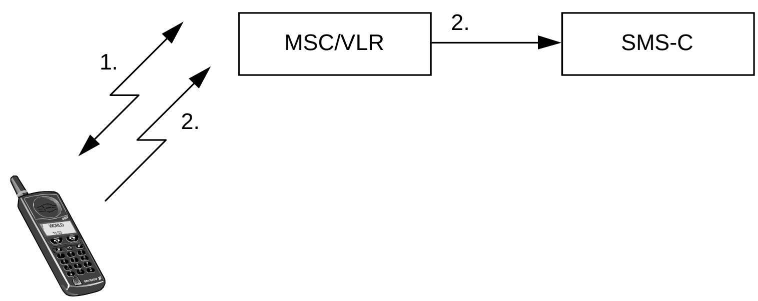


Figure 9-24 Mobile originating short message

1. An MS establishes a connection to the network, as in the case of a normal call set-up. This step is not performed if the MS is in active mode, since the connection already exists.
2. If authentication is successful, the MS sends the short message using SDCCH to the SMS–C via the MSC/VLR. The SMS–C in turn forwards the short message to its destination. This could be an MS or a terminal in the fixed network, such as a PC.

MOBILE TERMINATED SMS

Mobile terminated SMS has the capability to transfer a short message from the SMS–C to an MS.

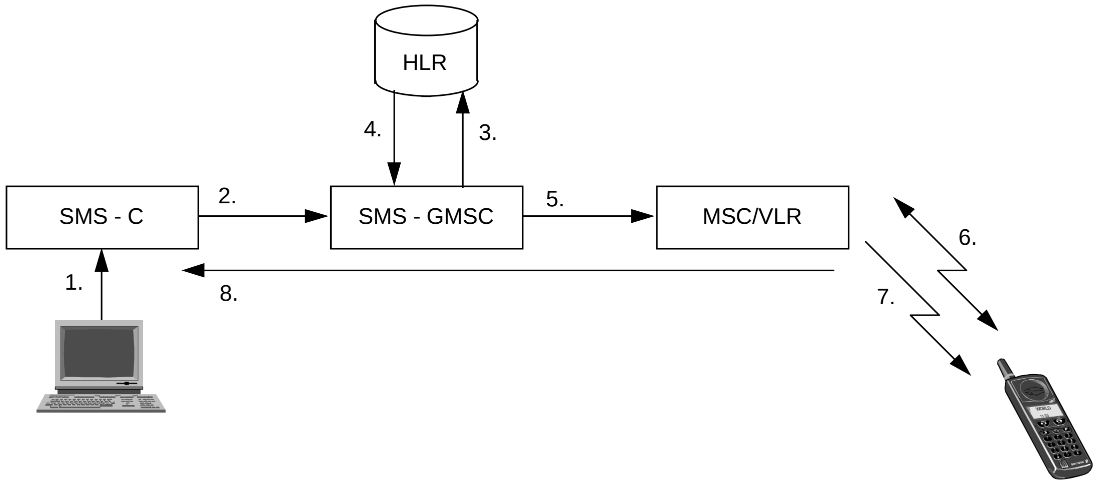


Figure 9-25 Mobile terminating short message

1. A user sends a message to a SMS–C.
2. The SMS–C sends the message to the SMS–GMSC.
3. The SMS–GMSC queries the HLR for routing information.
4. The HLR returns routing information to the SMS-GMSC.
5. The SMS-GMSC re-routes the message to the MSC/VLR.
6. The MS is paged and a connection is set up between the MS and the network, as in the normal call set-up case.
7. If authentication is successful, the MSC/VLR delivers the message to the MS. Short messages are transmitted on the allocated signaling channel, SDCCH.
8. If the delivery was successful, a report is sent from the MSC/VLR to the SMS–C. If not, the HLR is informed by the MSC/VLR, and a failure report is sent to SMS–C.

In the case of an unsuccessful delivery, the SMS-C informs the HLR and VLR that there is a message waiting to be delivered to the MS. The HLR then informs the SMS–C when the MS becomes available.

Mobile terminated SMS can be input to the SMS–C via a variety of sources, e.g. speech, telex, facsimile or internet.

Intentionally Blank

Cell Planning

Chapter 10

This chapter is designed to provide the student with an overview of cell planning. It describes basic cell planning concepts and outlines the cell planning process.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

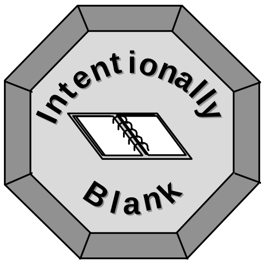
- Describe basic cell planning concepts
- Describe the problems encountered during the cell planning process
- Describe the cell planning process

Intentionally Blank

10 Cell Planning

Table of Contents

Topic	Page


Intentionally
Blank

INTRODUCTION

Cell planning can be described as all the activities involved in:

- Selecting the sites for the radio equipment
- Selecting the radio equipment
- Configuring the radio equipment

Every cellular network requires cell planning in order to provide adequate coverage and call quality.

CELLS

> ☞ Did you know?
>
> *Although the concept of mobile telephony originated in the 1920s, it was only in 1947 that the cellular network structure was devised. Up to then, no solution enabled an MS to roam far from the antenna system.*

A cell may be defined as an area of radio coverage from one BTS antenna system[1]. It is the smallest building block in a mobile network and is the reason why mobile networks are often referred to as cellular networks. Typically, cells are represented graphically by hexagons.

There are two main types of cell:

- **Omni directional cell:** An omni directional cell (or omnicell) is served by a BTS with an antenna which transmits equally in all directions (360 degrees).

- **Sector cell:** A sector cell is the area of coverage from an antenna which transmits in a given direction only. For example, this may be equal to 120 degrees or 180 degrees of an equivalent omni directional cell. One BTS can serve one of these sector cells with a collection of BTSs at a site serving more than one, leading to terms such as two-sectored sites and more commonly, three-sectored sites.

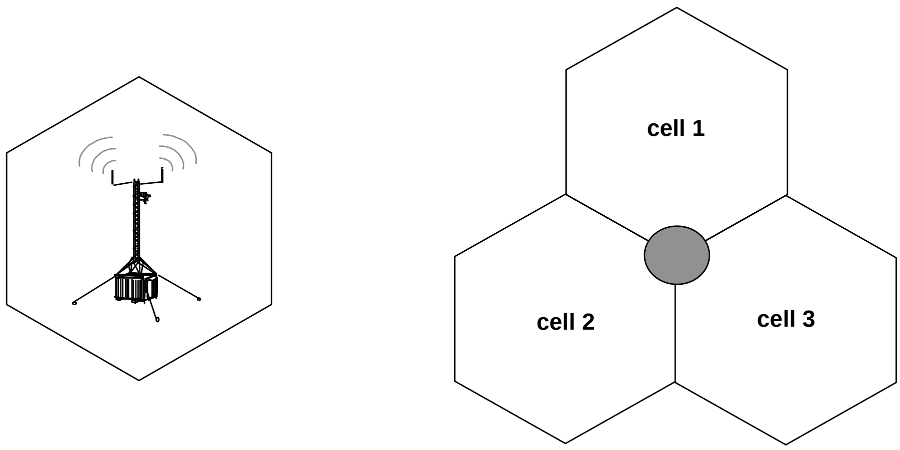


Figure 10-1 Omni directional and sector cells

Typically, omni directional cells are used to gain coverage, whereas sector cells are used to gain capacity.

[1] Note: In some cases, such as pico cells, a single cell can be served by 2 antenna systems. Although there are two distinct areas of coverage, both areas can be associated with the same set of cell parameters.

The border between the coverage area of two cells is the set of points at which the signal strength from both antennas is the same. In reality, this line will be determined by the environment, but for simplicity, it is represented as a straight line.

If six BTSs are placed around an original BTS, the coverage area - that is, the cell - takes on a hexagonal shape.

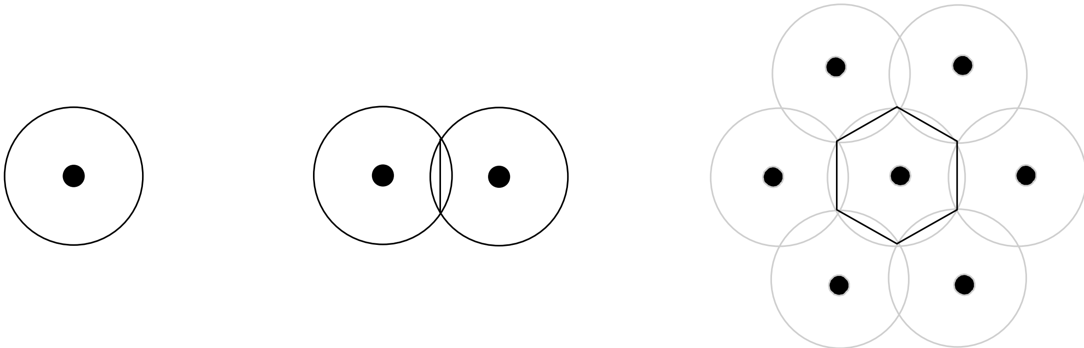


Figure 10-2 Border between omni directional cells

CELL PLANNING PROCESS

The major activities involved in the cell planning process are shown below.

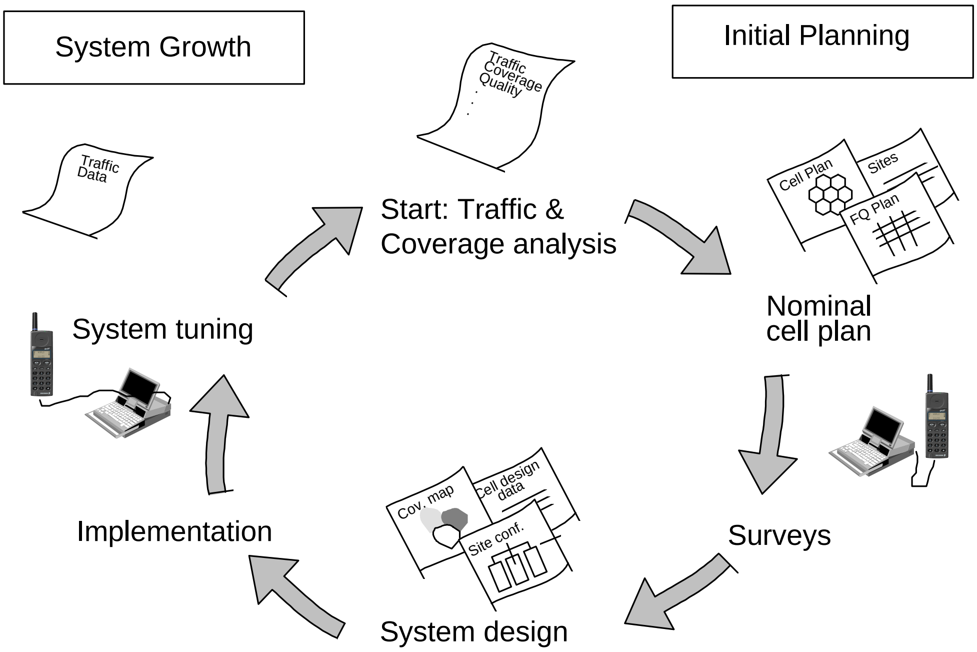


Figure 10-3 Cell planning process

STEP 1: TRAFFIC AND COVERAGE ANALYSIS

Cell planning begins with traffic and coverage analysis. The analysis should produce information about the geographical area and the expected capacity (traffic load). The types of data collected are:

- Cost
- Capacity
- Coverage
- Grade Of Service (GOS)
- Available frequencies
- Speech quality
- System growth capability

The basis for all cell planning is the traffic demand, i.e. how many subscribers use the network and how much traffic they generate. The Erlang (E) is a unit of measurement of traffic intensity. It can be calculated with the following formula:

$A = n \times T / 3600$ Erlang

Where,

A = offered traffic from one or more users in the system

n = number of calls per hour

T = average call time in seconds

The geographical distribution of traffic demand can be calculated by the use of demographic data such as:

- Population distribution
- Car usage distribution
- Income level distribution
- Land usage data
- Telephone usage statistics
- Other factors, like subscription/call charge and price of MSs

Calculation of required number of BTSs

☞ Did you know?

Based on experience, Ericsson recommends between 25mE and 33mE when planning GSM networks.

To determine the number and layout of BTSs the number of subscribers and the Grade Of Service (GOS) have to be known. The GOS is the percentage of allowed congested calls and defines the quality of the service.

If n=1 and T=90 seconds then the traffic per subscriber is:

A = 1 x 90 / 3600 = 25mE

If the following data exists for a network:

- Number of subscribers: 10,000
- Available frequencies: 24
- Cell pattern: 4/12
- GOS: 2%
- Traffic per subscriber: 25mE

this leads to the following calculations:

- Frequencies per cell = 24 / 12 = 2
- Traffic channels per cell = 2 x 8 - 2 (control channels) = 14 TCH
- Traffic per cell = 14 TCH with a 2% GOS implies 8.2 Erlangs per cell (see Table 10-1)
- The number of subscribers per cell = 8.2E / 25mE = 328 subscribers per cell
- If there are 10,000 subscribers then the number of cells needed is 10,000 / 328 = 30 cells.
- Therefore, the number of three sector sites needed is 30 / 3 = 10

n	.007	.008	.009	.01	.02	.03	.05	.1	.2	.4	n
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667	1
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000	2
3	.39664	.41757	.43711	.45549	.60221	.71513	.89940	1.2708	1.9299	3.4798	3
4	.77729	.81029	.84085	.86942	1.0923	1.2589	1.5246	2.0454	2.9452	5.0210	4
5	1.2362	1.2810	1.3223	1.3608	1.6571	1.8752	2.2185	2.8811	4.0104	6.5955	5
6	1.7531	1.8093	1.8610	1.9090	2.2759	2.5431	2.9603	3.7584	5.1086	8.1907	6
7	2.3149	2.3820	2.4437	2.5009	2.9354	3.2497	3.7378	4.6662	6.2302	9.7998	7
8	2.9125	2.9902	3.0615	3.1276	3.6271	3.9865	4.5430	5.5971	7.3692	11.419	8
9	3.5395	3.6274	3.7080	3.7825	4.3447	4.7479	5.3702	6.5464	8.5217	13.045	9
10	4.1911	4.2889	4.3784	4.4612	5.0840	5.5294	6.2157	7.5106	9.6850	14.677	10
11	4.8637	4.9709	5.0691	5.1599	5.8415	6.3280	7.0764	8.4871	10.857	16.314	11
12	5.5543	5.6708	5.7774	5.8760	6.6147	7.1410	7.9501	9.4740	12.036	17.954	12
13	6.2607	6.3863	6.5011	6.6072	7.4015	7.9667	8.8349	10.470	13.222	19.598	13
14	6.9811	7.1154	7.2382	7.3517	8.2003	8.8035	9.7295	11.473	14.413	21.243	14
15	7.7139	7.8568	7.9874	8.1080	9.0096	9.6500	10.633	12.484	15.608	22.891	15
16	8.4579	8.6092	8.7474	8.8750	9.8284	10.505	11.544	13.500	16.807	24.541	16
17	9.2119	9.3714	9.6171	9.6516	10.656	11.368	12.461	14.522	18.010	26.192	17
18	9.9751	10.143	10.296	10.437	11.491	12.238	13.385	15.548	19.216	27.844	18
19	10.747	10.922	11.082	11.230	12.333	13.115	14.315	16.579	20.424	29.498	19
20	11.526	11.709	11.876	12.031	13.182	13.997	15.249	17.613	21.635	31.152	20
21	12.312	12.503	12.677	12.838	14.036	14.885	16.189	18.651	22.848	32.808	21
22	13.105	13.303	13.484	13.651	14.896	15.778	17.132	19.692	24.064	34.464	22
23	13.904	14.110	14.297	14.470	15.761	16.675	18.080	20.737	25.281	36.121	23
24	14.709	14.922	15.116	15.295	16.631	17.577	19.031	21.784	26.499	37.779	24
25	15.519	15.739	15.939	16.125	17.505	18.483	19.985	22.833	27.720	39.437	25
26	16.334	16.561	16.768	16.959	18.383	19.392	20.943	23.885	28.941	41.096	26
27	17.153	17.387	17.601	17.797	19.265	20.305	21.904	24.939	30.164	42.755	27
28	17.977	18.218	18.438	18.640	20.150	21.221	22.867	25.995	31.388	44.414	28
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074	29
30	19.637	19.891	20.123	20.337	21.932	23.062	24.802	28.113	33.840	47.735	30
31	20.473	20.734	20.972	21.191	22.827	23.987	25.773	29.174	35.067	49.395	31
32	21.312	21.580	21.823	22.048	23.725	24.914	26.746	30.237	36.295	51.056	32

Table 10-1 Erlang table

STEP 2: NOMINAL CELL PLAN

A nominal cell plan can be produced from the data compiled from traffic and coverage analysis. The nominal cell plan is a graphical representation of the network and looks like a cell pattern on a map. Nominal cell plans are the first cell plans and form the basis for further planning.

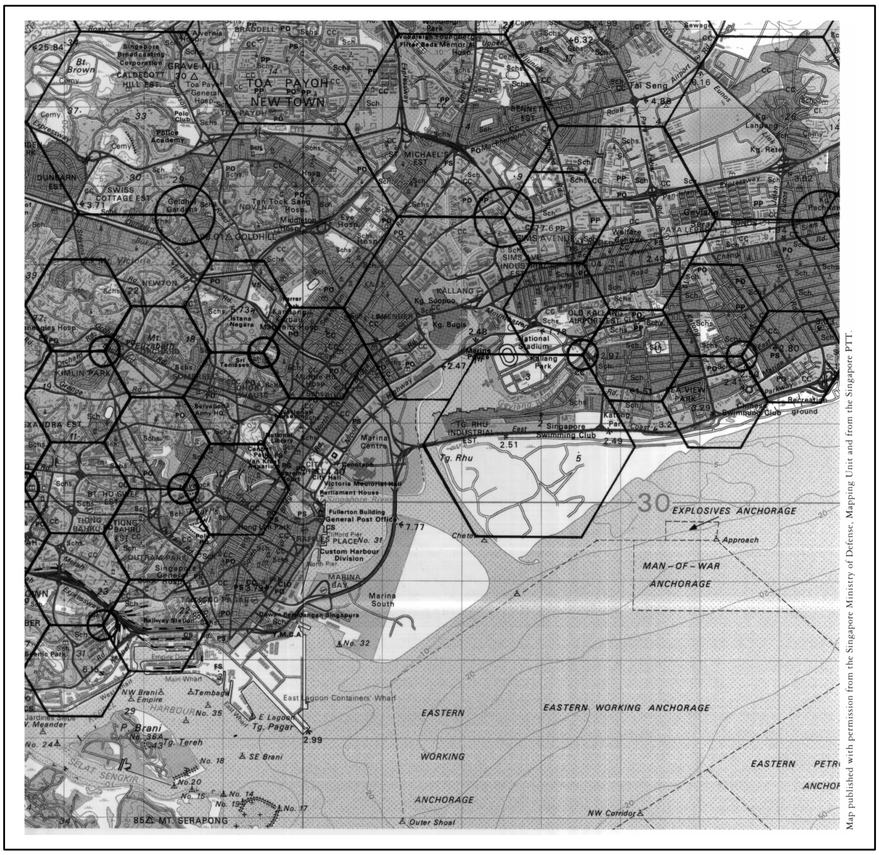


Figure 10-4 Nominal cell plan

Successive planning must take into account the radio propagation properties of the actual environment. Such planning needs measurement techniques and computer-aided analysis tools for radio propagation studies. Ericsson's planning tool, TEst Mobile System (TEMS) CellPlanner, includes a prediction package which provides:

- Coverage predictions
- Composite coverage synthesis
- Co-channel interference predictions
- Adjacent channel interference predictions

TEMS cell planner is a software package designed to simplify the process of planning and optimizing a cellular network. It is based on ASSET by Airtouch.

With TEMS CellPlanner, traffic can be spread around on a map to determine capacity planning. The traffic can be displayed using different colors for different amounts of Erlangs/km^2 or the user can highlight the cells that do not meet the specified GOS.

It is possible to import data from a test MS and display it on the map. TEMS CellPlanner can also import radio survey files which can be used to tune the prediction model for the area where the network is to be planned. Data can also be imported from and exported to OSS.

For example, if there are doubts about the risks of time dispersion at a particular site the following steps could be taken:

- The site location could be changed
- The site could be measured with respect to time dispersion
- The site could be analyzed with a carrier–to–reflection ratio (C/R) prediction tool

Radio Propagation

> ☞ Did you know?
>
> *The antennae of some base stations in Hong Kong are positioned on top of tall buildings, with the antenna at a 45 ° angle to the building to ensure street coverage.*

In reality, hexagons are extremely simplified models of radio coverage patterns because radio propagation is highly dependent on terrain and other factors. The problems of path loss, shadowing and multipath fading all affect the coverage of an area. For example, time dispersion is a problem caused by the reception of radio signals which are reflected off far away objects. The carrier-to-reflection (C/R) ratio is defined as the ratio between the direct signal (C) and the reflected signal (R).

Also, due to the problem of time alignment the maximum distance a MS can be from a BTS is 35 km. This is the maximum radius of a GSM cell. In areas where large coverage with small capacity is required, it is possible to allocate two consecutive TDMA time slots to one subscriber on a call. This enables a maximum distance from the BTS of 70km.

Frequency Re–use

Modern cellular networks are planned using the technique of frequency re-use. Within a cellular network, the number of calls that the network can support is limited by the amount of radio frequencies allocated to that network. However, a cellular network can overcome this constraint and maximize the number of subscribers that it can service by using frequency re-use.

Frequency re-use means that two radio channels within the same network can use exactly the same pair of frequencies, provided that there is a sufficient geographical distance (the frequency re-use distance) between them so they will not interfere with each other. The tighter the frequency re-use plan, the greater the capacity potential of the network.

Based on the traffic calculations, the cell pattern and frequency re-use plan are worked out not only for the initial network, but so that future demands can be met.

Interference

Co-channel Interference (C/I)

Cellular networks are more often limited by problems caused by interference rather than by signal strength problems. Co-channel interference is caused by the use of a frequency close to the exact same frequency. The former will interfere with the latter, leading to the terms interfering frequency (I) and carrier frequency (C).

The GSM specification recommends that the carrier-to-interference (C/I) ratio is greater than 9 decibels (dB). However, Ericsson recommends that 12 dB be used as planning criterion.

This C/I ratio is influenced by the following factors:

- The location of the MS
- Local geography and type of local scatters
- BTS antenna type, site elevation and position

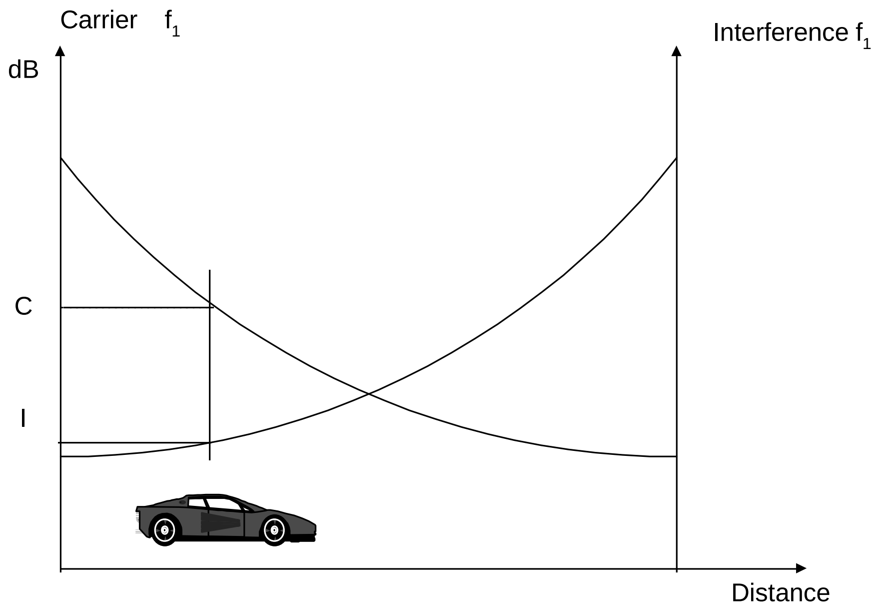


Figure 10-5 Co-channel interference

Adjacent channel interference (C/A)

Adjacent frequencies (A), that is frequencies shifted 200kHz from the carrier frequency (C), must be avoided in the same cell and preferably in neighboring cells also. Although adjacent frequencies are at different frequencies to the carrier frequency they can still cause interference and quality problems.

The GSM specification states that the carrier-to-adjacent ratio (C/A) must be larger than -9dB. Ericsson recommends that higher than 3 dB be used as planning criterion.

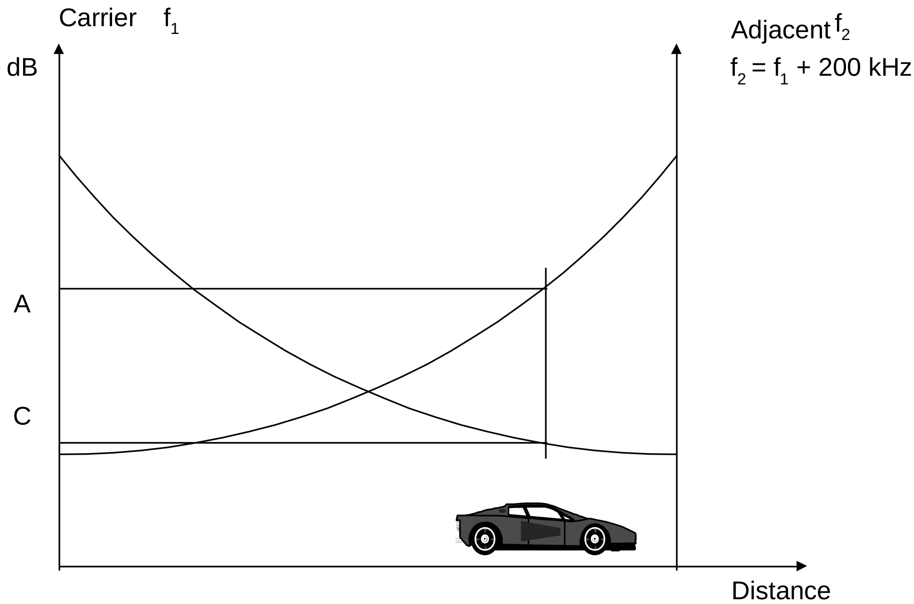


Figure 10-6 Adjacent channel interference

By planning frequency re-use in accordance with well established cell patterns, neither co-channel interference nor adjacent channel interference will cause problems, provided the cells have homogenous propagation properties for the radio waves. However, in reality cells vary in size depending on the amount of traffic they are expected to carry. Therefore, real cell plans must be verified by means of predictions or radio measurements to ensure that interference does not become a problem. Nevertheless, the first cell plan based on hexagons, the nominal cell plan, provides a good picture of system planning.

Clusters

Groups of frequencies can be placed together into patterns of cells called clusters. A cluster is a group of cells in which all available frequencies have been used once and only once.

Since the same frequencies can be used in neighboring clusters, interference may become a problem. Therefore, the frequency re-use distance must be kept as large as possible. However, to maximize capacity the frequency re-use distance should be kept as low as possible.

The re-use patterns recommended for GSM are the 4/12 and the 3/9 pattern. 4/12 means that there are four three-sector sites supporting twelve cells using twelve frequency groups.

☞ Did you know?

Other frequency re-use patterns such as 7/21, with a long frequency re-uses distance, are recommended for networks which are sensitive to interference, for example analogue networks.

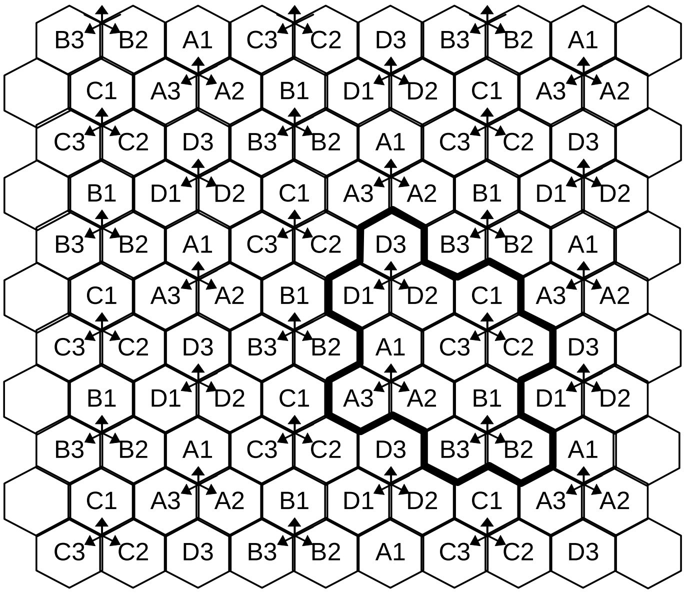


Figure 10-7 4/12 cell pattern

The 4/12 cell pattern is in common use by GSM network operators.

Below is an example of how a network operator could divide 24 available frequencies (1-24) into a 3/9 cell pattern:

Frequency group	A1	B1	C1	A2	B2	C2	A3	B3	C3
Channels	1	2	3	4	5	6	7	8	9
	10	11	12	13	14	15	16	17	18
	19	20	21	22	23	24			

Table 10-2 24 frequencies in a 3/9 cell pattern

In the 3/9 cell pattern there are always 9 channels separating each frequency in a cell. However, when compared with the 4/12 pattern, cells A1 and C3 are neighbors and use adjacent frequencies (10 and 9 respectively). Therefore, the C/A interference will increase. In this case, an operator may use frequency hopping which, if planned correctly, could reduce the possibility of such adjacent channel interference .

☞ Did you know?

Mobile networks based on non-GSM standards may find it difficult to use the 3/9 pattern due to its tight frequency re-use. The modulation technique in GSM enables greater tolerance of such interference.

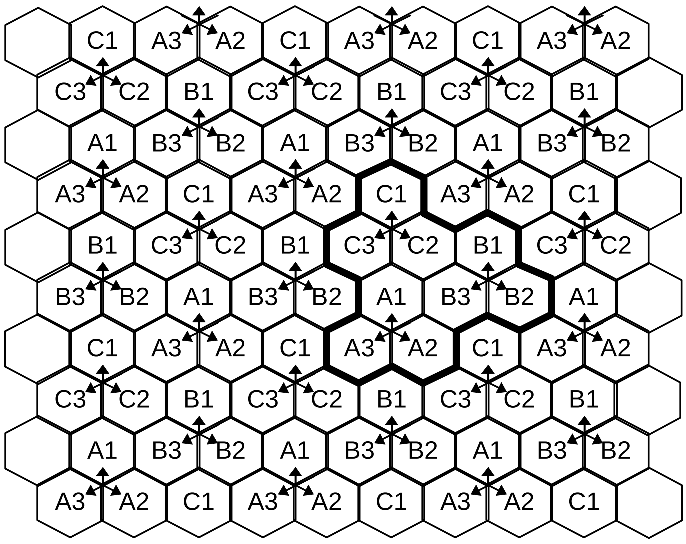


Figure 10-8 3/9 cell pattern

In a real network the allocation of channels to cells will not be as uniform as in table 6-2 above, as some cells will require more channels and some will require less. In this case, a channel may be taken from a cell with low traffic load and moved to one with a higher traffic load. However, in doing so, it is important to ensure that interference is still minimized.

STEP 3: SURVEYS

Once a nominal cell plan has been completed and basic coverage and interference predictions are available, site surveys and radio measurements can be performed.

Site Surveys

> ☞ Did you know?
>
> *One of the most expensive aspects of cellular network operation is payment of rent for sites, e.g. hotel rooms. Great care is often taken to ensure public support for sites. (e.g. In California some BTSs are hidden within fibre glass palm trees.)*

Site surveys are performed for all proposed site locations. The following must be checked for each site:

- Exact location
- Space for equipment, including antennas
- Cable runs
- Power facilities
- Contract with site owner

In addition, the radio environment must be checked to ensure that there is no other radio equipment on site that causes problems.

Radio Measurements

Radio measurements are performed to adjust the parameters used in the planning tool to reality. That is, adjustments are made to meet the specific site climate and terrain requirements. For example, parameters used in a cold climate will differ from those used in a tropical climate.

A test transmitter is mounted on a vehicle, and signal strength is measured while driving around the site area. Afterwards, the results from these measurements can be compared to the values the planning tool produces when simulating the same type of transmitter. The planning parameters can then be adjusted to match the actual measurements.

STEP 4: SYSTEM DESIGN

Once the planning parameters have been adjusted to match the actual measurements, dimensioning of the BSC, TRC and MSC/VLR can be adjusted and the final cell plan produced. As the name implies, this plan can then be used for system installation.

New coverage and interference predictions are run at this stage, resulting in Cell Design Data (CDD) documents containing cell parameters for each cell.

STEP 5 AND 6: SYSTEM IMPLEMENTATION AND TUNING

Once the system has been installed, it is continuously monitored to determine how well it meets demand. This is called system tuning. It involves:

- Checking that the final cell plan was implemented successfully
- Evaluating customer complaints
- Checking that the network performance is acceptable
- Changing parameters and taking other measurements, if necessary

TEst Mobile Systems (TEMS)

TEst Mobile Systems (TEMS) is a testing tool used to read and control the information sent over the air interface between the BTS and the MS. It can be used for radio coverage measurements. In addition, TEMS can be used both for field measurements and post processing.

TEMS consists of a MS with special software, a portable Personal Computer (PC) and optionally a Global Positioning System (GPS) receiver.

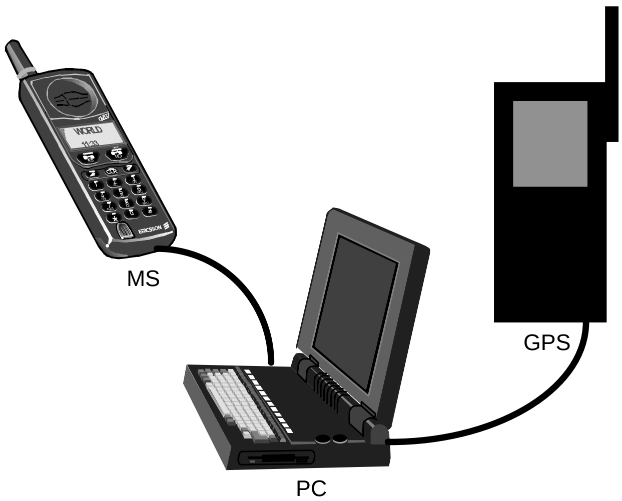


Figure 10-9 TEMS Hardware

The MS can be used in active and idle mode. The PC is used for presentation, control and measurements storage.

The GPS receiver provides the exact position of the measurements by utilizing satellites. When satellite signals are shadowed by obstacles, the GPS system switches to dead reckoning. Dead reckoning consists of a speed sensor and a gyro. This provides the position if the satellite signals are lost temporarily.

TEMS measurements can be imported to TEMS CellPlanner. This means that measurements can be displayed on a map. For example, this enables measured handovers to be compared with the predicted cell boundaries. Measurements can also be downloaded to spreadsheet and word processing packages.

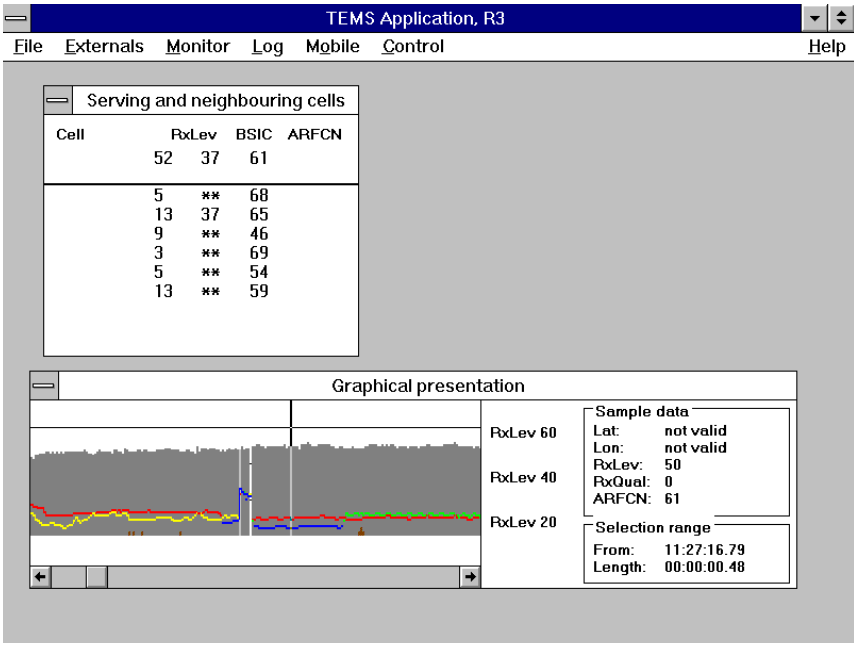


Figure 10-10 TEMS graphical user interface

STEP 7: SYSTEM GROWTH/CHANGE

Cell planning is an ongoing process. If the network needs to be expanded because of an increase in traffic or because of a change in the environment (e.g. a new building), then the operator must perform the cell planning process again, starting with a new traffic and coverage analysis.

HIERARCHICAL CELL STRUCTURES (HCS)

☞ Did you know?

It may not be feasible for fast moving MSs to use the lowest layer as many handovers will occur. In this case, Ericsson's GSM systems will handover the call to a higher layer, resulting in less handovers.

The feature Hierarchical Cell Structures (HCS) divides the cell network into two or three layers. The higher layers are used for large cells and the lower layers for small cells. For example, large cells are added to a cellular network to provide coverage at coverage gaps. The large cells then act as umbrella cells for medium sized cells. Additionally, micro cells can be added to a cellular network in order to provide hot spot capacity. The medium sized cells then act as umbrella cells for the micro cells.

The different cell layers can be seen as a priority designation with the lower layer as the highest priority. Thus, when selecting a BCCH carrier, an MS will choose an acceptable signal in as low a layer as possible. HCS makes it possible to pass between cell layers in a controlled way, facilitating dimensioning and cell planning in cell structures where large and small cells are mixed.

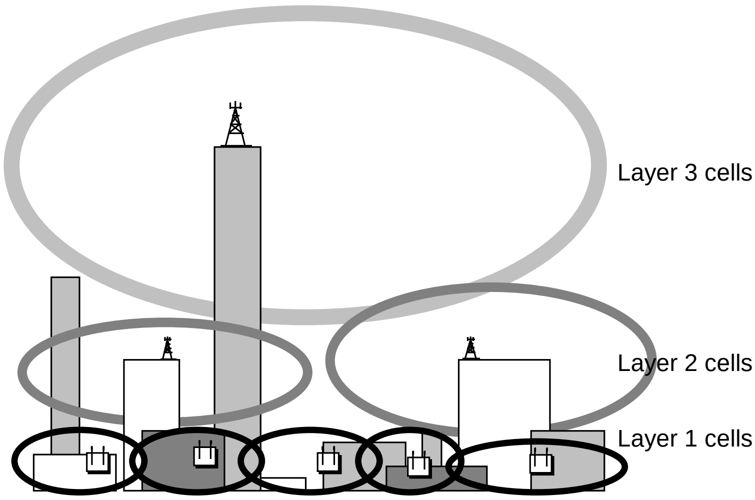


Figure 10-11 Three layers of cells

OVERLAID/UNDERLAID SUBCELLS

The overlaid/underlaid subcells feature provides a way to increase the traffic capacity in a cellular network without building new sites.

A set of channels in a BTS are assigned to transmit at a certain power level. These are the underlaid subcell channels. Another set of channels in the same BTS are assigned to transmit at a lower power level. These are the overlaid subcell channels.

The feature makes it possible to use two different frequency re-use patterns: one pattern for overlaid subcells and another pattern for underlaid subcells. Each overlaid subcell serves a smaller area than the corresponding underlaid subcell and the frequency re-use distance for the overlaid subcells can therefore be made shorter. Consequently, the number of frequencies per cell can be increased providing an increased traffic capacity in the cellular network.

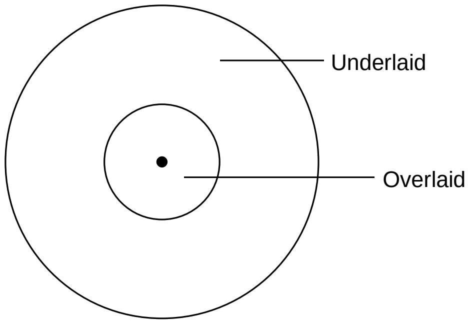


Figure 10-12 Overlaid/underlaid subcells

OSS and TMOS

Chapter 11

This chapter is designed to provide the student with an overview of the operation and maintenance systems used in Ericsson GSM networks. The chapter describes the functions and features of OSS, TMOS, SOG and BGW.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the Telecommunications Management and Operations Support philosophy
- Describe the functions of Operations and Support System
- Describe the architecture of Operations and Support System
- Describe the implementation of the Service Order Gateway
- Describe the implementation of the Billing Gateway

Intentionally Blank

11 OSS and TMOS

Table of Contents

Topic	Page

Intentionally Blank

INTRODUCTION

Mobile networks require an efficient and easy-to-use operation and maintenance (O&M) system because:

- Mobile networks are extremely complex
- The structure of a mobile network is often altered to allow for extension and optimization of the network
- Mobile network operators demand the reduction of O&M costs

Ericsson's Operation and Support System (OSS) provides an efficient and easy-to-use O&M system.

OSS is an application within the Telecommunications Management and Operations Support (TMOS) product family. This chapter describes OSS and TMOS.

TMOS

TELECOMMUNICATIONS MANAGEMENT NETWORK (TMN)

TMOS is defined as the Ericsson management and operations support solution for public telecommunications networks.

TMOS has been developed in accordance with Telecommunications Network Management (TMN) standards. The TMN standardization effort involves several organizations, such as the International Telecomunications Union (ITU), ANSI, ETSI and the International Standards Organisation (ISO). TMN specifies an O&M network which is:

- Centralized
- Separate from the telecommunications network
- Connected to the telecommunications network via standardized interfaces

One of the basic principles of the TMN system architecture is the network model concept. This means that the physical network elements (NEs) such as MSCs are represented in a model of the network. Databases are used to store data about NEs.

TMOS STRUCTURE AND FUNCTIONS

TMOS consists of a “family” of management application systems for different telecom networks. For example,

- Service Management Application System (SMAS) for Intelligent Networks (IN)
- eXchange Management system (XM) for switched networks
- Cellular Management Application System (CMAS) for cellular mobile networks

All TMOS application systems are built on the TMOS PlatForm (TPF). The TPF comprises all hardware and software for interaction with a telecommunications network. The platform is a multi-computer system based on industrial standards, such as UNIX.

The TMOS Development Platform (TDP) makes it possible for the operator to create market specific functions using the C++ Application Programming Interface (API).

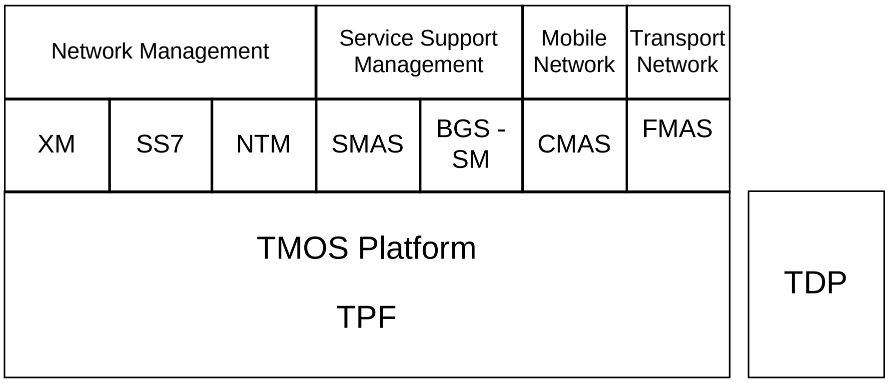


Figure 11-1 The structure of TMOS

Typically, TMOS resides in several independent computers that are connected over a Local Area Network (LAN) or Wide Area Network (WAN).

TMOS communication with the NEs is based on the Open System Interconnection (OSI) model. OSS is connected directly, or via the PSTN, to the MSCs, HLRs, BSCs and AUC/EIRs. Communication with BTSs is provided via BSCs. Additionally, other Ericsson certified nodes are supported. These include the MXE, MIN nodes and the DXX.

TMOS performs the following functions in line with TMN:

- Configuration management
- Fault management
- Performance management
- Security management
- Accounting management

ADVANTAGES OF TMOS

Input to the development of TMOS has largely consisted of demands from operators for a network administration system which will give lower administration and personnel costs. The most significant advantages of TMOS are:

- It gives the user the ability to remotely and centrally control NEs, subscribers, traffic, etc.
- In a large network, optimal performance is impossible to achieve without a support system like TMOS
- TMOS is easy to use, employing menus, forms and graphics to interact with the operators
- New TMOS functions are continuously being developed which means that the system adapts to new and changing conditions and requirements

OSS

OSS STRUCTURE AND FUNCTIONS

OSS is the product name for Ericsson’s O&M system for cellular networks. OSS consists of XM features and CMAS features built on top of the TPF.

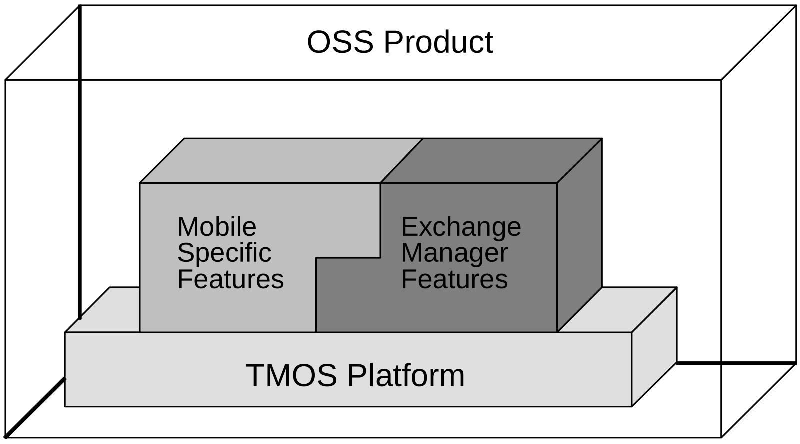


Figure 11-2 Structure of OSS

The GSM network contains many NEs which may be spread over a large geographical area. OSS enables centralized, remote controlled O&M of all NEs in a uniform and user-friendly manner. OSS is physically implemented on a LAN consisting of servers and workstations. The functions provided by the graphical user interfaces of OSS are translated into commands, which are then sent to a NEs.

Although the GSM network is complex, OSS is easy to use. It offers menus, windows and graphics with which the operators can interact. No long, complicated commands are needed to operate the system.

NMC AND OMC

According to GSM specifications, a system such as OSS can be seen as a two level management function that provides centralized control of the network. The levels are:

- Network Management Center (NMC)
- Operation and Maintenance Center (OMC)

In order to achieve increased overall efficiency, NMC staff can concentrate on long-term system-wide issues, whereas personnel at the OMCs concentrate on short-term regional issues.

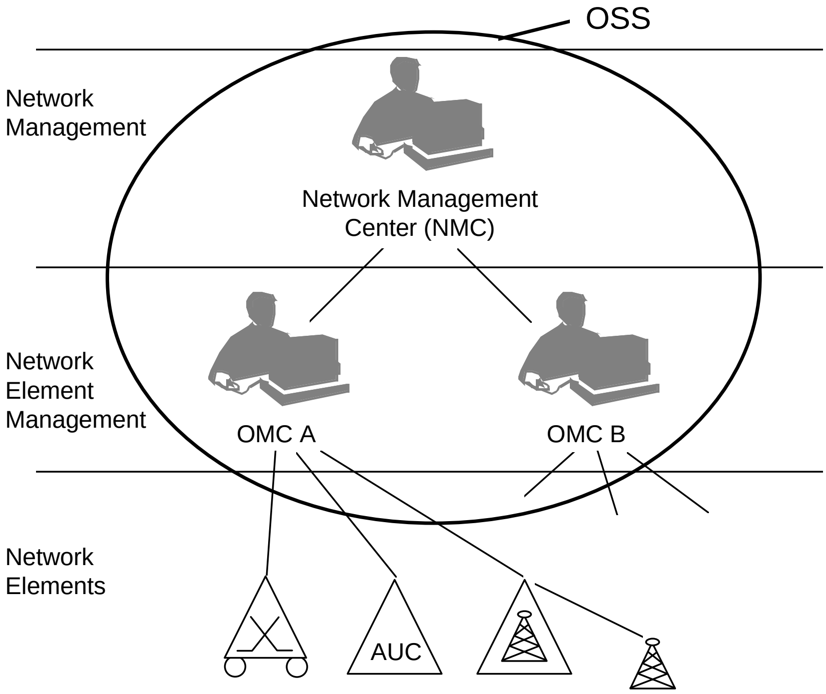


Figure 11-3 NMC and OMC

In OSS, the OMC and NMC functions can be combined in the same physical installation or implemented at different sites.

OSS APPLICATIONS

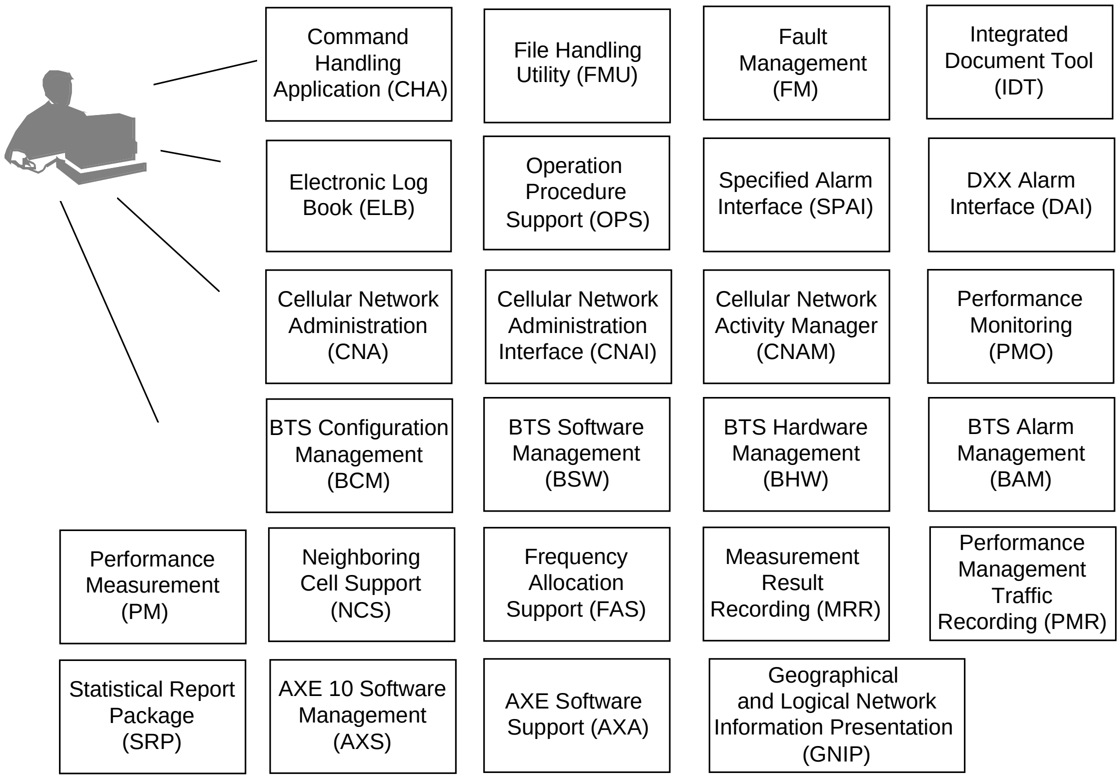


Figure 11-4 OSS applications

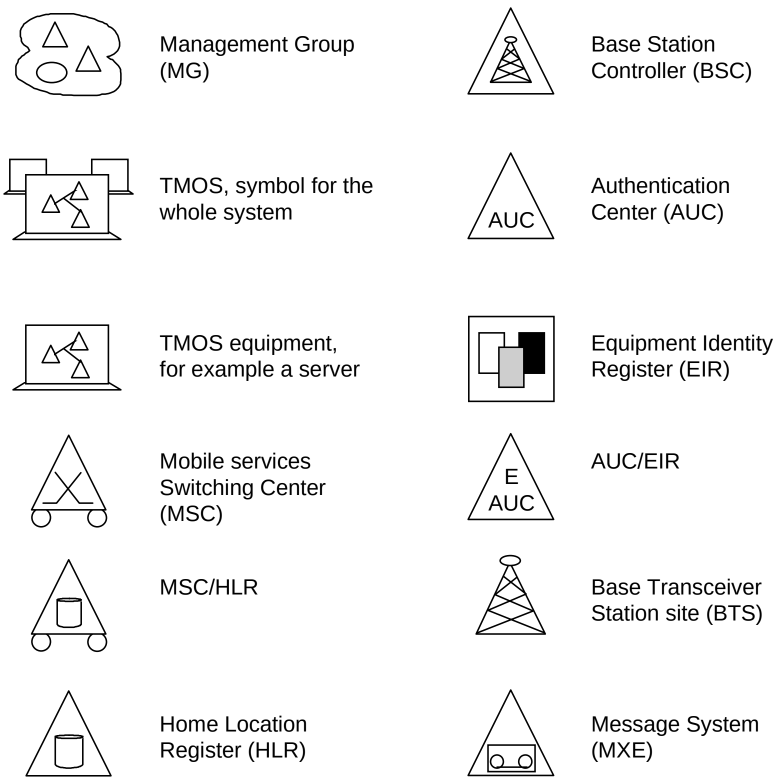


Figure 11-5 OSS symbols

CONFIGURATION MANAGEMENT APPLICATIONS

Cellular Network Administration (CNA)

Cellular Network Administration (CNA) is an application within OSS that is used to:

- Plan and operate the cellular part of the GSM network
- Plan major future changes off-line
- Implement new cells or new parameter values in the network

CNA is one of the most powerful OSS applications. It registers new cells and maintains cell parameters in an efficient and controlled manner.

☞ Did you know?

OSS can support networks that have up to 5,000 cells. Each cell has approx. 200 parameters. Therefore, OSS can handle up to 1 million cell parameters.

In large PLMNs the amount of network data is huge. CNA provides an efficient tool for handling cell data consisting of approximately 200 parameters per cell. Most of these parameters identify the cell and control the cell behavior.

The operator can edit cell parameters and cell related parameters through a table mode, a menu mode and a geographical mode that displays cell shapes and cell parameters on top of map layers.

CNA Network Model Structure and Areas

Network structure and parameters change over time. Operators are not just interested in the current set-up, but also interested in information about previous set-ups and possible future ones. Therefore, OSS provides the following three different views of the network:

- The **valid area** represents the current cellular network. That is, it provides current information about the cell parameters in the network. There is only one valid area corresponding to each cellular network. The valid area is used when retrieving information about current network parameter values and as a basis when creating a new planned area.
- **A planned area** represents planned changes in the cellular network. This area is used for off line planning of large network changes. It is locked and connected to one user at a time.

- **A fallback area** is a snapshot of the valid area at a specific moment and reflects an historical view of the network. A fallback area can be created for back-up purposes before an update to the network takes place. It is also possible to create a new planned area from a fallback area.

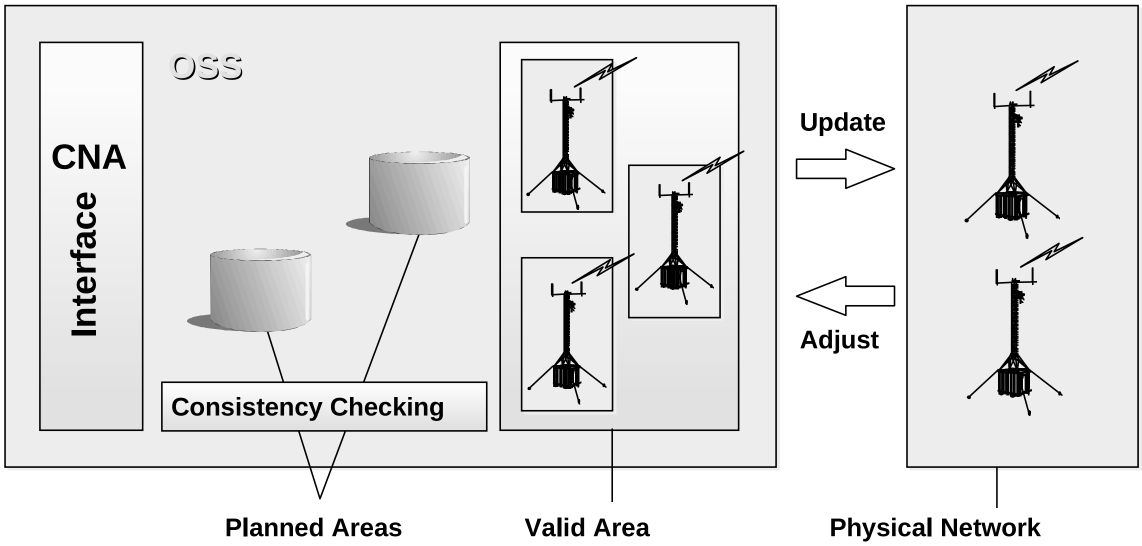


Figure 11-6 CNA area concept

Consistency check

The CNA consistency check automatically performs separate validity checks on the network's parameters. It ensures that the values of parameters are valid and that they are within predefined intervals. All parameters are checked against parameter consistency rules. The consistency check can be performed on:

- Area level (Valid and Planned Area)
- MSC
- BSC
- Cell level

A consistency report generates warnings but does not prevent a faulty value from being entered. Consistency checks can be performed on all parameters or only on new parameters.

CNA Interface (CNAI)

The Cellular Network Administration Interface (CNAI) tool serves as an import and export interface to the CNA application. It provides easy exchange of information between the OSS and an external system. For example, CNAI could be used to transfer a file of cell parameter data from the external cell planning application, EET, into the OSS. Otherwise, the cell parameter data from EET would have to be manually input using CNA.

Graphical Cell Configuration (GCC)

Graphical Cell Configuration (GCC) is a geographical presentation tool which displays cells on maps. Layers of maps can be displayed on top of each other, e.g. road maps on top of topological maps. The cells can be displayed with approximated cell shapes or hexagon cell shapes.

GCC can be used together with menus to display the actual outcome of cell introductions or parameter changes. GCC can also be used to display cell parameters such as estimated cell coverage, cell frequencies, neighbor relations, etc, in a user friendly way. For immediate understanding, frequency reuse and neighbor relations are better displayed in a geographical presentation than in a list mode.

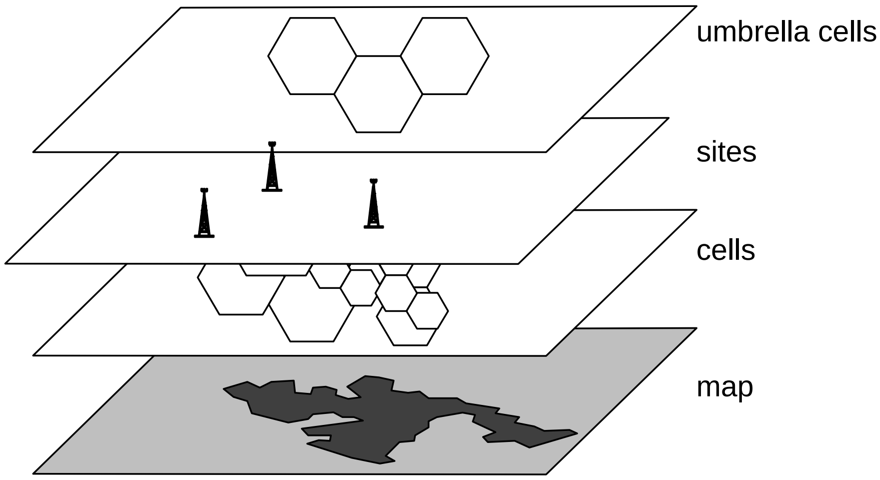


Figure 11-7 Map layer structure in GCC

BTS Management Family

The BTS Management Family application supports an operator's daily BTS-related operations in the network. It can be distinguished by its use of a graphical browser which shows the internal base station structure. The concept is based on a "plug-in" approach, whereby new features can be added to the family and used in the same manner as all other features.

The graphical browser enables the operator to navigate through the BTS/Transceiver Remote Interface (TRI) managed object structure in a consistent and efficient way.

The BTS Management Family consists of:

BCM:	BTS Configuration management
BSW:	BTS SoftWare management
BHW:	BTS HardWare management
BAM:	BTS Alarm Management

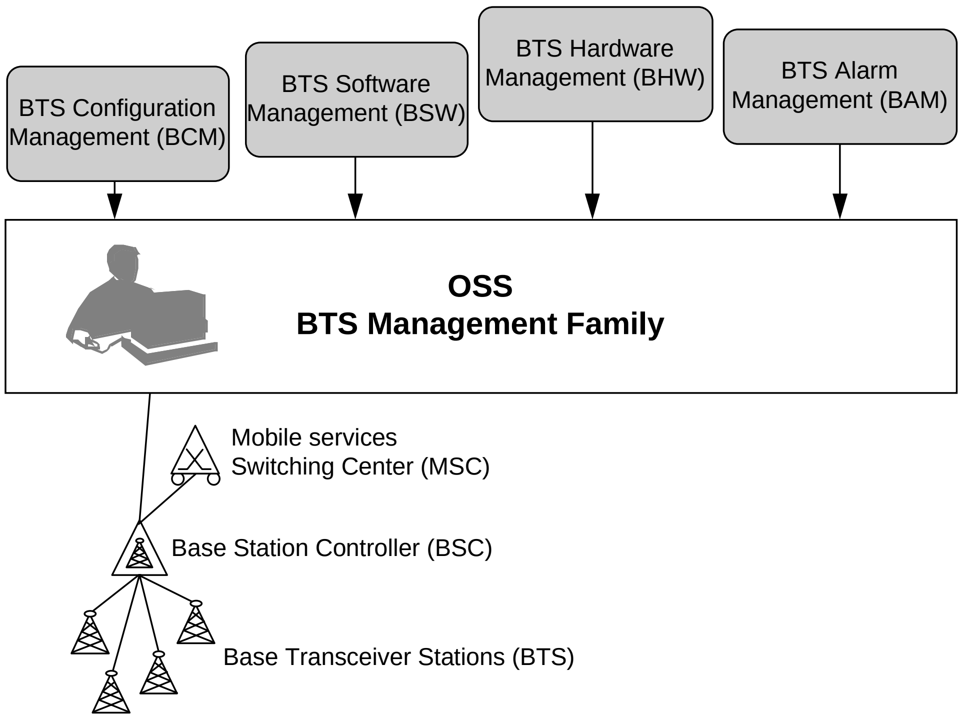


Figure 11-8 BTS Management Family

BTS Configuration Management (BCM)

Operating companies must be able to ensure that the planning, maintenance and expansion of mobile networks is accurately and easily carried out. The BTS Configuration Management (BCM) application offers a centralized interface to handle BTS configuration. BCM provides the operator with a user friendly view of the BTS/TRI managed objects and their different parameters throughout the network.

BCM helps the operator in the following areas:

- Introduction of a new BTS. When a new BTS is added to the system, BTS related data must be entered by the operator. This includes software, hardware, future expansion options, etc. The browser enables the operator to easily navigate through the BTS structure and fill in the appropriate data values.
- Reconfiguration of an existing BTS. BTS reconfiguration follows the same procedures as for a new BTS. In this case, only the new data values are entered by the operator.
- Servicing of a BTS. The operator has the ability to enable or disable the entire BTS or subordinate parts of the BTS to perform network service. From the browser, the user may block individual boards of a BTS structure all the way up to the entire BTS. Deblocking is also possible.

BTS SoftWare management (BSW)

BTSs are equipped with a large number of different software units. Often, the software needs to be updated due to new versions, etc. To facilitate the maintenance of a great number of BTSs spread over a large area, it is essential to have a centralized tool for the installation and upgrading of software.

The BTS SoftWare management (BSW) feature caters for the downloading and handling of BTS related software in a centralized manner. Software can be read into the OSS and stored there for subsequent transfer to the BTS via the BSCs.

BSW enhances the operator’s control over BTS related software, and reduces the overall risk of introducing errors when updating or maintaining the software. BSW includes functions for:

- Storing and administering BTS software in the OSS
- Retrieving all relevant information about the stored packages
- Loading BTS software, either directly or via a schedule, and logging details
- Displaying BTS software status
- Displaying BTS software history
- Automatically updating software register
- Providing search capabilities

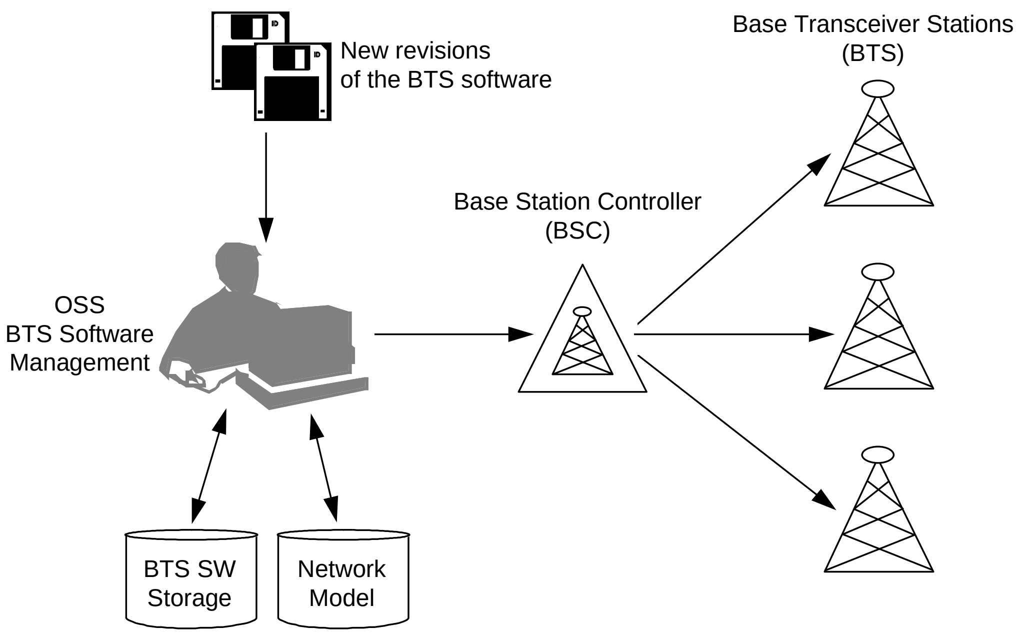


Figure 11-9 Distribution of new revisions of BTS software

BTS HardWare management (BHW)

The BTS HardWare management (BHW) application provides the operator with a centralized register of the installed BTS hardware.

BHW enables the operator to perform the following tasks:

- Audit the installed BTSs
- Search and compare on various BTS criteria
- Compare installed hardware

BHW enables the operator to easily set up cost effective measures for parts cataloguing, inventory, statistics etc. For example, data from BHW can be passed to external systems responsible for spare parts inventory and maintenance repair centers. Even installation history data can be retrieved on each specific item.

BTS Alarm Management (BAM)

The BTS Alarm Management (BAM) application provides support for handling the alarm reporting function in the BSC. This allows the operator to configure the BTS alarm reporting and make the fault finding process easier by filtering and customizing the alarm flow.

BAM contains functions for:

- Configuration of BTS alarm reporting
- Interworking with fault management
- BTS error log administration
- Retrieving suppressed alarms

AXE Software management (AXS)

The AXE Software management (AXS) application provides the operator with a set of administrative tools for loading and handling software revisions in Ericsson's AXE based NEs (HLR, MSC, TRC and BSC) in a centralized manner. AXS uses a browser similar to eth BTS family browser to present different NEs. A database used for storing information about software gives the operator a good overview of the software revisions in the NEs.

The major functions of AXS are to:

- Review the software revisions in order to maintain consistency between NEs
- Download new or updated software to different exchanges
- Upload software units and program corrections

FAULT MANAGEMENT APPLICATIONS

Fault management is referred to as the tasks which are necessary to supervise NEs and to take action on alarms. The fault management tools in OSS are described below.

Network Alarm Status Presentation

A common operator task is to supervise the network alarm status and to act upon incoming alarms. All alarms, including internal and external alarms, can be routed to OSS. NE alarms will be forwarded to OSS if the alarms in the NE are defined to be routed to the OSS and if the alarms are defined in the OSS as expected output from the NE.

Depending on alarm severity and operator defined parameters, an alarm bell can be activated. It is also possible to filter alarms so that only certain alarms are presented. The alarms are presented on a graphical map of the operating area, called Network Status Presentation (NSP). The alarms are displayed next to the affected NE. Different symbols are used to depict different alarm categories:

Critical	Action must be taken immediately
Major	Action must be taken as soon as possible
Minor	Action should be taken when there is time, or the situation should be observed
Warning	Take corrective action during routine maintenance
Indeterminate	An alarm has been generated for which there is no alarm severity defined in the system

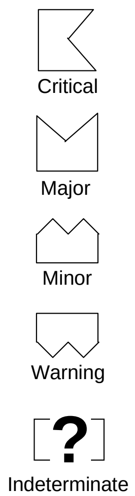


Figure 11-10 Alarm symbols

Alarm List Presentation (ALP)

Alarm List Presentation (ALP) provides information about how many alarms there are and where they are located. An operator can open an alarm expansion window to find the complete alarm information. An operator may also attach comments to incoming alarms, which are then stored with the alarm. The operator can retreive these with the information related to each alarm.

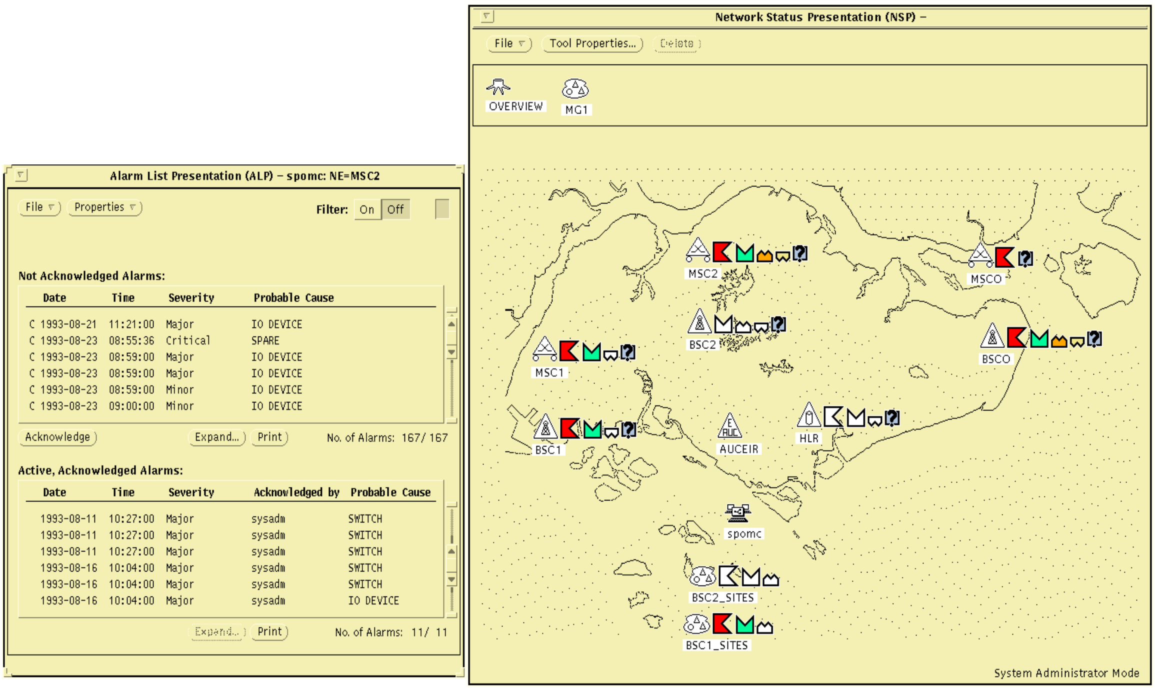


Figure 11-11 Alarm list presentation

Alarm Log Presentation

All alarm records are stored in an alarm log. The alarm log provides a history of alarm information for a selected NE or a management group. Alarm records are stored with the following attributes:

- Event time
- Alarm type
- Alarm severity
- Probable cause
- Alarm slogan
- Operator identity

In addition, these attributes can be used as search criteria for searching the alarm log. This is useful when the user is looking for specific types of faults which have previously occurred.

Command Handling (CHA)

Command HAndling (CHA) enables an OSS user to send Man-Machine Language (MML) commands to a NE. MML commands can be sent individually or as a block. It is also possible to store several commands in a command file and execute the file or parts of it whenever needed. All executed commands are logged and can be retrieved and displayed from the command log mainly for security and trouble shooting. The results of the commands can be routed to all connected user interfaces or to a file.

CHA allows OSS to be connected directly to several NEs at the same time using multiple windows. CHA windows are used with other fault management applications to act directly on incoming alarms.

PERFORMANCE MANAGEMENT APPLICATIONS

There are six performance management functions within OSS:

- Performance Measurement Data Collection and Data Processing
- Statistical Reports Package (SRP)
- Performance Management traffic Recording (PMR)
- Mobile Results Recording (MRR)
- Frequency Allocation Support (FAS)
- Neigboring Cell Selection and handling (NCS)

Performance Measurement Application (PMA)

The Performance Measurement Application (PMA) function supports measuring the performance, utilization and availability of the network resources. This feature supports collecting and aggregating data from NEs.

Performance measurements in AXE that are of interest for long term reports are those performed by Operation and Maintenance Subsystem (OMS), and Statistic and Traffic measurement Subsystem (STS).

OMS collects statistics about traffic on routes, distinguishes between traffic types and checks the dispersion of traffic between different routes.

STS collects statistics concerning the network capacity using different types of counters. These results are used for early detection of needs and planning for future improvements.

Statistical Reports Package (SRP)

SRP is a set of reports developed with Ericsson's expertise in network planning and engineering. The reports focus on collecting and presenting data used for managing, planning, and engineering a cellular network. The reports are divided into three categories, giving different target groups reports especially designed for their needs:

- Management reports
- Planning and engineering reports
- Operation reports

Performance Management traffic Recording (PMR)

Performance Management traffic Recording (PMR) functions provide an easy to use radio network behavior analysis tool.

PMR is intended to be used for detailed performance analysis when seeking the reason behind identified problems. Such problems can be an increased rate of dropped calls as identified by statistics or customer complaints. Also, specific customers complaining about insufficient service quality can be traced to identify probable causes.

PMR supports traffic recording of three types:

- **Mobile Traffic Recording (MTR):** This provides measurement reports for identified mobiles (up to 64). This gives the operator the possibility to trace certain mobiles to identify the causes of problems. It can also be used to study network behavior in different situations by tracing measurements from test mobiles. PMR takes short term measurements on individual IMSIs.

- **Cell Traffic Recording (CTR):** This gives the operator the possibility to study the network behavior in certain cells by tracing measurements from up to 16 cells at the same time.

- **Channel Event Recording (CER):** The performance of channel allocation functions in the BSC can be studied, and improvements can be identified to increase the capacity and quality of the network.

Mobile Results Recording (MRR)

Mobile Results Recording (MRR) is a graphical tool which supports the supervision of network performance and trouble shooting by enabling the recording of radio characteristics such as:

- Uplink/downlink signal strength
- Uplink/downlink path loss
- Power level used by MS

Frequency Allocation Support (FAS)

The interference level in GSM networks has to be kept to a minimum in order to achieve a high speech quality. Due to increased network complexity, it is difficult to perform frequency planning to increase the capacity without increasing interference levels. Frequency Allocation Support (FAS) is a tool that supports the operator in performing efficient frequency planning so that tighter frequency re-use and less interference levels in the network can be achieved.

The operator can order FAS to perform recordings of the interference levels on up to 150 frequencies in up to 2,000 cells handled by one OSS. Once the recording is complete, the result values are reported to OSS where they are processed and presented to the operator in tabular form or graphically on a map.

Neighboring Cell Support (NCS)

Handovers between cells have to be based on reliable and accurate measurements to keep speech quality high, even near cell borders.

For each cell the operator has to define a list of neighboring cells (BA-list). The MS will measure on these defined neighboring cells and deliver the measurements to the BSC, where an evaluation of the measurements can be made in order to make handover decisions.

Due to the increased complexity of the radio network, it is more difficult to define an optimal list that includes all possible handover cell candidates. Neighboring Cell Support (NCS) supports the operator with this task.

SERVICE ORDER GATEWAY (SOG)

SOG FUNCTIONS

☞ Did you know?

One of Ericsson's SOGs is capable of handling networks with up to 750,000 subscribers and can add up to 100,000 new subscriptions each day.

A network operator requires administrative systems to analyze and manage network information such as customer subscriptions, billing information and for fraud detection. An operator's administrative systems are normally called Customer Administration Systems (CAS). They are complex systems which are often inflexible and costly to adapt to the specific needs of individual network operators.

The Service Order Gateway (SOG) is an Ericsson product which enables CASs to exchange information with network elements such as the HLR which contain service information.

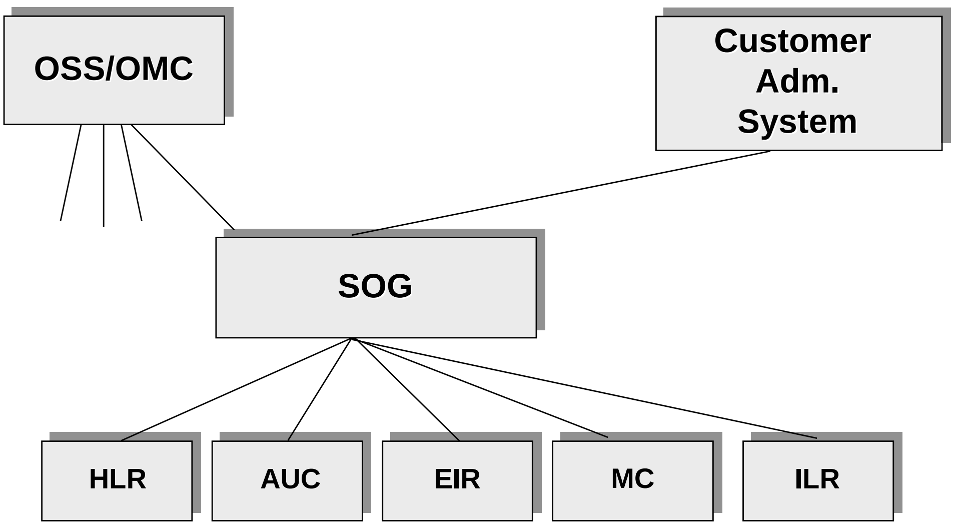


Figure 11-12 Service Order Gateway (SOG)

SOG IMPLEMENTATION

In Ericsson's GSM systems the SOG is Unix-based. It contains a user-friendly GUI to enable access to the required network nodes and CASs. It can be connected to a maximum of 8 different CASs. For operation and maintenance of the SOG, it can be connected to OSS.

BILLING GATEWAY (BGW)

BGW FUNCTIONS

A Billing GateWay (BGW) collects billing information or Call Data Record (CDR) files from network elements such as MSCs and forwards them to post-processing systems that use the files as input. A BGW acts as a billing interface to the network elements in an Ericsson network and its flexible interface supports adaptation to any new types of network elements.

A BGW is usually connected to the customer administration and billing systems and is handled by the administrative organization. The figure below shows some of the possible billing information required when analyzing a specific call.

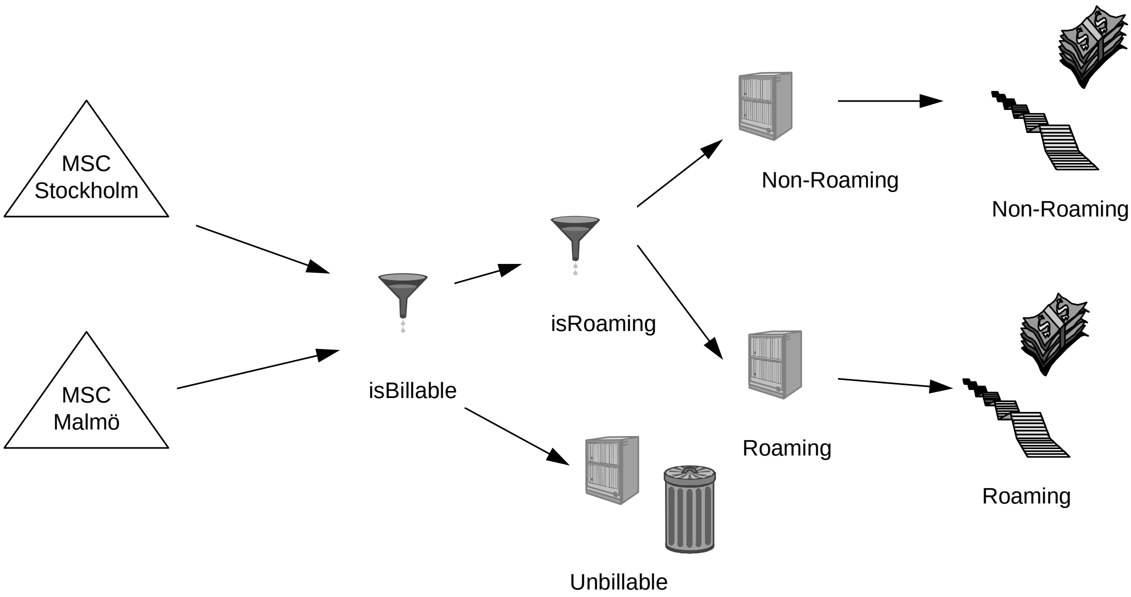


Figure 11-13 Billing information

BGW IMPLEMENTATION

In Ericsson's GSM systems the BGW is implemented using Unix. Like the SOG, it contains a GUI enabling simple management of the billing information. It can also be connected to OSS for operation and maintenance purposes.

Intentionally Blank

Subscriber Services

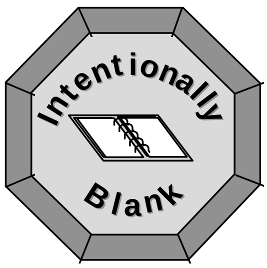
Chapter 12

This chapter is designed to provide the student with an overview of subscriber services. It introduces the main types of subscriber services and describes their functions, features, and specifications.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

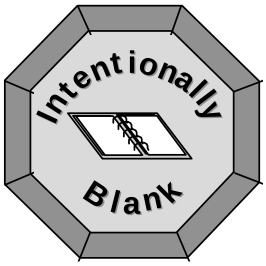
- Describe the types of services available in the network
- Identify one of the teleservices in the network
- Identify one of the bearer services in the network
- Identify one of the supplementary services in the network
- Identify one of the Ericsson innovative services in the network


Intentionally
Blank

12 Subscriber Services

Table of Contents

Topic	Page


Intentionally
Blank

INTRODUCTION

The primary objective of a mobile telephony system is to allow mobile subscribers to communicate effectively. Ericsson's GSM systems provide this by offering a number of different basic telecommunication services.

The service functionality of Ericsson's GSM system improves with each system release. Technical specifications are continuously being developed in order to incorporate new and improved functions into the system.

SERVICE CATEGORIES

There are two main types of telecommunications services:

- **Basic services:** These are services which are available to all susbcribers to a mobile network. For example, the ability to make voice telephone calls is a basic service.
- **Supplementary services:** These are additional services which are available by subscription only. Call forwarding is an example of a supplementary service.

In addition, basic telecommunication services can be divided into two main categories:

- **Teleservices:** A teleservice allows the subscriber to communicate (usually via voice, fax, data or SMS) with another subscriber. It is a complete system including necessary terminal equipment.
- **Bearer services:** A bearer service transports speech and data as digital information within the network between user interfaces. A bearer service is the capability to transfer information and does not include the end-user equipment. Every teleservice is associated with a bearer service. For example, a bearer service associated with the speech telephony teleservice is the timeslot assigned to a call on a TDMA frame over the air interface.

The basic telecommunication services of Ericsson's CME 20 and CMS 40 systems are complemented by a variety of supplementary services such as call barring. Ericsson's GSM systems are also designed to enable operators to differentiate their services from their competitor's services using a technique based on Ericsson's Mobile Intelligent Network (MIN) solutions. For more information on MIN, refer to the appendix titled "Mobile Intelligent Network Services".

BASIC TELECOMMUNICATIONS SERVICES

BEARER SERVICES

Ericsson's GSM systems offer a wide range of bearer services. The DTI supports data services offered by the system. Rates up to 48 kbits/s are possible.

Traffic to PSTN: for data traffic external to PLMN such as internetworking with ISDN or directly to PSTN, the system selects a suitable modem in the DTI.

Traffic to ISDN: an entire set of data communication services with ISDN terminals is available. Unrestricted digital information is transferred and no modem is necessary.

Traffic to Packet Switched Public Data Networks (PSPDN): this packet service supports synchronous data transfers with the PSPDN with rates from 1.2 to 48 kbits/s. With synchronous data transfers a packet mode terminal can be directly connected to the MS. Asynchronous data communication between an MS and a packet switched network is possible via the Packet Assembler-Disassembler (PAD) facility. Rates between 300 and 9600 bits/s are supported.

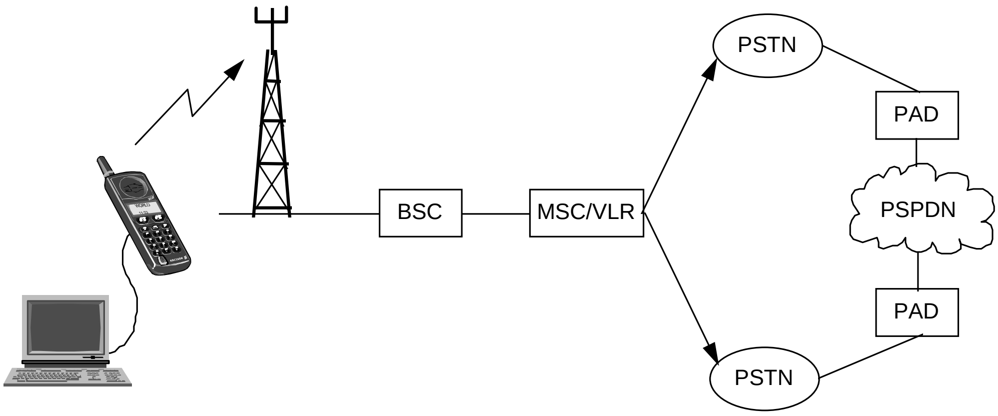


Figure 12-1 Data call in GSM to PSPDN

Traffic to Circuit Switched Public Data Networks (CSPDN): Data communications with a CSPDN is possible via the PSTN or ISDN, depending on the CSPDN-transit network interface.

Traffic to Internet: traditionally, an MSC accessed Internet nodes via existing networks such as the PSTN. However, the direct access function enables an MSC to communicate directly with Internet nodes, thus reducing call set-up time.

ISDN Primary Rate Access (PRA): this function enables an MSC to provide PRA services to subscribers. For example, this could be used by a network operator to offer PABX connection services through the PLMN. In this way the operator can compete directly with PSTN operators for ISDN business subscribers. PRA provides a data rate of up to 2 Mbits/s.

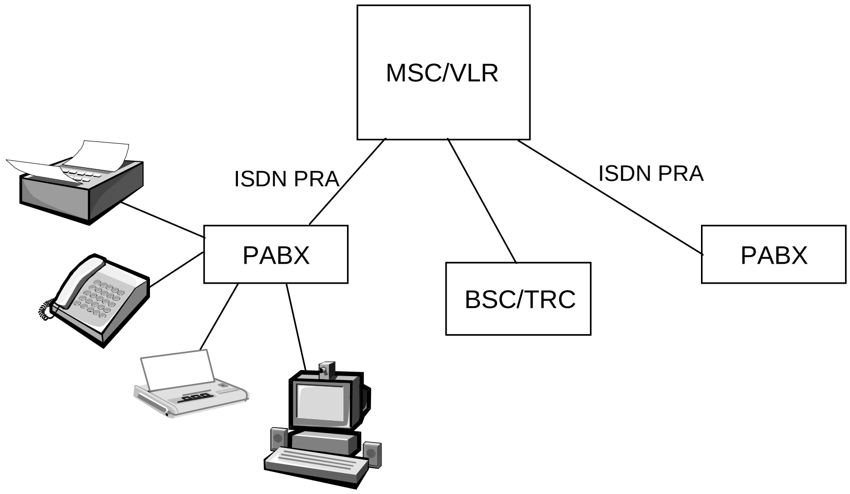


Figure 12-2 ISDN Primary rate access provided by an MSC

TELESERVICES

This section describes the major teleservices supported by Ericsson's GSM systems.

Speech: This is normal telephony (two-way voice communication) with the ability to make and receive calls to/from fixed and mobile subscribers worldwide. This is the most fundamental service offered.

Emergency calls: The emergency call function enables a subscriber to make an emergency call by pressing a predefined button or by using the emergency number. With an emergency area origin identifier, the call is automatically routed to the emergency center nearest to the subscriber. Emergency calls can be made by a subscriber without a valid SIM-card.

The emergency number in GSM 900 & 1800 is 112 and in GSM 1900 it is 911.

Facsimile group 3: GSM supports International Telecommunications Union (ITU) group 3 facsimile. Because standard fax machines are designed to be connected to a telephone using analog signals, a special fax converter is connected to the exchange. This enables a connected fax to communicate with any analog fax in the fixed network.

Dual Tone Multi Frequency (DTMF): This is a tone signaling facility which is often used for various control purposes, such as remote control of answering machines and interacting with automated telephone services.

Alternative Speech/Fax: This service allows the subscriber to alternate between speech and fax within one call setup. The subscriber can start the call either with speech or fax and then alternate between the two call types. The subscriber can switch several times within the same call.

Short Message Services (SMS): This service allows simple text messages consisting of a maximum of 160 alphanumeric characters to be sent to or from an MS.

If the MS is switched off, or has left the coverage area, the message is stored in a Short Message Service Center (SMS-C). When the mobile is switched on again or has re-entered the network coverage area, the subscriber is informed that there is a message. This function guarantees that messages are delivered.

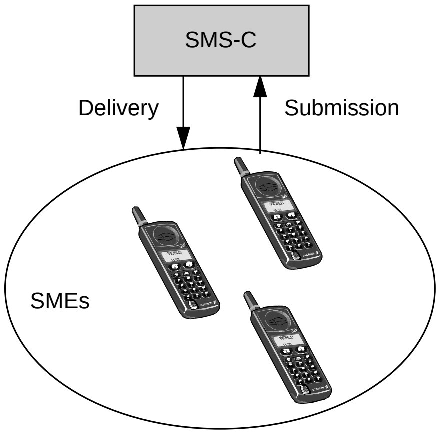


Figure 12-3 SMS-C

SMS Cell Broadcast (SMSCB): The cell broadcast facility is a variation of the short message service. A text message with a maximum length of 93 characters can be broadcast to all mobiles within a certain geographic area. Typical applications are traffic congestion warnings and accident reports, and in the future, possibly advertisements.

Voice mail: This service is an answering machine within the network which is controlled by the subscriber. Calls can be forwarded (see supplementary services, call forwarding) to the subscriber’s voice mailbox. The subscriber accesses the mailbox using a personal security code.

Fax mail: This service allows the subscriber to receive fax messages at any fax machine via the MS. Fax messages are stored in a network service center. The subscriber accesses the fax mail via a personal security code and the fax is then sent to the desired fax number.

SUPPLEMENTARY SERVICES

This section describes the main supplementary services supported by Ericsson's GSM systems.

Call forwarding: This service provides the subscriber with the ability to forward incoming calls to another telephone number in the following situations:

- Call forwarding on MS not reachable
- Call forwarding on MS busy
- Call forwarding on no reply
- Call forwarding, unconditional

Barring of outgoing calls: The subscriber can activate or deactivate this service from the MS with a variety of options for barring outgoing calls. For example, the subscriber can:

- Bar all outgoing calls
- Bar all outgoing international calls
- Bar all outgoing international calls except those directed to the home PLMN

Barring of incoming calls: With this function, the subscriber can prevent incoming calls. This is desirable because in some cases the called mobile subscriber is charged for parts of an incoming call (e.g. during international roaming).

There are two incoming call barring options:

- Barring of all incoming calls
- Barring of incoming calls when outside home PLMN

Advice of Charge: The Advice of Charge (AoC) service provides the MS with information needed to calculate the charge of a call. This information is provided at call set-up.

Charges are indicated for the call in progress when mobile originated. For a mobile terminated call, AoC only offers information on the roaming leg.

Account Codes: This service enables a subscriber, e.g. a business, to identify an account number which is to be charged for particular call components. Account codes can be identified on a per call basis.

Call waiting: This service notifies the mobile subscriber, usually by an audible tone, that a call is incoming. The call can then be answered, rejected or ignored. The incoming call can be any type of basic service including speech, data or fax. There is no notification in the case of an emergency call or SMS.

Call hold: This supplementary service enables the subscriber to put the basic normal telephony service on hold in order to set up a new call or accept a waiting call. Communication with the original call can then be re-established.

Multiparty service: The multiparty service enables a mobile subscriber to establish a multiparty conversation, that is, a simultaneous conversation between up to six subscribers. This service can only be used with basic speech telephony.

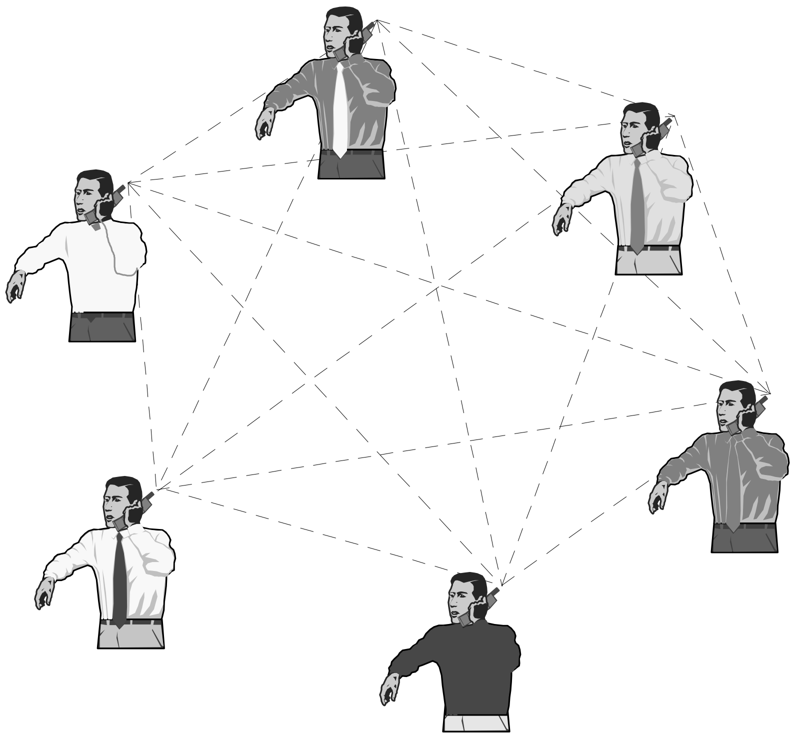


Figure 12-4 Multiparty service

Calling line identification services: These supplementary services cover both the presentation and restriction of the calling line identity. The presentation part of the service supplies the called party with the ISDN or MSISDN number of the calling party. The restriction service enables calling parties to restrict the presentation of their numbers on the MSs of called parties. Restriction overrides presentation.

Connected line identification presentation/restriction: These supplementary services supply the calling party with the ISDN number of the connected (called) party. The restriction enables the connected party to restrict the presentation. Restriction overrides presentation.

This service is useful when the call is forwarded or when it is connected via a switchboard.

Closed User Group (CUG): The CUG service enables subscribers connected to the PLMN/ISDN and possibly other networks, to form groups in which access is restricted. For example, members of a specific CUG can communicate with each other, but generally not with users outside the group.

ERICSSON’S INNOVATIVE FEATURES

Ericsson’s innovative features offer a level of service beyond the basic network standards. New features are developed on an ongoing basis as customer demands and competition increase. Some features are described in this section.

Single personal number: The single personal number service allows a subscriber to arrange call forwarding to other networks when the mobile is not reached in the subscriber’s primary network. With this feature, the subscriber can be reached by one directory number even though the subscriber may have subscriptions in several different networks.

Dual numbering: This feature allows the subscriber to have two different directory numbers connected to the same subscription and the same mobile equipment. In this way different accounts can be connected to the different directory numbers. For example, the subscriber may want one business account and one private account connected to the same subscription. Support for this feature is required in the MS.

Immediate call itemization: This feature is also called ‘Hot billing’. It is used when it is necessary to have immediate call charging data output (e.g. to bill a third party for use of a telephone which is rented).

Regional and local subscription: These features allow subscribers to subscribe to a service in a specified geographical area. Requests for service outside the area are rejected with the exception of emergency calls and SMS. For local subscriptions, the geographical area consists of a number of cells, and for regional subscriptions, the area consists of LAs. The cells or LAs do not need to be adjacent but can be spread out over the PLMN. For regional subscriptions, LAs in other PLMNs in other countries may be included. Handovers are not influenced.

Geographically differentiated charging: This feature enables the GSM PLMN area to be divided into different tariff regions. A tariff region is defined as a set of cells. A subscriber may be offered cheaper calls within certain areas. This feature can be combined with the service regional subscription.

Intentionally Blank

Charging and Accounting

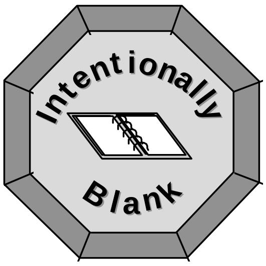
Chapter 13

This chapter is designed to provide the student with an overview of charging and accounting. It addresses charging and accounting components, their functions, features, and required specifications.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the charging principles
- Describe the tariff structure and call components
- Describe how accounting is performed between operators


Intentionally
Blank

13 Charging and Accounting

Table of Contents

Topic	Page

Intentionally Blank

PRINCIPLES OF CHARGING

The basic principles for charging in a GSM network are the same as for charging in a PSTN because for most calls, the calling subscriber (A-subscriber) pays for the call. However, there is one major difference. In a mobile network, the only thing known by the calling subscriber (A-subscriber) about the called subscriber (B-subscriber) is the country in which B’s subscription is located.

If the B-subscriber is in the home PLMN, the A-subscriber may also pay for the parts of the call within this country. However, the B-subscriber usually pays for those parts of the call associated with the B-subscriber roaming in another network.

In GSM 1900, charging is done differently than in other GSM versions. Traditionally in North America the mobile user pays for both incoming and outgoing calls. The reason for this is that the A-subscriber can not tell if the B-subscriber is a mobile subscriber because of the American integrated numbering plan.

It should be noted that the GSM specifications do not govern charging tariffs or packages. This is handled at a local level by each operator. It does however deal with the charging mechanisms related to GSM mobile originated calls and with the "forwarded-to" element (when the mobile subscriber is roaming) of a call to a GSM subscriber (mobile terminated calls).

STRUCTURES FOR TARIFFS AND CHARGING

NETWORK TARIFF COMPONENTS

The network tariff structure is based on two main components:

- The network access component
- The network utilization component

Network Access Component

Network access charges for each subscription consist of:

- An once-off initial fee
- A subscription charge (paid monthly or quarterly, e.g. until the subscription is terminated)

The access charges vary according to subscription privileges and the number of basic and supplementary services subscribed to.

The network access charges are based on data registered in the subscription handling procedures and are collected by the home PLMN operator from subscribers.

Network Utilization Component

The network utilization component is registered on a per call basis. The basic principle is to start charging the moment the B-subscriber (or the C-subscriber if call forwarding is activated) answers, or on connection to an answering machine internally in the network. The main issues involved in the calculation of charging are:

- Use of GSM PLMNs
- Use of national/international PSTNs
- Use of connection between different networks
- Use of Signaling System no.7 (SS7)

Network utilization charges vary according to, e.g. which country/regional area the call is originated, its destination, day and time, use of supplementary services, if the calling party is roaming internationally and the service used.

CALL COMPONENTS

Each call is divided into a number of components which are used in determining charges. This facilitates the charging of the A-subscriber and B-subscriber separately for different parts of a call. The main call components are described below.

Originating Call Component

The originating call component is the part of a mobile originated call from the MSC/VLR to the network entity pointed to by the MSISDN. The A-subscriber pays for this component.

Roaming Call Forwarding Component

The roaming call forwarding component charges for the part of a call to a mobile subscriber from the home PLMN to the MSC/VLR pointed to by the MSRN. Depending on the operator, the A-subscriber or the B-subscriber can be charged for this.

Call Forwarding Component

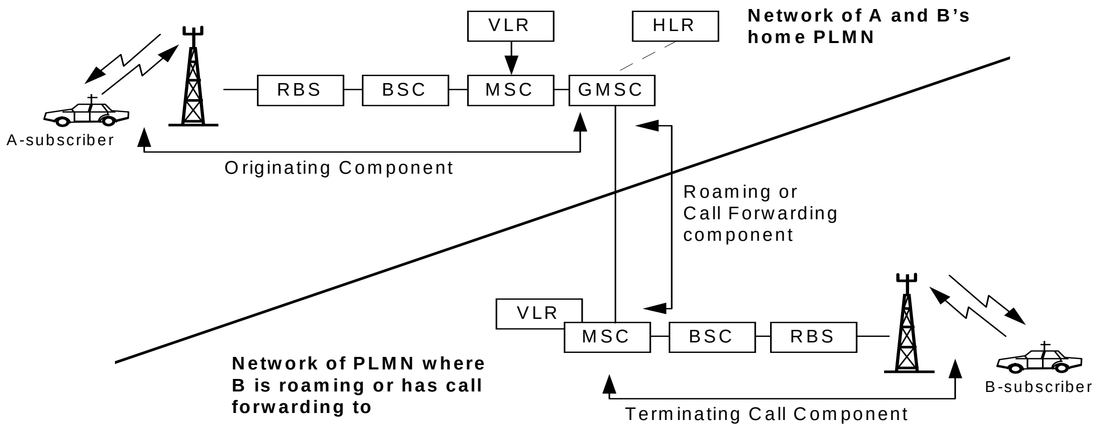
The call forwarding component is the part of a call from the GMSC or MSC/VLR to the Network Entity (NE) pointed to by a "forwarded-to" number. The A- or B-subscriber pays for this, depending on the operator.

Terminating Call Component

This is the part of the call from the serving MSC/VLR to the mobile subscriber. Depending on the operator, either the A-subscriber or the B-subscriber pays for this component.

Transiting Call Component

The originating, roaming and/or call forwarding call component may include a transiting component using the PSTN. This depends on the network structure between the serving MSC/VLR and GMSC for the A-subscriber and the B-subscriber respectively.



BSC = Base Station Controller
GMSC = Gateway Mobile services Switching Center
HLR = Home Location Register
MSC = Mobile services Switching Center
RBS = Radio Base Station
VLR = Visitor Location Register

Figure 13-1 Originating, Roaming, Call Forwarding and Terminating Components

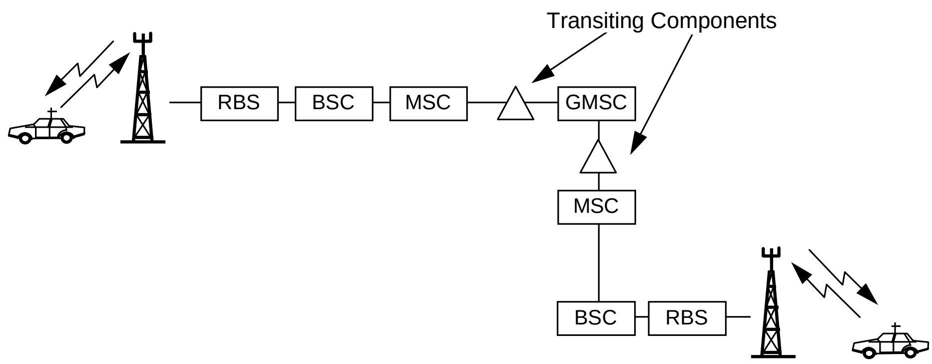


Figure 13-2 Transiting Call Component

RECEPTION AND PROCESSING OF CHARGING DATA

To charge a subscriber, the system requests the necessary data from the relevant network components. In Ericsson’s GSM systems the subsystems CHS and CHSS in the MSC/VLR or GMSC handle charging functions. The AM Formatting and Ouput AM (FOAM) also processes the output of charging functions in an MSC/VLR for use by, for example, a billing center.

TOLL TICKETING

All charging within a PLMN is performed by means of Toll Ticketing (TT). TT is a charging method which provides detailed output information for all, or certain types of calls, as defined by the charging analysis function. When a call is charged using TT, the data which is needed to calculate the charge and bill the customer is collected, formatted into a Call Data Record (CDR) and transferred to an output medium.

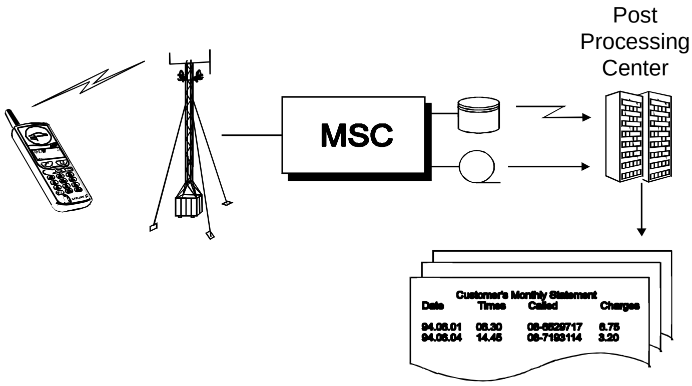


Figure 13-3 Billing procedure

The CDRs are transferred to a hard disk in the MSC/VLR or GMSC. From the hard disk, the TT records can be sent to a data link for transfer directly to a billing center or to magnetic tapes, which can then be sent to the billing center. When a data link is used, data can either be sent automatically when a pre-defined amount has been registered or can be pooled from the billing center.

The types of call records that can be output correspond to the types of call components such as the originating call component etc.

WHEN IS DATA TRANSFORMED INTO A RECORD?

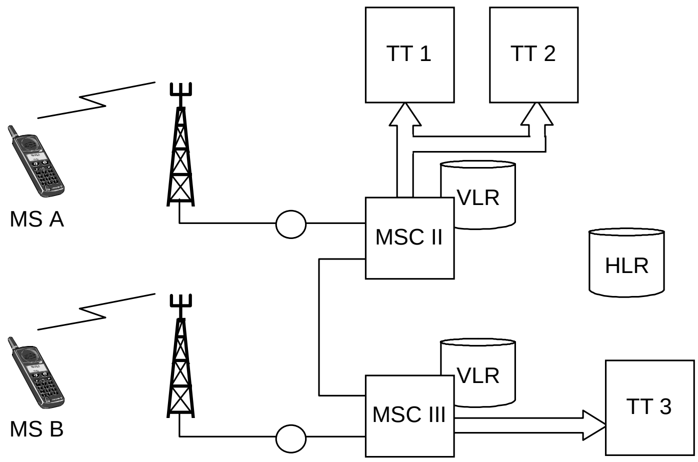
Data from a call is generated when one of the following conditions is fulfilled:

- The call is disconnected
- The time limit for partial generation is reached
- The limit for call related events has been reached

The charging analysis function is the basis of toll ticketing. This analysis is performed by the exchange to determine whether or not TT is to be used. It is possible to charge using TT for outgoing, incoming, internal and transit calls.

The TT function collects output data into a detailed output record. Thus, the subscriber is provided with a detailed bill. A detailed bill decreases the number of subscriber inquiries by providing clear, itemized billing information.

An example of toll ticketing is shown in the following figure:



First TT-record:	MS A - MSC II	(output in MSC II)
Second TT-record:	MSC II - MSC III	(output in MSC II)
Third TT-record:	MSC III - MS B	(output in MSC III)

Figure 13-4 MS A calls MS B

BILLING GATEWAY (BGW)

The Billing GateWay (BGW) collects CDRs in files from the network elements and immediately forwards these to post-processing systems that use CDR files as input. The Billing Gateway (BGW) acts as a billing interface to all network elements in a GSM network.

The functions of the BGW include:

- Collection of billing information from network elements of different types and releases
- Processing of billing information
- Distribution of billing information to post-processing systems of different types
- Graphical configuration and supervision of the gateway
- Alarm handling

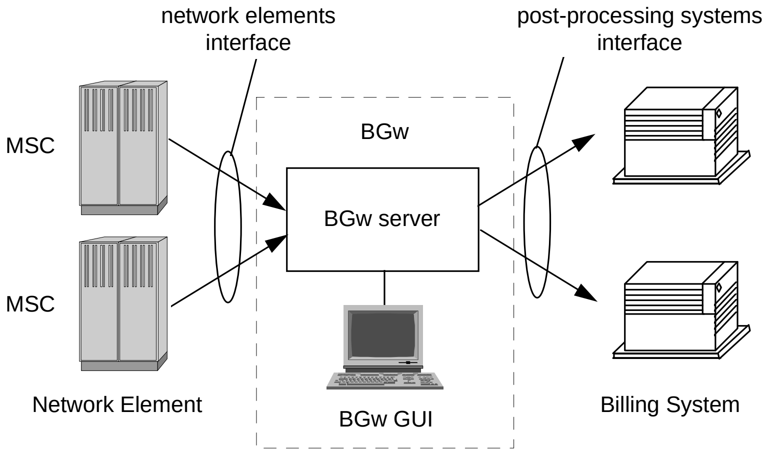


Figure 13-5 The interfaces in a Billing Gateway

A Graphical User Interface (GUI) is connected to each BGW. The GUI makes it possible to visualize the network structure through a directed graph, corresponding to the different data streams in the system.

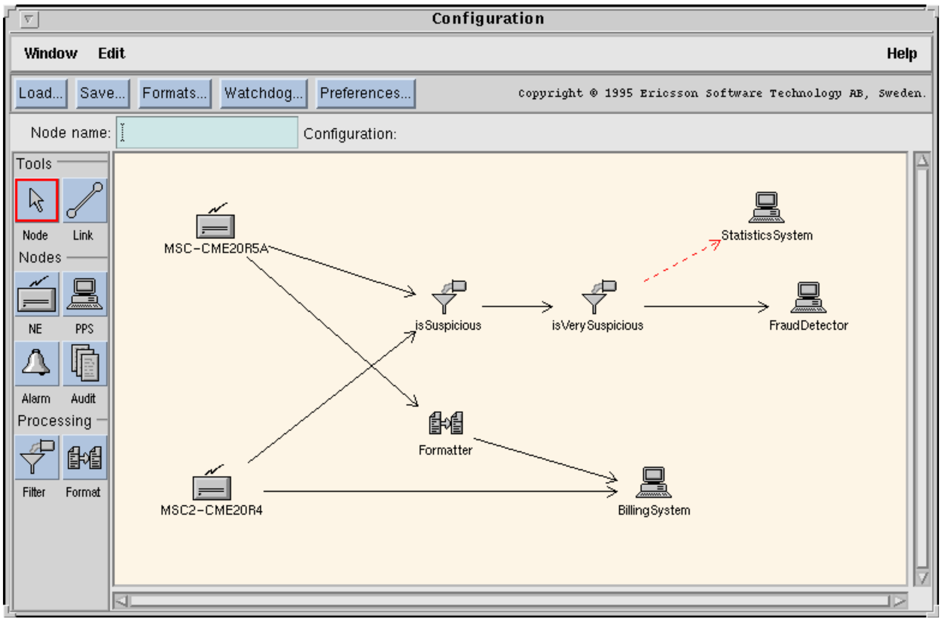


Figure 13-6 Graphical User Interface (GUI)

The BGW has an internal alarm system. Abnormal situations, such as unexpectedly high levels of hard disk usage (a shortage of disk space could interfere with charging calculations) are displayed on the GUI. Serious errors are also sent (with an alarm status) to the OSS and the application called Fault Management.

There is no system limit on the number of network element connections and post-processing systems that the BGW can handle.

A TRAFFIC CASE

This section describes an example of charging in which several subscribers are involved. Many of the subscribers are not in their home PLMNs and the networks must determine which subscriber is responsible for paying each call component.

Note: The MSCs and call case are fictitious.

There are four mobile subscribers:

- **Fowler:** a subscriber who's home network is in Australia and who is currently located in China
- **Lee:** a subscriber who's home network is in South Korea, but who is currently on business in the United States
- **Walker:** a subscriber to a South African network who is on vacation in Brazil
- **Rush:** a subscriber who's home network is in the United Kingdom, but who is on business in Saudi Arabia

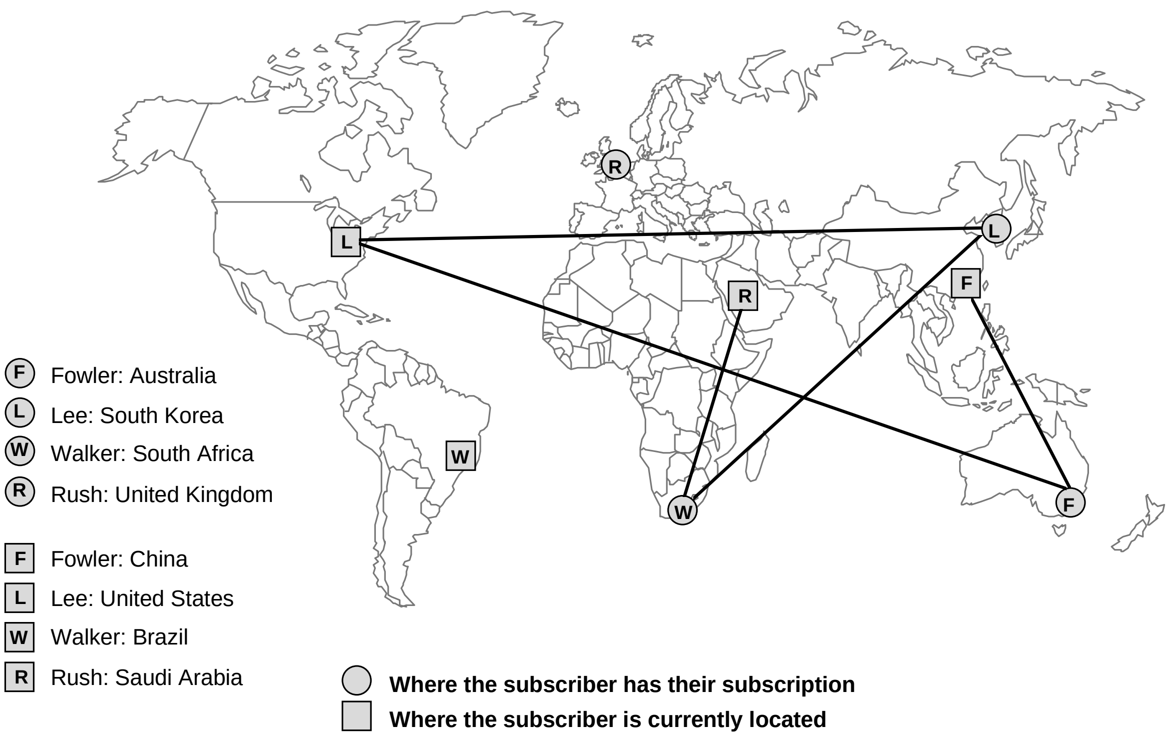


Figure 13-7 Charging case

1. Rush calls Walker. The Saudi Arabian network identifies from Walker’s MSISDN that it must contact the South African network.
2. Walker has the service "Call Forwarding on no reply" activated, to Lee in South Korea. The South African network initiates contact with the South Korean network.
3. Lee is in the United States (roaming internationally) and is talking on the phone. Rush activates the service "Completion of calls to busy subscribers" (the network will automatically set up the call when Lee disconnects from the phone call).
4. Lee finally hangs up after his conversation. Rush's MS tries to place the call again, starting with the another attempt to connect to Walker.
5. The call is forwarded to South Korea.
6. The call is forwarded to the United States.
7. During the call Lee has to consult Fowler from Australia. He activates "Three-party-call" service.
8. Fowler is in China, so Australian network routes the call to China.

Fowler, Rush and Lee finish talking, and hang up.

Question: Who pays for which part of the call?

Rush
- Saudi Arabia to South Africa (originating component)
- Activation of the service "Call completion to busy subscriber"

Walker
- South Africa to South Korea (call forwarding component)
- Activation of the service "Call forwarding" (if not included in the subscription)

Lee
- South Korea to the United States (roaming component)
- United States to Australia (originating component)
- Activation of the service "Three-party call"

Fowler
- Australia to China (roaming component)

ACCOUNTING BETWEEN OPERATORS

Agreements for international charging are drawn up between network operators. Operator A bills operator B when a visiting subscriber from B uses operator A’s PLMN. Subscribers are only billed for their own operator's administration costs.

Every operator who has a roaming agreement with other PLMNs must be able to support the "transferred account" procedures which allow the visited PLMN to be paid by the subscriber's home PLMN.

When calculating international charges, the accounting analysis covers:

- Destination information
- Outgoing route
- Incoming route
- Calling subscriber number

If the result of the analysis indicates that accounting between operators is to be performed, a suitable accounting class is selected which will be used for the call.

Accounting data collection starts when a call is connected. Examples of collected data include:

- Number of calls
- Call duration
- Number of sent meter pulses, if used

All these are stored in counters per accounting class.

The time of the day and the interval between output of all, or part of the accounting classes, may also be ordered and performed directly as an answer to a command.

NEW TARIFFING SCHEMES

Due to the deregulation of telecommunications markets around the world, mobile cellular markets in particular have become increasingly competitive. This competition has led to a reduction in the charging rates for mobile telephony and to the introduction of attractive subscription deals which include free or greatly subsidized MSs.

Many network operators also offer subscriptions which include a certain amount of free calls per month. Many of these schemes are aimed at business users and other people who typically make a high number of calls. When a subscriber exceeds the quota of free calls, any extra calls are charged at rates which vary depending on the subscription and the times set for peak rates.

A common practice for operators is to market one subscription type for business users and another for personal users. For example, a business package may have reduced charges for calls during business hours but expensive charges outside of those hours.

PRE-PAID SIM

☞ Did you know?

A version of pre-paid SIM was released in Italy in 1997. Within 3 months, 600,000 extra subscribers had joined the operator's network.

The concept of a pre-paid SIM card is a new idea which is becoming quite popular with subscribers. With a pre-paid SIM the subscriber does not enter into a standard contract and pay a monthly or quarterly fee, instead the subscriber gets a special MS which is already connected to the network. The MS charges by using pre-paid SIM cards which allow the user to make a certain number of calls for a fixed price. When the quota of calls is used up, the subscriber will have to buy a refill of the SIM card.

This method of payment is often used by people who only need to use a mobile phone occasionally and who do not want to pay monthly rates for a phone they are not using. Alternatively it could be used to assign an individual a limit of call credits with the knowledge that the limit cannot be exceeded.

Mobile Intelligent Network Services

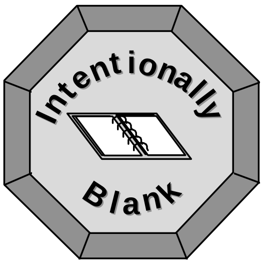
Appendix A

This appendix is designed to provide the student with an overview of the mobile intelligent network services available with Ericsson's GSM systems. It includes the network nodes and functions used to provide these services, along with a sample traffic case.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

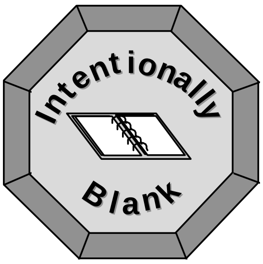
- Describe the concept of mobile intelligent network services
- Describe the mobile intelligent network services available with Ericsson's GSM systems
- Describe the mobile intelligent network nodes
- Describe a sample mobile intelligent network traffic case


Intentionally
Blank

A: Mobile Intelligent Network Services

Table of Contents

Topic	Page


Intentionally
Blank

MOBILE IN (MIN) SERVICES

INTRODUCTION

A Mobile Intelligent Network (MIN) is a telecommunications concept that meets the market demand for advanced services within the existing telephony network, from both the network operator's and service provider's perspective.

In recent years, Intelligent Networks (IN) has become an established concept in the PSTN. With the increasing use of cellular systems, the Public Land Mobile Network (PLMN) has begun to adapt the MIN functionality to meet requirements of mobile network providers, service providers and mobile subscribers. The "intelligence" in the MIN is realized in computer software and data. The ultimate objective of MIN is to increase revenue for the network operator and the service provider.

MIN offers a number of advantages to a GSM network operator:

- Increased subscriber numbers due to more attractive services
- Increased revenue due to use of services
- Increased subscriber loyalty
- Increased flexibility in deploying services in a network
- Decreased development time for services
- Reusability of service modules

The following MIN services are available for Ericsson's GSM systems[1]:

- Personal Number
- Pre-Paid SIM Card
- Cellular Virtual Private Network (CVPN)

[1] This is a list of services which have been designed specifically for Ericsson's GSM systems. It should be noted that a mobile subscriber is not restricted from making calls to PSTN-based IN services such as Freephone, Premium Rate and Universal Access Number.

PERSONAL NUMBER

This MIN service assigns a single number to a subscriber. This personal number is used to contact that subscriber at defined connections, using a time-based routing profile for that subscriber. For example, if the personal number is dialed between 9am and 5pm the call may be routed to the subscriber's work number. However, if the personal number is dialed between 5pm and 9am the next morning, the call may be routed to the subscriber's mobile phone.

The target market for this service is mobile subscribers with high existing mobile communication expenditures. The service can be used to keep, attract, and possibly migrate customers from different networks. Increased profitability will come from long term effects such as customer loyalties, as well as short term effects such as increased air time, call completion, and new service charges.

PRE-PAID SIM CARD

This service enables a subscriber to pay in advance for an agreed amount of call charges. This amount is stored on the subscriber's SIM card or in SCF in the network. When the limit of call charges is exceeded, the subscriber will no longer be able to make calls, but may purchase more call charges as desired.

In addition, there is no fixed term of subscription, meaning that a subscriber is not bound to a contract of subscription and its associated fees. Advantages for an operator include:

- Increased number of subscribers
- Increased number of calls
- Payment in advance for calls

CELLULAR VIRTUAL PRIVATE NETWORK (CVPN)

The Cellular Virtual Private Network (CVPN) service allows groups of users to define a common short numbering plan to simplify communication within the group. In the CVPN service, both mobile and fixed- subscribers can be integrated as well as PABX users. Subscribers in the cellular private network are able to make calls outside the network by dialing an escape code.

Within this service it is possible to design a personal profile for each subscriber by combining call barring and terminating screening functions. Subscribers can also have a personal routing of their calls based on conditions (e.g.‘No reply’).

MIN INTERESTED PARTIES

There are four interested parties in a MIN service:

- **Service User:** the party which makes a call to a MIN service
- **Service Subscriber:** the party which offers the MIN service to the marketplace
- **Service Provider:** the party which operates the network and designs the MIN services
- **Service Equipment Supplier:** the party which supplies the hardware and software platforms for MIN services

SERVICE ARCHITECTURE

MIN service intelligence consists of modular software blocks called service scripts. Each script is designed to perform a particular function. For example, there may be a script which requests the user to enter a security code and checks that it is the correct code for their account. This could be one of many scripts used as part of a credit card calling service.

Service scripts are collections of smaller blocks of logic, each designed to perform a particular task.

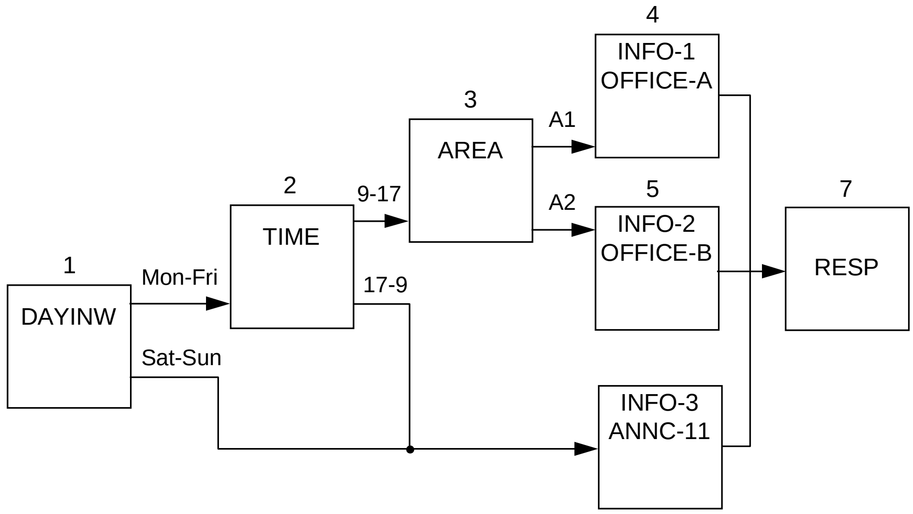


Figure A-1 Example of logic in a script for a time-based routing service

MIN NETWORK ARCHITECTURE

The Mobile Intelligent Network (MIN) provides an architecture for the introduction of new services throughout the network, with a minimum impact on the switching elements and the signaling systems.

To introduce MIN into an Ericsson-based GSM network requires the introduction of the following functions and environments:

- Service Switching Function (SSF)
- Service Control Function (SCF)
- Service Data Function (SDF)
- Special Resource Function (SRF)
- Service Management Environment (SME)
- Service Creation Environment (SCE)

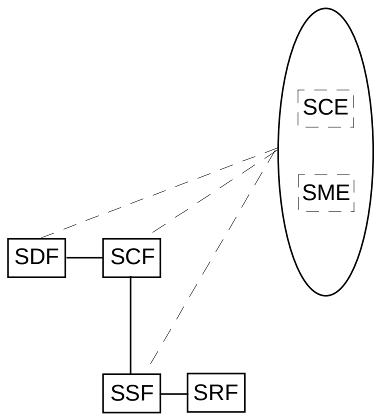


Figure A-2 MIN network functions

THE SERVICE SWITCHING FUNCTION (SSF)

The Service Switching Function (SSF) acts as an interface between the normal mobile call control functions of an MSC/VLR and the functions which control a MIN service. The node in which an SSF is located is termed the Service Switching Point (SSP). The SSP performs the necessary switching, signaling and charging to implement a MIN service, in response to the instructions it receives from the Service Control Function (SCF).

An SSF includes functions for:

- Initiating a MIN service
- Call handling and switching
- Activation of resources such as announcement machines
- Charging
- Communication with the MSC/VLR and with the SCF

In Ericsson’s GSM systems, SSF functions are implemented using the Service Switching Function Application Module (SSFAM), which uses function blocks from the SErvice provisioning Subsystem (SES). The SSFAM is integrated within an MSC/VLR.

THE SERVICE CONTROL FUNCTION (SCF)

A node in which the SCF is implemented is termed a Service Control Point (SCP). The logic and data required to execute a MIN service is located in an SCP. The SCP is the platform for the execution of MIN services.

An SCF contains functions for:

- Service script interpretation
- Service script storage
- Error handling
- Communication with the SSF and SDF

In Ericsson's GSM systems, SCF functions are implemented using the Service Control Function Application Module (SCFAM), which uses function blocks from SES. The SCFAM is located stand-alone on a dedicated AXE node. Alternatively, the SCF and SSF functions can be located together on one node termed the Service Switching and Control Point (SSCP).

THE SERVICE DATA FUNCTION (SDF)

In a MIN with more complex services or a larger number of services, it is often more efficient to store the data used by a service in a dedicated database. This node is called the Service Data Point (SDP). The function which administers the data is called the Service Data Function (SDF). Depending on the amount of data to be handled, this database may be a stand-alone or it may be integrated within the SCP node.

Each item of data is stored in a data module (DM), which may include 100s of parameters about, e.g. a particular subscriber to a service.

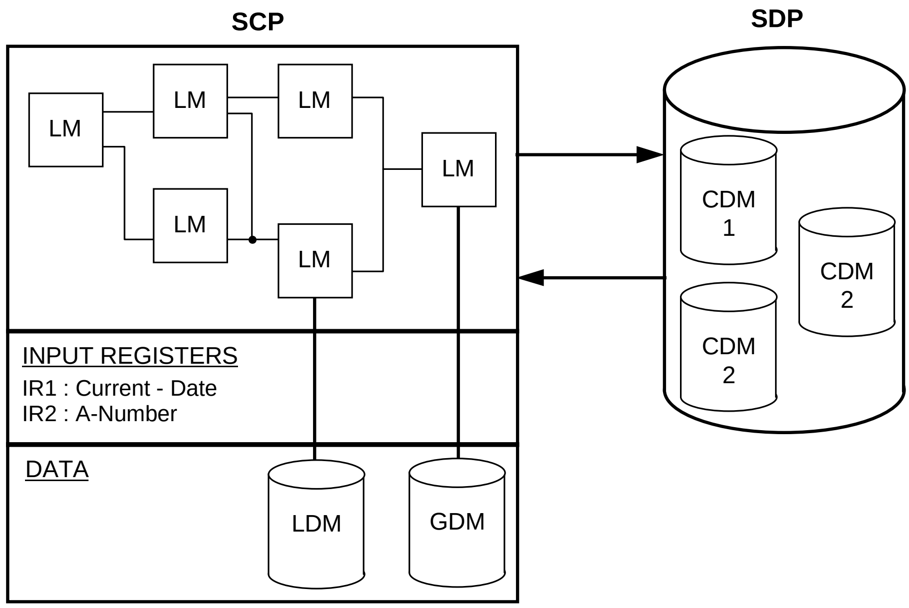


Figure A-3 Data modules are stored in the SDP

In addition, for some services there may be large amounts of data which already exists on a database which is not part of a MIN. One example may be a bank which has data about credit card accounts. It is neither secure nor economical to copy all these details into a node in a telecommunications network (i.e. an SDP) on a regular basis. Instead, using the SDP's External Gateway Function (EGF), it is possible to contact such an external database for data during a MIN call.

In Ericsson's GSM systems, the SDP is implemented in a Hewlett Packard UNIX-based computer. Communication between operator staff and the SDP takes place by the use of the Service Management Application System (SMAS).

THE SPECIAL RESOURCE FUNCTION (SRF)

In order to complete some MIN services, interaction is required between a call party and network devices. For example, for authorisation purposes a MIN service may request a call party to enter a sequence of digits which is the call party's Personal Identity Number. Such an announcement is handled by a Special Resource Function (SRF). A machine which implements the SRF is termed an Intelligent Peripheral (IP). In Ericsson's GSM systems there are several platforms which can act as IPs, including, e.g. the AST-DR as supplied by the ESS in AXE.

SERVICE MANAGEMENT ENVIRONMENT (SME)

In order to ensure that the MIN services operate correctly, it is necessary to use a Service Management Environment (SME). The SME supports installation and management of the MIN services and their data. In Ericsson's GSM systems, the SME is implemented using the application Service Management Application System (SMAS) on the TMOS platform.

SERVICE CREATION ENVIRONMENT (SCE)

The Service Creation Environment (SCE) is used to define the logic and data which MIN services consist of. In Ericsson's GSM systems, the SCE is implemented using the application Service Management Application System (SMAS) on the TMOS platform.

MIN CALLS

For every MIN call the following procedures are followed:

1. MSC/VLR functions identify that the call requires a MIN service and contacts the SSF.

2. The SSF determines which SCF must be contacted for the service and identifies the call data which must be sent to that SCF. The SSF requests instructions from the SCF about how to implement the MIN service.

3. The SCF executes the logic for the requested service and retrieves the necessary data from the SDF.

4. The SCF sends instructions to the SSF about the processing of the service.

5. The SSF performs actions to process the service, interacting with the MSC/VLR's call control functions where necessary.

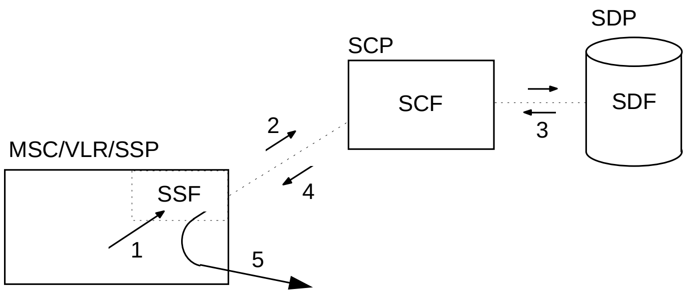


Figure A-4 Inter-working of MIN nodes in a call

MIN TRAFFIC CASE: THE PERSONAL NUMBER SERVICE

With the Personal Number service the service user can redirect calls to different points of contact. For each service user a routing profile is built which defines how the redirecting will occur.

Attempt	Connection to try	
	1	2
1st Option	5551234 (fixed home phone)	
2nd Option	5550000 (fixed work phone)	087-5559876 (mobile phone)
3rd Option		
...		
Last Option	Voicemail	

Table A-1Routing profile for mobile subscriber “Y” (PN=+353 87 2071234)

This routing profile indicates that an outgoing leg will be set-up first to 5551234. If the user does not answer any of the connections in the first row, then the MIN will try those in the second. In this case, there is more than one number on the same row. The MIN will attempt to set-up the call with all of the connections simultaneously. The call will be routed to the connection which the user answers first. In the example shown, the MIN will create an outgoing leg to 5550000 and another to 087-5559876 at the same time.

(Note: if the user does not answer any of the connections within one minute, the call will be either routed to a voicemail or disconnected. The user in the example has chosen the Voicemail option.)

The following sample call shows the usage of the Personal Number service in a call from a mobile subscriber in the north America to a mobile subscriber in a European country. The European subscriber has the Personal Number service and is currently located in their country of subscription. For the purpose of explanation, this sample call has been broken into five parts.

Part 1: From North America to a European GSM Network

1. A mobile subscriber in North America ("X") wants to contact subscriber Y (who subscribes to a European GSM network). X looks at Y's business card which shows just one number (+353872071234)! X dials the number and presses the Send button. The access signal reaches the MSC which is serving X's MS (MSC-NA).
2. MSC-NA performs analysis of the number. It identifies the international prefix and immediately identifies that the call is to be routed internationally to a European network. MSC-NA passes the number to an International Exchange (IE) in North America.
3. The IE also performs number analysis and routes the call to an IE in the European network.
4. The IE there performs number analysis and determines that the call is to a mobile subscriber. It passes the B-number to a GMSC in that country's GSM network.

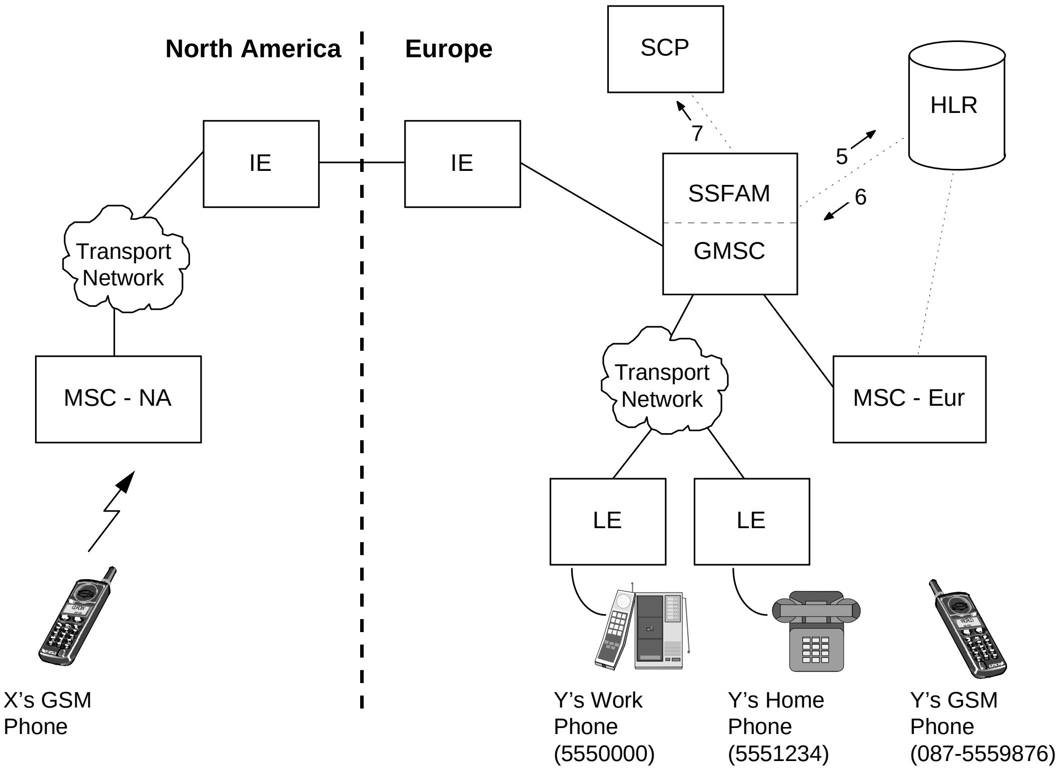


Figure A-5 Part 1:From North America to a European GSM Network

Part 2: From the European GMSC to the European SCP

5. The GMSC analyses the B-number in order to determine which HLR to interrogate for Y’s subscription information. It performs routing interrogation by sending a signal to the appropriate HLR.
6. The HLR looks at the data it has for Y and identifies that the MIN service category is active. This means that the call will require MIN involvement. The HLR passes a signal to the GMSC indicating that it should contact the MIN for further routing information.
7. The GMSC analyses the information from the HLR and duly contacts the SSF. Functions in the SSFAM then analyze the call information and identify the SCF to contact for the service Personal Number. The SSF then requests instructions from the SCF.

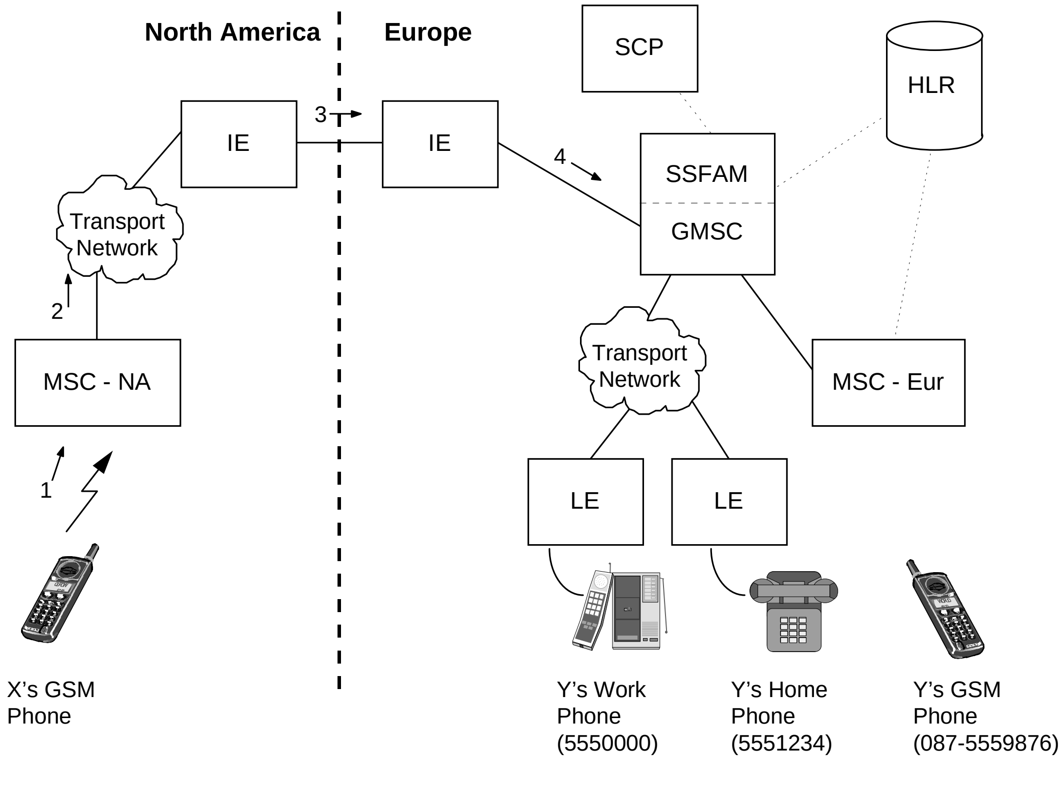


Figure A-6 Part 2: from the European GMSC to the European SCP

Part 3: Execution of the Service: First Attempt

8. The SCF accesses the correct service logic and executes the service. It refers to the routing profile for Y’s Personal Number, which is located in a DM in the SDP. The SCF orders the SSF to create an outgoing leg to the first number in the list: 5551234. In addition it orders the SSF to monitor the leg for the event “Answer” and for the event “No-Answer”.
9. The SSF creates an outgoing leg to the number and monitors the leg for the requested events. In this case the outgoing leg is created to a phone in the fixed network so the GMSC contacts a Transit Exchange (TE) in the European country’s PSTN.
10. The PSTN then continues to set-up the outgoing leg to Y’s fixed phone.
11. There is no reply from the fixed phone, resulting in the “No-Answer” event being sent to the SCF.

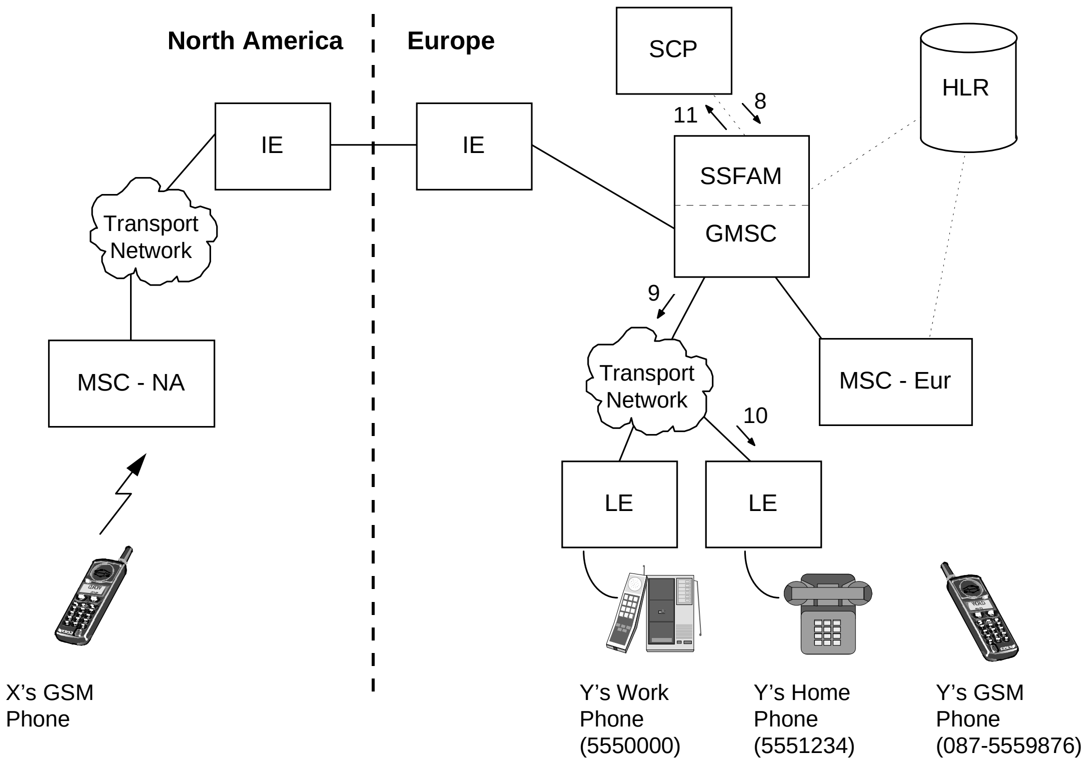


Figure A-8 Part 3: Execution of the service: first attempt

Part 4: Execution of the Service: Next Attempt

12. The SCF looks at the next row in Y's routing profile. It orders the SSF to simultaneously create outgoing legs to 5550000 and to 087-5559876 and to monitor both legs for Answer.
13. The SSF creates an outgoing leg to the fixed network to contact 5550000.
14. At the same time, an outgoing leg to the mobile subscription is created. The GMSC interrogates the HLR again. This time it is looking for a roaming number (MSRN) for Y's mobile subscription. The HLR fetches the MSRN from the MSC which is serving Y at the moment (MSC-Eur).
15. The HLR returns the MSRN to the GMSC and the GMSC then contacts MSC-Eur based on analysis of the MSRN.
16. The MSC-Eur then pages Y's subscription in the appropriate area(s). The attempt to contact Y at the work phone is continuing.
17. Y answers the call at the mobile number 087-5559876. The Answer event is sent from SSFAM to SCF.

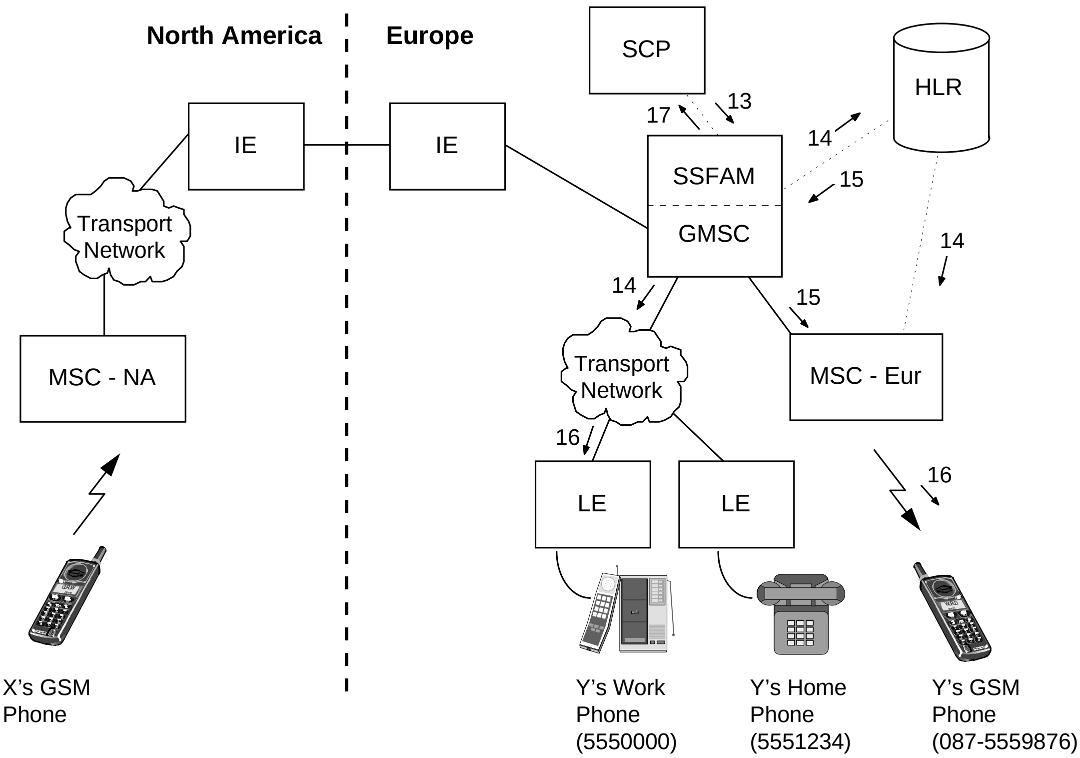


Figure A-7 Part 4: Execution of the service: next attempt

Part 5: Through Connection

18. The SCF sees the Answer event and orders the SSF to connect the incoming leg from X to the outgoing leg to Y. The SCF also orders the SSF to take control of the call from now on. The service has been implemented successfully.

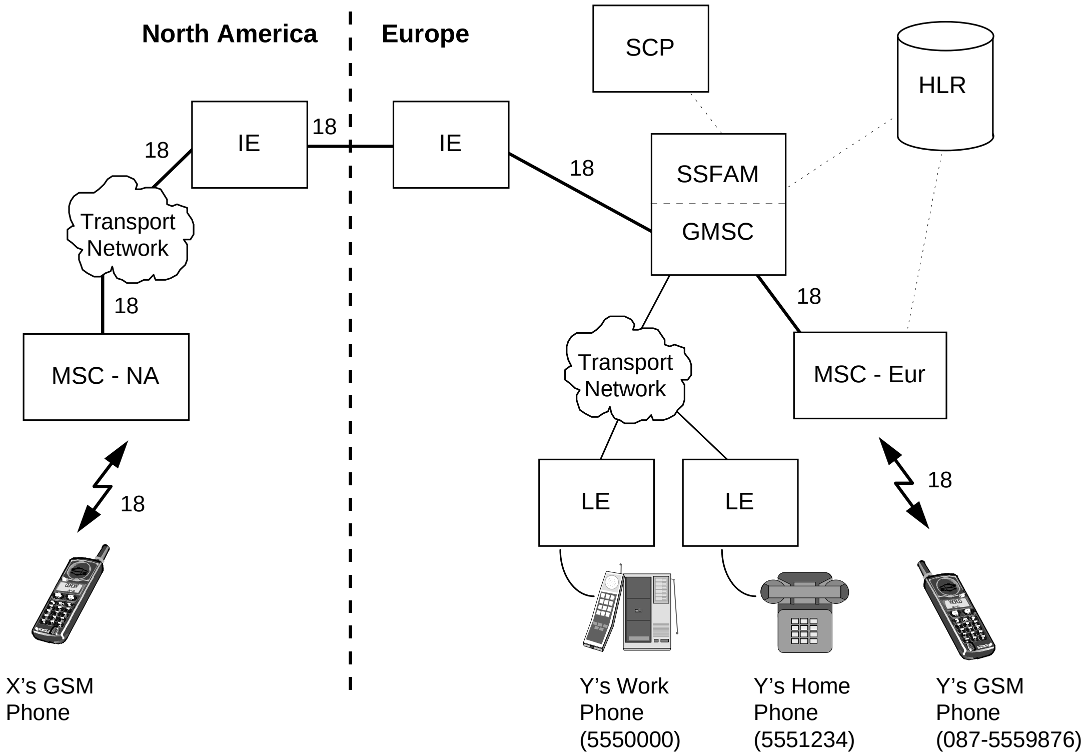


Figure A-8 Part 5: Through connection

Data Services

Appendix B

This appendix is designed to provide the student with an overview of the data transmission capabilities and services of Ericsson's GSM systems.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe the data transmission services which GSM offers
- Describe a GSM data traffic case

Intentionally Blank

B: Data Services

Table of Contents

Topic	Page

Intentionally Blank

INTRODUCTION

As competition for subscribers increases worldwide, there is increasing pressure on mobile network operators to offer services at least equal to those which subscribers can find on a PSTN network. In the past this has led to the development of improved call handling capabilities, such as voicemail and call forwarding.

With the advent of data communications, and the internet in particular, there has been an increasing demand for improved data handling capabilities. In recent years the data rates of fixed modems has increased from 9.6kbits/s to 56kbits/s, and the recommended minimum speed is now 28.8kbits/s. GSM phones have been capable of only 9.6kbits/s however, and have not been able to effectively compete with fixed networks for data communications purposes.

With Ericsson’s GSM systems, a data rate of 48kbits/s is now possible. This gives GSM network operators the possibility to offer new competitive data applications that attract and maintain new end-users.

It is possible to sent and receive data to and from many network types, including:

- Public Switched Telephony Network (PSTN)
- Integrated Services Digital Network (ISDN)
- Circuit Switched Public Data Network (CSPDN)
- Packet Switched Public Data Network (PSPDN)

DATA CONNECTION TYPES

The two basic types of telecommunications connection are:

- **Circuit switched:** the circuit is set-up from end to end and is maintained for the duration of the call, regardless of whether it is being used or not. This is suitable for speech calls.

- **Packet switched:** the circuit is set-up from end to end when it is necessary to transmit or receive information. With each new packet of information, a different connection may be set-up. This is better suited to applications which have bursty type transmissions. For example, Internet browsing involves downloading information, reading it and then downloading more.

Data can be sent with either of the above methods, but at the present time, only circuit switched connections are possible in GSM. The method uses is called High-Speed Circuit Switched Data (HSCSD) and it enables up to four time slots for one user connection. It is not a requirement that the time slots be consecutive.

HSCSD supports the following types of data transmission connections:

- **Transparent:** by adding error correction bits to the basic data, a more reliable connection is ensured. However, the basic data rate is restricted to a maximum of 38.4kbits/s.

- **Non-transparent:** in contrast with transparent connections, this form does not add information to the basic data and is therefore less reliable. However, higher basic data rates are possible - up to 48kbits/s.

The following tables identify the exact data rates capable with each of these connections:

Time Slots	End-user Data Rate (kbits/s)
1	4.8
2	9.6
3	14.4
4	19.2

Table B-1 Transparent data using half-rate channel

Time Slots	End-user Data Rate (kbits/s)
1	9.6
2	19.2
3	28.8
4	38.4

Table B-2 Transparent data using full-rate channel

Time Slots	End-user Data Rate (kbits/s)
1	12
2	24
3	36
4	48

Table B-3 Non-transparent data using full-rate channel

Within the network all connections are circuit switched. In order to access a PSPDN a connection to Packet Assembler/Disassembler (PAD) is needed. The PAD transforms the bit stream from an asynchronous terminal to data packages.

IMPLEMENTATION IN ERICSSON'S GSM SYSTEMS

The DTI implements the GSM Inter-Working Function (IWF) for data communications. It performs data handling functions such as data rate conversion and provides the functions necessary for data interworking between the GSM network and otehr networks, including the following:

- **Traffic to/from PSTN:** this involves modem and fax calls. For connections to the PSTN a modem is selected by the DTI to perform the necessary rate and format conversions.

- **Traffic to/from ISDN:** the whole set of data communications towards ISDN is available, since the MSC is capable of signalling and mapping basic service information between the ISDN and the GSM network.

- **Traffic to/from PSPDN:** the packet services use the bit-oriented synchronous service in GSM. Supported user data rates are 2.4, 4.8, and 9.6 kbits/s. This service consists of two establishment phases. The MSC/VLR establishes the call to a Packet Handler (PH) or to an Access Unit (AU), while the second phase establishes the call to the X.25 terminal in-band

- **Traffic Between Mobiles:** the data traffic inside the PLMN has to pass through the DTI to handle the protocol used for rate adaptation in the radio path.

- **HSCSD:** this version of High Speed Circuit Switched Data (HSCSD) allows the connection of 2, 3, or 4 timeslots on one radio channel each carrying 9.6 kbits/s. PSTN connections supporting V.34 modems (up to 28.8 kbits/s) and ISDN connections using rate adaptation are possible.

- **HDLC Encapsulation on ISDN:** the Interworking Function (IWF) supports High level Data Link Control (HDLC) encapsulation in order to handle Point to Point Protocol (PPP) and X.75 protocol links via the ISDN networks. This will allow a maximum data rate of 9.6 kbits/s (38.4 kbits/s using HSCSD) excluding start and stop bits which are included in UDI calls using V.110 protocol.

- **Bearer Services:** with a bearer service, the GSM network provides a transmission path for data between two access points and also a user-network interface. The network will be responsible for delivering in one interface what was received in the other. Interworking attributes may be defined for supporting bearer services over transit networks.

  These Bearer Services will enable a subscriber to run applications like:

  – E-mail

  – Database access

  – File transfer

  – Digital communication with an ISDN terminal

  – Access to a Packet Assembly/Disassembly (PAD) port in PSPDN, providing access to X.25 services

DTI IMPLEMENTATION

Data services in Ericsson’s GSM systems are provided by the hardware device Data Transmission Interface (DTI) and the software of the subsystem Data Transmission Subsystem (DTS).

DATA CALL TRAFFIC CASE

HSCSD DURING A CALL

Each MS is assigned a multislot class which, when sent to the network, identifies the number of time slots which the MS can handle simultaneously.

During call set-up, by default, the network chooses the maximum rate possible, limited by the MS’s multislot class and by a user-set maximum number of time slots.

The number of time slots in use during a call is dynamic and can be changed by any of the following events:

- **User action:** the user may choose to decrease or increase the number of simultaneous time slots which they are using. The user may wish to reduce their bandwidth due to costs or because they do not need it for some time during a call (e.g. when browsing a directory) and may wish to increase bandwidth later in the call (e.g. for file transfer).
- **Handover:** the network attempts to assign the same number of time slots in the new cell. If this is not available, the network reduces the number being used and informs the MS to do so also.
- **Cell congestion:** the network may choose either to prioritize incoming calls or reduce the number of time slots which the HSCSD user is using.

If the number of time slots is reduced by the network in the handover or cell congestion cases, if a time slot becomes available at a later stage, the network may assign it to the HSCSD user.

EXAMPLE: DATA CALL TO PSPDN

As explained previously, each MSC/VLR must have a dedicated DTI to handle data calls. The MSC/VLR is always in control of the data call and can execute changes in the resources despite the MS mobility.

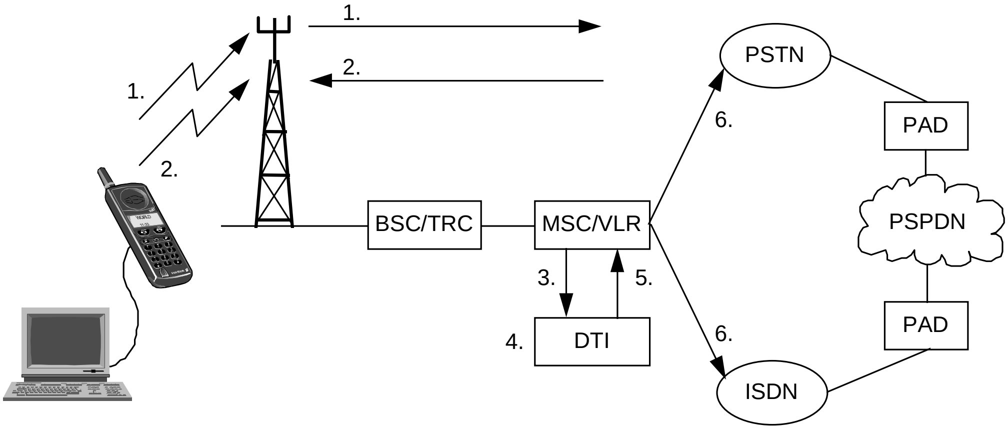
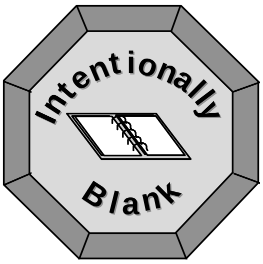


Figure B-1 Data call

1. An MS initiates a data call. In the call set-up message, the MS's multislot class is included along with the Bearer Capability (BC) requested. The BC includes the bearer service type (fax, data) and the requested transmission rate.
2. A connection between the MS and the network is set-up, as in a normal call, and authentication is performed.
3. The MSC/VLR analyzes the BC. The B–number and the BC are transferred to the DTI.
4. The DTI is configured to perform the required service (i.e. rate adaptation, fax or modem service).
5. The DTI re-routes the call to the MSC/VLR.
6. The MSC/VLR routes the call to the destination network. (PSPDN is used as an example in the figure above.) The connection to this network may be via an existing network such as the PSTN or ISDN.


Intentionally
Blank

Case Study: New Telerica's GSM networks

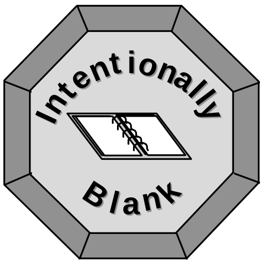
Appendix C

This appendix is designed to provide the student with an overview of a sample network: New Telerica. It shows the network set-up and growth over a number of years.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

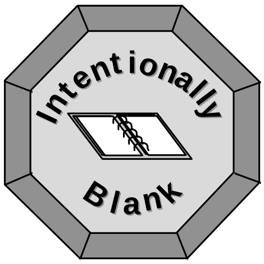
- Describe the basic development of a fictional operator's network from inital set-up to maturity


Intentionally
Blank

C: Case Study: New Telerica's GSM networks

Table of Contents

Topic **Page**


Intentionally
Blank

INTRODUCTION TO NEW TELERICA

New Telerica is located on the shores of the Blue Sea. The western and southern borders are coastlines and the northern and eastern borders are covered by mountains and forests. New Telerica has a high GDP per person according to World Bank statistics. The currency is the Telerican Dollar (TED).

Gross Domestic Product (GDP)	92,100 TED/person
Area	507,500 km^2
Population	31,253,000
Population Density	61.6 inhabitants/km^2

Table C-1 Statistics of New Telerica

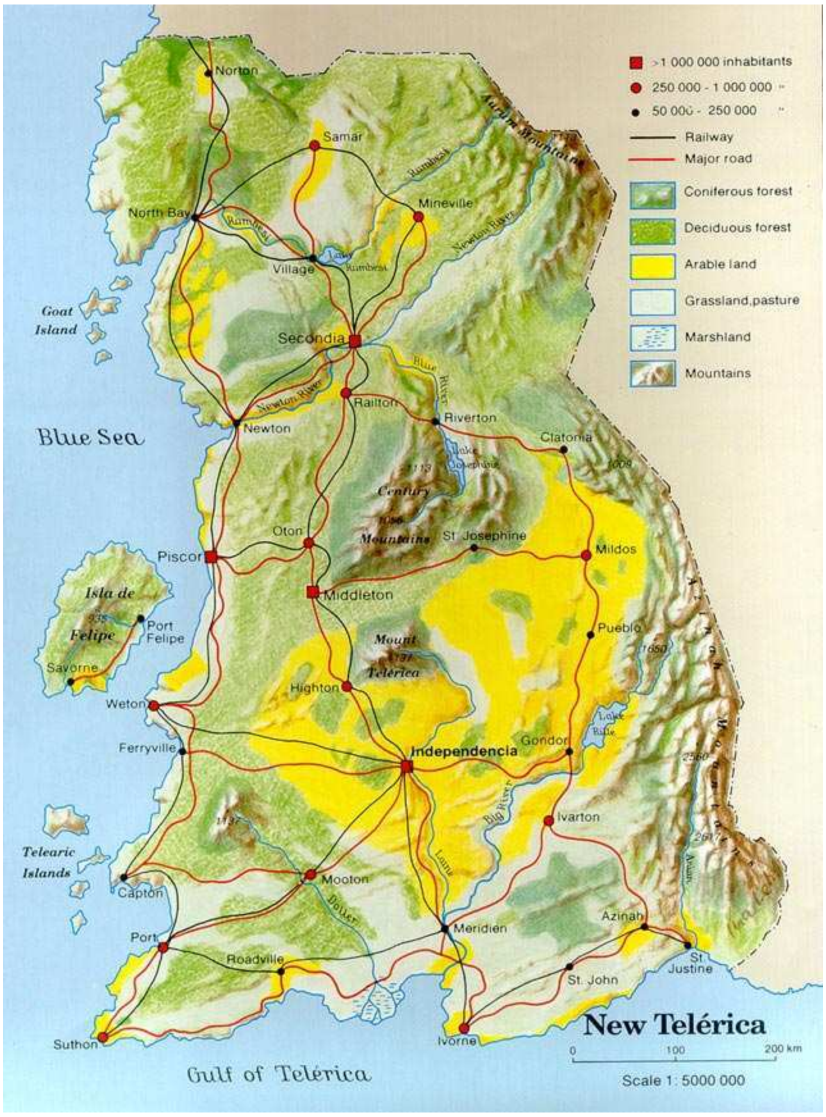


Figure C-1 New Telerica

Businesses

Industry and business development have a high priority in New Telerica.

The petroleum, petrochemical, mining and electronic industries operate at a high level of technology. Foodstuffs, textiles, clothing, plastic goods, cements, building materials and plywood are produced in somewhat less advanced facilities. These sort of activities are still mainly concentrated in the cities, especially Secondia and Mildos, but the process is ongoing to relocate them to minor places and rural areas. The west coast of Isla de Felipe is the main centre of the fishing industry and there are many small and medium fishing-related companies.

New Telerica has many large companies covering a wide range of businesses including building, food production, chemicals, medical products, electronics, computers and communications.

Transport Systems

The country is served by the following transport systems:

- **Shipping:** Port, in the south-western edge of New Telerica, is the largest port, followed by Piscor
- **Airports:** New Telerica has five main commercial airports, in Indenpendencia, Secondia, Middleton, Port and Savorne. The airports in Indenpendencia, Secondia and Savorne are the international airports for passenger traffic
- **Railways:** The railway system in New Telerica is operated by Ericorail and was modernised recently to enable high-speed passenger traffic and carriage of heavy goods traffic
- **Highways:** The country's highways, which are of good standard, cover a total of 19,750 km. The highway and railway carry the major part of all transport in New Telerica

Ten-Year Plan

New Telerica is a country with strong economic growth. The targets for continuing growth have been set forth in a comprehensive ten-year plan covering the period 1995 to 2005. The plan focuses on the following areas, among others: education, industrialisation, communications, agriculture and urbanisation.

TELECOMMUNICATIONS IN NEW TELERICA

THE NEW TELERICAN TELECOM ADMINISTRATION (NTTA)

Telecommunications in New Telerica are governed by the Ministry of Communications. This is divided into four departments, including one for telecommunications. The Department of Telecommunications has legal supervision of the New Telerican Telecom Administration (NTTA), even though they are, strictly speaking, two different organisations.

NTTA is a member of ITU and takes part in the work carried out by several work groups and committees of the standardisation sector of ITU. All solutions and equipment introduced in the NTTA network shall comply with the recommendations of ITU.

The corporate goals for NTTA are:

- To apply, at the lowest possible cost, the facility of telecommunication services of all types to subscribers over the whole country of New Telerica
- To extend and develop the New Telerican telecommunications network with the highest possible degree of self-financing
- To operate and maintain the network as efficiently as possible

A retrospective study of the telecommunications development during the last 15-year period was performed. According to the figures of main lines and telephone sets, the development has been progressive with an average yearly increase of 9-10%.

CURRENT CELLULAR TELECOMMUNICATIONS

Six years ago the Ministry of Communications in conjunction to the Ministry of Commerce issued an operating licence for a PLMN based upon GSM cellular technology. The network licence was granted to Telcell, half-owned by NTTA.

Following the trends ongoing in several countries concerning liberalisation of the market for telecommunication services, the licence was based on an open market principle and competition at a convenient time in the future.

Since the start of the cellular network, demand for mobile services has been growing and so has the number of mobile subscribers.

One explanation for this, which is worth closer consideration is the fact that less than 5% of the cellular subscribers are private. Business people in New Telerica very soon discovered that the mobile telephone is a powerful tool with a short pay-off time.

The number of subscribers in the cellular network today is 730,000, a penetration of 2.68%. The cellular network is also used to meet demands for sophisticated services in the rural areas, so called "fixed mobile" subscribers. About 40,000 subscribers are connected to the telecommunication network this way.

Overview of Telcell

The operating company, Telcell, was formed by NTTA (50%), Independent Insurance Company (25%) and private investment (25%). Telcell has to meet the following conditions:

- The operator is obliged to provide coverage to at least 90% of the population by the seventh year of operation. This will be done in four phases

- The operator shall retail the service to subscribers, but terminals are supplied in unrestricted competition by manufacturers. Any manufacturer may supply subscriber equipment subject to approval from Telcell

- Subscription and usage fees must be submitted to the Ministry of Communications for approval

- The design of the cellular network must not necessitate any significant changes in the existing telephone networks. As much as possible, the same facilities that exists for fixed telephone subscribers should be available to mobile subscribers

Telcell cell planning was performed by the NTTA. The goal of 90% population coverage was fulfilled after five years due to the unexpected growth of demand.

Overview of Peertel

In order to boost progress in industry, commerce and transport, it is now time to introduce a second GSM cellular network operator. Peertel was formed by Middlemedia (25%), NormData (25%), Ericorail (25%) and private investment (25%).

At the licensing contest, Peertel bound itself to the ambition of building a hierarchical digital cellular network for personal communications based on compatibility between macrocells, microcells and picocells. Peertel is expected to create high capacity and coverage in a short time and at low cost. The fulfilment of these requirements and the competition between Telcell and Peertel are expected to give lower cellular subscriber costs.

Peertel cell planning was performed by the supplier of the network elements. The goal of 70% population coverage was fulfilled after four years.

SETUP OF PEERTEL’S NETWORK

Market Strategy

When Peertel won the licence to operate the second GSM network, they immediately set about analysing the marketplace to determine what their market strategy would be.

The results of this analysis showed that most Telerican’s did not have a favourable image of NTTA (PSTN). Among potential business users NTTA scored 55% satisfaction. Among potential residential users the figure was 30%. However, NTTA has changed its business practices and image considerably and can no longer be discounted as a significant competitor.

Peertel’s initial strategy was thus to sell itself as an aggressive market-driven operator and to establish a niche market. Their aim was to get both business and residential subscribers as a primary goal, with increasing subscriber traffic as a secondary goal. In the start-up phase, Peertel did not wish to compete directly with other network operators, as it would be very difficulty to win a price war with either Telcell and/or NTTA.

In particular Peertel saw scope for attracting residential subscribers - only 5% of Telcell’s subscribers were residential.

Phase 1: From Network set-up to Network Operation

As part of their network setup, Peertel drew up interface agreements, started negotiations for transmission services, invited tenders for equipment, developed initial tariff plans, etc.

Interface Agreements

Peertel formed an agreement with NTTA to enable subscribers to both networks to make and receive calls across the networks. (NTTA has a separate deal with Telcell - in this way subscribers from Peertel can call those in Telcell.) They agreed that the charges applied for use of the other network would be 55% of the normal price of a call.

Transmission Services

Following difficult negotiations, Peertel agreed to use NTTA's network for transmission services. Basically, NTTA will provide 30 voice channels (2Mbits/s PCM link) to Peertel at a price of approximately 150,000 TED per year. This agreement is to be re-evaluated every two years.

Initial Tariff Plans

Peertel have decided that their tariff scheme must be lower than their competitior's. Peertel's initial tariffs were as follows:

Business Usage	**TED**
Connection	500
Monthly subscription	500
Call charges:	
• 8.00 - 18.00	4
• Other times	2
• Between Peertel mobiles	1
Residential Usage	
Connection	300
Monthly subscription	500
Call charges:	
• 8.00 - 18.00	6
• Other times	2
• Between Peertel mobiles	1
Free local calls (<15km) 19.00 to 24.00	

Table C-2 Tariff Plans

Phase 2: Network Roll-out

Board Decisions

Since the population is largely concentrated in the towns and along main roads, Peertel management made an early decision that initial network coverage was to be of main roads only. The intention was that this would achieve the following benefits:

- Provide coverage of business-people travelling between business centers
- Provide coverage for residents near the main roads
- Provide a strong sales argument by offering security to travellers in the case of vehicle breakdown

During the roll-out phase a decision was made to offer free local calls (<15 km) after 18.00 hours for all subscribers. It was decided that the sales benefit from such an offer would outweigh the decrease in potential income.

Also at this stage, Ericorail expressed dissatisfaction with the transmission services agreement with NTTA, largely because Ericorail itself could offer some limited transmission capacity using its rail network as the basic infrastructure. To appease Ericorail a decision was made to ask planners to develop estimates and plans for alternative transmission systems (e.g. fibre optic cable from Independencia and Secondia), including Ericorail’s network. In this it was recognised that very often the shortest feasible route between two towns was along the rail tracks.

Contingency Plans

The marketing department of Peertel provided their best estimate of expected subscriber growth. However, the inevitable uncertainty involved, called for maximum flexibility in terms of network support and expansion priorities.

In the radio access network, the initial problems of network structure were the number of installed transceivers for individual BTSs and the capacity of the attached BSCs. The transmission capacity was ample in the beginning since the star network had 30 channels (per BTS) and 1 transceiver uses only 3 of these. For flexibility the number of BTSs per link to the BSC was limited to 4 (using drop and insert). On average this allowed 2 transceivers per BTS.

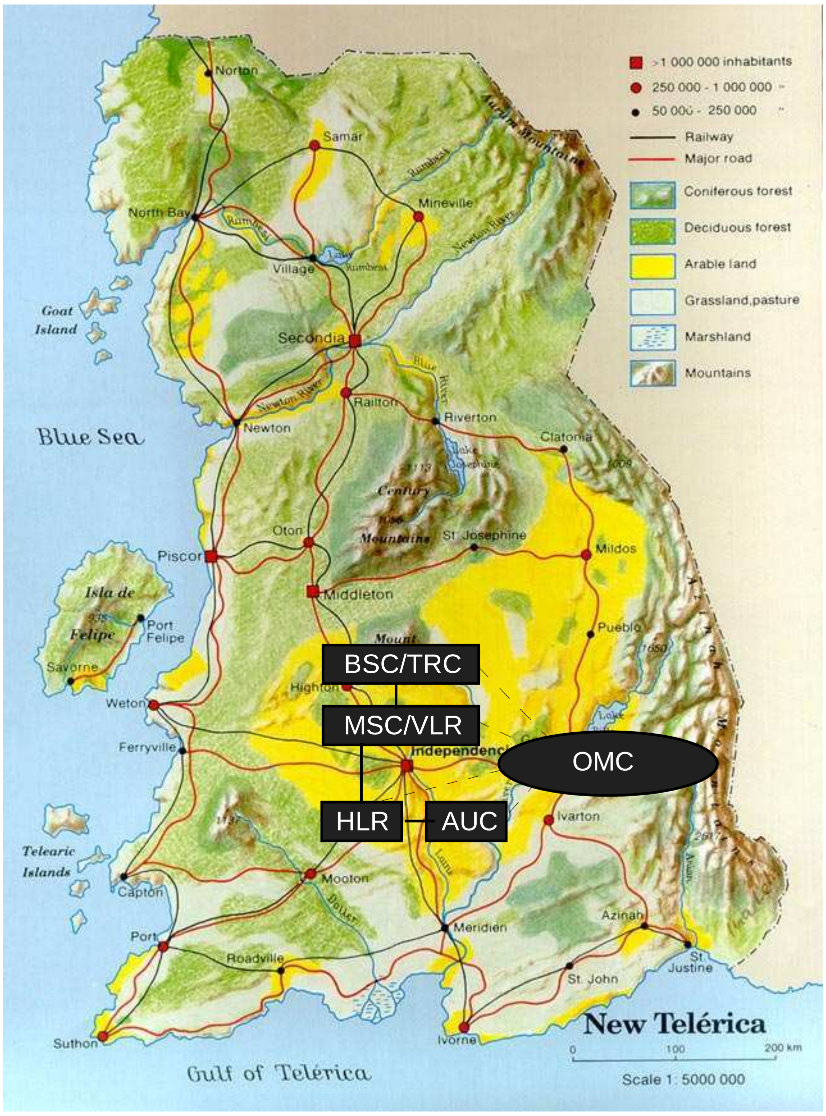


Figure C-2 Network layout

With flexibility in mind, ample physical space was planned in BTSs for expansion. In addition, planning permission was requested for additional strategic sites. This decision was made with the knowledge that, traditionally, the use of additional transmission capacity takes 9 months from initial request to actual service. These measures would enable quick expansion in the event of higher than expected cell traffic requirements.

BSC and MSC sites were located together at the center of Independencia, thus eliminating BSC-MSC transmission costs and enabling easier operation and maintenance (as both were at the same site). Peertel accepted that high traffic demands may have required remote BSCs at a later stage.

With regard to staff, Peertel recognised that its expert switching-related staff should be located in an OMC at the same location as the MSC and BSC. Its radio engineers were based in various remote locations, each supplied with the necessary transport and equipment to perform their BTS repairs[1]. Peertel also put in place the necessary training programs for its staff.

[1] Note: For simplification, it may be considered that one radio engineer has responsibility for approximately 35 BTSs. This is dependent on the geographical spread of the sites however

Planning Information

Financial data	
Depreciation period Buildings Equipment Cars	 20 yrs 10 yrs 5 yrs
Car costs	200,000 TED
Depreciation interest	15 %
Average annual interest	12 %
Taxation	17 %
VAT	15 %
Average annual inflation	4 %
Annual premium	2 %

Table C-3 Financial data

Call Projections					
Year	**2**	**4**	**6**	**8**	**10**
Incoming Calls (%)					
Low	20	20	20	20	20
High	26	28	33	40	50
Expected	24	26	28	33	40
Outgoing Calls (%)					
Low	76	74	72	70	65
High	64	60	52	43	30
Expected	69	65	60	53	44
Mobile to Mobile Calls (%)					
Low	4	6	8	10	15
High	10	12	15	17	20
Expected	7	9	12	14	16

Table C-4 Call Projections

Roll-out phases					
		Population	Subscribers (1,000s)		
Year	Town	(1,000s)	Low	High	Expected
1	Independencia	2,312	20	57	48
	Secondia	3,237	32	90	73
	Total	**5,549**	**52**	**147**	**121**
3	Independencia	2,312	39	84	73
	Secondia	3,237	61	133	116
	Middleton	1,467	12	18	18
	Piscor	1,353	11	16	16
	Highton	443	3	5	5
	Oton	714	5	9	9
	Railton	343	3	5	5
	Suthon	692	3	4	4
	Port	620	2	4	4
	Mooton	394	1	2	2
	Ivorne	573	2	3	3
	Meridien	84	0	0	0
	Village	272	1	2	2
	North Bay	213	1	1	1
	Samar	355	1	2	2
	Mineville	437	2	3	3
	Total	**13,509**	**147**	**291**	**263**
5	Independencia	2,312	54	116	102
	Secondia	3,237	85	183	182
	Middleton	1,467	22	39	38
	Piscor	1,353	20	35	34
	Highton	443	8	11	10
	Oton	714	10	19	18
	Railton	343	8	11	10
	Suthon	692	8	14	13
	Port	620	7	14	13
	Mooton	394	4	5	7
	Ivorne	573	7	11	11
	Meridien	84	0	2	2
	Village	272	3	6	6
	North Bay	213	3	5	4
	Samar	355	4	8	7
	Mineville	437	5	9	9
	Riverton	208	2	4	3
	Clatonia	108	0	2	2
	Mildos	299	2	2	2
	Pueblo	156	0	2	2
	Gondor	180	0	2	2
	Ivarton	299	1	2	2
	St. Josephine	239	1	2	2
	Ferryville	143	0	2	2
	Weton	479	3	8	7
	Port Felipe	81	0	1	0
	Newton	201	1	1	1
	Norton	83	0	1	1
	Capton	167	1	1	1
	Roadville	107	0	1	1
	St. John	72	0	1	1
	Azinah	60	0	0	0
	St.Justine	107	0	1	1
	Total	**16,498**	**759**	**1,520**	**1,096**

Table C-5 Subscriber Projections

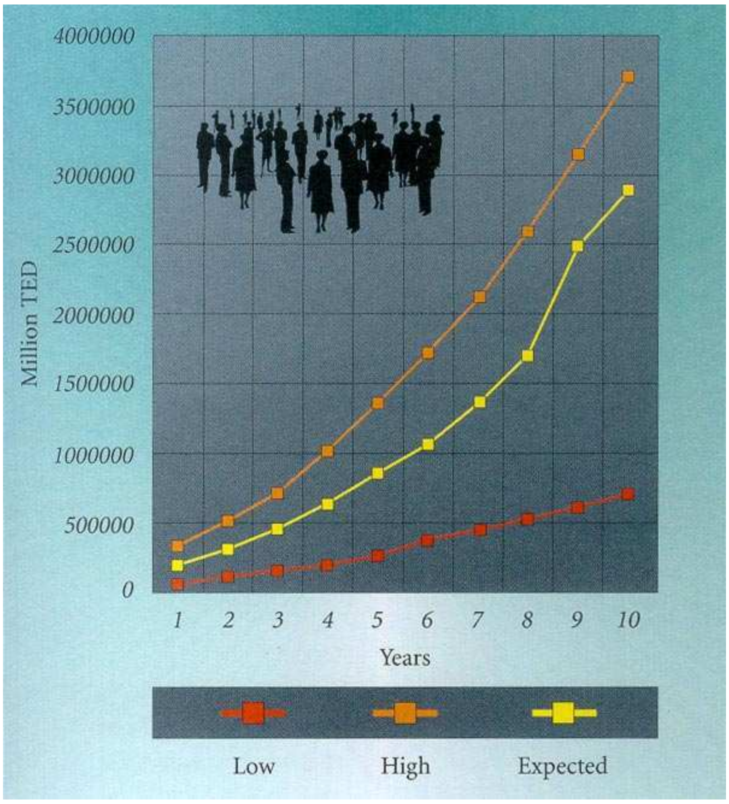


Figure C-3 Expected subscriber growth

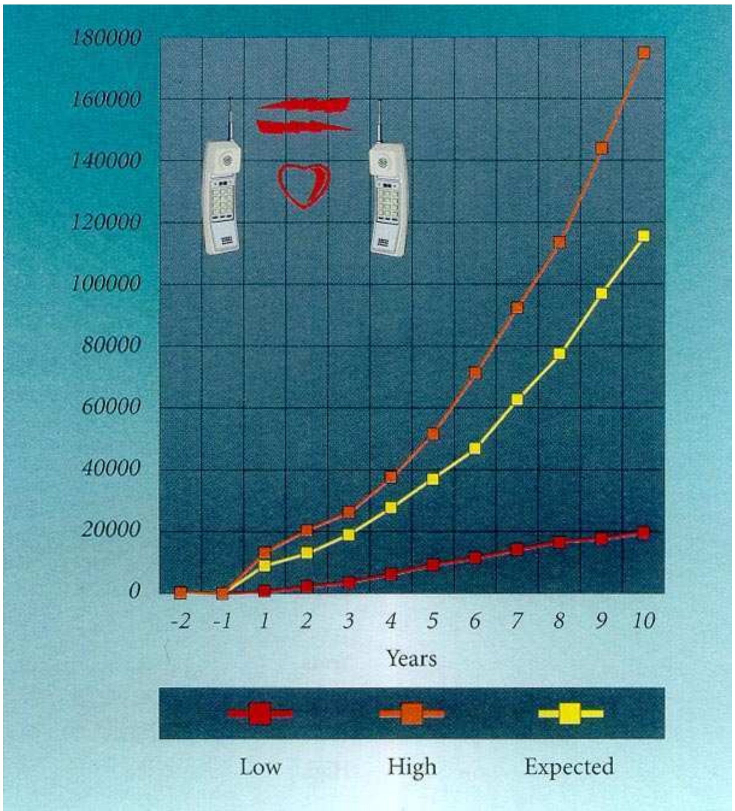


Figure C-4 Expected traffic

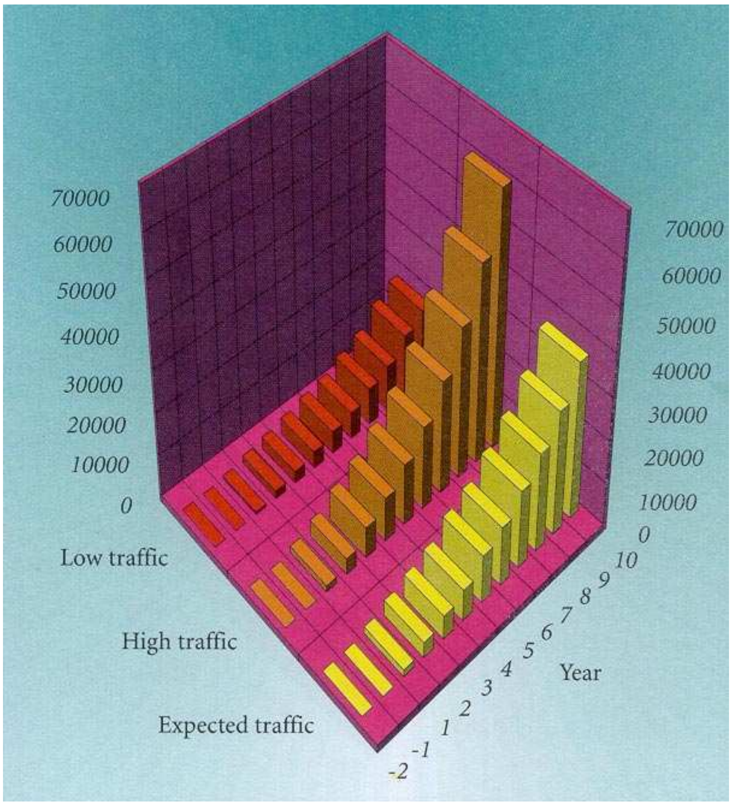


Figure C-5 Expected revenue

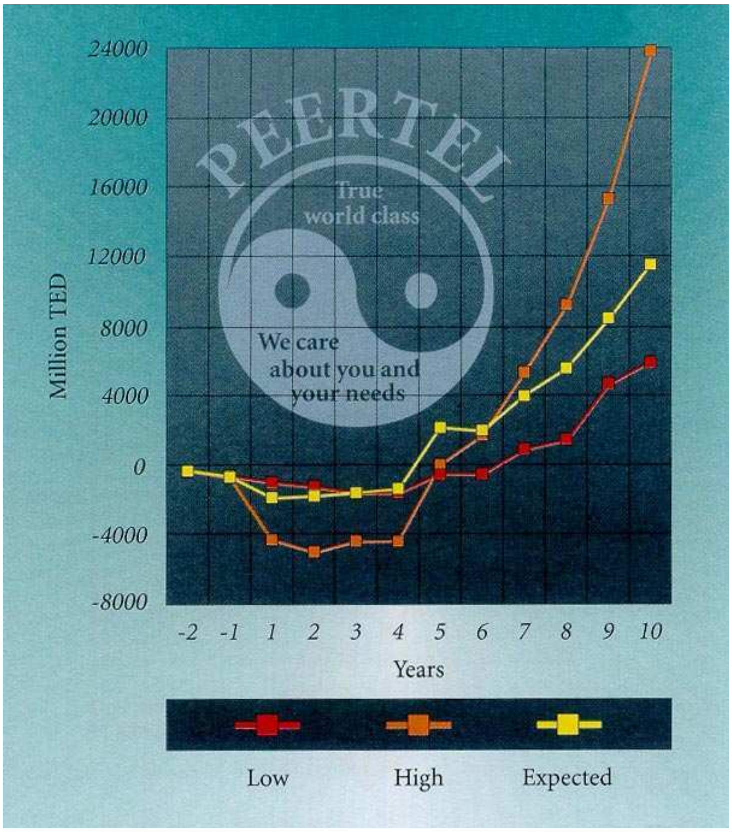


Figure C-6 Expected profit

Cell Planning Information

Peertel performed detailed cell planning for their network as it was vital that it could successfully compete with Telcell's existing network.

A requirement of the licence was that the network coverage in towns must allow for indoor coverage. This fact, among others, limited the cell sizes which they could use in some cases (e.g. concrete buildings and windows with heat-reflecting layers). Peertel calulated the average cell sizes listed in the following table.

Town and road:	**City**	**Urban**	**Suburban**
Cell Size:	**Radius (km)**	**Radius (km)**	**Radius (km)**
Independencia	0.5	2	4
Weton	1	3	5
Highton	2	3	6
Mildos	2	3	6
Clatonia	2	3	6
St. Josephine	3	5	8
Gondor	3	5	8
Ivarton	3	5	8
Pueblo	3	5	8
Middleton	1.5	3	6
Piscor	0.5	3	6
Port Felipe	1.5	3	6
Savorne	1	3	6
Riverton	2	4	8
Oton	2	3	5
Secondia	0.5	2	4
Railton	0.15	2	4
Village	3	5	8
Newton	1	3	5
Mineville	1	3	6
Samar	1	3	6
North Bay	1	3	6
Norton	3	5	8
Suton	1.5	3	6
Port	1.5	3	6
Ivorne	1.5	3	6
Moton	3	5	8
Capton	1.5	3	6
Ferryville	1.5	3	6
Roadville	2	4	6
Meridien	3	5	8
St. John	2	4	8
Azinah	3	5	8
St. Justine	2	4	6

Table C-6 Cell sizes

In addition to the above, the number of needed cells at end of year one was calculated as:

- Number of subscribers: 121,000
- Available frequencies: 48
- Cell pattern: 4/12
- GOS: 2%
- Traffic per subscriber: 25mE

Therefore:

- Frequencies per cell = 48 / 12 = 4
- Traffic channels per cell = 4 x 8 - 2 (control channels) = 30 TCH
- Traffic per cell = 30 TCH with a 2% GOS implies 21.932 Erlangs per cell (see table 6-1)
- The number of subscribers per cell = 21.932E / 25mE = 877 subscribers per cell
- If there are 121,000 subscribers then the number of cells needed is 121,000 / 877 = 138 cells.

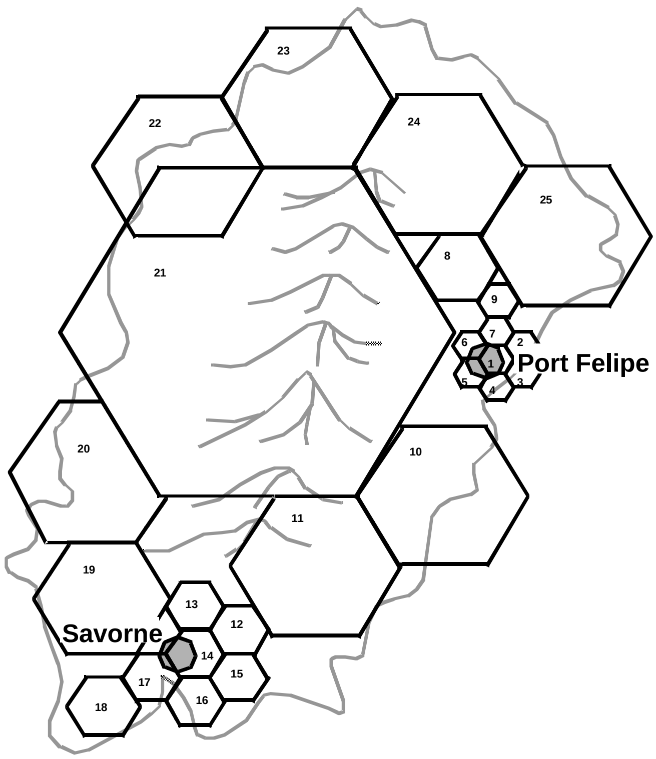


Figure C-7 Example of cellular network in Isla de Felipe

The Future of GSM

Appendix D

This appendix is designed to provide the student with an overview of the possible future functionality of GSM-based systems.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

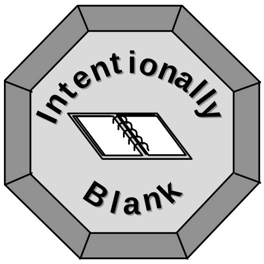
- Describe the possible future functionality available with GSM systems

Intentionally Blank

D: The Future of GSM

Table of Contents

Topic	Page


Intentionally
Blank

INTRODUCTION

The future for GSM includes more subscribers, more networks and more services. The primary concept which is driving this future is that of the third generation of mobile systems. Other developments which are taking place are also outlined here.

THE THIRD GENERATION OF MOBILE SYSTEMS

INTRODUCTION

Analog mobile networks are considered to be the first generation of mobile systems. Digital mobile network are are considered to be the second generation of mobile systems. The third generation of mobile systems is currently being defined in various standardization groups around the world.

One characteristic of true third-generation services and applications will be the infrastructure’s capabilities to deliver several services in parallel to each individual end user/terminal. This means subscribers to services can carry on a voice conversation in parallel to accessing an intranet or extranet to obtain important information or participate in a video conference and at the same time exchanging e-mails and/or multimedia mails.

Predictions for the future of such a system include statistics such as “Mobile multimedia will account for 16% of mobile subscribers, 25% of operator revenues and 60% of network traffic in the year 2005”.

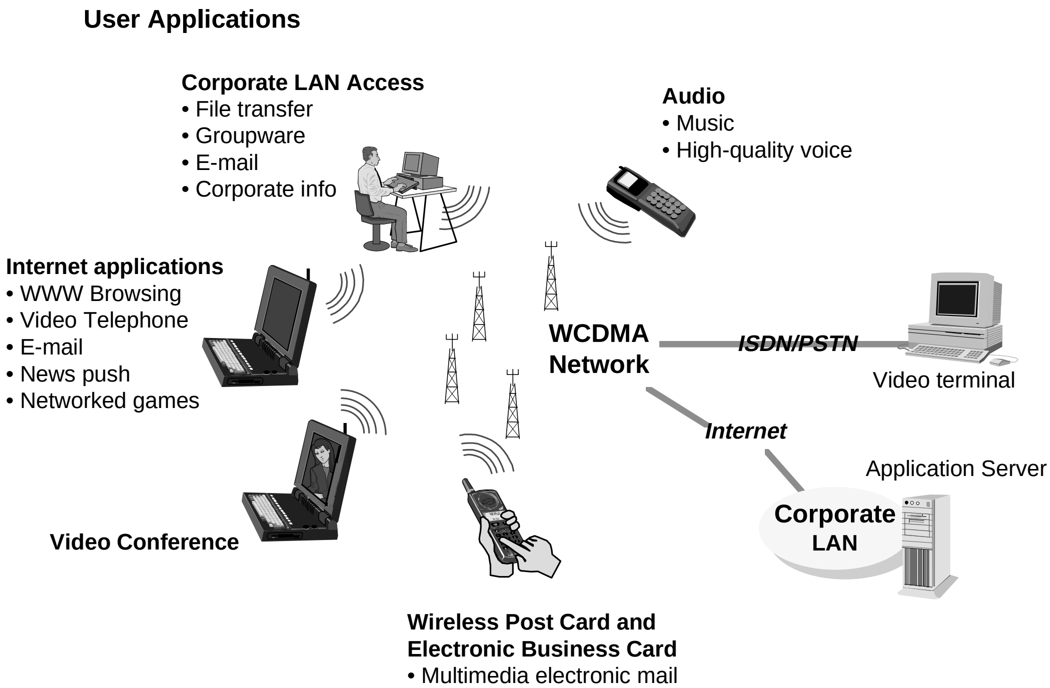


Figure D-1 Mobile multimedia services

SERVICES

The general concepts for third generation systems are grouped under the concept of the International Mobile Telecommunications 2000 (IMT-2000) system, as being defined by ITU-T. This is complemented by development of Universal Mobile Telecommunications System (UMTS) by ETSI. UMTS aims to deliver wide-area/high-mobility data rates of 384 kbits/s and up to 2 Mbits/s for local-area/low-mobility coverage.

Frequency spectrum has already been allocated for these third-generation services in the 2 GHz frequency band.

Some basic planned UMTS services include:

- Voice/high-quality audio
- High-speed data transmission including still photographs
- E-postcard in combination with digital cameras
- Video conferencing and multimedia

Some future wireless scenarios for wideband wireless multimedia can comprise the following services:

- Interactive news delivery (voice, video, e-mail, graphics)
- Multimedia e-mail (text, graphics, video clips)
- Interactive audio (CD-quality voice, video, graphics)
- Video conferencing, large file transfer
- Web browsing (dynamic Internet-based games, etc)
- Downloading large files from intranets
- Position/location-dependant "push" info
- Electronic commerce
- Telemetry for traffic and security systems

IMPLEMENTATION

Ericsson is currently working on supplying a solution for UMTS using Wideband Code Division Multiple Access (WCDMA) and GSM.

Wideband Code Division Multiple Access (WCDMA)

As an access method, Code Division Multiple Access (CDMA) is an alternative to TDMA. However, there are several key differences in implementation between TDMA and CDMA.

The basic concept of CDMA is to simultaneously handle several users's MSs without dividing the radio carrier by time slots. Instead, each MS is given a decoding key. Then the information for several MSs is transmitted downlink at the same time. Functions in each MS can then be used to analyze the information and to decode only that information which is relevant to itself. Security is ensured as each MS does not have the decoding key for other MSs, it will not be able to decode any other MS's information.

The problem of interference is avoided using such intelligent functions, but as the number of users of the same carrier increases, the more difficult it becomes for an MS to decode its own information. For this reason, it is desireable to have a wide bandwidth when using CDMA solutions. This leads to the term WCDMA.

The services proposed within UMTS involve transferring large amounts of data to and from MSs. Ericsson is developing the new WCDMA concept operating with a 5 MHz carrier separation to fully use the inherent benefits of code division multiple access technology.

Given the large bandwidth, each WCDMA terminal connection may access several services simultaneously. Each service can be optimized at the required data rate and quality.

Evolution of GSM to UMTS

Going forward, GSM will continue to evolve to meet demands for high-data rates through two complementary developments.

First, the existing MS-network interface has evolved to include high bit rates for wide-area coverage, through HSCSD and packet-switched data through General Packet Radio Services (GPRS) that will provide data rates up to 115 kbits/s.

Second, GSM will evolve to meet with third generation requirements by offering data rates up to 384 kbits/s in all existing GSM frequencies. To do this, a high-level modulation method will be used to support both packet-switched and circuit-switched data.

To reach this level of throughput, two air interfaces will co-exist: the evolved GSM (TDMA) and the new UMTS interface (WCDMA).

Using dual-mode GSM/UMTS global handsets - with GSM providing coverage and UMTS delivering new functionality - operators will be able to fully leverage additional wideband services in their GSM networks with full service transparency across the enormous GSM worldwide presence.

The radio access network will be a distinct overlay network for the two types of air interfaces. For the UMTS radio access network, some of the existing GSM concepts will be reused but many principles and structures will be new. The core network for UMTS will be an evolution of today’s GSM circuit and packet switching networks.

As a result the GSM MSC will be evolved to support circuit-switched accesses from the MS towards either telecommunications-based networks (e.g. PSTN, PLMN) or data communications-based networks (e.g. Internet), thus becoming a GSM-UMTS MSC. This means that in the future the same MSC will be handling both TDMA and WCDMA accesses. This will likely include roaming and handover between these two radio access networks for the same MS.

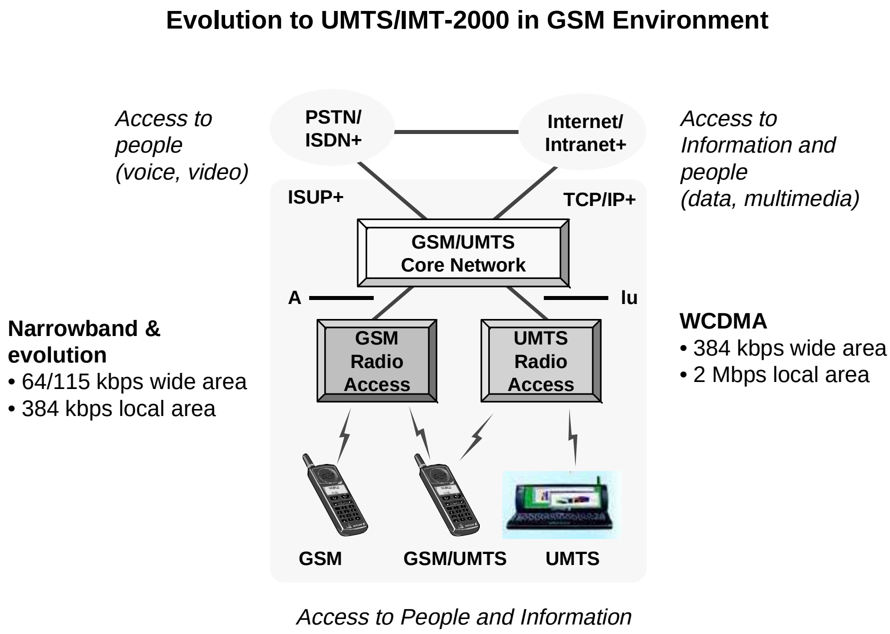


Figure D-2 Evolution of GSM to UMTS

OTHER DEVELOPMENTS

GSM as a second generation mobile system continues to evolve. Some of the key areas for GSM in the future which are not third generation-related are outlined here.

ENHANCED MOBILE INTELLIGENT NETWORK (MIN) SERVICES

The integration of Mobile Intelligent Network (MIN) concepts with GSM is being currently defined in ETSI. It centers around the concept of Customized Application for Mobile Enhanced Logic (CAMEL).

The primary focus of CAMEL-related developments is to provide a system in which it is possible to use MIN services while roaming internationally. This is currently not possible. It is intended that this will be enabled by treating an SCP similarly to a HLR, where interrogation for service intelligence from other networks is possible.

MULTI-BAND MOBILE STATIONS

At present, a GSM MS works with only one of the GSM frequency bands 900, 1800 and 1900. It is envisaged that in the near future phones will be available which can operate on both GSM 900 and GSM 1800. This requires an MS capable of dealing with both bands, but does not involve new signaling capabilities.

In the more distant future it is expected that a GSM MS will become available which can operate with all GSM frequency bands. This will require operation not only according to signaling protocols for GSM 900 and GSM 1800, but also for GSM 1900, which is based on ANSI signaling.

GSM IN CORDLESS APPLICATIONS

The term cordless refers to a phone which replaces a PSTN wireline phone and which has limited mobility, such as a within home or office.

PSTN operators are increasingly looking for access solutions which involve lower infrastructure costs than those associated with traditional copper wire-based phones.

One possible solution is to use a normal GSM phone as both a cellular phone and a cordless. When the user is in the area of their home, the services they use can be provided by the PSTN via the GSM network.

This could be implemented by a small home base station and new software in the MS which automatically registers with the home base station when within its area of coverage. All services used by the subscriber can then be charged at PSTN prices instead of PLMN prices.

Ericsson's Customer Services

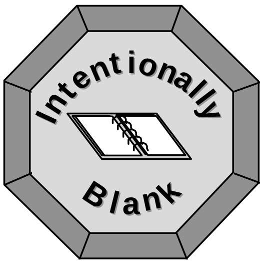
Appendix E

This appendix is designed to provide the student with an overview of the customer services which Ericsson offers for cellular network operators.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

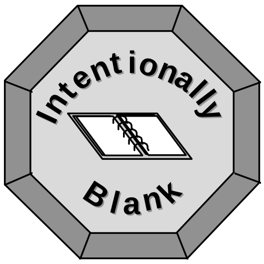
- Identify and describe Ericsson's customer services


Intentionally
Blank

E: Ericsson's Customer Services

Table of Contents

Topic	Page


Intentionally
Blank

INTRODUCTION

Ericsson’s services for network operators enable operators to maximize the benefit of their investments in technology and to increase long-term cost-efficiency and competitiveness. Together with the operator, Ericsson analyze the operator's activities, processes and expertise, and plan programmes that complement and enhance overall operations. The scope of the analysis is adapted to the status of the operator organization.

New operators, as well as established operators who are taking on new roles or branching into new markets, are supported by solutions that speed up roll-out and minimize financial risks. For these operators, a complete business analysis might be necessary. Established operators might require help in optimising and fine-tuning specific parts of their organizations and networks.

The customer services offering is a concept for integrated service solutions that are tailored to fit the needs of individual operators. Service solutions cover every phase of network development, from initial planning to ongoing operations. By means of the customer services program, Ericsson ensures that the complete network - not just traffic-carrying functions, but also billing and customer care - are up and running from the very start, thereby facilitating a rapid flow of revenue.

The services, which apply to all major digital and analog technologies and standards, include advice on network performance and planning, and hands-on operation and maintenance.

The long-term objective of the service commitment is to make operators more successful by:

- Reducing time to market
- Cutting overall cost
- Improving service order activation
- Ensuring more efficient customer care

CUSTOMER SERVICES

The Ericsson service portfolio for network operators comprises four service areas:

- **Professional services:** for helping operators to plan network and business operations
- **Implementation and integration services:** for helping operators to implement and install nodes or networks
- **Maintenance and support services:** for helping operators to operate and maintain networks and end-user services
- **Customer training:** for helping operators to establish and develop necessary competencies

SERVICE EXAMPLES

Business Consulting

For operators tackling new market sectors, Ericsson assists with the development of business plans and marketing strategies. Output can include recommendations on processes, organizational structures, and business support systems.

Network Design

Network design involves planning a network that will support the operator's business plan. The output is a complete technical solution and network design plan.

Network Implementation and Integration

This service involves building a new network or enhancing an existing network, integrating multi-vendor equipment and systems, including installation and commissioning. The output is the handover of a fully-operational, fully-tested network.

Competence Development

Within this service, based on training needs analysis, training and certification is undertaken to meet agreed competence goals. The result is staff which are competent to handle the network.

Network Support

Network support offers day-to-day operational support, with backup from global response centers, to ensure continuous, smooth, profitable network operation. The result is a network that meets key network performance parameters agreed at the outset.

Network Performance Improvement

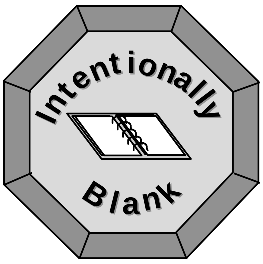
With this service, Ericsson offers to analyze the performance of an existing network, leading to improvement recommendations and implementation. Result is improved coverage, capacity, efficiency and reliability.

Network Management

Network management offers a network management solution that is tailored to the operator’s business plan, general strategies and available resources. It can combine Ericsson resources with the operator’s in-house organization, or Ericsson can undertake complete operation of the network on behalf of the operator.

Intentionally Blank

Index


Intentionally
Blank

Index

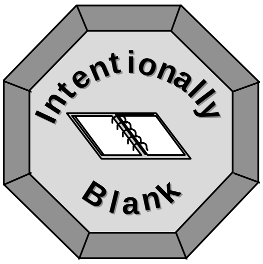
Table of Contents

Topic	Page

Intentionally Blank

INDEX

—S—


Intentionally
Blank