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OVERVIEW OF LTE ARCHITECTURE

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ABSTRACT

Long Term Evolution (LTE) is a new communication platform which has been developed to fulfil the increasing demand of users in the field of mobile communication. LTE is a successor to the third generation mobile communication system. Major changes were made in architectural construction of this new radio interface. The advantages being shown by LTE is due to its advanced and simple architecture. The responsibilities of the architectural block are divided depending upon the radio access network in which the communication is taking place. When the communication is taking place within LTE it is handled by Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and when the communication is taking place with other radio access network then it is supported by Evolved Packet Core (EPC), which provides a seamless communication experience. This paper provides a detailed study of the whole LTE architecture and its components.

I. INTRODUCTION TO LTE

The mobile telecommunication industry is improving everyday by introducing new technologies and new facilities because of which millions of peoples are using different services provided by the mobile networks every day. As the number of mobile data users increased the demand for faster connections and increased capacity also increased, to satisfy the user demand 3GPP designed a successor to the widely popular 3rd generation technology. The resulting new technology was named as Long Term Evolution (LTE) which is a completely new and efficient radio access technology.

The standardization of the LTE technology was completed in March 2009 by the Third Generation Partnership Project (3GPP).LTE is better than the existing technologies in many ways, asit is an IP based system with flat architecture which provides high data ratesof about 100 Mbps in downlink and 50 Mbps in uplink. Moreover it provides better mobility, efficient radio usage, high level of security, flexible spectrum utilization, reduced delay/latency, cost efficient deployment and many more advancement which makes LTE more reliable and user friendly.

One of the major changes which were made in LTE so as to improve its performance as compared to the previous systems was its new network structure. In this new network architecture both the Radio Access Network and the Core Network have been renewed. LTE has specified a new Evolved Packet Core (EPC) network architecture which supports the Evolved Universal Terrestrial Radio Access Network

(E-UTRAN) by bringing favourable changes in the reduction in number of network elements, improved redundancy, simpler functionality etc. But apart from all these, most importantly it allows for connections and hand-over to other fixed lines and wireless access technologies, providing the mobile users a seamless mobility experience.

LTE System Architecture

LTE possesses a Simple and Flat architecture that gives an optimized usage of the network and also minimizesthe number of network elements. A seamless IP connectivity is provided by LTE between the user and the Packet Data Network (PDN) in the network. To fully support the mobility of UE in LTE so that the users should not face any disruption in getting services while they move, many changes were made in the architecture. Firstly an evolution was made in the radio access network and then some major changes were brought in the core network. The evolved radio access network part of LTE is called as E-UTRAN while the evolved core network part is called as EPC. The UE and E-UTRAN together with EPC represents the Evolved Packet System (EPS) which inturn is connected to the service domain. Bearers are used for successful transmission and reception of data here with the help of bearers data is routed from a gateway to the UE. A bearer may also be defined as an IP packet flow with a defined quality of service which establishes a connection between the EPC and the UE.

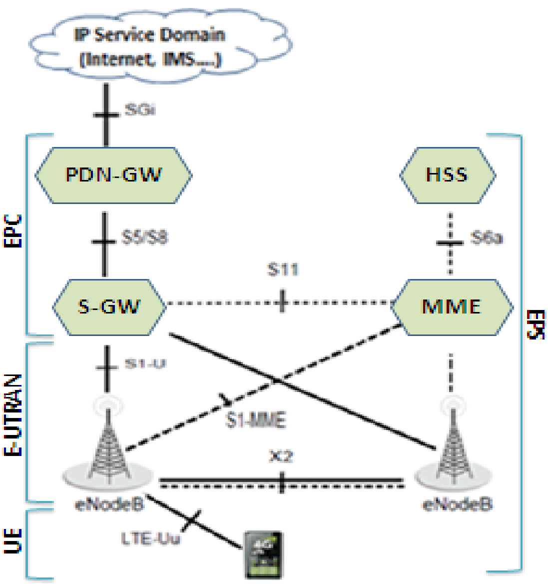

Figure 1: LTE Network Architecture

The above figure describes the LTE Network Architecture with its basic system configuration and logical nodes.All these nodes are interlinked with each other to perform some specific set of functions. The high-level network architecture of LTE is comprised of the following main components:

- The Evolved Packet Core (EPC).
- Evolved Universal Terrestrial Radio Access Network (E-UTRAN).
- The User Equipment (UE).
- Service Domain.

2.1. Evolved Packet Core (EPC)

The Evolved Packet Core in LTE when compared to its predecessors is equivalent of Core Network in GSM/UMTS System. This is very important part of the LTE architecture as it allows the user to communicate with other existing networks.It contains all the functional core network entities like MME, S-GW, PDN-GW and HSS which handles voice call management, data call management, billing and other functions.

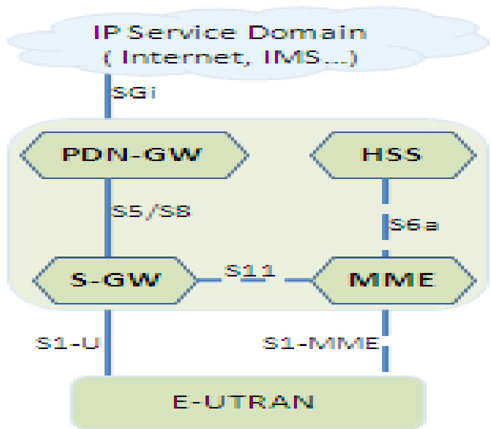

Figure 2: Basic EPC Architecture

A brief description of the components shown in the above EPC architecture is as follows:

2.1.1. Mobility Management Equipment(MME)

In EPC, the MMEacts as a server and is considered as the main control element.It is responsible for the signal exchange between base stations and core networks or between the subscriber and core network, so in a way we can say that it acts as a mediator. In brief following are the basic tasks performed by MME.

- **Authentication and security:** The MME initiates the authentication of the UE when the UE registers itself in the network for the first time.

The eNodeB exchanges the data and information between the subscriber and MME, it communicates with MME by S1 control plane interface. The MME then obtains the permanent identity of the UE andrequests the authentication information from HSS through the S6 interface and after getting the information it authenticates the subscriber. For protecting the UE's privacy the MME also allocates a temporary identity to each of the UE in the network which is called Globally Unique Temporary Identity (GUTI).

- **Bearers Establishment:** MME basically handles the control data and so it establishes a bearer by communicating with the core network entities like SGW and PDN-GW so as to provide a user IP tunnel between a mobile subscriber and the service domain. It also helps in selecting the best possible gateway router out of the available gateway routers.
- **Mobility management:** The MMEcontinuously keeps an eye on the UE's position so as to provide it proper service. The most appropriate resource which is available for the UE is defined by the MME. If the UE is in idle mode the MME keeps a track on the UE, means whether UE is in connected mode or not and is in which Tracking Area (TA). Based on the UE activity mode the MME establishes and releases the resources to the UE.If there is any data arriving for this device then MME sends a paging message to all the eNodeBs in the same tracking area and when the mobile device responds to this message the connection re-establishes.
- **Handover support:** When the X2 interface connectivity is not available between any two eNodeBs and the mobile unit is moving from one eNodeB to other eNodeB. Then in this case MME provides connectivity between these two eNodeBs so that they can communicate with each other.
- **Interworking support:** When a mobile unit is about to connect with a different radio access network other than LTE, then the eNodeB selects a suitable cell for the UE in that network (GSM or UMTS). MME continuously stays connected with the core network components of the other radio network like GSM, UMTS and CDMA, to provide proper connectivity.

2.1.2. Serving Gateway (S-GW)

One of the main responsibilities of S-GW is switching and user plane tunnel management. The S-GW does not play a major role in the controlling part. Serving gateway communicates with eNodeB through S1-U interface and to PDN-GW through S5/S8 interface. It communicates with MME through S11 interface which provides the connection and modification of the tunnels. The S-GW works on the basis of requirement and request given to it byMME or P-GW and so accordingly it allocates or releases its resources. If the request is initiated by P-GW, the S-GW sends a copy of this request to the MME so that the MME can control the tunnels to link it with eNodeB.

At the time of handover, the S-GW receives a switching command from the MME to switch the tunnel from one eNodeB to another eNodeB. If there is a need of data forwarding, MME may also command S-GW to provide proper tunnelling resources for data forwarding from the source eNodeB to the target eNodeB. If during the handover process S-GW re-allocation is required, then the MME handles the task of changing the tunnel from the old S-GW to the new S-GW.

In the idle mode no relaying is required whereas when the UE is in the connected mode or active state, then all the data that flows from an eNodeB are relayed to the PDN-GW and vice-versa. When the UE is in idle mode and if at the same time the S-GW receives some packets from a P-GW, the S-GW starts to buffer the data and asks the MME to page the UE. Once the paging is done and the tunnel is established, the S-GW can transmit the buffered data. The S-GW can also monitor the data in the tunnels for the charging purposes.

2.1.3. Packet Data Network Gateway (PDN-GW)

The PDN-GW basically acts as a router which is located between an external packet data network and EPS. When talking in the sense of mobility PDN-GW may be called as the highest level mobility anchor in the system. It provides connectivity to the S-GW through S5/S8 interface and to Internet through SGi interface. When the transmission is taking place from EPC to service domain, the data packets from S-GW are transmitted to the internet through SGi interface. Whereas when the transmission is taking place in opposite direction, data packets are transmitted through S5 interface and are then forwarded to S-GW which handles that particular user.

PDN-GW also has the responsibility of assigning IP addresses to the mobile devices. UE can use IP address for communicating with IP hosts in external networks such as Internet. As soon as UE requests for a PDN connection an IP address will be allotted to the UE. Mobile unit first sends its request to eNodeB which then forwards it to MME through S1-CP. Once the authentication is completed the MME sends a request to the PDN-GW for IP address. If PDN gateway approves the request then it sends back an assigned IP address to MME. MME forwards this address to eNodeB which further forwards it to the mobile unit. According to the need of UE IPv4, IPv6 or both addresses can be allocated to the UE. When a mobile subscriber uses multiple services provided by its network such as IP multimedia subsystem then it needed Multiple IP address allocation.

2.1.4. Home Subscriber Server (HSS)

HSS basically acts as a data base server that stores all the information about every user which is present in the network. The HSS also contains the information about the user location. The authentication and authorization of the usersand the services provided to them are also done by HSS. The HSS also keeps the original copy of the user subscription profile. This user subscription profile has all the information about the user such as the services that the user can use e.g. SMS, call forwarding etc., the PDNs to which the UE is allowed to connect to, ID of MME or SGSN which is used in case user's HSS profile is updated and the networks where the UE is allowed to roam.

HSS should be connected to all the MMEs in the network that controls the UE, so it keeps on interacting with the MMEs.When the communication is taking place through MME, the MME updates the HSS about the user location. The HSS also updates the MME about the user profile. When HSS receives the user location from another MME, the HSS will cancel the previous location information and it will then be updated based on the new MME information.

2.2. Evolved Universal Terrestrial Radio Access Network (E-UTRAN)

E-UTRAN is an air interface of 3GPP's Long-Term Evolution (LTE) mobile networks. The LTE's E-UTRAN is a totally new air interface system, which provides higher data rates and lower latency as compared to the existing networks.Evolved NodeB (eNodeB) is the only physical node present in EUTRAN. The eNodeBs are distributed throughout the whole coverage region. The main function of eNodeB is to provide bridging between UE and the EPC. This simplification is done so as to reduce the latency of all the radio interface operations. The eNodeBs are connected to each other via X2 interface, and they connect to the core network via S1 interface.

2.2.1. The eNodeB

The eNodeB can be called as a termination point of all the radio protocols towards the UE. It also acts as a data relay between the radio connection and the corresponding IP based connectivity for the EPC.The eNodeB may be connected to multiple UEs within its coverage area, but each UE is connected to only one eNodeB at a time. The eNodeB will need to be connected to those neighbouring eNodeBs with which a handover may be required.A set of MMEs and S-GWs are assigned to serve and maintain a particular set of eNodeBs,whereas each UE will be handled by only one MME and S-GW at a time. The main features supported by eNodeB are as follows:

- **Radio Bearer management** –This controls all functions related to the radio functionality in LTE for both user plane and control plane. This is a very important part which includes Radio Bearer setup & release procedures and also involves Radio Resource Management (RRM) functionalities for a proper bearer allocationand initial admission control. One more RRM responsibility is to make the mobility feasible in wireless networks so that the network can take care of the UE mobility without user interference. RRM basically handles the responsibilities and functions related to scheduling, admission control, radio bearer control and radio mobility control.

- **Mobility management** – The eNodeB has an important role in Mobility Management (MM), sincethis function handles the mobility of the UE while the UE is in an active state. It is responsible for deciding that whether a handover is required or not and this decision is made on the basis of measurements sent by the UE. It also handles the functions of radio measurement configuration and processing as well as the handover algorithms for mobility decision and target cell determination during the handover process.
- **Radio interface transmission and reception** – This basically handles the radio transmission by performing proper modulation/demodulation and channel coding/decoding.

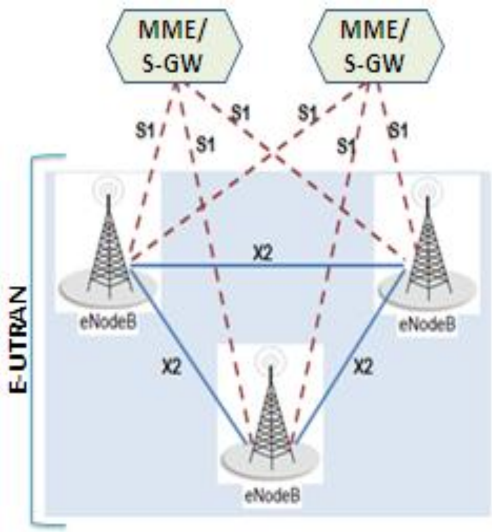

Figure 3: E-UTRAN Architecture

- **User data IP header compression and encryption** – This is important to fulfil the requirements to maintain privacy over the radio interface and transmit IP packets while transmission. IP packet headers results to a huge overheads; therefore headers should be compressed for the efficient use of the radio interface.
- **Network security** –The network signalling security is necessary for avoiding the access of data by any unauthorized user. The signalling messages which are exchanged between the eNodeBand the terminal or between the MME and the terminal, the information present in the message are protected. For the maintenance of security ciphering and integrity protection functions are used which are always activated together by the RRC.

2.3. User Equipment (UE)

User equipment is basically a device that the end users use for communication like smartphones, laptops, mobile tablets etc. The UE is an end-user platform that sets up and maintains the necessary communication links by the use of proper signalling with the network. The UE also handles the mobility function like handover procedure and sends reports about the terminal location to the network so as to keep the network updated aboutUE location.

The mobile equipment comprised of mainly two important modules, Terminal Equipment (TE) and Universal Integrated Circuit Card (UICC). The terminal Equipment basically terminates the data streams whereas the UICC which is also known as the SIM card, runs an application that keeps information about the user's phone number, home network identity and security keys etc.

2.4. Service Domain

The service domain basically handles all the multimedia based services. This domain supports IP based multimedia services by acting as IP multimedia sub-system (IMS) whereas it also supports non-IMS operator based services and some other services which are provided through the internet. In IMSthe services may be provided by using the Session Initiation Protocol (SIP). In non-IMS operator based services the operator may simply put a server in its network so that the UEs are able to connect with the server. The UE may connect to a server in the internet, e.g. to a web-server for web browsing services, or to a SIP server for internet telephony service depending upon the user requirement.

3. Conclusion

LTE has shown a great improvement in terms of its architecture and services. Major changes were made in the architectural block by simplifying its elements to provide a level of ease during transmission and reception of data. LTE also provides a seamless communication within the same and different radio access network. The high data rates supported by it and other user friendly services, makes LTE better than the existing technologies.

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