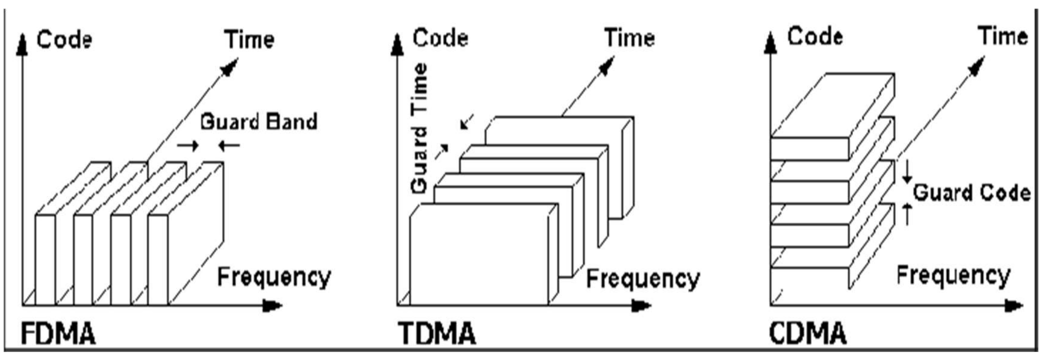
Multiple Access in a Radio Cell

In each radio cell, the transmission from the base station in the downlink can be heard by each and every mobile user in the cell. For this reason, this mode of transmission is referred to as broadcasting. On the other hand, a transmission from the mobile user in the uplink to the base station is many-to-one, and is referred to as multiple access.

Multiple Access method allows several terminals connected to the same multi-point transmission medium to transmit over it and to share its capacity. Examples of shared physical media are wireless networks, bus networks, ring networks, hub networks and half-duplex point-to-point links. Multiple Access technique is based on a multiplex method that allows several data streams or signals to share the same communication channel or physical media. Multiple access is a signal transmission situation in which two or more users wish to simultaneously communicate with each other using the same propagation channel.



a) **FREQUENCY DIVISION MULTIPLE ACCESS** (FDMA)

FDMA is based on frequency-division multiplex (FDM). It gives users an individual allocation of one or several frequency bands, or Channels.

FDMA provides different frequency bands to different users or nodes. In FDMA, the total bandwidth is divided into non-overlapping frequency sub-band. Each user is allocated a unique frequency sub-band for the duration of the connection, whether the connection is an active or idle state. Orthogonality among transmitted signals from different mobile users is achieved by bandpass filtering in the frequency domain. An example of FDMA systems were the first-generation (1G) cell-phonesystems.

b) **TIME-DIVISION MULTIPLE ACCESS** (TDMA)

TDMA is based on time-division multiplex (TDM). It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using his own time slot. This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only a part of its channel capacity. TDMA provides different time-slots to different transmitters in a cyclically repetitive frame structure. In a TDMA, the channel time is partitioned into frames. The length of a frame is long enough so that every user in service has an opportunity to transmit once per frame. To achieve this, a TDMA frame is further partitioned into time slots. Users have to transmit in their assigned slots from frame to frame. For example, user 1 may use time slot 1, user 2 time slot 2, etc until the last user. Then it starts all over again. TDMA is used in the digital

2G cellular systems such as Global System for Mobile Communications (GSM). It is also used extensively in satellite systems.

c) **CODE DIVISION MULTIPLE ACCESS** (CDMA)

CDMA is a spread spectrum multiple access method. The principle of spread spectrum communications is that the bandwidth of the baseband information-carrying signals from the different users is spread by different signals with a bandwidth much larger than that of the baseband signals. Ideally, the spreading signals used for different users are orthogonal to each other. Thus, at the receiver, the same spreading signal is used as the dispreading signals to coherently extract the baseband signal from the target user, while suppressing the transmissions from any other users. An example of CDMA is the 3G cell phone system.

Overview of UMTS

Overview

The 3rd Generation Mobile Communication System (3G) is put on agenda when the 2nd generation (2G) digital mobile communication market is booming. The 2G mobile communication system has the following disadvantages: limited frequency spectrum resources, low frequency spectrum utilization, and weak support for mobile multimedia services (providing only speech and low-speed data services). Also, thanks to incompatibility between 2G systems, the 2G mobile communication system has a low system capacity, hardly meeting the demand for high-speed bandwidth services and impossible for the system to implement global roaming. Therefore, the 3G communication technology is a natural result in the advancement of the 2G mobile communication.

As the Internet data services become increasingly popular nowadays, the 3G communication technology opens the door to a brand new mobile communication world. It brings more fun to the people. In addition to clearer voice services, it allows users to conduct multimedia communications with their personal mobile terminals, for example, Internet browsing, multimedia database access, real-time stock quotes query, videophone, mobile e-commerce, interactive games, wireless personal audio player, video transmission, knowledge acquisition, and entertainments. What more unique are location related services, which allow users to know about their surroundings at any time anywhere, for example, block map, locations of hotels and super markets, and weather forecast. The 3G mobile phone is bound to become a good assistant to people's life and work.

The 3G mobile communication aims at meeting the future demand for mobile user capacity and providing mobile data and multimedia communication services. Compared with the existing 2G system, the 3G system has the following characteristics as summarized below:

1. Support for multimedia services, especially Internet services
2. Easy transition and evolution
3. High frequency spectrum utilization

Currently, the three typical 3G mobile communication technology standards in the world are CDMA2000, Universal Mobile Telecommunication System (UMTS) and Time division synchronous -CDMA (TD-SCDMA). CDMA2000 and UMTS work in the FDD mode, while TD-SCDMA works in the TDD mode, where the uplink and downlink of the system work in different timeslots of the same frequency.

The 3G mobile communication is designed to provide diversified and high-quality multimedia services. To achieve these purposes, the wireless transmission technology must meet the following requirements:

1. High-speed transmission to support multimedia services

- Indoor environment: >2 Mbps
- Outdoor walking environment: 384 Mbps
- Outdoor vehicle moving: 144 kbps

2. Allocation of transmission rates according to needs
3. Accommodation to asymmetrical needs on the uplink and downlink

In the concept evaluation of the 3G mobile communication specification proposals, the UMTS technology is adopted as one of the mainstream 3G technologies thanks to its own technical advantages.

UMTS Technical Standards Development Trends

UMTS was originated by standardization organizations and manufacturers in European countries and Japan. UMTS inherits the high standardization and openness of GSM, and its standardization progresses smoothly. UMTS is the third generation mobile communication standard developed by 3GPP, with the GSM MAP as its core and UTRAN (UMTS Terrestrial Radio Access Network) as its wireless interface. Using the chip rate of 3.84 Mbps, it provides data transmission rate up to 14.4 Mbps within 5 MHz bandwidth.

The UMTS technology has the following characteristics:

- Supporting both asynchronous and synchronous BTSs, for easy and flexible networking
- Using QPSK modulation mode (the HSDPA services also use the 16QAM modulation mode)
- Using pilot assisted coherent demodulation
- Accommodating transmission of multiple rates, and implementing multi-rate and multimedia services by changing the spread spectrum ratio and using multi-mode concurrent transmission
- Rapid and efficient power control of uplink/downlink greatly reduces multiple access interference of the system, but increases the system capacity while reducing the transmission power.
- The core network is evolving based on the GSM/GPRS network, and maintains compatibility with the GSM/GPRS network.
- Supporting soft handover and softer handover, with three handover modes, inter-sector soft handover, inter-cell soft handover, and inter-carrier hard handover

3GPP Standard Development Status

3GPP standard versions include R99, R4, R5, R6 and R7.

R99 version was frozen formally in Mar, 2000, and refreshes once every three months. Current commercial version of R99 is based on the version of June, 2001, for in later version, the number of CR is decreasing rapidly and there are no larger modifications and non-compatible upgrade.

R4 version was frozen in Mar, 2001. It passed in Mar, 2002 and is stable currently. R5 version was frozen in June, 2002 and is stable currently. Most R5 versions that providers support are the version of June, 2004. R6 version was frozen in June, 2005 and may be stable in a year. At present, R7/LTE has started up and its functional features are still in initial phase.

R99 and R4 versions are put into commercial use maturely. R6 version protocols are in developing status.

Basic Network Structure Based on R99

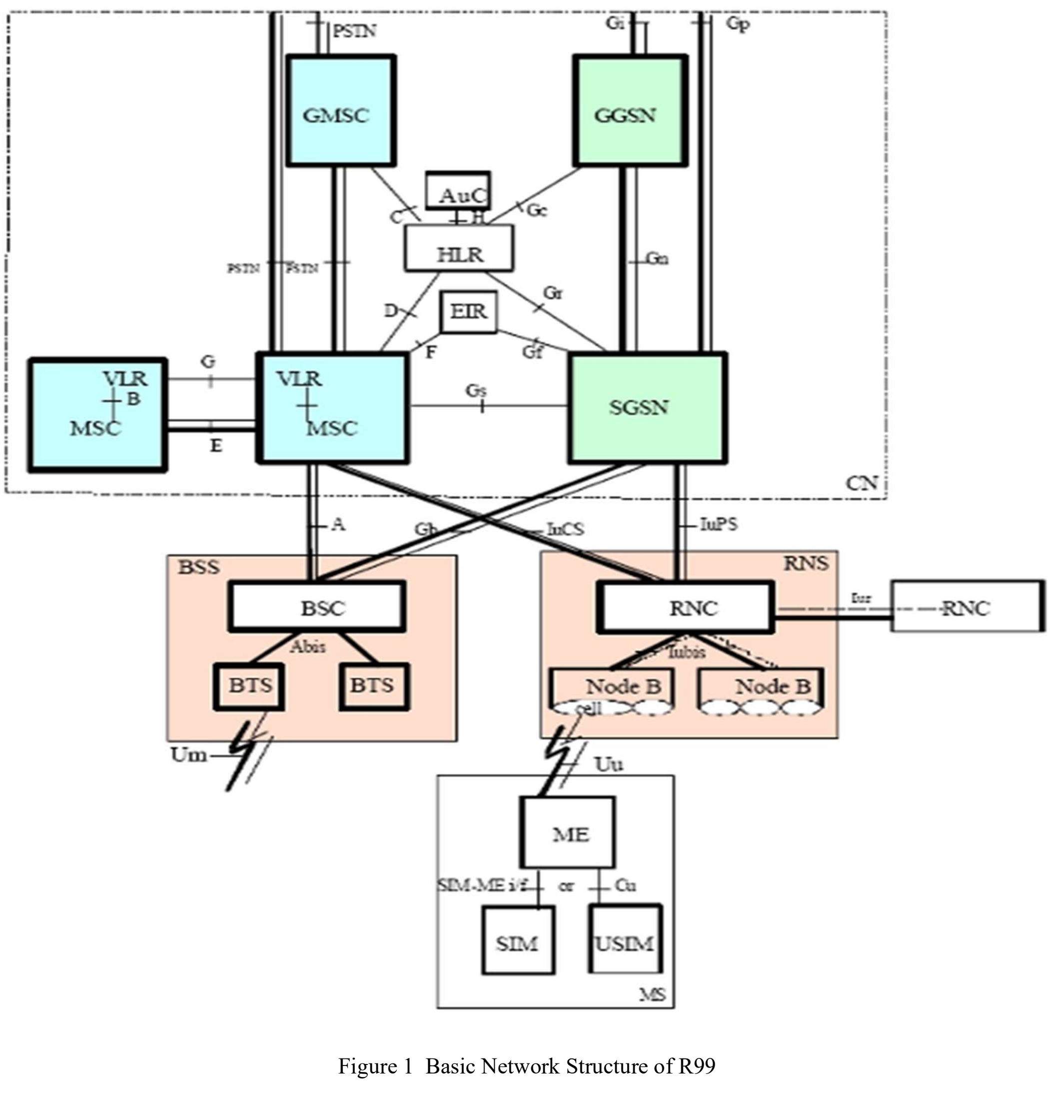


Figure 1 Basic Network Structure of R99

The R99 is the first phase version of 3GPP in 3G network standardization. The R99 was already frozen in June 2001, and subsequent revision is made on the R4. The basic configuration structure of the R99 is illustrated in Figure 1. To guarantee the investment interests of telecom operators, the network structure of the R99 is designed with 2G/3G compatibility fully in mind, for smooth evolution to 3G. Therefore, the core network in the basic network structure remains unchanged. To support 3G services, some NEs are added with appropriate interface protocols, and the original interface protocols are also improved by different degrees.

Analysis on 3GPP standard Version Evolution

During the evolution from GSM/GPRS to 3GPP R99, brand UTRAN introduced includes such key technologies as UMTS, power control, multipath Rake receiver. In addition, four QoS service types are put forward and cell peak rate supports up to 2 Mbps. CN basically develops from GSM/GPRS CN. It reduces the influence on GSM/GPRS CN caused by the introduction of UTRAN CN furthest. Most representative features of R4 from R99: Separation of CS domain control layer and transmission layer, convergence of transmission resources in CS and PS domains, and increase of resource transmission efficiency.

UTRAN in R4 version does not have substantive evolution and only performs some optimizations.

During the evolution from R4 to R5, IP multimedia subsystem is introduced into CN and the interface connecting GERAN is added. There is great change in UTRAN: IP transmission technology and HSDPA are introduced, which makes peak rate of the cell up to about 10 Mbps, much greater than the peak bandwidth that R4 and R99 versions can support (in the field, UMTS supporting HSDPA is called 3.5 G). R5 also supports Iu Flexible, allowing a RNC to access several MSCs or SGSNs simultaneously, which saves investment on access network resources for operators.

intercommunication of WLAN and UMTS. UTRAN evolution includes: MBMS, HSUPA, enhanced HSDPA, wave cluster figuration technology to increase coverage capacity, 3GPP RET and MOCN.

In R7 plans. UMTS will be developing in total IP direction. In addition, intercommunication of UTMS with other networks (such as, VLAN) and enhanced MBMS will be increased.

Evolution of Radio Access Network Technologies

- High-speed broadband access

  Compared with GSM/GPSR RAN, R99 introduced new UTRAN. UTRAN is based on UMTS radio interface technology. Its signal bandwidth is 5 MHz. Its code chip rate is 3.84 Mbps. Its cell downlink service bandwidth is about 2 M.

  R4 version has no large change in radio access.

In R5 version, High Speed Downlink Packet Access (HSDPA) is introduced. It adopts 16 QAM modulation mode, which greatly increases spectrum utilization ratio. Cell downlink peak rate reaches 14 Mbps. In the field, the system supporting HSDPA is defaulted as 3.5 G system.

In R6 version, High Speed Uplink Packet Access (HSUPA) is introduced, which makes cell uplink peak rate up to 5.7 Mbps.

In R7 version, High Speed Packet Access plus (HSPA+) where Multiple Input Multiple Output (MIMO) antenna technology is introduces, which enables several transmitting and receiving antennas to send and receive signals in same band. As a result, system capacity and spectrum utilization ratio is increased in propagation. MIMO antenna technology meets the requirements for high speed services in future mobile communication system.

In a word, evolution process of radio access network on access bandwidth is: 2 Mbps (R99) → HSDPA DL 14 Mbps (R5) →HSUPA UL 5.7 Mbps (R6) --> (HSPA+) MIMO (R7) → OFDM (LTE)(R8). Its evolution is to introduce all kinds of technologies, increasing spectrum utilization ratio furthest and meeting the requirements for high speed data transmission.

IMT2000 Frequency Band Allocation

In 1992, World Radio-communication Conference (WRC-92) allocated the frequency bands for the 3G mobile communication, with a total bandwidth of 230 MHz.

At WRC92, ITU planned the symmetric frequency spectrum resources of 120MHz (1920MHz ~ 1980MHz, 2110MHz ~ 2170MHz) for use by the FDD, and asymmetric frequency spectrum resources of 35MHz (1900MHz ~ 1920MHz, 2010MHz ~ 2025MHz) for use by the TDD.

At WRC2000, the 800 MHz band (806MHz ~ 960MHz), 1.7GHz band (1710MHz ~ 1885MHz), and 2.5GHz band (2500MHz ~ 2690MHz) were added for use by the IMT-2000 services. These two combined make the future spectrum for 3G reach over 500 MHz, reserving enormous resource space for future applications.

Composition of UMTS System

The Universal Mobile Telecommunication System (UMTS) is a 3G mobile communication system adopting UMTS air interface. Therefore, the UMTS is usually called a UMTS system.

In terms of functions, the network units comprise the Radio Access Network (RAN) and Core Network (CN). The RAN accomplishes all the functions related to radio communication. The CN handles the exchange and routing of all the calls and data connections within the UMTS with external networks. **The RAN, CN, and the User Equipment (UE) together constitute the whole UMTS.**

UE (User Equipment)

The UE is an equipment which can be vehicle installed or hand portable. Through the Uu interface, the UE exchanges data with network equipment and provides various CS domain and PS domain services, including common voice services, broadband voice services, mobile multimedia services, and Internet applications (such as E-mail, WWW browse, and FTP).

UTRAN (UMTS Terrestrial Radio Access Network)

The UMTS Terrestrial Radio Access Network (UTRAN) comprises Node B and Radio network Controller (RNC).

1) **Node B**

As the base station (wireless transceiver) in the UMTS system, the Node B is composed of the wireless transceiver and baseband processing part. Connected with the RNC through standard Iub interface, Node B processes the Un interface physical layer protocols. It provides the functions of spectrum spreading/despreading, modulation/demodulation, channel coding/decoding, and mutual conversion between baseband signals and radio signaling.

2) **RNC**

The RNC manages various interfaces, establishes and releases connections, performs handoff and macro diversity/combination, and manages and controls radio resources. It connects with the MSC and SGSN through lu interface. The protocol between UE and UTRAN is terminated here.

The RNC that controls Node B is called Controlling RNC (CRNC). The CRNC performs load control and congestion control of the cells it serves, and implements admission control and code word allocation for the wireless connections to be established.

If the connection between a mobile subscriber and the UTRAN uses many RNS resources, the related RNC has two independent logical functions:

Serving RNC (SRNC). The SRNC terminates the transmission of subscriber data and the Iu connection of RANAP signaling to/from the CN. It also terminates the radio resource controlling signaling (that is the signaling protocol between UE and UTRAN). In addition, the SRNC performs L2 processing of the data sent to/from the radio interface and implements some basic operations related to radio resources management.

Drift RNC (DRNC) All the other RNCs except the SRNC are DRNCs. They controls the cells used by the UEs.

Evolution of 3GPP HSPA+ to LTE-A (Release 5 to 10)

The 3GPP UMTS/WCDMA standard started with the Rel.99 in 1999 and run through Rel.4, Rel.5, Rel.6 and Rel.7. Rel.8 upward is actually considered as LTE, as the evolution path of UMTS/WCDMA is towards LTE. The cellular network system which is divided into two parts has the radio network part and the core network part. Comparatively, the Rel.99 and Rel.4 core network did not differ much from each other.

As we move from Rel.4 to Rel.5, there was a tremendous change both in the core network and in the UTRAN where IP multimedia subsystem was introduced in the core network while IP transmission technology and the High Speed Data Packet Access (HSDPA) technology were introduced in the UTRAN. Rel.5 thus brought with it the introduction of smart antenna in the UTRAN. Although not a full fledge multiple input, multiple output (MIMO) antenna system, it has a great impact on the throughput. The MIMO technology which allows the transmission of signals using multiple input and multiple output antennas was actually introduced in Rel.7

Comparing how the various Releases were able to enhance throughput, we see that the difference between Rel.5/Rel.6 and Rel.7 which necessitated the doubling of the throughput in Rel.7 is the introduction of MIMO technology. Below in table 1 and 2 are the expected data rates for different releases of UMTS/WCDMA in both downlink and uplink respectively in relation to the rank of MIMO and multiple carrier frequency used.

Bandwidth	HSPA+ P1 (3GPP R7)		HSPA+ P2 (3GPP R8)		HSPA+ P3 (3GPP R9/R10)	
5MHz	SISO	21.09	SISO	21.09	SISO	21.09
	2x2 MIMO	27.95	2x2 MIMO	42.19	2x2 MIMO	42.19
10MHz	N/A		SISO	42.19	SISO	42.19
			2x2 MIMO	84.38	2x2 MIMO	84.38
			4x4 MIMO	168.76	4x4 MIMO	168.76
20MHz	N/A		N/A		SISO	84.38
					2x2 MIMO	168.76
					4x4 MIMO	337.52

Table 1: Expected downlink peak data rate.[11]

Bandwidth	HSPA+ P1 (3GPP R7)	HSPA+ P2 (3GPP R8)		HSPA+ P3 (3GPP R9/R10)	
5MHz	11.498	SISO	17.247	SISO	17.247
		2x2 MIMO	34.494	2x2 MIMO	34.494
		N/A	N/A	4x4 MIMO	68.988
10MHz	N/A	SISO	34.494	SISO	34.494
		2x2 MIMO	68.988	2x2 MIMO	68.988
		N/A	N/A	4x4 MIMO	137.976
20MHz	N/A	N/A		SISO	68.988
				2x2 MIMO	137.976
				4x4 MIMO	275.952

Table 2: Expected uplink data rate. [11]

Rel.8 came out with further enhancement for HSPA+ such as a dual carrier operation in the downlink and simultaneous operation of MIMO and 64QAM modulation which push the data rate to 42.2Mbps in the downlink while latency was further improved upon. In Rel.9, dual carrier operation was combined with MIMO capabilities to push downlink data rate to 84.4Mbps while the dual cell HSUPA feature supports two carrier frequencies in the uplink leading to 23Mbps data rate. The latest Rel.10 specification uses four carriers HSDPA that enables a single user access to four carrier frequencies of 5MHz each leading to 20MHz bandwidth which is what is available with LTE and WiMAX.[12]

GSM Basic

2G Mobile Communication Technology Evolution

Brief History of Evolution

The outline of GSM history is shown below:

- 1979 - Europe wide frequency band reserved for cellular
- 1982 - Groupe Spécial Mobile (GSM) created
- 1988 - ETSI took over GSM Committee
- 1990 - The phase 1 GSM recommendations frozen
- 1991 - GSM Committee renamed Special Mobile Group and GSM renamed as Global System for Mobile Communication
- 1992 - GSM launched for commercial operations
- 1993 – Major part of GSM phase 2 standard completed
- 1994 – A new research phase (Phase 2+) added to improve GSM for mobile data services

Standards of Second Generation

Different standards of second generation are:

- GSM
- CDMA IS95
- Personal Digital Cellular (PDC)

Advantages of 2G

Compared with 1G mobile communication system, 2G mobile communication system has the following advantages:

- Provides high spectrum utilization and large system capacity.
- Provides diversified services (voice services and low-rate circuit-switched data services).
- Enables automatic roaming.
- Provides better voice quality.

- Provides good security.
- Can be interconnected with Integrated Services Digital Network (ISDN) and Public Switched Telephone Network (PSTN).

GSM Features

GSM system has the following features:

High Spectrum efficiency

GSM system features high spectrum efficiency due to the high-efficient modulator, channel coding, interleaving, balancing, and voice coding technologies adopted.

Large capacity

Volumetric efficiency (number of channels/cell/MHz) of GSM system is three to five times higher than that of Total Access Communication System (TACS).

High voice quality

Digital transmission technologies and GSM specifications, voice quality is irrelevant with radio transmission quality.

Open interfaces epic

GSM standard provides open air interface, also open interfaces between networks and those between network entities, such as A interface and Abis interface.

High security

MS identification code encryption makes eavesdropper unable to determine the MS number, ensuring subscriber's location security. Voice encryption, signaling data, and identification codes make the eavesdropper unable to receive the communication contents.

Interconnection with Integrated Services Digital Network (ISDN) and Public Switched Telephone Network (PSTN).

GSM can interconnect with other networks through current standard interfaces, such as Integrated Service User Part (ISUP) or Telephone User Part (TUP).

Roaming function

GSM supports roaming by introducing Subscriber Identity Module (SIM) card that separates subscriber from the terminal equipment.

Diversified services

GSM provides diversified services, tele-services, bearer services, and supplementary services.

Inter-cell handover

During conversation, MS continues to report the detailed radio environment of local cell and neighboring cells to serving base station. If inter-cell handover is required, MS sends a handover request to serving base station.

GSM Specifications

European Telecommunications Standards Institute (ETSI) initiated and made GSM standard. ETSI developed GSM in several phases and set up more Special Mobile Groups (SMG) to make the related GSM standard.

GSM detailed specifications conform on functions and interfaces only, not on hardware. Purpose is to reduce the restriction on designers, enabling the operators to purchase equipment from different manufacturers.

GSM technical specifications consist of 12 fields:

GSM Network Structure

The GSM architecture consists of three major interconnected subsystems that interact with themselves and with users through certain network interface. The subsystems are Base Station Subsystem (BSS), Network Switching Subsystem (NSS) and Operational Support Subsystem (OSS). Mobile Station (MS) is also a subsystem but it is considered as a part of BSS.

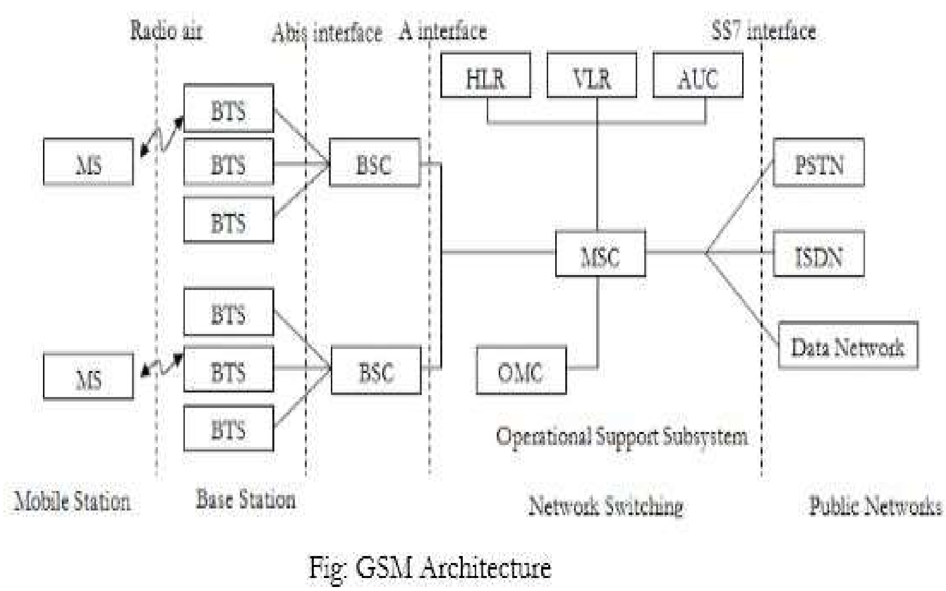


Figure 1: GSM Architecture

Interfaces used for GSM network : (ref fig 2)
1) UM (unified messaging) Interface –Used to communicate between BTS with MS
2) Abis (Automatic biometric identification system database) Interface— Used to communicate BSC TO BTS
3) A Interface-- Used to communicate BSC and MSC
4) Singling protocol (SS 7)- Used by MSC to communicate with other network .

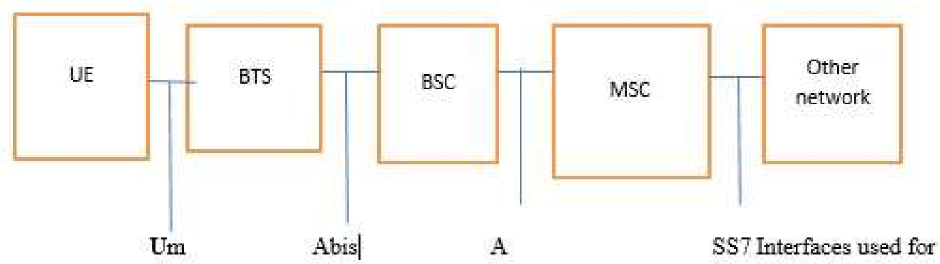


Fig 2 GSM network Interfaces

GSM system consists of:

- Network Subsystem (NSS)
- Base Station Subsystem (BSS)
- Operation and Maintenance Subsystem (OMS)
- Mobile Station (MS)

Network Switching Subsystem

NSS is the core element of network switching which interfaces with subscriber services for voice and data.

NSS Main components are:

- Mobile Switching Centre (MSC)
- Home Location Register (HLR)
- Visitor Location Register (VLR)
- Equipment Identification Register (EIR)
- Authentication Centre (AUC)
- Short Message Centre (SMC)

Home Location Register - HLR is a central database of the system. HLR stores all the information related to subscribers, including the roaming authority, basic services, supplementary services, and current location information. It provides routing information for MSC for call setup. HLR may cover several MSC service areas or even the whole (Public Land Mobile Network) PLMN.

Visitor Location Register - VLR stores all subscriber information in its coverage area and provides call setup conditions for the registered mobile subscribers. As a dynamic database, VLR must exchange large volume of data with HLR to ensure data validity. When an MS leaves the controlling area of a VLR, it registers in another VLR. The original VLR deletes the temporary records of that subscriber. VLR integrated within MSC.

Equipment Identification Register - EIR stores the parameters related to MS. It can identify, monitor, and block the MS. preventing unauthorized MS from accessing the network.

Authentication Centre - AUC is a strictly protected database that stores subscriber authentication information and encryption parameters. AUC integrated with HLR physically.

Base Station Subsystem

BSS serves as a bridge between network subsystem (NSS) and MS. It performs radio channel management and wireless reception and transmission. Base Station Controller (BSC) and Base Transceiver Station (BTS) are main components of BSS.

BSS Main components are:

- Base Station Controller (BSC)
- Base Transceiver Station (BTS)

Base Station Controller - Located between MSC and BTS, it controls and manages more than one BTS. It performs radio channel assignments. BTS and MS transmit power control, and inter-cell handover. BSC is a switch that converge and connects local network with the MSC through A interface. Abis interface connects BTS to BSC.

Base Transceiver Station - BTS is a wireless transceiving equipment controlled by the BSC in BSS. BTS carries radio transmission. It performs wired-related wireless conversion, radio diversity, radio channel encryption, and hopping. Um interface connects BTS to MS.

Operation and Maintenance Subsystem OMS

This is the operation & maintenance part of GSM. Functional units in GSM are connected to OMS internal networks. OMS monitors various functional units in GSM network, submits status report, and performs **fault diagnosis.**

OMS consist of two parts: OMC – System (OMC-S) and OMC-Radio (OMC-R). The OMC-S performs operation and NSS maintenance, while OMC-R performs operation and BSS maintenance.

Mobile Station Subsystem (MSS)

MSS is subscriber equipment in GSM, it can be vehicle installed or hand portable. MSS consists of mobile equipment and SIM.

Mobile equipment processes voice signals, receives and transmits radio signals. SIM stores all information required for identifying a subscriber and security information, preventing unauthorized subscribers. Mobile equipment cannot access GSM network without a SIM card.

Network Service Area

GSM service area refers to the total area covered by networks of all GSM operators. Network consists of several MSC service areas, each of which consists of several cells. Logically, several cells form a location area (LA).

MSC Service Area - A Public Land Mobile Network (PLMN) includes multiple MSC service areas. MSC service area refers to the MSC coverage area, that is, the total area covered by BTS under control of BSC connected to MSC. All MSs in the service area table register in local VLR. Therefore, in actual network, MSC is always integrated with VLR as a node.

Location Area - Each MSC/VLR service area includes multiple of LAs. MS can move freely without performing location update in LA. Hence, LA is the paging area of a broadcast paging message. An LA belongs to one MSC/VLR only, that is, LA cannot cross MSC/VLR. The system can identify different LA via LA Identity (LAI).

Cell - LA contains several cells. Each cell has a unique Cell Global Identification (CGI), which indicates a basic radio coverage area in a network.

Figure 3 shows the relationship among different coverage areas in a GSM network.

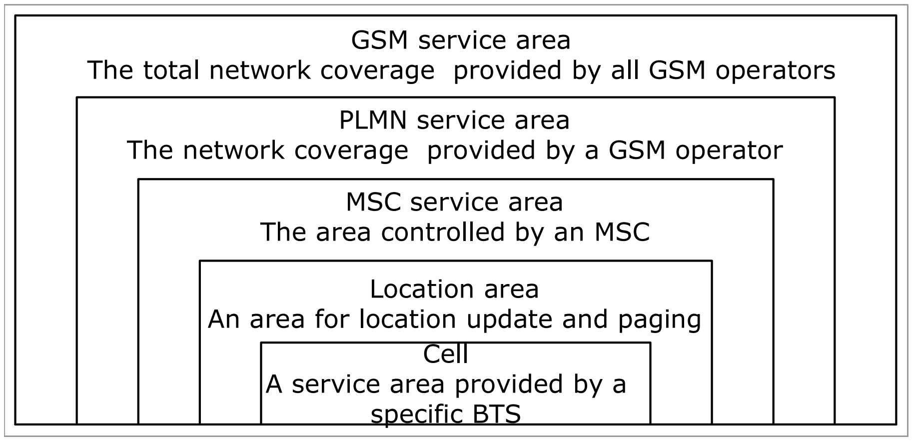


Figure 3: Relationship among Coverage Areas in a GSM Network

GSM Protocol Platform

GSM technical specifications make clear and normative definition of interfaces and protocols between subsystems and various functional entities. Interface refers to the point where two adjacent entities are connected. Protocol defines the rules for information exchange at the connection point.

GSM Interfaces

Figure 4 shows the GSM interfaces.

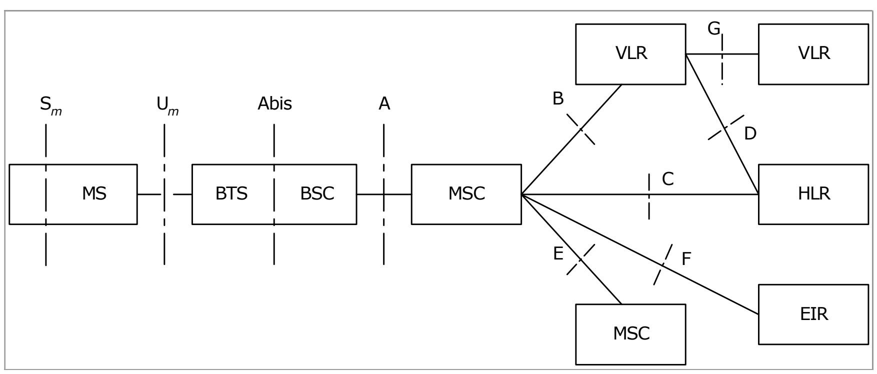


Figure 4: shows the GSM interfaces.

Sm Interface: Man-machine interface implemented in MS. It is an interface between subscribers and PLMN. MS consists of keyboard, LCD, and SIM card.

Um Interface: Radio interface between MS and BTS. It is an important interface in PLMN. Digital mobile communication network has different radio interface as compared to analogue mobile communication network.

A Interface: It is an interface between BSC and MSC. Base station management information, call processing interface, mobility management information, and specific communication information are transferred through A interface.

Abis Interface: It is an interface between BSC and BTS. Supports all services provided to subscribers. Also supports the control of BTS radio equipment and management of radio resources assigned.

B Interface: It is an interface between MSC and VLR. VLR is a database locating and managing MS when MS roams in the related MSC control area. MSC can query the current location of MS from VLR and update MS location. When subscriber uses a special supplementary service or changes a relevant service, MSC notifies the VLR. Sometime VLR also updates information in HLR.

C Interface: It is an interface between MSC and HLR. C interface transfers management and route selection information. When a call finishes, MSC sends the billing information to HLR. When PSTN cannot get location information of a mobile subscriber, the related GMSC queries HLR of the subscriber to obtain the roaming number of the called MS, and then transfers it to the PSTN.

D Interface: It is an interface between HLR and VLR. Exchanges MS location information and subscriber management information. To enable a mobile subscriber to originate or receive calls in the whole service area, data must be exchanged between HLR and VLR. VLR notifies HLR about the current location of MS belonging to HLR, and then provides MS roaming number. HLR sends VLR all the data required to support the services of the MS. When an MS roams to the service area of another VLR, HLR notifies the previous VLR to delete the relevant MS information. When MS uses supplementary services, or some parameters are changed, D interface is also used to exchange the related information.

E Interface: It is an Interface between MSCs. It exchanges the handover information between two MSCs. When MS in a conversation moves from one MSC service area to another MSC service area, inter-cell handover occurs to maintain the conversation. At that time, related MSCs exchange the handover information through E interface.

F Interface: It is an interface between MSC and EIR. It exchanges the MS management information, such as IMEI, between MSC and EIR.

G Interface: It is an interface between VLRs. When MS uses a Temporary Mobile Subscriber Identity (TMSI) to register with a new VLR, the relevant information is exchanged between VLRs through G interface. This interface also searches IMSI of the subscriber from VLR that registers TMSI.

Operation Band

1. Working band

Currently, the GSM communication system works at 900 MHz, extended 900 MHz and 1800 MHz, or 1900 MHz band in some countries.

1 GPRS Technology

1.1 GPRS Definition

GPRS is a packet data service introduced in GSM Phase2+. GPRS provides subscribers the end-to-end mobile data services based on packet switching and transmission technology.

GPRS has following features:

- **Seamless connection with IP network**

  Internet Protocol (IP) technology is adopted in GPRS core network, and many transmission technologies are employed in GPRS bottom layer. Thus, it is easy to implement the seamless connection with the highly developed IP network.

- **High rate**

  With help of multi-slot binding and high-speed coding scheme, GPRS phase I adopts CS1 and CS2 coding schemes, and provides the access rate up to 115 kbps. GPRS phase II adopts CS3 and CS4 coding schemes, and provides rate up to 171 kbps.

- **Always online and flow charging**

  GPRS provides the 'availability for connection and always online performance', offering new means for mobile subscribers to access Internet and Intranet rapidly. Once GPRS terminal is powered on and connected with GPRS network, it can maintain the online status all the way. Subscriber can receive and send information at any time without dial-up process required in circuit switching. As long as GPRS terminal does not transmit data, it will not occupy network and radio resources. Thus, the mobile subscribers can benefit from flow charging. That is, mobile subscribers can stay online as long as possible without bothering the prohibitive bill.

- **Mature technology**

  GPRS provides solutions to implement data services in GSM technologies and current networks. GPRS can save investment and makes quick returns.

1.2 GPRS Specifications

In Europe, it was suggested in 1993 for GPRS to be deployed in GSM network. In 1997, great progress was made in GPRS standardization. GPRS phase 2 was completed at the end of 1999.

1.3 GPRS Network Structure

GSM introduces two new equipment to support GPRS: **Serving GPRS Support Node**

(SGSN) and **Gateway GPRS Support Node (GGSN)**. BSC is added with Packet Control Units (PCUs), and concerned BSS software is upgraded.

SGSN provides similar functions as MSC. It performs GPRS channel assignment, mobility management, encryption, and charging.

GGSN provides various interfaces. It supports interconnection with external Public Data Networks (PDNs) like Internet and X.25 etc.

1.3.1 Border Gateway

The border gateway (BG) is in fact a router. It implements the routing function of SGSNs and GGSNs on different GPRS networks and security management. This function entity is not exclusive to the GPRS.

1.3.2 Main Network Interfaces

Figure 5 5: shows the main interfaces of the GPRS network.

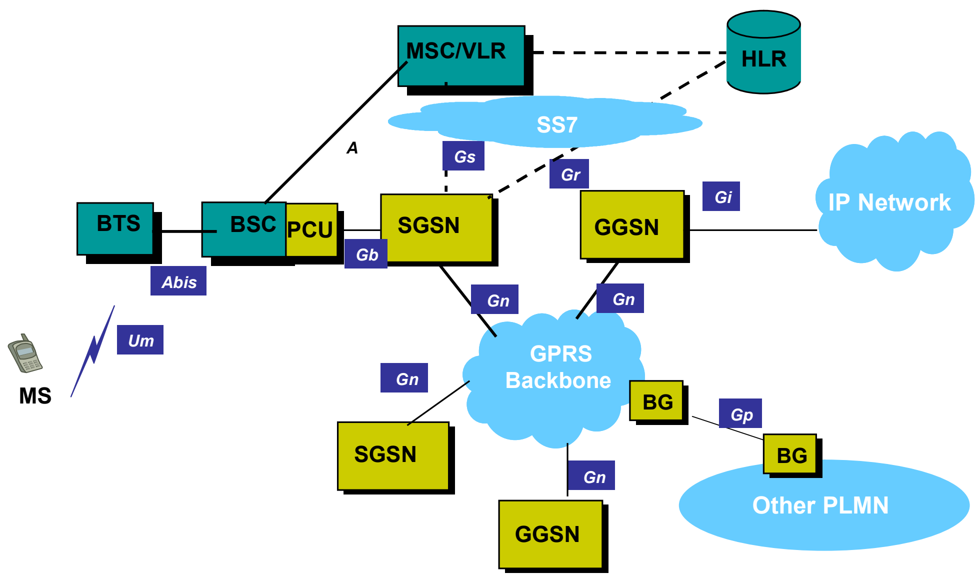


Figure 5: GPRS Network Interfaces

2 EDGE Technology

2.1 Definitions

Enhanced Data for GSM Evolution (EDGE) includes Enhanced General Packet Radio Service (EGPRS) and Enhanced Circuit Switched Data (ECSD). EDGE is a method used to improve the data transmission rate during GSM radio connection.

Essentially, EDGE is only a new modulating and channel encoding technology, which can be used to transmit Packet switching (PS) and Circuit Switching (CS) data/voice. As an evolved GPRS-to-UMTS solution, EDGE enables the network operator to use current radio network equipment to the maximum extent. It also provides PC multimedia communication services ahead of time before the third-generation mobile network become commercialized.

2.2 Features

The system architecture of EDGE network is similar to that of GSM network. The following lists features of the EDGE technology in the access service and network establishment:

1. Access service

- The bandwidth is increased greatly. The peak transmission rate of mobile data service is up to 384 kbps.
- It provides more precise network-layer positioning service.

2. Network establishment

- As a modulating and encoding technology, EDGE changes the transmission rate at the air interface.
- EDGE's air interface features, including the air channel allocation mode and TDMA frame structure, are the same as those of GSM.
- EDGE does not change the architecture of GSM network or GPRS network, and does not have new NEs. It only updates BSS
- The core network adopts the three-layer model: service application layer, communication control layer, and communication connection layer. The interface between layers is standard. The hierarchical architecture makes the call control and communication connection mutually independent. It also fully uses advantages of the packet switching network, making the bandwidth allocation closely related to the traffic. It especially suits the VoIP service.
- Media Gateway (MGW) is adopted in EDGE. MGW has the same functions as Signaling Transfer Point (STP), and can realize the signaling network establishment

in IP network. Moreover, MGW is not only the interface between GSM circuit switching service and PSTN but also the interface between Radio Access Network (RAN) and 3G core network.

- EDGE supports two data transmission modes: packet switching and circuit switching. With the packet data service, a rate of 11.2 kbps ~ 69.2 kbps per timeslot can be realized. EDGE supports the circuit switching service with a rate of 28.8 kbps. EDGE also supports symmetric/asymmetric data transmission, which is very important for the mobile equipment to access network. For example, in EDGE system, the user can have a higher rate in downlink than in uplink.

2.3 Specifications

The EDGE standardization involves the following three aspects:

- Standardizes the relevant change in physical layer (the definition of modulation and coding method)
- Standardizes the change in ECSD protocol
- Standardize the change in EGPRS protocol

Two jobs are done in the above aspects:

- EDGE NSS, which is related to the change in network subsystem
- EDGE BSS, which is related to the change in base station subsystem

EDGE is realized in two phases:

- Phase 1: provides the single/multiple-timeslot packet switching service with a rate of less than 64 kbps and the single/multiple-timeslot circuit switching service.
- Phase 2: provides real-time services not included in phase 1 and adopts the new modulating technology.

The EDGE standardization, which was initiated by ETSI/SMG2, has started from the feasibility research by Ericsson and Nokia since 1997. The research was completed in 1998, and the radio and service requirement for EDGE was drafted in that research.

In 2000, the EDGE standardization was transferred from ETSI to 3GPP. The work of EDGE phase 1 was summarized in the R99 standard, and the work of EDGE phase 2 was included in the 3GPP standard. In EDGE phase 2, the technology is developed into satisfying UMTS standard as well as providing IP multimedia. 3GPP standardizes EDGE, which is now known as GERAN.

2.4 EDGE Modulation Modes

EDGE adopts 8-PSK as its modulation mode. 8-PSK has the same modulation quality as

GMSK, considering the interference generated from adjacent channels. It enables EDGE channels to be completely integrated in the current frequency planning, and can allocate the new EDGE channel as standard GSM channel.

8-PSK is a linear modulation, in which three consecutive bits are mapped to one symbol in the I/Q diagram. Its symbol rate, the number of symbols sent within a certain period of time, is the same as that of GMSK. But each symbol represents three bits in 8PSK, not one bit as in GMSK, thus the total data transmission rate triples.

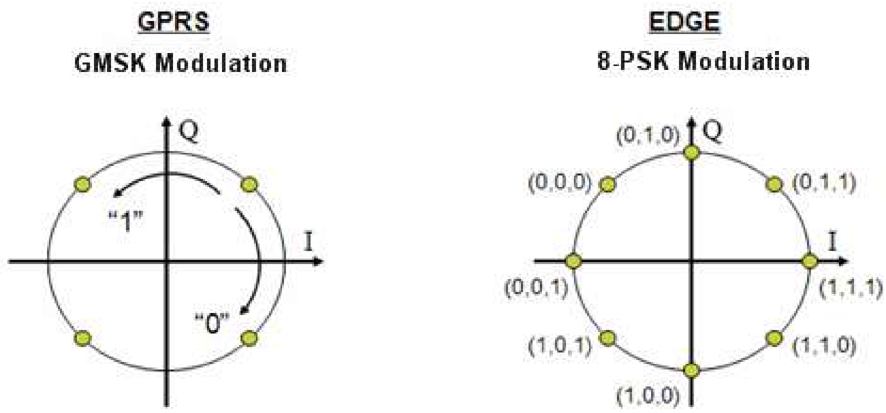


Fig **Error! No text of specified style in document.**-1 8-PSK Modulation Mode

Compared with GMSK, 8-PSK has the same symbol rate, but the bit rate triples, as shown in Table Error**! No text of specified style in document.**-1.

Table **Error! No text of specified style in document.**-1 GMSK vs. 8-PSK

Performance	**8-PSK**	**GMSK**
Symbol rate	270.833 ksym/s	270.833 ksym/s
Number of bits per symbol	3bit/symbol	1bit/symbol
Valid payload per pulse	342bit	114bit
Total rate per timeslot	68.4kbps	22.8kbps
User data rate at RLC layer in each timeslot	59.2 kbps	20 kbps