Comparison of 3G and LTE with other Generation

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ABSTRACT
In this paper we give an overview of wireless mobiles, starting form first generation (1G) based on analogue system in 1980, while second generation (2G) which sets initial digital standards focuses on capacity and coverage. Emergence of GSM also belongs to 2G. After that third generation (3G) continues with the upgradation and adoption of new technologies such as UMTS-HSPA and CDMA200 EV-DO to provide high speed, low cost and bring the quality in services. Now Long Term Evolution (LTE)technology encompasses the pillars for next generation i.e. fourth generation(4G) for higher throughput, low latency mobile access, multicast and broadcast media and it sets standards for the deployment of 4G around the world.

This paper provides a view of these generations and gives a comparative study of 3G and LTE. It also provides some important issues and challenges related to LTE.

General Terms
Wireless communication, Mobile Broadband, mobile generations

Keywords
1G, 2G, 3G, LTE, 4G, UMTS

1. INTRODUCTION
Over the past two decades, there are exponential growths which have been recorded in the field of wireless communication and it going to continue due to the emergence of new interactive multimedia application. A key requirement in future wireless system is their ability to provide broadband connectivity with end to end quality of services (QOS), a high network capacity and throughput at low cost [2]. In last few years there have been clear shifts from fixed to mobile cellular telephony. By the end of 2010, there was four times more cellular subscription than fixed telephone line. Evolutions ofmobile network are crosses more than three generation.

Starting with first generation (in 1980's), based on analogue standards fulfills basic mobile voice (voice calls), moving towards second generation (2G) based on initial digital standards introduced the capacity and coverage, in 1990's. On the way to 3G there are many more designing scenarios that have deployed in between 2G and 3G like 2.5G. 2.5G includes all advances upgrade to build 2G a stronger network [2]. 2.5G act as bridge between 2G and 3G. 3G provides data at higher speeds to open the gate for truly "mobile broadband". 3G provides 144kbps of throughput at mobile speeds, 384 kbps at pedestrian speeds and 2 mbps in indoor environment [1]. These requirements are specified by ITU. Now a days LTE (Long Term Evolution) becoming the network technology for choice of 4G deployment around the world, it has the ability to provide very fast, highly responsive data services at low cost. LTE is the initial step taken for the coming generation i.e. fourth generation (4G).

2. EVOLUTION OF GENERATIONS
Electromagnetic waves were first discovered as a communication medium at the end of 19th century. For offering mobile telephone services there are single cell systems which were constrained by restricted mobility, low capacity limited services and poor speech quality beside all these constraints, the equipment was heavy, bulky and expensive.

2.1 First Generation (1G)
In late 1970's and early 1980's the cellular era had started. First generation mobile system provides voice services based on analogue radio transmission techniques. The first cellular system in the world becomes operational by Nippon telephone and Telegraph (NTT) in Tokyo, Japan, in 1979. Semiconductor technology and microprocessor made smaller, lighter weight and more sophisticated mobile systems. The most popular analogue system was:

- *Nordic Mobile Telephone (NMT):*It was the first operational analogue system and was originally introduced into the Nordic countries of Denmark, Finland Sweden and Norway. NMT runs at 450 MHz and 900 MHz, some NMT-450 are still operational but NMT-900 has been closed.
- *Advanced Mobile Phone System (AMPS):*It was launched in 1982 and first has been in operation in North and Latin America. It allocates 40 MHz bandwidth within the 800 to 900 MHz frequency range. Omnidirectional antennas were used in the earlier AMPS implementation then it switched to directional antennas which would yield better cell reuse i.e. 7-cell reuse pattern was adopted for AMPS. AMPS uses frequency division multiple access (FDMA) technology.
- *Total Access Communication System (TACS):*It was derived from AMPS and was introduced as analogue standards for UK. It operates on 900 MHz in UK and 800-900 MHz in China and Japan.
- *Cellular Digital Packet Data (CDPD):* It makes use of excess capacity on the Amps network to provide packetized connection up to 19.2 kbps, inherent data overheads reduce this to a practical operating data rate of around 10kbps.

AMPS and TACS uses the frequency was the frequency modulation (FM) technique for radio transmission. 1G uses FDMA and circuit switched technologies in the network core. All these systems offer handover and roaming capabilities but

the cellular networks were unable to interoperate between countries. This was one of the important disadvantages of 1G mobile network.

2.2 Second Generation (2G)

Second generation (2G) was come into existence at the end of 1980's. It supports low bit rate data services as well as traditional speech services. 2G uses Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) technology. As compared with 1G it provides higher spectrum efficiency, better data service and more advance roaming facilities. Three primary benefits of 2G networks were

- phone conversation were digitally encrypted
- more efficient to offer wider spectrum
- Introduce data services for mobile starting with SMS (short message service) and also serve as battery saver.

To provide a single unified standard the scenario of Global System for Mobile communication (GSM) came into existence. GSM was first deployed by Europe, this enabled services throughout Europe by means of international roaming. GSM provide services like short message service (SMS), picture message and MMS. Through this technology all text messages were digitally encrypted due to which only the intended receiver receives the message. These digital signals consume less battery power, so it helps in saving the battery power of mobile[1]. In GSM main elements are BTS (Base Transceiver Station) , BSC (Base Station Controller) and NSS (Network Switching Subsystem) in which there are a MSC (Mobile Switching Centre), VLR (Visitor location Register), HLR (home Location Register), AC (Authentication Centre) and EIR (Equipment Identity Register). It is capable of providing all the basic services upto 9.6kbps, fax etc. In 2G main attention was devoted to interoperability and standardization. With the enhancement of MSC design, handoff mechanism was introduced. As the requirement for sending data on the air-interface increased, GPRS (General Packet Radio Services) came into existence. This GPRS added new elements such as SGSN (Servicing GPRS) and GGSN (Gateway GPRS) in existing GSM system. These elements of GPRS possible to send packet data on the air-interface, this part of network handling the packet data is called the packet data core network. GPRS also contains IP routers, DNS (Domain Name Server) and firewall servers. GPRS is a radio technology for GSM network which adds packet-switching-protocol, this make it possible to charge by the amount of data sent rather than connection time. Through packet switching, data is sent in the form of packets and then it is routed to the destination based on the address within each packet. GPRS is the most significant step towards 3G and it is scenario that is used in 2.5G which act as a bridge between 2G and 3G. Beside GPRS 2.5G also contain some other technologies such as HSCSD (High Speed Circuit Switched Data), EDGE (Enhanced Data Rates for Global Evolution), these upgrades 2G network to make the existence of 3G possible[1,2,4].

Low power consumption, better security and better bandwidth usage are the advantages over its precedent technologies. 2G supported a large number of calls in the same radio bandwidth and ensures lower power consumption that improved battery life in mobile phones. 2G introduced digital encryption method for better security and privacy. GPRS makes mobile data access faster and cheaper, offers continuous connectivity and access to online services. Addition of EDGE in GSM help in increasing the data rate and this is done by using more sophisticated coding method over the internet which increased the data rate upto 384 Kbps [5]. Difference of 1G and 2G is shown in table 1.

Table 1 . Difference between 1G and 2G

1G	2G
It is analogue based i.e. it transfer voice in analog wave.	It introduced Digital standards i.e. it convert voice into digital code and then into signal.
Technologies: AMPS, NMT, CDPA	Technologies: GSM, CDMA, TDMA etc.
It only support voice calls	It support data along with voice calls
No concept of multiplexing	Allow multiple users on single channel via multiplexing.
No encryption	Data send through network in an encrypted form to provide privacy
Limited network availability (within the country)	More coverage and capacity (connecting all over the world)
Data speed is 5-9 Kbps	Data speed is 9.6-30 Kbps

2.3 Third Generation (3G)

In 2000, 3G enters in the world of wireless mobile communication. EDGE make high-volume movement of data possible, but packet transfer on the air interface still behaves as circuits switch call. It was decided to have a network which serve services that are independent of technology platform and whose network design standards are same globally[1]. Besides these reasons in response to the subscriber growth and demand for data services that require high speed access, 3G came into existence. IMT-200 standards for 3G were defined by the International Telecommunication Union (ITU). Third Generation Partnership Project (3GPP) in an organization that has continued that work by defining a mobile system that fulfill the IMT-200 standards.in Europe it was called UMTS (Universal Terrestrial Mobile System) and CDMA is the name of the American 3G variant. This offers video calls, mobile TV, Location-based services and internet browsing at faster speed. It also provides variable transfer speed ranging between 128 Kbps and 3 Mbps depending on the speed with which mobile device is moving within the network. 3G also provides users with better security. Additional features of 3G upgradation are HSPA (High Speed Packet Access) which helps to improve performance of UMTS. It uses improved modulation scheme which refining the protocols that mobile devices and base station use to communicate. HSDPA (High Speed Downlink Packet Access) and (High Speed Uplink Packet Access) are 14.4 Mbps and 5.76 Mbps respectively. HSPA+ (High Speed Packet Access) which is able to deliver speeds up to 11.5 Mbps and the downlink and 2.8 Mbps on the uplink. IMT-200 standards define the following characteristics for 3G system:

- Used worldwide
- Used for all mobile application
- Support both packet-switched and circuit switched data transmission

- Offer high data rates up to 2 Mbps (depending on mobility)
- Offers high spectrum efficiency

Beyond mobile telephony, the higher speed allowed 3G connection in PC's, gaming consoles, tablets and other portable devices that provide higher quality internet connection.

2.3.1 CDMA2000 1xEv-DO*:* Introduced high speed , packet switch technique for data transmission which enables peak data rate beyond 2 Mbps. 1xEV-DO was initially released as Release 0 (Rel. 0) and then its upgrade known as 1xEV-DO Revision A (Rev. A)

2.3.2 CDMA2000 1xEV-DO Rel. 0: It provides peak speed up to 2.3 Mbps with an average user throughput of between 400 Kbps and 100 kbps. Rel. 0 makes use of existing internet protocols enabling it t support IP base connectivity and Software application. It provides services like music, video, downloads, gaming and television broadcasts.

2.3.3 CDMA2000 1xEV-DO Rev. A: It supports the framework which offers quality of services (QOS) application, reduce latency. It provides services such as ability to send large files, email attachments, pictures and video from mobile devices. Average speeds of Rev. A are 600 to 1400 Kbps for downloads and 500 to 800Kbps for uploads. And peak speeds of 3.1 Mbps for download and 500 to 800 Kbps for upload [6].

3G network was delayed in same countries because of various reasons such as in many countries 3G network do not use the same radio frequencies as 2G, so building an entirely new network and license entirely new frequencies were the biggest issues. Beside these Licensing fees in some European countries were extremely high, other delays were due to the expense of upgrading equipment for the new system. United State is the exception of some of these reasons as there carrier operates 3G services in the same frequencies as other services. But 3G technology is much more flexible as it can support major radio technologies that operate under CDMA, TDMA and FDMA. The main aim of this technology is to allow much better coverage and growth with minimum investment [11]. Difference of 2G and 3G is shown in table 2.

Table 2 . Difference between 2G and 3G

2G	3G
Digital narrow band Circuit data and Packet data	Digital Broadband Packet data
Comparatively slow speed than 3G	Support much higher throughput and speed than 2G
Data services such as SMS, MMS, internet access and SIM cards	Introduced term Mobile Broadband because of its speed and capability , also provide universal access and portability across different device types
Speed : 9.6-30 Kbps	Speed : 3.1 Mbps (peak)/500-700 Kbps
Frequency band: Initially 900 MHz spectrum was used but later GSM introduced 1800 MHz band	Frequency band:1.8-2.5MHz
Technologies: GSM with technological backbone of TDMA	Technologies: UMTS as its core network architecture with HSPA protocol
Voice and data cannot be simultaneously supported	Simultaneously voice and data supported
It consist of only circuit switched network	It uses combination of both circuit switched and packet switched

2.4 Long Term Evolution (LTE)

Although 3G technologies deliver significantly higher bit rate than 2G, there is still more opportunities for wireless operators to fulfill the ever changing demand of wireless broadband such as low latency and multi-megabit throughput. The solution for this is Long Term Evolution (LTE), a Third Generation Partnership Project (3GPP) standards that provides much greater spectral efficiency that the most advanced 3G network [7]. Migration of 2G to LTE is shown in fig. 1[7].

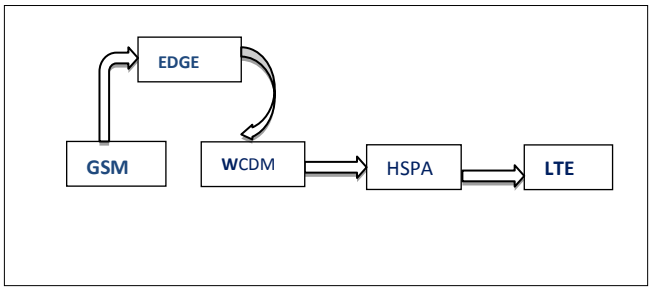

Fig. 1 Migration of wireless broadband

LTE is designed to provide multi-megabit bandwidth, more efficient use of radio network, latency reduction and improved quality. Changes in mobile communication have always been evolutionary and the deployment of LTE will be the same. LTE is the transition from 3G to 4G, as we are still in the stage of transition from 2Gto 3G. As a result mobile operators must look for strategies and solution that enhance their existing 2G and 3G network towards 4G without requiring a complete equipment upgradation. LTE is a solution for this upgradation which is based on new radio access network called OFDM (Orthogonal Frequency Division Multiplexing) technology. Release 8 of 3GPP specified the air-interface for LTE which combines OFDMA base modulation and multiple access schemes for the downlink with SC-FDMA (Single Carrier FDMA) for the uplink. OFDM scheme split available spectrum into thousands of extremely narrowband carriers each carrying a part of the signal and further enhanced with higher order modulation and sophisticated FEC (Forward Error correction) scheme. The result of these radio interface feature is significantly improved radio interface features is significantly improved radio performance yielding up to 5times the average throughput of HSPA [9]**.** Uplink Downlink rates compared for HSPA and LTE shown in fig 2 [9].

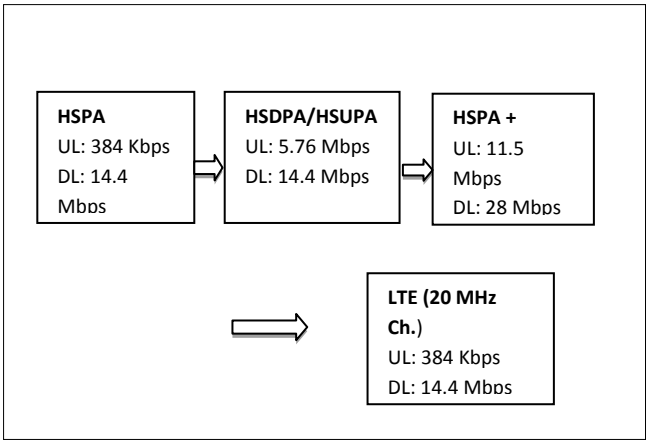

Fig. 2 Uplink Downlink rates compared for HSPA and LTE

The multimedia are network of LTE will pay a central role in enhancing mobility, efficient use of network resources, service control and a smooth migration from 3G to 4. This is the multimedia core network which meets the requirements of System Architecture Evolution (SAE), the 4G core architecture of the LTE standards. SAE calls for a transition to a flat, all IP core network called Evolved Packet Core (EPC), which features a simplified architecture and open interfaces as defined by the 3GPP standard body. EPC enables operates to launch services and application with internet speed while also reducing the overall cost per packet. EPC also able to address divergent mobility management problem. It supports all access technologies, including 2G, 3G, and 4G from all standards-defining organization. EPC specification call out the Mobility management Entity (MME), Servicing Gateway (SGW) and Packet Data Network Gateway (PGW) as specific network function, these three functions can logically be integrated into one node [7].

2.4.1 Key consideration of LTE is[7,9]:

- Integration of intelligence at the access edge: this intelligence includes quality of services (QOS) and policy enforcement.
- Simplified network topology: in order to deliver the enhanced performance of LTE effectively, the network need to be simplified and patterned, by reducing the elements involve in data processing and transport.
- Converged mobility and policy: maintain the subscriber session is an important consideration during 4G to 2G or 4G to 3G mobility events
- Increase performance characteristics.
- Migration from 2G to 4G or 3G to 4G: mobile operators needs to minimize costs to avoid a complete equipment upgrade while deploying solution based on open standards.

Solution designed for the specific requirements of the next generation multimedia core network include the capacity to support2G, 3G and 4G function in a single platform [7,9]. Difference of 3G and LTE is shown in table 3.

2.4.2 Implication of LTE on mobile Transport:

- High capacity at lower cost
- Multiservice transport
- Low latency and quality of services (QOS)
- Convergence of backhaul/backbone
- Increased connectivity and load sharing
- Re-configurability and network agility
- Accurate clock synchronization
- Security

Table 3. Difference between 3G and LTE

3G	LTE
Comparatively less speed and quality than LTE	Support much more speed and quality than 3G
Video calling and seamless streaming of video possible with download speed up to 3.1Mbps	Support HD video streaming, download speed as high as 299.6 Mbps
Radio technology: Uses TDMA , CDMA	Radio technology: OFDM (orthogonal FDMA)
Speed : 3.1 Mbps (peak)/500-700 Kbps	100-300Mbps (peak)/ 3-5 Mbps
Frequency band : 1.8-2.5GHz	Frequency band : 2-8 GHz
UMTS and CDMA2000 standards are used	In this multiple radio standards unified into a single IP network
Simultaneously voice and data supported	Simultaneously voice and data supported at higher data rates than 3G
It uses combination of both circuit switched and packet switched	Use only packet switched network

Table 4 : Comparison between 1G 2G 3G and LTE

	1G	2G	3G	4G-LTE
Definition	Analogue based	Digital narrow band Circuit data and Packet data	Digital Broadband Packet data	Integration of intelligence at the access edge include quality of service
Services	Voice calls only	SMS, MMS, internet access and SIM cards	Video call, mobile TV, location based service, internet access at faster speed. Universal access and portability across different device types	High definition streaming,IPv6 support and QOS

Radio Technologies	None	CDMA, TDMA	CDMA, TDMA, FDMA	OFDMA (Orthogonal FDMA), SC-FDMA (Single Carrier FDMA)
Throughput/ Speed	5.9 Kbps	9.6-30 Kbps	3.1 Mbps (peak)/500-700 Kbps	100-300Mbps (peak)/ 3-5 Mbps
Frequency band		Initially 900 MHz spectrum was used but later GSM introduced 1800 MHz band	1.8-2.5GHz	2-8 GHz
Technologies	AMPS,NMT,TACS,CDPA	GSM with backbone of TDMA	UMTS as its core network architecture with HSPA protocols	MIMO(multiple input and multiple output) with backbone f OFDMA and SC-FDMA
Standards	Analogue	GSM, GPRS(2.5G), EDGE(2.75G)	UMTS and CDMA2000 standards	Multiple radio standard unified into a single IP network
Voice and data support	Voice support only	Voice and data cannot be simultaneously supported	Simultaneously voice and data supported	Simultaneously voice and data supported at higher data rates than 3G
Switching technique	None	circuit switched network	circuit switched and packet switched network	Use only packet switched network, thus lowering latency and enhancing access quality

3. ISSUES AND CHALLENGES OF LTE

- Lack in providing traditional services: biggest issue of LTE is that it is lack in supporting of traditional services such as voice calls, text messages, multimedia messaging etc. Due to which LTE cannot replace current 2G and 3G network. Recently solution of this problem is proposed by adding VoLTE (Voice over LTE) but further research is continues to overcome other difficulties relate to traditional services in LTE.
- LTE Roaming Issue: LTE global roaming is impossible because of LTE spectrum bands which don't match across different countries.
- Migration of 3G to LTE: Cost is the major issue in migration of 3G in LTE. Currently, commercial services are available from the most wireless carriers and these commercial services charge on monthly basis which prove costly for large agencies. Commercial networks are not built to be- mission critical. Tower sites are built without taking care to protect the network components, and without generators, to make them sustainable at the line of long power failure [13].
- Handover calls from 3G to LTE and vice-versa is an issue in using LTE.
- Battery life: LTE consumes more battery in LTE-enable devices due to its high bandwidth technology [13].

4. CONCLUSION

In this paper the evolution of various generations of wireless mobile communication is provided. Overview of services, technologies, standards of 1G, 2G, 3G and LTE were discussed. Comparison of LTE (which is current technology of mobile wireless) with their preceding technologies are given. It also highlights few potential issues and challenges of LTE. In order to achieve the complete implementation of LTE we should promote further research and innovation to meet the issues and challenges of LTE.

In this literature study we have identified few major issues and challenges of LTE. More research work needs to be done to overcome these limitations. We shall do further research and find out some solution to resolve the issues related to security and battery life.

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