

EVOLVEMENT OF MOBILE GENERATIONS : 1G To 5G

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Abstract: Evolution is inevitable, be it in the Nature or in the Man Made stuff. GSM (Global System for Mobile Communications, originally Groupe Special Mobile), is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular networks used by mobile phones. It is the most widely used 2nd generation digital cellular standard, with over 3 billion subscribers in some 213 countries and adding about 1000 new users per minute! Originally GSM was developed in the early 1980s, and first deployed in 1991; GSM is a TDMA+FDMA system, providing wide area voice communications using 200 KHz carriers. Subsequently, GSM evolved into a 2.5G standard with the introduction of packet data transmission technology (GPRS) and higher data rates via higher order modulation schemes (EDGE). More recently, GERAN standards organization has been evolving further to coexist with and provide comparable services to 3G technologies. In this paper, we provide an over view of evolution of Mobile Generations and also the framework of 4G technology that will provide access to wide range of telecommunication services, including advanced in mobile services, supported by mobile and fixed networks, which are increasingly packet based, along with a support for low to high mobility applications and wide range of data rates, in accordance with service demands in multiuser environment.

Keywords: 1G, 2G, 3G, 4G, 5G, Mobile Broadband.

I. INTRODUCTION

The last few years have witnessed a phenomenal growth in the wireless industry, both in terms of mobile technology and its subscribers. There has been a clear shift from fixed to mobile cellular telephony, especially since the birth of the century. By the end of 2010, there were over four times more mobile cellular subscriptions than fixed telephone lines systems. Both the mobile network operators and vendors have felt the importance of efficient networks with equally efficient design. This resulted in Network Planning and optimization related services coming in to sharp focus. [3]

With all the technological advances, and the simultaneous existence of the 2G, 2.5G, 3G and 4G networks, the impact of services on network efficiency have become even more critical. Many more designing scenarios have developed with not only 2G networks but also with the evolution of 2G to 2.5G or even to 3G and 4G networks. Along with this, inter-operability of the networks has to be considered. 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 the same 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. UMTS-HSPA and CDMA2000 EV-DO are the primary 3G technologies, although recently WiMAX was also designated as an official 3G technology. 3G technologies began to be deployed last decade.

The ITU has recently issued requirements for IMT-Advanced, which constitutes the official definition of 4G. Requirements include operation in up-to-40 MHz radio channels and extremely high spectral efficiency. The ITU recommends operation in up to- 100 MHz radio channels and peak spectral efficiency of 15 bps/Hz, resulting in a theoretical throughput rate of 1.5 Gbps. Previous to the publication of the requirements, 1 Gbps was frequently cited as a 4G goal. No available technology meets these requirements yet. It will require new technologies such as LTE-advanced (with work already underway) and IEEE 802.16m. Some have tried to label current versions of WiMAX and LTE as 4G, but this is only accurate to the extent that such designation refers to the general approach or platform that will be enhanced to meet the 4G requirements. With WiMAX and HSPA significantly outperforming 3G requirements, calling these technologies 3G clearly does not give them full credit, as they are a generation beyond current technologies in capability. But calling them 4G is not correct. Unfortunately, the generational labels do not properly capture the scope of available technologies and have resulted in some amount of market confusion.

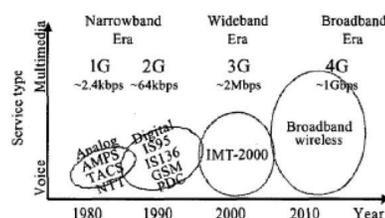


Figure 1: Evolution of the mobile networks

II. EVOLUTION OF MOBILE NETWORKS

Mobile Cellular Network evolution has been categorized in to 'generations' as shown in above figure.

A. 1G or the first generation system (ANALOG)

In 1980 the mobile cellular era had started, and since then mobile communications have undergone significant changes and experienced enormous growth. Figure above shows the evolution of the mobile networks.

1G (or 1-G) 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. First-generation mobile systems used analog transmission for speech services. The first commercially automated cellular network (the 1G generation) was launched in Japan by NTT (Nippon Telegraph and Telephone) in 1979, initially in the metropolitan area of Tokyo. By 1981, the cellular era reached Europe. The two most popular analogue systems were Nordic Mobile Telephones (NMT) and Total Access Communication Systems (TACS). Other than NMT and TACS, some other analog systems were also introduced in 1980s across the Europe.

All of these systems offered handover and roaming capabilities but the cellular networks were unable to interoperate between countries. This was one of the inevitable disadvantages of first-generation mobile networks. In the United States, the Advanced Mobile Phone System (AMPS) was launched in 1982. The system was allocated a 40-MHz bandwidth within the 800 to 900 MHz frequency range by the Federal Communications Commission (FCC) for AMPS.

In 1988, an additional 10 MHz bandwidth, called Expanded Spectrum (ES) was allocated to AMPS. It was first deployed in Chicago, with a service area of 2100 square miles². AMPS offered 832 channels, with a data rate of 10 kbps. Although Omni directional antennas were used in the earlier AMPS implementation, it was realized that using directional antennas would yield better cell reuse. In fact, the smallest reuse factor that would fulfill the 18db signal-to-interference ratio (SIR) using 120-degree directional antennas was found to be 7. Hence, a 7- cell reuse pattern was adopted for AMPS.

Transmissions from the base stations to mobiles occur over the forward channel using frequencies between 869-894 MHz. The reverse channel is used for transmissions from mobiles to base station, using frequencies between 824-849 MHz. AMPS and TACS use the frequency modulation (FM) technique for radio transmission. Traffic is multiplexed onto an FDMA (frequency division multiple access) system.

B. 2G or THE SECOND-GENERATION and PHASE 2+ SYSTEMS (DIGITAL)

Second-generation (2G) mobile systems were introduced in the end of 1980s. Low bit rate data services were supported as well as the traditional speech service. Compared to first-generation systems, second-generation (2G) systems use digital multiple

access technology, such as TDMA (time division multiple access) and CDMA (code division multiple access). Consequently, compared with first- generation systems, higher spectrum efficiency, better data services, and more advanced roaming were offered by 2G systems. In Europe, the Global System for Mobile Communications (GSM) was deployed to provide a single unified standard. This enabled seamless services throughout Europe by means of international roaming. Global System for Mobile Communications, or GSM, uses TDMA technology to support multiple users. During development over more than 20 years, GSM technology has been continuously improved to offer better services in the market.

New technologies have been developed based on the original GSM system, leading to some more advanced systems known as 2.5 Generation (2.5G) systems. In the United States, there were three lines of development in second-generation digital cellular systems. The first digital system, introduced in 1991, was the IS-54 (North America TDMA Digital Cellular), of which a new version supporting additional services (IS-136) was introduced in 1996. Meanwhile, IS-95 (CDMA One) was deployed in 1993. The US Federal Communications Commission (FCC) also auctioned a new block of spectrum in the 1900 MHz band (PCS), allowing GSM1900 to enter the US market.

In Japan, the Personal Digital Cellular (PDC) system, originally known as JDC (Japanese Digital Cellular) was initially defined in 1990. Since the first networks appeared at the beginning of the 1991, GSM 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 element of this system are the BSS (Base Station Subsystem), in which there are BTS (Base Transceiver 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 up to 9.6kbps, fax, etc. This GSM network also has an extension to the fixed telephony network.

A new design was introduced into the mobile switching center of second-generation systems. In particular, the use of base station controllers (BSCs) lightens the load placed on the MSC (mobile switching center) found in first generation systems. This design allows the interface between the MSC and BSC to be standardized.

Hence, considerable attention was devoted to interoperability and standardization in second- generation systems so that carrier could employ different manufacturers for the MSC and BSCs.

In addition to enhancements in MSC design, the mobile-assisted handoff mechanism was introduced. By sensing signals received from adjacent base stations, a mobile unit can trigger a handoff by performing explicit signaling with the network.

The next advancement in the GSM system was the addition of two platforms, called Voice Mail Service (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

1G	2G	3G	4G
1) Paging systems 2) Cordless telephone 3) Private mobile radio 4) Cellular Systems (NMT ,AMPS etc) 5) Mobile Satellite Systems (INMARSAT)	1) Paging systems 2) Cordless telephone (DECT,PACS) 3) Private mobile radio(TETRA) 4) WLL Cellular systems (GSM, D-AMPS, PDC etc.) 6) Mobile Satellite Systems (IRIDIUM, ICO, GLOBALSTAR)	1) Single standard under IMT-2000, UMTS, MC-CDMA, TD-SCDMA	1) LTE Advanced 2) IEEE 802.16m 3) 3GPP Long Term Evolution (LTE) 4) Mobile WiMAX (IEEE 802.16e)

Table 1: Different standards used in different generations of mobile technologies.

traffic.

Along with 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 prepaid services are the result of the IN service.

GSM and GPRS (General Packet Radio Services): As requirement for sending data on the air-interface increased, new elements such as SGSN (Servicing 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 bit rate reaching to 150 kbps in optimum conditions.

The move into the 2.5G world began with General Packet Radio Service (GPRS). GPRS is a radio technology for GSM networks that adds packet-switching protocols, shorter setup time for ISP connections, and the possibility to charge by the amount of data sent, rather than connection time. Packet switching is a technique whereby the information (voice or data) to be sent is broken up into packets, of at most a few Kbytes each, which are then routed by the network between different destinations based on addressing data within each packet. Use of network resources is optimized as the resources are needed only during the handling of each packet. GPRS supports flexible data transmission rates as well as continuous connection to the network. GPRS is the most significant step towards 3G.

GSM and EDGE (Enhanced Data rates in GSM Environment): 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. Implementing EDGE was relatively painless and required relatively small changes to network hardware and software as it uses the same TDMA (Time Division Multiple Access) frame structure, logic channel and 200 kHz carrier bandwidth as today's GSM networks. As EDGE progresses to coexistence with 3G WCDMA, data rates of up to ATM-like speeds of 2 Mbps could be available. Nowadays, second-generation digital cellular systems still dominate the

mobile industry throughout the whole world. However, third generation (3G) systems have been introduced in the market, but their penetration is quite limited because of several technological reasons.

C. 3G or THE THIRD-GENERATION (WCDMA in UMTS, CDMA2000 and TD-SCDMA)

In EDGE, high-volume movement of data was possible, but still the packet transfer on the air-interface behaves like a circuit's switch call. Thus part of this packet connection efficiency is lost in the circuit switch environment. Moreover, the standards for developing the networks were different for different parts of the world. Hence, it was decided to have a network which provides services independent of the technology platform and whose network design standards are same globally. Thus, 3G was born.[4]

The International Telecommunication Union (ITU) defined the demands for 3G mobile networks with the IMT-2000 standard. An organization called 3rd Generation Partnership Project (3GPP) has continued that work by defining a mobile system that fulfills the IMT-2000 standard. In Europe it was called UMTS (Universal Terrestrial Mobile System), which is TSI-driven. IMT2000 is the ITU-T name for the third generation system, while cdma2000 is the name of the American 3G variant. WCDMA is the air-interface technology for the UMTS. The main components includes BS (Base Station) or node B, RNC (Radio Network Controller), apart from WMSC (Wideband CDMA Mobile Switching Centre) and SGSN/GGSN. 3G networks enable network operators to offer users a wider range of more advanced services while achieving greater network capacity through improved spectral efficiency. Services include wide-area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. Additional features also include HSPA (High Speed Packet Access) data transmission capabilities able to deliver speeds up to 14.4 Mbps on the downlink and 5.8 Mbps on the uplink.

The first commercial 3G network was launched by NTT DoCoMo in Japan branded FOMA, based on W-CDMA technology on October 1, 2001 [2]. The second network to go commercially live was by SK Telecom in South Korea on the 1xEV-DO (Evolution-Data Optimized) technology in January

2002 followed by another South Korean 3G network was by KTF on EV-DO in May 2002. In Europe, the mass market commercial 3G services were introduced starting in March 2003 by 3 (Part of Hutchison Whampoa) in the UK and Italy. This was based on the W-CDMA technology. The first commercial United States 3G network was by Monet Mobile Networks, on CDMA2000 1x EV-DO technology and the second 3G network operator in the USA was Verizon Wireless in October 2003 also on CDMA2000 1x EVDO. The first commercial 3G network in southern hemisphere was launched by Hutchison Telecommunications branded as Three using UMTS in April 2003. The first commercial launch of 3G in Africa was by EMTel in Mauritius on the W-CDMA standard. In North Africa (Morocco), a 3G service was provided by the new company Wana in late March 2006. Roll-out of 3G networks was delayed in some countries by the enormous costs of additional spectrum licensing fees.

In many countries, 3G networks do not use the same radio frequencies as 2G, so mobile operators must build entirely new networks and license entirely new frequencies; an exception is the United States where carriers operate 3G service in the same frequencies as other services. The license fees in some European countries were particularly high, bolstered by government auctions of a limited number of licenses and sealed bid auctions. Other delays were due to the expenses of upgrading equipment for the new systems. Still several major countries such as Indonesia have not awarded 3G licenses and customers await 3G services. China delayed its decisions on 3G for many years. In January 2009, China launched 3G but interestingly three major companies in China got license to operate the 3G network on different standards, China Mobile for TD-SCDMA, China Unicom for WCDMA and China Telecom for CDMA2000 [4].

D. FOURTH GENERATION (ALL-IP)

The emergence of new technologies in the mobile communication systems and also the ever increasing growth of user demand have triggered researchers and industries to come up with a comprehensive manifestation of the up-coming fourth generation (4G) mobile communication system.

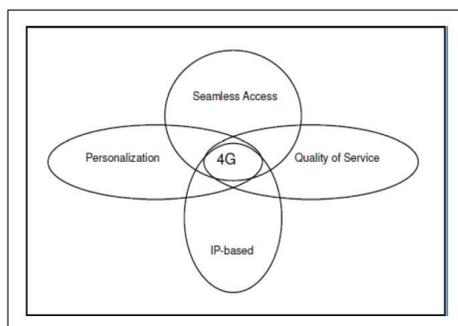


Figure 2: 4G

In contrast to 3G, the new 4G framework to be established will try to accomplish new levels of user experience and multi-service capacity by also integrating all the mobile technologies

that exist (e.g. GSM - Global System for Mobile Communications, GPRS - General Packet Radio Service, IMT-2000 (International Mobile Communications, Wi-Fi - Wireless Fidelity, Bluetooth) [5]. The fundamental reason for the transition to the All-IP is to have a common platform for all the technologies that have been developed so far, and to harmonize with user expectations of the many services to be provided. The fundamental difference between the GSM/3G and All-IP is that the functionality of the RNC and BSC is now distributed to the BTS and a set of servers and gateways. This means that this network will be less expensive and data transfer will be much faster. 4G will make sure the user has freedom and flexibility to select any desired service with reasonable QoS and affordable price, anytime, anywhere. 4G mobile communication services started in 2010 but will become mass market in about 2014-15.

The next Generation Mobile Communication Systems IMT-Advanced 4G standards will usher in a new era of mobile broadband communications, according to the ITU-R. IMT-Advanced provides a global platform on which to build next generations of interactive mobile services that will provide faster data access, enhanced roaming capabilities, unified messaging and broadband multimedia. According to ITU, ICTs and broadband networks have become vital national infrastructure - similar to transport, energy and water networks - but with an impact that promises to be even more powerful and far-reaching. These key enhancements in wireless broadband can drive social and economic development, and accelerate progress towards achieving the United Nations' Millennium Development Goals, or MDGs.

The current agreements on the requirements for IMT-Advanced are:

- a) Peak data rate of 1 Gbps for downlink (DL) and 500 Mbps for uplink (UL).
- b) Regarding latency, in the Control plane the transition time from Idle to Connected should be lower than 100ms. In the active state, a dormant user should take less than 10ms to get synchronized and the scheduler should reduce the User plane latency at maximum.
- c) Downlink peak spectral efficiency up to 15 bps/Hz and uplink peak spectral efficiency of 6.75 bps/Hz with an antenna configuration of 4×4 or less in DL and 2×4 or less in UL.
- d) The average user spectral efficiency in DL (with inter-site distance of 500m and pedestrian users) must be 2.2 bps/Hz/cell with MIMO 4×2 , whereas in UL the target average spectral efficiency is 1.4 bps/Hz/cell with MIMO 2×4 .
- e) In the same scenario with 10 users, cell edge user spectral efficiency will be 0.06 in DL 4×2 . In the UL, this cell edge user spectral efficiency must be 0.03 with MIMO 2×4 .
- f) Mobility up to 350 km/h in IMT-Advanced. IMT-Advanced system will support scalable bandwidth and spectrum aggregation with transmission bandwidths more than 40MHz in DL and UL.
- g) Backward compatibility and inter-working with legacy systems.

Generation	Requirements	Throughput/Speed	Comments	Time Period
1G	No official requirements. Analog technology.	14.4 Kbps (max)	Deployed in the 1980s	1980-1990
2G	No official requirements. Digital Technology.	9.5-14.6 kbps	First digital systems. Deployed in the 1990s. New services such as SMS. Primary technologies include IS-95 CDMA and GSM.	1990-2000 (2G). 2001-2004 (2.5G)
3G	ITU's IMT-2000 required 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors	3.1 Mbps(peak) 500-700 Kbps	Primary technologies include CDMA2000 1X/EVDO and UMTS-HSPA. WiMAX now an official 3G technology.	2004-2005 (3G), 2006-2010 (3.5G)
4G	ITU's IMT Advanced Requirements. Include ability to operate in up to 40 MHz radio channels and with very high spectral efficiency.	100-300 Mbps(Peak) 3-5 Mbps 100 Mbps(Wi-Fi)	No technology meets requirements today. IEEE 802.16m and LTE Advanced being designed to meet requirements.	2010-Present

Table 2: 1G to 4G

After completion of its Release-8 specifications, Third Generation Partnership Project (3GPP) has already planned for a work item called LTE- Advanced to meet the IMT-Advanced requirements for 4G. Also, WiMAX Forum and IEEE are also evolving WiMAX through IEEE 802.16m or WiMAX-m to satisfy 4G requirements. The table below summarizes the generations of wireless technology.

E. FUTURE GENERATIONS

5G (5th generation mobile networks or 5th generation wireless systems) is a term used in some research papers and projects to denote the next major phase of mobile telecommunications standards beyond the current 4G/IMT-Advanced standards. 5G is also referred to as beyond 2020 mobile communications technologies. 5G does not describe any particular specification in any official document published by any telecommunication standardization body. 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. Americas. [Online]

The fifth generation communication system is envisioned as the real wireless network, capable of supporting Wireless World Wide Web (www) applications in 2010 to 2020 time frame. There are two views of 5G systems: evolutionary and revolutionary. In evolutionary view the 5G (or beyond 4G) systems will be capable of supporting www allowing a highly flexible network such as a Dynamic Adhoc Wireless Network (DAWN). In this view advanced technologies including intelligent antenna and flexible modulation are keys to optimize the ad-hoc wireless networks. In revolutionary view, 5G systems should be an intelligent technology capable of interconnecting the entire world without limits. An example application could be a robot with built-in wireless communication with artificial intelligence.

Currently there is 5G technology in research. When this becomes available it will provide very high speeds to the con-

sumers. Data Transfer speed is predicted to cross the barrier of gigabits per sec. It would also provide efficient use of available bandwidth as has been seen through development of each new technology. 5G services would probably be available for use by the year 2020.

III. CONCLUSION

The last few years have witnessed a phenomenal growth in the wireless industry. The ever increasing demands of users have triggered researchers and industries to come up with a comprehensive manifestation of the up-coming fifth generation (5G) mobile communication system. As the history of mobile communications shows, 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, while the second generation (2G) has introduced capacity and coverage. 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 is further realized by the fourth generation (4G). Fifth Generation (5G) will bring higher data transfer speeds (reaching up to few gigabits per sec) and other high quality services.

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