



Mobile Communication Technologies: 1G to 4G

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Abstract

Mobile communication has gone through revolutionary changes during past decade. Mobiles, nowadays has all functionalities of computer and trying to replace it. It was a step by step process. Each change marks an improvement over previous one and termed as a generation of technology. A generation largely indicates the type of services and the data transfer speeds of each class of technology. In this paper all the technological changes occurring in mobile communication technologies have been presented and compare various advantages and improvements over previous one. The paper also discusses the competition between 3G and 4G technology. At the end, paper throws some light on the latest researches in the mobile communication.

Keywords: Mobile Communication; Pre-Cellular; 1G; 2G; 3G; 4G; 5G.

1. Introduction

Mobile communication technology uses the radio waves for communication facility which is known as very old technology for transmitting voice signals. Presently the same is used for transmitting text, image as well as video data along with audio signals. The mobile communication is explained in terms of generations of mobile technologies starting from first generation (1G) to fourth generation (4G). The researchers have already started thinking and working on fifth generation (5G) and have started their design issues. Prior to 1973, mobile telephony was limited to phones installed in cars and other vehicles. It is termed as pre-1G (i.e. 0G). Motorola was the first company to produce a hand held mobile phone. On 3rd April, 1973 when Martin Cooper, a Motorola researcher and executive, made the first mobile telephone call from hand held subscriber equipment, placing a call to Dr. Joel S. Engel of Bell Labs. The prototype handheld phone used by Dr. Cooper weighed about 1.1 kg and measured 23 cm long, 13 cm deep and 4.45 cm wide. The prototype offered a talk time of just 30 minutes and it took 10 hours to re-charge. This was termed as 1G i.e. first generation of mobile communication. 1G uses analog signal transmission through frequency division multiplexing technique (FDMA) [1], [5]. Then comes the 2G technology which uses digital signal transmission technology with time division multiplexing technique (TDMA) and code division multiple access technique (CDMA). It has offered voice as well as text (SMS) transmission facility. It uses circuit switching for digital voice transmission and packet switching for text data transmission. The signals of 2G are secure and efficient as compared to 1G and provide greater mobility to the user. The 2G has two variations named 2.5G and 2.75G, where 2.5G is based on the technology named as GPRS. It facilitates the user to access the internet using mobile phones with very low data rates. 2.75G is based on the EDGE technology which provides higher data rates than GPRS.

By this time, researches for high data rates and bandwidth sensitive application progressed much and, hence, a new generation of technology emerged, which is named as 3G i.e. third generation of mobile communication. It facilitates the user with online video transmission at high data rates. 3G is based on CDMA and WCDMA technology, which is totally packet switching technology as compared to 2G. User can do video calls, watch online movies and T.V on their mobile phones. This has increased the demand for more data rates/speed and bandwidth in video applications. 4G technology has come up with solution to higher data rates and more bandwidth. It is completely wireless technology based on VoIP i.e. wireless technology of telephony. It uses orthogonal frequency division multiplexing technique (OFDM). 4G Offer divergent levels of data transfer from sources to a device with a speed of 100 Mbit/s [2], [3]. The first two commercially available 4G technologies are named as the WiMAX standard and the LTE standard. Now, scientist and researchers already working on a completely wireless scenario denoted as WWW (World Wide Wireless Web). This will be the future generation of mobile communication technology and termed as 5G.



2. Pre-Cellular Generation (0G)

0G is also called "Mobile Radio Telephone" technology considered as the dawn of wireless connectivity. MTS (Mobile Telephone System) was the first commercially used mobile telephone service started in 1946. Such mobile phones were installed in different vehicles with bulky transceiver placed in the trunk of vehicle like car and a headset and a dialler positioned near the driver seat. Both headset and transceiver were connected through a wire. Some models are designed with briefcase used for extreme connectivity by the specialists. 0G systems provide half duplex communication in which only one person can speak at a time and the other has to listen. These systems were expensive, heavy weight, big size and provide limited connectivity. In 1962, IMTS (Improved mobile Telephone System) fully automatic mobile telephone system was introduced. No operator is required to connect the calls [2], [8]. Atlay introduced by Russia, PTT (Push to Talk), AMTS (Advanced MTS), MTD are other technologies used in 0G.

0.5G was the advance version of 0G (Mobile Radio Telephone system). This 0.5G technology had introduced the first commercial public mobile phone network. This ARP network was launched in 1971 at Finland. Its transmission power was in a range of 1 to 5 watts. ARP was successful and became very popular until the network became congested. The ARP mobile terminals were too large to be fixed in cars and were expensive too. These limitations led to invention of Autotel. It is also known as PALM (Public Automated Land Mobile) [1]. It is a radio telephone service which in terms of technology lies between MTS and IMTS. It was developed in Canada and Columbia.

3. First Generation (1G)

Martin Copper who is known as father of cell phone had given the concept of cellular network structure. The first generation mobile phones are based on cellular network structure, in which one frequency is divided into different cells so that each cell could support a decent number of users for placing calls independently on same frequency channel. These cellular networks facilitate voice transmission using analog signals, by simply modulating analog voice signal to a very high frequency of 150MHz. The very first commercial 1G network was AMPS (Advanced Mobile Phone System) introduced in US in 1980s.

NMT (Nordic Mobile Telephony) is another 1G cell phone technology developed by European countries. It was a free and open standard which led to lower price and high accessibility. Total Access Communication System (TACS), C-NETZ, Radio Telephone Mobile System (RTMS), Nippon Telephone and Telegraph (NTT) and later NTACS (Narrow band Total Access Communications System) and JTACS (Japanese Total Access Communication System) were some other technologies of 1G. This mobile system provides full duplex communication. The limitations of 1G system were unsecure communication, which led to eavesdropping and theft of airtime [6], [8]. 1G mobile phone provided less mobility and less number of subscribers covered because it requires a significant amount of wireless spectrum support. 1G network were very slow less than 1 kilobits per sec (kbps).

4. Second Generation (2G)

2G was a period of very rapid expansion for mobile communication technology introduced in 1990s. They were the first digital cellular networks; instead of analog. This technology was based on binary codes like a series of zeros and ones. At the receiver's end, it was converted back to voice through switch on and switch off of the inbuilt circuit. The two major standards of 2G were named - GSM (created in Europe) and CDMA (created in the US). 2G brought many new opportunities in mobile technology. The very first smartphone-IBM Simon, having many features from phone to calendar, notepad and even email also emerged in 2G. This was the beginning of smaller, sleeker and more attractive phones. 2G networks introduced a feature that all of us are using every day - SMS. Picture messages, access to media content on mobile phones and extra storage (memory cards) are other facilities given by 2G networks. One of the best things about this generation is that as carriers continued to install more and more cell sites, their networks became denser, requiring cell phones to use less battery in order to maintain a normal signal level. This technology allowed manufacturers to leave the brick-phones in the past and start producing much more compact and lighter handsets at lower cost. This generation also started the trend of prepaid mobile phones and brought many benefits like faster connections, better service and support for new features [5].

2G introduced internet access in mobile phones in 2000 using GPRS (General Packet Radio Service) and it was called as 2.5G. It was a packet switching technology used in GSM mobile phones. It provided data rates from 56 kbps up to 115 kbps. CDMA also introduced 1xRTT. They facilitated WAP (Wireless Application Protocol) access, MMS (Multimedia Messaging Service) services. Then GPRS1 networks evolved provide higher data rates than GPRS and



termed as 2.75G. It was also called as EDGE (Enhanced Data rates for GSM Evolution) networks. It provided three-fold increase in capacity of GSM/GPRS networks.

5. Difference between 1G and 2G Systems

The main difference between the two is that first generation is analog cellular networks and second generation is digital cellular networks. The other differences as follows:

- Encryption- 2G systems provide encryption to prevent eavesdropping and give secure mobile communication. All text messages sent over 2G are digitally encrypted. The only intended receiver can receive and read it.
- Error Detection and Correction- 2G digital traffic allows for detection and correction of errors in data. It provides clear voice reception.
- Channel Access- 2G systems allow channels to be dynamically shared by number of users. It facilitates global roaming.
- Capacity- Digital voice data can be compressed and multiplexed more effectively than analog voice encoding. It allows transmitting more calls in same amount of bandwidth.

One advantage of analog systems had over digital ones is that analog has a smooth decay curve, but digital has a jagged steppe one. Under good conditions digital sound better. But, under bad conditions digital systems shows no signal problem while analog signals may provide low quality audio communication.

6. Third Generation (3G)

The first commercial 3G network was launched on 1st October, 2001 in Tokyo region by NTT DoCoMo. It was powered by WCDMA (Wideband Code Division Multiple Access) technology or UMTS (Universal Mobile Telecommunication Systems). It was a generation of rapid growth and improvement for wireless technology. With its focus on faster speeds and reliability, it brought us stuff like streaming audio and video, VoIP capabilities and usable internet access among many others. This generation has made mobile phones work just like a mini computer with large number of mobile applications. User can now surf internet, upload or download data, make video call, audio and video streaming, use GPS (Global Positioning System) at the blink of eye using 3G technology. The main aim of 3G services is to provide user with highest speed of data and voice transfers, GPS and other applications in secure manner. In 3G services the transmitted data is in encrypted format only the end user can decrypt the data. 3G provides a maximum data rate of 1Mbps to 2Mbps. Other technologies that are being used in 3G are HSPA (High Speed Packet Access), HSPA+ provides much higher speeds 7.2 Mbps to 14.0 Mbps and 21 Mbps to 42 Mbps respectively. These technologies are called as 3.5G. High Speed Uplink Packet Access (HSUPA) is named as 3.75G. This technology is used in compliance with 2G technology [1], [3]. The limitations of 3G technology is the requirement high bandwidth, high spectrum licensing fees and huge capital investment.

7. Fourth Generation (4G)

4G is the next step into wireless and cellular technologies. It is the result of human hunger to get more and more. This hunger is the constant force behind every development. This technology is associated with high speed and remote connectivity anywhere in the world. 4G provides speed of 100 Mbps for moving users and 1Gbps for stationary users. It is fully IP-based integration of several wireless broadband access communication systems, not only one cellular telephone system as shown in Fig 1. The two main standards competing for 4G are Wimax (Worldwide Interoperability for Microwave Access) and GSM's LTE (Long Term Evolution) introduced in 21st century. WiMAX is also called Broadband Wireless Access because it does not require any cabled infrastructure.

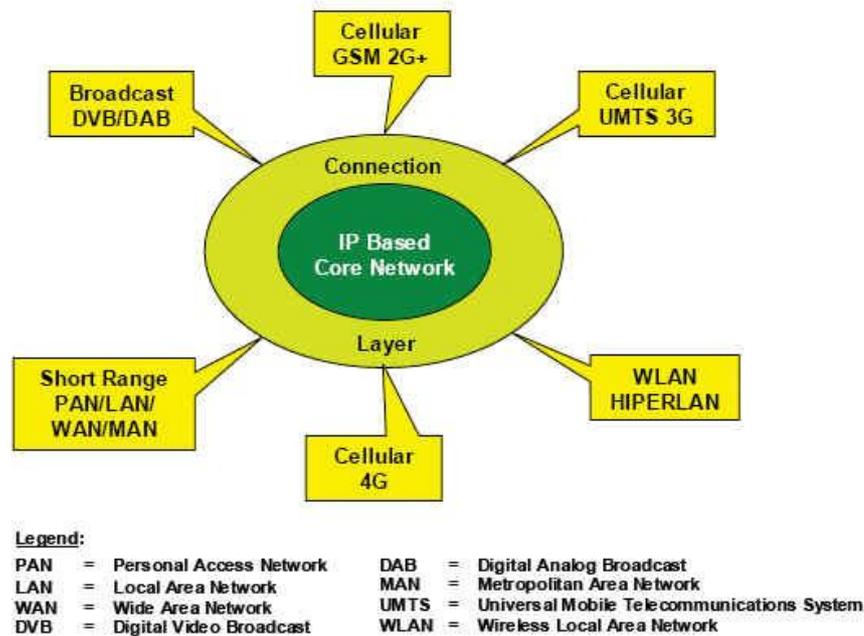


Fig 1: 4G – Integration of networks

4G technology is based on OFDM (Orthogonal Frequency Division Multiplexing). The basic principle of OFDM is to split a high rate data-stream into multiple lower rate data-streams that are transmitted simultaneously over a number of sub carriers. MC-CDMA, a combination of CDMA and OFDM is going to be used in 4G for providing high speed communication. MC-CDMA in combination with adaptive modulation may give more speed with lower error rate to 4G. MIMO (Multiple Input Multiple Output), Smart Antenna are other key technologies used in 4G [4], [5]. It uses signal multiplexing between multiple transmitting antennas and time or frequency. 4G technology will allow users to download full-length feature film within five minutes and users will also be able to stream high-definition television and radio to hand-held devices.

8. Difference between 3G and 4G

The major difference between the two is that 3G technologies are not compatible with 4G. Therefore, 4G will completely replace the 3G technology in future.

- Speed- The maximum speed attained by 3G is 14Mbps in downlink and 5.8 Mbps in uplink. 4G standards are designed to provide speed from 100 Mbps to 1 Gbps. This gives a very high speed internet access, video streaming applications over mobile phones.
- Switching technique- 3G uses combination of circuit and packet switching but 4G is completely replacing circuit switching with packet switching. With packet switching resources are only used when there is information to be sent across. This increases the bandwidth of the network. 4G uses VoIP technology for watching movies as well as for video calling.
- Terminals- 3G uses mobile phones, tablet and keyboard as its terminal devices. 4G is going to advance in this concept to new interfaces based on speech, vision, touch and soft buttons etc.
- Cost- It is a parameter due to which 3G is delayed or not completely deployed everywhere. 3G spectrum license fees is additional cost and meanwhile 4G emerged.

Therefore, 4G is best described by the word “MAGIC” where M stands for Mobile multimedia, A stands for Anytime Anywhere Anyone, G stands for Global mobile support and I stands for Integrated wireless solutions and C for customized personalized service[7], [9]. It is blended with good Quality of Service (QOS) and high security.

9. Applications of 4G

The applications of 4G are heterogeneous in nature and require time varying quality of services [4]. Some are listed as follows:

- Better usage of multimedia applications.
- Virtual Presence- 4G provides user services at all times, even if use is off the site. For example always on connections to keep people on event- video conferencing.
- Virtual Navigation- 4G provides user with virtual navigation through which a user can access database of streets, building etc.
- Tele-geo processing Applications- This is a combination of GIS (Geographic Information System) and GPS (Global Positioning System) in which user can get the location by querying.
- Telemedicine and Education- 4G supports remote health monitoring of patients. 4G also provides long life education opportunities.
- Crisis Management- Natural disasters can cause breakdown in communication system. 4G is expected to restore such crisis issues in few hours.
- Traffic Control- mobile phone sensors on public vehicle.

Table 1: Comparison of 1G-4G Technologies

Technology / Features	1G	2G	2.5G	3G	4G
Start/ Deployment	1970/ 1984	1980/ 1991	1985/ 1999	1990/ 2002	2000/ 2006
Data Bandwidth	1.9 kbps	14.4 kbps	14.4 kbps	2 Mbps	200 Mbps
Standards	AMPS	TDMA, CDMA, GSM	GPRS, EDGE, 1xRTT	WCDMA, CDMA-2000	Single unified standard
Technology	Analog cellular technology	Digital cellular technology	Digital cellular technology	Broad bandwidth CDMA, IP technology	Unified IP and seamless combination of broadband, LAN/WAN/PAN and WLAN
Service	Mobile telephony (voice)	Digital voice, short messaging	Higher capacity, packetized data	Integrated high quality audio, video and data	Dynamic information access, wearable devices
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CDMA
Switching	Circuit	Circuit	Circuit for access network & air interface; Packet for core network and data	Packet except circuit for air interface	All packet
Core Network	PSTN	PSTN	PSTN and Packet network	Packet network	Internet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal and Vertical

Now, we can summarize the main features of each generation and compare them. Table-1 describes briefly the technological features of all generations 1G to 4G.

10. Conclusion

Mobile technology has come a long way. In the beginning users were happy just to be able to talk using 1G. 2G improved communication quality and extended the meaning of “long distance calls” with roaming capabilities. 2G also gave text facility to its users. 3G perfected the voice calls and introduced high speed internet & video chatting. Now, the most recent 4G technology allows mobile devices to operate at blazing fast speeds. The 4G would completely replace 3G in a long run. Currently 3G and 4G are competing for their growth in the future market. And 4G is acquiring 3G’s Customers. There are plenty of opportunities for 4G to meet the needs of consumer demands at a right time. A new generation of 5G standards may be introduced approximately in 2020. From a user point of view between 4G and 5G techniques must be something else than increased maximum throughput; for example lower battery consumption, lower



outage probability (better coverage), high bit rates in larger portions of the coverage area, cheaper or no traffic fees due to low infrastructure deployment costs, or higher aggregate capacity for many simultaneous users. The mobile industry has earned the reputation of not remaining stagnant; it is exciting to ponder what technology might be in store.

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