A COMPARATIVE STUDY OF 1G, 2G, 3G AND 4G

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ABSTRACT

Mobile communication is continuously one of the hottest areas that are developing at a booming speed, with advanced techniques emerging in all the fields of mobile and wireless communications. This paper deals with the comparative study of wireless cellular technologies namely First Generation, Second Generation, Third Generation, and Fourth Generation. A cellular network or mobile network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. In a cellular network, each cell uses a different set of frequencies from neighbouring cells, to avoid interference and provide guaranteed bandwidth within each cell. The First Generation were referred to as cellular, which was later shortened to "cell", Cell phone signals were based on analog system transmissions, and First Generation devices were comparatively less heavy and expensive. Second Generation phones deploy GSM technology. Global System for Mobile communications or GSM uses digital modulation to improve voice quality but the network offers limited data service. The Third Generation revolution allowed mobile telephone customers to use audio, graphics and video applications. Fourth Generation is short for fourth-generation cell phones or/and hand held devices.

Keywords— Cellular network, First Generation, Second Generation, Third Generation, and Fourth Generation

INTRODUCTION

The past few years have witnessed a phenomenal growth in the wireless industry, both in terms of mobile technology and subscribers. The first-generation mobile systems were the analogue (or semi-analogue) systems, which came in the early 1980s - they were also called NMT (Nordic Mobile Telephone). They offered mainly speech and related services and were highly incompatible with each other. 1G refers to

analog cellular technologies; it became available in the 1980s. 2G denotes initial digital systems, introducing services such as short messaging and lower speed data. CDMA2000 1xRTT and GSM are the primary 2G technologies, although CDMA2000 1xRTT is sometimes called a 3G technology because it meets the 144 kbps mobile throughput requirement. EDGE, however, also meets this requirement. 2G technologies became available in the 1990s. 3G requirements were specified by the ITU as part of the International Mobile Telephone 2000 (IMT-2000) project, for which digital networks had to provide 144 kbps of throughput at mobile speeds, 384 kbps at pedestrian speeds, and 2 Mbps in indoor environments [5]. UMTS-HSPA and CDMA2000 EV-DO are the primary 3G technologies, although recently WiMAX was also designated as an official 3G technology [5]. The present time is just right to start the research of 4G mobile communications because of:

- Possibility, according to the historical indication of a generation revolution once a decade, and now we are near the end of 3G standardization phase and the beginning of 3G deployment.
- Necessity: according to 3G goals, 3G is necessary but not sufficient to the mobile communication strategy, in which many problems are only partly solved and there are still many problems left to be solved in the next generation, i.e. 4G [1-3].

This paper is organized as follows. Section II provides a brief review of the development history and status of mobile communications. From first generation of cellular networks how mobile industry has grown till fourth generation. Description of First, Second, Third and Fourth generation. Section III portrays a comparison between all the four generation. Section IV gives the conclusion of the paper and also about the future prospects of the paper.

EVOLUTION OF MOBILE CELLULAR NETWORKS

A cellular network or mobile network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. In a cellular network, each cell uses a different set of frequencies from neighbouring cells, to avoid interference and provide guaranteed bandwidth within each cell. When joined together these cells provide radio coverage over a **w**ide geograp**h**ic area. **T**his enables a large number of portable **t**ransceivers (**e**.g., mobile phones, pag**e**rs, etc.) to communicat**e** with each other and **w**ith fi**x**ed transceivers and teleph**o**nes anywhere in the n**e**twork, via **b**ase stations, even if so**m**e of the tr**a**nsceivers ar**e** moving thr**o**ugh more than one cell d**u**ring transmi**s**sion.

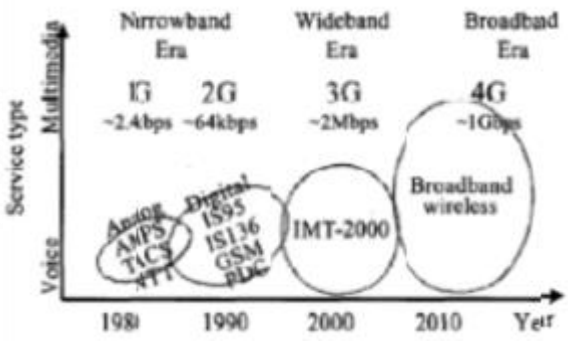

FIGURE I: EVOLUTION OF MOBLIE CELLULAR NETWORKS[7]

FIRST GENERATION

The first generation of wireless mobile communications was based on analog signalling. Analog systems, implemented in North America, were known as Analog Mobile Phone Systems (AMPS), while systems implemented in Europe and the rest of the world was typically identified as a variation of Total Access Communication Systems (TACS). Analog systems were primarily based on circuit-switched technology and designed for voice, not data. Roaming was not possible and the efficient use of frequency spectrum was not possible. 1G refers to the first-generation of wireless telephone technology, mobile telecommunications. These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications.

The main difference between two succeeding mobile telephone systems, 1G and 2G, is that the radio signals that 1G networks use are analog, while 2G networks are digital. 1G- technology replaced 0G technology, which featured mobile radio telephones and such technologies as Mobile Telephone System (MTS), Advanced Mobile Telephone System (AMTS), Improved Mobile Telephone Service (IMTS), and Push to Talk (PTT). . Through 1G, a voice call gets modulated to a higher frequency of about 150MHz and up as it is transmitted between radio towers. This is done using a technique called Frequency-Division Multiple Access (FDMA). But its fail in some field such as in terms of overall connection quality, 1G compares unfavourably to its successors. It has low capacity, unreliable handoff, poor voice links, and no security at all since voice calls were played back in radio towers, making these calls susceptible to unwanted eaves dropping by third parties.

With the introduction of 1G phones, the mobile market showed annual growth rate of 30 to 50 per cent, rising to nearly 20 million subscribers by 1990.

FIGURE II: NOKIA 650 1G MOBILE PHONE

2.2 Second Generation

The second generation, 2G system, fielded in the late 1980s and finished in the late 1990s, was planned mainly for voice transmission with digital signal and the speeds up to 64kbps. 2G wireless cellular mobile services was a step ahead of 1G services by providing the facility of short message service(SMS) unlike 1G that had its prime focus on verbal communication. The bandwidth of 2G is 30-200 KHz. During the second generation, the mobile telecommunications industry experienced exponential growth in terms of both subscribers and value-added services. In the early 1990s, 2G phones deploying GSM technology were introduced. Global System for Mobile communications or GSM uses digital modulation to improve voice quality but the network offers limited data service. As demand drove uptake of cell phones, 2G carriers continued to improve transmission quality and coverage. The 2G carriers also began to offer additional services, such as paging, faxes, text messages and voicemail. The limited data services under 2G included WAP, HSCSD and MLS.An intermediary phase, 2.5G was introduced in the late 1990s. It uses the GPRS standard, which delivers packet-switched data capabilities to existing GSM networks. It allows users to send graphics-rich data as packets. The importance for packet-switching increased with the rise of the Internet and the Internet Protocol, or IP. In the mid-1980s the European commission started a series of activities to liberalise the communications sector, including mobile communications. This resulted in the creation of ETSI, which inherited all the standardisation activities in Europe. This saw the birth of the first specifications, and the network based on digital technology; it was called the Global System for Mobile Communication or GSM. Since the first networks appeared at the beginning of 1991, GSM has gradually evolved to meet the requirements of data traffic and many more services than the original networks.

GSM (Global System for Mobile Communication):

The main elements of this system are the BSS (Base Station Subsystem), in which there are the BTS (Base Tran receiver Station) and BSC (Base Station Controllers); and the NSS (Network Switching Subsystem), in which there is the MSC (Mobile Switching Centre); VLR (Visitor Location Register); HLR (Home Location Register); AC (Authentication Centre), and EIR (Equipment Identity Register) This network is capable of providing all the basic services such as speech and data services up to 9.6 kbps, fax, etc. This GSM network also has an extension to the fixed telephony networks.

GSM and VAS *(Value Added Services):*

The next advancement in the GSM system was the addition of two platforms, called Voice Mail System (VMS) and the Short Message Service Centre (SMSC). The SMSC proved to be incredibly commercially successful, so much so that in some networks the SMS traffic constitutes a major part of the total traffic. Along with the VAS, IN (Intelligent services) also made its mark in the GSM system, with its advantage of giving the operators the chance to create a whole range of new services. Fraud management and 're-paid' services are the result of the IN service.

GSM and GPRS *(General Packet Radio Services):*

As the requirement for sending data on the air-interface increased, new elements such as SGSN (Serving GPRS) and GGSN (Gateway GPRS) were added to the existing GSM system. These elements made it possible to send packet data on the air-interface. This part of the network handling the packet data is also called the 'packet core network'. In addition to the SGSN and GGSN, it also contains the IP routers, firewall servers and DNS (domain name servers). This enables wireless access to the Internet and the bit rate reaching to 150 kbps in optimum conditions.

GSM and EDGE (*Enhanced Data rates for global evolution*):

With both voice and data traffic moving on the system, the need was felt to increase the data rate. This was done by using more sophisticated coding methods over the Internet and thus increasing the data rate up to 384 kbps. EDGE/EGPRS is implemented as a bolt-on enhancement for 2.5G GSM/GPRS networks, making it easier for existing GSM carriers to upgrade to it. EDGE is a superset to GPRS and can function on any network with GPRS deployed on it, provided the carrier implements the necessary upgrade. EDGE can carry a bandwidth up to 236 kbit/s (with end-

to-end latency of less than 150 ms) for 4 timeslot in packet mode. This means it can handle four times as much traffic as standard GPRS.

FIGURE III: 2G TECHNOLOGY

*GSM technology is a combination of **Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA).** The first GSM systems used a 25MHz frequency spectrum in the 900MHz band. FDMA is used to divide the available 25MHz of bandwidth into 124 carrier frequencies of 200 kHz each. Each frequency is then divided using a TDMA scheme into eight timeslots. The use of separate timeslots for transmission and reception simplifies the electronics in the mobile units. Today, GSM systems operate in the 900MHz and 1.8 GHz bands throughout the world with the exception of the Americas where they operate in the 1.9 GHz band*

2.3 Generation or 2G+ Wireless Network

The virtual explosion of Internet usage has had a tremendous Impact on the demand for advanced wireless data communication services. The mobile technology using general packet radio service (GPRS) standard has been termed as 2.5G. 2.5G systems enhance the data capacity of GSM and mitigate some of its limitations the effective data rate of 2G circuit-switched wireless systems is relatively slow -- too slow for today's Internet. As a result, GSM, PDC and other TDMA-based mobile system providers

and carriers have developed 2G+ technology that is packet-based and increases the data communication speeds to as high as 384kbps. These 2G+ systems are based on the following technologies: **High Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE) technologies.**

HSCSD is one step towards 3G wideband mobile data networks. This circuit-switched technology improves the data rates up to 57.6kbps by introducing 14.4 kbps data coding and by aggregating 4 radio channels timeslots of 14.4 kbps.**GPRS** adds packet-switched capabilities to existing GSM and TDMA networks. Working on the basis of emails, it sends text and graphics-rich data as packets at very fast speed. **EDGE** technology is a standard that has been specified to enhance the throughput per timeslot for both HSCSD and GPRS. Although **GPRS** is an extension to the radio access network, it requires whole new packet based IP data links, servers, and gateways in the core network. Thus GPRS adds several new components besides changing the existing GSM or TDMA network

FIGURE IV: SIEMENS S57 2.5G PRS PHONE

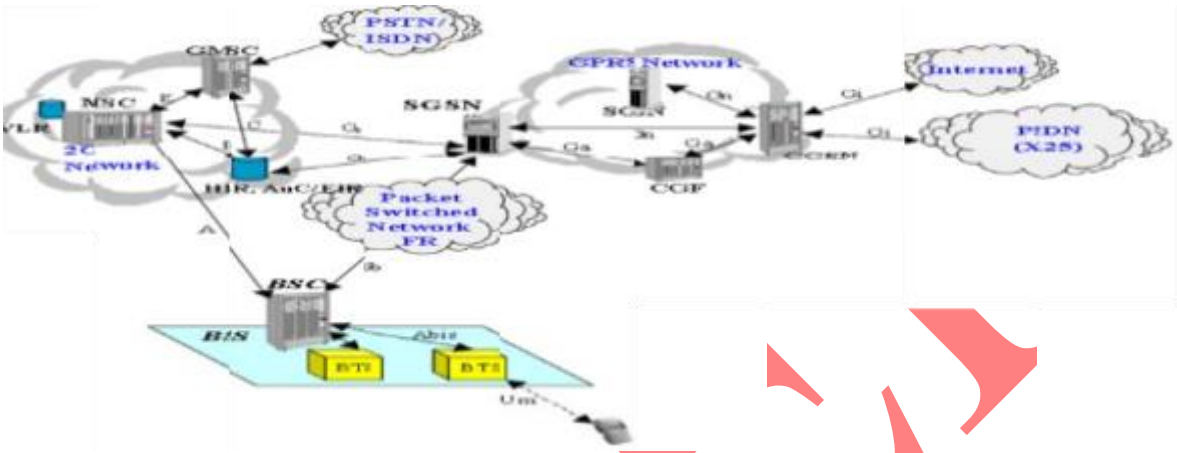

FIGURE V: **G**PRS NET**W**ORK [9]

Mobile Station: The **M**S includes **r**adio equipm**e**nt and the Man Mach**i**ne Interface (MMI) tha**t** a subscrib**e** needs in **o**rder to acc**e**ss the servi**c**es provide**d** by the GSM**.** The **MS** is a combination of terminal equipmen (called **ME (M**o**b**ile **E**quipm**e**nt)) and su**b**scriber data (stored in a s**e**parate module called **SIM** (**S**ubscriber **I**dentity **M**odule)).

Base Transceiver System (BTS): The physical a**n**d radio trans**m**ission interface between **s**ubscriber station and the BSC are pro**v**ided by the BTS. The r**a**dio equipme**n**t's that are **r**equired to se**r**vice each cell in the network are components of the BTS. Cells are the logical divisions in the Radio transmission coverage. BTS controls each cell in a network, and in turn, one BSC controls a group of BTSs. It takes care of Air interface signalling, Air interface ciphering and speech processing.

Base Station Controller (BSC): The management of several Base Transceiver Stations (BTS) is done by the BSC. It also provides all the control functions and physical links among the different BTS and between the switching center (SC) and the BTS's. Being a high-capacity switch, it provides functions such as cell configuration data, and control of radio frequency power levels in BTS. One SC serves a number of BSCs

Base Station Subsystem (BSS): BSS is the point where all radio transmission related functions are performed. The BSS is composed of the BSC and the BTS.

Home Location Register (HLR): All the administrative information related to each subscriber registered in the respective communication network, including the current location of the subscriber, is contained in the HLR **Visitor Location Register (VLR):** The VLR is a database containing all the temporary information about the subscribers. This information is needed by the MSC to service the visiting subscribers. **Equipment Identity Register (EIR):** The EIR is a database containing a list of all the valid mobile subscriber stations on the network.

2.3 Third Generation

The third generation mobile technology based on wide band wireless network fulfilling the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. As per the IMT-2000 standards, a system is required to provide peak data rates of at least 200 Kbit/s. 3G functions in the range of 2100 Hz and bandwidth 15-20 MHz The communication provides enhanced clarity and perfection like the real conversation. Recent 3G releases provide mobile broadband access of several M bit/s to smart phones and mobile modems in laptop computers. The first release of (Third Generation Partnership Project) 3GPP Long Term Evolution (LTE) standard completely fulfil the (International Telecommunications Union) ITU 4G requirements called the IMT-Advanced. 4G or 3.9G technology is the first release LTE. Its evolution LTE Advanced is a 4G technology.

3G offers a vertically- integrated, top-down, service-provider approach to delivering wireless Internet access. 3G is a technology for mobile service providers. Mobile services are provided by service providers that own and operate their own wireless networks and sell mobile services to end-users, usually on a monthly subscription basis. Mobile service providers use licensed spectrum to provide wireless telephone coverage over some relatively large contiguous geographic serving area. Historically, this might have included a metropolitan area. Today it may include the entire country. From a user's perspective, the key feature of mobile service is that it offers (near) ubiquitous and continuous coverage that is, a consumer can carry on a telephone conversation while driving along a highway at 100Km/hour. To support this service, mobile operators maintain a network of interconnected and overlapping mobile base stations that hand-off customers as those customers move among adjacent cells. Each mobile base station may support users up to several kilometres away. The cell towers are connected to each other by a backhaul network that also provides interconnection to the wire line Public Switched Telecommunications Network (PSTN) and other services. The mobile system operator owns the end-to-end network from the base stations to the backhaul network

to the point of interconnection to the PSTN (and, perhaps, parts thereof). These can support data rates of from 384Kbps up to 2Mbps, although most commercial deployments are expected to offer data rates closer to 100Kbps in practice. While this is substantially below the rates supported by the current generation of wire line broadband access services such as DSL or cable modems, it is expected that future upgrades to the3G or the transition to 4G mobile services will offer substantially higher bandwidths. Although wire line systems are likely to always exceed the capacity of wireless ones, it remains unclear precisely how much bandwidth will be demanded by the typical consumer and whether 3G services will offer enough to meet the needs of most consumers. Auctions for 3G spectrum licenses occurred in a number of countries in 2000 and the first commercial offerings of 3G services began in Japan in October 2001. More recently, Verizon Wireless has announced "3G" service in portions of its serving territory (though this is not true-3G service). 3G offers much narrower bandwidth but over a wider calling area and with more support for rapid movement between base stations.

The IMT-2000 framework sets the following goals for the so called 3G wireless systems:

- Global standards to allow for low cost and worldwide roaming.
- High Quality of Service (QoS) especially for voice.
- Support for advanced services: Multimedia, Bandwidth on Demand, High speed data.
- Flexibility for evolution allowing for backward compatibility and to cope with any future market discontinuity.
- Multi-environment capabilities.
- Compatibility of services with fixed networks.
- In building/Private Systems Integration.

FIGURE VII: 3G TECHNOLOGY

The following is a brief description of each protocol layer in a 3G wireless network infrastructure:

- **Global Mobility Management (GMM)**: protocol that includes attach, detach, security, and routing area update functionality.
- **Node B Application Part (NBAP)**: provides procedures for paging distribution, broadcast system information and management of dedicated and logical resources
- **Radio Link Control (RLC)**: provides a logical link control over the radio interface.
- **Medium Access Control (MAC)**: controls the access signaling (request and grant) procedures for the radio channel.
- **Radio resource Control (RRC)**: manages the allocation and maintenance of radio communication paths.
- **Radio Access Network Application Protocol (RANAP)**: encapsulates higher layer signaling. Manages the signaling and GTP connections between RNC and 3G-SGSN, and signaling and circuit-switched connections between RNC and 3G MSC.
- **Radio Network Service Application Part (RNSAP)**: provides the communication between RNCs.
- **GPRS Tunnel Protocol (GTP)**: protocol that tunnels the protocol data units through the IP backbone by adding routing information. GTP operates on top of TCP/UDP over IP.
- **Mobile Application Part (MAP)**: supports signaling between SGSN/GGSN and HLR/AuC/EIR.
- **AAL2** Signaling (Q.2630.1, Q.2150.1, Q.2150.2, AAL2 SSSAR, and AAL2 CPS): protocols suite used to transfer voice over ATM backbone using ATM adaptation layer 2.
- **Sigtran** (SCTP, M3UA): protocols suite used to transfer SCN signaling protocols over IP network

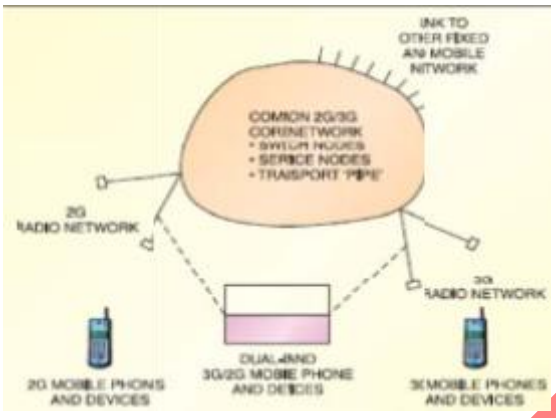

FIGURE VIII: 3G NETWORKS [8]

2.4 Fourth Generation:

4G (or 4-G) is short for fourth-generation cell phones or/and hand held devices. It is a wireless access technology. It will be the successor of 3G. Currently we are undergoing a transition between 2G and 3G which is also known as 2.5G. 4G mobile communications will have transmission rates up to

20 Mbps higher than of 3G. When It is still to estimate as to how many number of people have moved on from 2G to 3G , technology has come up with the latest of its type namely 4G.A successor of 2G and 3G, 4G promises a downloading speed of 100Mbps. Then with the case of Fourth Generation that is 4G in addition to that of the services of 3G some additional features such as Multi-Media Newspapers, also to watch T.V programs with the clarity as to that of an ordinary T.V. In addition, we can send Data much faster than that of the previous generations.

Currently 2.5G provides WAP and also access to the internet from a mobile phone, but the data rate is a big resistance to the development of better features. We will definitely see very high data rates in 4G phones. 802.15, commonly known as Bluetooth is very popular these days. Currently the connectivity between wired and wireless devices is bit painful as the vendors are reluctant in providing a bridge between both the technologies. But I think in

4G we would definitely see a change in this attitude as it will be very easy to transfer huge files or other data from a PC to wireless devices. Email messages, contacts, remainders, etc will synchronize in no time and thus giving more power to the users. It is easy to say, based on the developing trends of mobile communication, that 4G will have broader bandwidth, higher data rate, smoother and quicker handoff, wider mobile area, more various service, lower cost, etc.

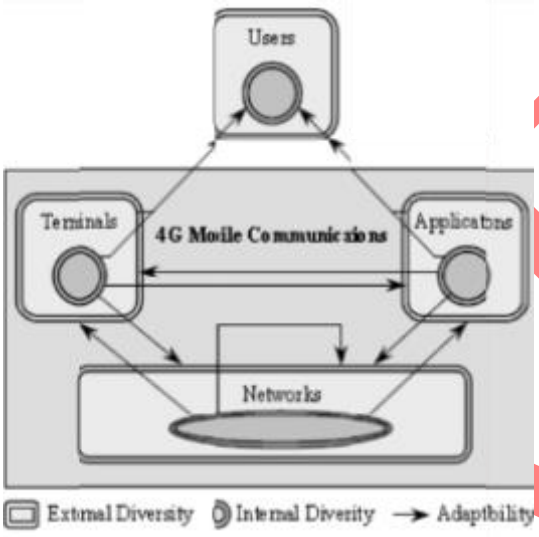

FIGURE IX: 4G FRAMEWORK NETWORK

[3] ***User Diversity:*** The external diversity of users, i.e. people in different situations, includes e.g. culture, educational background, economic capability, physical property, personal preference, etc. The internal diversity of users, i.e. people with different interfaces, include e.g. vision, hearing, speech, touch sense, hands and fingers, body, etc.

Terminal Diversity and Adaptability: The terminals' external diversities are the differences of terminals in both static and mobile attributes. Static attributes include e.g. functionality, weight, size, battery life, human interface, antenna, processing capability, security, style, and cost. Mobile attributes include dynamic attributes of both temporal and spatial features.

Network Diversity and Adaptability: The external diversity of

networks is obvious. Internet is assorted by nature, while wireless networks keep the same property. For instance air interfaces can integrate all kinds of standards and work on different frequencies. Moreover, multiple operators deploy networks with multiple standards and protocols. The internal diversity of networks means that one network can interconnect with other different networks and transfer various kinds of loads, e.g. cellular systems with various coverage.

3. COMPARISON BETWEEN 1G, 2G, 3G AND 4G

Here Table I. summarises the comparison between 1G, 2G, 3G and 4G.

TABLE I: COMPARISON OF 1G, 2G, 3G AND 4G[3]

PROPERTY	FIRST GENERATION	SICOND GENERATION	SECOND+ (2.5)GENERATION	THIRD GENERATION	FOURTH GENERATION
Stared	1970-1984	1980-1991	1985-1999	1990-2002	2000-2006
Technolcgy Used	Analog signalling used	Digital signalling	Digital signalling	Broad Band Width	Unified IP and seamless combination of broadband
Standard	AMPS, TACS, NMT	GSM, TDMA,CDMA	GPRS, I-MODE, HSCSD, EDGE	WCDMA ,CDMA-2000	Single unified standard
Bandwidth (bps)	1.9kbps	14.4kbps	14.4kbps	2nbps	200mbps
Multi-address Technique	FDMA	TDMA,CDMA	TDMA,CDMA	CDMA	CDMA
Core network	PSTN	PSTN	PSTN and packet network	Packet network	Internet
Switching	Circuit	Circuit	Circuit for access network and air interface, packet for core and network data	Packet except ciscuit for air interface	All packet
Service type	Voice Mono-service Person-to-person	Voice, sms Mbno-media Person-to person	Higher capacity, packetized data	Integrated high quality audio, video and data	Dynamic information access, wearable devices

CONCLUSION

The last few years have witnessed the phenomenal growth of wireless generations. There is ever increasing demands of the cellular networks which motivated the researchers and industrialists to come up with fourth generation (4G) mobile

communication and further more with 5G technology.. As the history of mobile communications shows, many attempts have been made to reduce a number of Technologies to a single global standard. The first generation (1G) has fulfilled the basic mobile voice using analog techniques, while the second generation (2G) has introduced capacity and coverage using digital techniques. This is followed by the third generation (3G), which has quest for data at higher speeds to open the gates for truly "mobile broadband" experience, which will be further realized by the fourth generation (4G). 4G will provide better-than-TV quality images and video-links. The communications model has new developed versions of HTML, Java, GIF, HTTP, and many more. New standards will need to be developed for use in 4G.

5G technology has changed the means to use cell phones within very high bandwidth. User never experienced ever before such a high value technology. Nowadays mobile users have much awareness of the cell phone (mobile) technology. The 5G technologies include all type of advanced features which makes 5G technology most powerful and in huge demand in near future.5G Although updated standards that define capabilities beyond those defined in the current 4G standards are under consideration, those new capabilities are still being grouped under the current 4G standards. New mobile generations are typically assigned new frequency bands and wider spectral bandwidth per frequency channel (1G up to 30 kHz, 2G up to 200 kHz, 3G up to 5 MHz, and 4G up to 40 MHz), but the main issue that there is little room for new frequency bands or larger channel bandwidths.

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