Performance Analysis of Location Update in LTE Based Network

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***Abstract* – Heterogeneous Network (HetNet) architecture has attracted attention to boost performance and requirement of coverage in the most cost effective way. In this HetNet, users are able to move between home networks to other foreign networks while maintaining their access to the subscribed services. However, a long signaling traffic to be processed and tunneled through network may increase signaling load and long signaling delay. The aim of this project is to reduce signaling cost incurred in these different HetNet. Two schemes, centralized location management and distributed location management are proposed in LTE network to provide a cost-efficient signaling traffic. A simulation algorithm is developed using MATLAB software to evaluate location update for different scenarios. The simulation is carried out using different parameters which are number of UEs at one time within network and network size. The result shows that, distributed location management scheme has better performance in reducing signaling cost when number of UEs and network size increased.**

Keyword – heterogeneous, signaling load, signaling delay, traffic, location management

I. INTRODUCTION

The increasing numbers of people into an expending urban areas putting pressure on networks, especially in hotspot areas, thus network operators have to provide a better and efficient service to satisfy the users need. Heterogeneous network architecture allows operators to provide the most cost-effective in term of coverage and data capacity. Network operators can benefits from HetNet network as it increases capacity in hotspots area as traffic is not uniformly distributes and it also improves coverage at places where macro coverage is not available. Mobile devices with multiple communication interfaces such as WLAN, WiMax and UMTS are becoming very common and thus, mobile users will be able to roam across this IP-based heterogeneous wireless networks environment without any noticeable disruptions to ongoing communication flows [1].

The LTE network architecture is designed with the goal of supporting packet-switched traffic with seamless mobility, Quality of Service (QOS) and minimal latency. A packet-switched approach allows for the supporting of all services including voice through packet connections. The LTE architecture is a highly simplified flatter architecture with only two types of node namely evolved Node-B (eNB) and Mobility Management Entity (MME) [2]. As shown in Figure 1, in LTE architecture, eNBs provide wireless connectivity to every UEs while MMEs support for tracking area update and handover via S1 interface. On the other hand, HSS acts as a permanent central subscriber database. All the network interfaces in LTE architecture is based on IP protocols with X2 interface interconnect the eNBs to the MME entity.

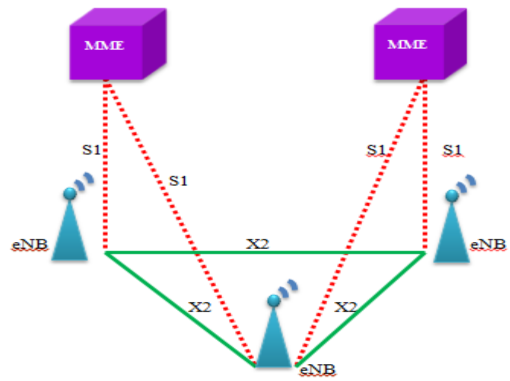

Figure 1. LTE Network Architecture

Regardless of the network, an efficient and effective handover mechanism with seamless mobility support to ensure active ongoing connections is essential while maintaining the quality of experience to the users. It is very important to have a seamless mobility support across heterogeneous networks. Seamless mobility is referred to as the event when all sessions of a UE continue to maintain their connection even as a UE changes its point of attachment [4].

The rest of this paper is organized as follows. The related works that contribute to this paper is discussed in Section II. Section III describes the proposed location management scheme in detail. Section IV presents signaling cost algorithm and Section V performance of numerical and simulation results of the proposed schemes. Finally, Section IV includes the conclusions of this study and ideas for future work.

II. RELATED WORKS

The cells in LTE are grouped into a location area and each have a unique Location Area Identity (TAI) which are broadcasted by eNB [5]. When a UE moves and detects that location area code broadcasted on a channel is different from its current location area, the UE will updates its new registered location area. UE updates its new location area to the network regardless whether it is in idle or active mode. However, when UE changes MME while moving, it initiates location update message upon detecting new location area. The eNB selects the MME responsible for the new location area upon receiving the location update request. The MME will then update the location area of the

UE to the HSS to ensure that data is correctly routed to the correct MME. In [6], the authors proposed two LTE architectures, which are Distributed MME and centralized MME. These two architectures are compared in term of signaling loads. A multicast paging procedures is also proposed to reduce the MME signaling load and compared the performances with unicast paging procedures.

In [7], the author proposed Bayesian-based Location Update and Entropy Coding-based Location Update Scheme to optimize the location update cost. In Bayesian-based Location update, whenever a UE registers with a new eNB, it updates to the MME. The UE will updated the MME by sending the cell ID of the new eNB. On the other hand, Entropy Coding-based Scheme reduces the update cost by processing the cell ID in chunks. Since the last update cell IDs to the MME is in encoded form, thus the entire sequences of cell IDs are withheld.

In [8], the authors assumed that a network is formed by a group of cells and each location area consists of only a single cell. The characteristics of UE as well as geographical elements are considered as an optimal location area design for an individual UE. By doing this, the optimal network size for a UE can be designed individually. In order to avoid frequent location update while the UE moves between two location areas repeatedly, LTE allows the UE to connect to various location area at one time. However this may cause heavy burden to the network mobility management.

III. PROPOSED LOCATION MANAGEMENT

This section introduces architectural model proposed for location management in LTE which improves network performance in term of signaling cost.

A. Centralized Scheme

When UE first arrives at a location area, it performs a home registration with its HSS. During this, the HSS registers the location area information (LAI) of the UE. This information is routable to the MME. When a UE changes eNB within the same location area it performs a regional registration to the MME to update its eNB LAI. When it moves from one location area to another, it performs a home registration with its HSS. During an ongoing communication, when packets are sent to the UE by P-GW, they are addressed to the HSS of the UE first before HSS intercept and encapsulates these packets that are addressed to the UE. These packets are tunneled until they arrived at the registered MME of the UE. The MME then will check the visitor list and forward these packets to the corresponding eNB where these packets then further relays to the UE.

However, because of all the traffics are manages within the location area, the regional registration are prone to failures. The failure will prevent packet route successful. Another issue is the optimal value of eNB to be managed by an MME. A small number of eNBs will lead to excessive location update, whereas large number of eNBs will degrade the performance of network with high traffic load on MME. The architecture of this scheme is as shown in Figure 2.

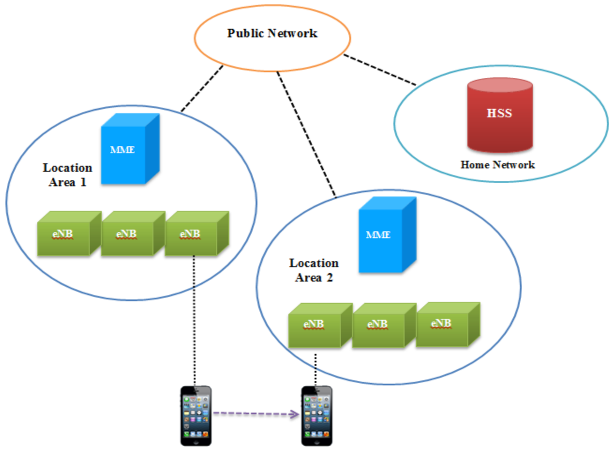

Figure 2. Centralized Scheme Architecture

B. Distributed Scheme

Distributed system architecture enabled an eNB to act either as an eNB or an MME and this function depended on user mobility. The optimal network size is set to a suitable value for this architecture. When a UE enters a location area, the first eNB that it enters will function as MME. The system architecture as shown in Figure 3 where eNB8 functions as the MME for UE1 at first. The optimal network size is equal to 4. While it moving within the same location area, UE1 will perform regional registration to update its location to MME. After UE1 has visiting 4 different eNB within the location area which are eNB2, eNB3, eNB8 and eNB9, the UE1 then moves to eNB10. As eNB10 is the first eNB visited by UE1, it functions as MME for the new location area. The same routine is applied to UE2. eNB7 functions as MME at first. After visiting 5 different eNB which is eNB1, eNB2, eNB8 and eNB9, eNB10 functions as MME as it is the first eNB UE2 visit. While it is moving within the same location area, UE2 will perform regional registration to MME and UE2 will then perform home registration to update its LAI to HSS as it moves to another location area.

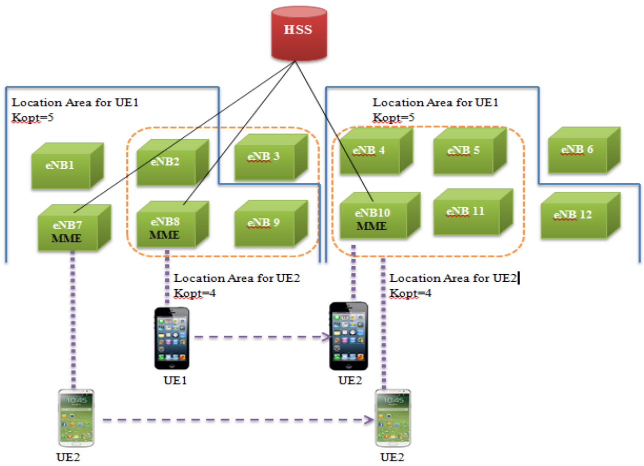

Figure 3. Distributed Scheme Architecture

The advantages of distributed scheme are [9]:

1. The traffic load for all the users in an area is distributed to each mobility agent.
2. The system robustness is enhanced since the failure of a GFA will only effect the packets routing to UEs managed by the failing MME.
3. Each UE has its own optimized system configuration from time to time.

IV. SIGNALING COST

In this section, the cost function of location update and packet delivery is derived to analyze on the system performances.

A. Location Update Cost

The parameters for location update in the rest of this paper are as in TABLE I [10]:

TABLE I: PARAMETERS FOR LOCATION UPDATE

a_{hss}	The processing cost of location update at HSS.
a_{mme}	The processing cost of location update at MME.
a_{eNB}	The processing cost of location update at eNB.
C_{hm}	The transmission cost of location update between the HSS and MME.
C_{me}	The transmission cost of location update between MME and eNB.
C_{eu}	The transmission cost of location update between eNB and UE.

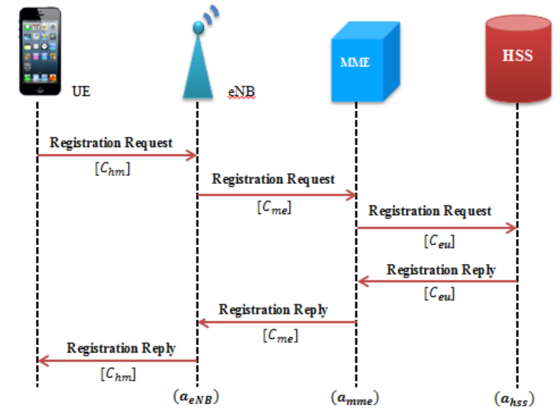

Figure 4. Process of Home Location Registration

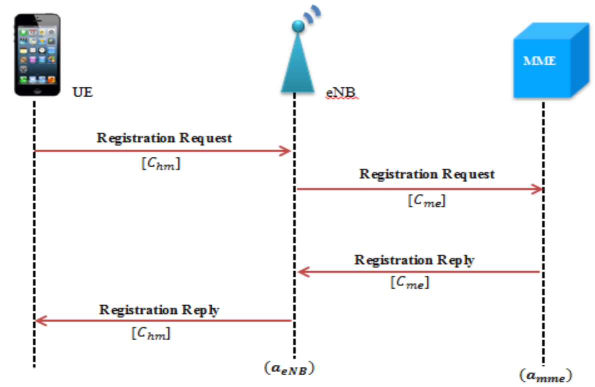

Figure 5. Process of Regional Location Registration

Figure 4 and Figure 5 illustrate the signaling message flows for location registration with the home registration and regional registration respectively. According to these message flows, both home registration cost and the regional registration cost for each location update can be calculated as follows [10]:

$$C_{vh} = 2a_{eNB} + 2a_{mme} + a_{hss} + 2C_{hm} + 2C_{me} + 2C_{eu} \quad (1)$$

$$C_{vr} = 2a_{ue} + a_{mme} + 2C_{me} + 2C_{eu}, \quad (2)$$

Let l_{hm} be the average distance between the HSS and the MME in terms of the number of hops of packets travel, and l_{me} be the average distance between the MME and the eNB. The transmission cost is assumed to be proportional to the distance between the source and the destination mobility agents and the proportionality constant is δv. Thus, C_{hm} and C_{me} can be expressed as $C_{hm} = l_{hm}\delta_v$ and $C_{me} = l_{me}\delta_v$. We assumed that the transmission cost between the eNB and the UE can be written as $l_{eu} = \rho\delta v$. Then, the home registration and regional registration can be expressed as [10]:

$$C_{vh} = 2a_{eNB} + 2a_{mme} + a_{hss+}2(l_{hm} + l_{me} + \rho)\delta v \quad (3)$$

$$C_{vr} = 2a_{ue} + a_{mme} + 2(l_{me} + \rho)\delta v \quad (4)$$

For distributed MME architecture, the first eNB of the location area the UE visits functions as an MME. This special region is define as C_{sp}. Thus [10]:

$$C_{sp} = 2C_{me} + a_{mme} = a_{mme} + 2\rho\delta v \quad (5)$$

Assume a UE may move randomly between N eNB and there are k numbers of eNB within a location area. The UE may visit an eNB more than once and may move back and forth between two eNB.The action of a UE moving out of a location area as "*a movement*". Define a random variable M so that an MN moves out of a location area at *movement M*. At movement 1, UE may reside in either eNB 1, 2, … or N. At movement 2, the UE may move to any of the other N-1 eNB. It is assumed that the UE moving out to the other N-1 eNB with probability $\frac{1}{N-1}$. Thus, the probability of UE performing a home registration at movement m and the expectation of M is [10]:

$$P_{cf}^{m} = \frac{N-k}{N-1} \cdot \left(\frac{k-1}{N-1}\right)^{m-2}, \quad \text{where } 2 \le m < \infty, \quad (6)$$

$$E[M]_{cf} = \sum_{m=2}^{\infty} m P_{cf}^{m} = 1 + \frac{N-1}{N-k} \quad (7)$$

Therefore, the average location update cost for centralized scheme is [10]:

$$C_{LU\_cf} = \frac{E[M]_{cf} C_{vr} + C_{vh}}{E[M]_{cf} T_f} \quad (8)$$

The expectation of the moment at which a UE moves out of a location area is [10]:

$$E[M]_{df} = 1 + (N-1)\sum_{i=1}^{k} \frac{1}{N-i} \quad (9)$$

The total location update cost per unit time for distributed fixed scheme is as shown in Figure 4 [10]:

$$C_{LU\_df} = \frac{C_{sp}+(E[M]_{df}-1)C_{vr}+C_{vh}}{E[M]_{df}T_f} \quad (10)$$

B. Packet Delivery Cost

Packet delivery cost includes the transmission and processing cost to route a tunneled packet from the HSS to the serving eNB of a UE as shown in TABLE 2 [10]:

TABLE 2. PARAMETERS FOR PACKET DELIVERY COST

T_{hm}	The transmission cost of packet delivery between HSS and MME.
T_{me}	The transmission cost of packet delivery between MME and eNB.
v_h	The processing cost of packet delivery at HSS.
v_m	The processing cost of packet delivery at MME.

The cost for packet delivery procedure can be expressed as [10]:

$$C_{PD} = v_h + v_m + T_{hm} + T_{me} \quad (11)$$

It is assumed that the transmission cost of delivering data packets is proportional to the distance between the sending and the receiving mobility agents with the proportionality constant δ_D. Then, the transmission cost of packet delivery between HSS and MME is [10]:

$$T_{hm} = l_{hm}\delta_D \quad (12)$$

The transmission cost of packet delivery between MME and eNB is [10]:

$$T_{me} = l_{me}\delta_D \quad (13)$$

The load on an MME for processing and routing packets to each eNB depends on k. Assume that there are ω UEs in a location area. For centralized system architecture, an MME serve all the UEs locate under a location area and the average total number of UEs under a location area is ωk. However, for distributed system architecture, different UEs select different eNBs as their MMEs. The MME only serves the UEs which first enter the location area. The packet processing cost function at MME for centralized scheme and distributed scheme is [10]:

$$v_{g\_cf} = \xi k\lambda_a(\alpha\omega k + \beta\log(k)) \quad (14)$$

$$v_{g\_df} = \xi k\lambda_a(\alpha\omega + \beta\log(k)) \quad (15)$$

Where

λ_a Packet arrival rate at each UEs.
ξ Bandwidth allocation cost at MME.
α Weighting factors of visitor list.
β Weighting factors of routing table lookups.

The processing cost function at HSS can be defined as [10]:

$$v_h = \eta\lambda_a \quad (16)$$

Where

η Packet delivery processing cost at HSS.

Thus, the total packet delivery cost per unit time for centralized scheme and distributed scheme [10]:

$$C_{PD\_cf} = \eta\lambda_a + \xi k\lambda_a(\alpha\omega k + \beta\log(k)) + (l_{hm} + l_{me})\delta_D \quad (17)$$

$$C_{PD\_df} = \eta\lambda_a + \xi k\lambda_a(\alpha\omega + \beta\log(k)) + (l_{hm} + l_{me})\delta_D \quad (18)$$

C. Total Signaling Cost

Based on the analysis of both location update cost and packet delivery cost, the overall signaling cost function for centralized scheme and distributed scheme, respectively is defined as [10]:

$$C_{Tot\_cf}(k,\lambda_a,T_f) = C_{LU\_cf} + C_{PD\_cf} \quad (19)$$

$$C_{Tot\_df}(k,\lambda_a,T_f) = C_{LU\_df} + C_{PD\_df} \quad (20)$$

V. RESULT AND DISCUSSION

This section evaluates the performances of the proposed centralized location management scheme and distributed location management scheme by comparing performances of both schemes with changes on the number of UEs and the number of eNBs under a location area.

A. Numerical Result and Discussion

In this section, numerical result of centralized scheme and distributed scheme is demonstrate in term of packets delivery cost and location update cost. It is assumed that the performance analysis parameters are as shown in TABLE 3 [9]:

TABLE 3. PERFORMANCE ANALYSIS PARAMETERS.

Packets Process Cost	a_{hss}	25.0
	a_{mme}	15.0
	a_{eNB}	10.0
Distance Cost Unit	δv	0.1
	δ_D	10
Wireless Multiple	ρ	10
Num of UE	ω	15
Weight	α	0.3
	β	0.7
Packet Process Constant	ξ	0.01
	η	10.0

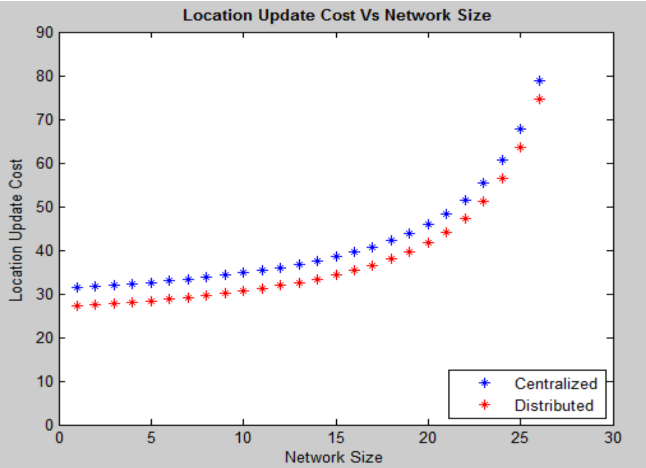

Figure 6. Comparison of location update cost between centralized scheme and distributed scheme.

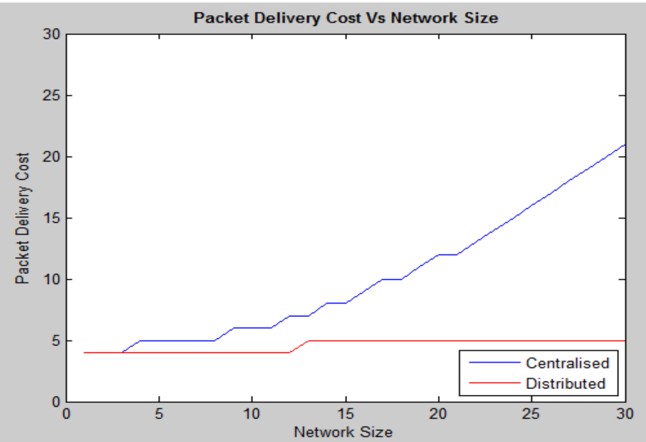

Figure 7. Comparison of packet delivery cost between centralized scheme and distributed scheme.

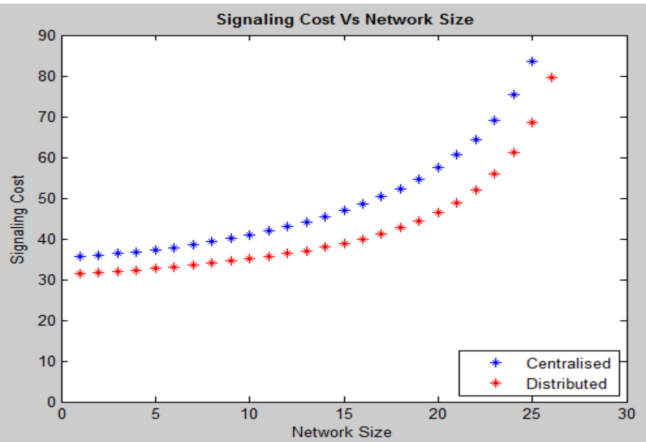

Figure 8. Comparison of overall signaling cost between centralized scheme and distributed scheme.

Figure 6, 7 and 8 shows the performances of location update cost, packet delivery cost and signaling cost, respectively. As shown in Figure 6, distributed scheme has relatively lower cost than centralized scheme as the network size increased. It can be observed from Figure 7 that packet delivery cost for centralized scheme is higher than the cost for distributed scheme. Figure 8 shows the comparison of packet delivery cost between centralized scheme and distributed scheme. It shows that centralized scheme always have higher cost than distributed scheme. In distributed scheme architecture, different eNB is chose by different UE as their MME, thus the traffic is allocated evenly among eNBs. It could be observed from figures below that distributed scheme is more cost-efficient than centralized scheme.

B. Simulation Result and Discussion

In this section, simulation result of Centralized Scheme and Distributed Scheme are presented in term of home registration, regional registration and location update. The simulation is carried out using different number of UEs and different network size.

1. The Impact on Different Number of UEs

In this section, centralized scheme and distributed scheme is compared due to different number of UE. Figure 9, 10 and 11 shows the performances of home registration, regional registration and location update cost, respectively. As shown in Figure 9, high different between both scheme as number of UE increased could be seen. Centralized scheme perform more home registration compared to distributed scheme. However, in Figure 10, distributed scheme perform more regional registration than centralized scheme. From both figures, it shows that UE has frequently updates its location area to HSS whenever it changes location area. However, centralized scheme has lower regional registration as number of UE increased. This shows that UE seldom perform registration to MME. The location area for the scheme has been fixed to a certain group of eNBs. Thus UE that is randomly moves around the network area perform more home registration. On the other hand, distributed scheme architectures require UE to select its own MME and the location area are fixed after it moves into optimal network size of eNBs. Thus, the UE under distributed scheme perform more regional registration rather than centralized scheme. As shown in Figure 11, the overall of location update cost performance for both schemes and it shows that distributed scheme is more cost efficient than centralized scheme as number of UE increased.

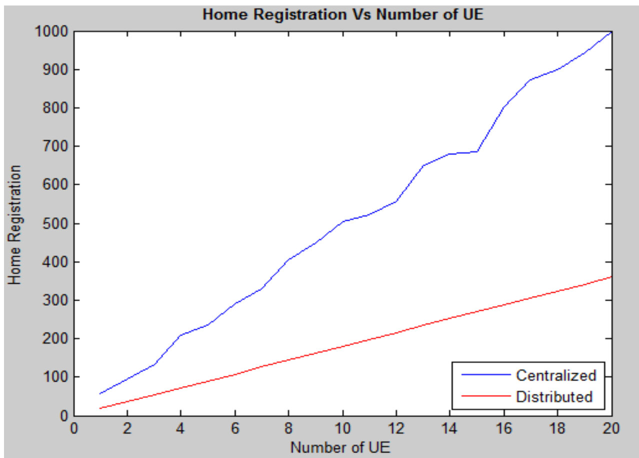

Figure 9. Comparison of home registration for centralized scheme and distributed scheme due to number of UE.

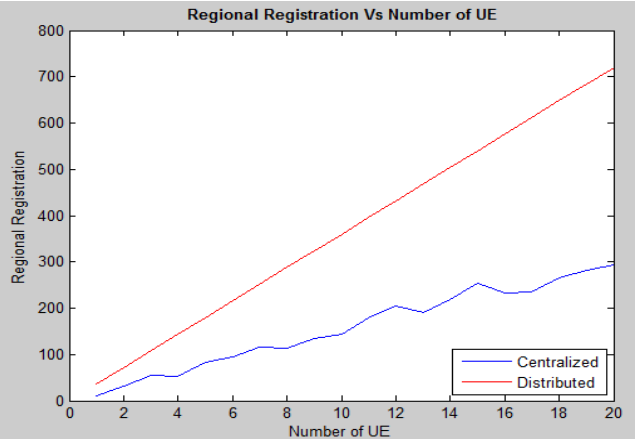

Figure 10. Comparison of regional registration for centralized scheme and distributed scheme due to number of UE.

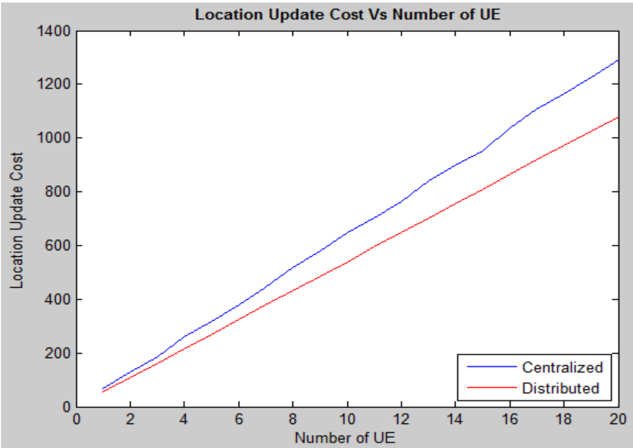

Figure 11. Comparison of location update cost for centralized scheme and distributed scheme due to number of UE.

2. The Impact on Different Network Size

In this section, comparison between centralized scheme and distributed scheme are compared due to network size. Figure 12, 13 and 14 shows performances of home registration, regional registration and location update cost, respectively. As shown in Figure 12, centralized scheme number of home registration is lower as compared to distributed scheme as the network size increased. Figure 13 shows that distributed scheme perform more regional registration compared to centralized scheme as the network size increased. Figure 14 shows that centralized scheme has higher location update cost compared to distributed scheme as network size increased. Bigger network size means increasing in numbers of eNBs because of the centralized architecture that requires an eNB to manage all the traffic within the network. Thus more home registration is perform for a UE to updates it location to HSS. This indicates that distributed scheme is cost efficient.

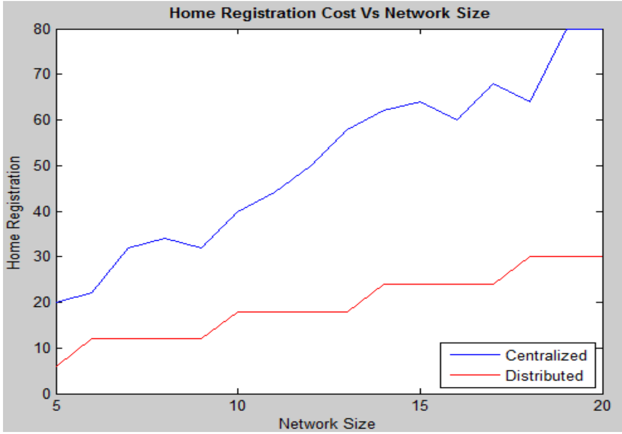

Figure 12. Comparison of home registration for centralized scheme and distributed scheme due to network size.

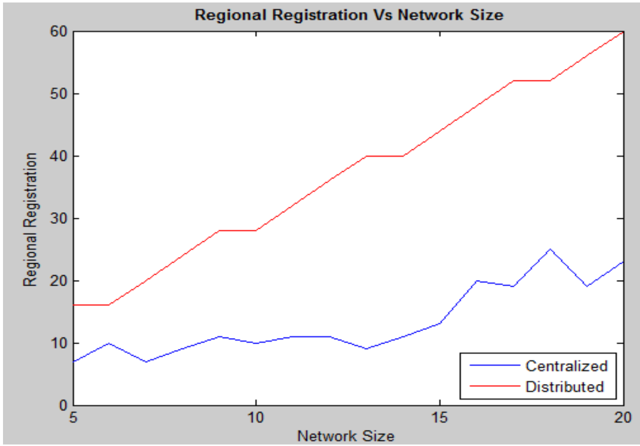

Figure 13. Comparison of regional registration for centralized scheme and distributed scheme due to network size.

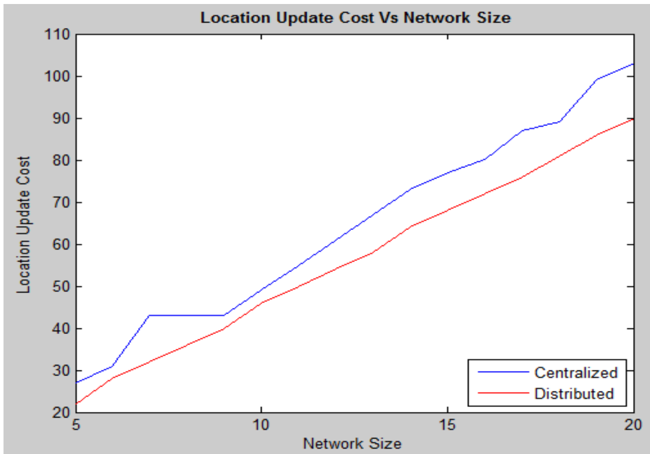

Figure 14. Comparison of location update cost for centralized scheme and distributed scheme due to network size.

VI. CONCLUSION

In this paper, it could be conclude that distributed scheme incurs lower signaling cost than the centralized scheme. This is due to evenly allocation of signaling load throughout the network. Distributed scheme requires that all eNB to be able to function as both eNB and MME. For future work, a scheme for low cost location management for femtocell and macrocell can be proposed. Besides that, it is known that there are other events that may impact the signaling load, such as UE originated-terminated session, paging and handover. These events should also be considered for future work.

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