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An Overview of 4G-LTE Networks

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Abstract

Today, mobile communications play very essential part in arena of our everyday life begin of voice call to internet access, to cater for the enormous growth in mobile data and the huge number of user the operator need to know how to design and update their networks so that they can provide best services to the lowest possible cost. This paper provide an overview of the Long Term Evolution (4G-LTE), which is being developed by the 3rd Generation Partnership Project (3GPP). LTE constitutes the latest step towards the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile communications. Particular attention is given to the releases of LTE and it architecture, its use of OFDM and MIMO and the security evaluation in LTE, Furthermore new future research areas are proposed here.

Keywords: *LTE, EPC, OFDMA, SC-FDMA, MIMO, 5G.*

I. Introduction

The term 4G stands for 4th Generation Wireless Networks – which defines set of wireless standards related to connectivity speed for mobile devices as defined by the International Telecommunication Union (ITU-R) .4G -LTE, is an acronym for (Long-Term Evolution), which is a wireless standard for communication of high-speed data for mobile devices on the Radio Interface. Developed by Third-Generation Partnership Project (3GPP), LTE is an evolutionary progression of technologies related to the radio interface from a GSM (2G) standard to UMTS (3G) standards by providing significant increased in peak data rates for mobile operators. More importantly, the LTE is designed to support Packet Switched (PS) IP-based data services .however, LTE's upper layers use TCP/IP, enabling all traffic -- data, voice, video and messaging -- to be carried over an all-IP network in flat networking architecture. [1]

It was first proposed by NTT DoCoMo of Japan in 2004. In June 2007, the standard for new mobile technology is being committed, In 2008, Ericsson unveils the Mobile World Congress in Barcelona, the first time establishes a connection between two compact LTE terminals and there will be a transfer rate of 25 mbps per second achieved, End of 2008, the Korean company LG introduce the first-install LTE chip, it could reach peak speed at 60Mbps. Finally, in December 2009, the first commercial LTE network in Sweden as put into operation, in late summer of 2010 in Germany, the first LTE phone masts was ready. [2]

LTE significantly address major networks issues that were prevailing before in 2G and 3G standards. This include addressing network issues such as reduced network latency, Increased bandwidth capacity and scalability and providing backwards compatibility with existing GSM and UMTS technologies in Mobile Broadband (MBB) Core Network Leading to good QoS. This was all made possible due to number of other developments that emerges in addition to development in LTE high-speed radio access technologies, such as rapid advances in the processing capacity of semiconductors for mobile devices, and in the development of new software and Interface protocols that help in creating new IP-based services. [3]

LTE designed to increase the capacity and speed of wireless data networks by provide IP-based voice, data and multimedia streaming at speeds of at least 100 Mbit per second and up to as fast as 1 GBit per second. Also provides significantly higher peak data rates than the earlier 3GPP technologies, with the potential for 100 Mbps downstream and 30 Mbps upstream, reduced latency, scalable bandwidth capacity, good mobility , great quality of service and backwards compatibility with existing GSM and

UMTS technology. Future developments could yield peak throughput on the order of 300 Mbps.

The remainder of this paper is organized as follows. In Section II, I show the releases of LTE, in III,I provide an overview of the network architecture that support LTE. Then, I cover the concept of both multiple access technology in LTE and MIMO techniques in Section IV and V. In Section VII, I present a brief overview in LTE security. Section VIII shows some future research of LTE, Finally, I conclude this paper with Section IX.

II. Releases of LTE

Release 8: frozen in Dec 2008 provide all ip network Architecture and the main achievements are high peak data rates : Up to 300 Mbps in downlink and 75 Mbps in uplink when using 4x4 MIMO and 20 MHz bandwidth, Flexible bandwidths: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz, High spectral efficiency ,Short round trip time: 5 ms latency for IP packets in ideal radio conditions.

Release 9: frozen in Dec 2009 new requirements were added to Enhancement over release 8 this includes: PWS (Public Warning System): Public should always receive timely and accurate alerts related to natural disasters or other critical situations. Commercial Mobile Alert System (CMAS) was introduced in release9. **FemtoCell**: Femtocell is basically a small cell used in offices or homes and connected to providers' networks through landline broadband connection. 3G Femto cells are deployed around world and in order for LTE users, Femtocell base stations allow mobile phone users to make calls inside their homes via their Internet broadband connection. Femtocells provide small area coverage solutions operating at low transmit powers. Femtocells are consumer deployable base stations that utilize consumer's broadband connection as backhaul, may have restricted association and power is less than 100 mW.[4] **Self Organizing Networks (SON):** SON means self installation, optimization and healing of networks in order to reduce manual work and cost associated with technical support.

eMBMS: With Multimedia broadcast Multicast Services (MBMS), operators have capability to broadcast services over LTE network. The idea is not novel to the LTE and has been used in legacy networks as well but for LTE, the MBMS channel has evolved from data rate and capacity perspective. The MBMS was already defined at physical layer in release8 but with release 9, higher layer and network layer aspects were completed.LTE Positioning: Three position methods are specified in LTE release 9 i.e. Assisted GPS (A-GPS), Observed Time difference of arrival (OTDOA) and Enhanced Cell ID (E-CID). The goal is to improve the accuracy of user locations in case of emergency scenarios where the user itself is unable to disclose his whereabouts.

Release 10: Frozen in March 2011,It is improvements to fulfill ITU IMT-Advanced requirements which set higher speeds than what UE can achieve from 3GPP release 8 specifications. Some key requirements lay down by IMT-Advanced are 1Gbps DL / 500 Mbps UL throughput, High spectral efficiency, worldwide roaming, this can be done by

- Enhanced Uplink multiple access by introduces clustered SC-FDMA in uplink,
- MIMO enhancements by allow up to 8x8 MIMO in downlink and on the UE side it allows 4X4 in uplink direction.
- Enhanced inter-cell interference coordination (eICIC): eICIC introduced in 3GPP release 10 to deal with interference issues in Heterogeneous Networks (HetNet).
- **Carrier Aggregation** (CA): CA introduced in release 10 is a cost effective way for operators to utilize their fragmented spectrum spread across different or same bands in order to improve end user throughput as required by IMT-Advanced. User throughput is increased by sending data simultaneously over two or more carriers. LTE-Advanced supports bandwidths up to 100 MHz formed by combining up to five 20MHz component carriers. Contiguous and non-contiguous carriers may be aggregated.

- Support for Heterogeneous Networks: The combination of large macro cells with small cells results in heterogeneous networks.

Release 11: Frozen in September 2012 it provides enhancements to the LTE-Advanced technologies introduced in Rel-10, such as: Carrier Aggregation (CA), Multimedia Broadcast Multicast Services (MBMS) and Self Organizing Networks (SON). Rel-11 also introduces the Coordinated Multi-Point (CoMP) feature for enabling coordinated scheduling and/or beam forming, Enhanced Physical Control Channel (EPDCCH) and Further enhanced Inter-Cell Interference Coordination (FeICIC) for devices with interference cancellation

Finally, Rel-11 introduces several network and service related enhancements to Machine Type Communications (MTC), IP Multimedia Systems (IMS), Wi-Fi integration related enhancements, Home NodeB (HNB) and Home e-NodeB (HeNB) enhancements, etc. most of which apply to both HSPA and LTE. [5]

III. LTE Architecture

The term LTE defines the complete technology path that a mobile operator or data service provider needs to implement in order to have a fully deployed LTE Network. This includes network implementation on the mobile operator's Radio Access Network (RAN) and the non-radio aspect of LTE Network – i.e. - System Architecture Evolution (SAE) which includes EPC (Evolved Packet Core) Network – in order to achieve 4G speeds. Thus, a mobile operator can deploy LTE Network by deployment of eNodeB's on the Radio Access Network (RAN), and Network Integration and deployment of (SAE) with RAN. This includes the Installation, Integration and Configuration of LTE network called EPS (Evolved Packet System) – which an end-to-end (E2E) all IP traffic that manage the Core Network of an LTE.

EPS is divided into two parts - LTE part which deals with the technology related to a radio access network (E-UTRAN) and EPC part which deals with the technology related to a core network.

1- The Access Network (LTE) simply consists of a network of eNodeB's that served as a base station for LTE Radio Access Network (RAN). The eNodeB's are optionally also interconnected with each other by means of some interfaces. Table 1 shows a description for LTE interface.
2- EPC the Core network that responsible for the overall control of the end-user's UE devices and establishment of the bearers channels between UE and LTE Network, the main logical nodes of the EPC are Mobility Management Entity (MME),Serving Gateway (S-GW),PDN Gateway (P-GW) . Table 2 shows a brief description of the logical node for ESP.[6][7][8]

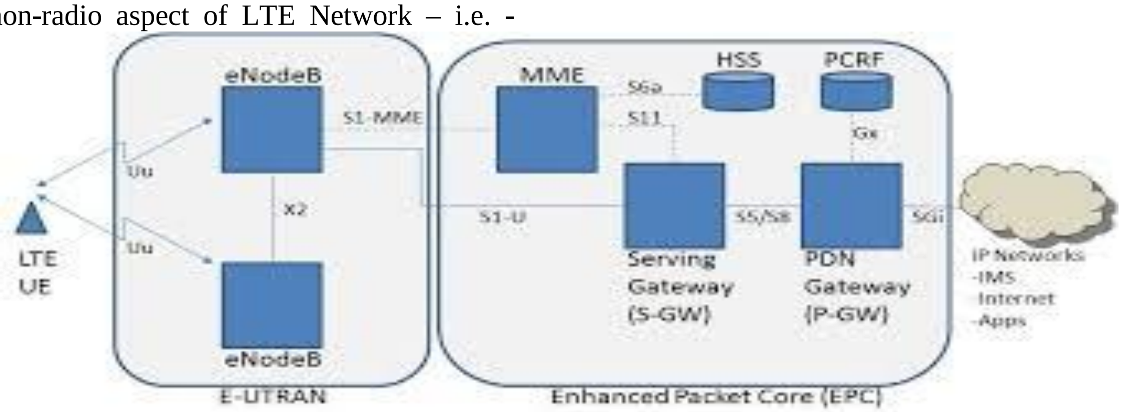

Figure 1: LTE Network Architecture. [9]

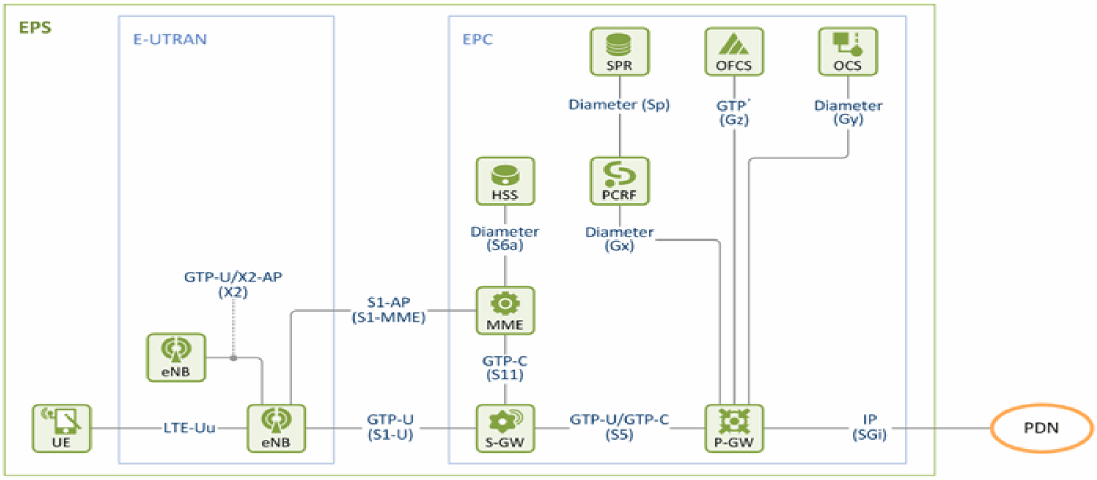

Figure 2: LTE Network Reference Model

Table 1: LTE interfaces [5]

Reference point	Protocol	Description
LTE-Uu	E-UTRA (control plane and user plane)	An interface for the control and user planes between a UE and an E-UTRAN (eNB). The signaling connection over the LTE-Uu is the RRC connections represented by Signaling Radio Bearers (SRBs), and the user plane connection is the logical channels represented by Data Radio Bearers (DRBs).
X2	X2-AP (control plane) GTP-U (user plane)	An interface for the control and user planes between two eNBs. It is used during X2 handover and/or for Self Organizing Network (SON)-related functions. X2-AP protocol is used in the control plane and a GTP-U tunnel per bearer is provided for data forwarding in the use plane.
S1-U	GTP-U	An interface for the user plane between an E-UTRAN (eNB) and an S-GW. It provides a GTP tunnel per bearer.
S1-MME	S1-AP	An interface for the control plane between an E-UTRAN (eNB) and an MME.
S11	GTP-C	An interface for the control plane between an MME and an S-GW. It provides a GTP tunnel per user.
S5	GTP-C (control plane) GTP-U (user plane)	An interface defined between an S-GW and a P-GW for the control plane and user plane. The S5 interface provides a GTP tunnel per bearer for the user plane and GTP tunnel management (creation, modification and deletion) per user for the control plane. For inter-PLMN, however, an S8 interface is used instead. The S8 interface is out of the scope of this document and will be described in other LTE interworking document to follow.
S6a	Diameter	An interface for the control plane between an HSS and an MME. It exchanges user subscription and authentication information.
Sp	Diameter	An interface for the control plane between an SPR and a PCRF.
Gx	Diameter	An interface for the control plane between a PCRF and a P-GW. It transfers policy control and charging rules from the PCRF to the P-GW to support QoS policy and charging control.
Gy	Diameter	An interface for the control plane between an OCS and a P-GW.
Gz	GTP'	An interface for the control plane between an OFCS and a P-GW.
SGi	IP	An interface for the control and user planes between a P-GW and a PDN. The IETF-based IP packet forwarding protocols are used in the user plane while DHCP and RADIUS/Diameter protocols are used in the control plane.

Table 2: EPC entities [5]

Entity	Description
MME	An MME is the main control entity for the E-UTRAN. It communicates with an HSS for user authentication and user profile download, and provides UEs with EPS Mobility Management (EMM) and EPS Session Management (ESM) functions using NAS signaling. The main functions supported by a MME are as follows: • NAS signaling (EMM, ESM and NAS Security) • User authentication and roaming with HSS over the S6a interface • Mobility management (paging, Tracking Area List (TAI) management and handover management) • EPS bearer management
S-GW	An S-GW terminates the interface towards an E-UTRAN. It serves as the local mobility anchor point of data connections for inter-eNB handover and inter-3GPP handover.
P-GW	A P-GW provides a UE with access to a PDN by assigning an IP address from the address space of the PDN. The P-GW serves as the mobility anchor point for handover between 3GPP and non-3GPP. It also performs policy enforcement, packet filtering and charging based on the PCC rules provided by a PCRF. The main functions supported by a P-GW are as follows: • IP routing and forwarding • Per-SDF/Per-User based packet filtering • UE IP address allocation • Mobility anchoring between 3GPP and non-3GPP • PCEF functions • Charging per-SDF/per-User
HSS	An HSS is the central DB where user profiles are stored. It provides user authentication information and user profiles to the MME.
PCRF	A PCRF is the policy and charging control entity. It makes policy decisions for SDFs and provides the PCC rules (QoS and charging rules) to the PCEF (P-GW).
SPR	A SPR provides subscription information (access profile per subscriber) to the PCRF. Receiving the information, the PCRF performs subscriber-based policy and creates PCC rules.
OCS	An OCS provides (i) real-time credit control and (ii) charging functions based on volume, time and event.
OFCS	An OFCS provides CDR-based charging information.

IV. Multiple Access Technology in LTE

The basic modulation scheme in LTE depends on the multicarrier modulation, namely OFDM (frequency division multiplexing) which is used due to its numerous advantages such as its robustness against the Inter Symbol Interference (ISI). In LTE physical layer, both of the Frequency Division Duplexing (FDD) mode and Time Division Duplexing (TDD) mode are used with different frame structures. OFDMA scheme is the adopted multiple access scheme in the downlink direction. However in the uplink direction, SC-FDMA is preferred. [10]

A-Down Link: OFDMA is a variant of orthogonal frequency division multiplexing (OFDM) which is a form of transmission that uses a large number of close spaced carriers that are modulated with a low rate date. Normally these signals would be expected to interfere with each other, but by making the signals orthogonal to each other there is no mutual interference. The date to be transmitted is split across all the carries to gives resilience against selective fading from multi-path effects. It supports both FDD and TDD duplex modes for transmission on paired and unpaired spectrum. The generic radio frame has time duration of 10 ms, consisting of 20 slots of each 0.5 ms. Two adjacent slots form a sub-frame of 1 ms duration, which is also one transmit-time-interval (TTI). Each slot consists of seven OFDM symbols with short/normal cyclic prefix (CP) or six OFDM symbols with long/extended CP.

One of the primary reasons for using OFDM as a modulation format within LTE is its resilience to multipath delays and spread. However it is still necessary to implement methods of adding resilience to the system. This helps overcome the inter-symbol interference (ISI) that results from this. In areas where inter-symbol interference is expected, it can be avoided by inserting a guard period into the timing at the beginning of each data symbol. It is then possible to copy a section from the end of the symbol to the beginning. This is known as the cyclic prefix, CP. The receiver can then sample the waveform at the optimum time and avoid any inter-symbol interference caused by reflections that are delayed by times up to the length of the cyclic prefix, CP. The symbol length is defined by the fact that for OFDM systems the symbol length is equal to the reciprocal of the carrier spacing so that orthogonality is achieved. With a carrier spacing of 15 kHz, this gives the symbol length of 66.7 µs. OFDM channel equalizers are much simpler to implement than are CDMA equalizers, as the OFDM signal is represented in the frequency domain rather than the time domain.

OFDM is better suited to MIMO. The frequency domain representation of the signal enables easy proceeding to match the signal to the frequency and phase characteristics of the multi-path radio channel.

Although all these distinct advantages of OFDM compared with other technology used in 2G, 3G however it has some disadvantages. The subcarriers are closely spaced making OFDM sensitive to frequency errors and phase noise. For the same reason, OFDM is also sensitive to Doppler shift, which causes interference between the subcarriers. Pure OFDM also creates high peak-to average signals While this is not a problem for the base station where power is not a particular problem, it is unacceptable for the mobile , that is why a modification of the technology called SC-FDMA is used in the uplink.[11]

B- Uplink: One of the key parameters that affect all mobiles is that of battery life. Even though battery performance is improving all the time, it is still necessary to ensure that the mobiles use as little battery power as possible

The high peak-to-average ratio (PAR) associated with OFDM led 3GPP to look for a different transmission scheme for the LTE uplink. SC-FDMA was chosen because it combines the low PAR techniques of single-carrier transmission systems, such as GSM and CDMA, with the Multi-path resistance and flexible frequency allocation of OFDMA. And here a brief description of SC-FDMA data symbols in the time domain are converted to the frequency domain using a discrete Fourier transform (DFT); then in the frequency domain they are mapped to the desired location in the overall channel bandwidth before being converted back to the time domain using an inverse FFT (IFFT). Finally, the CP is inserted. Because SC-FDMA uses this technique, it is sometimes called discrete Fourier transform spread OFDM or (DFT-SOFDM). [12]

V. Dynamic Resource Allocation and Link Adaptation

The radio resources in the LTE are allocated as time-frequency domain grid. The smallest resource that can be allocated to a specific user is called the resource block which consists of 12 subcarriers and one time slot. The role of the scheduler includes the radio frequency resource allocation (Resource Blocks) and the adaptation of the used modulation and coding techniques according to the radio-link quality for each user. In LTE standard the defined modulations are QPSK, 16QAM and 64QAM, which are adaptively selected based on traffic types, available bandwidths and radio channel quality.

VI. Multiple-Input Multiple-Output (MIMO)

MIMO is smart techniques enhance system performance, service capabilities, and both. At its highest level.LTE supports MIMO as the base option, with multiple transmitter and receiver antennas in a same eNond-B.and up to four antennas can be used by single LTE cell (gain: spatial multiplexing) ,the technique done by averaging the signals received from the two antennas, thereby avoiding the deep fading dips that occur per antenna. The latter employs multiple antennas at the transmitter and receiver side to provide simultaneous transmission of multiple parallel data streams over a single radio link, therefore increasing significantly the peak data rates over the radio link. Additionally, LTE supports SDMA (Spatial Division Multiple Access). With multiple users in same radio resource.

Also it supports Beam-forming for coverage, which used to increase cell edge throughput by directing beam towards specific UE by position estimation at eNB ,that will enhances signal reception through directional array gain, extends cell coverage and system capacity ,suppresses interference in space domain ,prolongs battery life and provides angular information for user tracking. [13][14]

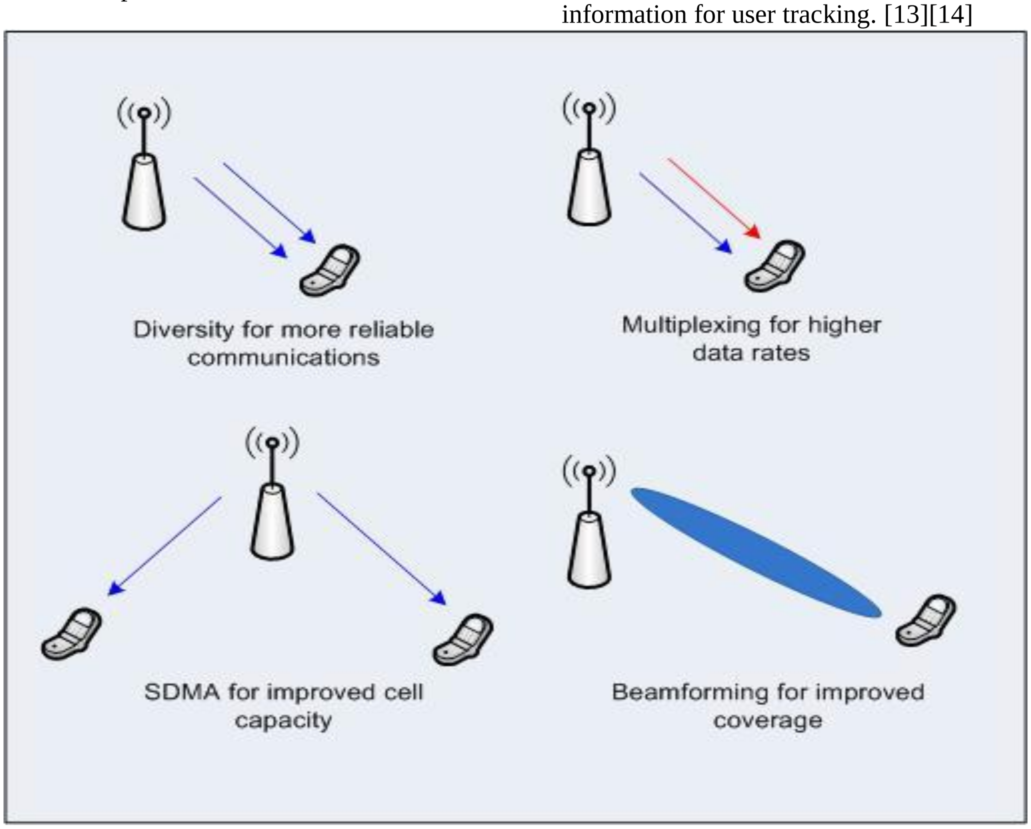

Figure 3: MIMO techniques in LTE

VII. LTE Security

Nevertheless with the level of sophistication of security attacks growing, it is necessary to ensure that LTE security allows users to operate freely and without fear of attack from hackers. Additionally the network must also be organized in such a way that it is secure against a variety of attacks. [15]

1- LTE - Security Evolution

In cellular network Security architecture evolved constantly. In the first generation hackers can eavesdrop on conversations and access for fraudulent Network In 2G GSM (Global System for Mobile Communications authentication algorithms was not very strong. Just with little interaction with a SIM card (subscriber identity module) could show the master security key. In UMTS (3G) wireless, the authentication mechanism was improved to a two-way process. Both the network and the mobile user used encryption and integrity keys to create stronger security. Also, some mechanisms were introduced to ensure freshness of the integrity keys. Which means if a key is broken; the damage will only last for a little period of time that is the validity of the key will last just a short time then goes invalid. Also 128-bit encryption and integrity keys were utilized to create stronger security.

In 4G-LTE just like the transition from 2G to UMTS additional improvements were introduced, further layers of abstraction were added in terms of the unique identifiers (ID) for an end-mobile device (UE). In 2G, a solitary unique ID was used on the SIM card, in 3G and subsequently 4G LTE, temporary ID and moreover abstraction was used so that smaller windows of Opportunity exist for hackers to steal identities, another mechanism to strengthen security in 4G was to add secure signaling between the UE and MME (Mobile Management Entity) Finally, security measures were put in place for interworking between 3GPP networks and trusted non-3GPP users– using for example, the EAP-AKA (UMTS Authentication and Key Agreement) protocol although all significant security protection Witnessed during the evolution from 1G to 4G. The analysis indicates that the dual manifestation of operating an open IP-based architecture as well as the sophistication of security hackers means that security issues remain a matter of key concern in 4G network systems, so that important attention need to be given to analyzing security challenges in 4G wireless and rapid development of solutions for threat detection and mitigation.

2- LTE- Security Concepts

It is describes basic security features offered by LTE networks, including LTE authentication, NAS (Non Access Stratum) security and AS (Access Stratum) security. LTE authentication is the process of determining whether a user is an authorized subscriber to the network that he/she is trying to access and it performs mutual authentication between a UE and a network, while NAS security performs integrity protection/verification and ciphering (encryption/decryption) of NAS signaling between a UE and an MME. and AS security performs integrity protection/verification and ciphering of RRC signaling between a UE and an eNB, also it performs ciphering of user traffic between a UE and an eNB.[16]

It is expected that a range of security risks will emerge in 4G wireless due to a number of factors including: (a) departure from proprietary operating systems for hand held devices to open and standardized operating systems and (b) open nature of the network architecture and protocols (IP-based). With this move to open protocols and standards, 4G wireless networks are now susceptible to computer attack techniques present on the Internet. Such networks will be increasingly vulnerable to a range of security attacks including for example Malware, Trojans and Viruses .Apart from end-user equipment posing traditional security risks, it is expected that new trends such as SPIT (SPAM for VoIP) will also become a security concern in 4G LTE ,Other VoIP-related security risks are also possible such as SIP registration hijacking where the IP address of the hijacker is written into the packet header, thus, overwriting the correct IP address.

VIII. Future Research

In this section I identify few examples of future research areas. With the overall vision of a Networked Society, the number of “communicating machines”, that is, machines sending or receiving data via LTE, is expected to increase dramatically. Machine-type communication is a very wide range of requirements, but in many cases the focus of the requirements is on low-cost, low-power, simple devices rather than high data rates and large amounts of data per device. Also good mobility has been and continues to be, a cornerstone in LTE. The possibility for the devices to seamlessly move around without losing connection to the network is essential for most applications and an enabler for many new use cases, Therefore, Research must continue the work started in LTE Advance release 12 thinking around the LTE evolution in release 13 (**5G**) by introducing new functionality to support massive QoS, focusing in improving the spectral efficiency of the LTE system through the introduction of higher order modulations to 256QAM, advanced 3D MIMO technologies and massive antenna beam forming with arrays of as many as 64 antenna elements enable additional frequency reuse within cell sectors, and multi-cell coordination techniques. **5G**, in early stages of definition through global efforts and many proposed Technical approaches, could start to be deployed close to 2020 and continue.

Through 2030.5G will be designed to integrate with LTE networks, and many 5G features may
Be implemented as LTE-Advanced extensions prior to full 5G availability.

Another fundamental way to improve the network capacity is to expand the system bandwidth, but newly available licensed spectrum in the lower frequency bands, which have traditionally been individually allocated to each mobile network operator, has become very scarce. This way Researchers turned to enable the operation of an LTE system in unlicensed 5GHZ spectrum, which ideal for new small cell deployments, offers higher capacity and coverage and enhanced user experience in a unified LTE network. There are two version unlicensed LTE (LTE-U) and Licensed-Assisted Access (LAA) that introduced in 3GPP release 13. It uses carrier aggregation in the downlink to combine LTE in unlicensed spectrum (5 GHz) with LTE in the licensed band. This aggregation of spectrum provides for a fatter pipe with faster data rates and more responsive user experience. [17]

Network power and user equipment battery saving are important development objectives being spearheaded through 3GPP standards work. According to Telefonica, electrical power accounts for 30% of OPEX, of which 50% is for power amplifiers. While, Low power modes and solar energy sources reduce electric grid consumption, mitigate demand for costly diesel generation in remote locations and reduce carbon footprints. Flatter networks, with decentralized as well as centralized architectures (e.g., using baseband resource pooling and virtualization) will also reduce the cost per bps of network capacity and per byte of data traffic transported. Therefore a new research may be done in this area to ensure a good economy, reduce energy and save environment. [18]

IX. Conclusion

In this paper I provided an overview of the LTE network, which focused on releases of LTE, The network architecture, the multiple access technology using in both uplink and downlink, MIMO, and the security evaluation in LTE, the paper also discusses some of new research area for example, LTE system in unlicensed 5GHZ spectrum, LTE evolution in release 13to the way of (5G), and the using of solar energy sources instead of diesel generation for reduce the cost and save environment.

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