E1-E2 UPGRADATION COURSE –CONSUMER MOBILITY

Overview of GSM

CHAPTER-ONE

Overview of GSM

The Global System for Mobile communications is a digital cellular communications system. It was developed in order to create a common European mobile telephone standard but it has been rapidly accepted worldwide. GSM was designed to be compatible with ISDN services.

Cellular Systems

The Cellular Structure

In a cellular system, the covering area of an operator is divided into cells. A cell corresponds to the covering area of one transmitter or a small collection of transmitters. The size of a cell is determined by the transmitter's power.

The concept of cellular systems is the use of low power transmitters in order to enable the efficient reuse of the frequencies. In fact, if the transmitters used are very powerful, the frequencies can not be reused for hundred of kilometers as they are limited to the covering area of the transmitter.

The frequency band allocated to a cellular mobile radio system is distributed over a group of cells and this distribution is repeated in all the covering area of an operator. The whole number of radio channels available can then be used in each group of cells that form the covering area of an operator. Frequencies used in a cell will be reused several cells away. The distance between the cells using the same frequency must be sufficient to avoid interference. The frequency reuse will increase considerably the capacity in number of users.

In order to work properly, a cellular system must verify the following two main conditions:

- The power level of a transmitter within a single cell must be limited in order to reduce the interference with the transmitters of neighboring cells. The interference will not produce any damage to the system if a distance of about 2.5 to 3 times the diameter of a cell is reserved between transmitters. The receiver filters must also be very performant.
- Neighboring cells can not share the same channels. In order to reduce the interference, the frequencies must be reused only within a certain pattern.

In order to exchange the information needed to maintain the communication links within the cellular network, several radio channels are reserved for the signaling information.

Cluster

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

Types Of Cells

The density of population in a country is so varied that different types of cells are used:

Macro cells

The macro cells are large cells for remote and sparsely populated areas

Micro cells

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

Selective cells

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

Umbrella cells

A freeway crossing very small cells produces an important number of handovers among the different small neighboring cells. In order to solve this problem, the

concept of umbrella cells is introduced. An umbrella cell covers several micro cells. The power level inside an umbrella cell is increased comparing to the power levels used in the micro cells that form the umbrella cell. When the speed of the mobile is too high, the mobile is handed off to the umbrella cell. The mobile will then stay longer in the same cell (in this case the umbrella cell). This will reduce the number of handovers and the work of the network.

A too important number of handover demands and the propagation characteristics of a mobile can help to detect its high speed.

The GSM Network

Architecture of the GSM Network

The GSM technical specifications define the different entities that form the GSM network by defining their functions and interface requirements.

The GSM network can be divided into four main parts:

The architecture of the GSM network is presented in figure 1.

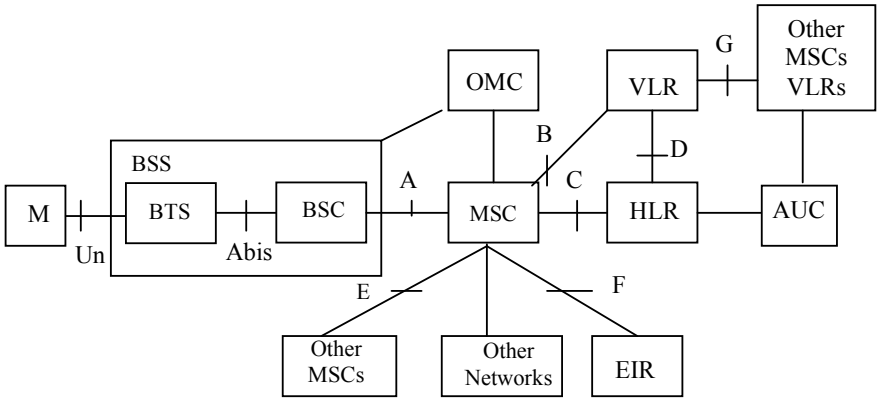

Fig : 1 Architecture of the GSM network

Mobile Station

A Mobile Station consists of two main elements:

The Terminal

There are different types of terminals distinguished principally by their power and application:

- The `fixed' terminals are the ones installed in cars. Their maximum allowed output power is 20 W.
- The GSM portable terminals can also be installed in vehicles. Their maximum allowed output power is 8W.
- The handheld terminals have experienced the biggest success thanks to the weight and volume, which are continuously decreasing. These terminals can emit up to 2 W. The evolution of technologies allows decreasing the maximum allowed power to 0.8 W.

The SIM

The SIM is a smart card that identifies the terminal. By inserting the SIM card into the terminal, the user can have access to all the subscribed services. Without the SIM card, the terminal is not operational.

The SIM card is protected by a four-digit Personal Identification Number (PIN). In order to identify the subscriber to the system, the SIM card contains some parameters of the user such as its International Mobile Subscriber Identity (IMSI).

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

The Base Station Subsystem

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

The Base Transceiver Station

The BTS corresponds to the transceivers and antennas used in each cell of the network. A BTS is usually placed in the center of a cell. Its transmitting power defines the size of a cell. Each BTS has between one and sixteen transceivers depending on the density of users in the cell.

The Base Station Controller

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

The Network and Switching Subsystem

Its main role is to manage the communications between the mobile users and other users, such as mobile users, ISDN users, fixed telephony users, etc. It also includes data bases needed in order to store information about the subscribers and to manage their mobility. The different components of the NSS are described below.

The Mobile services Switching Center (MSC)

It is the central component of the NSS. The MSC performs the switching functions of the network. It also provides connection to other networks.

The Gateway Mobile services Switching Center (GMSC)

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

Home Location Register (HLR)

The HLR is considered as a very important database that stores information of the subscribers belonging to the covering area of a MSC. It also stores the current location of these subscribers and the services to which they have access. The location of the subscriber corresponds to the SS7 address of the Visitor Location Register (VLR) associated to the terminal.

Visitor Location Register (VLR)

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

The VLR is always implemented together with a MSC; so the area under control of the MSC is also the area under control of the VLR.

The Authentication Center (AuC)

The AuC register is used for security purposes. It provides the parameters needed for authentication and encryption functions. These parameters help to verify the user's identity.

The Equipment Identity Register (EIR)

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

The Operation and Support Subsystem (OSS)

The OSS is connected to the different components of the NSS and to the BSC, in order to control and monitor the GSM system. It is also in charge of controlling the traffic load of the BSS.

However, the increasing number of base stations, due to the development of cellular radio networks, has provoked that some of the maintenance tasks are transferred to the BTS. This transfer decreases considerably the costs of the maintenance of the system.

The geographical areas of the GSM network

The figure 2 presents the different areas that form a GSM network.

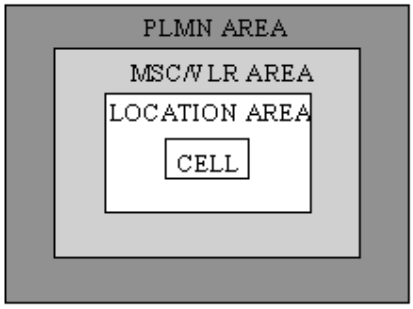

Fig : 2 GSM network areas

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

The GSM Radio Interface

The radio interface is the interface between the mobile stations and the fixed infrastructure. It is one of the most important interfaces of the GSM system.

One of the main objectives of GSM is roaming. Therefore, in order to obtain a complete compatibility between mobile stations and networks of different manufacturers and operators, the radio interface must be completely defined.

The spectrum efficiency depends on the radio interface and the transmission, more particularly in aspects such as the capacity of the system and the techniques used in order to decrease the interference and to improve the frequency reuse scheme. The specification of the radio interface has then an important influence on the spectrum efficiency.

Frequency Allocation

Two frequency bands, of 25 MHz each one, have been allocated for the GSM system:

- The band 890-915 MHz has been allocated for the uplink direction (transmitting from the mobile station to the base station).
- The band 935-960 MHz has been allocated for the downlink direction (transmitting from the base station to the mobile station).

But not all the countries can use the whole GSM frequency bands. This is due principally to military reasons and to the existence of previous analog systems using part of the two 25 MHz frequency bands.

DISCONTINUOUS TRANSMISSION (DTX)

This is another aspect of GSM that could have been included as one of the requirements of the GSM speech codec. The function of the DTX is to suspend the radio transmission during the silence periods. This can become quite interesting if we take into consideration the fact that a person speaks less than 40 or 50 percent during a conversation. The DTX helps then to reduce interference between different cells and to increase the capacity of the system. It also extends the life of a mobile's battery. The DTX function is performed thanks to two main features:

- The Voice Activity Detection (VAD), which has to determine whether the sound represents speech or noise, even if the background noise is very important. If the voice signal is considered as noise, the transmitter is turned off producing then, an unpleasant effect called clipping.
- The comfort noise. An inconvenient of the DTX function is that when the signal is considered as noise, the transmitter is turned off and therefore, a total silence is heard at the receiver. This can be very annoying to the user at the reception because it seems that the connection is dead. In order to overcome this problem, the receiver creates a minimum of background noise called comfort noise. The comfort noise eliminates the impression that the connection is dead.

TIMING ADVANCE

The timing of the bursts transmissions is very important. Mobiles are at different distances from the base stations. Their delay depends, consequently, on their distance. The aim of the timing advance is that the signals coming from the different mobile stations arrive to the base station at the right time. The base station measures the timing delay of the mobile stations. If the bursts corresponding to a mobile station arrive too late and overlap with other bursts, the base station tells, this mobile, to advance the transmission of its bursts.

Power Control

At the same time the base stations perform the timing measurements, they also perform measurements on the power level of the different mobile stations. These power levels are adjusted so that the power is nearly the same for each burst.

A base station also controls its power level. The mobile station measures the strength and the quality of the signal between itself and the base station. If the mobile station does not receive correctly the signal, the base station changes its power level.

Discontinuous Reception

It is a method used to conserve the mobile station's power. The paging channel is divided into sub channels corresponding to single mobile stations. Each mobile station will then only 'listen' to its sub channel and will stay in the sleep mode during the other sub channels of the paging channel.

Multipath and Equalisation

At the GSM frequency bands, radio waves reflect from buildings, cars, hills, etc. So not only the 'right' signal (the output signal of the emitter) is received by an antenna, but also many reflected signals, which corrupt the information, with different phases.

An equalizer is in charge of extracting the 'right' signal from the received signal. It estimates the channel impulse response of the GSM system and then constructs an inverse filter. The receiver knows which training sequence it must wait for. The equalizer will then, comparing the received training sequence with the training sequence it was expecting, compute the coefficients of the channel impulse response. In order to extract the 'right' signal, the received signal is passed through the inverse filter.

GSM REFERENCE MODEL

SYSTEM ENTITIES

The GSM system entities represent groupings of specific wireless functionality.

The following figure shows the GSM reference Model.

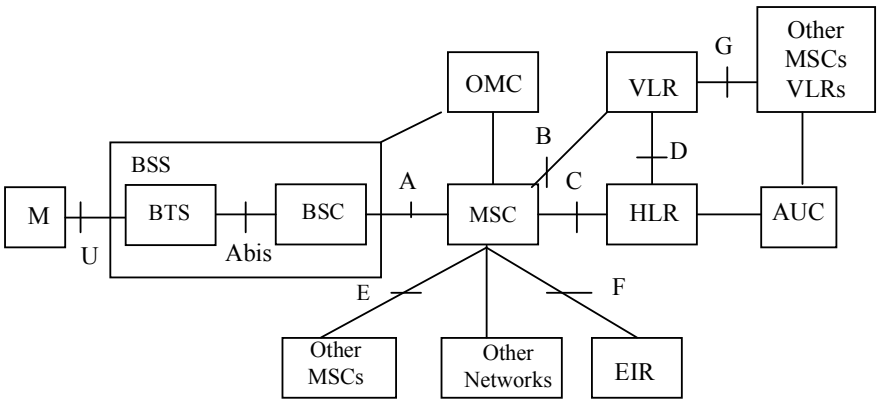

Fig : 3 GSM Reference Model

A Public Land Mobile Network (PLMN), as represented by the GSM reference model on the opposite page, includes the following system entities:

Mobile-services Switching Center (MSC)

Mobile-services Switching Center (MSC) performs the switching functions for all mobile stations located in the geographic area covered by its assigned BSSs. Functions performed include interfacing with the Public Switched Telephone Network (PSTN) as well as with the other MSCs and other system entities, such as the HLR, in the PLMN.

Functions of the MSC include:

- Call handling that copes with mobile nature of subscribers (e.g., paging)
- Management of required logical radio-link channel during calls
- Management of MSC-BSS signalling protocol
- Handling location registration and ensuring interworking between Mobile Station and VLR
- Control of inter-BSS and inter-MSC handovers
- Acting as a gateway MSC to interrogate the HLR
- Exchange of signalling information with other system entities
- Standard functions of a local exchange switch in the fixed network (example: charging)

Home Location Register (HLR)

The Home Location Register (HLR) contains the identities of mobile subscribers (called International Mobile Subscriber Identities or IMSIs), their service parameters, and their location information.

In summary, the HLR contains:

- Identity of mobile subscriber
- ISDN directory number of mobile station
- Subscription information on teleservices and bearer services
- Service restrictions (if any)
- Supplementary services
- Location information for call routing

Visitor Location Register (VLR)

The Visitor Location Register (VLR) contains the subscriber parameters and location information for all mobile subscribers currently located in the geographical area (i.e., cells) controlled by that VLR.

In summary, the VLR contains:

- Identity of mobile subscriber
- Any temporary mobile subscriber identity
- ISDN directory number of mobile
- A directory number to route calls to a roaming station
- Location area where the mobile station is registered
- Copy of (part of) the subscriber data from the HLR

Equipment Identity Register (EIR)

The Equipment Identity Register (EIR) is accessed during the equipment validation procedure when a mobile station accesses the system. It contains the identity of mobile station equipment (called International Mobile Station Equipment Identity or IMEI) which may be valid, suspect, or known to be fraudulent.

This contains:

- White or Valid list - List of valid MS equipment identities
- Grey or Monitored list - List of suspected mobiles under observation
- Black or prohibited list - List of mobiles for which service is barred.

Authentication Center (AUC)

The Authentication Center (AUC):

- Contains subscriber authentication data called Authentication Keys (Ki)
- Generates security related parameters needed to authorize service using Ki
- Generates unique data pattern called a Cipher Key (Kc) needed for encrypting user speech and data

Base Station System (BSS)

BSS comprises of BTS (Base Transceiver Station) and BSC (Base Station Controller).

Characteristics of the Base Station System (BSS) are:

- The BSS is responsible for communicating with mobile stations in cell areas
- One BSC controls one or more BTSs and can perform inter-BTS and intra- BTS handovers
- The BTS serves one or more cells in the cellular network and contains one or more TRXs (Transceivers or radio units).
- The TRX serves full duplex communications to the MS.

In the GSM network implementation of Lucent/Alcatel Technologies the BSC includes the TRAU (Transcoder/Rate Adapter Unit). The TRAU adapts the transmission bit rate of the A-interface (64kbit/s) to the Abis-interface (16 kbit/s).
Note that in the GSM network implementation of Lucent Technologies, the interface between the BSC and the TRAU is known as the M-interface (which is a proprietary interface).

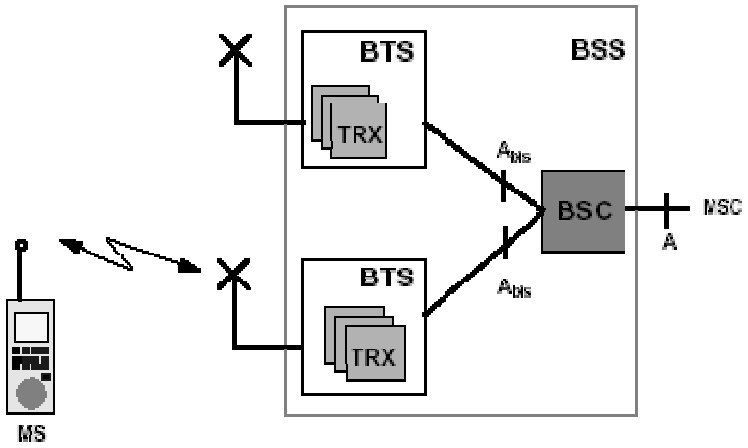

Fig : 4 BSS Configuration

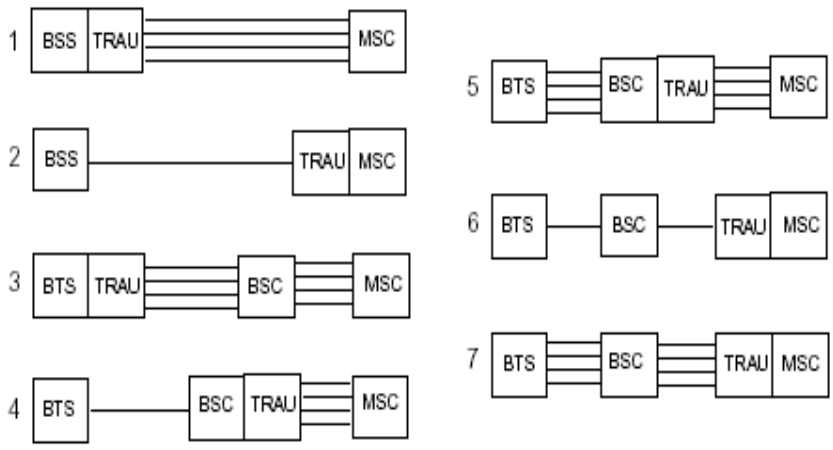

Fig : 5

BSS types are differentiated by the following characteristics:

The BSS can be an integrated (Intg) BSS or a distributed (Dist) BSS.
An integrated BSS is a BSS, which has the BSC, and BTS functionality located in the same physical unit. In a distributed BSS, the BTS and BSC are physically separated.
The BSS can have internally (Int) or externally (Ext) located speech transcoding.
Speech transcoding to 64 kbit/s takes place either in the BSC for BSS types 1, 4 and 5, or external to the BSS (i.e. the transcoder is co-located with the MSC) for BSS types 2, 6 and 7. For BSS type 3 transcoding takes place in the BTSs.
The Abis interface uses multiplexing (Mult) or rate adaptation (RA) on its links.

The first option means that four 16 kbit/s links are multiplexed into one 64 kbit/s channel. The latter option means that no multiplexing of the 16 kbit/s channels takes place.

Mobile Station (MS)

The Mobile Station (MS) represents the terminal equipment used by the wireless subscriber supported by the GSM Wireless system

The MS consists of two entities:

Subscriber Identity Module (SIM)
Mobile equipment

The SIM may be a removable module. A subscriber with an appropriate SIM can access the system using various mobile equipments. The equipment identity is not linked to a particular subscriber. Validity checks made on the MS equipment are

performed independently of the authentication checks made on the MS subscriber information.

Functions of a SIM

The functions of the Subscriber Identity Module (SIM) are:

- Authentication of the validity of the MS when accessing the network
- User authentication
- Storage of subscriber-related information, which can be: data fixed during administrative phase (e.g., subscriber identification), and temporary network data (e.g., cell location identity).

Dual SIM to one MSISDN

Dual SIM to one MSISDN allows subscribers to have 2 SIMs (i.e. to MSs) for one MSISDN. This means that two handsets are associated with the same MSISDN. This means that two handsets are associated with the same MSISDN, and have thee same subscriber data. Both handsets can simultaneously originate calls, however only one of the two SIMs can be active at one time for call terminations.

The users of the two SIMs are provided with the same services from the network operator. These services are charged on the same bill although the billing records at the HLR will record the actual SIM involved.

It should be noted that when one SIM user is changing has VLR both SIM subscriber records will be updated in the HLR.

Operation and Maintenance Center (OMC)

The Operations and Maintenance Center (OMC) is the centralized maintenance and diagnostic heart of the Base Station System (BSS). It allows the network provider to operate, administer, and monitor the functioning of the BSS.

Other Network Elements

Other optional network elements that the MSC can interface include:

Billing Center:
Each MSC writes call accounting records to local disk memory. The Billing Center periodically polls the disk records of each MSC to collect the billing data for the PLMN.

Service Center:
The Service Center interfaces with the MSCs to provide special services, such as the Short Message Service (SMS), to mobile subscribers in the PLMN.
The Billing Center and Service Center are not a basic part of the GSM system.

Conclusion

The aim of this paper was to give an overview of the GSM system and not to provide a complete and exhaustive guide.

As it is shown in this chapter, GSM is a very complex standard. It can be considered as the first serious attempt to fulfill the requirements for a universal personal communication system. GSM is then used as a basis for the development of the Universal Mobile Telecommunication System (UMTS).

Questions

1) How will you determine the total number of Channels per cell?
2) What are the network elements in BSS?
3) What are the functions performed by MSC?
4) What are the lists maintained by EIR?
5) What are the two features of discontinuous transmission?
6) What is the name of the GSM feature which makes burst from mobile station arriving base station without too late or overlap with other bursts?
7) Draw the architecture of GSM Network with interfaces?