4G TO 5G MIGRATION THROUGH CORE NETWORK

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Abstract— In this paper, we consider 5G as an evolution of 4G, thus we propose logical connections between LTE-A entities such as SGW, PDN firstly. Then, we present a new configuration and accordingly data/control realization of 5G EPS (Evolved Packet System) based on a carrier-grade hypervisor and an intelligent core server (IC server) to provide virtualization and flexibility to the network. In addition, we define two new entities hAN (heterogeneous access network) and TNT-Gateway (TENANT Gateway) for access and core, respectively and define their functions and data/signaling connections. Some important advantages of these configurations are: 1) cost reduction, 2) network efficiency improvement, and 3) increase of network flexibility and service availability which approaches LTE to 5G.

Index Terms— 5G, EPS, hAN, TNT-Gateway, LTE.

I. INTRODUCTION

MOBILE networks were based on distinct circuits and are packet switched parts from 3GPP R4 to R7. Data was supported via GPRS and voice via a circuit switched modules in these releases. A fully packet switched network was established in LTE from 3GPP R8 onward. Besides, RNC and eNodeB were integrated to constitute E-UTRAN node in LTE [1].

5G mobile network concept appeared since 2012 to improve QoS of the legacy networks and offer new services [2]. Network functions in UMTS and LTE are distributed among network nodes such as UE, eNB, MME, etc. These nodes communicate through control/data messages and are classified into Non-Access-Stratum (NAS) and Access-Stratum (AS). NAS is a functional layer between UE and core network elements such as MME, SGSN, MSC and includes messages such as Location Update, Attach/Detach, Authentication, Service request, etc. These messages provide session management, call control management, and mobility management. NAS messages pass the air interface transparently [3].

On the contrary, Access stratum (AS) is responsible for transporting the messages in wireless network section i.e. UE and eNB [4]. Since we need to improve QoS parameters in 5G and we must reduce the E2E QoS parameters such as latency through a well-designed NAS. For instance, AS and NAS consolidation may reduce the control signal exchanges in the network and consequently reduce the E2E latency. In line with that, developing NAS protocols in the future networks may results in better data rates, service definition and availability [5]. Fig. 1 depicts the reference LTE infrastructure model.
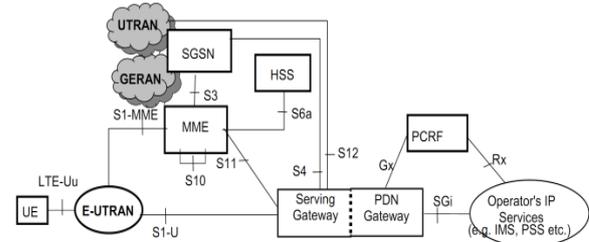
Fig. 1 LTE infrastructure basic model [6]

As it is shown in Fig. 1, infrastructure is composed of two components E-UTRAN and EPC. E-UTRAN is composed of UE and eNB and EPC which constitutes core network composed of some distinct and independent entities such as MME, Serving-GW, PDN-GW, PCRF and HSS. These entities are made up of individual software and hardware. In addition, EPC together with E-UTRAN is called (Evolved Packet System) EPS which we must build it in 5G as an integrated architecture [7].

In non-virtual networks and for each vendor, network function (NF) is generally composed of a dedicated and distinct software on a hardware while in a virtual network whole the software is separated from the hardware. Here, a pool of hardware resources convened which provide computing, storage and network elements to whole the software or functional entities. In addition, VNs provide dynamic network function deployment advantage [8, 9].

Guerzoni et al. proposed in [10] an SDN architecture which relies on a unified control plane made by three logical controllers: the Device controller, the Edge controller, and the Orchestration controller. Authors in [11, 12] have defined a network based on three items: an adaptive allocated of network functions, a software defined mobile network controller (SDMC) and, joint optimization of mobile access and core network functions. Authors in [13] have used a session border controller (SBC) with the NFV and SDN to promote the network functionalities.

Based on LTE and in line with those and to provide higher flexibility and QoS, in this paper, we have demonstrated a modified infrastructure, their entities, and functions in Section 2, proposed architecture, signaling and data connections in Section 3 and finally explained the conclusion.

II. 5G ARCHITECTURE AND FUNCTIONALITIES

Since our contribution in this paper is based on developing the LTE-A infrastructure, we explain it shortly and then develop it to approach to 5G infrastructure.

Fig. 1 shows the Virtual LTE Functions: eNB, MME, S-GW, PCRF, and PDN-GW. Since 5G includes different

technologies, we should develop LTE- infrastructure in two domains i.e., access and core network [2]. In the access section, we have defined a comprehensive heterogeneous access network hAN entity including eNodeB functionalities and new capabilities such as separating the BBU from RRH and establishing small cells for 5G. Therefore, we may provide multi mobile technologies. hAN contains pools of BBUs that facilitate data/control signal flows between RRHs and core network (Fig. 2).
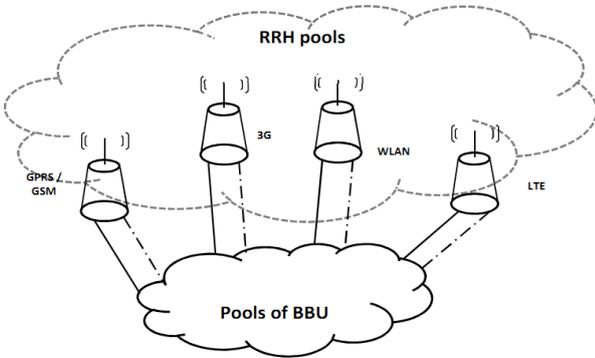

Fig. 2 RRH to hAN connections [2]

To develop LTE functionalities in the core domain, we have created a new entity by the name of TENANT Gateway (TNT Gateway) in the core infrastructure to provide functionalities for vertical market players such as operators, utility companies and other organs such as YouTube, Netflix and OTT applications.
We have provided and summarized entities and functionalities of LTE EPS in Table 1 firstly [14, 15, 16], then to improve the above functionalities, we have added some functions for hAN, and TNT Gateway in Table 1. To improve the QoS parameters in 5G, we should augment flexibility to the network. Thus, we have defined the entity functionalities as distinct f1, f2 etc. functions in Table 1. f1, f2, etc. are EPS functions written in the right side of Table 1. These functions will be dynamically invoked according to the user's requested service.

III. PROPOSED ARCHITECTURE

In 5G, we intend to consolidate different network equipment via making a pool of servers, switches, and storages deployed using SDN. Consequently, we have provided cost saving and flexibility in network operation and better service availability and facilities in this reconfiguration of networks [16]. We can envisage the Evolved Packet Core (EPC) entities e.g., Serving Gateway (SGW) and Packet Data Network Gateway (PGW) as VNFs. To provide the new architecture including the entities and their logical and data connections, we first reviewed the ladder diagrams in [4] and [6] which represent the entities, signalling and data messages following between different network entities in LTE. Table 2 has been derived from those ladder diagrams and reveals control and data entity connections.We put a tick mark in cross section of a row and a column when a control/data message follows between them. In addition, we inserted TGW (TENANT Gateway) entity in Table 2.
To provide the flexibility to 5G infrastructure we use network slicing. This feature allocates the suitable nodes, functions, and topology to a specific service to provide an optimum QOS for it. We may use Tables 1 and 2 to provide functions and logical and data connections.

EPS entity (Virtual Function)	EPC Functions
eNB hosts / hAN	f1: Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in uplink, downlink, and sidelink (scheduling); f2: IP header compression and encryption of user data stream; f3: Selection of an MME at UE attachment when no routing to an MME can be determined from the information provided by the UE; f4: Routing of User Plane data towards Serving Gateway; f5: Scheduling and transmission of paging messages (originated from the MME); f6: Scheduling and transmission of broadcast information (originated from the MME or O&M); f7: Measurement and measurement reporting configuration for mobility and scheduling; f8: Scheduling and transmission of PWS (which includes ETWS and CMAS) messages (originated from the MME); f9: CSG handling; f10: Transport level packet marking in the uplink; f1: S-GW relocation without UE mobility, as defined in [6]; f1: Optionally registering with the X2 GW (if used).
DeNB host	f1: S1/X2 proxy functionality for supporting RNs; f2: S11 termination and S-GW/P-GW functionality for supporting RNs.
MME host	f1: NAS signalling; f2: NAS signalling security; f3: AS Security control; f4: Inter CN node signalling for mobility between 3GPP access networks; f5: Idle mode UE Reachability (including control and execution of paging retransmission); f6: Tracking Area list management (for UE in idle and active mode); f7: PDN GW and Serving GW selection; f8: MME selection for handovers with MME change; f9: SGSN selection for handovers to 2G or 3G 3GPP access networks; f10: Roaming; f11: Authentication; f12: Bearer management functions including dedicated bearer establishment; f13: Support for PWS (which includes ETWS and CMAS) message transmission; f14: Optionally performing paging optimisation; f15: S-GW relocation without UE mobility, as defined in [6]. NOTE 1: The MME should not filter the PAGING message based on the CSG IDs towards macro eNBs.
Serving Gateway (S-GW) host	f1: The local Mobility Anchor point for inter-eNB handover; f2: Mobility anchoring for inter-3GPP mobility; f3: E-UTRAN idle mode downlink packet buffering and initiation of network triggered service request procedure; f4: Lawful Interception; f5: Packet routing and forwarding; f6: Transport level packet marking in the uplink and the downlink; f7: Accounting on user and QCI granularity for inter-operator charging; f8: UL and DL charging per UE, PDN, and QCI.
PDN Gateway (P-GW) host	f1: Per-user based packet filtering (by e.g. deep packet inspection); f2: Lawful Interception; f3: UE IP address allocation; f4: Transport level packet marking in the uplink and the downlink; f5: UL and DL service level charging, gating, and rate enforcement; f6: DL rate enforcement based on APN-AMBR;

PCRF	f1: The PCRF checks that if the policy set-up information received from the AF is consistent with operator policies defined in the PCRF. f2: The PCRF authorizes QoS resources (bandwidth, etc.) for the AF session. The PCRF uses the policy set-up information received from the AF to calculate the proper authorization. The authorization includes the limits on QoS for the set of IP flows and restrictions on individual IP flows (e.g. destination address and port). f3: The PCRF decides if new QoS authorization (bandwidth, etc.) is needed due to a mid-call media or codec change. The PCRF re-authorizes QoS resources when the resources requested by the UE for a flow exceeds previous authorization, or a new flow is added, or when elements of the packet classifier(s) for authorized flows change. f4: The PCRF provides the policy decision information to the GGSN via the Gx interface. f5: The PCRF provides gating control decisions controlling the gate for the authorized media stream. At AF session release, the PCRF revokes the QoS resource authorization for the AF session. The Application Function (AF) is an element offering applications that require the control of IP bearer resources (e.g. UMTS PS domain/GPRS domain resources). One example of an Application Function is the P-CSCF in the IMS architecture.
TNT Gateway (vertical market players)	f1: Per vertical/user-based packet filtering (by e.g. deep packet inspection); f2: Lawful Interception; f3: Verticals IP address allocation;

TABLE II
CONTROL/DATA MESSAGE FLOW BETWEEN LTE ENTITIES

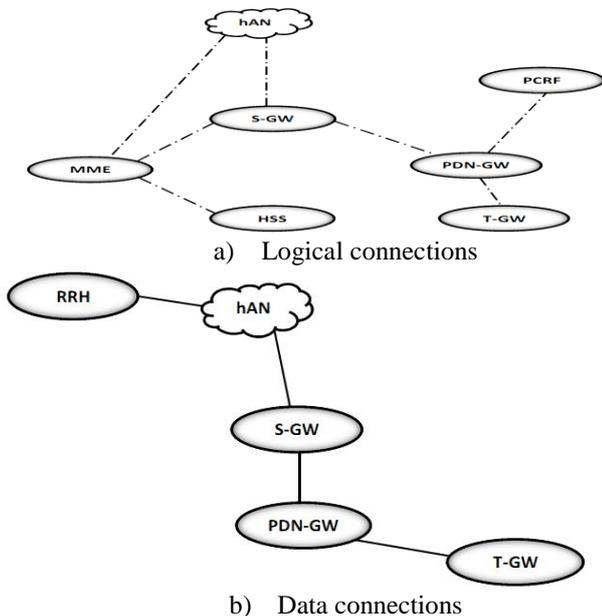| Entities	UE		Serving GW		PDN GW		MME		TGW	
	Data	Control	Data	Control	Data	Control	Data	Control	Data	Control
Serving GW		✓				✓		✓		
PDN GW			✓	✓					✓	✓
MME		✓		✓						
HSS								✓		
PCRF						✓				
eNB	✓	✓	✓					✓		

a) Logical connections

b) Data connections

Fig. 3 Logical / Data connections in 5G EPS

Ellipses show Virtual Network Functions (VNF) and the lines between them show logical connections through which control/data messages pass. Then we demonstrate the network configurations in a small and large scale network.

Fig. 4 depicts the proposed view of 5G EPS virtualization in a small scale network which is based on a carrier-grade hypervisor and only one intelligent core server (IC server). Carrier grade hypervisor is a component that is extremely reliable, well tested and proven in its capabilities and the Intelligent Core –Server (IC-Server) is an advanced commercial-off-the-shelf (COTS) hardware platform for software solutions.
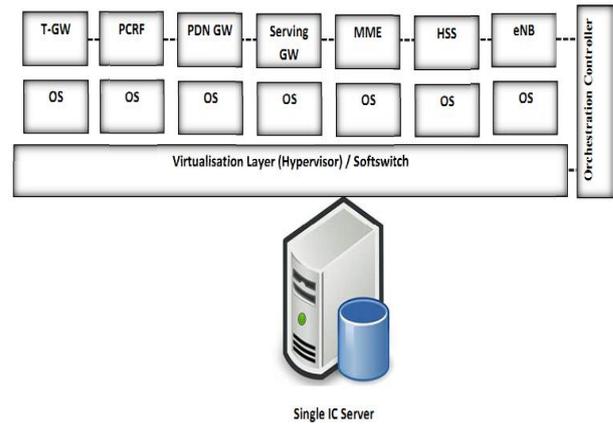

Fig. 4 Virtualization of 5G EPS by a server

To present our architecture we provide to Figs. 5 and 6. Fig. 5 depicts the proposed view of the control plane for 5G EPS virtualization in a large-scale network by a carrier grade hypervisor and a pool of intelligent core servers (IC servers). Fig. 6 depicts the proposed view of a data plane of 5G EPS virtualization in a large-scale network by a carrier grade hypervisor and a pool of servers.

We may use dynamic scheduler module to allocate functions from VNFs in Figs. 5 and 6. Besides, Orchestration controller is responsible for management and maintenance of virtual nodes.

Virtual functions eNB, MME, PCRF, etc. nodes in Figs.5 and 6 are located on top of the hypervisor and provided from Table 1 EPS functions and are made out of IC-server pools.
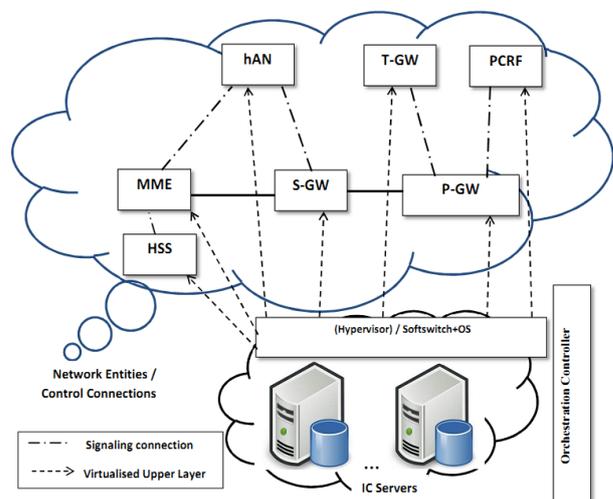

Fig. 5 Control plane virtualization of 5G EPS by a pool of IC servers

The hypervisor has embodied the hardware resources somehow that all of them are recruited optimally which results in cost saving in hardware resources. On the other hand, since all the above nodes are constituted of a unified infrastructure, data exchanges more easily among them. This provides more efficiency in the system throughput. In addition node accessibility is easier in this integrated system which provides service more easily for the users.
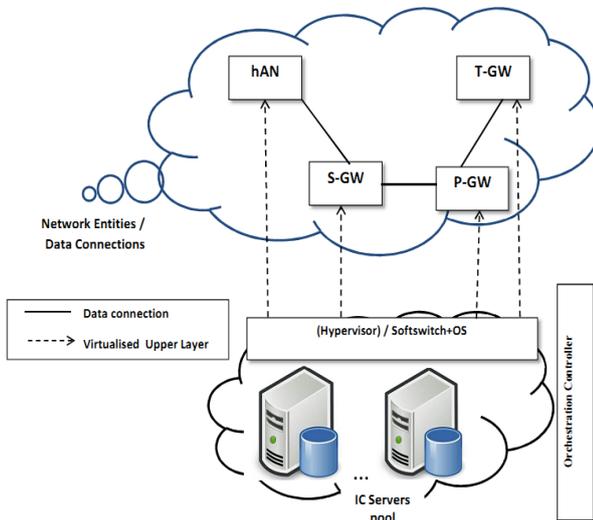

Fig. 6 Data plane virtualization of 5G EPS by a pool of IC servers

IV. CONCLUSION

We defined network entities and functions and new hAN and TGW functionalities in the existing access and core network respectively to upgrade the network to 5G capabilities. We used carrier grade hypervisor and an intelligent core server (IC server) to provide enough processing power and flexibility to the network to improve the QoS network parameters such as delay reduction and increasing the throughput. Besides, each of the functions f1, f2, etc. may be invoked according to the user's service request to provide enough flexibility.

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