The Next Generation Mobile Communication Technologies

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Abstract - The goal of this paper is to examine the characteristics of the mobile system and to clarify the constraints that are imposed on existing mobile services. The paper will also investigate successively the enabling technologies and the improvements they brought. A variety of data services is offered. GSM users can send and receive data, at rates up to 9600 bps, to users on POTS (Plain Old Telephone Service).Second generation 2G cellular telecom networks were commercially launched on the GSM standard. Three primary benefits of 2G networks over their predecessors were that phone conversations were digitally encrypted; 2G systems were significantly more efficient on the spectrum allowing for far greater mobile phone penetration levels; and 2G introduced data services for mobile, starting with SMS text messages.3G, short form of third generation, is the third generation of mobile telecommunications technology. This is based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. 3G finds application in wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV. This paper gives the reasons for the evolution of 4G, though 3G has not deployed completely. And then gives the information on the structure of the transceiver for 4G followed by the modulation techniques needed for the 4G. Later this gives the information about the 4G processing .Finally concludes with futuristic views for the quick emergence of this emerging technology. While 3G hasn't quite arrived, designers are already thinking about 4G technologies. With it comes challenging RF and baseband design headaches. Cellular service providers are slowly beginning to deploy third-generation (3G) cellular services. As access technology increases, voice, video, multimedia, and broadband data services are becoming integrated into the same network. The hope once envisioned for 3G as a true broadband service has all but dwindled away. It is apparent that 3G systems, while maintaining the possible 2-Mbps data rate in the standard, will realistically achieve 384-kbps rates. To achieve the goals of true broadband cellular service, the systems have to make the leap to a fourth-generation (4G) network.

Keywords: - AMPS, BTS, TDMA, AGCH, IMT-D

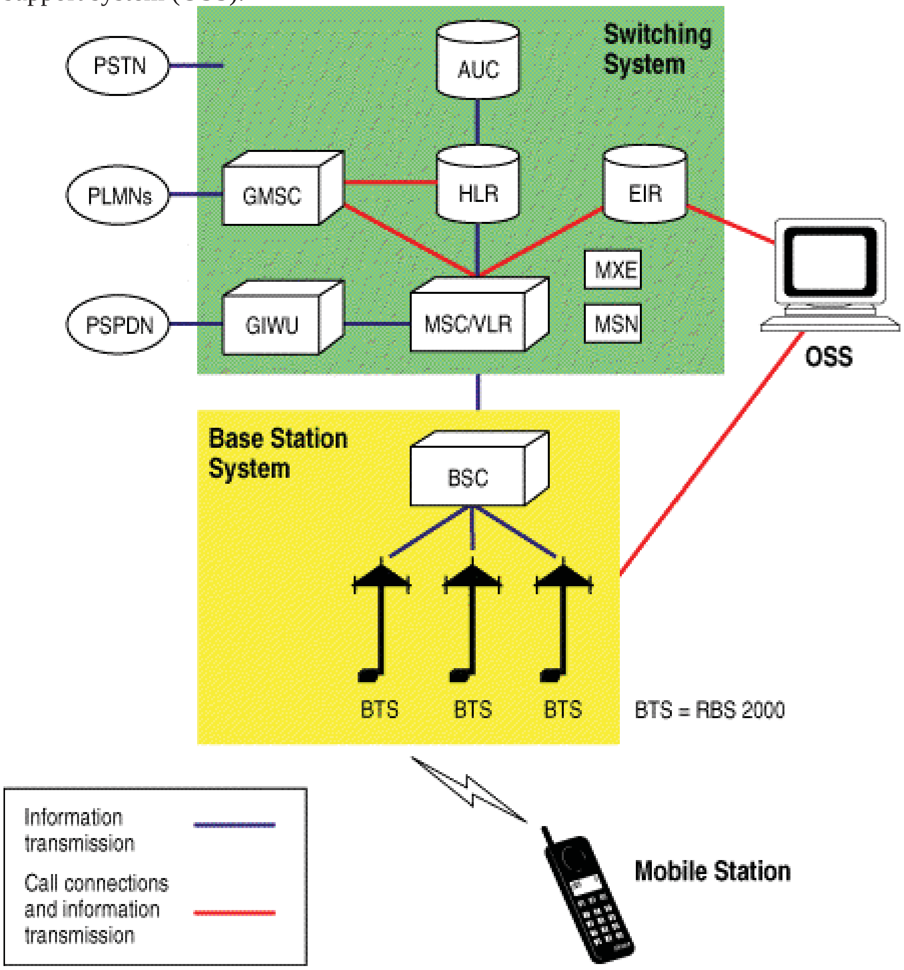
I. INTRODUCTION TO GSM, THE GLOBAL SYSTEM FOR MOBILE COMMUNICATION

1. Introduction: The Evolution of Mobile Telephone Systems

Cellular is one of the fastest growing and most demanding telecommunications applications. Today, it represents a continuously increasing percentage of all new telephone subscriptions around the world. The concept of cellular service is the use of low-power transmitters where frequencies can be reused within a geographic area. The idea of cell-based mobile radio service was formulated in the United States at Bell Labs in the early 1970s. However, the Nordic countries were the first to introduce cellular services for commercial use with the introduction of the Nordic Mobile Telephone (NMT) in 1981.Cellular systems began in the United States with the release of the advanced mobile phone service (AMPS) system in 1983. The AMPS standard was adopted by Asia, Latin America, and Oceanic countries, creating the largest potential market in the world for cellular.

II.THE GSM NETWORK

GSM provides recommendations, not requirements. The GSM specifications define the functions and interface requirements in detail but do not address the hardware. The reason for this is to limit the designers as little as possible but still to make it possible for the operators to buy equipment from different suppliers. The GSM network is divided into three major systems: the switching system (SS), the base station system (BSS), and the operation and support system (OSS).



III. ARCHITECTURE OF THE GSM NETWORK

A GSM network is composed of several functional entities, whose functions and interfaces are specified. Figure 1 shows the layout of a generic GSM network. The GSM network can be divided into three broad parts. The Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile services Switching Center (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. The MSC also handles the mobility management operations. Not shown is the Operations and Maintenance Center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface.

3.1 Mobile Station

The mobile station (MS) consists of the mobile equipment (the terminal) and a smart card called the Subscriber Identity Module (SIM). The SIM provides personal mobility, so that the user can have access to subscribed services irrespective of a specific terminal. By inserting the SIM card into another GSM terminal, the user is able to receive calls at that terminal, make calls from that terminal, and receive other subscribed services.

3.2 Base Station Subsystem

The Base Station Subsystem is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). These communicate across the standardized Abis interface, allowing (as in the rest of the system) operation between components made by different suppliers.

The Base Transceiver Station houses the radio transceivers that define a cell and handles the radio-link protocols with the Mobile Station. In a large urban area, there will potentially be a large number of BTSs deployed, thus the requirements for a BTS are ruggedness, reliability, portability, and minimum cost.

3.3 Network Subsystem

The central component of the Network Subsystem is the Mobile services Switching Center (MSC). It acts like a normal switching node of the PSTN or ISDN, and additionally provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber. These services are provided in conjunction with several functional entities, which together form the Network Subsystem.
The Home Location Register (HLR) and Visitor Location Register (VLR), together with the MSC, provide the call-routing and roaming capabilities of GSM. The HLR contains all the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the mobile. The location of the mobile is typically in the form of the signaling address of the VLR associated with the mobile station. The Visitor Location Register (VLR) contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. Although each functional entity can be implemented as an independent unit, all manufacturers of switching equipment to date implement the VLR together with the MSC, so that the geographical area controlled by the MSC corresponds to that controlled by the VLR, thus simplifying the signaling required. Note that the MSC contains no information about particular mobile stations --- this information is stored in the location registers.

IV. GSM RADIO ASPECTS

In GSM the uplink (mobile-to-base) frequency band is 890-915 MHz and the corresponding downlink (base-to-mobile) band is 935-960 MHz, resulting in a 45 MHZ spacing for duplex operation. The GSM uses time division multiple access (TDMA) and frequency division multiple access (FDMA), whereby the available 25 MHz spectrum is partitions into 124 carriers (carrier spacing = 200 KHz), and each carrier in turn is divided into 8 time slots (radio channels). Each user transmits periodically in every eighth time slot in an uplink radio carrier & receives a corresponding time slot on the downlink carrier. Thus several conversations can takes place simultaneously at the same pair of transmit/receive radio frequencies. The radio parameters for GSM are summarized in the following table:

System Parameter	**Value (GSM)**
Multiple Access	TDMA/FDMA/FDD
Uplink frequency (mobile-to-base)	890-915 MHz
Downlink frequency (base-to-mobile)	935-960 MHz
Channel Bandwidth	200KHz
Number of channels	124
Channels/carrier	8 (full rate), 16 (half rate)
Frame duration	4.6 ms
Interleaving duration	40 ms
Modulation	GMSK
Speech coding method	RPE-LTE convolution
Speech coder bit rate	13 kb/s (full rate)
Associated control channel	Extrea frame
Handoff scheme	Mobile-assisted
Mobile station power levels	0.8, 2, 5, 8 W

Table - Radio parameters and characteristics for GSM

In the GSM system a digitized speech is passed at 64 Kb/s through a speech coder (transcoder), which compresses the
64 Kb/s PCM (pulse code modulated) speech to a 13 Kb/s data rate.

4.1 Multiple access and channel structure

since radio spectrum is a limited resource shared by all users, a method must be devised to divide up the bandwidth among as many users as possible. The method chosen by GSM is a combination of Time- and Frequency-Division Multiple Access (TDMA/FDMA). The FDMA part involves the division by frequency of the (maximum) 25 MHz bandwidth into 124 carrier frequencies spaced 200 kHz apart. One or more carrier frequencies are assigned to each base station. Each of these carrier frequencies is then divided in time, using a TDMA scheme. The fundamental unit of time in this TDMA scheme is called a burst period and it lasts 15/26 ms (or approx. 0.577 ms). Eight burst periods are grouped into a TDMA frame (120/26 ms, or approx. 4.615 ms), which forms the basic unit for the definition of logical channels.

4.1.1. Control channels

Common channels can be accessed both by idle mode and dedicated mode mobiles. The common channels are used by idle mode mobiles to exchange the signaling information required to change to dedicated mode. Mobiles already in dedicated mode monitor the surrounding base stations for handover and other information. The common channels are defined within a 51-frame multiframe, so that dedicated mobiles using the 26-frame multiframe TCH structure can still monitor control channels. The common channels include:

Broadcast Control Channel (BCCH) :- Continually broadcasts, on the downlink, information including base station identity, frequency allocations, and frequency-hopping sequences.

Frequency Correction Channel (FCCH) and Synchronization Channel (SCH):- Used to synchronize the mobile to the time slot structure of a cell by defining the boundaries of burst periods, and the time slot numbering. Every cell in a GSM network broadcasts exactly one FCCH and one SCH, which are by definition on time slot number 0 (within a TDMA frame).

Random Access Channel (RACH):- Mobile uses Slotted Aloha channel to request access network. Paging Channel (PCH):- Used to alert the mobile station of an incoming call.

Access Grant Channel (AGCH):- Used to allocate an SDCCH to a mobile for signaling (in order to obtain a dedicated channel), following a request on the RACH.

4.2. Speech coding

GSM is a digital system, so speech that is inherently analog, has to be digitalized. The method employed by ISDN, and by current telephone systems for multiplexing voice lines over high speed trunks and optical fiber lines, is Pulse Coded Modulation (PCM). The output stream from PCM is 64 kbps, too high a rate to be feasible over a radio link. The 64 kbps signal, although simple to implement, contains much redundancy. The GSM group studied several speech coding algorithms on the basis of subjective speech quality and complexity before arriving at the choice of a Regular Pulse Excited -- Linear Predictive Coder (RPE--LPC) with a Long Term Predictor loop. Basically, information from previous samples, which does not change very quickly, is used to predict the current sample. The coefficients of the linear combination of the previous samples, plus an encoded form of the residual, the difference between the predicted and actual sample, represent the signal. This is the so-called Full-Rate speech coding. Recently, an Enhanced Full-Rate (EFR) speech coding algorithm has been implemented by some North American GSM1900 operators. This is said to provide improved speech quality using the existing 13 kbps bit rate.

4.3. Channel coding and modulation

Because of natural and man-made electromagnetic interference, the encoded speech or data signal transmitted over the radio interface must be protected from errors. GSM uses convolutional encoding and block interleaving to achieve this protection. The exact algorithms used differ for speech and for different data rates. The method used for speech blocks will be described below. Recall that the speech code produces a 260-bit block for every 20 ms speech sample. From subjective testing, it was found that some bits of this block were more important for perceived speech quality than others. The bits are thus divided into three classes: Class IA 50 bits - most sensitive to bit errors, Class IB 132 bits - moderately sensitive to bit errors and Class II 78 bits - least sensitive to bit errors

Class IA bits have a 3 bit Cyclic Redundancy Code added for error detection. If an error is detected, the frame is judged too damaged to be comprehensible and it is discarded. It is replaced by a slightly attenuated version of the previous correctly received frame .Each input bit is encoded as two output bits, based on a combination of the previous 4 input bits. The convolutional encoder thus outputs 378 bits, to which are added the 78 remaining Class II bits, which are unprotected. Thus every 20 ms speech sample is encoded as 456 bits, giving a bit rate of 22.8 kbps. To further protect against the burst errors common to the radio interface, each sample is interleaved.

4.4. Multipath equalization

At the 900 MHz range, radio waves bounce off everything - buildings, hills, cars, airplanes, etc. Thus many reflected signals, each with a different phase, can reach an antenna. Equalization is used to extract the desired signal from the unwanted reflections. It works by finding out how a known transmitted signal is modified by multipath fading, and constructing an inverse filter to extract the rest of the desired signal. This known signal is the 26-bit training sequence transmitted in the middle of every time-slot burst. The actual implementation of the equalizer is not specified in the GSM specifications.

4.5. Frequency hopping

The mobile station already has to be frequency agile, meaning it can move between a transmit, receive, and monitor time slot within one TDMA frame, which normally are on different frequencies. GSM makes use of this inherent frequency agility to implement slow frequency hopping, where the mobile and BTS transmit each TDMA frame on a different carrier frequency. The frequency hopping algorithm is broadcast on the Broadcast Control Channel. Since multipath fading is dependent on carrier frequency, slow frequency hopping helps alleviate the problem. In addition, co-channel interference is in effect randomized.

V. AUTHENTICATION AND SECURITY

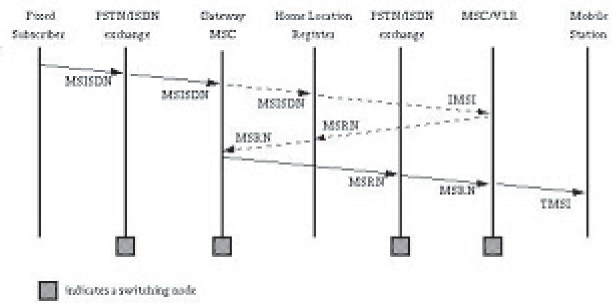
Since the radio medium can be accessed by anyone, authentication of users to prove that they are who they claim to be, is a very important element of a mobile network. Authentication involves two functional entities, the SIM card in the mobile, and the Authentication Center (AuC). Each subscriber is given a secret key, one copy of which is stored in the SIM card and the other in the AuC. During authentication, the AuC generates a random number that it sends to the mobile. Both the mobile and the AuC then use the random number, in conjunction with the subscriber's secret key and a ciphering algorithm called A3, to generate a signed response (SRES) that is sent back to the Au. If the number sent by the mobile is the same as the one calculated by the AuC, the subscriber is authenticated.

5.1Communication management

The Communication Management layer (CM) is responsible for Call Control (CC), supplementary service management, and short message service management. Other functions of the CC sub layer include call establishment, selection of the type of service and call release.

5.1.1. Call routing

A GSM user can roam internationally. The directory number dialed to reach a mobile subscriber is called the Mobile Subscriber ISDN (MSISDN), which is defined by the E.164 numbering plan.



A number in E.164 numbering plan includes a country code and a National Destination Code, which identifies the subscriber's operator. The first few digits of the remaining subscriber number may identify the subscriber's HLR within the home PLMN.

Introduction to 2G Technology and 3G Technology

Second Generation (2G) technology was launched in the year 1991 in Finland. It is based on the technology known as global system for mobile communication or in short we can say GSM. This technology enabled various networks to provide services like text messages, picture messages and MMS. In this technology all text messages are digitally encrypted due to which only the intended receiver receives message. These digital signals consume less battery power, so it helps in saving the battery of mobiles.

The technologies used in 2G are either TDMA (Time Division Multiple Access) which divides signal into different time slots or CDMA (Code Division Multiple Access) which allocates a special code to each user so as to communicate over a multiplex physical channel.3G technology generally refers to the standard of accessibility and speed of mobile devices. It was first used in Japan in the year 2001. The standards of the technology were set by the International Telecommunication Union (ITU). This technology enables use of various services like GPS (Global Positioning System), mobile television and video conferencing. It not only enables them to be used worldwide, but also provides with better bandwidth and increased speed.

This technology is much more flexible as it can support 5 major radio technologies that operate under CDMA, TDMA and FDMA. CDMA accounts for IMT-DS (direct speed), IMT-MC (multi carrier). TDMA holds for IMT-TC (time code), IMT-SC (single carrier). This technology is also comfortable to work with 2G technologies. The main aim of this technology is to allow much better coverage and growth with minimum investment.

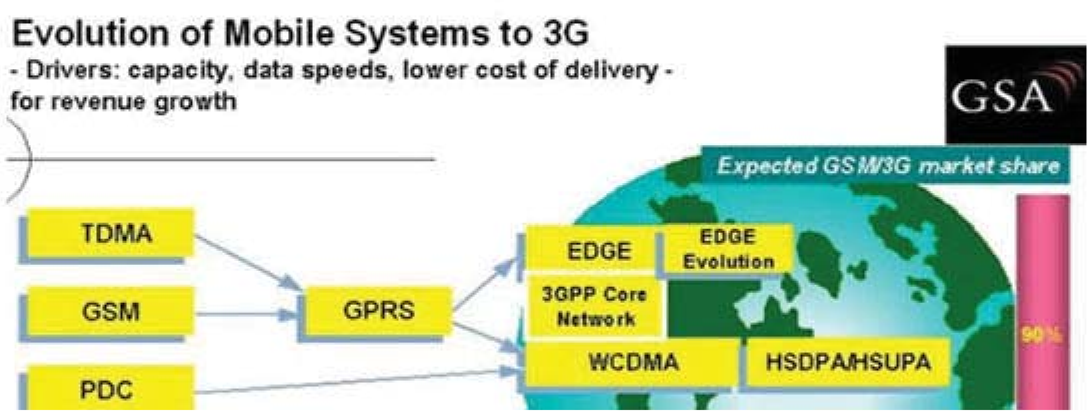


Figure: Evolution of Mobile system from 2G to 3G

Difference between 2G and 3G Technology

- *Cost:* The license fee to be paid for 3G network is much higher as compared to 2G networks. The network construction and maintenance of 3G is much costlier than 2G networks. Also from the customers point of view the expenditure for 3G network will be excessively high if they make use of the various applications of 3G.
- *Data Transmission:* The main **difference between 2G and 3G** networks is seen by the mobile users who download data and browse the Internet on the mobile phones. They find much faster download speeds, faster access to the data and applications in 3G networks as compared to 2G networks. 2G networks are less compatible with the functions of smart phone. The speed of data transmission in 2G network is less than 50,000 bits per sec while in 3G it can be more than 4 million bits per sec.
- *Function:* The main function of 2G technology is the transmission of information via voice signals while that of 3G technologies is data transfer via video conferencing, MMS etc.
- *Features:* The features like mobile TV, video transfers and GPS systems are the additional features of 3G technology that are not available with 2G technologies.
- *Frequencies:* 2G technology uses a broad range of frequencies in both upper and lower bands, under which the transmission depends on conditions such as weather. A drawback of 3G is that it is simply not available in certain regions.
- *Implication:* 3G technology offers a high level of security as compared to 2G technology because 3G networks permit validation measures when communicating with other devices.
- *Making Calls:* Calls can be made easily on both 2G and 3G networks with no real noticeable differences except that in 3G network video calls can also be made. The transmission of text messages and photos is available in both the networks but 2G networks have data limit and the speed of the data transmission is also very slow as compared to 3G.
- *Speed:* The downloading and uploading speeds available in 2G technologies are up to 236 Kbps. While in 3G technology the downloading and uploading speeds are up to 21 Mbps and 5.7 Mbps respectively.

Introduction to 4G

The fourth generation of wireless standards for cellular systems is 4G, the planned successor to the 3G standard. The ITU (International Telecommunications Union) has specified that the peak speed requirements for the 4G standard are to be 100Mbps for a mobile connection (such as in a car) and 1Gbps for stationary connections (such as sitting at a computer). 4G services that meet these requirements are not publically available yet (as of June 2011) but telecommunications providers are looking to upgrade their infrastructure to cater for 4G services in the not too distant future. The 4G service is set to offer a fast and secure all-IP, roaming mobile broadband solution to devices such as laptops with wireless 4G modems, 4G smartphone mobile phones and other 4G mobile devices that require internet access with speed intensive facilities being made available, including on-demand HD television, IP telephony, on-demand gaming and, of course, high speed internet access 4G network is the fourth generation of wireless, mobile communication. The overall goal for the network is to provide a comprehensive and secure network communication solution with much faster data speeds than previous generations. While still in development, the foundations for upgrading from 3G to 4G services started in the early 21st Century as companies began to introduce new technology. New standards such as WiMax and Long Term Evolution (LTE) have been referred to as 4G, though there is some debate regarding their status.

Comparison of 3G and 4G

3G	4G
The predecessor network to 4G with a higher data transfer rates to access audio and internet data.	The successor to 3G network with much higher speed and access to audio and video files without any buffers.
It is termed as Broadband Mobile Technology and uses packet data transmission.	It is termed as 'MAGIC'.
Major 3G technologies are EDGE, CDMA2000, UMTS, etc.	Major 4G technologies are HSPA+, LTE, Wimax2, etc.
3G permits a minimum speed of 2Mpbs for stationary mobile and 384 Kbps for moving	The data transfer rates measured in 'mega' and the range is 20 to 1Gbps.
Switching Technique – Packet Switching	Switching Technique – Packet Switching and Message Switching
The frequency band is only 1.5-2.8 GHZ	The frequency band is 2-8 GHZ

4G Processing

The amount of processing performance needed to deliver these new 4G applications will be large. Integrated, multi-core architectures that deliver microprocessors and DSPs on a single chip will be critical to 4G's success.
Products such as TI's OMAP applications processors enable ore sophisticated and intuitive user's interfaces and provide a web browsing experience similar to traditional PCs.

Integration and Power Management

To be able to deliver the performance needed for 4G technologies, process technologies must continue towards higher integration. The current 45 nanometer (nm) process in use today allows up to two times the density compared to the previous 65nm process. In addition to cost savings, the 45nm process achieves a 25% performance increase over the 65nm process. Continued integration will increase performance while decreasing costs over time. But all this integration comes at a price, namely the need for sophisticated power management technologies. Shrinking the process technology down to 45nm has an exponential effect on leakage power until it becomes a significant part of a device's total power.

The big challenge in brining 4G to the market will be using the right applications processors as well as modem and power management technologies to deliver the performance, size and battery life that consumers demand. The path is clear to bring 4G to reality and deliver compelling application and performance that will pave the way for the future of wireless.

Features of 4G

- Wireless Internet with a bandwidth much wider than the 2G or 3G networks - 100 MHz
  Significantly increased the speed of data transmission - up to Gbps
- Calls video conference - with more than 2 speakers, and because the flow of data faster will be less problems, not so often as to break with the 3G.
- The enhanced security features to prevent fraud and theft.
- Support interactive multimedia, voice, video, wireless internet and other broadband services.
  High speed, high capacity and low cost per bit.
- Global mobility, service portability, scalable mobile networks.
- Seamless switching, variety of services based on Quality of Service (QoS) requirements.
- The features of 4G will be new technologies for gaps in 3G. Personal Area Networks (PANs), body LANs, low power sensors, networked applications and self-configuring ad hoc networks will be encompassed in the 'sphere' of 4G.
- Another role will be to integrate all systems, offering all services, all the time, allowing for the integrated provision of personalized, enhanced services, over efficient/preferred networks, adjusting content delivery depending on terminal profile
- Application adaptability and being highly dynamic will be the main features of 4G services of interest to users. These features mean services can be delivered and be available to the personal preference of different users and support the users' traffic, air interfaces, radio environment, and quality of service
- It also promises the following features:
  Broader bandwidth - higher data rates

Applications of 4G

- Better usage of Multimedia Applications.
- 4G system gives mobile users a “virtual presence”.
- Virtual Navigation
- Tele- Geo Processing
- Traffic Control
- Mobile Phones
- Sensor on Public Vehicle

Advantages of 4G

- 4G is very easy to install and to maintain. All it takes is a cell phone that is 4G capable or a PC card or USB port that you can easily plug into a laptop. No need for modems, cords, cables, and special software.

- 4G internet connections are about 4 times faster than predecessors. For instance you can download an entire movie in just minutes as opposed to several hours. 4G wireless gives you the capacity to download videos, games, and music. You can also stream live videos and shows without any interruptions.

- 4G is the latest in internet technology so expect better signal. In fact, 4G is known to have a more reliable signal than any other service available on the market Wider Coverage.

- 4G technology turns your block or city into a hotspot. Coverage can go as far as 30 miles or more.

- 4G guarantees high security. Its protocol makes use of a security plan that is the most advanced in wireless technology. It’s very strong and reliable network prevents information from being taken or hacking to take place.

Limitations of 4G

- Though the concept of 4G mobile networks is steadily gaining popularity, connectivity is still limited to certain specified carriers and regions.

- Though the hardware compatible with 4G networks is available at much cheaper rates today than earlier, the fact remains that this new equipment would necessarily have to be installed in order to supply these services. This would prove to be a cumbersome process for most mobile carriers planning to launch these services.
- Since 4G mobile technology is still fairly new, it will most likely have its initial glitches and bugs, which could be quite annoying for the user.
- 4G mobile networks use multiple antennae and transmitters and hence, users would experience much poorer battery life on their mobile devices, while on this network. This would mean that they would have to use larger mobile devices with more battery power, in order to be able to stay online for longer periods of time.
- Users would be forced to make do with 3G or Wi-Fi connectivity in the areas that do not yet have 4G mobile network coverage. This loophole has already resulted in many disgruntled customers.

VI. CONCLUSION

GSM is the first system to make extensive use of the Intelligent Networking concept, in in which services like 800 numbers are concentrated and handled from a few centralized service centers, instead of being distributed over every switch in the country. Another point where GSM has shown its commitment to openness, standards and interoperability is the compatibility with the Integrated Services Digital Network (ISDN) that is evolving in most industrialized countries and Europe in particular (the so-called Euro-ISDN**.** The last decade stood witness to an astounding growth in the network communication industry. The ever-increasing demands of users triggered research and led to development of various generations of technologies, which recently led to a comprehensive manifestation of upcoming 5G system. 5G promises to bring higher data transfer speeds (reaching up to few GB/sec) and various other high quality services. It was a monumental task that the original GSM committee undertook, and one that has proven a success, showing that international cooperation on such projects between academia, industry, and government can succeed. Telecommunications are evolving towards personal communication networks, whose objective can be stated as the availability of all communication services anytime, anywhere, to anyone, by a single identity number and a pocket able communication terminal. Having a multitude of incompatible systems throughout the world moves us farther away from this ideal. The economies of scale created by a unified system are enough to justify its implementation, not to mention the convenience to people of carrying just one communication terminal anywhere they go, regardless of national boundaries.

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