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A Technical Review of Long Term Evolution (LTE) Operations

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ABSTRACT : *Over the years, the third generation (3G) broadband technology has been used for wireless communication in numerous countries due to its wireless network access and promising features. In order to overcome the capacity, speed, and network coverage limitation of the 3G network, Long Term Evolution (LTE) which is a fourth generation (4G) network was introduced to enhance the role of the 3G network. The LTE is a wireless broadband technology used to eradicate these issues by enabling improvements in capacity increase, fast data transfer speed, low latency, and a packet optimized radio access technology to support the deployment of bandwidth. The network architecture of the LTE system is designed to support a packet-switched traffic with seamless mobility and excellent network quality of service. Hence, this paper examines the LTE operations, using the LTE system architecture diagram, Prospects and Challenge.*

Keywords – *Antennas, Bandwidth, broadband, Core Network (CN), Long Term Evolution (LTE)*

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I. INTRODUCTION

The United States began to develop the Advanced Mobile Phone Service (AMPS) network, while European countries were developing their own forms of communication. However, when Europeans quickly realized the disadvantages of each European country operating on their mobile network, it prevented cell phone use from country to country within Europe. With the emerging European Union and high travel volume between countries in Europe, this was seen as a problem. Rectifying the situation, the Conference of European Posts and Telegraphs (CEPT) assembled a research group with intentions of researching the mobile phone system in Europe. This group was called Group Spécial Mobile (GSM). In 1989 work done by the GSM group was transferred to the European Telecommunication Standards Institute (ETSI). The name GSM was transposed to name the type of service invented. The acronym GSM had been changed from Group Spécial Mobile to Global System for Mobile Communications [1]. In order to overcome the capacity, speed, and network coverage limitation of the 3G network, Long Term Evolution (LTE) which is a fourth generation (4G) network was introduced to enhance the role of the 3G network [2]. The evolution of mobile communication network is depicted diagrammatically in figure 1 [7] below.

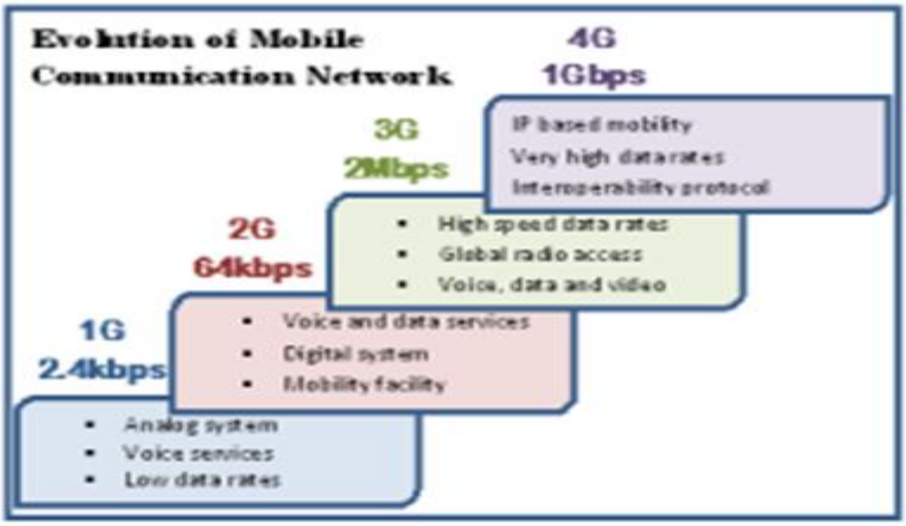

Fig 1. Evolution of Mobile Communication Network

LTE has become the most successful wireless broadband technology, providing wireless service to over one billion users as of the beginning of 2016 and handling a wide range of applications. LTE has greatly evolved from the analog voice-only service it rendered over 25 years ago, to the current stage of development of the fourth generation, and heading towards the fifth generation of mobile broadband technology [3]. LTE has revolutionized our communication services by ensuring telephony and internet access availability from almost everywhere and anytime with extremely fast data speeds for uploads and downloads. LTE enables voice calls, data services, video calls and multimedia applications [10]

LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) for system improvement, such as; improved capacity and coverage, improved end-user throughputs, improved user experience with full mobility, reduced operation cost, flexible bandwidth operation and seamless integration with existing systems [10]. LTE uses an Internet Protocol based core network to achieve a successful network service. Quality of service operations are made standard on all interfaces for the purpose of ensuring that the prerequisite of voice calls for delay reduction and improved bandwidth can be sufficiently met when capacity limits have been attained. LTE system provides a peak data rate of 100Mbps in the downlink and 50 Mbps in the uplink [5]. 4G also known as IMT-Advanced was first launched in 2010 to implement the only packet-switching technique. It is integrated with one Core Network and several Radio Access Networks (RANs) and provides a complete IP-based network of 100 Mbps to 1 Gbps speed with a frequency of 2–8 GHz. Since the range of coverage was smaller due to high speed, it became necessary to incorporate multiple smart antennas to support long-range communication. Good Quality of Service (QoS) and data rates in 4G support services with better clarity; such services include but are not limited to Mobile Television, High Definition Television (HDTV) content, Digital Video Broadcasting (DVB), Video Chat, Multimedia Newspapers, and High-Quality Live streaming. 4G offers ultra-low latency compared to 3G. Long Term Evolution (LTE) and WiMAX (World Wide Interoperability for Microwave Access) are the dominant technologies employed by 4G. While LTE offers downlink data rates of 100 Mbps and uplink of 50 Mbps, WiMAX on the other hand allows downlink data rates of 75 Mbps and uplink of 25 Mbps [12]

II. LTE ADVANCED (LTE-A)

The LTE Advanced is a mobile communication technology, which is a major enhancement of the Long Term Evolution technology. LTE is often times called 4G whereas the LTE Advanced is the true step toward the future of LTE [6]. LTE Advanced is compatible with the initial LTE technology. LTE Advanced engaged a good number of techniques that aided better performance and higher data rates, particularly at cell edges and other areas where performance would not usually have been great [6].

LTE and LTE Advanced make use of multiple input multiple output (MIMO) which enables data rates to be increased to a great length. MIMO is a type of antenna technology which makes use of multiple antennas to allow signals travelling through different paths to be unconnected, thus, their capacity is used to enhance the data throughput and/or the signal to noise ratio, which ultimately improves the system performance [5].

Key features of LTE Advanced include:

- Spectrum efficiency which is three (3) times greater than LTE.

- Peak data rates of 1Gbps in the downlink and 500Mbps in the uplink.
- Peak spectrum efficiency of 30bps/Hz in the downlink and 15bps/Hz in the uplink.
- Spectrum use: scalable bandwidth use and spectrum aggregation are both supported.
- Low Latency: From idle time to connected in less than 50ms and then shorter than 5ms one way or for individual packet transmission.
- Cell edge user throughput is two (2) times that of LTE.
- Average user throughput time is three (3) times that of LTE.
- Mobility is the same as that of LTE.
- Compatibility state between LTE-A and LTE is very good [4]

III. LTE NETWORK PRINCIPLE OF OPERATIONS

The main components of the LTE network architecture are the User Equipment (UE), the Evolved UMTS terrestrial radio access network (E-UTRAN), and the Evolved Packet Core (EPC).

The EPC key components include:

- The Mobility Management Entity (MME): This handles the session states and ensures authentication of a user as well as tracking a user across the network.
- Serving Gateway (S-Gateway): This routes data packets through the access network.
- Packet Data Node Gateway (PGW): This acts as the interface between the LTE network and other packet data networks [2].

These are all shown in fig. 2 [2] below.

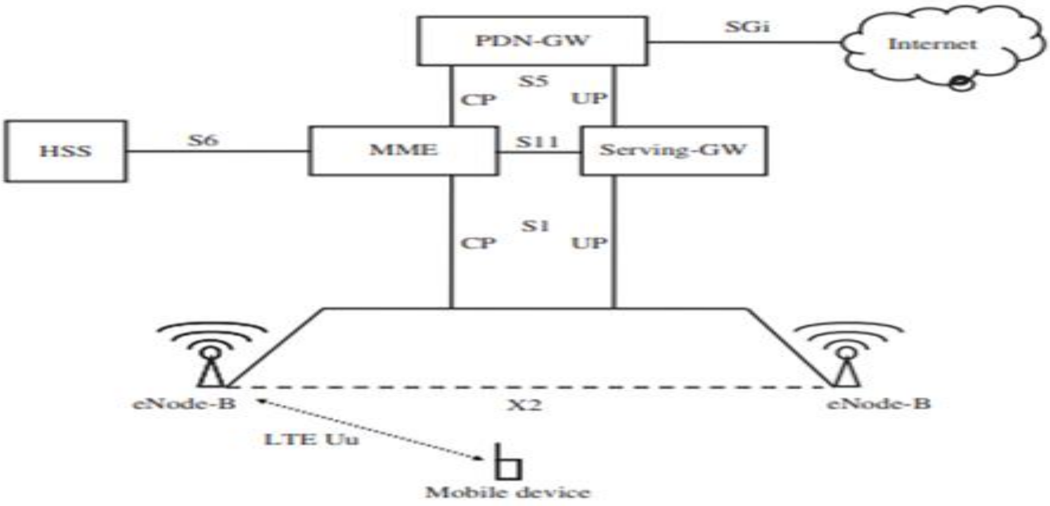

Figure 2: LTE Network Architecture

LTE UEs are also known as Mobile stations (MS) or LTE data terminals or devices that are of standard to access the internet via 4G LTE network, such as the mobile phones, smart TVs, WiFi devices, tablets etc. LTE E-UTRAN consists mainly of the eNodeB (eNB), providing air interface for data traffic to and fro user equipment, eNodeB does several important functions such as Radio Resource Management (RRM), radio bearer control, radio admission control, mobility connection control, radio resource scheduling , packet compression and ciphering, routing of User Plane Data towards S-GW (Serving Gateway), packet scheduling and transmission of broadcast information and paging messages, measurement, reporting, configuration and reconfiguration of E-UTRAN parameters, load control, admission control etc [13]. The eNode-Bs consist of three major elements: The antennas, which are the most visible parts of a mobile network; Radio modules that modulate and demodulate all signals transmitted or received on the air interface; Digital modules that process all signals transmitted and received on the air interface and that act as an interface to the core network over a high- speed backhaul connection.

The general LTE network architecture has two parts, which are; radio network part and a core network part [4]. One of the complex mechanisms in the LTE network is the radio base station, referred to as eNode- B. The name is obtained originally from the UMTS base station (Node- B) with an 'e' referring to 'evolved' [6]. The UMTS radio network is referred to as the UTRAN (Universal Mobile Telecommunications System Terrestrial Radio Access Network), while the LTE radio network is referred to as the E- UTRAN [4].

The eNode- Bs consist of three major elements:

1. The antennas. They are the most visible parts of a mobile network;

2. Radio modules. These modulate and demodulate all signals being transmitted or received on the air interface;

3. Digital modules. They process all signals transmitted and received on the air interface which interface with the core network over a high- speed backhaul connection [3].

This means that the eNode- B is responsible for air interface as well as the following outlined below:

- ✓ Air interface resources and user management is scheduled efficiently;
- ✓ QoS management, such as; enabling latency and minimum bandwidth requirements for real- time bearers and maximum throughput for background applications based on user profile;
- ✓ Load is balanced between various simultaneous radio bearers to different users;
- ✓ Mobility management;
- ✓ Interference management, which means, minimizing the effect of its downlink transmissions on surrounding base stations in cell- edge scenarios [2].

The physical routing of the S1 and the X2 interface is depicted below in fig. 3 [2].

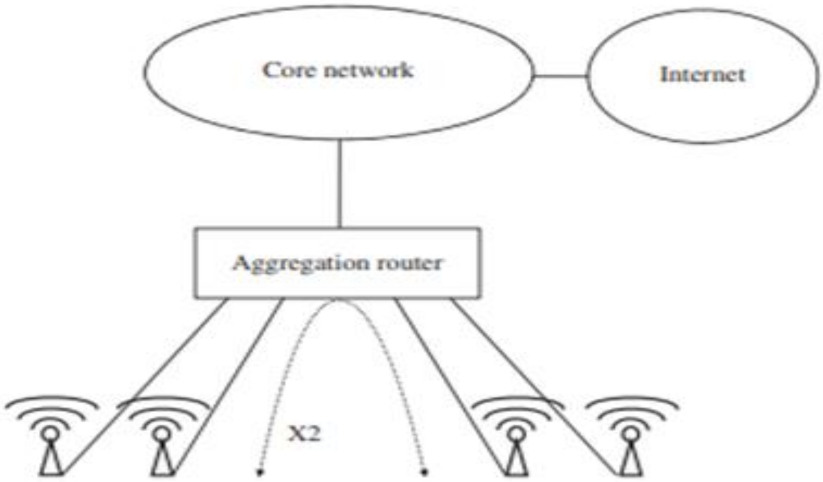

Fig. 3 Physical Routing of the S1 and the X2 Interface

The SI interface is the interface between the core network and the base station. Similar to the S1 interface, the X2 interface is self-reliant, while IP is used on layer 3. The X2 interface connects base stations directly with each other [6]. The network node tasked with signaling exchanges between the base stations and the core network between users is the Mobility Management Entity (MME). The MME is responsible for authentication, establishment of bearers, NAS mobility management, handover support, interworking with other radio networks, SMS and voice support [4].

The S- GW handles management of user data tunnels between the eNode- Bs in the radio network and the Packet Data Network Gateway (PDN- GW), which is the gateway router to the Internet. Single user S1 and S5 tunnels are not dependent on one another and can be changed [3]. The PDN- GW equally assigns IP addresses to mobile devices. The HLR and the HSS are joined to ensure seamless roaming between the various radio access networks [2]. There are some very essential user parameters in the HSS and they are:

- The user's International Mobile Subscriber Identity (IMSI), which uniquely identifies a subscriber.
- Authentication information which is used to authenticate the subscriber and generate encryption keys on a session basis;
- Circuit- switched service properties, such as; the user's telephone number, referred to as the Mobile Subscriber Integrated Services Digital Network (MSISDN) number.
- A copy of the IMSI is stored on the subscriber identity module (SIM) card of the subscriber;
- Packet- switched service properties such as the Access Point Names (APNs) the subscriber is allowed to use.
- IMS- specific information
- the ID of the current serving MSC so that incoming circuit- switched calls and SMS messages can be routed correctly;
- The ID of the SGSN or MME, is used in the event that the user's HSS profile is updated, so as to move the changes to the network elements.

The basic architecture of LTE contains a separate IP connectivity layer for all the IP based services and evolved packet system (EPS) which handles the overall communication procedure.

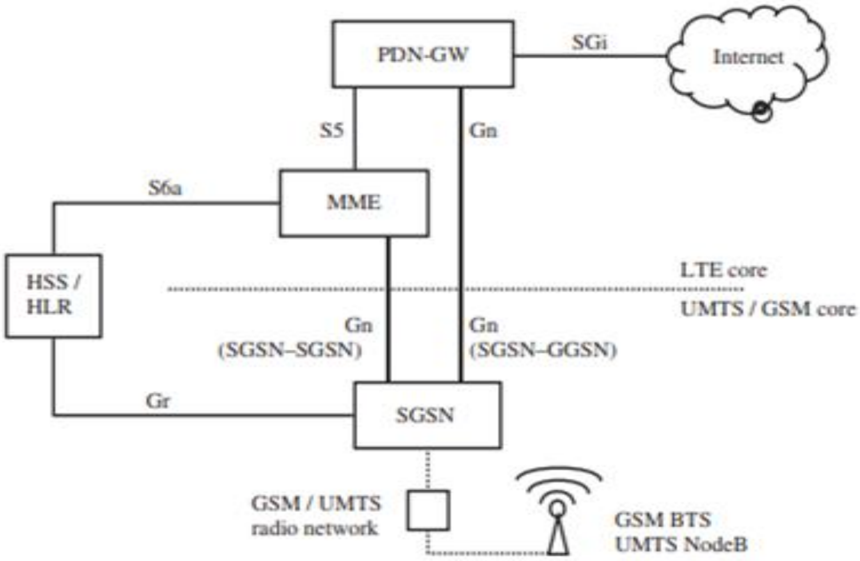

Fig. 4 Interconnection of LTE to GSM and UMTS Networks

There has to be a connection between the LTE network, GSM and UMTS networks to ensure that the subscriber's context, which is; the assigned IP address, quality of service settings, authentication and ciphering keys, etc., can be exchanged in a seamless way between all the core network components. This is depicted in fig. 4 [2].

The basic principles for LTE include:

- A packet-based architecture where events in real-time can take place.
- Reduction in number of interfaces.
- Reduction of delay variation for traffic which needs low delay jitter.
- An end-to-end quality of service to manage the different types of traffic.
- An enhanced user experience focusing on more services with reduced cost and high speed [14].

IV. ADVANTAGES AND DISDVANTAGES OF LTE SYSTEMS

Table 1.0 [11] summarizes the advantages of the LTE system and the disadvantages of the LTE system. It shows that the advantages of the LTE system surpass the disadvantages of the LTE system. This essentially means that the LTE system is more of an advantage to be in existence than a disadvantage.

Table 1.0 Advantages and Disadvantages of the LTE System

S/N	Advantages	Disadvantages
1	Higher bandwidth (faster data transfer speed)	LTE is not currently available in all cities in countries all over the world.
2	Lower Latency (faster response time)	LTE is a complex system that requires only skilled people to maintain and manage the system.
3	Improved spectrum efficiency (increase in overall network capacity)	More towers and new technologies need to be developed for better signals while in transit, for instance; in buses and trains.
4	High security wireless cellular network	LTE technology cannot be used in old versions of smart phones. It requires smart mobile phones which support LTE functionality.
5	Highly reliable when a good LTE signal is available	Purchase of new current version of smart phones for the sole purpose of making use of the LTE system is a costly affair.
6	Data and voice exchange between participants due to packet switching	It requires smart mobile phones which support LTE functionality
7	Transfer of high amount of data between the sender and receiver	More towers and new technologies need to be developed for better signals
8	All data consumption occurs to low power consumption leading to longer and better lifespan of smart phone batteries	Purchase of new current version of smart phones for the sole purpose of making use of the LTE system is a costly affair
9	High speed of file uploads and downloads	More towers and new technologies need to be developed for better signals
10	Higher versions of LTE such as; LTE Advanced (LTE-A) will further improve the performance of existing LTE standard based products.	More towers and new technologies need to be deployed

V. CONCLUSION

LTE has become the most successful mobile wireless broadband technology, with the fifth generation already in place and the sixth generation in the beginning stages. Currently, there are over 5 billion 4G LTE and over 300 million 5G subscriptions globally. The LTE wireless technology have evolved from the voice-only 1G to 6G having voice, SMS, data, video, etc., capacities currently. The LTE Advanced is a major enhancement of LTE technology. This is a massive evolution, which is still on-going by the day. Within the next 5 years, we expect LTE to be even more successful than it already is today. We expect LTE to be available in all cities in countries all over the world, to have more towers and new technologies for better signals while in transit, for instance; in buses and trains, to be able to provide faster data transfer speed, faster response time, and more increase in overall network capacity.

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