A New Proposed Location Registration Procedure in Next Generation Cellular Networks (NGCN)

Azita Laily Yusof, Mahamod Ismail, and Norbahiah Misran

Abstract— **The objective of this research is to propose a new location registration procedure for System Architecture Evolution (SAE) which is the core network architecture of 3GPP's future Long Term Evolution (LTE) wireless communication standard. Under the proposed procedure, the authentication between access systems supporting different IP versions is carried out. A signaling message for a new location registration procedure is developed to evaluate the performance of the signaling procedure. The numerical results showed that the proposed procedure reduces the registration costs and latency for location registration. Therefore, this procedure results in significant performance improvements for SAE.**

Index Terms— **registration, authentication, IP, signaling, latency.**

I. Introduction

As 3G mobile systems evolve toward the NGCN, a major upgrading modification of the mobile systems is being considered in various mobile technology organizations such as the Third Generation Partnership Project (3GPP), Third Generation Partnership Project 2 (3GPP2) and WiMAX Forum. A major effort is focused on incorporating new technologies for the radio interface, but the effort extends beyond the radio system to encompass all aspects of the system architecture [2]. Part of the motivation for this upgrading modification of the system architecture is to obtain improvements in performance, such as signaling latency and improvement of the simplicity and overall cost of the system. Therefore, upgrading modification of the system architecture is a need for future wireless networks, and brings many benefits to both end users and service providers.

There have been many proposals to propose a new system architecture. Reference [3] has proposed some modifications to the architecture of the 3G radio network. To reach the performance to reduce latency and packet loss, Reference [3] has proposed a system architecture that contains fewer network nodes, because this reduces the overall amount of protocol related processing, number of interfaces, and cost of interoperability testing. Fig. 1 shows the architecture of 3GPP Release 6 and a possible evolution of this architecture.

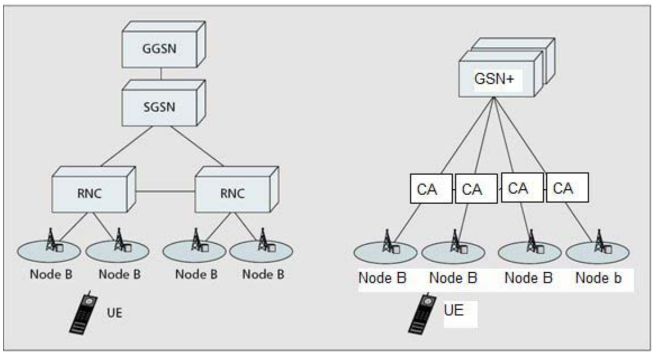


Fig. 1 Left: Architecture of 3GPP Rel-6. Right: Possible evolution of the architecture; the number of nodes along the user plane data path has been reduced from four to three.

In Release 6 (Rel 6), the gateway GPRS support node GGSN serves as an anchor node in the home network. All traffic is typically routed to the home network to maintain a concise service environment. This allows operators to filter traffic and provide security. The RNC manages radio resources and local mobility, controls the bearers, and optimizes the transport network. It also serves as a termination point for some radio protocols. The SGSN functions as an anchor node in the visited network and manages mobility and sessions.

In the evolved architecture, the GGSN functionality continues to reside in the home network to ensure roaming and consistency in the service environment. Similarly, the Node B continues to handle the lower layers of the radio interface. Therefore, a logical evolution might be to merge the SGSN and RNC into a central anchor node. An alternative solution might be to distribute the functionality of the SGSN and RNC, thereby completely eliminating these nodes. The evolved architecture might also require a central anchor node in the visited network, in order to ensure mobility, security and transport network efficiency.

Reference [4] also presents candidate technical solutions for the evolved radio access and RAN. In the proposed LTE architecture, the Rel-6 nodes GGSN, SGSN, and RNC are merged into a single central node, the access core gateway(ACGW) as shown in Fig. 2. The ACGW terminates the control and user planes for the user equipment (UE), and handles the core network functions provided by the GGSN and SGSN in Rel-6. The control plane protocol for the UE will be similar to radio resource control (RRC) in Rel-6, for

Manuscript received March 17, 2010. This work was supported in part by the Universiti Teknologi Mara.

Azita Laily Yusof is with the Faculty of Electrical Engineering, Universiti Teknologi Mara, Shah Alam, Selangor, Malaysia (phone: 603-5543-6015; fax: 603-5544-5077; e-mail: laily012001@ yahoo.com).

Mahamod Ismail, was with Department of Elebtrical, Electronics & System, Faculty of Engineering and Built Environment, University Kebangsaan Malaysia, Bangi, Selangor, Malaysia (e-mail: mahamod@eng.ukm.my).

Norbahiah Misran, was with Department of Elebtrical, Electronics & System, Faculty of Engineering and Built Environment, University Kebangsaan Malaysia, Bangi, Selangor, Malaysia (e-mail: norbahiah@eng.ukm.my).

example handling control of mobility and radio bearer configuration. In the user plane the ACGW will handle functions like header compression, ciphering, integrity protection, and automatic repeat request (ARQ).

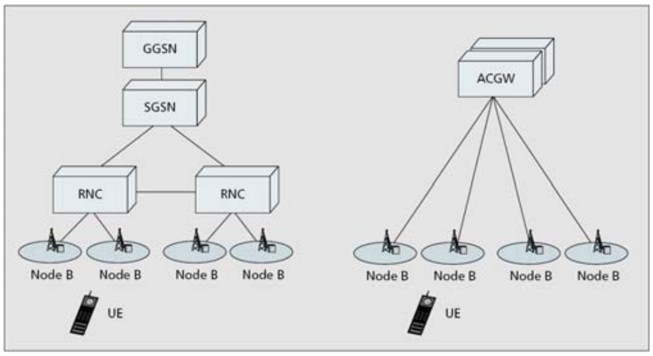


Fig. 2 The current 3GPP Release 6 architecture (left) and one possible evolved 3G architecture reducing the number of nodes along the data path from 4 to 2 (right).

To develop a new system architecture for an evolved 3GPP system that accommodates and migrates to the LTE, a new feasibility study was started under the name SAE. SAE is the core network architecture of 3GPP's future LTE wireless communication standard. Fig. 3 shows the SAE designed to provision network convergence between different types of access networks.

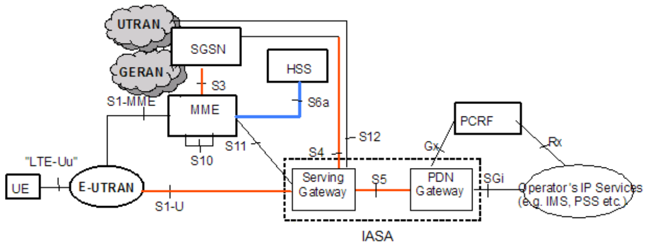


Fig. 3 SAE.

As a conclusion, each architecture has its advantages and disadvantages but neither alone addresses the complete requirements for NGCN. Among all the architecture discussed, the SAE has been chosen as the best architecture for NGCN. The SAE offered by 3GPP, is designed to provision network convergence between different types of access networks. The SAE supports the migration of the existing 3GPP system and also the inter-working with non-3GPP radio access systems, such as WLAN, WiMAX, 3GPP2 and others. One change is that a number of network nodes along the data path had reduced. The functions previously handled by the core network have been transferred out to the periphery. Essentially this provides a much flatter form of network architecture. In this way latency times can be reduced and data can be routed more directly to its destination. A reduction of the number of nodes also makes it possible to reduce call setup times, as fewer nodes will be involved in the call setup procedure. Such a reduction also gives greater possibilities to merge control plane protocols, thereby potentially further reducing call setup times. In addition, by its ability to integrate multiple services as application servers, the IMS Core enables various services to be defined and deployed. The SAE architecture is expected to become the part of the IMS able to connect the signaling with the QoS on the access networks in the 3GPP IMS specifications, thus connecting the offered signaled services to the data transmission path in a standardized manner. In this research, a new location registration procedure is proposed for SAE. A numerical results are provided to analyze and compare the proposed procedure.

II. SYSTEM ARCHITECTURE EVOLUTION

SA WG2 started its own Study for SAE whose objective is to develop a framework for an evolution or migration of the 3GPP system to a higher-data-rate, lower-latency, packetoptimized system that supports, multiple RATs. The focus of this work is on the PS domain with the assumption that voice services are supported in this domain. SA2's SAE work is conducted under Work Item "3GPP system architectural evolution", approved in December 2004. It was initiated when it became clear that the future was clearly IP with everything and that access to the 3GPP network would ultimately be not only via UTRAN or GERAN but by WiFi, WiMAX, or even wired technologies. Thus SAE has its main objectives [9]:

- Impact on overall architecture resulting from RAN's LTE work
- Impact on overall architecture resulting from SA1's AIPN work
- Overall architectural aspects resulting from the need to support mobility

between heterogeneous access networks.

An Evolved Packet Core was introduced in order to transparently unify the parameters of different technologies, like the UMTS, the 3GPP WLAN, non-3GPP access technologies and a future Evolved Radio Access Network called Long Term Evolution (LTE) or Evolved - UMTS Terrestrial Radio Access Network (E-UTRAN). Each of these technologies comes with its own specific access functions. The core itself manages and stores the user end-point context in a Mobility Management Entity (MME) and the user end-point services and network information in a User Plane Entity (UPE) which are coalesce in one entity. The IASA is in charge of mobility between different access systems. The traffic from all the networks is gathered in an Inter Access System Anchor (IASA), making the access technology transparent to other parties involved in the service provisioning. It is composed of a 3GPP anchor that executes mobility between 3GPP access systems and of a SAE anchor that handles mobility between 3GPP and non-3GPP access systems. The SAE anchor does not take any decision regarding mobility, it just executes it. It is the UE that takes this decision.

Despite this, it is possible to improve the cost structure of the network based on examining how many distinct types of network elements are required to execute certain functions. In the 3GPP network, it is found that the paging and mobility anchoring operations are performed at multiple levels of hierarchy in the network, all executing conceptually similar operations with some variations. Having multiple distinct elements increases development costs, in addition to the expense of deploying and managing multiple types of platforms.

ISBN: 978-988-18210-7-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

III. LOCATION REGISTRATION PROCEDURE

As discussed before, since the system architecture has been simplified, the number of distinct types of elements would be reduced, potentially lowering costs. Clearly, the determination of the appropriate number of hierarchical levels for a given function involved many technical aspects of performance and latency. The main point being made in SAE is that the cost improvements resulting from flattening the number of hierarchical levels should also be considered in upgrading modification the network architecture. Therefore, in this research a new location registration procedure is proposed to evaluate the signaling cost and latency of location registration for the SAE.

A. A New Location Registration Procedure for SAE

NGCN consists of many heterogeneous systems and the network domains will be owned by different operators that may not be willing to provide registration with information about the access network. From the location registration procedure proposed by 3GPP [9], it can be seen that the procedure does not described in detailed how the authentication between access systems supporting different IP versions is carried out. The interaction between the Home AAA Server (AAAH) and the HSS is not explicitly presented in the location registration procedure proposed by 3GPP. After a UE has successfully been authenticated by the AAAH, the AAAH registers its address to the HSS, unless already done. In turn, the HSS should store the address of the registered AAAH for the given user and mark the user as registered in the AAAH. In the response, the HSS returns user profile data. This process is not explained in the location registration procedure proposed by 3GPP. Therefore, in this research a modification of location registration for different access system is proposed for SAE to reduce overhead of signaling costs.

The modification is done by combining the 3GPP procedure as described above and project done by [7]. Reference [7] proposed security architecture for AMC by including AAAH in the location registration procedure. However, the proposed architecture introduces extra signaling overhead by adding two new entities, Network Interworking Agent (NIA) and Interworking Gateway (IG) to the system. Therefore, in this proposed procedure two new entities proposed by [7] is removed and the location registration procedure proposed by 3GPP is modified based on SAE.

When a mobile user requests service from a foreign network (FN) and the FN determines that it has no service level agreement (SLA) with the home network (HN) provider, it forwards the request to access gateway (aGW) that comprise Mobility Management Entity (MME) and User Plane Entity (UPE) to authenticate the user. Then, aGW talks to the HN provider and mediates between FN and HN for authentication message exchanges. Finally, the HN and FN will be mutually authenticated. Home network includes a AAAH which is able to check credentials originating from mobile nodes administered by that home network. The AAAH thus provides authentication of the user terminals. The modification done here is by including AAAH of the UE in the signaling messages to show in detailed how the authentication between UE and home service subscriber (HSS) is carried out.

AAAH is needed to authenticate the UE when the user roams to a FN. The AAAH must communicate with the designated HSS to select a suitable home address for the UE and to deliver to the HSS the necessary configuration parameters. Therefore, in this research, AAAH is presented as one entity in the location registration procedure to show in detailed how the registration process is carried out. However in this research, an interface between the AAAH server and the HSS is not defined for parameter exchange. The signaling messages for a new location registration procedure are shown in Fig. 4.

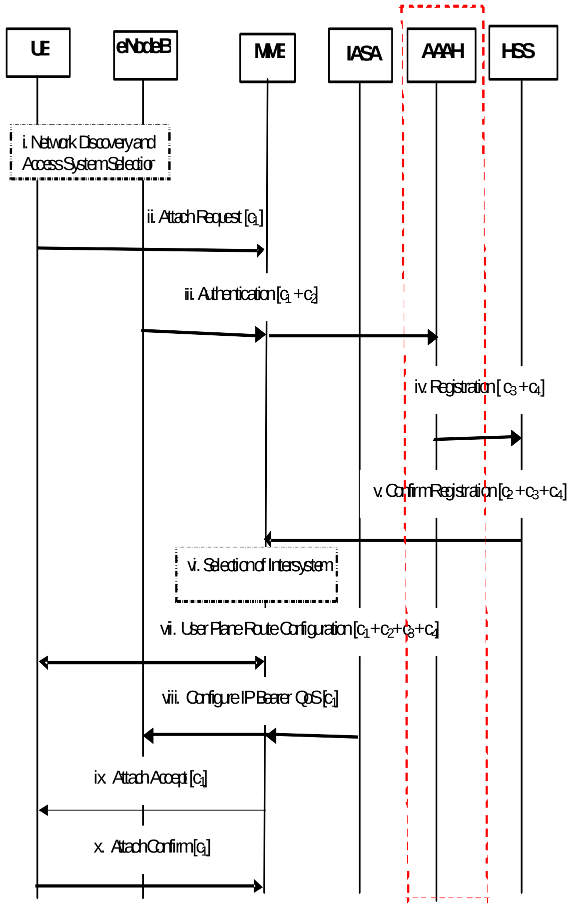


Fig 4. The location registration procedure.

IV. PERFORMANCE ANALYSIS

A. Assumptions and Parameters

As described in the previous section, the signaling procedure of location registration involves the exchange of signaling messages among the network elements. The costs for location management are associated with the traffic of messages between the entities and the accessing cost of databases.

A mobile was assumed that keeps the same mobility pattern when it moves into another system. Further, the updating, deletion and retrieval in the database were assumed to have the same cost, where *ah* is the HSS access cost, *ae* is the evolved RAN access cost, *aa* is the aGW access cost, *aah* is the AAAH access cost and *ai* is the IASA access cost. Further, each of the HSS, Evolved RAN, aGW, AAAH and IASA is modeled as a single exponential server with an infinite buffer. The average service time of each of them is $1/\mu h$ for HSS, $1/\mu e$ for Evolved RAN, $1/\mu a$ for aGW, $1/\mu ah$ for AAAH and $1/\mu i$ for IASA, respectively. The average

ISBN: 978-988-18210-7-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

system time in each of the databases is the total time including waiting time in the queue and the service time. The system time is represented by *sh, se, sa, sah* and s*i* for the HSS, Evolved RAN, aGW, AAAH and IASA, respectively. The corresponding waiting times are denoted as *wh, we, wa, wah* and *wi*.

B. Overhead of Signaling Costs

Based on the calculation of the total cost proposed by [1], the signaling cost is formulated. Under the proposed procedure, the signaling cost related to the transmission cost based on Figure 4 is $\alpha(6c1 + 3c2 + 3c3 + 2c4)$ and the cost associated with databases is $\beta(ae + aa + aah + ai + ah)$. So, the total cost of the proposed procedure is then calculated as $T = \alpha(6c1 + 3c2 + 3c3 + 2c4) + \beta(ae + aa + aah + ai + ah)$.

C. Latency of Location Registration

The latency of location registration is evaluated based on the processing time, which consists of two parts. One of them is the retrieval time of database and the other part is the waiting time for service. By deploying an M/G/1 queuing model to analyze the performance, the latency of accessing each database, *s(.)*, can be computed as

$$s(.) = 1/\mu(.) + w(.) \qquad (1)$$

where *(.)* indicates the sequence number of a signaling message and $1/\mu(.)$ represents the average service time for the database such as Evolved RAN, aGW, AAAH, IASA and HSS. *w(.)* is used to denote the waiting time for the above databases. As an example, *wh* of HSS was analyzed where the average arrival rate of the HSS is assume ηh. By using the well-known Pollaczek-Khinchin (P-K) formula, the average waiting time, *wh* is obtained by [5]

$$wh = \eta h \ x \ \mu h^2 + \eta h \ x \ \sigma h^2/2(1-\eta h/\mu h) \qquad (2)$$

where σh^2 is the variance of processing time in the HSS. The latency of accessing the HSS, *sh* can be computed from

$$sh = 1/\mu h + wh = 1/\mu h + \eta h(\mu h^2+\sigma h^2)/2(1-\eta h/\mu h)) \qquad (3)$$

where *wh* is the result from (2). Similarly, the latency of accessing for the Evolved RAN, aGW, AAAH and IASA can be obtained by substituting the corresponding parameters into (3). Therefore, the latency of location registration is $L = se + sa + sah + si + sh$.

D. Numerical Results

In this section, numerical results are provided to demonstrate the performance of location registration operation completion supported by [7] and proposed proposal. Table 1 lists all parameters used in the performance analysis [6] & [8]. The cost and latency of location registration dependent on operation completion probabilities are compared for [7] and proposed proposal.

TABLE 1
PERFORMANCE ANALYSIS PARAMETERS

Database access cost	$a_h = 8$, $a_e = 5$, $a_m = 5$, $a_{ah} = 5$, $a_i = 5$, $a_{fa} = 5$, $a_{ig} = 5$, $a_{nia} = 5$, $a_{ah} = 5$, $a_{auc} = 5$, $a_{ha} = 8$
Average arrival rate ($msec^{-1}$)	$\eta_h = 0.001$, $\eta_e = 0.001$, $\eta_m = 0.001$, $\eta_{ah} = 0.001$, $\eta_i = 0.001$, $\eta_{fa} = 5$, $\eta_{ig} = 0.001$, $\eta_{nia} = 0.001$, $\eta_{ah} = 0.001$, $\eta_{auc} = 0.001$, $\eta_{ha} = 0.001$
Average service time (msec)	$1/\mu_h = 1$, $1/\mu_e = 0.5$, $1/\mu_m = 0.5$, $1/\mu_{ah} = 0.5$, $1/\mu_i = 0.5$, $1/\mu_{ha} = 1$, $1/\mu_{fa} = 0.5$, $1/\mu_{ig} = 0.5$, $1/\mu_{nia} = 0.5$, $1/\mu_{ah} = 0.5$, $1/\mu_{auc} = 0.5$, $1/\mu_{ha} = 1$
Variance of processing time (msec)	$\mu^2{}_h = 0.04$, $\mu^2{}_e = 0.01$, $\mu^2{}_m = 0.01$, $\mu^2{}_{ah} = 0.001$, $\mu^2{}_i = 0.01$, $\mu^2{}_{fa} = 5$, $\mu^2{}_{ig} = 0.01$, $\mu^2{}_{nia} = 0.01$, $\mu^2{}_{ah} = 0.01$, $\mu^2{}_{auc} = 0.01$, $\mu^2{}_{ha} = 0.04$
Signaling transmission cost	$c_1 = 1$, $c_2 = 1$, $c_3 = 1$, $c_4 = 1$, $c_5 = 1$
Weighting factors	$\alpha = 0.4$, $\beta = 0.6$

Fig. 5 shows the comparison of location registration cost as a function of operation completion probability. To compare the effect of weight factor α and β, three cases of $\alpha = 0.4$, $\alpha = 0.5$ and $\alpha = 0.7$ are considered in evaluating the location registration cost as shown in Fig. 5(a), (b) and (c), respectively. In all cases, the proposed proposal yields less location registration cost than [7] regardless of the origination of incoming calls to a roaming user as shown in Figure 5(a), (b) and (c), respectively. For the same alpha, the improvement is up to 16%. It can also observe that, as the operation completion probability increases, the location registration cost increases as shown in Fig. 5. When the operation completion probability is small, the location registration cost is dominated by only involving less databases access. If the operation completion probability is high, the registration cost is dominated by accessing more databases, resulting in higher cost. Fig. 5(c) reveals the comparison of location registration cost when $\alpha = 0.7$, which means the transmission cost is the major part of the location registration cost. Considering the access and retrieval cost of the databases is very likely higher than the transmission cost, causing higher location registration cost. Fig. 6 shows that the registration cost reduced considerably for each case in SAE proposal. Therefore, the location registration cost of SAE proposal is much lower than [5] because of the simplified architecture.

ISBN: 978-988-18210-7-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

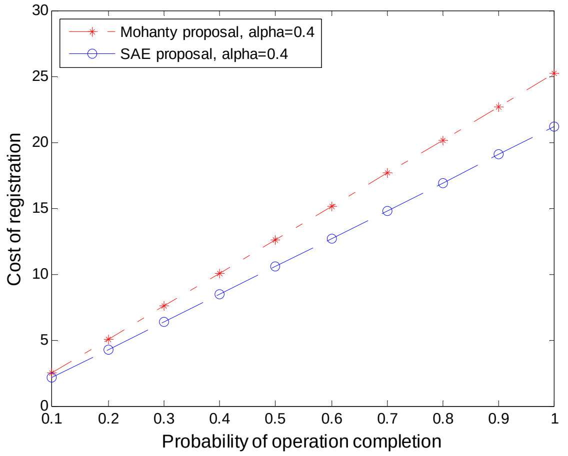
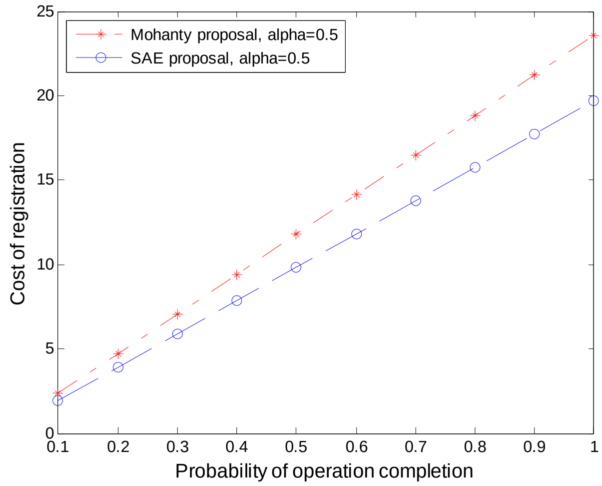
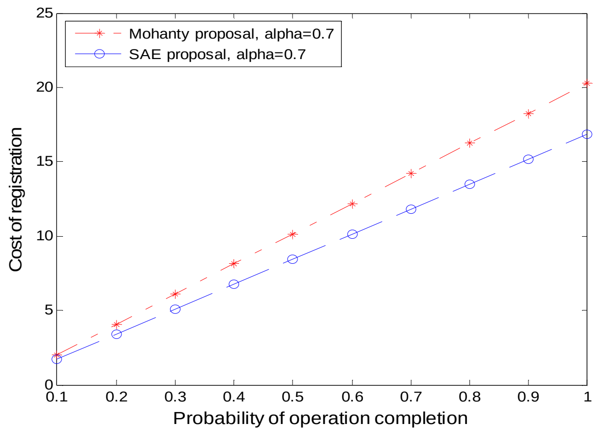


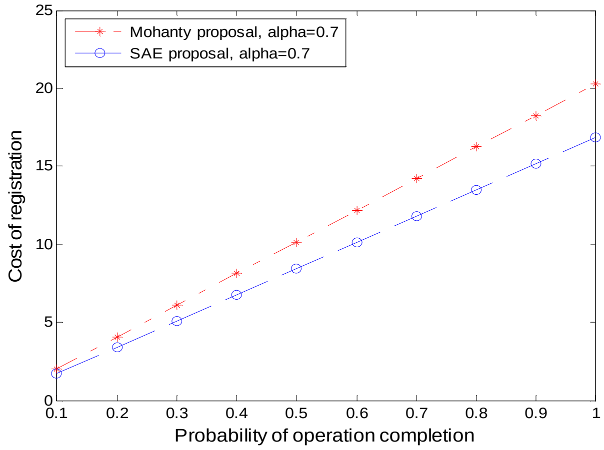
Fig. 5 Cost of registration for (a) alpha = 0.4, (b) alpha = 0.5, (c) alpha = 0.7.



(a)



(b)



(c)

Fig. 6 Comparison cost of registration for different alpha for SAE proposal.

The latency of location registration is shown in Fig. 7 in which the proposed proposal causes less delays up to 29% than [7] does. Similar to the case of location registration cost, the latency of location registration increases with the increasing operation completion probability. In the same way as for the location registration cost, it is associated with NIA and IG. When operation completion probability is small, the registration delay is mainly determined by accessing less databases while it is dominated by accessing more databases when operation completion probability is high. Fig. 7 shows the latency of location registration obtained. Therefore, SAE proposal reduces the registration costs and latency for location registration so that it is more suitable for roaming environment.

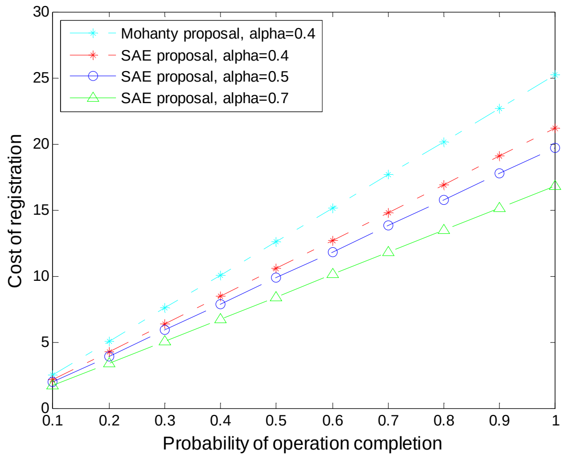


Fig. 7 Latency of location registration.

ISBN: 978-988-18210-7-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

V. CONCLUSIONS

In this research, SAE was studied which is the core network architecture of 3GPP's future LTE wireless communication standard. The detailed location registration procedure is proposed which is based on the concept of SAE. To evaluate the signaling cost and latency of location registration based on SAE, the generalized equation for the signaling cost and latency of location registration were formulated. The signaling cost is formulated as the sum of the transmission cost and the cost associated with database access while the latency of location registration is composed of waiting time and the service time at a specific database. In summary, the numerical results showed that the proposed location registration procedure result in significant performance improvements for SAE.

REFERENCES

[1] Akyildiz, I. F. & Wang, W, "A New Signaling Protocol for Intersystem Roaming in Next Generation Wireless Systems," IEEE Journal on Selected Area in Communications 19(10): 2040 2052, 2001.

[2] Agrawal, R. & Bedekar, A, "Network Architecture for 4G: Cost Considerations," IEEE Communications Magazine 45(12): pp. 76-81, 2007.

[3] Dahlman, E., Ekstrom, H., Furuskar, A., Karlsson, J., Meyer, M., Parkvall, S., Torsner, J. & Wahlqvist, M., "The Long-Term Evolution of 3G," Ericsson Review 02: 118-125, 2005.

[4] Ekstrom, H., Furuskar, A., Karlsson, J., Meyer, M., Parkvall, S., Torsner, J. & Wahlqvist, M., "Technical Solutions for the 3G Long-Term Evolution," Communications Magazine, IEEE 44(3): 38- 45, 2006.

[5] Kleinrock, L, "Queueing Systems Volume 1: Theory," Wiley,1975.

[6] Leung, K.K., Y. Levy, Y., "Global Mobility Management by Replicated Databases in Personal Communication Networks," IEEE Journal on Selected Areas in Communications, Vol.15(.8): 1582-1596,1997.

[7] Mohanty, S., "A New Architecture for 3G and WLAN Integration and Inter System Handover Management," ACM-Springer Journal of Wireless Networks (WINET), 2005.

[8] Zeng, M., Annamalai, A. & Bhargava, V.K., "Recent Advances in Cellular Wireless Communicationn," IEEE Communications Magazine 37: 128-138, 1999.

[9] 3GPP home page: http://www 3GPP.org.

ISBN: 978-988-18210-7-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)