

# OVERVIEW OF THE GSM CELLULAR SYSTEM

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## ABSTRACT

GSM, the Global System for Mobile communications, is a digital cellular communications system which has rapidly gained acceptance and market share worldwide, although it was initially developed in a European context. In addition to digital transmission, GSM incorporates many advanced services and features, including ISDN compatibility and worldwide roaming in other GSM networks. The advanced services and architecture of GSM have made it a model for future third-generation cellular systems. This paper will give an overview of the, the system architecture, and services offered by GSM.

## INTRODUCTION

The development of GSM started in 1982, when the Conference of European Posts and Telegraphs (CEPT) formed a study group called Group Special Mobile (the initial meaning of GSM). The group was to study and develop a pan-European public cellular system in the 900 MHz range, using spectrum that had been previously allocated. At that time, there were many incompatible analog cellular systems in various European countries. Some of the basic criteria for their proposed system were:

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

In 1989, the responsibility for GSM was transferred to the European Telecommunication Standards Institute (ETSI), and the Phase I recommendations were published in 1990. At that time, the United Kingdom requested a specification based on GSM but for higher user densities with low-power mobile stations, and operating at 1.8 GHz. The specifications for this system, called Digital Cellular System (DCS1800) were published 1991. Commercial operation of GSM networks started in mid-1991 in European countries. By the beginning of 1995, there were 60 countries with operational or planned GSM networks in Europe, the Middle East, the Far East, Australia, Africa, and South America, with a total of over 5.4 million subscribers.

## SYSTEM ARCHITECTURE

The functional architecture of a GSM system can be broadly divided into the mobile station, the base station subsystem, and the network subsystem. Each subsystem is comprised of functional entities which communicate through the various interfaces using specified protocols.

### Mobile Station

The mobile station in GSM is really two distinct entities. The actual hardware is the mobile equipment, which is anonymous. The subscriber information, which includes a unique identifier called the International Mobile Subscriber Identity (IMSI), is stored in the Subscriber Identity Module (SIM), implemented as a smart card. By inserting the SIM card in any GSM mobile equipment, the user is able to make and receive calls at that terminal and receive other subscribed services. By decoupling subscriber information from a specific

terminal, personal mobility is provided to GSM users.

### **Base Station Subsystem**

The Base Station Subsystem is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). The BTS houses the radio transceivers that define a cell and handles the radio (Um) interface protocols with the mobile station. Due to the potentially large number of BTSs, the requirements for a BTS are ruggedness, reliability, portability, and minimum cost.

The Base Station Controller (BSC) manages the radio resources for one or more BTSs, across the Abis interface. It manages the radio interface channels (setup, teardown, frequency hopping, etc.) as well as handovers.

### **Network Subsystem**

The central component of the Network Subsystem is the Mobile services Switching Center (MSC). It acts like a normal switching node of the PSTN or ISDN, and in addition provides all the functionality needed to handle a mobile subscriber, including registration, authentication, location updating, inter-MSC handovers, and call routing to a roaming subscriber. These services are provided in conjunction with four intelligent databases, which together with the MSC form the Network Subsystem. The MSC also provides the connection to the public fixed networks.

The Home Location Register (HLR) contains all the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the subscriber. The location assists in routing incoming calls to the mobile, and is typically the SS7 address of the visited MSC. There is logically one HLR per GSM network, although it may be implemented as a distributed database.

The Visitor Location Register contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. Although the VLR can be implemented as an independent unit, to date all manufacturers of switching equipment implement the VLR together with the MSC, so that the geographical area

controlled by the MSC corresponds to that controlled by the VLR. The proximity of the VLR information to the MSC speeds up access to information that the MSC requires during a call.

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

### **Radio transmission aspects**

The radio spectrum in the bands 890-915 MHz for the uplink (mobile station to base station) and 935-960 MHz for the downlink has been reserved in Europe for mobile networks. At least 10 MHz in each band was reserved explicitly for GSM. This 2x25 MHz spectrum is divided into 200 kHz carrier frequencies using FDMA. One or more carrier frequencies are assigned to individual base stations, and each carrier is divided into eight time slots using TDMA. Groups of eight consecutive time slots form TDMA frames, with a duration of 4.615 ms. A transmission channel occupies one time slot position within a TDMA frame. TDMA frames of a particular carrier frequency are numbered, and both the mobile station and the base station are synchronized on this number. Larger frames are formed from groups of 26 and 51 TDMA frames (there are also larger groups), and position within such frames defines the type and function of a channel.

There is a basic distinction between dedicated and idle modes that arises from on-demand channel allocation due to spectrum scarcity. Dedicated, or traffic, channels provide a bi-directional point-to-point transmission link to a mobile subscriber. Full-rate Traffic Channels (TCH/F) and half-rate

Traffic Channels (TCH/H) are allocated together with a low bit-rate Slow Associated Control Channel (SACCH), which typically transmits measurements needed for handover decisions. There are also eighth-rate Traffic Channels, also

called Stand-alone Dedicated Control Channels (SDCCH), which are used primarily for transmitting location updating information. In addition, a TCH slot can be pre-empted for signalling, in which case it is called a

Fast Associated Control Channel (FACCH), which can be either full-rate or half-rate. TCHs are defined within a 26-frame multiframe. Common channels can be accessed both by idle mode mobiles, in order to change to dedicated mode, and by dedicated mode mobiles, to monitor surrounding base stations for handover information. The common channels, which are defined within a 51-frame multiframe, include:

#### Broadcast Control Channel (BCCH)

Continually broadcasts, on the downlink, information including base station identity, frequency allocations, and frequency-hopping sequences.

Frequency Correction Channel (FCCH) and Synchronisation Channel (SCH) Used to synchronise the mobile to the time slot structure of a cell by defining the beginning of a TDMA frame.

#### Random Access Channel (RACH)

Slotted Aloha channel used by the mobile to request access to the network.

#### Paging Channel (PCH)

Used to alert the mobile station of incoming call.

#### Access Grant Channel (AGCH)

Used to allocate an SDCCH to a mobile for signalling (in order to obtain a dedicated channel), following a request on the RACH.

#### Speech and channel coding

Speech in GSM is digitally coded at a rate of 13 kbps, so-called full-rate speech coding. This is quite efficient compared with the standard ISDN rate of 64 kbps. One of the most important Phase 2 additions will be the introduction of a half-rate speech codec operating at around 7 kbps, effectively doubling the capacity of a network.

This 13 kbps digital stream (260 bits every 20 ms) has forward error correction added by a

convolution encoder. The gross bit rate after channel coding is 22.8 kbps (or 456 bits every 20 ms). These 456 bits are divided into 8 57-bit blocks, and the result is interleaved amongst eight successive time slot bursts for protection against busy transmission errors.

Each time slot burst is 156.25 bits and contains two 57-bit blocks, and a 26-bit training sequence used for equalization. A burst is transmitted in 0.577 ms for a total bit rate of 270.8 kbps, and is modulated using Gaussian Minimum Shift Keying (GMSK) onto the 200 kHz carrier frequency. The 26-bit training sequence is of a known pattern that is compared with the received pattern in the hope of being able to reconstruct the rest of the original signal. Forward error control and equalization contribute to the robustness of GSM radio signals against interference and multipath fading.

The digital TDMA nature of the signal allows several processes intended to improve transmission quality, increase the mobile's battery life, and improve spectrum efficiency. These include discontinuous transmission, frequency hopping and discontinuous reception when monitoring the paging channel. Another feature used by GSM is power control, which attempts to minimize the radio transmission power of the mobiles and the BTS, and thus minimize the amount of co-channel interference generated.

#### Network aspects

Radio transmission forms the lowest functional layer in GSM. In any telecommunication system, signalling is required to coordinate the necessarily distributed functional entities of the network. The transfer of signalling information in GSM follows the layered OSI model. On top of the physical layer described above is the data link layer providing error-free transmission between adjacent entities, based on the ISDN's LAPD protocol for the Um and Abis interfaces, and on SS7's Message Transfer Protocol (MTP) for the other interfaces. The functional layers above the data link layer are responsible for Radio Resource management (RR), Mobility Management (MM) and Call Management (CM).

The RR functional layer is responsible for providing a reliable radio link between the mobile station and the network infrastructure. This includes the establishment and allocation of radio

channels on the Um interface, as well as the establishment of a interface links to the MSC. The handover procedures, an essential element of cellular systems, are managed at this layer, which involves the mobile station, the base station subsystem, and, to a lesser degree, the MSC. Several protocols are used between the different network elements to provide RR functionality.

The MM functional layer assumes a reliable RR-connection, and is responsible for location management and security. Location management involves the procedures and signalling for location updating, so that the mobile's current location is stored at the HLR, allowing incoming calls to be properly routed. Security involves the authentication of the mobile, to prevent unauthorised access to the network, as well as the encryption of all radio link traffic. The protocols in the MM layer involve the SIM, MSC, VLR, and the HLR, as well as the AuC (which is closely tied with the HLR). The machines in the network subsystem exchange signalling information through the Mobile Application Part (MAP), which is built on top of SS7.

The CM functional layer is divided into three sublayers. The Call Control (CC) sublayer manages call routing, establishment, maintenance, and release, and is closely related to ISDN call control. The idea is for CC to be as independent as possible from the underlying specifics of the mobile network. Another sublayer is Supplementary Services, which manages the implementation of the various supplementary services, and also allows users to access and modify their service subscription. The final sublayer is the Short Message Service layer, which handles the routing and delivery of short messages, both from and to the mobile subscriber.

### **Advantages of GSM**

- GSM is a more stable network with robust features.
- Less signal deterioration inside buildings.
- Ability to use repeaters.

- The availability of Subscriber Identity Modules allows users to switch networks and handsets at will.
- GSM covers virtually all parts of the world so international roaming is not a problem.

### **Disadvantages of GSM**

- GSM has a fixed maximum cell site range of 35 km, which is imposed by technical limitations.
- Intellectual property is concentrated among a few industry participants, creating barriers to entry for new entrants and limiting competition among phone manufacturers.

### **Applications of GSM**

- Access control devices
- Transaction terminals
- Supply Chain Management

### **CONCLUSION**

The development of GSM is the first step towards a true personal communication system that will allow communication anywhere, anytime, and with anyone. The functional architecture of GSM, employing intelligent networking principles, and its ideology, which provides enough standardization to ensure compatibility, but still allows manufacturers and operators freedom, has been widely adopted in the development of future wireless systems.

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