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Evolution of Modern Communication Systems

Krishn Kumar Gupt[1], Vinay Kumar Singh[2]

UG Scholar, Department of Electronics, Zakir Husain Delhi College, New Delhi, India[1]

Assistant Professor, Department of Electronics, Zakir Husain Delhi College, New Delhi, India[2]

Abstract: Modern communications technology revolutionized the way, mobility and efficiency of electronic communications. Starting from with Alexander Graham Bells' telephone experiments to widely practiced W-CDMA network and the nearly achieved 4G mode of communications, all had and will have great contributions in today's voice/data network arena. Wireless technology has achieved evolutionary success aiming at unified target: efficiency, performance and feasibility in high mobile environment. The mobile experience is expanding everywhere fulfilling the basic electronic communication needs. The first generation (1G) was analog. 1G established seamless mobile connectivity used for basic mobile voice until being replaced by the second generation (2G) digital telecommunications technologies which increased voice capacity delivering mobile to the masses with network infrastructure supporting text messaging. The success of digital voice and simple data prompted to the development of cellular wireless communication system with improved data connectivity and more accessible features leads to followed by the third generation (3G). Third generation system having mobile optimization for data enabling mobile broadband services with better and higher speed of data transfer and connectivity. The fourth generation (4G) having more capacity for faster and better wireless mobile broadband experiences with accessing capability to wide range of communication services, including advanced mobile services, and enhancement in the quality of services with increase in the bandwidth. In this paper we address the evolution of wireless modern mobile communication systems, from first generation (1G) to the widely practiced third generation (3G), recently introduced fourth generation (4G) and some glimpse of foreseeable future of fifth generation (5G).

Keywords: 1G, 2G, 3G, 4G. 5G, EDGE, GPRS, GSM, LTE, LTE-A, UMTS, W-CDMA.

I. INTRODUCTION

Every year we observe the new dimensions of emerging technology and revolution enabling abundance of data and information to transfer at comparatively faster rate with more intelligible forms and directions all across the world with limitless boundaries. Starting from earliest wireless mobile communication generation (1G) to the newly commercially introduced fourth generation (4G) the paradigm has changed. The actual target of growing mobile generations is to provide the user access to an amazing global community reality, making the digital mobile communication revolution ubiquitous (every time, everywhere).

The past few years have witnessed an observable growth in the industries of wireless communication technologies, achieving appreciating number of subscribers. Especially from turn of running century, there has been a huge and clear shift from wired to wireless cellular. The relative shifting towards wireless mobile network from fixed line is really dramatic. In India, by the end of February 2016, total GSM subscriber base reaches 1.052.33 billion. And by the end of Oct-15 to end of Nov-15, the number of broadband subscribers increased with monthly growth rate of 5.01%, from 125.22 Million to 131.49 million.The mobile wireless generation (G) basically tries to improve and achieve a change in nature of communication system, higher bitrates, technology evolution, making them more feasible and easily accessible in a cost efficient way. Each generation has some unique features and standards that make them to stand and compete better than previous generations.

The raising developments in Radio frequency (RF) circuit fabrication, several miniaturization technologies and advancements in processing of digital signals had made it in achieving the possibility to deploy and deliver wireless mobile communication network at this appreciable scale and scope that we are seeing today. Today, the mobile generation is at the threshold of a major revolution in technology of wireless communication.

TABLE I BROADBAND USER AND MONTHLY GROWTH RATE

Segments	**Broadband Users (In Millions)**		**Monthly Growth Rate (%)**
	As on 31st Octob-er, 2015	**As on 30th November, 2015**	
Wired System Users	16.27	16.38	0.67
Mobile Device Users (Phone and Dongles)	108.48	114.63	5.67
Fixed Wireless Users (Wi-Fi, Wi-MAX, Point-to-Point Radio & VSAT)	0.47	0.48	1.47
Total	**125.22**	**131.49**	**5.01**

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Since mobile voice service is still the primary application but it is also clear that wireless data application of communication is at major demand and is driving its growth at an indispensable global information network.

With a quick look in past, in 1973, Motorola demonstrated the first portable radio telephone**.** December 1**,** 1979, in Japan, first commercial automated cellular network was launched by NTT(Nippon Telegraph and Telephone)**,** afterwards,in 1981, the launch of NMT (Nordic Mobile Telephone) system was successfully done in Denmark, Finland, Iceland, Norway and Sweden. And here began the journey ofmodern wireless mobile communication systems and generation (G).

II. FIRST GENERATION (1G) COMMUNICATION SYSTEM

The First Generation(1G) wireless mobile network was analog communication system, designed for basic voice communication purpose. FDMA/FDD and analog FM were the main technology behind the first generation wireless communication system. The world's first commercial wireless cellular system was launched in 1979 by NTT (Nippon Telephone and Telegraph Company), afterward, in 1981, Nordic Mobile Telephone system (NMT-400) was successfully deployed in Europe with international roaming support. AMPS (Advanced Mobile Phone Service) was the first successful U.S. mobile phone system deployed in Chicago in 1983 and its variant ETACS and NTACS (Total Access Communication Systems) in Europe and Japan. In Europe and North America, several wireless cellular communication systems were also designed and implemented during 1981-86, like NMT, AMPS, TACS, C450, Radiocom, and NEC in Nordic countries, North America, UK, Germany, France and Japan respectively.

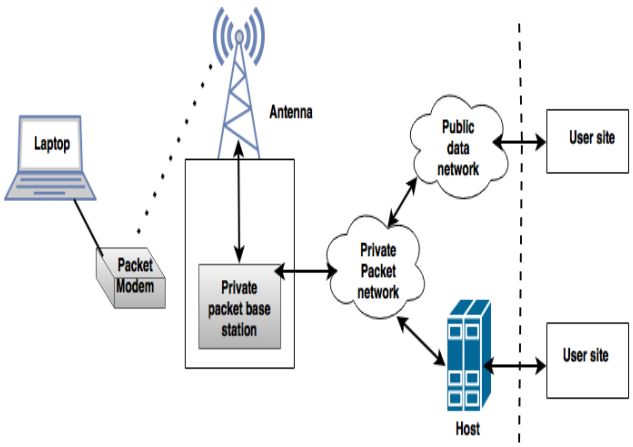

Fig. 1. 1G network architecture

The first generation wireless communication system provides supervisory signalling at the time of voice transmission to verify proper connection between mobile terminal and the base station. Which is achieved by sending tones above the audio band frequencies. The main drawback of first generation wireless system was their incompatibility, due, i.e. to frequency band of operation or different channel spacing. Although the first generation wireless communication system consumed considerable investment but its insufficient system capacity and outdated technology couldn't meet the rapidly growing user demands.

TABLE II MAJOR 1G NETWORKS

	NMT-450/NMT-900	**AMPS**	**ETACS**	**NTACS**
YearofIntroduction	1981	1983	1985	1988
Frequency Bands	NMT-450: 450-470MHz NMT-900:890-960MHz	DL: 869-894MHz UL:824-849MHz	DL: 916-949MHz UL: 871-904MHz	DL:860-870MHz UL: 915-925MHz
Multiple Access	FDMA	FDMA	FDMA	FDMA
Channel Bandwidth	NMT-450:25kHzNMT-900:12.5kHz	30kHz	25kHz	12.5kHz
Voice Modulation	FM	FM	FM	FM
Duplexing	FDD	FDD	FDD	FDD
Number of Channels	NMT-450:200 NMT-900:1999	832	1240	400

III. SECOND GENERATION (2G) COMMUNICATION SYSTEM

The second generation (2G) system was introduced with low-band digital data signalling and simple data features having capacity and coverage in late 1980s. Improvements in processing abilities of hardware and advancements of integrated circuits (IC) technology over time, made digital communication technology practical and economical than first generation analog technology. Second generation digital system got several improvements over 1G through implications of spectrally efficient digital speech codecs. Several users were multiplexed on same radio channel using CDMA (Code Division Multiple Access) and TDMA (Time Division Multiple Access) techniques. In addition to facility of SMS (Short Message Service) in second generation systems, robust link level signal processing and good speech codecs improved the voice quality having the speed of 64 kbps. Global System for Mobile communications (GSM), IS-95 CDMA, and IS-136 TDMA systems are some major second generation cellular systems. GSM is the most widely deployed digital mobile telecommunication, supporting voice call and data transfer speeds of up to 9.6 kbps, in more than 190 countries of the world. IS-95, deployed in North America and some parts of Asia. IS-54, which was later enhanced to IS-136, was a

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TDMA-based system designed as a digital evolution of AMPS **(**Advanced Mobile Phone System) was deployed initially inNorth America but after some time it was mostly replaced by GSM. GPRS, CDMA and EDGE uses packet switched and circuit switched domain protocols.

TABLE III MAJOR 2G NETWORKS

	GSM	**IS-54/IS-136**	**IS-95**
YearofIntroduction	1990	1991	1993
FrequencyBands	850/900MHz, 1.8/1.9GHz	850MHz/1.9GHz	850MHz/ 1.9GHz
MultipleAccess	TDMA/ FDMA	TDMA/ FDMA	CDMA
ChannelBandwidth	200KHz	30kHz	1.25MHz
VoiceModulation	GMSK	π/4QPSK	DL-SS: BPSK, QPSK
Duplexing	FDD	FDD	FDD
Data Evolution	GPRS, EDGE	CDPD	IS-95-B
Typical User Rate	GPRS: 20-40 Kbps, EDGE: 80-120 Kbps	9.6kbps	IS-95B: < 64Kbps
Peak Data Rate	GPRS: 107 Kbps, EDGE: 384 Kbps	About 12Kbps	IS-95-B: 115Kbps
User Plane Latency	600-700ms	>600ms	>600ms

Packet switching is a technique or a mode of data transmission through which the information that is to be sent, are broken up into packets, in several packets of a few Kbytes each, and then send independently to different destinations based on addressing data within each packet and at last, reassembled those packets at destination. GPRS supports continuous connection between networks with flexible data transmission rate, being a significant step towards the Third Generation (3G).

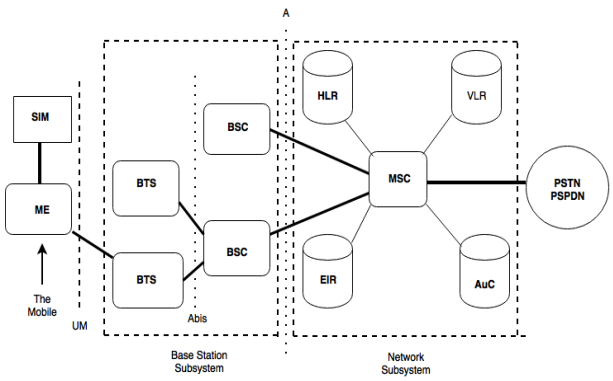

Fig. 1. 2G network architecture

IV. THIRD GENERATION (3G) COMMUNICATION SYSTEM

Third Generation (3G) provided multimedia support with higher rate of data transmission and capacity, with advanced services support like multimedia. Opening the world of truly mobile broadband experience to users, third generation wireless systems were a significant advancement over 2G. Apart from better communication speed, 3G made a revolutionary change in wireless communication world by its various value added services like internet access, e-mail services, live streaming facilities, GPS (Global Positioning System), video calling and Internet Protocol Television (IPTV) etc. Third generation network protocol follows the compatibility with International Mobile Telecommunications-2000 standards as stated by ITU (International Telecommunication Union). Bitrates for IMT-2000 standard as per ITU is expected to be 144Kb/s for a user moving at speed of or inside an automobile or train, 384Kb/s for user moving at speed of a pedestrian, and up to 2Mb/s for a stationary or fixed one. 3GPP (3rd Generation Partnership Project) worked on wireless mobile system to fulfil the criteria as expected by ITU for IMT-2000 standard and was a big step up from the second generation bandwidth toward third generation to transmit the signal using 8 to 13Kb/s per channel with better QoS (Quality of Service). In past years ITU approved six terrestrial radio interfaces from several proposals made for IMT-2000. IMT-DS (IMT-2000 CDMA Direct Spread) knows as WCDMA (Wideband Code Division Multiple Access), IMT-MC (IMT-2000 CDMA Multi-carrier) also called IX-EV-DO, IMT-TC (IMT-2000 CDMA TDD) known as TD-SCDMA or UMTS-TDD, IMT-SC (IMT-2000 TDMA Single Carrier) known as UWC-136, IMT-FT (IMT-2000 FDMA/TDM) and IMT-2000 IP-OFDMA also known as IEEE 802.16e or WiMAX.

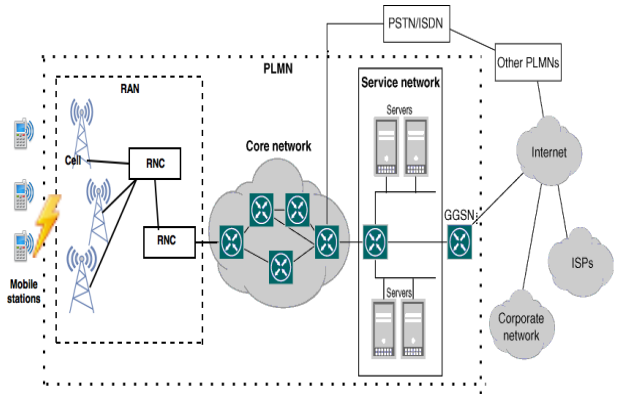

Fig. 2. 3G network architecture

Third generation is amazing and there is no flip to the same, but as technology is evolving and the practical requirements to improve the pre-existing architecture to gain better bitrates, we shift to next generation topology. Because of Wide Band Voice channel used by 3G, world has turned in a global village. Supporting 5 major radio technologies operated under CDMA, FDMA and TDMA, 3G is much flexible among other communication systems.

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TABLE IV MAJOR 3G NETWORKS

	WCDMA	**CDMA2 00001X**	**EV-DO**	**HSPA**
Standard	3GPP Release 99	3GPP2	3GPP2	3GPP Release 5/6
Channel Bandwidth	5 MHz	1.25 MHz	1.25 MHz	5 MHz
Frequency Bands	850/900 MHz, 1.8/1.9/ 2.1 GHz	450/850 MHz 1.7/1.9/ 2.1 GHz	450/85 0MHz 1.7/1.9/ 2.1 GHz	850/ 900 MHz, 1.8/1.9 /2.1 GHz
Peak Data Rate	384-2048 Kbps	307 Kbps	DL: 2.4-4.9 Mbps, UL: 800-1800Kbps	DL: 3.6-14.4 Mbps, UL: 2.3-5Mbps
Multiple Access	CDMA	CDMA	CDMA/ TDMA	CDMA / TDMA
Duplexing	FDD	FDD	FDD	FDD
Data Modulation	DS-SS: QPSK	DS-SS: BPSK, QPSK	DS-SS: QPSK, 8PSK, 16QAM	DS-SS: QPSK, 16QAM, 64QAM
Typical User Rate	150-300 Kbps	120-200 Kbps	400-600Kbps	500-700 Kbps
User Plane Latency	100-200ms	500-600ms	50-200ms	70-90ms

V. FOURTH GENERATION (4G) COMMUNICATION SYSTEM

The Fourth Generation (4G) mobile wireless communication system integrates third generation features with additional enhanced technologies, which is an evolutionary step to overcome the limitations of 3G wireless communication systems, which also raises the QoS (Quality of Service), increases the bandwidth in a cost efficient manner. In fact, the fourth generation network intend to integrate all those previous generation technology and wireless standards to achieve ubiquity, multi-service platform and comparatively low bit cost. Mainly, the enhancement in system was in the form of greater spectral efficiency, increased peak data rates, increased throughput and reduced latency. Many industries involved in wireless communication system, refer WiMAX and LTE (Long Term Evolution) as a fourth generation communication systems, but in actual they do not meet the necessary conditions and requirement for fourth generation as laid by ITU in section 1.7. Sometimes, LTE communication technology is called as 3.9G or Super 3G which was deployed by 3GPP as an improvement to the UMTS. Technically the 4G title is somewhat appropriate too, as both LTE and WiMAX have a better network architecture and air-interface technology than 3G. Terminal mobility has a great support in success of fourth generation networks and its ubiquity, which implies the transparent and automatic roaming between different networks for users.With additional features and enhancement, HSPA+, the 3GPP Release 7, was published in 2007 with numerous technical improvements like Single frequency network, Dual-carrier downlink operation, Flexible MAC and RLC segmentation, Higher-order modulation and MIMO (Multiple Input Multiple Output) to achieve higher peak rates.WiMAX (Worldwide Interoperability for Microwave Access) is designed using Internet Protocol (IP) based on IEEE 802.16 standard supporting VoIP (voice over IP).

TABLE V MAJOR 4G NETWORKS

	HSPA+	**WiMAX**	**LTE**
Standard	3GPP Release 7 & 8	IEEE802.16e-2005	3GPPRelease8
Frequency Bands (Early Deployment)	850/ 900MHz,1.8/ 1.9GHz,	2.3GHz,2.6GHz,and 3.5GHz	700MHz,1.7/ 2.1GHz,2.6GHz, 1.5GHz
Peak Downlink Data Rate	28–42Mbps	46Mbp (10MHz 2×2MIMO, 3:1DLtoUL ratio TDD); 32Mbps with 1:1	150Mbps (2×2MIMO, 20MHz)
Peak Uplink Data Rate	11.5Mbps	7Mbps(10MHz, 3:1DLtoULratioTDD); 4Mbpswith1:1	75Mbps (10MHz)
Channel Bandwidth	5MHz	5,7,8.75,and10 MHz	1.4,3,5,10 ,15 &20MHz
Duplexing	FDD	TDD; FDD option planned	FDD &TDD
Downlink Multiple Access	CDMA/ TDMA	OFDMA	OFDMA
Uplink Multiple Access	CDMA/ TDMA	OFDMA	SC-FDMA
Data Modulation	DS-SS:QPSK, 16QAM, and64QAM	OFDM:QPSK, 16QAM, and64QAM	OFDM:QPSK,16QAM,and64QAM

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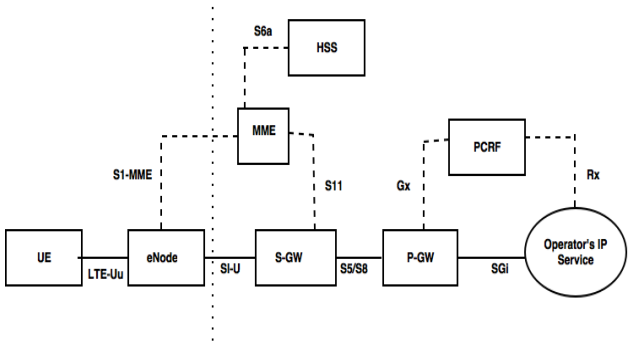

Fig. 3. 4G network architecture

VI. FIFTH GENERATION (5G) COMMUNICATION SYSTEM

Technology is already under evolution to achieve a better scope beyond LTE and 4G systems. Fifth Generation (5G) name is currently being used in various communication research and experiments for the coming generation technology, and it expected to be deployed beyond 2020 of this century with enhanced mobile broadband experience. Several experiments on WWWW (World Wide Wireless Web) and DAWN (Dynamic Adhoc Wireless Network) are under development. LTE-A (Long Term Evolution-Advanced) is expected to have amazing features like extreme data rates, user mobility and capacity, ultra-high density and reliability, ultra-low latency, complexity and energy, strong security and many more. Some preliminary parameters and requirements for LTE-Advanced has been developed by 3GPP, are summarized here.

TABLE VI MAJOR 5G NETWORKS

	Required parameters for LTE-A
Mobility	LTE equivalent performance; Considering speed up to 500kmph
Peak Data Rate	DL: 1Gbps; UL: 500Mbps (assuming100MHzchannel& low mobility)
Latency	from dormant to active: <10ms from camped to active: <50ms
Backward Compatibility	Reuse o f LTEarchitecture; co-existencewith previous 3GPP technologies
Downlink Cell-Edge Spectral Effi ciency	0.07bps/Hz/userassuming2×2MIMO; 0.12bps/Hz/userassuming4×4MIMO; IMT-Advancedrequires0.075bps/Hz/user
Average Downlink Cell Spectral Efficiency	2.4bps/Hz/cell assuming2×2MIMO; 3.7bps/Hz/cellassuming4×4MIMO; IMT-Advancedrequires2.6bps/Hz/cell
Peak Spectral Efficiency	DL: 30bps/Hzassumingnomorethan8×8MIMO; UL: 15bps/Hz assuming no more than 4×4MIMO
Spectrum Flexibility	FDD and TDD; wider channel

And to achieve these all, numerous technologies are being implemented for LTE-Advanced, like, higher order and some improved MIMO (Multiple Input Multiple Output) techniques (up to 8×8), use of self-optimizing and self-configuring networks, and to achieve high data rate coverage, multi-hop relay nodes techniques are under experiment to implement. Number of cells, width of spectrum and efficiency of spectrum are the basic three factors which define capacity of a wireless communication system. Much efforts are being focused on managing interference and cellular network topology to increase capacity of fifth generation network. In fact, fifth generation mobile network technology will open great real world experience of wireless technology to its users in coming future with better architecture.

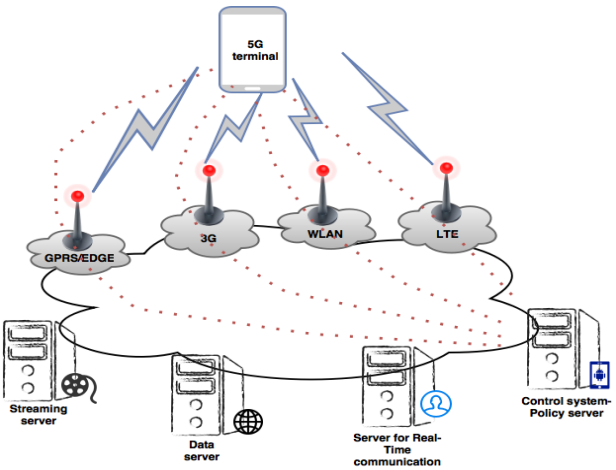

Fig. 4. 5G network architecture

VII. CONCLUSION

In this paper, we have reviewed the generation of wireless mobile communication through all its generation from basic voice cellular to the IP based real world broadband experience with predicted desired parameters and scope of the next generation fifth technology i.e. fifth generation. First generation system fulfilled the basic voice service with analog technology while the second generation improved its features via increased storage and capacity, and was digital unlike 1G, allowing SMS facility to its users. Demand and technology has never been stopped, and the same leads to the third generation having better data speed and real world mobile broadband experience, changing the goal of voice centric technology to data centric. Growing technology and user demand triggered researchers and wireless communication industries to deal with manifestation of the next generation 4G networks with wider bandwidth and spectrum. Enhancement in technical environmental and comprehensive use is leading fourth generation technology to a better global standard and user experience. However, it's not going to stop here, experiments have already been started to revolutionize the advent of fourth generation technology for sure. And 5G would be amazingly amazing with its ultra-features and global mobility that will turn the world in a small global village.

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BIOGRAPHIES

Krishn Kumar Gupt is currenlty pursuing his batchler degree in Electronics from Zakir Husain Delhi College, University of Delhi. He is doing innovation project on biosensor. He is a Summer Research Fellow under Indian Academy Science, erolagnaB. His area of interest is signal communication, robotics and social services. At present, he is engaged in research on Digital Video Broadcasting, Smart LNB and Mobile communication system.

Vinay Kumar Singh is currntly working as Assistant Professor in Department of Electronics. He is B.Tech and M.Tech in Electronics in 2011 and 2013 respectively. His area of interest is signal- system and communication technology.

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