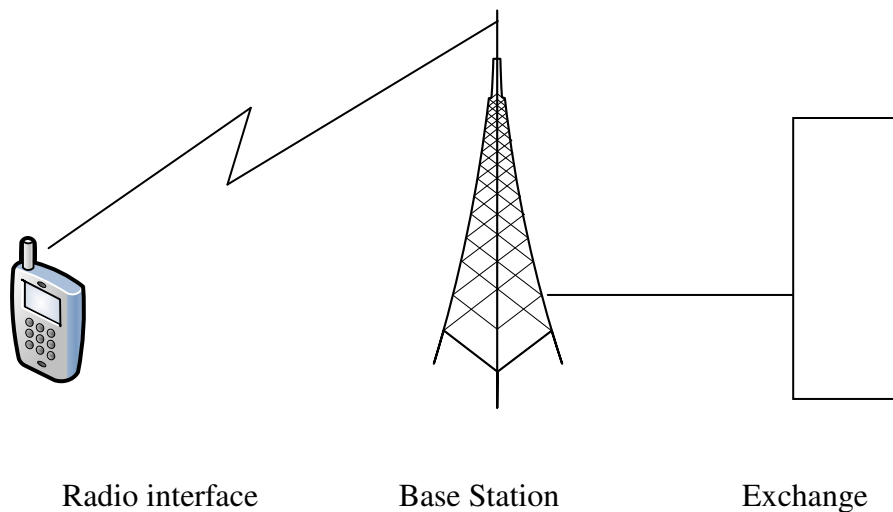# 7. Mobile Communication

Fundamentals

The main difference between fixed and mobile communication is the mobile subscriber's location changes with the time. Therefore the Access Network should be wireless. The subscriber connects to the switch via a base station. In other words there is a considerable similarity between the fixed and wireless communication networks.


Radio interface   Base Station   Exchange

The problems faced in the mobile communication are given below.

Limitations on bandwidth.

The service provider gets a fixed bandwidth from the Telecommunication Regulator. This bandwidth can be issued to the subscribers by using a radio multiple access technology such as FDMA, TDMA or CDMA.

In order to provide the service to a large number of subscribers the frequency re-use techniques to be used.

Normally this is done by the following manner.
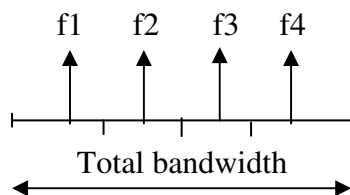
Total bandwidth

The total bandwidth of the service provider is divided into sub bands and their centre frequencies are f1, f2, f3, and f4 in the given example

The same frequency can e re-used by operating them in a limited area as shown in the figure……
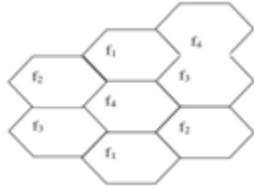

These areas are called cells. The centre of each cell has a Base station. If the same frequency sub band is used in 100 cells, the number of channels can be multiplied by 100 times. By increasing the number of cells the number of effective channels can be increased.

Radio Interference

The main problem in this method is the radio interference among the cells where the same frequency sub bend is used. In order to control this problem the transmit power of base station as well as the subscriber terminal (mobile phone) should be controlled.

Adjust the transmit power of mobile phone.
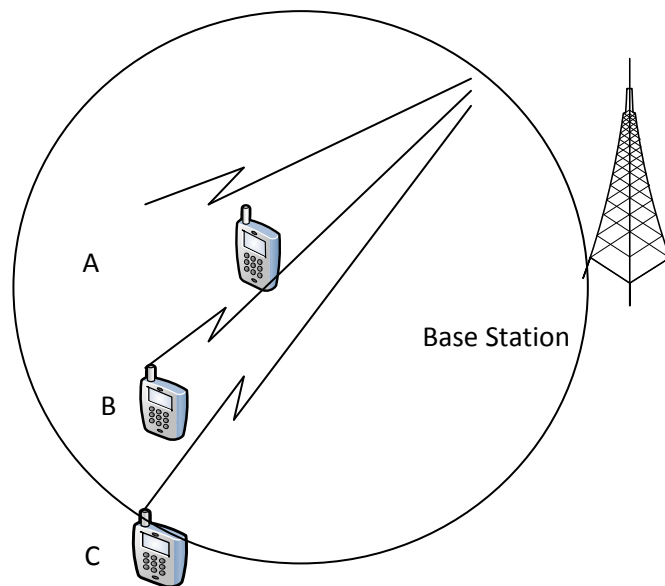
Consider the mobile user shown in the figure…. The location A is very close to the BS. Position C is the longest distance. The transmit power required at A, B, C, locations are different. A need less power and when the distance from BS

BS to mobile user increases transmit power also should increases. There should be a method to control the transmit power accordingly.
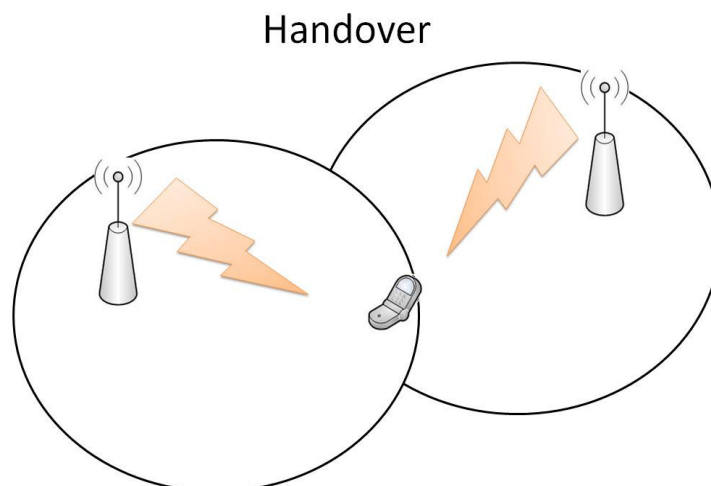
Allocation of a channel to user

Unlike the fixed wired communication the mobile user (subscriber) does not have a fixed channel in the Access Network. Since there are a limited number of channels in a Cell, the channels are in a pool of channels. When a user needs to get a call, one of the free channels is located to the user from the pool. Normally such intelligent functions are not handled by BS. It can be handled by the Mobile Telephone Exchange.

Security

Security is another problem in mobile communication. Before providing service to a user; the system should check whether he is a legitimate user. This is done by an authentication method. Other problem is eves drop. That is an outsider can listen to your conversation if they turned to the users channel. The solution for this problem is to "encrypt" the information before transmitting.
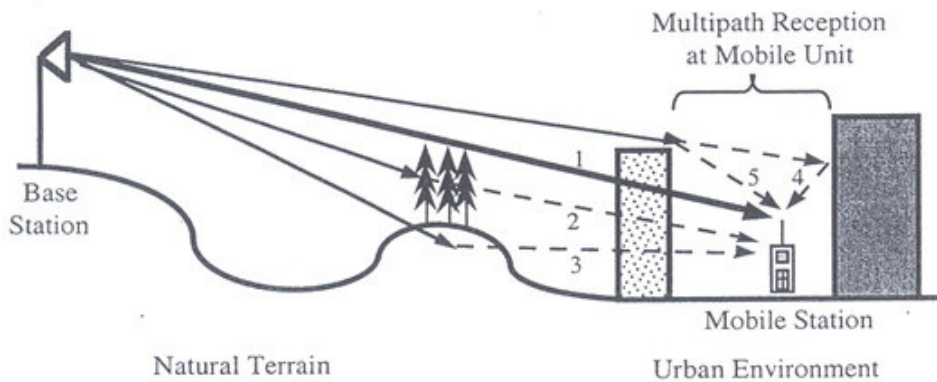
Hand over

Handover

When a user travels from one cell area to another cell area as shown in figure…………., the communication channel to be changed. When the user is at A, a channel is allocated by F1 cell. When the user is at B (overlapping area) user becoming closer to F2 cell. When the user is closer to F2 cell, the user should release the channel allocated by the F1 cell and change to a channel allocated by F2 cell. This process is called "hand over" and this can be done by the Mobile Exchange..
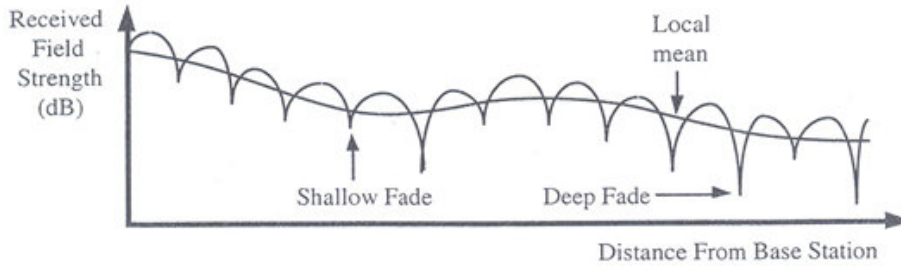
Fading

Fading is the changing of received signal level.

Base Station

Building
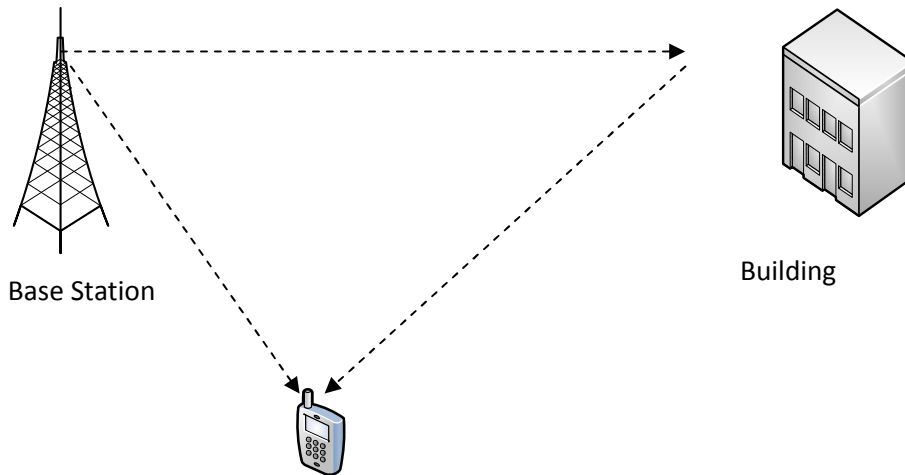
The user can receive the same signal in different paths. While traveling the resultant signal level can be varying as shown in the figure……………..

Multipath Reception at Mobile Unit

Base Station

Mobile Station

Natural Terrain

Urban Environment

Location Update

Suppose a user received a call from an another network or some network. In order to deliver the call, the system should know that where the user is travelling. Therefore location of the user should be recorded somewhere. This process is called Location update.

Evolution of Mobile Communication

Introduction

Nowadays it is considered as that there are four generations of mobile communication called 1G, 2G, and 3G. Again 2G has the versions of 2.25G, and 2.5G and 2.75G.

1G and 2G are used circuit switching ,digital switching, and C7 signaling for voice communication. 3G onwards based on IP technology.

1st Generation established in 1980s and it is considered as analogue mobile communication where as the radio multi access technology is FDMA. But the rest of the things are digital. That is, voice signal is converted to a digital signal, transmission and switching also digital.

The 2G uses the radio multiple access technology as TDMA or Combination of TDMA and FDMA.

The 3G is based on packet switching and it has many versions.

The 4G is fully IP based and it is expected to get 1 Gb/s bit rate.

1st Generation Mobile System

Year	System	Frequency Band	Countries Used
1981	Advanced Mobile Phone Service [AMPS]	850 MHz	USA Russia
1985	Total Access communication	900 MHz	Europe UK

The first generation used FDMA/FDD

Analogue network Architecture

Mobile Station   Base Station   MSC

Radio Interface   Fiber or Radio
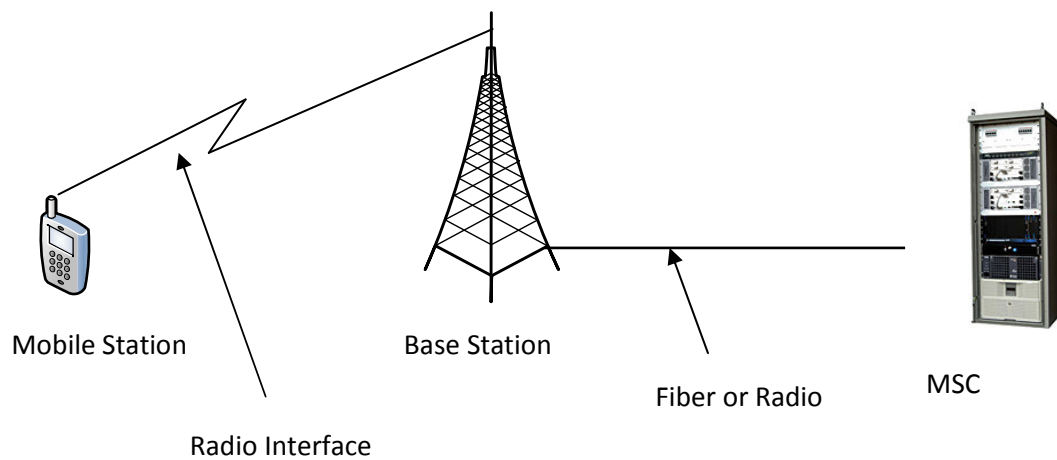
Mobile Switching Centre (MSC)

An MSC is basically a digital exchange. All intelligent works were done by MSC. It performed the switching function, signaling, location update to database call supervision and resource allocation.

Home Location Register (HLR)

HLR is a database which maintains information of all subscribers such as,

Subscriber identify number

MS identity numbers and Model type

Class of operation (Number of power levels, service capabilities etc.)

Present traffic area.

Visitor Location Register (VLR)

When a subscriber moves to a different MSC area (his network or any other mobile network) the subscriber information from his HLR is obtained and store temporarily in another and store database called Visitor Location Register (VLR).

Registration

The subscriber register when switch on his MS or whenever a call is set up or whenever other MS roams between two location areas. The network may allow request MSs to register periodically (typically every 15 minutes) so that and MS may be classed as inactive it if it does not respond. In such case a voice message is activated when another subscriber tried to get a call to him.

When performing an automatic or requested registration, the MS transmits its mobile identification numbers. A programmable read only memory (PRAM) stores the international mobile subscriber identity (IMSI) number which identifies the MS with its telephone number, its mobile network and its country of operation. It also stores the manufacture's 11 digit identification serial number given type and given phone number. These numbers are transmitted along with the location area code during registration. This information can be compared to that stored in the HLR to verify the MS and the services subscribed to and to update the location.

Cell Supervision

Mobile communication re-uses the same frequency in different cells. It may cause interference among close same frequency calls. This is call co-channel interference. To maintain quality of service, the level of this interference relative to the channel carrier level must be measured

At the time of set up the call as well as during the call is in progress a special signal called Supervisory Audit Tone (SAT) is transmitted from BS to the MS and loop back to MS. The S/N of SAT is measured and when it deteriorates the handover the call is required.

The MS is capable of transmit the signal of different power levels. The required power level is decided as per the carrier power to Interference power ratio (C/I). Typically up to 8 power levels are available. Depending on C/I level, the MSC issue four kinds of commands to MS calls.

Signal Strength Decrease – SSD

Signal Strength Increase - SSD

Signal Strength Handover - SSD

Signal Strength Blocking – SSD

Handover

When the hand over threshold is crossed, the MSC instructs the BS in the adjacent cells to measure the signal strength from the MS requiring hand over. The MSC selects a frequency (Channel) from the new BS and instruct to release the existing channel and change to new channel. However before changing over the SAT S/N is measured. If the SAT S/N is not sufficient the hand over will not be done.

Signaling Channels

There are analog signaling channels and digital signaling channels.

The SAT is an analog signaling channel and it has three centre frequencies 5.97, 6 and 6.05 KHz with a maximum deviation of 1.7 KHz transmitted over the forward voice channels (FVC) and Reverse Voice Channels (RVC).

The signaling Tone CST is another analog signal centered on 8 KHz with a maximum deviation of 6.4 KHz. It is used during receiving a call by MS and termination of a call. It is transmitted over a RVC only.

Digital Control Channels

In TACS the digital control channels are used for call setup process. There are three types of digital control channels.

Dedicated Control channels – These transmit basic information identifying the network and inform the MS of channel numbers of paging channels.

Optional Paging Channels - These are used to alert for incoming call, send network specific information such as location area and the access channel number.

Optional Access Channels – These are used when MS wishes to initiate a call, register, update location or respond to paging.

Incoming Call Processing

Consider a call originating from PSTN or any other mobile network. It will reach the Gateway MSC (GMSC). The GMSC is the MSC which is connected to other networks. The GMSC find out the location information of destination and direct the call to relevant MSC. The MSC delivered the call to relevant MS via the BS.

Out-going Call

The ms request a voice channel through a control channel. The MSC allocate a voice channel from the relevant HS. The MS dialed the number and MSC will switch the call to relevant destination.

1G Network Architecture
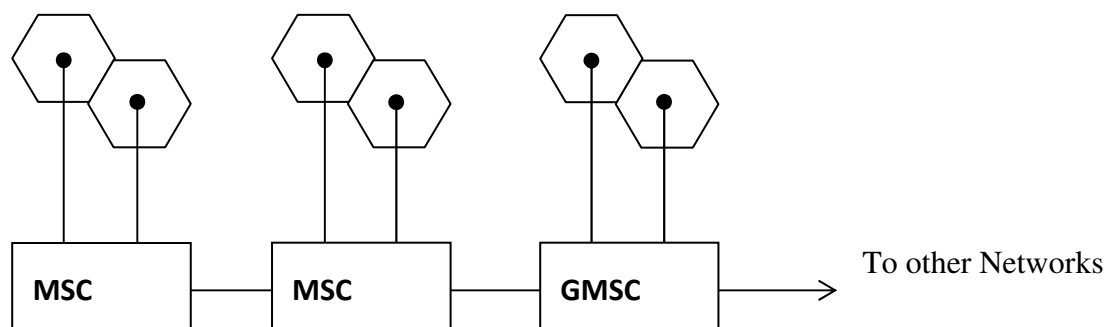
2nd Generation Networks

The emphasis for 2G was on compatibility and international transparency. The system should be regional (European, America etc.) and the users of the system should be able to access from anywhere of the region.

Year	System	Frequency Band	Countries Used
1991	Global System for mobile communication [GSM]	900 MHz	Worldwide
1992	Personal communication Network for DCS 1800	1800 MHz	German UK
1991	Personal Communication Service [PCS]	1900 MHz	USA

Of these, the commercial success story is the Global System for Mobile communication (GSM) where the specifications defined by ETSI. The main idea behind the GSM specification was to define several open interfaces, which determines the standardized components of the GSM System. Therefore operators could obtain different components of the network from different network suppliers. Also, when an interface is defines strictly how system functions are proceeding at the interface. This in turn determines which functions are left fo be implemented internally by the network elements on both sides of the interface.
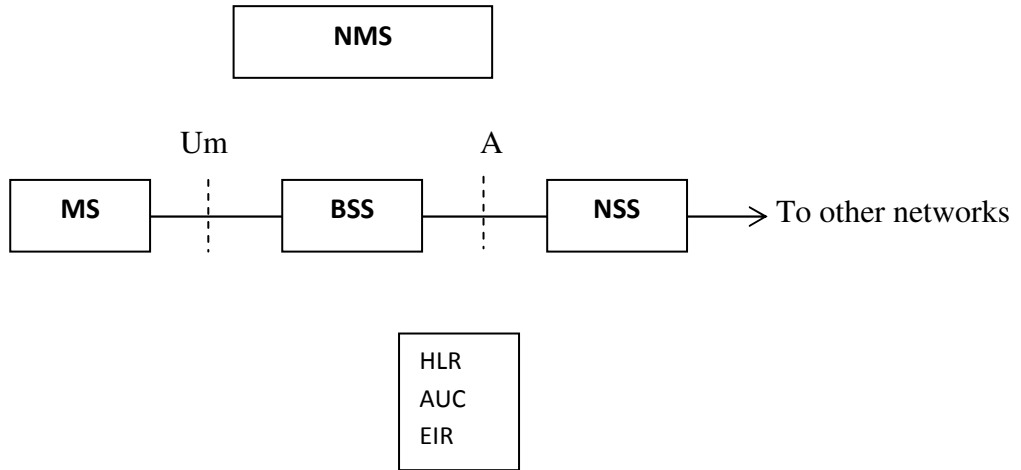
The GSM network can be separated into four separate subsystems.

Network Subsystem (NSS)

Bose Station Subsystem (BSS)

Network Management Subsystem (NMS)

Mobile Station (MS)

MS

The mobile phone is called the Terminal Equipment (TE), the subscriber information is stored in the Subscriber Identity Module (SIM).

The ME has its own pre-programmed International Mobile Equipment Identity Number (IMEI), which can be checked against the Equipment Identity Register (EIR) to detect stolen, non-type approved. The EIR is a database.

The SIM carries the International Mobile Subscriber Identity (IMSI) number which identities the HLR of the subscriber. It also stores the required information for authentication and encryption. In GSM System the digital signal (voice or data) is transmitted after encryption for secure transmission.
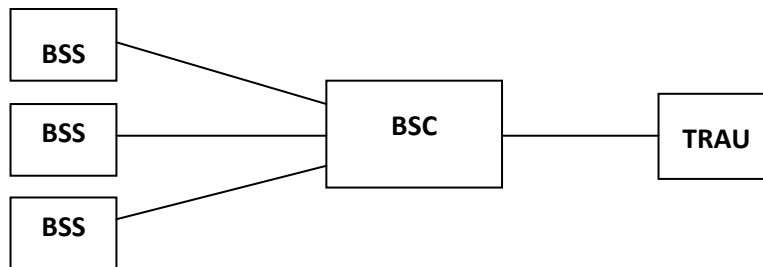
The BSS consists of one Base Station Controller (BSC) and Several Base Transceiver Stations (BTS). The BTS function is similar to BS function of 1G. Some of the MSC functions of 1G is

done by the BSC. In addition the Trans coding and Rate Adaption Unit (TRAU) also belongs to BSS.

BTS

A BTS comprises all radio equipment, ie antennas, signal processors, amplifiers necessary for radio transmission. A BTS can form a radio cell. By using a sector antenna one BTS can be used for a several cells.
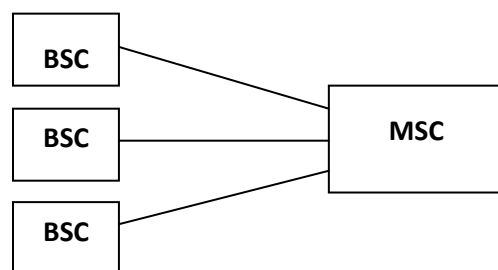
BSC

The BSC basically manages the BTS s. It reserves radio frequencies, handles the hand over from one BTS to another within the BSS and performs paging of MS.

TRAU

It is capable of speech from one digital coding format to another vice verse. In GSM system the speech coding in the radio interface is 13kb/s and 64kb/s in the MSC side.

Mobile Services Switching Centre

A number of BSCs are controlled by MSC, which is a high performance ISDN switch. Its function is to provide call heading for all MSs within its traffic area and the generation of charging records for billing. A gateway MSC (GMSC) has additional connections to other networks such as PSTN and other Mobile networks.

Functional Architecture of a GSM network
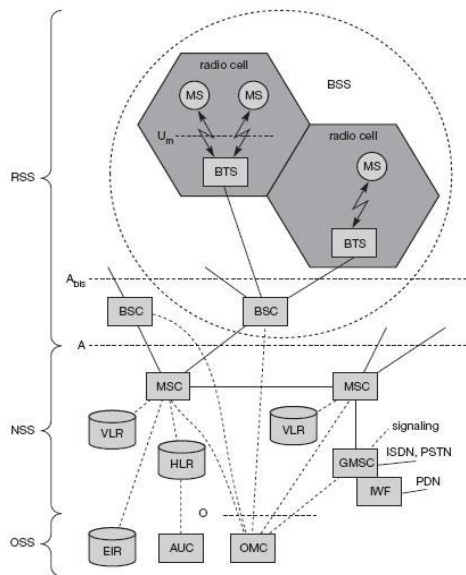
Radio Interface

The most interesting interface in a GSM system is UM, the radio interface.

The radio frequency band of GSM is divided to 248 channels of 200 KHz. 124 channels for uplink and 124 channels for down link. It is divided 8 time slots and used TDMA. One voice call is allocated one Time Slot. Therefore GSM uses a combination of FDMA and TDMA.

Since TX and RX have separate frequency bands, GSM uses FDD as duplexing.

FDMA carriers and TDMA Time slots make physical channels. A set of logical channels for signaling and traffic channels must be mapped onto the available physical channels. These logical channels are designated as follows,
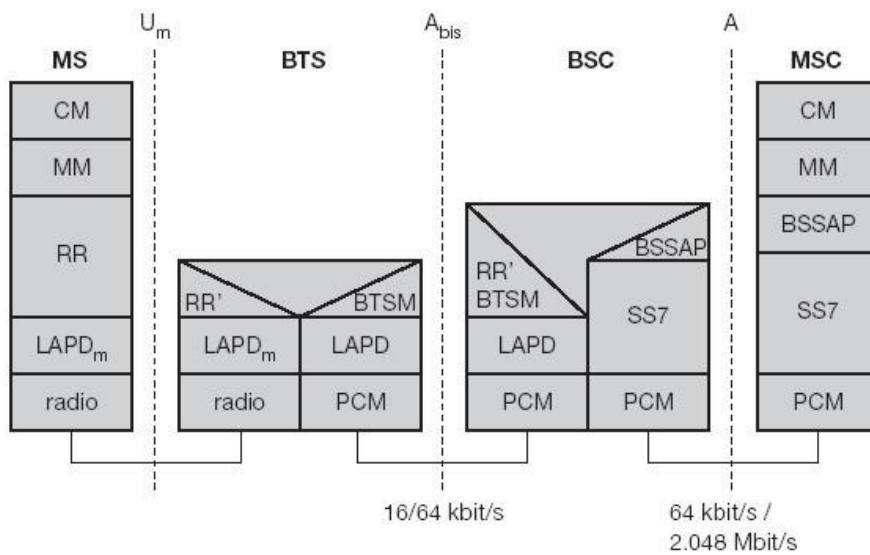
(A) Broadcast down link channel

        Channel over which local information, e.g. location area is broadcast by network to all MSs in area.
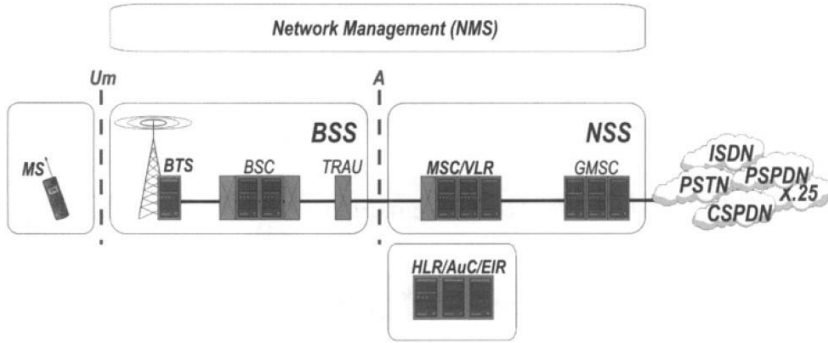
(B) Common downlink channel

        All MSs may listen to this shared downlink channel information is transmitted to individual MSs, e.g. when the network pages a mobile.
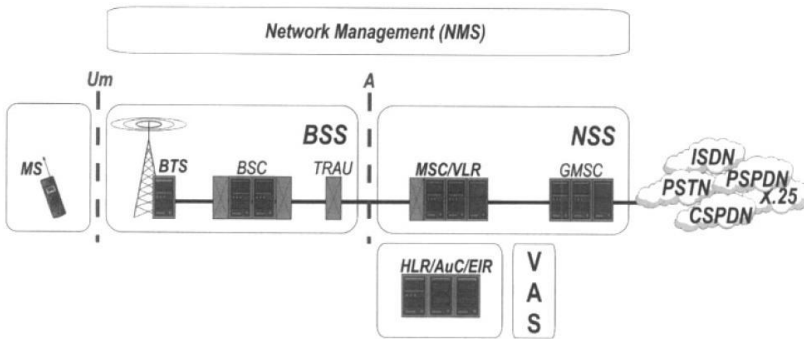
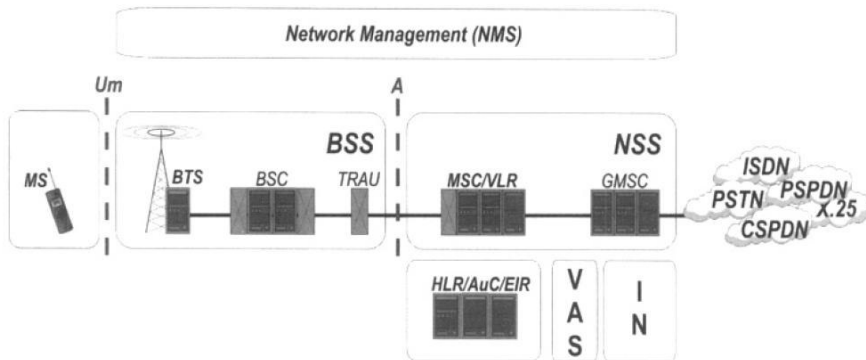**Protocol Architecture for Signaling**
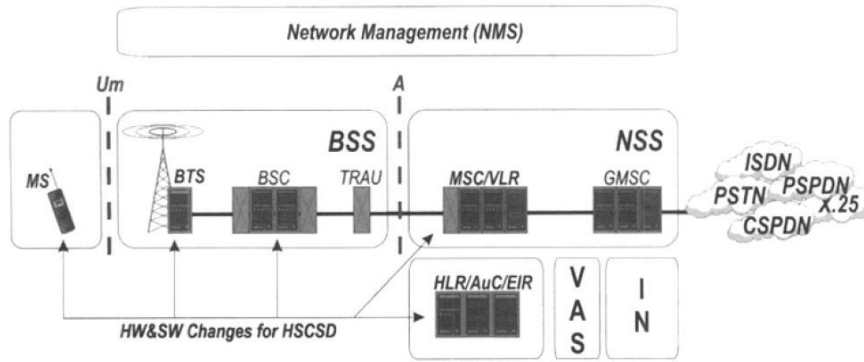
GSM Network Architectures

Basic GSM network and its subsystems

Value added service platform

Intelligent network

Channel coding and HSCSD effects
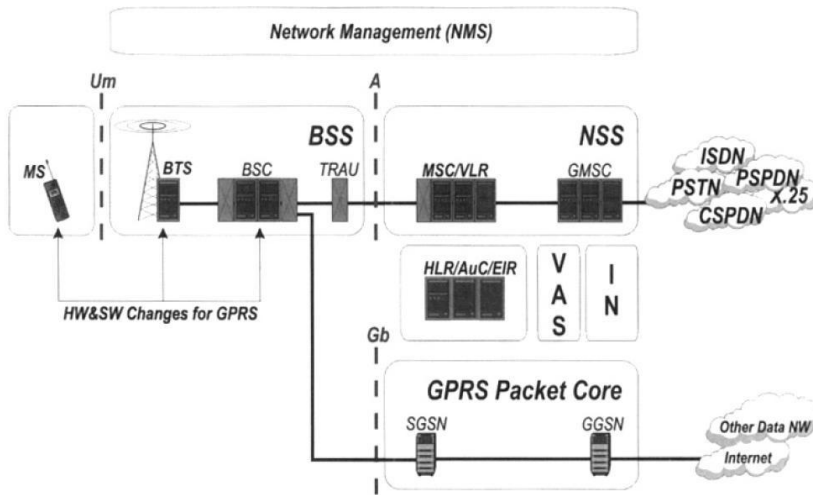
General packet radio service (GPRS)

3G

The 3rd Generation of mobile communication required a global standardization. But the different names are uses for 3G by different standard bodies/ regions.

UTMS – Universal Mobile Telecommunication System by ETSI

IMT-2000 by ITU-T

CDMA 2000 – US

ETSI, ARI of Japan, CWTS of china and standardization committee T1 of US together formed the 3G partnership project or 3GPP. Later some other remaining organizations joined to 3GPP and named as 3GPP2.

The first set of 3GPP standard come in 1999 as 3GPP system release 99 or 3GPP 99. The next version was 3GPP00 and mainly the ETSI was leading on this task. Later 3GPPR4, 3GPPR5, 3GPPR6 and so on introduced. At this stage the latest one is 3GPP R10.
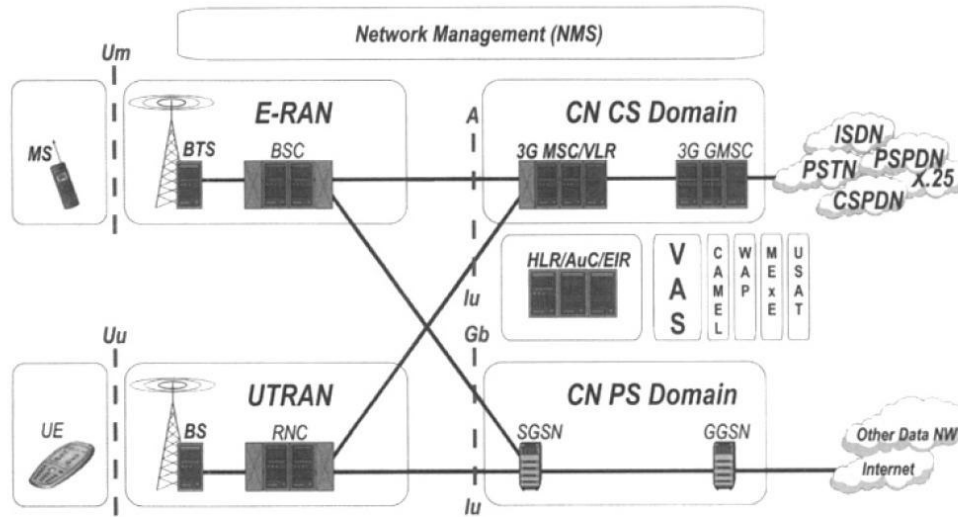
3GPP R99 network architecture

3G network scenario (3GPP R99)

3G introduced the new radio access methods, Wideband CDMA (WCDMA). This concept comes with, Base Station (BS) and Radio Network Controller (RNC). They all together is called UMTS Terrestrial Radio Access Network (UTRAN).

3GPP R99 supports for the GSM/Edge Radio Access Network (GERAN). The GSM air interface is modified in such a way that it is able to broadband system information about the WCDMA radio network in the down link direction. The WCDMA radio access network is able to broadcast system information about the surrounding GSM network in the downlink direction too.

Core Network (CN) nodes have also evolved technically. Circuit switch can handle both 2G and 3G subscriber.

The new services such as audio/video streaming services, multimedia messaging that utilities location services (LCs).

3GPP R4
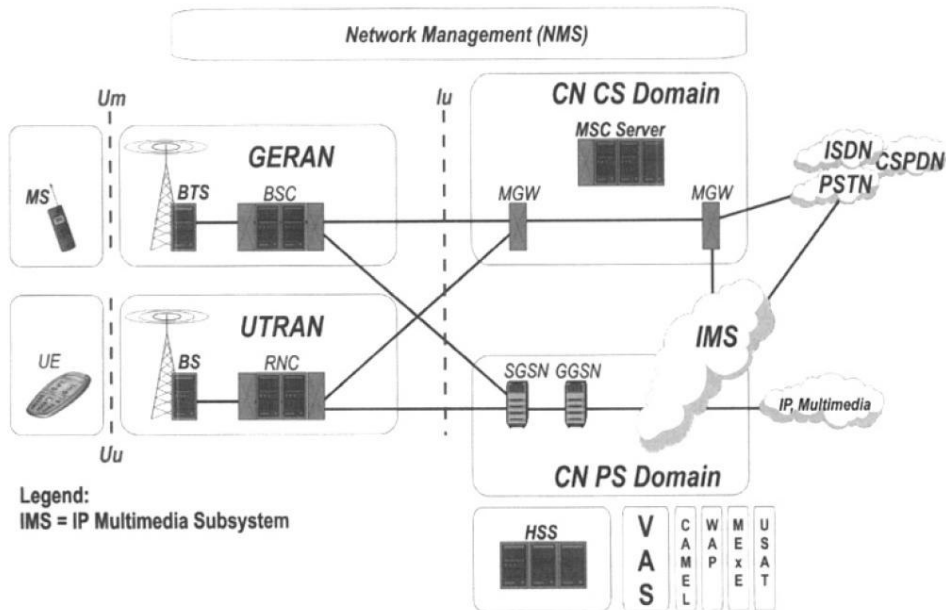
3GPP R4 implementation scenario

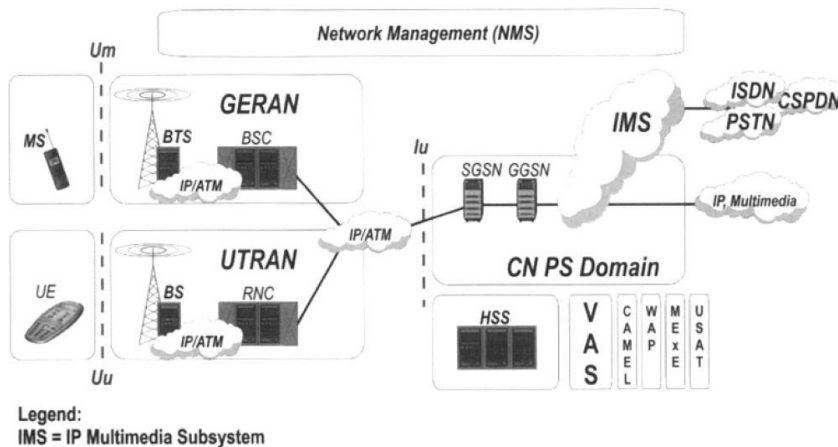3GPP R4 introduced IP transport for CN protocols. Also it splitted the function of MSC and newly introduced the Circuit Switched Media Gateway (SC-MGW) and it takes core of all physical connection setup matters. The node that maintains connection control capacity is called the MSC server. The MSC server and CS-MGW have a one to many relationships.

3GPP R5

Vision of 3GPP R5 (All IP)

3GPP R5 implements the following major items.

* IP transport over the whole system from BS up to the network border gateway.
* To introduce an IP Multimedia Subsystem (IMS) in order to start wide use of various multimedia services.
* To gain more capacity in the UTRAN air interface in the downlink direction.

4G

In telecommunications, **4G** is the fourth generation of cellular wireless standards. It is a successor to the 3G and 2G families of standards. In 2008, the ITU-R organization specified the **IMT-Advanced** (International Mobile Telecommunications Advanced) requirements for 4G standards, setting peak speed requirements for 4G service at 100 Mbit/s for high mobility communication (such as from trains and cars) and 1 Gbit/s for low mobility communication (such as pedestrians and stationary users).

A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smartphones, and other mobile devices. Facilities such as ultra-broadband Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users.

Pre-4G technologies such as mobile WiMAX and first-release Long term evolution (LTE) have been on the market since 2006[2] and 2009 respectively, and are often branded as 4G in marketing materials. The current versions of these technologies did not fulfill the original ITU-R requirements of data rates approximately up to 1 Gbit/s for 4G systems.

IMT-Advanced compliant versions of the above two standards are under development and called "LTE Advanced" and "WirelessMAN-Advanced" respectively. ITU has decided that "LTE Advanced" and "WirelessMAN-Advanced" should be accorded the official designation of IMT-Advanced. On December 6, 2010, ITU announced that current versions of LTE, WiMax and other evolved 3G technologies that do not fulfill "IMT-Advanced" requirements could be considered "4G", provided they represent forerunners to IMT-Advanced and "a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed.

In all suggestions for 4G, the CDMA spread spectrum radio technology used in 3G systems and IS-95 is abandoned and replaced by OFDMA and other frequency-domain equalization schemes. This is combined with MIMO (Multiple In Multiple Out), e.g., multiple antennas, dynamic channel allocation and channel-dependent scheduling

This article uses 4G to refer to **IMT-Advanced** (*International Mobile Telecommunications Advanced*), as defined by ITU-R. An IMT-Advanced cellular system must fulfill the following requirements:[7]

- Based on an all-IP packet switched network.
- Peak data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access, according to the ITU requirements.
- Dynamically share and utilize the network resources to support more simultaneous users per cell.
- Scalable channel bandwidth, between 5 and 20 MHz, optionally up to 40 MHz.
- Peak link spectral efficiency of 15 bit/s/Hz in the downlink, and 6.75 bit/s/Hz in the uplink (meaning that 1 Gbit/s in the downlink should be possible over less than 67 MHz bandwidth).
- System spectral efficiency of up to 3 bit/s/Hz/cell in the downlink and 2.25 bit/s/Hz/cell for indoor usage.
- Smooth handovers across heterogeneous networks.
- Ability to offer high quality of service for next generation multimedia support.

In September 2009, the technology proposals were submitted to the International Telecommunication Union (ITU) as 4G candidates. Basically all proposals are based on two technologies:

- LTE Advanced standardized by the 3GPP
- 802.16m standardized by the IEEE (i.e. WiMAX)

Present implementations of WiMAX and LTE are largely considered a stopgap solution that will offer a considerable boost while WiMAX 2 (based on the 802.16m spec) and LTE Advanced are finalized. Both technologies aim to reach the objectives traced by the ITU, but are still far from being implemented.

The first set of 3GPP requirements on LTE Advanced was approved in June 2008.[11] LTE Advanced will be standardized in 2010 as part of the Release 10 of the 3GPP specification. LTE Advanced will be fully built on the existing LTE specification Release 10 and not be defined as a new specification series. A summary of the technologies that have been studied as the basis for LTE Advanced is included in a technical report.

Current LTE and WiMAX implementations are considered pre-4G, as they don't fully comply with the planned requirements of 1 Gbit/s for stationary reception and 100 Mbit/s for mobile.

Confusion has been caused by some mobile carriers who have launched products advertised as 4G but which are actually current technologies, commonly referred to as '3.9G', which do not follow the ITU-R defined principles for 4G standards. A common argument for branding 3.9G systems as new-generation is that they use different frequency bands to 3G technologies; that they are based on a new radio-interface paradigm; and that the standards are not backwards compatible with 3G, whilst some of the standards are expected to be forwards compatible with "real" 4G technologies.

While the ITU has adopted recommendations for technologies that would be used for future global communications, they do not actually perform the standardization or development work

themselves, instead relying on the work of other standards bodies such as IEEE, The WiMAX Forum and 3GPP. Recently, ITU-R Working Party 5D approved two industry-developed technologies (LTE Advanced and WirelessMAN-Advanced) for inclusion in the ITU's International Mobile Telecommunications Advanced (IMT-Advanced program), which is focused on global communication systems that would be available several years from now. This working party's objective was not to comment on today's 4G being rolled out in the United States and in fact, the Working Party itself purposely agreed not to tie their IMT-Advanced work to the term 4G, recognizing its common use in industry already; however, the ITU's PR department ignored that agreement and used term 4G anyway when issuing their press release.

The ITU's purpose is to foster the global use of communications. The ITU is relied upon by developing countries, for example, who want to be assured a technology is standardised and likely to be widely deployed. While the ITU has developed recommendations on IMT-Advanced, those recommendations are not binding on ITU member countries.

4G features assumed in early literature

The 4G system was originally envisioned by the Defense Advanced Research Projects Agency (DARPA). The DARPA selected the distributed architecture, end-to-end Internet protocol (IP), and believed at an early stage in peer-to-peer networking in which every mobile device would be both a transceiver and a router for other devices in the network eliminating the spoke-and-hub weakness of 2G and 3G cellular systems. Since the 2.5G GPRS system, cellular systems have provided dual infrastructures: packet switched nodes for data services, and circuit switched nodes for voice calls. In 4G systems, the circuit-switched infrastructure is abandoned, and only a packet-switched network is provided, while 2.5G and 3G systems require both packet-switched and circuit-switched network nodes, i.e. two infrastructures in parallel. This means that in 4G, traditional voice calls are replaced by IP telephony.

Cellular systems such as 4G allow seamless mobility; thus a file transfer is not interrupted in case a terminal moves from one cell (one base station coverage area) to another, but handover is carried out. The terminal also keeps the same IP address while moving, meaning that a mobile server is reachable as long as it is within the coverage area of any server. In 4G systems this mobility is provided by the mobile IP protocol, part of IP version 6, while in earlier cellular generations it was only provided by physical layer and datalink layer protocols. In addition to seamless mobility, 4G provides flexible interoperability of the various kinds of existing wireless networks, such as satellite, cellular wirelss, WLAN, PAN and systems for accessing fixed wireless networks.

While maintaining seamless mobility, 4G will offer very high data rates with expectations of 100 Mbit/s wireless service. The increased bandwidth and higher data transmission rates will allow 4G users the ability to utilize high definition video and the video conferencing features of mobile devices attached to a 4G network. The 4G wireless system is expected to provide a comprehensive IP solution where multimedia applications and services can be delivered to the user on an 'Anytime, Anywhere' basis with a satisfactory high data rate, premium quality and high security.

4G is described as MAGIC: mobile multimedia, any-time anywhere, global mobility support, integrated wireless solution, and customized personal service. Some key features (primarily from users' points of view) of 4G mobile networks are,

High usability: anytime, anywhere, and with any technology

- Support for multimedia services at low transmission cost
- Personalization
- Integrated services

8. <u>Voice over IP</u>

8.1 Introduction

In VOIP we should follow the similar steps of PSTN to get a call.

* Establish the call
* Convert the voice to digital signal and transform to IP packets
* Terminate the call