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A Comparative Review of Improvements in Long Term Evolution

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***Abstract*— Long Term Evolution (LTE) is one of the major technologies on the rise in the world as of today. It is a 4G network launched by the Third Generation Partnership Project (3GPP). LTE Release 8 was the first standard that launched LTE network with an entire change of radio interface and core network. It was designed to offer higher data rate and capacity over mobile networks to accommodate increase in the number of users and data services. In addition the design was made to support simplified architecture with only packet switched services in order to ensure negligible interference; hence supporting real time application with reduced latency and higher efficiency. Furthermore, the continuous growth in data usage has created a need to take an evolutionary step for an efficient and continuous development of LTE. This step has brought about more upgrades and releases such as 3GPP Release 10, Release 11 and Release 12, otherwise known as LTE Advanced (LTE-A). It is widely believed that this will offer robust management of anticipated growth in network technology. This work reviews the improvements in LTE Advanced technology.**

***Index Terms*—4G, Release 8, Release 10, Release 11, Release 12, LTE, LTE-A**

I. INTRODUCTION

OVER the years cellular wireless generation has gone through phenomenal changes in services offered, air interface technologies and frequency band from 1G analog generation to the highly advanced 4G networks. These changes have led to significant growth in mobile communication industry in terms of users and mobile devices technology. The socio-economic benefit has been immense with many countries of the world experiencing exponential real growth in Gross Domestic Product (GDP).

Data usage has surpassed voice traffic due to innovation in mobile device technology that gives users the privilege to use diverse kinds of mobile devices to access various applications on the networks. This has created a continuous demand for bandwidth and subsequently an efficient broadband service. The quest for a very fast broadband service to meet this growing demand for data has formed the basis for the considerable advancement in LTE.

LTE is an evolution from Global system for communication (GSM) and Universal mobile telecommunication systems (UMTS). This improvements delivered by LTE system include the introduction of a completely new air-interface technology based on Orthogonal Frequency Division Multiple Access (OFDMA) as its radio access for the downlink transmission and single carrier frequency division multiple access (SC-FDMA) for the uplink transmission. Also, it can boast of efficient spectrum flexibility between 1.25MHz to 20MHz in addition to many other improvements [1, 2].

Based on the IMT-Advanced specification, LTE-A is an evolution of LTE that can facilitate further enhancement in the LTE system performance by the addition of some novel technological components such as carrier aggregate that allows operators to deploy larger bandwidth than 20MHz, enhanced multi-antenna techniques, improved support for heterogeneous network deployments and enhanced coordinated multipoint transmission / reception (CoMP) etc [1, 3]

Considering the trend in cellular networks, it is very clear that LTE-A will continue to yield an enormous impact on communication technology for the next decade. With the capability to allow smooth and backward compatibility evolution of LTE, such that LTE devices can operate in LTE-A network mode and also the LTE-A devices can operate in earlier LTE network without jeopardizing the existing investment; it is obvious that the relevance of the technology will be for a very long time in the society [4, 5].

II. STANDARDS AND TECHNOLOGIES FOR LTE ADVANCED NETWORKS

Release 10

The following are some of the specifications standardized on Release 10 for a basic LTE-A network [6]:

- Peak uplink data rate of 500Mbps and downlink of 1Gbps.
- 3 times higher spectrum efficiency of uplink 15bps/Hz and downlink 30bps/Hz as compared to that of LTE.
- Operating bandwidth of up to 100MHz.
- User throughput at the cell edge is 2 times higher than that of LTE.
- User average throughput is 3 times higher than that of LTE.

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- Mobility environments is comparable to that of LTE
- Compatibility for interworking with 3GPP and LTE.

The principal technological improvements that enable LTE-A to deliver improved mobile broadband services and network efficiency for users are:

2.10 Carrier Aggregation (CA)

In Release 8 the maximum bandwidth available for transmission was 20MHz. However with the introduction of carrier aggregation in LTE-A, it is now possible to increase the transmission bandwidth of the channel up to 100Mbps. This is achieved by combining 5 component carriers with each having a bandwidth capacity of 20MHz as shown in fig.1.

The goal is to enhance peak data rates for users thereby allowing operators to provide higher throughput and at the same time maintain backward compatibility with LTE [3, 7]. There are three major types of carrier aggregation: intra-band contiguous, intra-band non-contiguous and inter-band non-contiguous carriers.CA in release 10 allows both inter-band and intra-band combination of various carrier frequency bands. Despite the fact that carrier frequencies in the intra band may or may not be adjacent, contiguous and non- contiguous CA is possible for spectrum flexibility to be attained. For a network operator, an Inter-band non-contiguous aggregation is most appealing because it allows the merger of component carriers distributed across different frequency band [8].

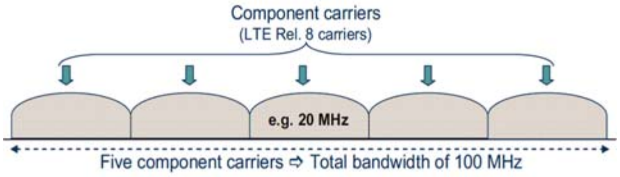

Fig. 1, Carrier Aggregation

2.11 Enhanced multi-antenna technique

This technique is based on signals being transmitted and received with the use of advanced multiple antennas. There are various types of multiple antenna technology such as Single User Multiple Input Multiple Output (SU-MIMO) which is used when there is a multiple transmission for a single user while Multi User Multiple Input Multiple Output (MU- MIMO) is used when there are multiple transmissions for multiple users. The better the communication channel that is been utilized by the system for multiple transmissions, the higher the capacity the system can offer.

The performance of the Enhanced multi-antenna (MIMO) is subject to different factors such as: the number of transmitting antenna and the receiving antenna, the reference signal and the response of the channel estimating the information from the receiver to the transmitter [3].

The advanced multiple antennas help to achieve higher peak data rate over the air interface, improved spectrum efficiency and reduced high Signal to Noise Ratio. LTE-A specifies up to 8 layers multiplexing in the downlink and 4 layers on the uplink to satisfy the spectral efficiency of 30bps/Hz downlink and 15bps/Hz uplink.

In other words; in the downlink, the User Equipment (UE) is required to support 8 receivers to permit downlink 8*8 spatial multiplexing while for the uplink the UE is required to support up to 4 transmitter to permit 4*4 transmission when combined with 4 eNodeB (eNB) receivers [3, 9].

2.12 Coordinated Multipoint (CoMP) Transmission/ Reception

In cellular systems where frequencies are reused in every cell, other cell interference is inevitable. Consequently this reduces the performance of the system capacity. The major aim in CoMP is to ensure that all the interference signals at cell edge are employed as useful signals. However in LTE-A, CoMP is the major method used to manage communication among multiple cells in order to improve the cell edge and system capacity. It allows more than one eNB to transmit or receive information to or from a single UE located at multiple cell sites at the same time. In other words, for every location of the UE, it will be able to receive signals from multiple cell sites as well as the UE's transmission been received at multiple cell sites irrespective of the system load.

When CoMP is applied; downlink performance of the system can be significantly enhanced if the signals transmitted from the multi cells are coordinated; while in the uplink, interference can be reduced through coordinated reception in eNBs to improve the reception performance. There are various types of CoMP schemes such as Coordinated Scheduling/ Coordinated Beamforming (CS/CB), Joint Processing/Dynamic Cell Selection (JP/DCS) and Joint Processing/Joint Transmission (JP/JT) [10].

2.13 Relay Nodes

The use of Relay nodes in LTE-A has brought about the possibility of efficient heterogeneous network planning. It has helped in the deployment of small cells in regions where wired connection is not practicable [3]. It can also be used to reduce the distance between transmitter and the receiver to allow higher data rate coverage especially at hotpot locations. Due to low Signal to Interference plus Noise Ratio, coverage and capacity at the cell edge are comparatively small.

Deployment of relay nodes helps to improve coverage, cell capacity at cell edges and performance throughput of the system. It also aids the reduction in power usage of the network; hence extending UEs battery life period [10].

2.14 Heterogeneous network

This network was deployed in order to improve network performance in areas with low power nodes made up of networks of small cells (femto and pico cells), macro cells, Remote Radio Head and relays. The major goal of this network is mostly to enhance the overall capacity of the network.

During deployment, heterogeneous network interference was a big challenge between the macro cells and small cells on access link due difference in transmission power [3]. This brought about CA and non-CA methods in order to support the network. Cross carrier scheduling is used to evade the interference of Physical Downlink Control

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Channel (PDCCH) between macro cell and small cell in the CA-based method. The PDCCH schedule for multiple component carriers in a macro cell is situated in one of the component carrier while in the small cells it is situated in another component carrier. Non-carrier aggregation-based heterogeneous network method improvement were made to control channel orthogonality, Channel State Information Reference Symbols (CSI RS) and the resource specific Channel Quality Indicator (CQI) in LTE Release 8.

Release 11

The evolutionary step in the development of network technology assumed another dimension in Release 11. The purpose was to support new features such as downlink MIMO and the introduction of a new carrier type. It also contains a new downlink control channel known as Enhanced Physical Downlink Control Channel (EPDCCH) to support certain purposes such as improved spatial reuse of control channel resources, increase in control channel capacity etc. [3, 14]. LTE-A witnessed further improvement on Carrier Aggregation technology, which brought the introduction of multiple Timing Advances (TAs) for uplink carrier aggregation.

2.20 Carrier Aggregation Enhancement

In Release 10 it was possible to synchronize several carriers in uplink due to single Timing Advance (TA) for all the component carriers based on Pico Cell. However, the first uplink transmission timing on random access channel is resolute on the downlink timing such that the UE on its own will adjust the timing based on the downlink reference timing only.

Due to this limitation, the uplink carrier aggregation is restricted in situations where transmission delay for the entire carrier is same. To address this challenge the following improvements were made: Introduction of Timing Advance Group (TAG): The TAG was initiated in Release 11 to enable multiple timing advances. A TAG consists of one or more serving cells in the same uplink timing advance and downlink timing reference cell. It is made up of Pico Cells also known as Primary Timing Advance Group (pTAG) while the macro cells are referred to as Secondary Timing Advance Group (sTAG). Carrier Aggregation is restricted to two downlink component carriers with only two TAGs maximum from the RF. A 2-bit TAG Identity and 6-bit timing advanced command field was also introduced to modify the control element in Release11 [11, 19]

Base station Requirements Upgrade: Due to the fact that data packets at the base station antennas are not properly aligned in timing, some specific requirement must be fulfilled for an efficient operation. These requirements and modifications include timing error between certain transmitters, multiple carrier frequencies and MIMO technique to adjust the connections. For intra-band non-contiguous CA with or without MIMO or transmit diversity, the Time Alignment Error must not exceed 260ns [12].

2.21 Enhanced Inter-cell interference coordination (FeICIC)

Inter-cell interference coordination(ICIC) involves the management of Radio Resources such that inter-cell interference is been controlled in a manner that certain restrictions are placed on radio resources maximum transmit power used by each of the base station. Mechanisms such as Frequency and Time domain components were included in Release 10 [14] with the Frequency-Domain ICIC controlling the radio resources, particularly, the radio resource blocks in a way that multi-cells coordinate can make use of the frequency domain resources. But for Time-Domain ICIC, the usage of the subframes across diverse cells is coordinated in time by Almost Blank Subframe (ABS) which enables interference freedom among the cells [19].

In Release 11 there was further enhancement to non carrier aggregation based eICIC (FeICIC) which is an additional reduction in interference by the cancellation of interference on the common control channel of ABS due to the Common Reference Signals (CRS) of the macro cells with high power.

The further enhancement is also for better detection within additional cell range areas around the picocell with important transmit system information. The major improvement in Release 11 remains the network ability to assist the UE with CRS critical transmit system information of the aggressor cells in order to assist it to mitigate interference [13]. This surely will increase the performance of the victim cell since severe interference from the aggressor cell negatively affects it in the first instance.

2.22 Enhanced Physical Downlink Control Channel (EPDCCH)

One of the major enhancements is the introduction of a novel downlink control channel EPDCCH to support other LTE technological improvements such as CoMP, CA, Machine Type Communication (MTC) and New carrier Type in Release 12 basically to increase control channel capacity, support the use of beamforming and accomplish improved spatial reuse of control channel resources etc. EPDCCH will also be able to coexist on the same carrier as legacy Release 8 and Release 10 devices [14, 19].

Release 12

Due to growing demand in data traffic, further improvements have been made in order to manage this growth and at the same time maintain the expected quality of service. LTE Release 12 improvement is centered on the capacity, coverage, coordination between cells, and cost. To accomplish improvements in these areas, several new technological features were introduced among which are device to device communication, Machine Type Communications (MTC) and small-cell enhancements etc with the major aim of making LTE network more cost and power efficient.

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2.30 Device to Device Communication (D2D)

The major advantage is that it offers improved spectral efficiency as well as reduction of delay in communication. This allows one device detect the presence of the other device by carrying out thorough search in its surrounding before communication takes place [15].

In D2D Discovery the air interface enables the UE to identify other UEs in its surrounding. This can be further categorized as open and restricted discovery. This form of communication requires the UEs to communicate directly with each other through the air interface such that communication does not entail the routing eNB and the core network [15, 16].

D2D Communication and Discovery has helped adjoining services in LTE [10]. For various control purposes D2D is being supported by the base station but at the same time can efficiently work when there is no connectivity between the devices and the base station, thereby making it to be very useful for applications under public safety [17].

2.31 Machine Type Communication (MTC)

LTE A network can be strengthened when several machine type communication are connected together. Release 12 focuses more on diverse MTC application support. MTC is a programmed way of exchanging data between different devices; generally between core network and the sensor. The device gathers the data and converts it to digital form for it to be analyzed, after which it is sent over the network. The application receives the data through the network, assesses it and then sends a feedback to the device [18].

In MTC, it is possible to manage several numbers of devices in each cell; hence time control and secure communication between the devices are guaranteed. In addition, requirement such as reduced power consumption and long battery life are also been fulfilled in MTC's different application areas such as smart home technology.

2.32 Small Cell Enhancement

With increase in traffic load it is expected that more cells and capacity will be required in order to manage the overall throughput. Small cell deployment has been assisted in Release 12 basically by reducing the mobility signaling in highly dense cells and also by enhancing users experience data rate with the use of macro cells and small cells collectively [14].

Large number of small cells increases signaling traffic in the core network as users often move from one small cell to another. The high signaling traffic can be controlled by separating the user plane and the control plane functions in the Radio Access Network architecture such that mobility is been handled by the macro cell while high data traffic is been offloaded to the small cells.

Table I compares the various LTE-A technologies.

III. CONCLUSION

The evolution of LTE continues in Release 12 and beyond by several improvement on LTE operations. The fifth generation (5G) wireless communication network is the next phase of mobile communication standard though it is yet to be implemented all over the world but it is available in some places like USA. At the moment 5G is not a term officially used for any particular specification or in any official document yet it has not been made public by the standardization bodies but it is expected to offer users 10Gbps peak data rate, lower latency, few milliseconds delay in user plane and within 10ms for control plane.

The 5G technology comprises all type of advanced technologies such as Centralized Radio Access Technology, millimeter wave frequencies, small base stations driven by nanotechnology etc. These technologies make 5G technology most potent and in huge demand. In near future it will be able to offer unusual data capabilities, tie together unrestricted volume of calls, infinite data broadcast within the latest mobile operating system and support virtual private network. 5G technology has a bright future since it can handle best technologies and offer priceless handset to users. Nevertheless 3GPP new releases beyond LTE-A Release 12 are also in progress to improve the network and each new release will further enhance system performance and add new capabilities in new application areas.

TABLE I
SUMMARY OF SOME LTE-A TECHNOLOGY

	Release 10	Release 11	Release 12
Technologies	Carrier Aggregation Coordinated Multipoint (CoMP) Transmission/ Reception Heterogeneou s network	Carrier Aggregation Enhancement Further Enhanced Inter-cell interference coordination Enhanced Physical Downlink Control Channel	Device to Device Communication Machine Type Communication Small cell enhancement

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