

Cellular and Mobile Communication
CSE-472
Global System for Mobile (GSM) [\[video\]](#)

Cellular network is an underlying technology for mobile phones, personal communication systems, wireless networking etc. The technology is developed for mobile radio telephone to replace high power transmitter/receiver systems. Cellular networks use lower power, shorter range and more transmitters for data transmission.

Features of Cellular Systems

Wireless Cellular Systems solves the problem of spectral congestion and increases user capacity. The features of cellular systems are as follows –

- Offer very high capacity in a limited spectrum.
- Reuse of radio channel in different cells.
- Enable a fixed number of channels to serve an arbitrarily large number of users by reusing the channel throughout the coverage region.
- Communication is always between mobile and base station (not directly between mobiles).
- Each cellular base station is allocated a group of radio channels within a small geographic area called a cell.
- Neighboring cells are assigned different channel groups.
- By limiting the coverage area to within the boundary of the cell, the channel groups may be reused to cover different cells.
- Keep interference levels within tolerable limits.
- Frequency reuse or frequency planning.

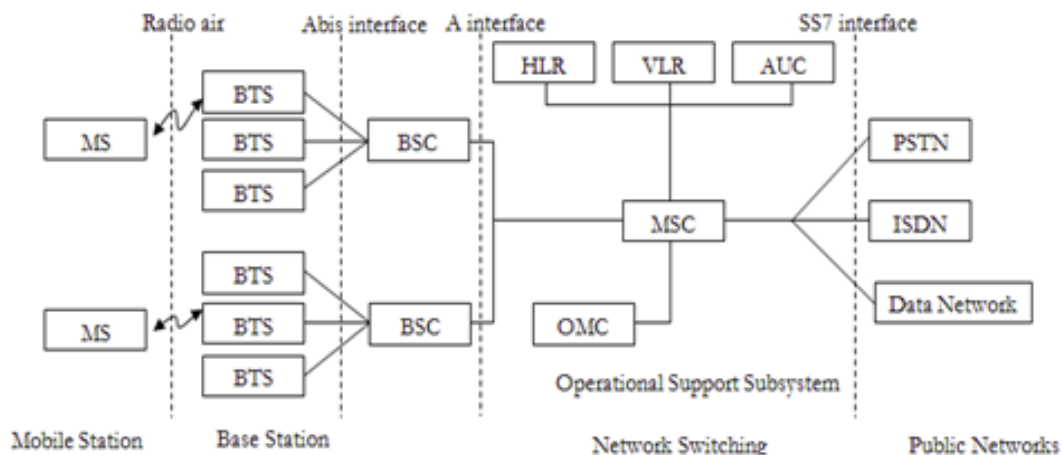


Fig: GSM Architecture

Shape of Cells

The coverage area of cellular networks are divided into **cells**, each cell having its own antenna for transmitting the signals. Each cell has its own frequencies. Data communication in cellular networks is served by its base station transmitter, receiver and its control unit. The shape of cells can be either square or hexagon –

Square

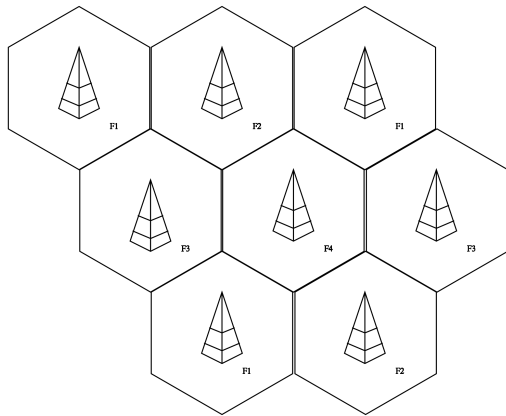
A square cell has four neighbors at distance **d** and four at distance **Root 2 d**

- Better if all adjacent antennas equidistant
- Simplifies choosing and switching to new antenna

Hexagon

A hexagon cell shape is highly recommended for its easy coverage and calculations. It offers the following advantages –

- Provides equidistant antennas
- Distance from center to vertex equals length of side



Frequency Reuse

Frequency reusing is the concept of using the same radio frequencies within a given area, that are separated by considerable distance, with minimal interference, to establish communication.

Frequency reuse offers the following benefits –

- Allows communications within cell on a given frequency
- Limits escaping power to adjacent cells
- Allows re-use of frequencies in nearby cells
- Uses same frequency for multiple conversations
- 10 to 50 frequencies per cell

For example, when **N** cells are using the same number of frequencies and **K** be the total number of frequencies used in systems. Then each **cell frequency** is calculated by using the formulae K/N .

In Advanced Mobile Phone Services (AMPS) when $K = 395$ and $N = 7$, then frequencies per cell on an average will be $395/7 = 56$. Here, **cell frequency** is 56.

GSM Architecture

The GSM network is divided into four major systems –

- Mobile Station (MS)
- Base Station SubSystem (BSS)
- Network and Switching SubSystem (NSS)
- Operation and Maintenance Center (OMC)

1. Mobile Station (MS):

A mobile station communicates across the air interface with a base station transceiver in the same cell in which the mobile subscriber unit is located. The MS communicates the information with the user and modifies it to the transmission protocols if the air-interface to communicate with the BSS. It consists of –

- SIM -Subscriber Identity Module
- Mobile Equipment

SIM is removable and with appropriate SIM, the network can be accessed using various mobile equipment. The equipment identity is not linked to the subscriber. The equipment is validated separately with IMEI and EIR. The SIM contains an integrated circuit chip with a microprocessor, random access memory (RAM) and read only memory (ROM). SIM should be valid and should authenticate the validity of MS while accessing the network.

SIM also stores subscriber related information like IMSI, cell location identity etc.

Functions of Mobile Station

- Radio transmission and reception
- Radio channel management
- Speech encoding/decoding
- Radio link error protection
- Flow control of data
- Rate adaptation of user data to the radio link
- Mobility management

2. Base Station Subsystem (BSS):

A base station subsystem consists of a base station controller and one or more base transceiver station. Each Base Transceiver Station defines a single cell. A cell can have a radius of between 100m to 35km, depending on the environment. A Base Station Controller may be connected with a BTS. It may control multiple BTS units and hence multiple cells. There are two main architectural elements in the BSS –

- Base Transceiver Station (BTS) also called Base Station.
- Base Station Controller (BSC).

BTS and BSC communicate across the standardized Abis interface. BTS is controlled by BSC and one BSC can have many BTS under its control.

Base Transceiver Station (BTS)

BTS houses the radio transceivers and handles the radio-link protocols with the Mobile Station. Each BTS comprises of radio transmission and reception devices including antenna, signal processors, etc. Each BTS can

support 1 to 16 RF carriers. The parameters differentiating the BTSs are Power level, antenna height, antenna type and number of carriers.

Functions of BTS

- It is responsible for Time and Frequency synchronization.
- The process of channel coding, Encryption, Multiplexing and modulation for trans-direction and reverse for reception are to be carried out.
- It has to arrange for transmission in advance from the mobiles depending upon their distance from BTS (Timing Advance).
- It has to detect random access requests from mobiles, measure and monitor the radio channels for power control and handover.

Base Station Controller (BSC)

BSC manages the radio resources for one or a group of BTSs. It handles radio-channel setup, frequency hopping, handovers, and control of the RF power levels. BSC provides the time and frequency synchronization reference signals broadcast by its BTSs. It establishes connection between the mobile station and the MSC. BSC is connected via interfaces to MSC, BTS and OMC.

3. Network and switching subsystem (NSS)

The NSS is responsible for the network operation. It provides the link between the cellular network and the Public switched telecommunicates Networks (PSTN or ISDN or Data Networks). The NSS controls handoffs between cells in different BSSs, authenticates user and validates their accounts, and includes functions for enabling worldwide roaming of mobile subscribers. In particular the switching subsystem consists of:

- Mobile switch center (MSC)
- Home location register (HLR)
- Visitor location Register (VLR)
- Authentications center (Auc)
- Equipment Identity Register (EIR)
- Interworking Functions (IWF)

The NSS has one hardware, Mobile switching center and four software database element: Home location register (HLR), Visitor location Register (VLR), Authentications center (Auc) and Equipment Identity Register (EIR).

Mobile Switching Center

Mobile Switching Center (MSC) performs all the switching functions for all mobile stations, located in the geographic area controlled by its assigned BSSs. Also, it interfaces with PSTN, with other MSCs, and other system entities.

Functions of MSC

- Call handling that copes with the mobile nature of subscribers considering Location Registration, Authentication of subscribers and equipment, Handover and Prepaid service.
- Management of required logical radio link channel during calls.
- Management of MSC-BSS signaling protocol.

- Handling location registration and ensuring inter-working between mobile station and VLR.
- Controls inter-BSS and inter-MSC hand overs.
- Acting as a gateway MSC to interrogate HLR. The MSC which is connected to the PSTN/ISDN network is called as GMSC. This is the only MSC in the network connected to the HLR.
- Standard functions of a switch like charging.

Home Location Register (HLR)

The HLR is database software that handles the management of the mobile subscriber account. It stores the subscriber address, service type, current locations, forwarding address, authentication/ciphering keys, and billings information. In addition to the ISDN telephone number for the terminal, the SIM card is identified with an International Mobile Subscribes Identity (IMSI) number that is totally different from the ISDN telephone number. The HLR is the reference database that permanently stores data related to subscribers, including subscriber's service profile, location information, and activity status.

Visitor Location Register (VLR)

The VLR is temporary database software similar to the HLR identifying the mobile subscribers visiting inside the coverage area of an MSC. The VLR assigns a Temporary mobile subscriber Identity (TMSI) that is used to avoid using IMSI on the air. The visitor location register maintains information about mobile subscriber that is currently physically in the range covered by the switching center. When a mobile subscriber roams from one LA (Local Area) to another, current location is automatically updated in the VLR. When a mobile station roams into anew MSC area, if the old and new LA's are under the control of two different VLRs, the VLR connected to the MSC will request data about the mobile stations from the HLR. The entry on the old VLR is deleted and an entry is created in the new VLR by copying the database from the HLR.

Authentication Center

The AuC database holds different algorithms that are used for authentication and encryption of the mobile subscribers that verify the mobile user's identity and ensure the confidentiality of each call. The AuC holds the authentication and encryption keys for all the subscribers in both the home and visitor location register.

Equipment Identity Register

The EIR is another database that keeps the information about the identity of mobile equipment such the International mobile Equipment Identity (IMEI) that reveals the details about the manufacturer, country of production, and device type. This information is used to prevent calls from being misused, to prevent unauthorised or defective MSs, to report stolen mobile phones or check if the mobile phone is operating according to the specification of its type.

- White list: This list contains the IMEI of the phones who are allowed to enter in the network.
- Black list: This list on the contrary contains the IMEI of the phones who are not allowed to enter in the network, for example because they are stolen.
- Grey list: This list contains the IMEI of the phones momentarily not allowed to enter in the network, for example because the software version is too old or because they are in repair.

Inter-working Functions (IWF)

It is a system in the PLMN that allows for non speech communication between the GSM and the other networks. The tasks of an IWF are particularly to adapt transmission parameters and protocol conversions. The physical

manifestations of an IWF may be through a modem which is activated by the MSC dependent on the bearer service and the destination network. The OSS (Operational Support Systems) supports operation and maintenance of the system and allows engineers to monitor, diagnose, and troubleshoot every aspect of the GSM network.

4. Operation and Maintenance Center (OMC)

It is the functional entity through which the network operator can monitor and control the system by performing the following functions –

1. Software installation
2. Traffic management
3. Performance data analysis
4. Tracing of subscribers and equipment
5. Configuration management
6. Subscriber administration
7. Management of mobile equipment
8. Management of charging and billing

Other Network Elements

Other network elements include components such as SMS Service Center, Voice Mail Box, and SMS Flow.

SMS Service Center

It interfaces with MSC having inter-working functionality to provide Short Message Service (SMS) to mobile subscribers. SMS can be destined to fax machine, PC on the internet or another MS. The location of the recipient MS is queried by MSC and delivered.

Voice Mail Box

When the mobile subscriber is not in a position to answer the incoming calls due to busy/out of service area, then the call gets diverted to a mail box which has already been activated by the subscriber. For this, a separate connectivity has been established from MSC. The subscriber will be alerted through SMS later and can retrieve the message.

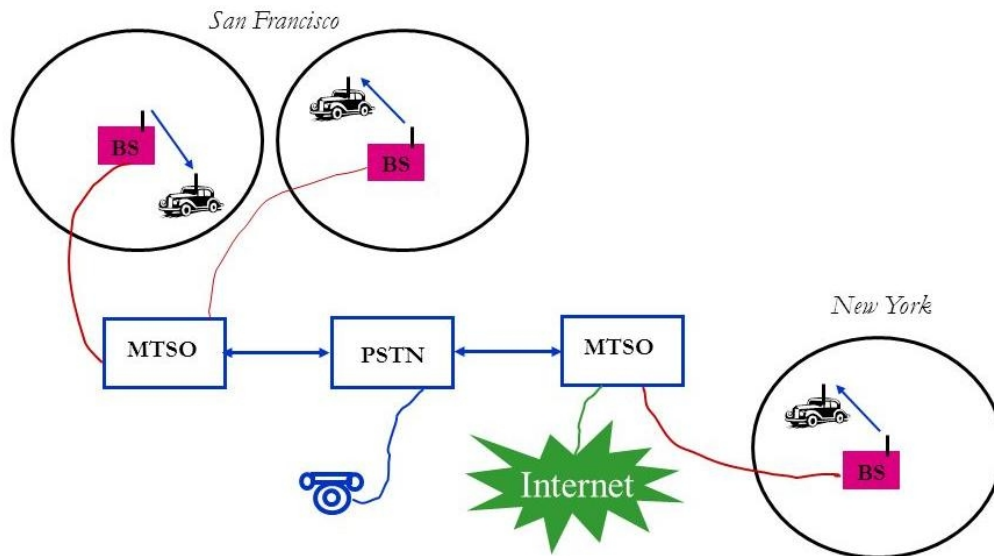
SMS Flow

- When a user sends an SMS, the request is placed via the MSC.
- The MSC forwards the SMS to the SMSC where it gets stored.
- The SMSC queries the HLR to find out where the destination mobile is and forwards the message to the destination MSC if the destination mobile is available.
- If the mobile is not available the message gets stored in the current SMSC itself. In most installations if a mobile is not available for SMS delivery the SMSC does not retry. Instead, the destination MSC informs the SMSC when the mobile comes back in range. SMS handling is a store and forward operation unlike USSD.
- SMS has got a validity period for which it will wait for the destination mobile to be available. After that time the SMSC will delete the message. The validity period can be set by the user. Normal validity is 1 day.

Cellular System Components

The cellular system offers mobile and portable telephone stations the same service provided fixed stations over conventional wired loops. It has the capacity to serve tens of thousands of subscribers in a major metropolitan area. The cellular communications system consists of the following four major components that work together to provide mobile service to subscribers:

1. public switched telephone network (PSTN)
2. mobile telephone switching office (MTSO)
3. cell site with antenna system
4. mobile subscriber unit (MSU)



PSTN

The PSTN is made up of local networks, the exchange area networks, and the long-haul network that interconnect telephones and other communication devices on a worldwide basis.

Mobile Telephone Switching Office (MTSO)

The MTSO is the central office for mobile switching. It houses the mobile switching center (MSC), field monitoring, and relay stations for switching calls from cell sites to wireline central offices (PSTN). In analog cellular networks, the MSC controls the system operation. The MSC controls calls, tracks billing information, and locates cellular subscribers.

The Cell Site

The term cell site is used to refer to the physical location of radio equipment that provides coverage within a cell. A list of hardware located at a cell site includes power sources, interface equipment, radio frequency transmitters and receivers, and antenna systems.

Mobile Subscriber Units (MSUs)

The mobile subscriber unit consists of a control unit and a transceiver that transmits and receives radio transmissions to and from a cell site.