SDN-based Distributed Mobility Management in LTE/EPC Network

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Abstract. As smart phone has rapidly proliferated over the past few years, it leads to new trend in data communication. Mobile data traffic is expected to continuously increase with an annual rate above 100%. Accordingly, LTE operators are in urgent need of means to cope with such increase in data volumes. The evolution of mobile network architectures toward flat architectures is being considered as a key solution to cope with the explosion of mobile data traffic. In this paper, we propose a new SDN-based distributed mobility management to solve these problems, which is proper to a new LTE/EPC network architecture supporting distributed P-GWs and virtually centralized control plane. For enhancing network performance, we also propose a route optimization strategy for internal traffic. The performance of the proposed solution is compared with the conventional LTE/EPC network in terms of the P-GW/PEGW's data processing volume per unit time and the number of valid data sessions. The comparison results showed that the proposed solution can be a more efficient way to support the scalability of LTE/EPC core network.

Keywords: Network Architecture, Distributed Mobility Management, Dynamic Mobility, LTE/EPC, SDN

1 Introduction

Due to the increasing popularity of smart-phones and other mobile devices, mobile data traffic is expected to continuously increase with an annual rate above 100% [1], [2]. Accordingly, LTE operators are in urgent need of means to cope with such increase in data volumes. The evolution of mobile network architectures toward flat architectures is being considered as a key solution to cope with the explosion of mobile data traffic [3]-[5]. For this, IETFs Distributed Mobility Management (DMM) working group is trying to make standardizations of IP mobility anchors at an access network level [6]-[9]. However, they try to standardize IP mobility solutions in general mobile network not specific network system like LTE/EPC network. Thus, the mobility support is still an ongoing research topic as there is still a strong need for a common mobility support solution for the Internet, especially LTE/EPC network.

As 3GPP evolves to the Evolved Packet Core (EPC) network, the network hierarchy is also being flattened. In the hierarchy, the number of LTE/EPC network elements decreases, where the main elements in the data plane are Packet Data Network Gateway (P-GW), Serving Gateway (S-GW), and Evolved Node B (eNodeB). The number of hierarchy levels is reduced in the EPC network compared with the GPRS/UMTS network. In later deployment, the P-GW and S-GW are expected to be co-located in the same physical element, thus further reducing the number of different network elements. In this hierarchy, the P-GW provides access to PDN by assigning an IP address to the UE. It serves as the mobility anchor point for 3GPP and non-3GPP handover. So, all data traffic for an UE is routed over the P-GW and thus the P-GW is needed to handle it. Furthermore, UEs do not change their mobility anchor points (P-GW) if they remain attached to the same operators access network.

DMM for distributing mobility anchors like as P-GW and the introduction of the SDN and NFV concept for virtually centralizing control plane in LTE/EPC network will lead to the deployment of flatter systems in which mobility anchor points are placed closer to the UEs. It is therefore expected that the change of UE's mobility anchors upon handover will happen far more often. DMM will have to provide the network with the possibility to keep ongoing sessions active also upon handovers that require mobility anchor change. Furthermore, a virtualized and centralized control plane allows for more flexibility and a higher degree of freedom by having the S-/P-GWs data-plane deployed on distributed P-GW.

In this paper, we propose a new distributed LTE/EPC network architecture based on SDN and NFV supporting distributed P-GWs. It is designed as three requirements about how to redesign LTE/EPC network: 1) Distributing data plane 2) Virtually centralizing control plane 3) Separation of the control and data planes. In order to distribute data plane, multiple distributed P-GWs are first deployed in different areas of the network. In order to satisfy other requirements, SDN and NFV were adapted to not only EPC networks but also the edge of the network. Next, the distributed mobility management, called SDN-based distributed mobility management, which is proper to the proposed architecture, is proposed. We also propose the route optimization in internal traffic for enhancing network performance.

For the performance evaluation, the proposed solution was implemented on the NS-3 LENA. The performance of the proposed solution was compared with the conventional LTE/EPC network system in terms of the P-GW/PEGWs data processing volume per unit time and the number of valid data sessions. The comparison results showed that the proposed LTE/EPC architecture and their DMM solution can be a more efficient way to support the scalability of LTE/EPC core network.

The rest of this paper is organized as follows. Section 2 proposes a SDN-based DMM approach in LTE/EPC. Section 3 investigates the performance of our proposal by simulations, and Section 4 finally concludes this paper.

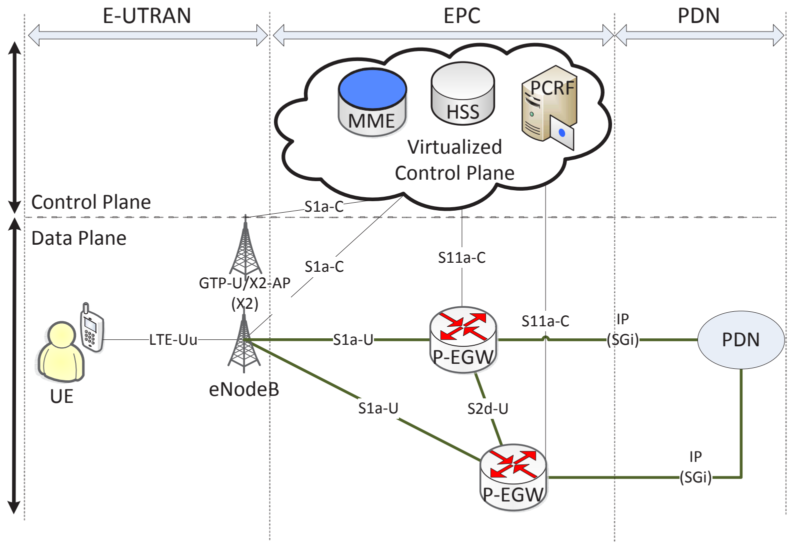


Fig. 1. Reference model for a SDN-based DMM architecture in LTE/EPC.

2 Proposed SDN-based DMM approach

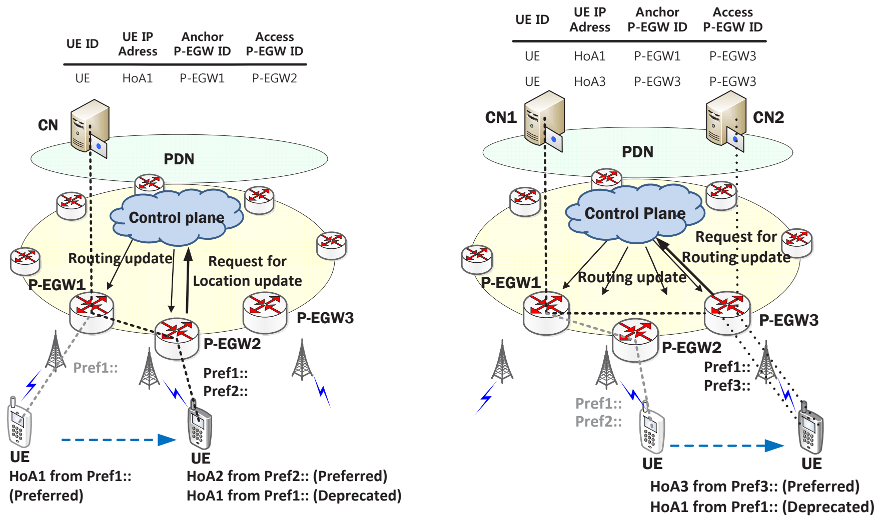
2.1 Proposed SDN-based DMM architecture

Fig.1 shows the reference model for the proposed SDN-based DMM architecture in LTE/EPC. It is designed as three requirements about how to redesign LTE/EPC network:

1) *Distributing data plane:* Instead of employing a single centralized infrastructure based on P-GW, multiple distributed components can be deployed in different areas of the network. A new network element, named packet data network edge gateway (P-EGW), is so similar to the existing P-GW in term of the functionalities and the roles. However, P-EGWs will be deployed near to the radio area network (RAN), so that their location will be somewhere between eNB and S-GW. P-EGW has also the role as SDN switch to communicate with SDN controller in a virtualized and centralized control plane. The distributing data plane allows scalability and flexibility to network;

2) *Virtually centralizing control plane:* The virtualized control plane is consists of MME, HSS, and PCRF being in charge of control parts in conventional LTE/EPC network. It is a cloud form using NFV and can communicate with the entities in data plane via SDN technology. The centralizing control plane can provide flexible and dynamic framework for optimization to network;

3) *Separation of the control and data planes:* In order to totally separate the LTE/EPC networks data and control planes, SDN is adapted to not only EPC networks but also the edge of the network. In other words, the functions



(a) Prior to handover.

(b) The change of access P-EGW and Access MME due to UE's movement.

Fig. 2. Updated tunnel bearer in case of the proposed handover management.

of whole networks entities including eNodeB, distributed P-GW, MME, and the others should be separated into the data and control planes and then should be managed by SDN technology. The separation of the control and data planes allows sophisticated traffic management to be driven by software, rather than purely by hardware routers.

2.2 Proposed SDN-based DMM

The proposed SDN-based DMM makes use of a routing protocol to support UE's mobility, instead of a tunnel protocol. The routing protocol is running in the control plane centralized cloud form. The routing update message between the control plane and P-EGW having role of SDN switch will be exchanged via SDN. SDN technique can provide a selective routing update method.

In this case, when the MN initially attaches to an anchor P-EGW, it obtains an IP address. The IP address is then internally advertised within the domain using an intra-domain protocol (e.g., IBGP). When the UE moves and attaches to a different P-EGW (Access P-EGW), the access P-EGW finds out the address assigned to the UE during the authentication phase via SDN controller in the control plane. If this is confirmed, a routing update between the anchor P-EGW and the access P-EGW is performed for session continuity by SDN controller in the control plane. In this way, the reachability of the UE is ensured while moving within the LTE/EPC network.

Meanwhile, when the UE in a new P-EGW's area tries to create a new PDN connection, the new P-EGW is in charge of creating the new PDN connection as the Anchor P-EGW. That is, a UE can have multiple PDN connections through multiple anchor P-EGWs. Therefore, these IP addresses related with multiple P-EGW will be managed. For this, the proposed DMM adopts distributed logical interface (DLIF) presented in [10].

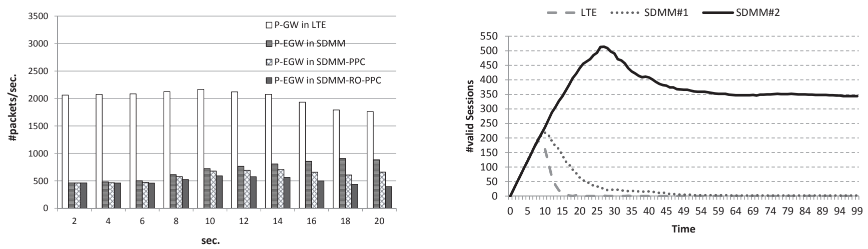
Therefore, the location information of UE in the proposed LTE/EPC network is ¡UE ID such as IMSI, UE IP Address, Anchor P-EGW ID, Access P-EGW ID¿ per UE's PDN connection. UE IP Address is unique for PDN connection anchored P-EGW. Anchor P-EGW ID and Access P-EGW ID are needed for finding the location of UE in distributed data plane. This location information of UE is naturally managed by this control plane. However, if the network system uses the other factor for data routing and forwarding and this factor is assigned per P-EGW, another factor can be used instead of UE IP Address.

An example of this solution is shown in Fig. 2. In Fig. **??**(a), a UE initially attaches to P-EGW #1 as anchor P-EGW and communicate with CN #1 in PDN. And then the UE move to P-EGW #2, P-EGW #2 acquires UE's information including address during the authentication phase via SDN controller in the control plane. And then P-EGW #2 request for routing update to the control plane via SDN. If the control plane receives this request, the control plane will perform a routing update between P-EGW #1 and access P-EGW #2. When the routing update is finished, the session data anchored P-EGW #1 between the UE and CN #1 is redirected to P-EGW #2. In 2 (b), the UE move to P-EGW #3, the session data anchored P-EGW #1 between the UE and CN #1 is redirected to P-EGW #3 though the same procedures. Meanwhile, when the UE create a new session to CN #2 in PDN, P-EGW #3 is anchor P-EGW for new session using new IP address. In this procedure, P-EGW #3 can create DLIF related with P-EGW #1, and then P-EGW #3 can send not only P-EGW #3's RA message but also P-EGW #1's RA message. At that time, P-EGW #3 do not have to create DLIF related with P-EGW #2 because there is no the session anchored P-EGW #2.

The data transfer after the movement of a UE in the proposed DMM is handled by suboptimal path not optimal path. However, this approach can reduce amount of signal messages related with routing update and the handover latency compared with previous routing based DMM approaches [11], [12]. However, the introduction of DLIF can solve this problem to some degree. Furthermore, it can be remove the cost related with tunnel compared with host and network based DMM approaches.

3 Performance Evaluation

In this section, we analyze the proposed mobility management schemes performance compared to the one in the conventional LTE/SAE network in terms of the P-GW/PEGWs data processing volume per unit time and the number of valid data sessions. For the analysis, we used the open source simulator NS-3.16 [13], with the LENA LTE module (M4 release).



(a) Prior to handover.

(b) Data throughput of P-GW or P-EGW per time.

Fig. 3. The number of valid data sessions.

The simulation area is $30km \times 30km$. As shown in the figure, the one P-GW, four S-GWs, and thirty-six eNBs are inter-connected in the conventional LTE/SAE network. On the other hand, we configured the two types of the proposed distributed LTE/SAE networks. The first one includes four P-EGWs, while the second one includes twelve P-EGWs. Therefore, the second one represents the more distribution of P-EGWs, each of which is directly connected to just three eNBs. Each wired link is a full-duplex link and provides a bandwidth of $10Gbps$. The delay of each link was configured to be the one between $25ms$ and $125ms$ considering the distance among each node. The LTE wireless channel and modulation/encoding models are set to be the default models provided by NS-3.16-LENA. Although MMEs are not shown in the figures, four MMEs are deployed closely to S-GWs or P-EGWs in each of three networks.

Fig. 3 (a) shows the P-GW and the P-EGWs data processing volume per unit time in traffic scenario. In the figure, the data processing volume of P-EGWs in all cases (SDMM, SDMM-PPC, SDMM-RO-PPC) is quite less than that of P-GW in the beginning of simulation due to the distributed architecture of P-EGWs. On the other hand, the total amount of data processing volume across all P-EGWs is more than the data processing volume of P-GW. It is due to the data traffic caused by routing between P-EGWs. However, as time goes by, the data processing volume of P-EGWs increases in the order of SDMM ¿ SDMM-PPC ¿ SDMM-RO-PPC. Especially, the one of the SDMM-RO-PPC is not nearly affected by the passing time.

Finally, Fig. 3 (b) plots the number of valid sessions in the conventional and proposed LTE/EPC networks. For the purpose of this thesis, a session is valid in terms of service quality if its packet drop rate is lower than 10%. In the experiment, we deployed 100 UEs randomly in the area and configured each UE to create a new session composed of 1Mbps UDP data traffic with another UE every 40ms. A handover situation was not generated. As shown in the figure, the proposed LTE/EPC network (SDMM#1, SDMM#2) can create valid sessions twice more than the conventional LTE/EPC network (LTE). Data traffic are concentrated to the P-GW in the conventional LTE/EPC network, while there is not such a single point in the proposed LTE/EPC network and all data traffic are directly tunneled between P-EGWs. That is, the proposed distributed LTE/EPC network does not suffer from the bottleneck problem at a specific node in the network, and thus it is more scalable than the conventional LTE/EPC network. In addition to that, the SDMM#2 can create valid sessions much more than the SDMM#1. That is, the proposed LTE/EPC network can permit more the number of UE and the data traffic volume as the number of deployed P-EGW is more larger and the PEGWs is deployed close to the RAN.

4 Conclusions

In this paper, we proposed a new distributed LTE/SAE network architecture supporting P-EGWs. We also proposed the distributed mobility management, called DMM-Anchoring, which is proper to the proposed architecture. The performance of the proposed distributed LTE/SAE network system was compared with the conventional LTE/SAE network system in terms of the P-GW's data processing volume per *unit* time and the number of valid data sessions. The comparison results showed that the proposed LTE/SAE architecture and DMM-anchoring can be a more efficient way to support the scalability of LTE/SAE core network.

In this thesis, a new distributed LTE/EPC network architecture based on SDN and NFV supporting P-EGWs is proposed. In addition, the distributed mobility management, called SDN-based distributed mobility management, which is proper to the proposed architecture, is also proposed. For the performance evaluation, the proposed solution is implemented on the NS-3 LENA. The performance of the proposed solution was compared with the conventional LTE/EPC network system in terms of the P-GW/PEGW's data processing volume per unit time, data end-to-end delay, handover latency, and the number of valid data sessions. The comparison results showed that the proposed LTE/EPC architecture and their DMM solution can be a more efficient way to support the scalability of LTE/EPC core network.

Future work remains to be done on the validation of the proposed scheme's dynamic management of PDN connections. We plan to evaluate the proposed scheme on the diverse mobility scenarios to show the advantage of the dynamic management. On the other hand, we will work on enhancing the scheme by developing new additional functions, such as route optimization on packet delivery.

In this paper, we .. The proposed solution will give LTE network operator increased scalability, flexibility, cost savings in short-term. Furthermore, this solution concept will allow for new service architectures, service exposure, new revenue opportunities and more efficient operations in the long term.

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