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LTE and SAE: The Protocol Architecture in Mobile Broadband

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Abstract— This paper is to describe the new wireless communication technology Long Term Evaluation. LTE became the most powerful technology in cellular system to achieve the high speed, spectral efficiency and reduce latency rate in uplink and downlink. The LTE architecture is known as (SAE) service architecture evolution. SAE is the combination of Evolved universal terrestrial radio access network and Evolved packet core. This paper explained the working principle and functionality of different entity in LTE architecture and also described the Protocol stacks between user equipment, ENodeB and Evolved packet Core. The protocols stacks are divided into control plane and user plane. The major function of these protocols is to manage the overall functionality of LTE architecture system.

Keywords: "LTE, S-GW, P-GW, PDCP, MAC"

I. INTRODUCTION

The growth of mobile user has fast evolution during in last few decades. Nowadays the Z Generation carries the smart devices in their hands which become the part of their life. These user wants more and more speed, efficiency and latest technology on their devices. Every services provider and organization are not full fill the demands of hungry users [3]. To overcome these problems 3 GPP (Generation Partnership Project) initiated in 1999 and continue working in the improvement and enhanced the efficiency, speed, architecture, QoS and many more areas [11]. 3GPP is the organization partner of different working groups likes RAN, G-RAN, SA, CT [12]. They provide one solutions in the form of LTE/LTE-A technology. LTE is known as Long Term Evolution it is also called 4th generation technology in cellular networks [22]. LTE technology used the OFDMA (orthogonal frequency division multiple access) for downlink, SC-FDMA (Single Carrier frequency division multiple access) for uplink and MIMO (Multiple input multiple output) antenna system used for communication [8][1]. In the earlier system communication, has been done by circuit switching (phone call) and packet switching (data stream, web pages, E-mail) component. Major problem in circuit switching system was inefficiency, inappropriate for data transfer and usually over dimensions [24]. To reduce these problems designed of LTE in a packet switching network. Aim to provide IP connectivity network to user device with packet data gateway [4].

Aim of the LTE/LTE-A is to achieved the

- Packets speed for download in 100 Mbps and 50Mbps in upload.
- Optimization terminal power efficiency.
- Reduce spectral efficiency.
- Enhanced mobility and security.
- Lower system complexity and implementation cost.
- High cell Coverage area.

This paper is dividing into 5 sections. Section 1 detailed about basic introduction of LTE its organization and aim of LTE technology. Sections 2 describe the architecture of LTE technology and its different entity and their major functionality. In continuous section 3, detailed about LTE interface. Protocol stacks and their working principle explain in section 4. The Conclusion of full paper described in section 5.

II. ARCHITECTURE OF LTE

In LTE technology, major changed has been done in physical layer of previous architecture [2]. LTE architecture is combination of EPC and E-UTRAN layer. E-UTRAN used to control the radio network and EPC is the enhanced in previous network known as core network shown in figure 1[8]. The architecture of the core network is also called Evolved Packet System or Services Architecture Evolution [4]. The new core architecture provides backward compatibility with previous technology GSM-HSPA networks and other wireless-technologies (CDMA2000 and Wi-Fi) [6].

E-UTRAN is the first entry point of the UE (User Equipment) to the LTE network. E-UTRAN is responsible for control all radio access from or to the UE. E-UTRAN contains the medium access control system to control and connect the number of user equipment by the same communication channel. Access Stratum (AS) is a protocol that works between the UE and E-UTRAN [8]. Major function of that protocol is to ensure link level reliability, IP header compression, segmentation and reassemble of higher layer protocol data unit [7]. All these functions have been done by a single node or entity called eNodeB in fig. 4. EPC is the enhancement and radical evolution in the previous architecture of LTE system [12]. EPC supports only IP packet. Major function of the EPC is handling end to end connection, charging function and authentication. EPC contains the different entity to handle these functions. These entities are MME, P-GW, S-GW and HSS in figure 1[4].

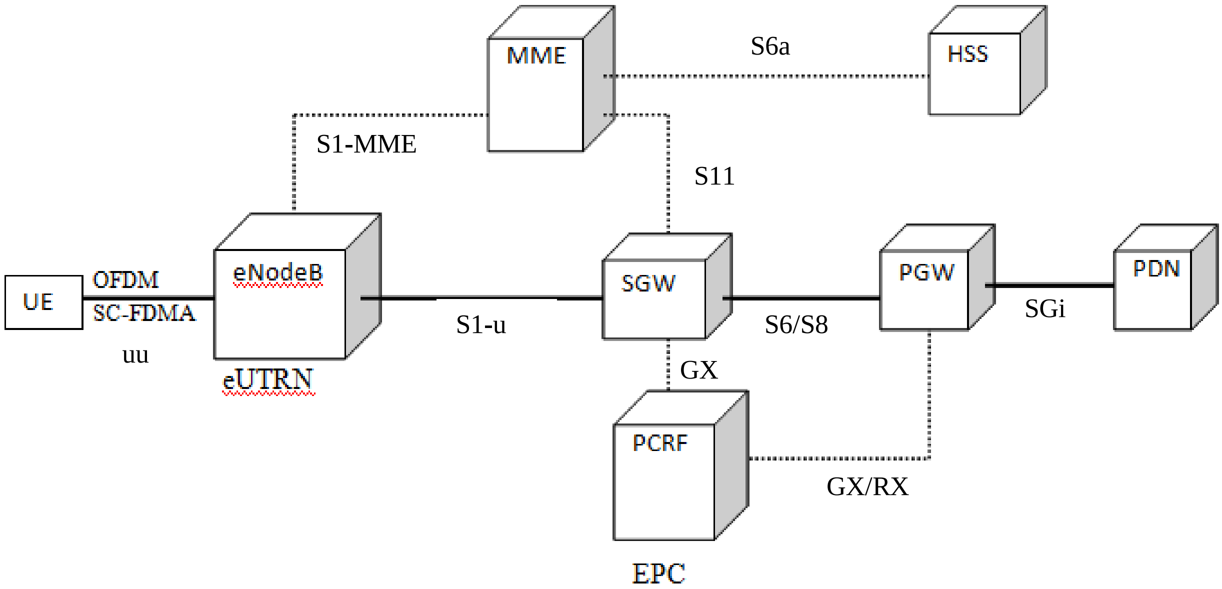

Fig. 1 LTE Architecture

A. Mobile Management Entity

MME is the primary control element in the evolved packet system. The MME operate only in control plane. MME is the first connection control point for UE [21]. Whenever a user wants to communicate, firstly it maintains a control plane to the MME after that it connects to the eNodeB. Main functions of MME are list below:

- Authentication and security.
- Mobility management.
- Managing services connectivity.
- Inter eNodeB handover.
- Bearer management.
- Paging.
- Location management.
- User profile.
- Handover between MME.
- Control of user plane tunnel.

B. Serving Gateway (S-GW)

The basic function of the S-GW is maintained and switching the user plane. Serving gateway is the inter mediator between the P-GW and eNodeB. S-GW uses the GTP tunnelling system to manage the user data [8]. P-GW is responsible for mapping between the IP packet and GTP tunnels. S-GW used two types of control interface s5/s8 and s5/s8 PMIP. Whenever its used the s5/s8 interface all the control information come from either MME or P-GW and its no need to connect with PCRF function. While using s5/s8 PMIP interface S-GW act as mapping the IP packet and GTP tunnels in S1 interface. Major role of the S-GW to manage the user plane and allocate the resource allocation to user based of the MME, P-GW and PCRF control plane request. Major functions of S-GW are given below [9]:

- Control the GTP tunnels.
- IP services flow.
- GTP tunnels for UL and DL data delivery.
- User plane tunnels for UL and DL data delivery.

C. Packet Data Network Gateway (P-GW)

Major function of PDN is to allocate the IP address to the user equipment. PDN allocate IP to user only when a UE send request for PDN connection. P-GW used Dynamic Host Configuration Protocol (DHCP) for connection. It connects the EPC to external network source [24]. Data traffic between the PDN and external source is in the form of IP packets that belong to the various IP services forwarding flow. When User moves from one S-GW to another S-GW, P-GW release the connection between S-GW and User and established a new connection between User and new S-GW. It controls the user plane tunnel for data delivery in downlink and uplink direction. P-GW also control the Policy and charging control request when S-GW used the s5/s8 PMIP interface. Major functions of P-GW are given below [9]:

- Packet filtering.
- Transport –level packet marking in UL and DL by using DSCP.
- QCI through the rate policy and shaping.
- Mobility between 3GPP and Non-3GPP access.

D. Policy charging Rule Function (PCRF)

First time PCRF introduced to improvement in 3GPP R-7. Before this P-GW used the policy and charging enforcement function (PCEF) that used for SDF detection, flow based charging and policy enforcement. That is the part of policy and charging control in PDN model. In R-8 it has been improved by PCRF function and defined as a node in EPS. PCRF is the combination of policy decision function (PDF) and charging rule function (CRF) [24]. It's defines the policy control and flow-based charging control function for real time traffic [4]. PCRF contain the application function (AF) that support the application that is required for policy and charging function for network elements. PCRF provides different data–bearer classes for different QoS for network element. Each data-bearer are allocate the QCI parameter which has include the minimum guaranteed bit rate required, scheduling priority number, packets delay budgets and packets error loss rate for specific network. That is shown in table [19].

E. Home Subscription/Subscriber Server (HSS)

It is combination node of home location register and authentication canter which has already exists in parent's architecture of LTE [4]. It contains all data base information and services which is applicable for permanent user. It also record information about the user in home location, visited and control node [20]. HSS record the all P-GW and MME that are used by network. It records the information of MME that is used by user, as soon as the user moves from one MME to another the HSS update information about new MME. A home network may contain one or more HSS depending on his capacity.

III.LTE INTERFACE

Interface is done by two major protocols that are control plane and data plane. Control plane contain all the protocol that is used to control the signal and manage the connection while data plane contain all the protocol that support for data transmission through the network shown in fig. 3. S1 and X2 are the interface responsible to connect the E-UTRAN to several entities of LTE architecture [4]. X2 interface provides communication among the eNodeB. It include the interference coordination, load management handover and data transmission.

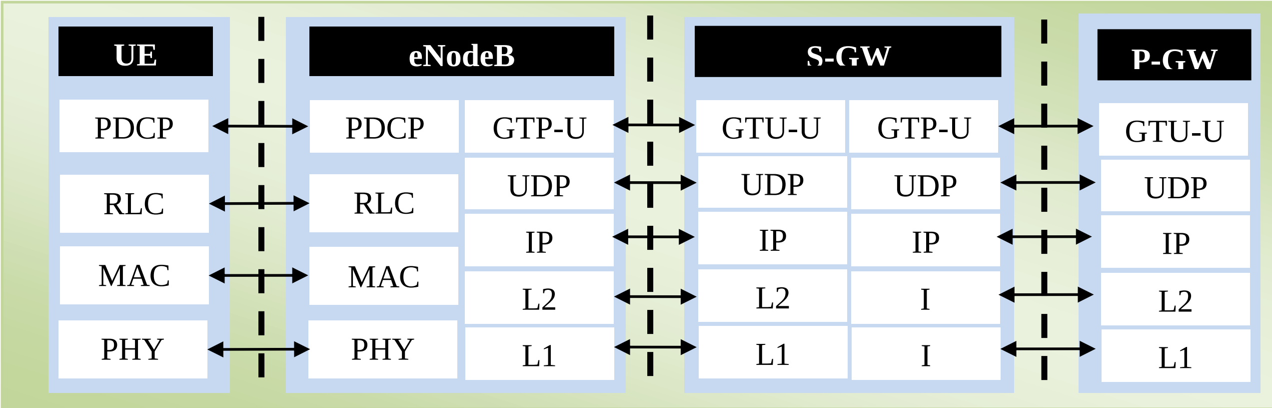

Fig. 2 User Plan Protocol Stack EPS in LTE interface

S1 have two type of interface S1-U and S1-MME to connect the eNodeB to the Evolved packet core. S1-U interface provide the connection between eNodeB and S-GW and it's used to transfer the user data. S1-MME interface is used between the eNodeB and HSS entity of EPC. It's used to transfer the control plane information likes mobility supports, location services network management and data services management [5].

IV. Protocol Stack of LTE Architecture

A protocol contains the set of rule for communication between two entities. In LTE/LTE-A protocol has been designed by the 3GPP and internet engineering task force (IETF). In 3GPP two type of protocol we have already discuss in previous section. Each entity in EPS has its own layer and set of protocol either in control plane or user plane. In this section, we are going to discuss some major protocols stack that is working among user equipment, eNodeB, MME, S-GW and P-GW [18].

A. Control plane protocol stack for E-UTRAN

E-UTRAN is a radio node, which is known as the eNodeB or a combination of eNodeB in LTE architecture. It is the enhancement in NodeB of UMTS architecture. Radio network control (RNC) has eliminated from the previous version and its application moved in eNodeB [24]. In EPS, E-UTRAN is a mediator between User equipment and evolved packet core shown in fig 2. Evolved packet core have contain many logical nodes. E-UTRAN connects these nodes with the help of different interface which we have already discussed. In this section, we are going to discuss the relationship between user equipment, E-UTRAN and EPC [16].

E-UTRAN interface with the User Equipment with Uu interface. It is radio interface or control plane. In fig 3, E-UTRAN has different protocol which we discussed one by one.

B. Radio Resource Control Protocol (RRC)

This protocol is Broadcast the system information related to the RRC connected and RRC idle state. When RRC in connected state it controls all the lower layer and perform different operation like establishment, maintaining and release the RRC connection, initial security activation, mobility management in inter and intra RAT, paging, establishment and maintaining signal radio bearer for control and data plane[20].

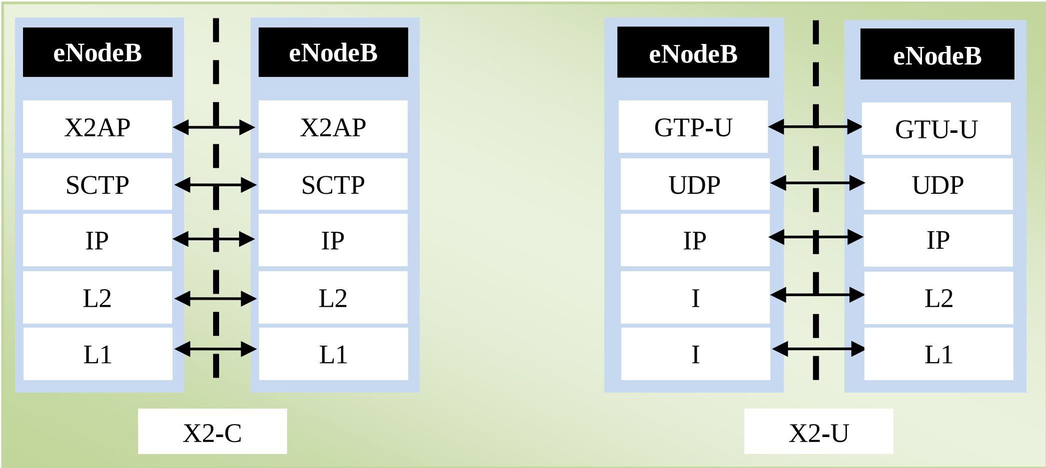

Fig. 3 Control and user plane protocol stacks for x2 interface in LTE Architecture

C. Packet Data Convergence Protocol (PDCP)

This protocol is responsible for transfer of user information (User Plane and Control Plane) to the RLC protocol. PDCP compressed the IP header to reduce the extra overhead latency. It arranges the sequence of user information, check integrity. This protocol also performs the ciphering and deciphering operation for user plane and control plane data.

D. Radio Link Control Protocol (RLC)

This layer is located between the packet data convergence protocol and medium access control protocol. The Radio link control protocol working in one of the three modes i.e. transparent, un-acknowledgement and acknowledgement mode [19]. Major function of that unit is to receive SDU's from the higher layer and segmentation the data into PDU's and sends it to the MAC. In transparent mode, it sends data as well as it received from higher layer. In un-acknowledgement mode breaks the SDU into PDU and attached the RLC header and send this to the multiplexer buffer [17]. The MUX is decided that which PDU and when PDU to send the MAC and which one logical channel is used for this. On the other in acknowledgement mode RLC use retransmission and transmission buffer. In this buffer, it contains a duplicate copy of transmitted PDU's when it receives positive acknowledgments from receiver side it deletes the duplicate copies from buffer. Otherwise these duplicate copies are used for retransmission the PDU's. Some major function of this protocol is in sequence delivery of higher layer PDU's, connection control, assembling and reassembling PDU, error correction and detection, duplication and flow control.

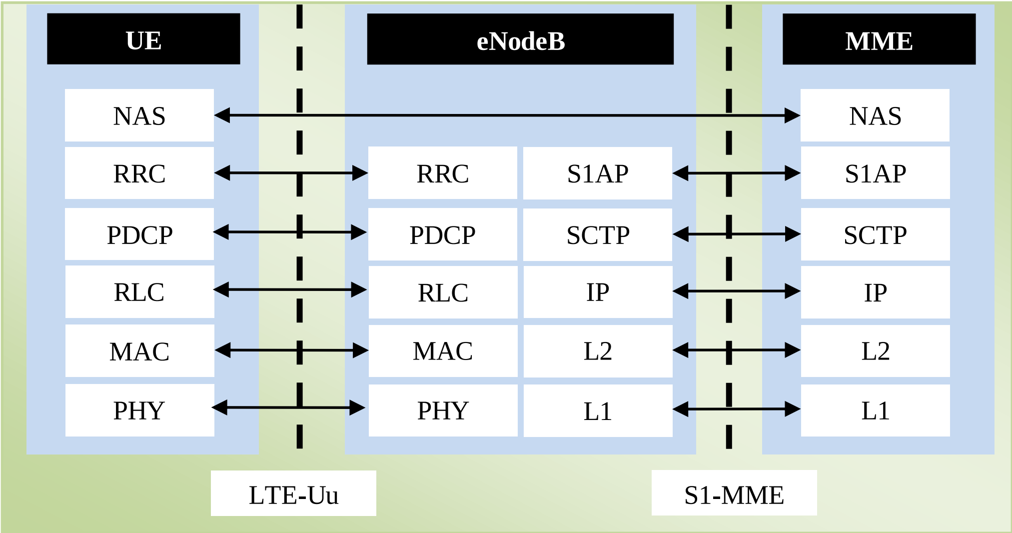

Fig. 4 Control plane protocol stacks for EPS in LTE architecture

E. Medium Access control (MAC)

Medium access control protocol is situated in between the radio link control protocol and physical protocol. Major function of this protocol is data transfer, radio resource allocation and map the logical channel into the transport channel [10]. This transport channel is used for transfer the MAC SDU to the physical protocol. 3GPP define two types of MAC entity these are UE and E-UTRAN. MAC protocol performs different function in both entities. MAC used radio network for communicated with these entities. Some other major functions of MAC protocols are scheduling, error correction with the help of HARQ techniques and selection of transport format physical protocol.

F. Physical Layer / Protocol (PHY)

Physical layer is responsible for control the data and signal between user equipment and eNodeB. A Uu radio link interface is used to control both operations. Physical layer map the transport channel into physical channel which came from the higher layer [11]. Major function of the physical layer is to provide the dynamic resource and data rate for the various users. Physical protocol used FDD and TDD types of frame structure for data and control resource. In FDD two different frequency resources is used for uplink and downlink. On the other TDD used same resource with different time synchronization slot for uplink and downlink.

G. Non-Access Stratum Protocol (NAS)

This protocol is used between the user equipment and mobility management Entity. This protocol is the part of control plane. Protocol is responsible for mobility management and session management between the user, E-UTRAN and EPS. Non-access stratum security has additional function provide the integrity and ciphering in NAS signal [12].

H. IP, UDP, L2 and L1

These protocols are designed by internet engineering task force. Internet protocol is responsible for delivering the packet from source host to destination with different routing scheme [15]. Data link layer protocol or L2 used for ARP Address resolution protocol to link the data between L3 and L1. User data gram protocol is connection less protocol defined by IETF [14].

I. S1AP and X2AP [7]

S1 Application Protocol is responsible for providing control information between E-UTRAN and EPC through S1 interface. Major function of S1AP protocol is E-RAB (Radio Access Bearer) management, modification and release. This bearer is established by MME. when it releases RAB it also release the connection between eNodeB [13]. This protocol also identifies the load balancing function, paging and location management.

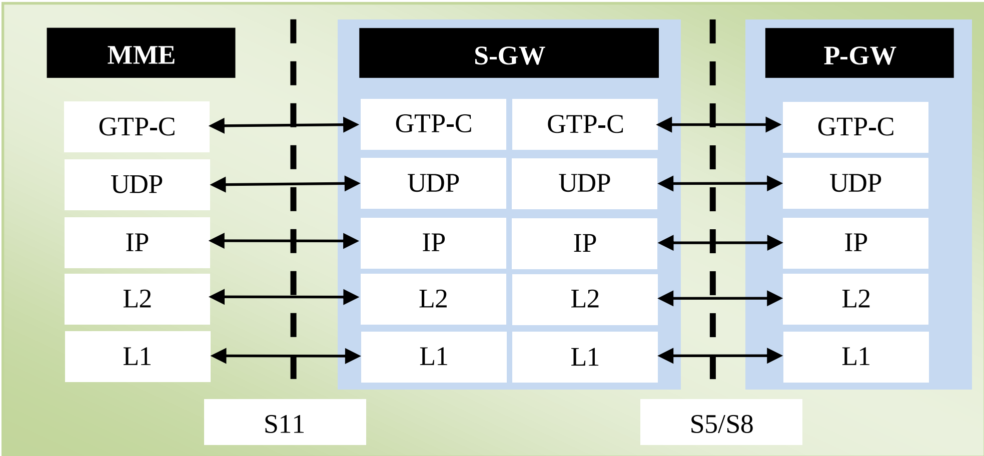

Fig. 5 User plane protocol stacks for EPS in LTE architecture.

J. GTP-C and GTP-U

GPRS tunnelling protocol control and user is based on the IP communication protocol. GTP-C used within the core network for providing the information between GGSN and SGSN. GTP-U protocol carries the user data between the radio access network and core network. This protocol can be used with UDP and TCP protocol.

K. SCTP

Stream control transmission protocol is designed by internet engineering task force (IETF) in RFC 4096 [14]. This protocol is used to communication in connection less packet network like 3gpp. Major function of this protocol is sequence delivery of user message between different streams, delivery error free non-repetition of user data and data fragmentation.

V. Conclusion

LTE become the most popular and power full radio access technology in cellular network reason behind this rapidly growing user. They all are hungry about fast access the technology. 3GPP working continuously enhancement in the cellular technology. They proposed new technology in released 8 in 2008 named long term evolution.

In this paper we describe the architecture and entities of new technology and their interface to each other by protocol stacks. These protocols are designed by 3GPP and internet engineering task force (IETF).

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