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A Flat Mobile Core Network for Evolved Packet Core Based SAE Mobile Networks

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Abstract

In the current mobile IPv6 (MIPv6) systems for the System architecture evaluation (SAE) networks, such as 4th generation (4G) mobile network, the data delivery is performed basing on a centralized mobility network anchor between Evolved Node B (eNB) and Serving Gateways (S-GW), and also between S-GW and Packet Data Network Gateway (P-GW). However, the existing network has many obstacles, including suboptimal data routing, injection of unwanted data traffic into mobile core network and the requirement of capital expenditure. To handle these challenges, here we describe a flat mobile core network scheme donated by F-EPC, based SAE mobile network. In the proposed scheme, the P-GW and S-GW gateways are features as one node named Cellular Gateway (C-GW). Further, we proposed to distribute and increase the number of C-GW in mobile core network, the Mobility Management Entity (MME) functioned as centralizing mobility anchor and allocating the IP address for the User Entity (UE). In this paper, the explained results of a simulation analysis showed that the proposed scheme provides a superior performance compared with the current 4G architecture in terms of total transmission delay, handover delay and initial attach procedure.

Keywords

SAE, EPC, F-EPC, Flat Network, DMM, Mobility

1. Introduction

One of the most challenging issues facing the mobile networks operators is how to design the future mobile network (*i.e.*, 5th generation Network (5G)) [1]. The need for the mobile system is based on the huge traffic demand and the increase in the use of smart phones and other mobile devices. This trend appears likely to continue, and the volume of mobile data traffic will increase eight-fold between 2015 and 2020 [2]. This growth in mobile data traffic places increasing demands on wireless communication systems, and represents a major challenge for cellular providers in terms of upgrading their core networks to accommodate future network requirements and keeping up with increasing customer demand [3] [4].

The need for a new network architecture is essential to support growth in demand for broadband services of various kinds delivered over the networks, and to support Internet of Things (IoT) services and applications [5].

The System Architecture Evolution (SAE) [6] is defined as the non-radio core architecture of Long Term Evolution (LTE) networks developed by 3 GPP and aims to support low latency, high throughput and the mobility between multi-heterogeneous networks. It is an evolution of the General Packet Radio Service (GPRS) network, the Evolved Packet Core (EPC) is the most important component. EPC networks are formed of several functional entities: 1) P-GWs, which provide mobile users an access to a PDN by allocating the IP addresses, and also provide IP routing and forwarding S-GWs; 2) Mobility Management Entities (MMEs) that provide several functions, including mobility management and handover management; 3) Home Subscriber Servers (HSSs) provide user profiles and authentication data and Policy and Charging Rules Function (PCRF) servers; 4) S-GWs act as local mobility anchors for inter-eNB handover; 5) PCRF controls the charging rules and quality of service.

At an EPC network, data paths are established between eNBs and P-GWs via S-GWs, and uses GPRS Tunneling Protocol (GTP) for tunneling. P-GWs and S-GWs perform as centralized mobility anchors for data packets; consequently, all data traffic is forward through a centralized anchor S-GW and P-GW.

As shown in **Figure 1**, the EPC architecture composed from several interfaces to forward the data, including X2, S1-MME, S11, S5 and S1-U. The X2 interface protocol supports UE mobility by creating a GTP tunnel between eNBs.

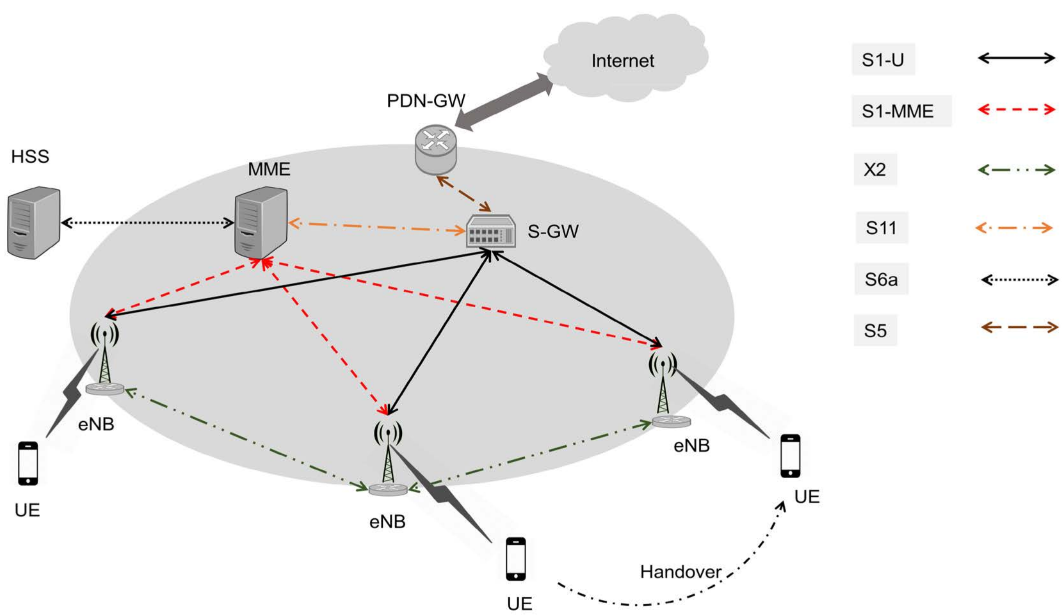

Figure 1. 4 G mobile network model.

S1-MME provides the initial UE context to MMEs, and is also responsible for establishing and controlling the GTP tunnel between MMEs and S-GWs. S5 provides GTP tunnel functionality between S-GWs and P-GWs. The S1-U interface provides GTP tunnel function between eNBs and S-GWs.

On the other hand, the 4G network has a number of limitations. First, there are load balance and latency issues; the growth in data traffic requires a reduction in the transmission and connection delays. In addition; simplifying the mobile core and reducing the number of identifications can make mobile core networks simpler and more efficient, and hence more cost-effective. The second problem is suboptimal routing; the uplink and downlink data packets are routed via mobility anchors, which often result in the suboptimal paths. For example, where a data packet is sent from one mobile device to another in the same network domain or local server, instead of taking the shortest path, the packet is routed via a P-GW and an S-GW. The last limitation is the required capital expenditure: The EPC network is simply not cost-effective, due to the huge number of routers that are required to support the core network.

To overcome these issues, a variety of approaches have been proposed. A mobility data offloading approach uses femtocell, where the data traffic is forwarded to the mobile device without using the core network [7]. Another approach to distribute the mobility in 4G network is the Distributed Mobility Management (DMM) [8], proposed by Internet Engineering Task Force (IETF), which provides mobility with localized mobility anchors that are distributed within the network, in combination with centralized anchors where the system is arranged in a hierarchical model [9].

Another approach to distribute mobility in 4G networks is the Ultra Flat Architecture (UFA). The key element of UFA is to decrease the number of the network nodes to one (*i.e.*, a single base station), based on the distribution of user and control plane roles in the node. UFA provides improved performance and seamless handover [10].

However, the previous proposed architectures have some problems associated with mobility anchoring and suboptimal data routing. Moreover, from the perspective of capital expenditure, most of the proposed architectures are not cost-effective.

In this paper, we propose a flat mobile core network scheme in EPC for SAE mobile based network, termed F-EPC. In this proposed scheme, the P-GW and S-GW gateways work as one node named Cellular Gateway (C-GW). We also propose to distribute and increase the number of C-GWs in mobile core network and which will be transferred between both gateways. The Mobile Management Entity (MME) will manage the control and the data plane, assign the IP addresses and control the C-GWs.

2. Mobility Management in 4G Networks

2.1. Initial Attach Procedure

Figure 2 shows the initial attach registration procedure for a 4G network. When

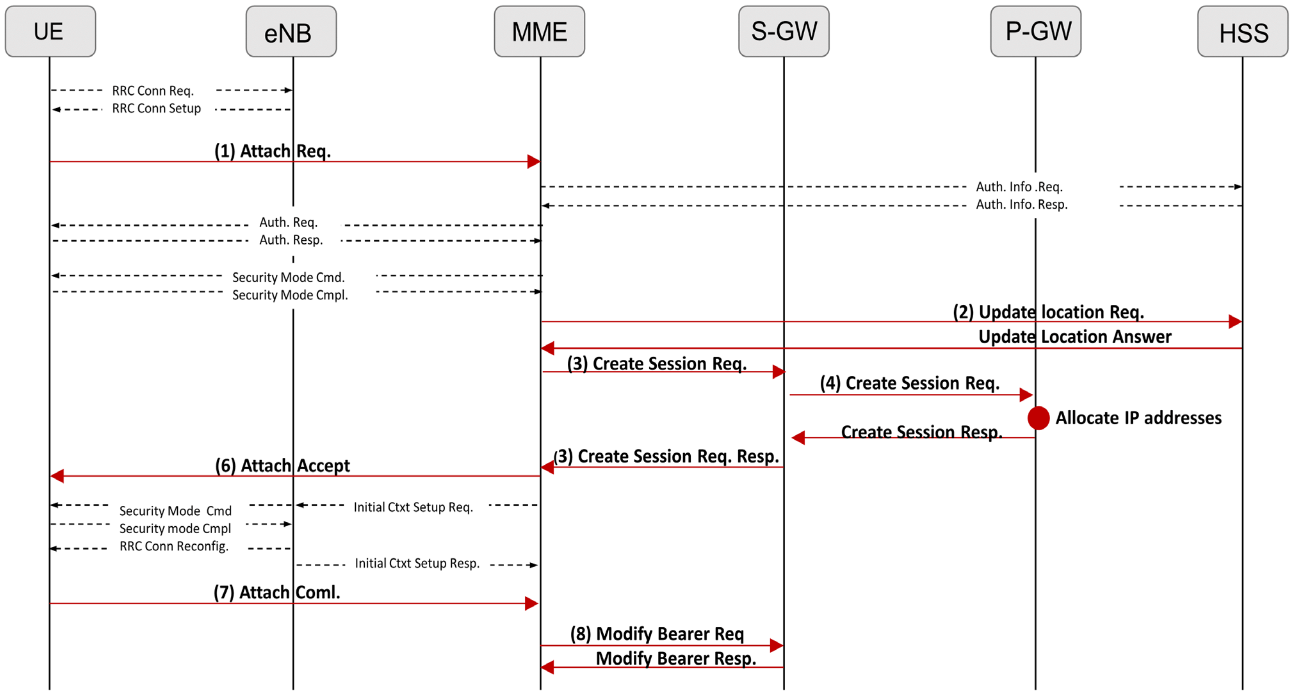

Figure 2. Initial attach procedure in a 4G network.

the UE establishes radio link synchronization with an eNB, the UE creates a connection for data delivery via an Attach Request message sent to the eNB, the eNB then forwards the attach request to an MME, which in its turn sends an Update Location Request to an HSS. The HSS responds via an Update Location Answer, and then the MME performs the required security related-operations with UE. The MME sends a Create Session Request to an S-GW to build a transmission path. The S-GW now sends a Create Session Request to a P-GW, which responds by sending a Create Session Request Response message. The S-GW then sends a Create Session Response to the MME, and the MME sends an Attach Accept message to the UE. The MME now performs an Initial Context Setup with the eNB, and the eNB sends an Initial Context Setup Response message to the MME. The UE then sends an Attach Complete message to the MME, which sends a Modify Bearer Request to the S-GW, which responds by sending a Modify Bearer Response message to the MME.

2.2. Initial Handover Procedure

Figure 3 shows handover procedure in 4G network, which takes the following steps:

- When the UE moves to another eNB region, the source eNB sends a Handover Request to the target eNB, which responds with a Handover Acknowledgment.
- The target eNB then sends a Path Switch Request to the MME.
- MME sends a Modify Bearer Request to the S-GW.
- The S-GW exchanges the modify bearer messages with the P-GW via a Modify Bearer Request and a Modify Bearer Response.

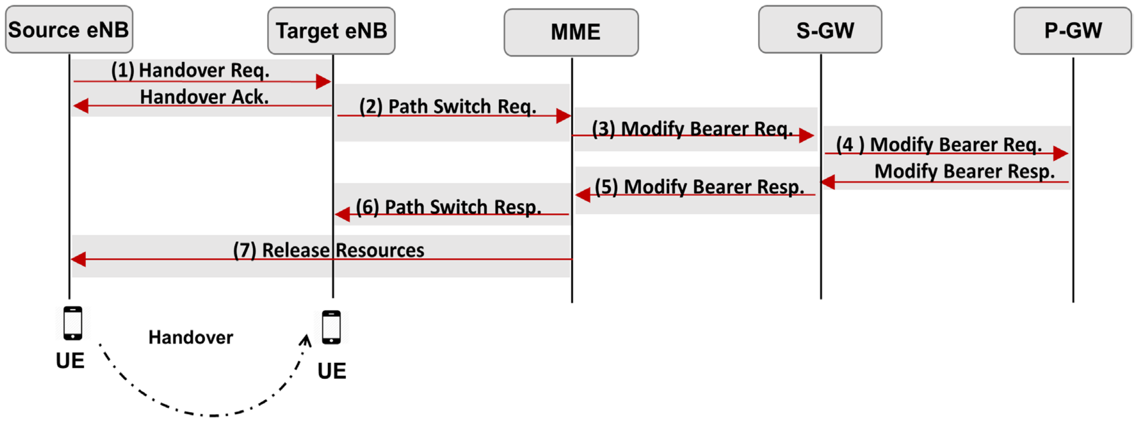

Figure 3. Handover procedure in a 4G network.

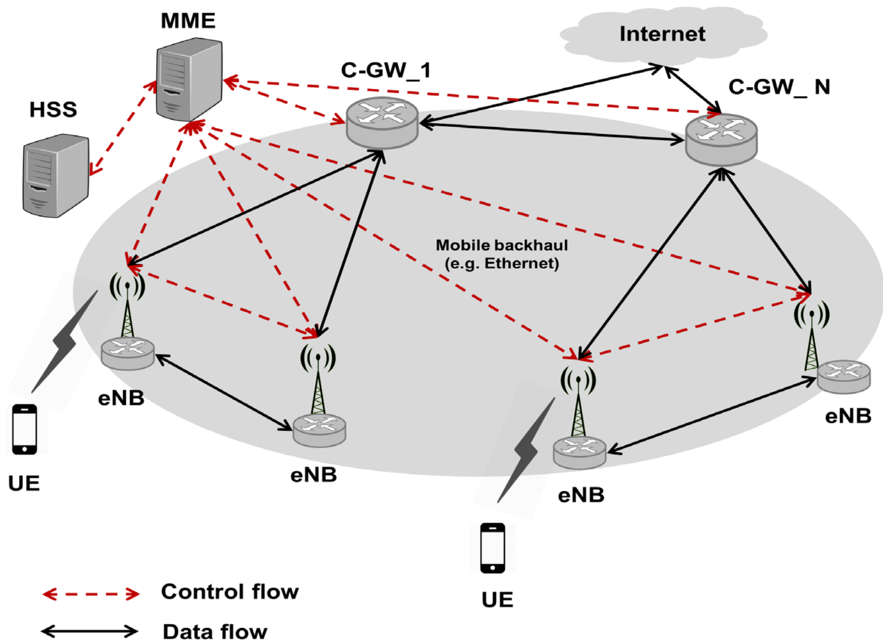

Figure 4. The proposed flat mobile core network (F-EPC).

- The P-GW sends a Modify Bearer Response to the MME.
- MME sends a Path Switch Response to the target eNB.
- Finally, the MME sends a Release Resources message to the source eNB.

3. Network Model

Figure 4 shows an overview of the proposed flat mobile core network (F-EPC). In the proposed scheme, S-GW and P-GW merged and function as one node named Cellular Gateway (C-GW), which will be distributed in the core mobile network and eNBs are connected directly to the C-GW. It is worth mentioning that the number of the C-GW will increase basing on the network capacity and they will be connected with each other. The MME will control the C-GWs distributed in the core network and will allocate the IP addresses for UEs and C-GWs. In addition, when the UE moves to a different eNB region at the same network or different network, MME will select another C-GW. MME with HSS is used for UE registration and to obtain subscription information on the UE. MME with HSS is also used to register the MME ID and indicate in which MME the UE is located.

3.1. F-EPC Initial Attach Procedure

Figure 5 shows the initial attach registration procedure used with F-EPC scheme, which explained on the following steps:

- When the UE establishes radio link synchronization with the eNB, the UE sends an Attach Request message to the eNB.
- The eNB sends the Attach Request to the MME, which sends an Authentication Information to the HSS, as well as a Network Attach Storage (NAS) request. Once these authentications and NAS security procedures are accomplished, the MME sends an Update Location Request to the HSS, which indicates in which MME the UE is located. The HSS responds by sending an Update Location Answer.
- In step 3, the MME sends a request to the C-GW to allocate a gateway address for the UE via the exchanging of Switch Control Request and Switch Control Response messages.
- An IP address is then allocated to the UE by the eNB via exchange of a Switch Control Request and a Switch Control Response.

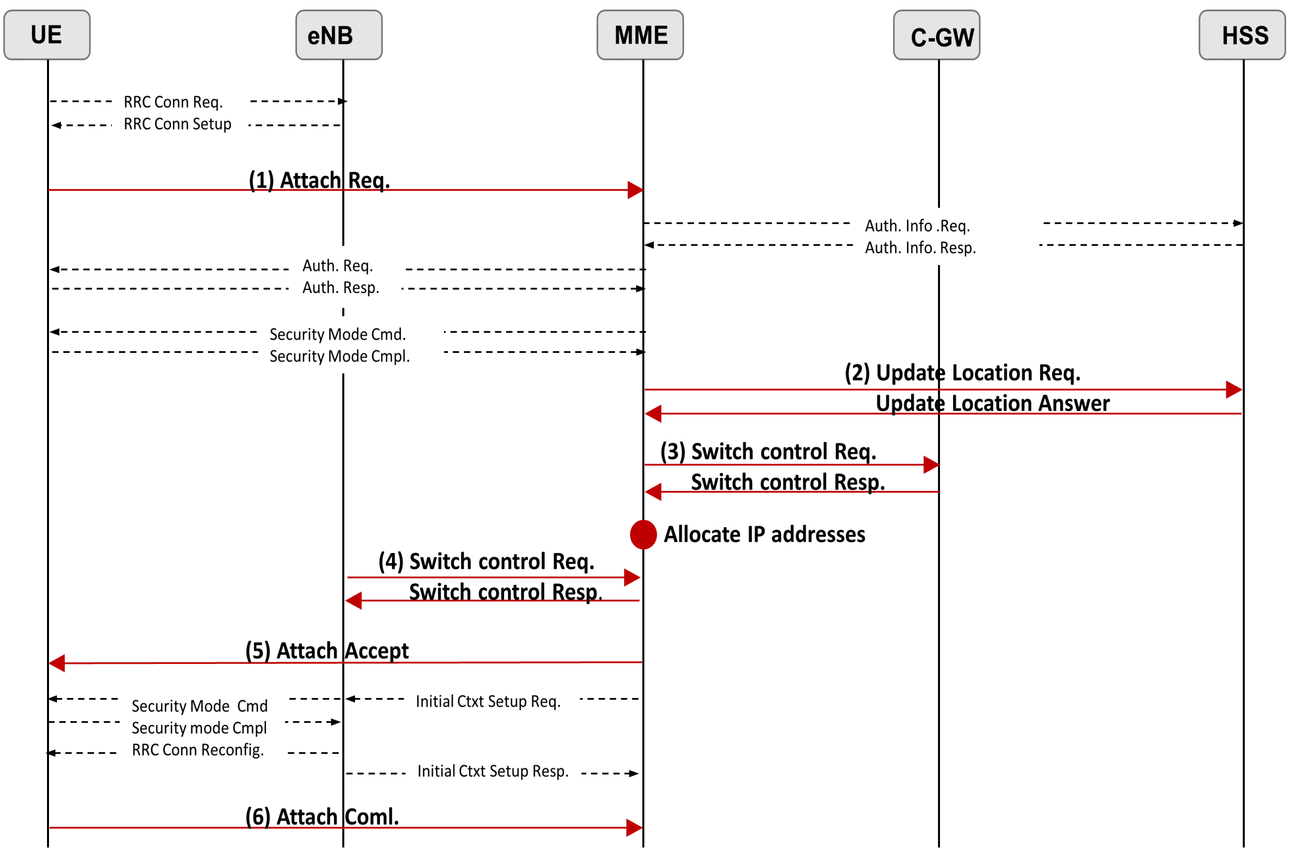

Figure 5. The initial attach procedure.

- Following allocation of the IP address and establishment of a gateway, the MME responds to the eNB with an Attach Accept message, which contains the IP addresses of the UE IP.
- The eNB then sends an Attach Accept message to the UE.
- The UE sends an Attach Complete message to the eNB.

3.2. F-EPCH and Over Procedure

Figure 6 shows the F-EBCH handover procedure, during which the following steps are taken:

- UE moves from the source eNB to the target eNB.
- The source eNB sends a Handover Request to the target eNB, which responds with a Handover Acknowledgment.
- The target eNB sends a Path Switch Request to the MME.
- The MME then sends a Path Control Request to the C-GW to inform the C-GW that the UE has moved to a new eNB.
- The C-GW sends a Path Control Response to the MME.
- The MME sends a Path Switch Response to the target eNB.
- Finally, the target eNB sends a Release Resources message to the source eNB.

4. Simulation Result

We evaluate the performance of the F-EPC model by using NS-3 simulation [11]. For the 4G network many simulations have been proposed *i.e.* LENA project [12] where the simulation composed of two models, LTE model and EPC model. The LTE model operates the lower and upper protocol stack, whereas the EPC model features mobile core network. However, LENA simulation has numerous drawbacks. First, S-GW and P-GW are combined within a single node. Thus, gateway relocation mobility and S5/S8 interfaces are not supported. Secondly, current 4G network uses GTP protocol version 2 (GTPv2), nerveless LENA simulation build up by the old version GTPv1. Finally, the socket transmission used for data plane (GTP-U) disregarding the control plane (GTP-C).

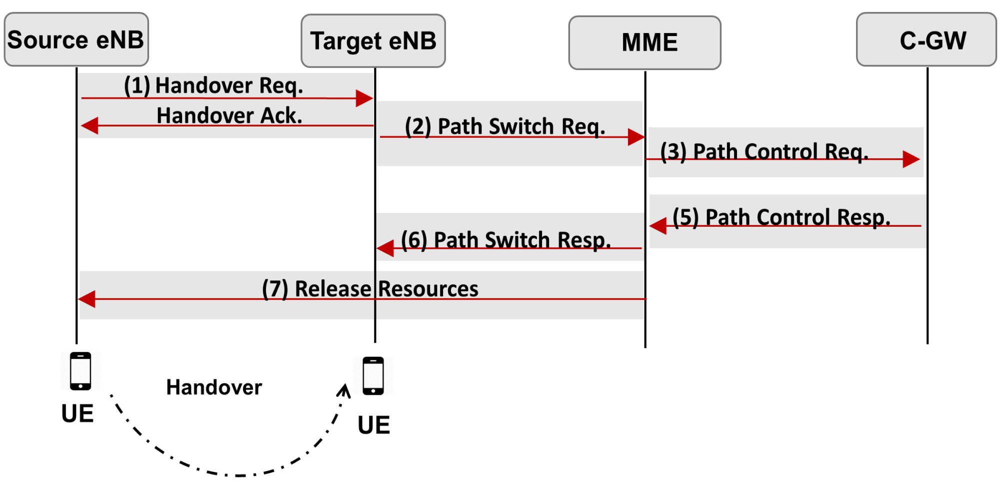

Figure 6. Handover procedure.

Consequently, these issues give inaccurate results to compare with the proposed work.

To overcome these challenges, we rebuild the current LENA simulation as follow: first decouple the S-GW and P-GW, by creating a separated S-GW node and modify the P-GW. Secondly, implement the latest version of GTP protocol GTP (GTPv2) with full features instead of the old version GTPv1. Third, we create a S5/S8 interface connection between S-GW and P-GW as well as implementing fully signaling messages between the two nodes (S-GW and P-GW). Finally, create a socket transmission to support both control plane (GTP-C) and data plane (GTP-U).

Moreover, we used the implementation, previously described, to run the F-EPC scheme simulation. The NS-3 version 3.22 in Linux environment has been used. The programming of proposed approach consists of building UE, eNB, MME and C-GW. Control plane and data plane implemented into corresponding interface. A remote host node is created to act as Internet server, which is able to send packets to other nodes. The rest of simulation parameters are configured as shown in Table 1.

This simulation is built to measure the performance between 4G network and the proposed F-EPC model as follow: total transmission delay for the data packets delivered from the UE to remote host, Handover delay and initial attach procedure delay. To measure the performance of the F-EPC, we will compare four different scenarios as follow:

First scenario: the first scenario presents the current 4G network as described previously in Figure 1.

Second scenario: Figure 7 depicts the second scenario, where we combine S-GW and P-GW in C-GW node. Also, we use two different C-GWs and each C-GW is connected with ten eNBs, and each eNB is connected with one UE.

Third scenario: Figure 8 explains the third scenario, where we create five C-GWs and each C-GW is connected with four eNBs and each eNB is connected with one UE.

Fourth scenario: Figure 9 shows this scenario, it illustrates F-EPC model, where we create 10 C-GWs, each C-GW is connected with two different eNBs and each eNB is connected with one UE.

Table 1. Simulation Parameters.

Parameter	Setting
Number of UE	One node
Speed of UE	Varies from 5 to 120 km/h
eNBTx power	46 dBm
Distance between eNB	100 meters
EPS Bearer	NGBR-VIDEO-TCP
QCI	9
Bandwidth	5 MHz
Data rate	10 Gbps

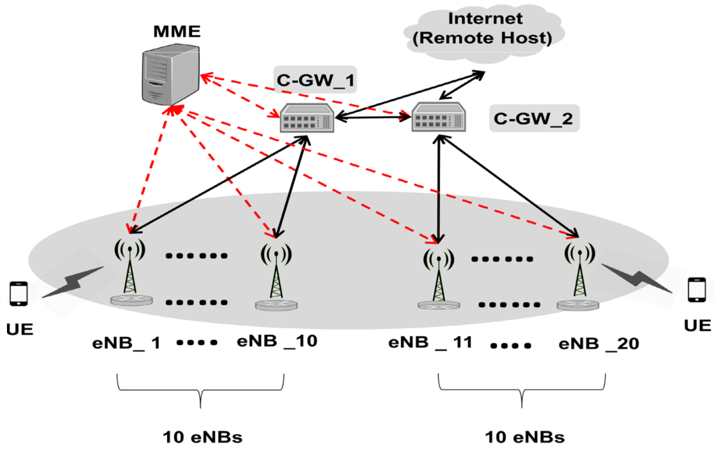

Figure 7. Second scenario.

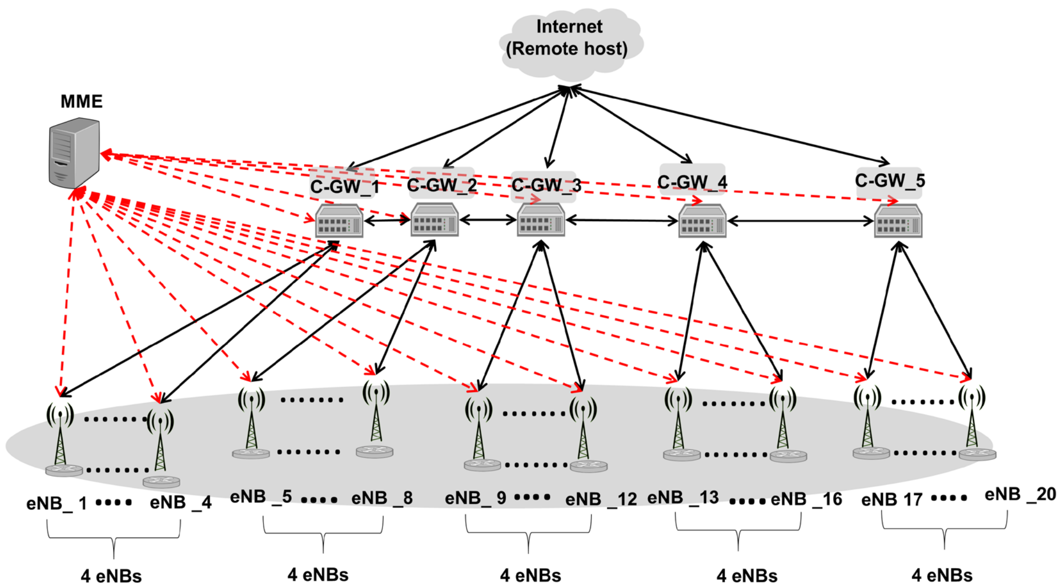

Figure 8. Third scenario.

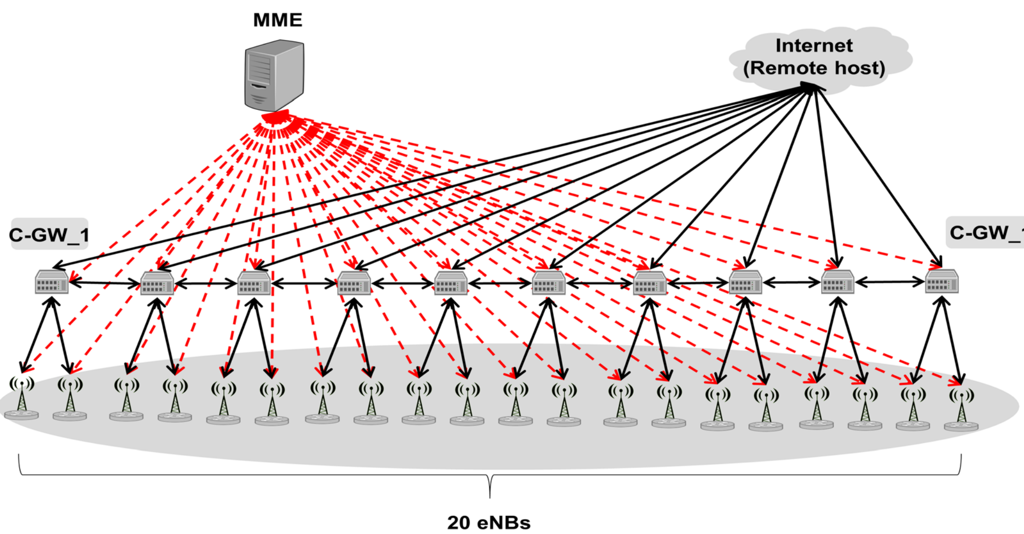

Figure 9. F-EPC Model.

Figure 10 shows the transmission delay between the UE and the remote host. The transmission delay for the first scenario is significantly increasing with the data path because the data packets are delivered by centralized anchor P-GW and S-GW. The second scenario increased too because the data packets are delivered to the remote host by two C-GWs. The third scenario has a better result comparing with the previous scenarios because the data packets are delivered via one C-GW for each four eNBs. Finally, the fourth scenario shows a superior performance because the data packets are delivered by one C-GWs for each two eNBs.

Figure 11 and Figure 12 shows the handover delay and initial attach delay for each signaling message. The simulation results for both procedures show that there is no big difference between the proposed scheme and 4G network. How-

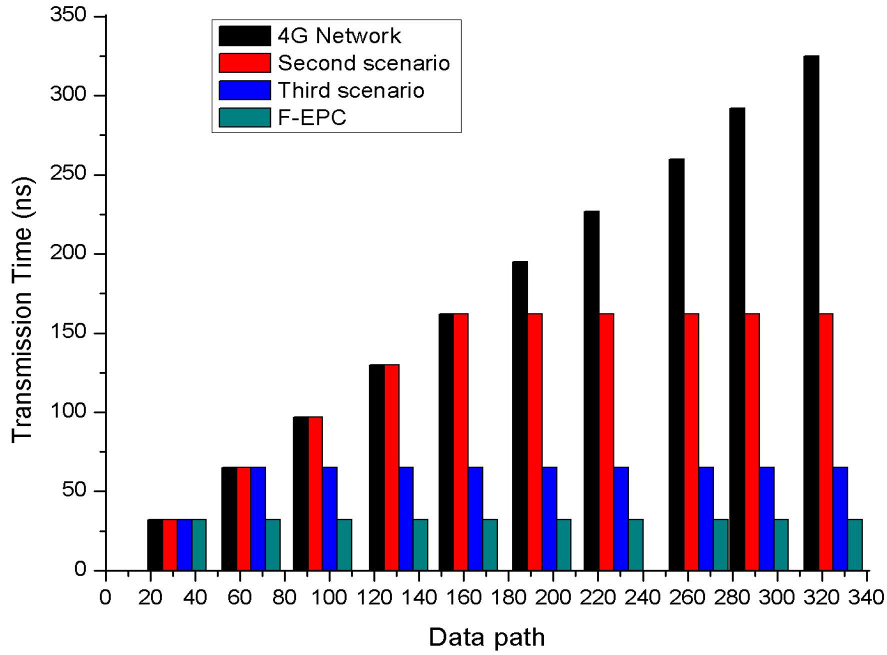

Figure 10. Total transmission delay.

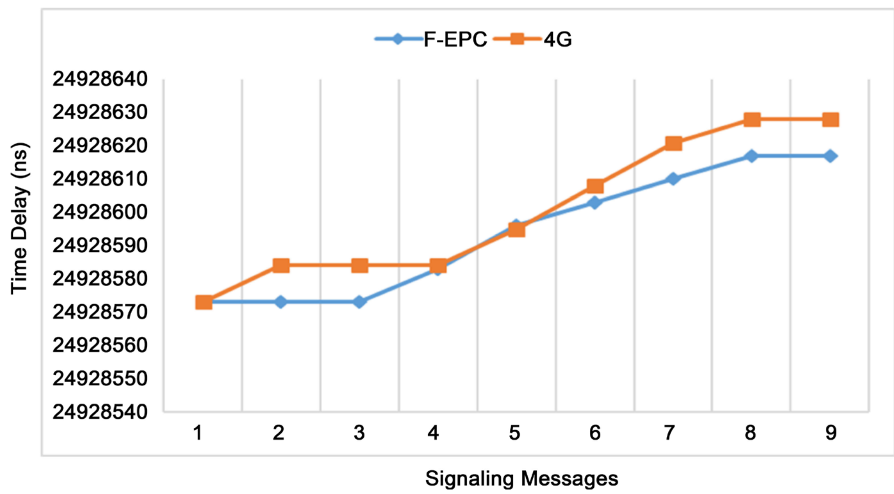

Figure 11. Handover delay.

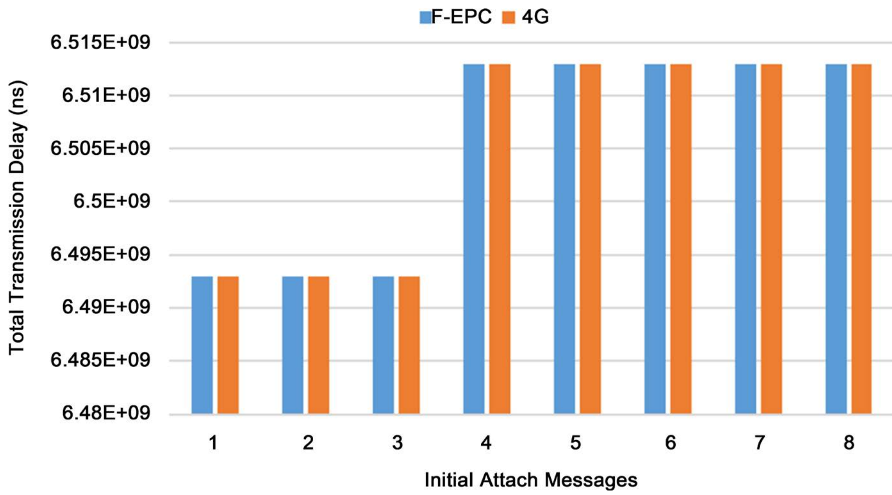

Figure 12. Initial attach delay.

ever, the number of signaling messages for the proposed work in handover delay and initial attach are less than those at the 4G network.

5. Conclusion

The current 4G mobile packet core (*i.e.*, EPC) is complex and expensive. We have described a flat mobile network basing on the merge of the S-GW and P-GW in one node and the increase of the C-GW amount. The proposed scheme (F-EPC) achieves better performance than 4G network particularly in total transmission delay for data delivery form the user equipment to the remote host. We compare our work with the existing 4G network architecture using NS-3 simulation. The results show that the proposed scheme results in better performance than 4G network in term of total transmission delay, the handover delay and initial attach procedure.

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