UNIT-5

DIGITAL CELLULAR NETWORKS

GSM Architecture

- European conference of postal and telecommunications administrations (CEPT) , a European group, began to develop the global system for mobile TDMA system in june 1982.
- System capacity was not an issue in the initial development of GSM, but due to unexpected, rapid growth of cellular service, 35 revisions have been made to GSM since the first issued specification.
- The first commercial GSM system, called D2 was implemented in Germany in 1992.
- GSM consists of many subsystems, such as the mobile station (MS), the base station subsystem (BSS), the network and switching subsystem (NSS), and the operation subsystem(OSS) in fig. 1.

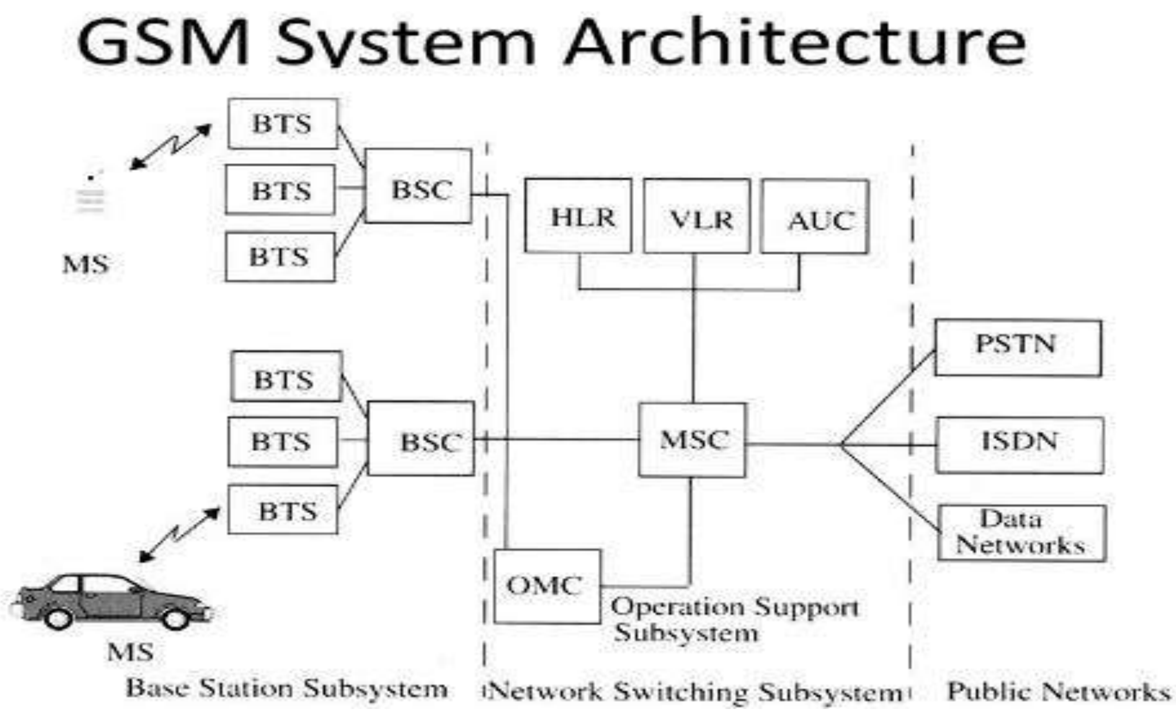


Fig :

Mobile Station:

The Mobile Station includes

1. Mobile equipment (ME)
2. Subscriber identity module (SIM).

Mobile equipment (ME) :

- It is a portable, Vehicle mounted, hand held device.
- It is uniquely identified by an IMEI (International mobile equipment identity).

- It is used for voice and data transmission.
- It monitors power and signaling quality of surrounding cells for optimum handover.
- Power level : 0.8W – 20 W.
- 160 characters long SMS.

subscriber identity module (SIM):

- The SIM is a subscriber module which stores all the subscriber related information.
- When a subscriber's SIM is inserted into the ME of an MS, that MS belongs to the subscriber, and the call is delivered to that MS.
- The ME is not associated with a called number—it is linked to the SIM.
- In this case, any ME can be used by a subscriber when the SIM is inserted in the ME.

Base station Subsystem (BSS):

- The BSS connects to the MS through a radio interface and also connects to the NSS.
- The BSS consists of a
    1. Base transceiver station (BTS) located at the antenna site
    2. Base station controller (BSC) that may control several BTSs.

Base transceiver station (BTS):

- The BTS consists of radio transmission and reception equipment similar to the ME in an MS.
- A transcoder /rate adaption unit (TRAU) carries out encoding and speech decoding and rate adaptation for transmitting data.
- The BTS contains the RF components that provides the air interface for a particular cell.
- Encodes, encrypts, multiplexes, modulates and feeds the RF signals to the antenna.

Base station Controller (BSC):

- Provides the control for the BSS.
- In charge of handovers, frequency hopping, exchange functions and control of power level of BTS.
- Communicates directly with the MSC.
- May control single or multiple BTS.

GSM uses the open system interconnection (OSI).

- There are three common interfaces based on OSI (Fig. 1.2.): a common radio interface, called air interface, between the MS and BTS, an interface A between the MSC and BSC, and an A-bi interface between the BTS and BSC.

- With these common interfaces, the system operator can purchase the product of manufacturing company A to interface with the product of manufacturing company B.

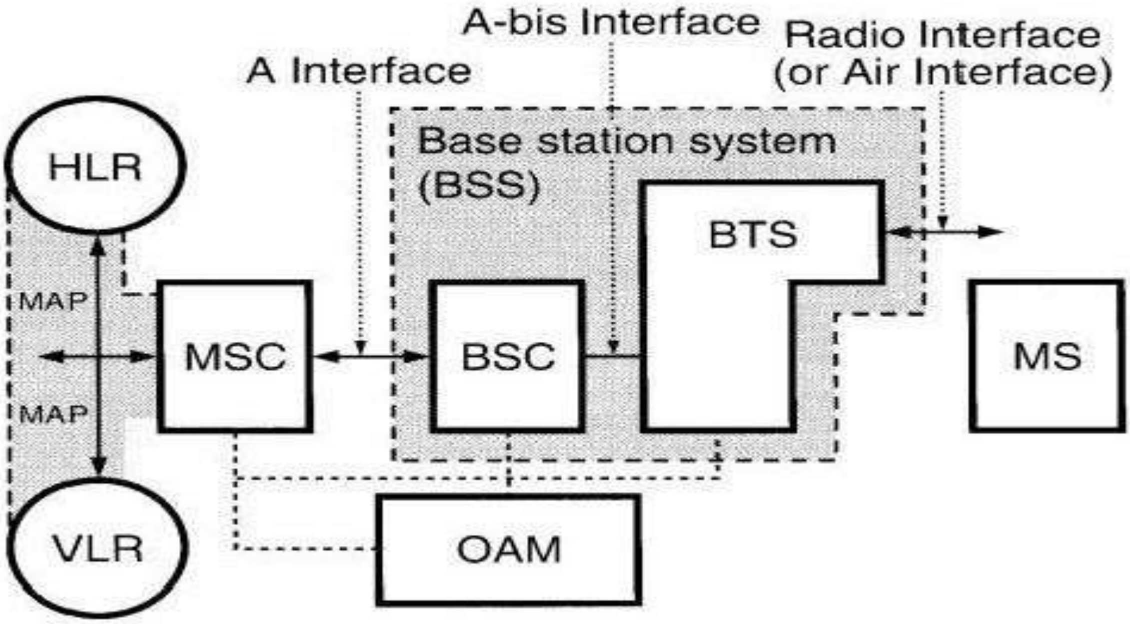


Fig.1.2. Functional architecture and principal interfaces

Network and Switching Subsystem:

- NSS (see Fig.1.3.) in GSM uses an intelligent network (IN).
- A signaling NSS includes the main switching functions of GSM.
- NSS manages the communication between GSM users and other telecommunications users.

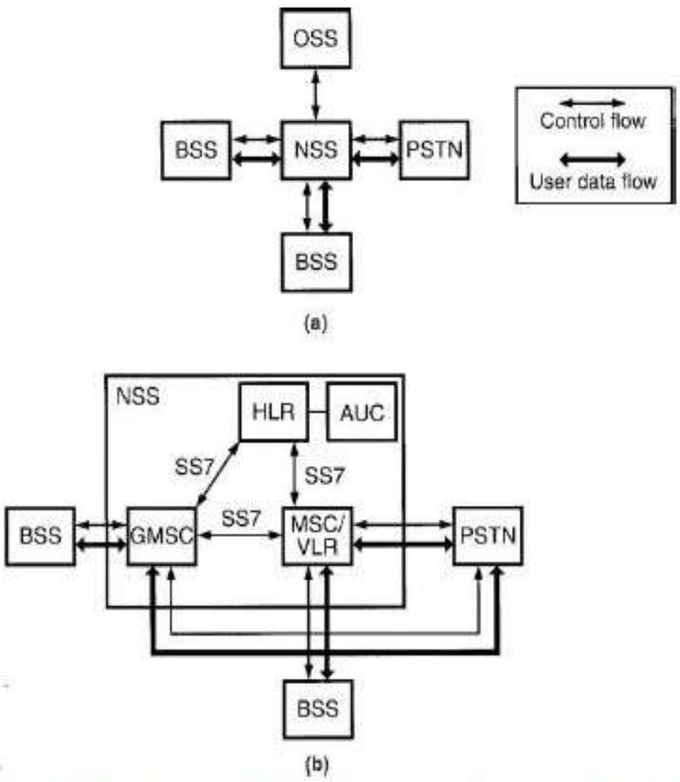


Fig.1.3. NSS and its environment (a) the external environment; (b) the internal structure

- NSS management consists of:
    1. Mobile service switching center (MSC)
    2. Interworking function (IWF)
    3. Home location register (HLR)
    4. Visitor location register (VLR)
    5. Gateway MSC (GMSC)
    6. Signaling transfer point (STP)
    7. Operation subsystem (OSS)

Mobile service switching center (MSC):

- Coordinates call set-up to and from GSM users. An MSC controls several BSCs.

Interworking function (IWF):

- A gateway for MSC to interface with external networks for communication with users outside GSM, such as packet-switched public data network (PSPDN) or circuit-switched public data network (CSPDN).
- The role of the IWF depends on the type of user data and the network to which it interfaces.

Home location register (HLR):

- Consists of a stand-alone computer without switching capabilities, a database which contains subscriber information, and information related to the subscriber's current location, but not the actual location of the subscriber.
- A subdivision of HLR is the authentication center (AUC).
- The AUC manages the security data for subscriber authentication. Another sub-division of HLR is the equipment identity register (EIR) which stores the data of mobile equipment (ME) or ME-related data.

Visitor location register (VLR):

- Links to one or more MSCs, temporarily storing subscription data currently served by its corresponding MSC, and holding more detailed data than the HLR.
- For example, the VLR holds more current subscriber location information than the location information at the HLR.

Gateway MSC (GMSC):

- In order to set up a requested call, the call is initially routed to a gateway MSC, which finds the correct HLR by knowing the directory number of the GSM subscriber.
- The GMSC has an interface with the external network for gate waying, and the network also operates the full Signaling System 7 (SS7) signaling between NSS machines.

Signaling transfer point (STP):

- Is an aspect of the NSS function as a stand-alone node or in the same equipment as the MSC.
- STP optimizes the cost of the signaling transport among MSC/VLR, GMSC, and HLR.

Operation subsystem (OSS):

There are three areas of OSS, as shown in Fig.1.4.

(1) network operation and maintenance functions.

(2) subscription management, including charging and billing.

(3) mobile equipment management.

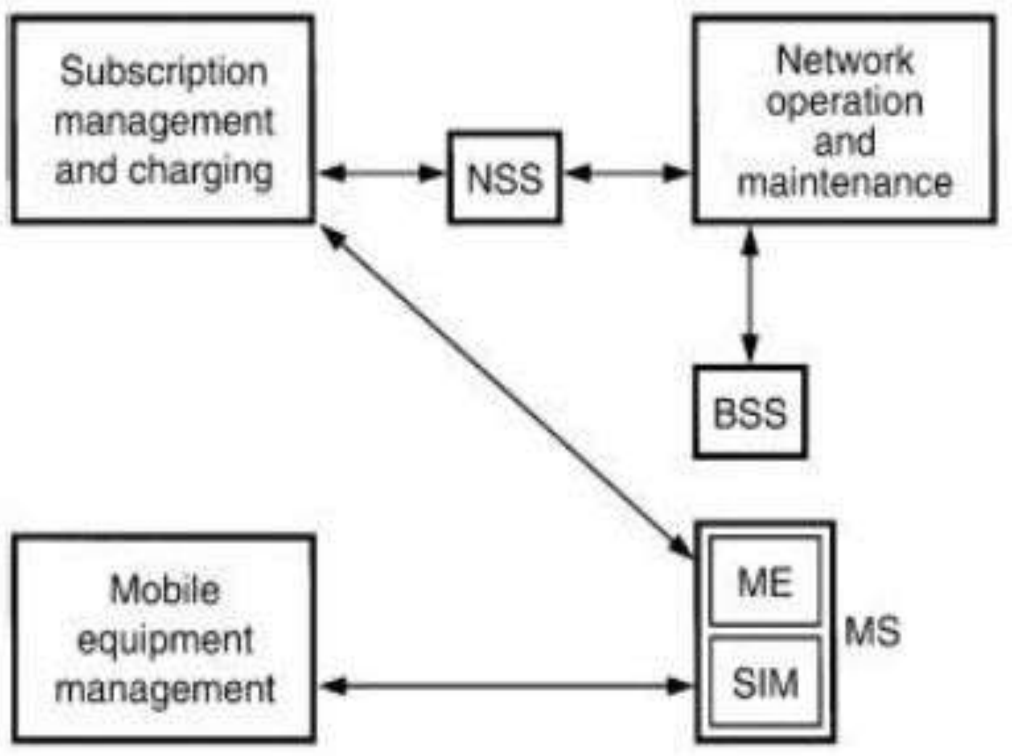
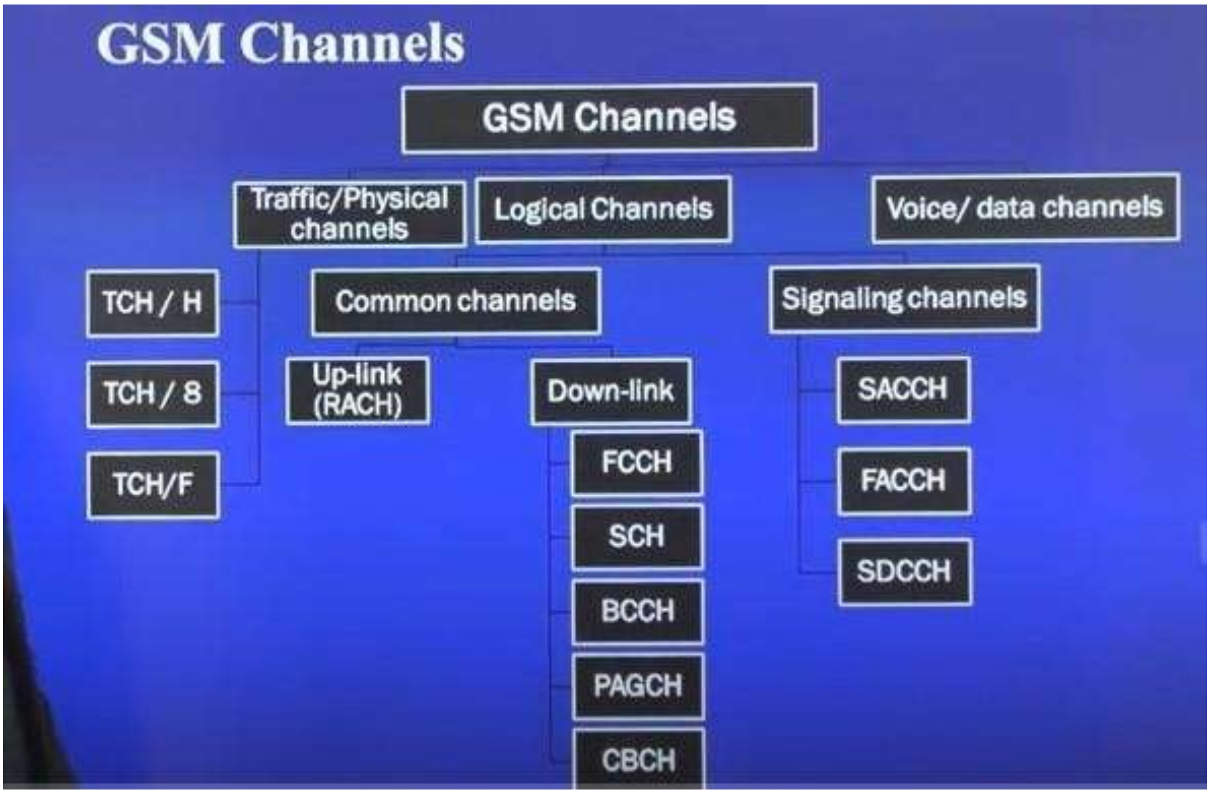


Fig.1.4. OSS organization

These tasks require interaction between some or all of the infrastructure equipment.

OSS is implemented in any existing network.

GSM Channels



- In telecommunications a channel, refers either to a physical transmission medium such as a wire or to a logical connection over a multiplexed medium such as a radio channel.
- The channel used in the air interface is divided into two types.

  1. Physical channels
  2. Logical channels

Physical channels: It is the medium over which the information is carried.

Logical channels: It consist of information carried over a physical channel.

Physical channels:

- There are three kinds of physical channels, also called traffic channels (TCHs)

  a.) TCH/F (full rate): Transmits a speech code of 13 kbps or three data-mode rates, 12, 6, and 3.6 kbps.

  b.) TCH/H (half rate): Transmits a speech code of 7 kbps or two data modes, 6 and 3.6kbps.

  c.) TCH/8 (one-eighth rate): Used for low-rate signaling channels, common channels,and data channels.

Logical channels:

- **Common channels:** All the common channels are embedded in different traffic channels.

- They are grouped by the same cycle (51 × 8 BP), where BP stands for burst period (i.e. Time slot), which is 577μs.
- **Uplink common channels:** The random-access channel (RACH) is the only common uplink channel. RACH is the channel that the mobile station chooses to access the calls.
- There are two rates: RACH/F (full rate, one time slot every 8 BP), and RACH/H (half rate, using 23 time slots in the 51 × 8 BP cycle, where 8 BP cycle [i.e. a frame] is 4.615ms).

Downlink logical Common channels:

- There are five downlink unidirectional channels, shared or grouped by a TCH.

  Frequency correction channel (FCCH) repeats once every 51×8 BPs; used to identify a beacon frequency.

  Synchronization channel (SCH) follows each FCCH slot by 8 BPs.

  Broadcast control channel (BCCH) is broadcast regularly in each cell and received by all the mobile stations in the idle mode.

  Paging and access grant channel (PAGCH) is used for the incoming call received at the mobile station. The access grant channel is answered from the base station and allocates a channel during the access procedure of setting up a call.

  Call broadcast channel (CBCH) . Each cell broadcasts a short message for 2s from the network to the mobile station in idle mode.

Signaling channels:

- All the signaling channels have chosen one of the physical channels, and the logical channels names are based on their logical functions:

  Slow Associated Control Channel (SACCH):

  - A slow-rate TCH used for signaling transport and used for non urgent procedures, mainly handover decisions. It uses one eighth rate.
  - The TCH/F is always allocated with SACCH.
  - This combined TCH and SACCH is denoted TACH/F.
  - SACCH occupies 1 time slot (0.577 ms) in every 26 frames (4.615ms × 26). The time organization of a TACH/F is shown in Fig.2.2.
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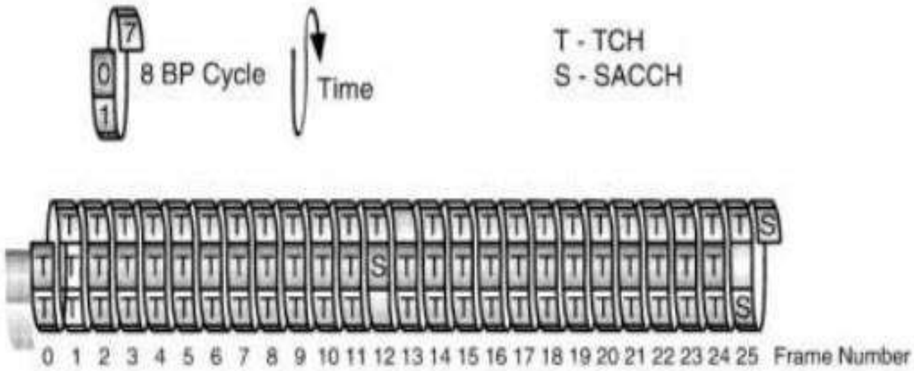


Fig.2.2. Time organization of TACH/F

Fast Associated Control Channel (FACCH):

- Indicates cell establishment, authenticates subscribers, or commands a handover.

Stand-alone Dedicated Control Channel (SDCCH):

- Occasionally the connection between a mobile station and the network is used solely for passing signaling information and not for calls.
- This connection may be at the user's demand or for other management operations such as updating the unit's location.
- It operates at a very low rate and uses a TCH/8 channel.

Voice and data channels:

- Each time slot of a voice channel contains 260 bits per block.
- The entire block contains 316 bits. Each time slot of a data channel contains 120 or 240 bits per block.

GSM Services

GSM services may be divided into three major categories

1. Telephony services or tele-services.
2. Data services or bearer services.
3. Supplementary services.

1. Telephony services or tele-services.

- These includes emergency calling, GSM also supports Videotex and Teletex.

2. Data services or bearer services.

- These are limited to layer 1,2 and 3 of open system inter-connection (OSI) reference model.
- Supported services include packet switched protocols and data rates from 300 bps to 9.6 Kbps.
- Data may be transmitted using transparent or non transparent mode.

3. **Supplementary services:**

- Supplementary services are additional services that are provided in addition to tele-services and bearer services.
- These services include caller identification, call forwarding, call waiting, multi-party conversations and baring of outgoing international calls, among others.
- A brief description of supplementary services are given here
  - **Conferencing:** It allows a mobile subscriber to establish a multiparty conversation i.e. a simultaneous conversation between three or more subscribers to setup a conference call.
  - **Call waiting:** These service notifies a mobile subscriber of an incoming call during a conversation. The subscriber can answer, reject, or ignore the incoming call.
  - **Call Hold:** This service allows a subscriber to put an incoming call on hold and resume after a while. The call hold service is applicable to normal telephony.
  - **Call forwarding:** call forwarding is used to divert calls from the original recipient to another number. It is normally setup by the subscriber himself. It can be used by the subscriber to divert calls from the mobile station when the subscriber is not available, and so that future calls are not lost
  - **Call barring:** call barring is useful to restrict certain types of outgoing calls such as ISD or stop incoming calls from undesired numbers. Call barring is a flexible service that enables subscriber to conditionally bar calls.

Number identification :

- There are following supplementary services related to number identification.
- Calling line identification presentation
- Calling line identification Restriction
- Connected line identification presentation
- Connected line identification Restriction
- Malicious call identification

The features of the GSM module include the following

- Improved spectrum efficiency
- International roaming
- Compatibility with ISDN
- SIM phone book management
- Fixed dialing number
- Real time clock with alarm management

- Uses encryption to make phone calls more secure
- Short message services

MULTIPLE ACCESS TECHNIQUES

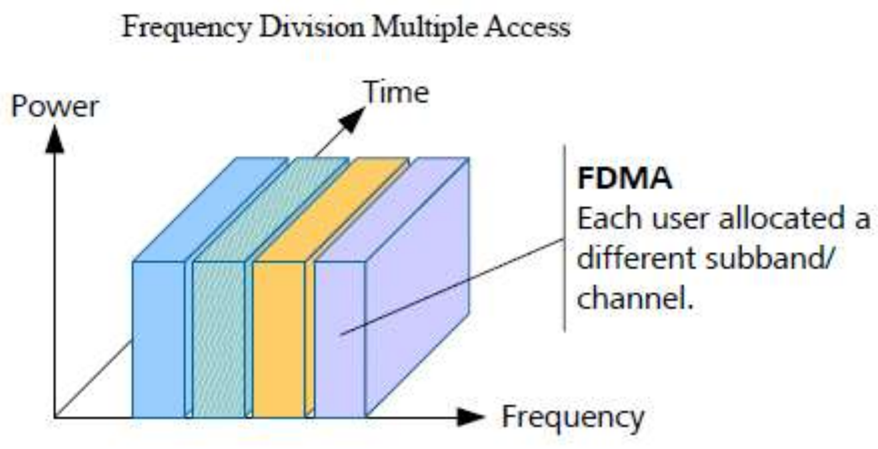
- Multiple access techniques are used to allow a large number of mobile users to share the allocated spectrum in the most efficient manner.
- As the spectrum is limited, so the sharing is required to increase the capacity of cell or over a geographical area by allowing the available bandwidth to be used at the same time by different users.
- And this must be done in a way such that the quality of service doesn't degrade within the existing users.

Multiple Access Techniques For Wireless Communication

- In wireless communication systems it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station.
- A cellular system divides any given area into cells where a mobile unit in each cell communicates with a base station.
- The main aim in the cellular system design is to be able to increase the capacity of the channel i.e. to handle as many calls as possible in a given bandwidth with a sufficient level of quality of service.
- There are several different ways to allow access to the channel. These includes mainly the following:

1. Frequency division multiple-access (FDMA)
2. Time division multiple-access (TDMA)
3. Code division multiple-access (CDMA)

1) FREQUENCY DIVISION MULTIPLE ACCESS



- This was the initial multiple-access technique for cellular systems in which each individual user is assigned a pair of frequencies while making or receiving a call as shown in Figure.
- One frequency is used for downlink and one pair for uplink. This is called frequency division duplexing (FDD).
- That allocated frequency pair is not used in the same cell or adjacent cells during the call so as to reduce the co channel interference.
- Even though the user may not be talking, the spectrum cannot be reassigned as long as

a call is in place.

- Different users can use the same frequency in the same cell except that they must transmit at different times. The features of FDMA are as follows:
  - The FDMA channel carries only one phone circuit at a time. If an FDMA channel is not in use, then it sits idle and it cannot be used by other users to increase share capacity.
  - After the assignment of the voice channel the BS and the MS transmit simultaneously and continuously.
  - The bandwidths of FDMA systems are generally narrow i.e. FDMA is usually implemented in a narrow band system The symbol time is large compared to the average delay spread.
  - The complexity of the FDMA mobile systems is lower than that of TDMA mobile systems. FDMA requires tight filtering to minimize the adjacent channel interference.

FDMA/FDD in AMPS

- The first U.S. analog cellular system, AMPS (Advanced Mobile Phone System) is based on FDMA/FDD.
- A single user occupies a single channel while the call is in progress, and the single channel is actually two simplex channels which are frequency duplexed with a 45 MHz split.
- When a call is completed or when a handoff occurs the channel is vacated so that another mobile subscriber may use it.
- Multiple or simultaneous users are accommodated in AMPS by giving each user a unique signal.
- Voice signals are sent on the forward channel from the base station to the mobile unit, and on the reverse channel from the mobile unit to the base station.
- In AMPS, analog narrowband frequency modulation (NBFM) is used to modulate the carrier.

FDMA/TDD in CT2

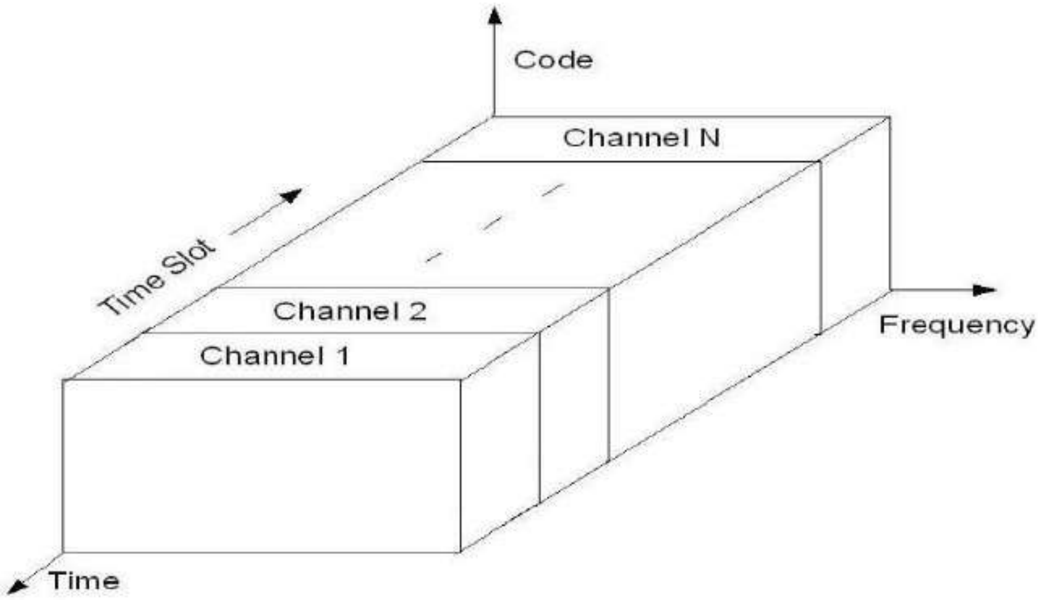
- Using FDMA, CT2 system splits the available bandwidth into radio channels in the assigned frequency domain.
- In the initial call setup, the handset scans the available channels and locks on to an unoccupied channel for the duration of the call.
- Using TDD(Time Division Duplexing), the call is split into time blocks that alternate between transmitting and receiving.

FDMA and Near-Far Problem

- The near-far problem is one of detecting or filtering out a weaker signal amongst stronger signals.
- The near-far problem is particularly difficult in CDMA systems where transmitters share transmission frequencies and transmission time.
- In contrast, FDMA and TDMA systems are less vulnerable. FDMA systems offer different kinds of solutions to near-far challenge.
- Here, the worst case to consider is recovery of a weak signal in a frequency slot next to strong signal.
- Since both signals are present simultaneously as a composite at the input of a gain stage, the gain is set according to the level of the stronger signal; the weak signal could be lost in the noise floor. Even if subsequent stages have a low enough noise floor to provide .

2) TIME DIVISION MULTIPLE ACCESS

- In digital systems, continuous transmission is not required because users do not use the allotted bandwidth all the time.
- In such cases, TDMA is a complimentary access technique to FDMA. Global Systems for Mobile communications (GSM) uses the TDMA technique.
- In TDMA, the entire bandwidth is available to the user but only for a finite period of time. In most cases the available bandwidth is divided into fewer channels compared to FDMA.
- The users are allotted time slots during which they have the entire channel bandwidth at their disposal, as shown in Figure



- TDMA requires careful time synchronization since users share the bandwidth in the frequency domain. The number of channels are less, inter channel interference is almost negligible.
- TDMA uses different time slots for transmission and reception. This type of duplexing is referred to as Time division duplexing (TDD).
- The features of TDMA includes the following:

  a. TDMA shares a single carrier frequency with several users where each users makes use of non overlapping time slots.

  b. The number of time slots per frame depends on several factors such as modulation technique, available bandwidth etc.

  c. Data transmission in TDMA is not continuous but occurs in bursts. This results in low battery consumption since the subscriber transmitter can be turned OFF when not in use. Because of a discontinuous trans- mission in TDMA the handoff process is much simpler for a subscriber unit, since it is able to listen to other base stations during idle time slots.

  d. TDMA uses different time slots for transmission and reception thus duplexers are not required.

- TDMA has an advantage that is possible to allocate different numbers of time slots per frame to different users.

- Thus bandwidth can be supplied on demand to different users by concatenating or reassigning time slot based on priority.

TDMA/FDD in GSM

- GSM is widely used in Europe and other parts of the world. GSM uses a variation of TDMA along with FDD.
- GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its

TDMA Frame Structure:

The below figure shows TDMA frame structure. One TDMA frame is divided into 3 catogories. That is preamble, information message and Trial bits.

Preamble: It consists of address and synchronization bits which is used by base stations subscribers toidentify each others.

Information message: It contains multiple slots of user information. Each slot will have Trail bits, Sync bits,information data and Guard bits

Trail bits are used for controlling power during transmission and reception. They are used for rising or lowering power level.

Sync bits are known as synchronization bits. They are essential for maintaining synchronization between transmitter and receiver.

Information data indicates user information for transmitting or receiving.

Guard bits are known as protection bits. They are used for avoiding interference.

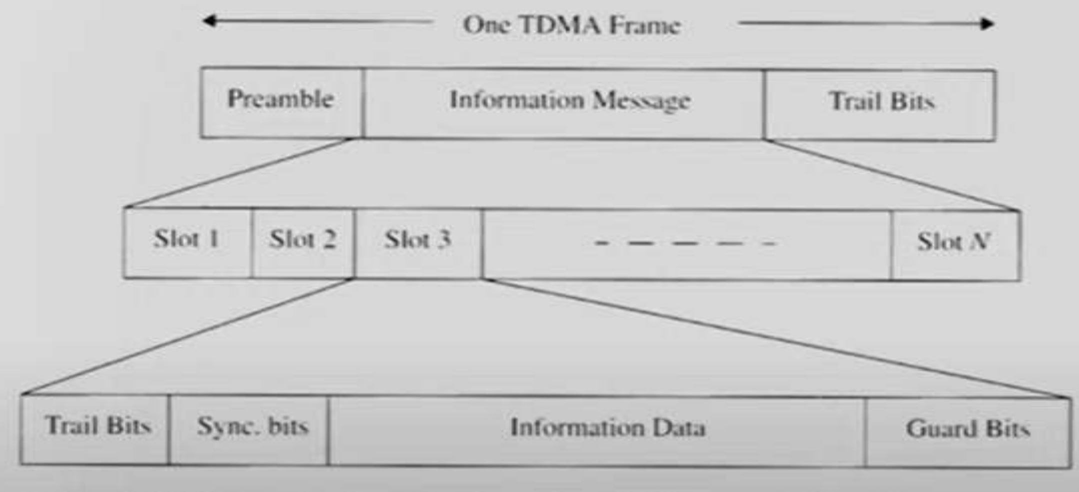


Figure 9.4 TDMA frame structure. The frame is cyclically repeated over time.

3) CODE DIVISION MULTIPLE ACCESS

- In CDMA, the same bandwidth is occupied by all the users, however they are all assigned separate codes, which differentiates them from each other shown in Figure .
- CDMA utilize a spread spectrum technique in which a spreading signal (which is uncorrelated to the signal and has a large bandwidth) is used to spread the narrow band message signal.

Direct Sequence Spread Spectrum (DS-SS)

This is the most commonly used technology for CDMA. In DS-SS, the message signal is multiplied by a Pseudo Random Noise Code.

- Each user is given his own codeword which is orthogonal to the codes of other users and in order to detect the user, the receiver must know the codeword used by the transmitter.

- There are, however, two problems in such systems which are discussed in the sequel.

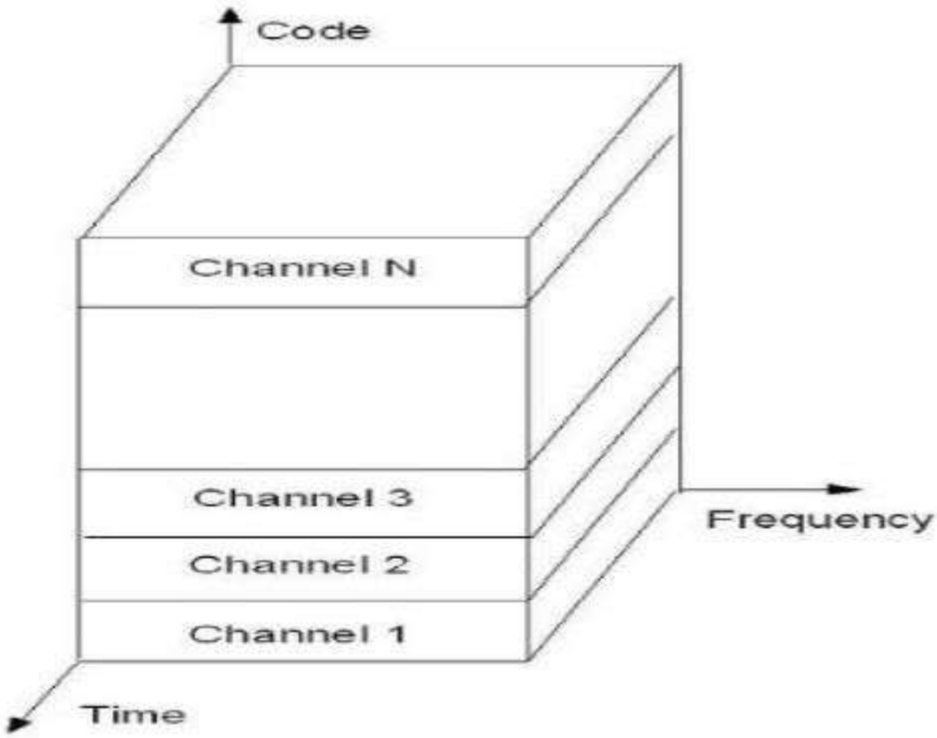


Figure : The basic concept of CDMA.

CDMA and Self-interference Problem

- In CDMA, self-interference arises from the presence of delayed replicas of signal due to multipath.
- The delays cause the spreading sequences of the different users to lose their orthogonality, as by design they are orthogonal only at zero phase offset.
- Hence in despreading a given user’s waveform, nonzero contributions to that user’s signal arise from the transmissions of the other users in the network.
- This is distinct from both TDMA and FDMA, wherein for reasonable time or frequency guardbands, respectively, orthogonality of the received signals can be preserved.

CDMA and Near-Far Problem

- The near-far problem is a serious one in CDMA. This problem arises from the fact that signals closer to the receiver of interest are received with smaller attenuation than are signals located further away.
- Therefore the strong signal from the nearby transmitter will mask the weak signal from the remote transmitter.
- In TDMA and FDMA, this is not a problem since mutual interference can be filtered. In CDMA, however, the near-far effect combined with imperfect orthogonality between codes (e.g. due to different time sifts), leads to substantial interference.
- Accurate and fast power control appears essential to ensure reliable operation of multiuser DS-CDMA systems.

OFDMA

Orthogonal frequency-division multiple access (OFDMA) is a feature of Wi-Fi 6 (802.11ax) that allows access points to serve multiple clients at the same time. OFDMA follows a set of rules created for the transmission of data between more than one terminal (any device at the end of a transmission channel, such as a computer or phone) over a transmission medium (such as a wireless network).

An example of how OFDMA works is when two phones send data over the same phone line. A time-interval may be assigned to each phone, and they will take turns sending their signal over the line at each assigned interval. However, these time frames are imperceptibly small, making the data transfer seem to happen simultaneously and seamlessly.

OFDMA is an updated version of frequency-division multiplexing (FDM) technology used to divide packets of information into separate bands that are carried by separate signals. This form of communication is an upgrade that parallels the switch of internet carriers to Wi-Fi 6 wireless, as well as the upgrade of phone carriers to 4G and 5G LTE. Instead of the traditional analog modulation used in multiplexing, OFDMA uses carrier signal waves, called subcarriers, to move small bits of information in a more streamlined fashion.

Advantages and disadvantages of OFDMA

Implementing OFDMA can provide the following advantages:

- Higher diversity and efficiency of frequency
- Provides lower interference between cells.
- More flexibility as channels and sub-channels can be toggled on and off.
- Better coverage over networks.

However, potential disadvantages include:

- The diversity of frequencies is conditional on how subcarriers are assigned to users, and can thus become very complex.
- Requires extra power because it is always on and ready to send a transmission.

Features

SECOND GENERATION (2G)

- 2G refers to the second generation of mobile networks based on GSM.
- The radio signals used by the 1G network were analog, while 2G networks were digital.
- 2G capabilities were achieved by allowing multiple users on a single channel via multiplexing
- During 2G, cellular phones were used for data along with voice.

Some of the key features of 2G were:

- Data speeds of up to 64 kbps
- Use of digital signals instead of analog
- Enabled services such as SMS and MMS (Multimedia Message)
- Provided better quality voice calls
- It used a bandwidth of 30 to 200 KHz

THIRD GENERATION (3G) :

- The 3G standard utilizes Universal Mobile Telecommunications System (UMTS) as its core network architecture.
- 3G network combines aspects of the 2G network with new technologies and protocols to deliver a significantly faster data rate.
- By using packet switching, the original technology was improved to allow speeds up to 14 Mbps.
- It used Wide Band Wireless Network that increased clarity.
- It operates at a range of 2100 MHz and has a bandwidth of 15-20 MHz.
- Some of the main features of 3G are:
- Speed of up to 2 Mbps
- Increased bandwidth and data transfer rates
- Send/receive large email messages
- Large capacities and broadband capabilities

FOURTH GENERATION (4G)

- The main difference between 3G and 4G is the data rate.
- There is also a huge difference between 3G and 4G technology.

- The key technologies that have made 4G possible are MIMO (Multiple Input Multiple Output) and OFDM (Orthogonal Frequency Division Multiplexing).
- The most important 4G standards are Wi-MAX and LTE. While 4G LTE is a major improvement over 3G speeds, it is technically not 4G. What is the difference between 4G and LTE?
- Even after it was widely available, many networks were not up to the required speed of 4G.
- 4G LTE is a "fourth generation long term evolution", capable of delivering a very fast and secure internet connection.
- Basically, 4G is the predetermined standard for mobile network connections.
- 4G LTE is the term given to the path which has to be followed to achieve those predefined standards.
- Some of the features of 4G LTE are:
  - ✓ Support interactive multimedia, voice, video.
  - ✓ High speed, high capacity and low cost per bit (Speeds of up to 20 Mbps or more.)
  - ✓ Global and scalable mobile networks.
  - ✓ Ad hoc and multi-hop networks.

FIFTH GENERATION (5G)

- 5G networks operate on rarely used radio millimeter bands in the 30 GHz to 300 GHz range.
- Testing of 5G range in mm Wave has produced results approximately 500 meters from the tower.
- Using small cells, the deployment of 5G with millimeter wave based carriers can improve overall coverage area.
- Combined with beam forming, small cells can deliver extremely fast coverage with low latency.
- Low latency is one of 5G's most important features.
- 5G uses a scalable orthogonal frequency- division multiplexing (OFDM) framework.
- 5G benefits greatly from this and can have latency as low as one millisecond with realistic estimates to be around 1 – 10 seconds.
- 5G is estimated to be 60 to 120 times faster than the average 4G latency.
- Active antenna 5G encapsulated with 5G massive MIMO is used for providing better connections and enhanced user experience.
- Big 5G array antennas are deployed to gain additional beam forming information and knock out propagation challenges that are experienced at mm Wave frequency ranges.
- Further, 5G networks clubbed with network slicing architecture enables telecom operators to offer on-demand tailored connectivity to their users that is adhered to Service Level Agreement (SLA).

- Such customized network capabilities comprise latency, data speed, latency, reliability, quality, services, and security.
- With speeds of up to 10 Gbps, 5G is set to be as much as 10 times faster than 4G.

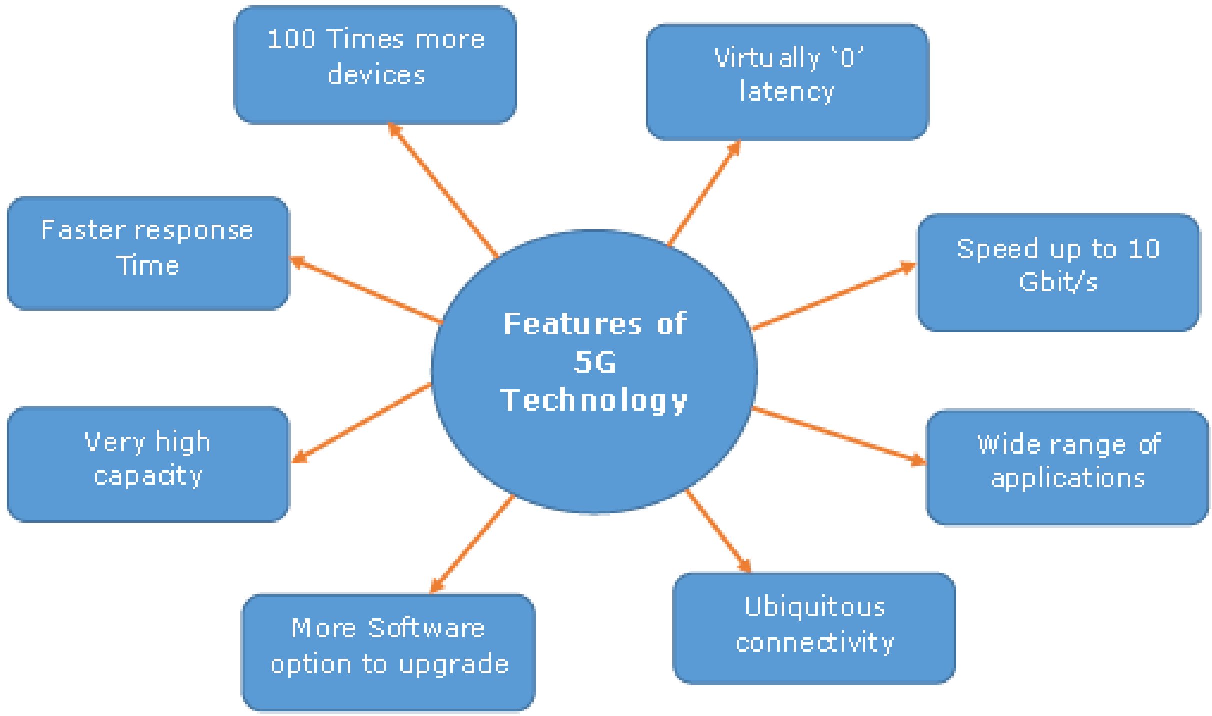
Comparison of 2G, 3G, 4G, and 5G

Comparison	2G	3G	4G	5G
Introduced in year	1993	2001	2009	2018
Technology	GSM	WCDMA	LTE, WiMAX	MIMO, mm Waves
Access system	TDMA, CDMA	CDMA	CDMA	OFDM, BDMA
Switching type	Circuit switching for voice and packet switching for data	Packet switching except for air interference	Packet switching	Packet switching
Internet service	Narrowband	Broadband	Ultra broadband	Wireless World Wide Web
Bandwidth	25 MHz	25 MHz	100 MHz	30 GHz to 300 GHz
Advantage	Multimedia features (SMS, MMS), internet access and SIM introduced	High security, international roaming	Speed, high speed handoffs, global mobility	Extremely high speeds, low latency
Applications	Voice calls, short messages	Video conferencing, mobile TV, GPS	High speed applications, mobile TV, wearable devices	High resolution video streaming, remote control of vehicles, robots, and medical procedures

FEATURES OF 4G

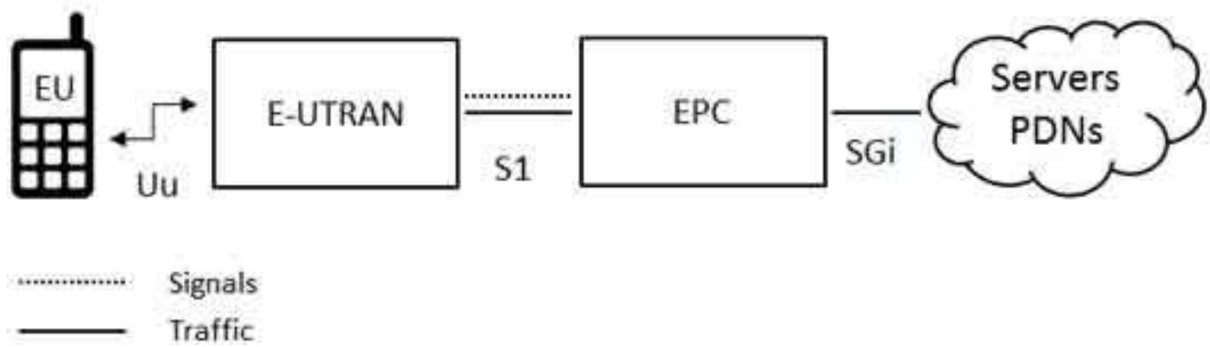
- Support for interactive multimedia, voice, streaming video, Internet, and other broadband services
- IP based mobile system
- High speed, high capacity, and low cost per bit
- Global access, service portability, and scalable mobile services
- Seamless switching, and a variety of Quality of Service driven services
- Better scheduling and call admission control techniques
- Ad hoc and multi hop networks (the strict delay requirements of voice make multi hop network service a difficult problem)
- Better spectral efficiency
- Seamless network of multiple protocols and air interfaces (since 4G will be all]IP, look for 4G systems to be compatible with all common network technologies, including802.11, WCDMA, Blue tooth, and Hyper LAN).

– An infrastructure to handle pre existing 3G systems along with other wireless technologies, some of which are currently under development.



LTE

- LTE stands for *Long Term Evolution.*
- The high-level network architecture of LTE is comprised of following three main components:
- The User Equipment (UE).
- The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
- The Evolved Packet Core (EPC).
- The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem.
- The interfaces between the different parts of the system are denoted Uu, S1 and SGi as shown below:

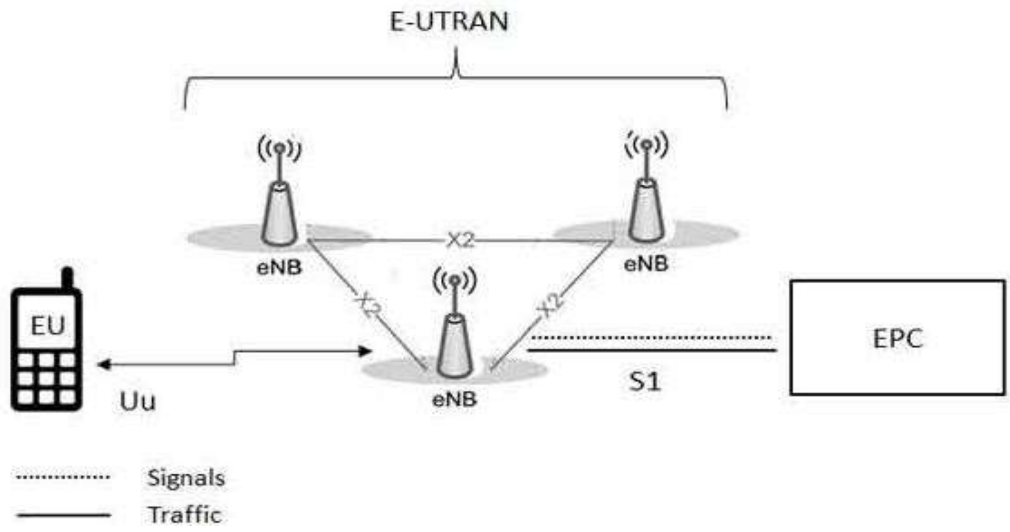


The User Equipment (UE):

- The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment (ME). The mobile equipment comprised of the following important modules:
- **Mobile Termination (MT)** : This handles all the communication functions.
- **Terminal Equipment (TE)** : This terminates the data streams.
- **Universal Integrated Circuit Card (UICC)** : This is also known as the SIM card for LTE equipments. It runs an application known as the Universal Subscriber Identity Module (USIM).
- A **USIM** stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

The E-UTRAN (The access network)

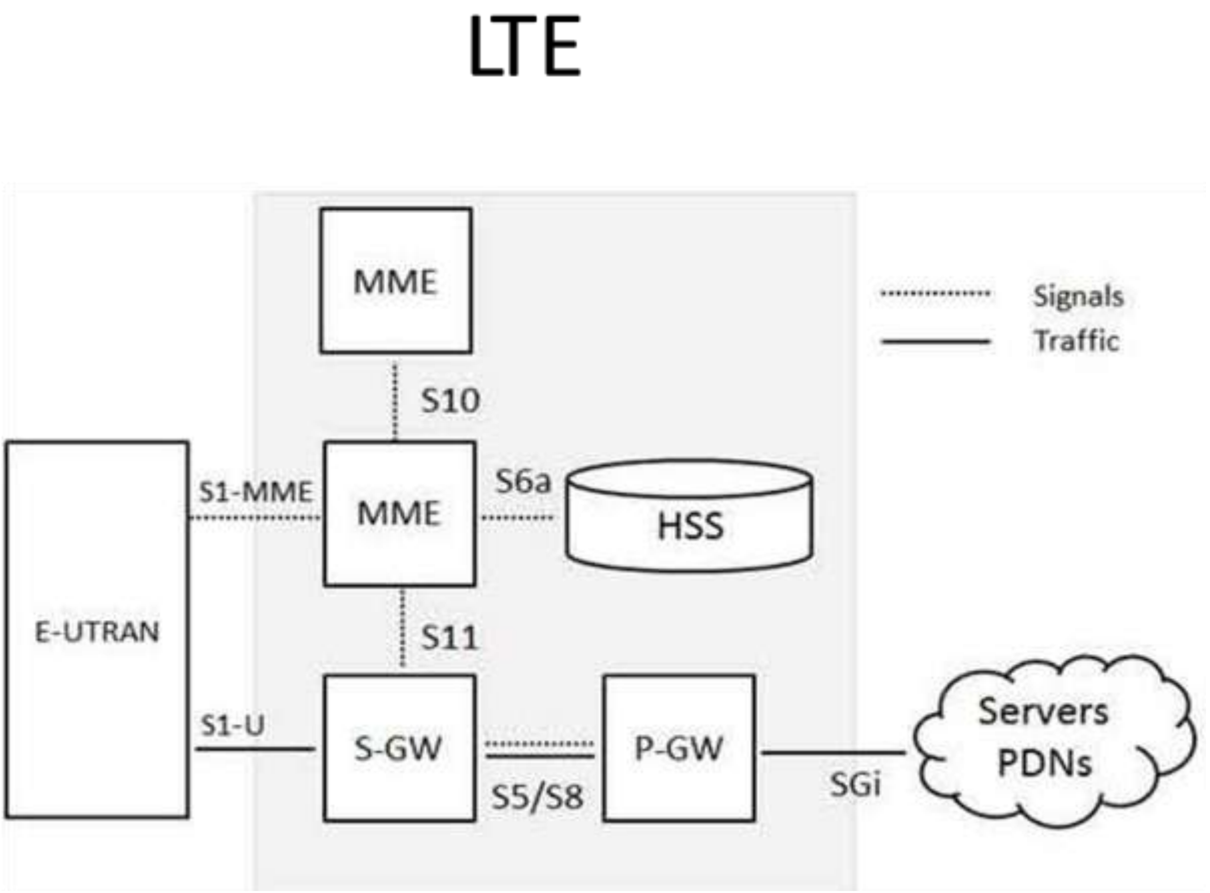
- The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been illustrated below.



- The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called **eNodeB** or **eNB**. Each eNB is a base station that controls the mobiles in one or more cells.
- The base station that is communicating with a mobile is known as its serving eNB.
- LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB:
- The eBN sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.
- The eNB controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.

The Evolved Packet Core (EPC) (The core network)

- The architecture of Evolved Packet Core (EPC) has been illustrated below.
- There are few more components which have not been shown in the diagram to keep it simple. These components are like the Earthquake and Tsunami Warning System (ETWS), the Equipment Identity Register (EIR) and Policy Control and Charging Rules Function (PCRF).



- Below is a brief description of each of the components shown in the above architecture:
- The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.
- The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world ie. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.
- The servinggateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.
- The mobility management entity (MME) controls the high-level operation of the mobile by means of signaling messages and Home Subscriber Server (HSS).

- The Policy Control and Charging Rules Function (PCRF) is a component which is not shown in the above diagram but it is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW.