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Exploration of Fourth Generation – LTE Wireless System and Design: A Survey

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***Abstract*—With the progressive and emerging technology in wireless communication, revolutionized the way people communicate. The development of Wireless Technologies in recent years reflected into significant growth of High Speed Communication means like LTE. To cope with the needs of users 4G-LTE (Fourth Generation-Long Term Evolution) is next generation in mobile network development which intended to provide seamless and much faster data services.**

This paper expresses evolution and growth of 4G-LTE networks. In addition, it presents a discussion about fundamental design, architecture of technology. A brief discussion regarding impact of this technology in market and It's ratio of acceptance in market.

Keywords—LTE;OFDMA;3GPP;UMTS;

I. INTRODUCTION

Recently, mobile Internet access has grown significantly. Each generation has been a giant stride which revolutionized the field of mobile communication. Many any technologies have revolutionized life throughout the history of humanity, from the creation of hand tools, to mechanical devices, powered machines and automated robotic processes and manufacturing. But among these myriad inventions and discoveries, mobile communications stands out as a giant in terms of the combined speed of adoption and the extent of the global transformation it has driven.

The organization of the paper is as follows. The next section provides an insight into evolution of LTE, Technical specification of LTE followed by Network Architecture and Protocol Stack Layer. Then, Section III gives a glance over OFDM Technology. In Section IV Acceptance of technology is highlighted. Finally, Section V concludes the study.

II. OVERVIEW TO LTE

A. LTE Evolution Over Time

LTE stands for Long Term Evolution and it was initiated as a project in 2004 by telecommunication body known as the Third Generation Partnership Project (3GPP). SAE (System Architecture Evolution) is the corresponding evolution of the GPRS/3G packet core network evolution. The term LTE is typically used to represent both LTE and SAE.

LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication System (UMTS), which in turn evolved from the Global System for Mobile Communications (GSM). Even related specifications were formally known as the evolved UMTS terrestrial radio access (E-UTRA) and evolved UMTS terrestrial radio access network (E-UTRAN) [1].

A rapid increase of mobile data usage and emergence of new applications such as MMOG (Multimedia Online Gaming), mobile TV, Web 2.0, streaming contents have motivated the 3rd Generation Partnership Project (3GPP) to work on the Long-Term Evolution (LTE) on the way towards fourth-generation mobile.

The main goal of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. Same time its network architecture has been designed with the goal to support packet-switched traffic with seamless mobility and great quality of service.

Year	**Event**
Mar 2000	Release 99 - UMTS/WCDMA
Mar 2002	Rel 5 - HSDPA
Mar 2005	Rel 6 - HSUPA
Year 2007	Rel 7 - DL MIMO, IMS (IP Multimedia Subsystem)
November 2004	Work started on LTE specification
January 2008	Spec finalized and approved with Release 8
2010	Targeted first deployment

Table 1. 3GPP Release

FDD evolution	WCDMA	HSDPA/ HSUPA	HSPA+	LTE and HSPA+	LTE-advanced
TDD evolution	TD-SCDMA	TD-HSDPA	TD-HSUPA	TD-LTE and TD-HSPA+	
3GPP release	3GPP Release 99/4	3GPP Release 5/6	3GPP Release 7	3GPP Release 8	3GPP Study Item initiated
App. year of network rollout	2003/4	2005/6 (HSDPA) 2007/8 (HSUPA)	2008/2009	2010	
Downlink data rate	384 kbps (typ.)	14 Mbps (peak)	28 Mbps (peak)	LTE: 150 Mbps* (peak) HSPA+: 42 Mbps (peak)	100 Mbps high mobility 1 Gbps low mobility
Uplink data rate	128 kbps (typ.)	5.7 Mbps (peak)	11 Mbps (peak)	LTE: 75 Mbps (peak) HSPA+: 11 Mbps (peak)	
Round Trip Time	~ 150 ms	< 100 ms	< 50 ms	LTE: ~10 ms	

Fig 1. LTE Evolution with 3GPP Release Time Line

Above Figure shows the evolution of LTE with respective release version associated with 3GPP [2].

LTE introduced to get higher data rates, 300Mbps peak downlink and 75 Mbps peak uplink. In a 20MHz carrier, data rates beyond 300Mbps can be achieved under very good signal conditions.

It is an ideal technology to support high date rates for the services such as voice over IP (VOIP), streaming multimedia, videoconferencing or even a high-speed cellular modem. It uses both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) mode. In FDD uplink and downlink transmission used different frequency, while in TDD both uplink and downlink use the same carrier and are separated in Time.

LTE supports flexible carrier bandwidths, from 1.4 MHz up to 20 MHz as well as both FDD and TDD. LTE designed with a scalable carrier bandwidth from 1.4 MHz up to 20 MHz which bandwidth is used depends on the frequency band and the amount of spectrum available with a network operator.

B. LTE Specifications

This Section will summarize the basic parameters of specification of the LTE [2].

Frequency Range	**UMTS FDD bands and UMTS TDD bands**					
Channel bandwidth, 1 Resource Block=180 kHz	**1.4 MHz** 6 Resource Blocks	**3 MHz** 15 Resource Blocks	**5 MHz** 25 Resource Blocks	**10 MHz** 50 Resource Blocks	**15 MHz** 75 Resource Blocks	**20 MHz** 100 Resource Blocks
Modulation Schemes	**Downlink:** QPSK, 16QAM, 64QAM **Uplink:** QPSK, 16QAM, 64QAM (optional for handset)					
Multiple Access	**Downlink:** OFDMA (Orthogonal Frequency Division Multiple Access) **Uplink:** SC-FDMA (Single Carrier Frequency Division Multiple Access)					
MIMO technology	**Downlink:** Wide choice of MIMO configuration options for transmit diversity, spatial multiplexing, and cyclic delay diversity (max. 4 antennas at base station and handset) **Uplink:** Multi user collaborative MIMO					
Peak Data Rate	**Downlink:** 150 Mbps (UE category 4, 2x2 MIMO, 20 MHz) 300 Mbps (UE category 5, 4x4 MIMO, 20 MHz) **Uplink:** 75 Mbps (20 MHz)					

Fig 2. LTE Key Parameters

Frequency bands for LTE are classified in UMTS FDD and TDD Bands. E-UTRA Operating bands are tabulated below. [3].

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) operating band BS transmit UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894MHz	FDD
6	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	FDD
10	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	FDD
11	1427.9 MHz – 1452.9 MHz	1475.9 MHz – 1500.9 MHz	FDD
12	698 MHz – 716 MHz	728 MHz – 746 MHz	FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	FDD
...			
33	1900 MHz – 1920 MHz	1900 MHz – 1920 MHz	TDD
34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
35	1850 MHz – 1910 MHz	1850 MHz – 1910 MHz	TDD
36	1930 MHz – 1990 MHz	1930 MHz – 1990 MHz	TDD
37	1910 MHz – 1930 MHz	1910 MHz – 1930 MHz	TDD
38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD

Table 2. E-UTRA Operating Bands

C. LTE Network Architecture

This section describes architectural components of LTE System. As shown below, It represents High Level Architecture of LTE comprised of three main Components [4].

1. The User Equipment (UE).
2. The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
3. The Evolved Packet Core (EPC)

The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem. The interfaces between the different parts of the system are denoted Uu, S1 and SGi as shown below [4]:

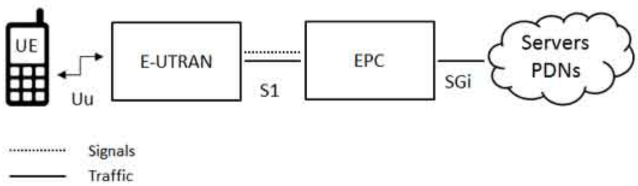

Fig 3. High-Level Network Architecture of LTE

1. The User Equipment (UE)

The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment (ME). The mobile equipment comprised of the following important modules [5]:

Mobile Termination (MT):
This handles all the communication functions.

Terminal Equipment (TE):
This terminates the data streams.

Universal Integrated Circuit Card (UICC):
This is also known as the SIM card for LTE equipments. It runs an application known as the Universal Subscriber Identity Module (USIM).

A USIM stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

2. The E-UTRAN (The Access Network)

The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been illustrated below [6].

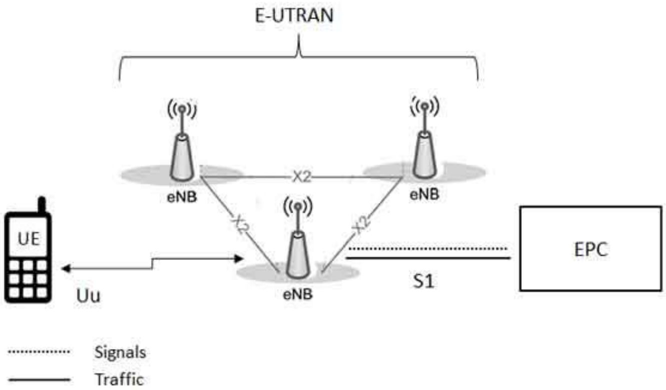

Fig 4. The E-UTRAN (The Access Network)

The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called **eNodeB** or **eNB**. Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB.

LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB:
The eBN sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.
The eNB controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.

Each eBN connects with the EPC by means of the S1 interface and it can also be connected to nearby base stations by the X2 interface, which is mainly used for signalling and packet forwarding during handover.

A home eNB (HeNB) is a base station that has been purchased by a user to provide femtocell coverage within the home. A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

3. The Evolved Packet Core (EPC) (The Core Network)

The architecture of Evolved Packet Core (EPC) has been illustrated below. There are few more components which have not been shown in the diagram to keep it simple. These components are like the Earthquake and Tsunami Warning System (ETWS), the Equipment Identity Register (EIR) and Policy Control and Charging Rules Function (PCRF) [7].

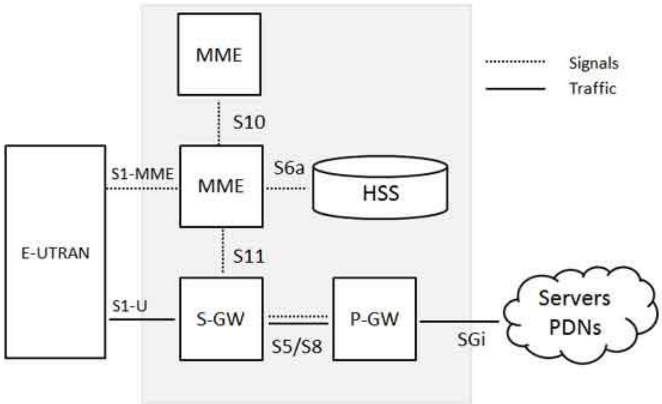

Fig 5. The Evolved Packet Core (EPC)

Below is a brief description of each of the components shown in the above architecture:

The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.

The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world ie. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.

The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.
The mobility management entity (MME) controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server (HSS).

The Policy Control and Charging Rules Function (PCRF) is a component which is not shown in the above diagram but it is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the

Policy Control Enforcement Function (PCEF), which resides in the P-GW.

The interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different networks.

Following diagram shows the functional split between the E-UTRAN and the EPC for an LTE network[6].

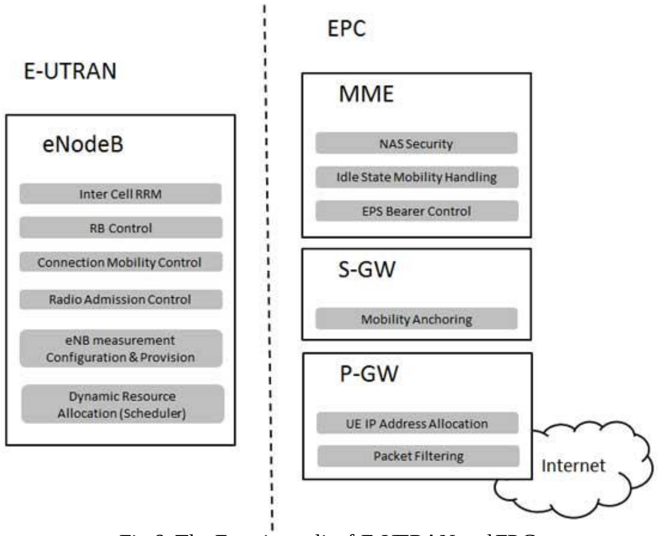

Fig 6. The Function split of E-UTRAN and EPC

III. OFDM TECHNOLOGY

Orthogonal frequency division multiplexing (OFDM) is a special case of multicarrier transmission in which a single information-bearing stream is transmitted over many lower rate sub-channels[8]. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL Internet access, wireless networks, power line networks, and 4G mobile communications.

OFDM is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels.

To overcome the effect of multi path fading problem available in UMTS, LTE uses Orthogonal Frequency Division Multiplexing (OFDM) for the downlink - that is, from the base station to the terminal to transmit the data over many narrow band careers of 180 KHz each instead of spreading one signal over the complete 5MHz career bandwidth i.e. OFDM uses a large number of narrow sub-carriers for multi-carrier transmission to carry data [4].

Orthogonal frequency-division multiplexing (OFDM), is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method.

OFDM meets the LTE requirement for spectrum flexibility and enables cost-efficient solutions for very wide carriers with high peak rates. The basic LTE downlink physical resource can be seen as a time-frequency grid, as illustrated in Figure below:

The OFDM symbols are grouped into resource blocks. The resource blocks have a total size of 180kHz in the frequency domain and 0.5ms in the time domain. Each 1ms Transmission Time Interval (TTI) consists of two slots (Tslot).

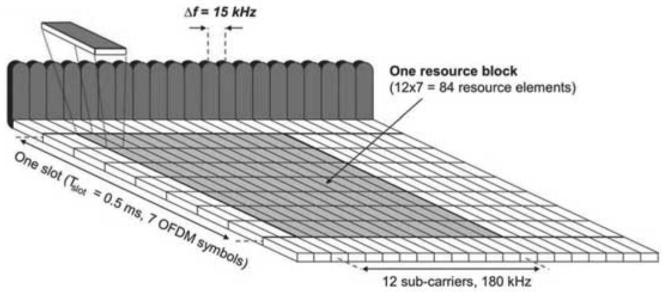

Fig 7. OFDM : Physical Resource in Time-Frequency Grid

Each user is allocated a number of so-called resource blocks in the time- frequency grid. The more resource blocks a user gets, and the higher the modulation used in the resource elements, the higher the bit-rate. Which resource blocks and how many the user gets at a given point in time depend on advanced scheduling mechanisms in the frequency and time dimensions.

The scheduling mechanisms in LTE are similar to those used in HSPA, and enable optimal performance for different services in different radio environments.

A. SC-FDMA Technology

LTE uses a pre-coded version of OFDM called Single Carrier Frequency Division Multiple Access (SC-FDMA) in the uplink. This is to compensate for a drawback with normal OFDM, which has a very high Peak to Average Power Ratio (PAPR).

High PAPR requires expensive and inefficient power amplifiers with high requirements on linearity, which increases the cost of the terminal and drains the battery faster.

SC-FDMA solves this problem by grouping together the resource blocks in such a way that reduces the need for linearity, and so power consumption, in the power amplifier. A low PAPR also improves coverage and the cell-edge performance.

IV. ACCEPETANCE IN MARKET

From present statistics of market, It seems LTE is having very booming and competitive platform. As per reference [9], Time on LTE by Country and Network is shown below:

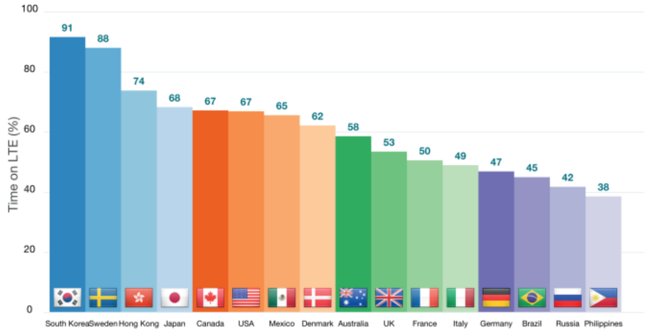

Fig 8. Time on LTE by Country

For the 'Time on LTE' metric, we see South Korea performing best, with the average SK user having access to LTE 91% of the time. The best performing individual network is Tele 2 Sweden, whose users have LTE access 93% of the time. Sweden perform extremely well overall, with the average user having access to LTE 88% of the time, showing the success of a rollout that began back in 2009 [9].

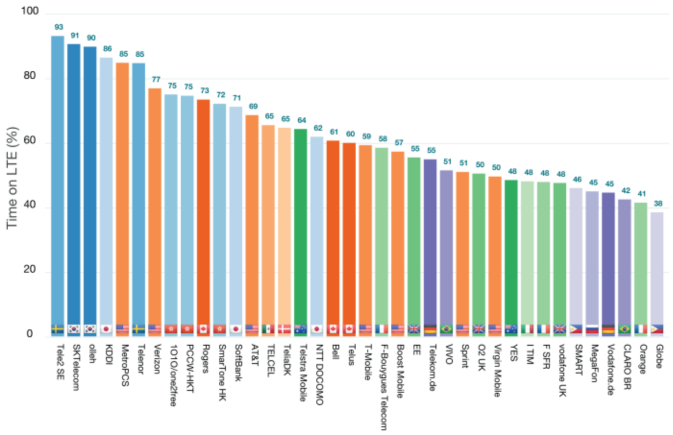

Fig 9. Time on LTE by Network

Looking at coverage goes some way towards mitigating the USA's speed performance. The USA performs well for coverage metric, with the average user experiencing LTE coverage 67% of the time, with Australia, the fastest country, on 58% [9].

Since Last Time (2013-2014) Mobile Networks rolling out to new areas and making improvements. Australia and Japan have made the biggest improvements, with Australia's average speeds increasing 42% to 24.5Mbps and Japan improving 66% to 11.8Mbps. The USA suffers the biggest decline, with average speeds falling 32% to 6.5 Mbps, the second slowest global average [9].

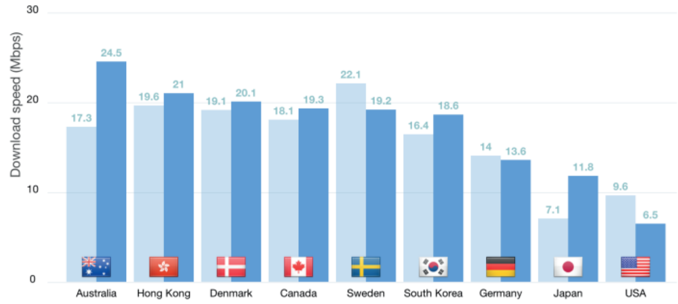

Fig 10. Year 2013-14 Q1 Data

Even LTE is having tremendous speed improvements compare to other technologies [9].

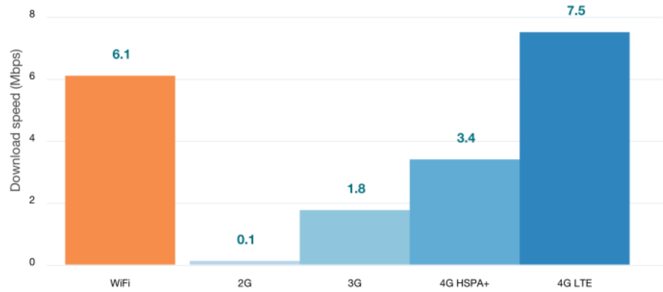

Fig 11. LTE vs Other Technologies

On average LTE is the fastest wireless technology worldwide, representing a real increase in speed on both 3G and HSPA+. 4G LTE is over 5x faster than 3G and over twice as fast as HSPA+ and represents a major leap forward in wireless technology [9].

V. CONCLUSION

From past to present, attempts have been made to reduce latency and to enhance the QoS of Mobile Communication. LTE is one of the widely used technologies at globe. This will fulfill and be the most adopted upcoming technology in near future.

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